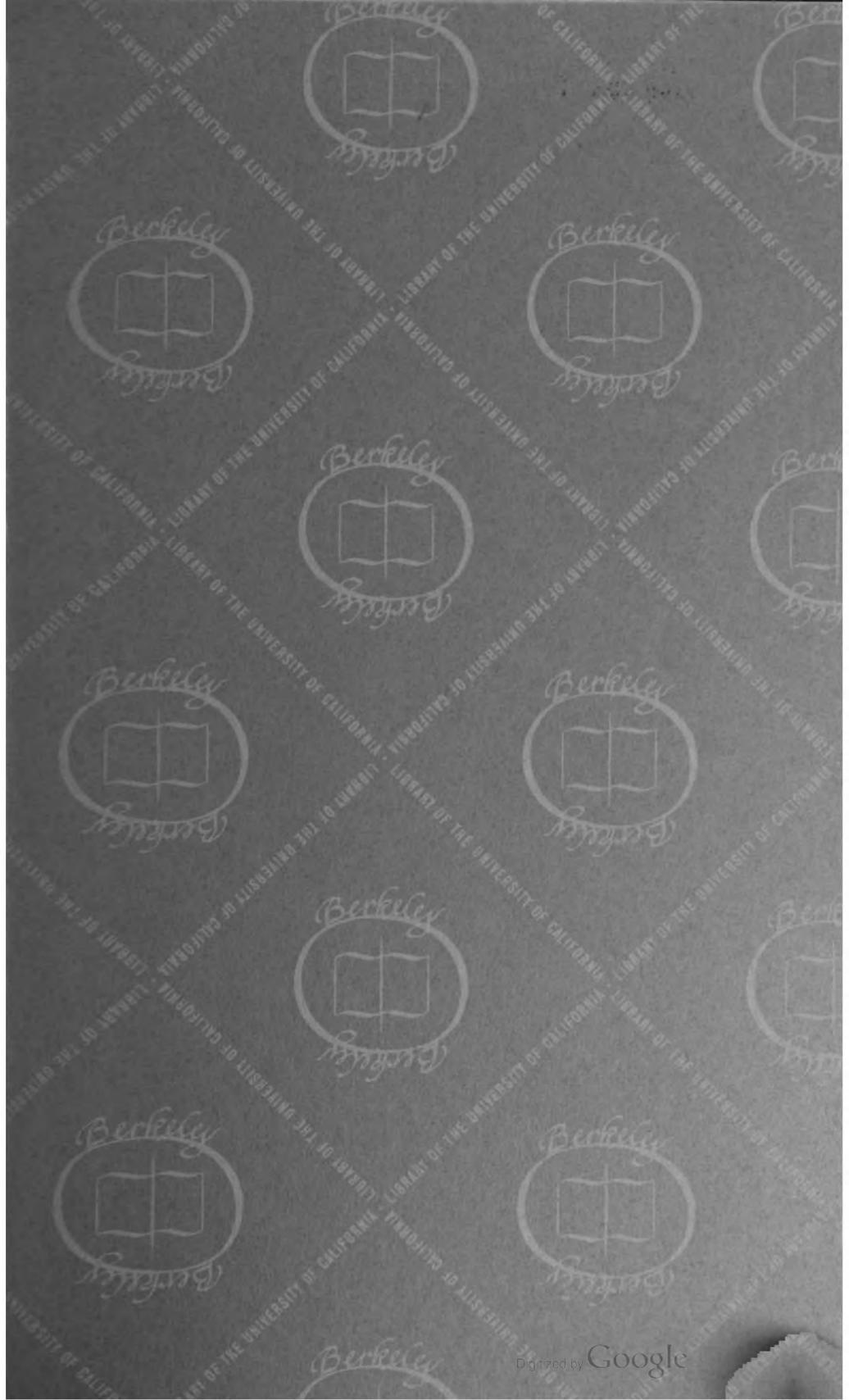

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Contributions to Bibliography of Mineral Resources 1955-59

GEOLOGICAL SURVEY BULLETIN 1019

*This bulletin was printed
as separate chapters, A-N*



UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1959

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

The U.S. Geological Survey Library has cataloged this publication as follows:

U. S. *Geological Survey.*

Contributions to bibliography of mineral resources, 1955-1959. Washington, U. S. Govt. Print. Off., 1959.

iii, 1046 p. 8 maps (6 fold. in pocket) 25 cm. (*Its Bulletin 1019*)

Contributions to bibliography of mineral resources

1. Mines and mineral resources—Bibl. 1. Title. (Series)
[QE75.B9 no. 1019] G S 59-195

QE75
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**A Selected Bibliography
on Quicksilver
1811-1953**

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A Selected Bibliography on Quicksilver 1811-1953

By M. JANE EBNER

A CONTRIBUTION TO BIBLIOGRAPHY OF MINERAL RESOURCES

G E O L O G I C A L S U R V E Y B U L L E T I N 1019-A



UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1954

UNITED STATES DEPARTMENT OF THE INTERIOR

Douglas McKay, *Secretary*

GEOLOGICAL SURVEY

W. E. Wrather, *Director*

**For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 25 cents (paper cover)**

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A CONTRIBUTION TO BIBLIOGRAPHY OF MINERAL RESOURCES

A SELECTED BIBLIOGRAPHY ON QUICKSILVER

By M. JANE EBNER

INTRODUCTION

This bibliography includes publications relating to the geology, mining, and metallurgy of quicksilver. The reports are grouped into the following categories: U. S. Geological Survey publications and open-file reports, U. S. Bureau of Mines publications, publications by state organizations, publications in scientific and professional journals, foreign publications, and miscellaneous publications. They are numbered consecutively from 1 to 908, and these numbers refer to the reports in the author and subject indexes found at the end of the bibliography:

Those reports that contain little information on quicksilver are excluded from the bibliography. Abstracts of reports and presentations of papers are omitted also. Most publications relating to the production of quicksilver are not included, but agencies and monthly publications that release information on production are listed at the end of each category.

U. S. Geological Survey publications for which prices are designated can be purchased from the Superintendent of Documents, Government Printing Office, Washington 25, D. C. Those preceded by an asterisk (*) are out of print, but they can probably be seen in many university and public libraries. Open-file reports and preliminary reports are not available in all libraries, but copies have been placed in the Geological Survey Library, Washington, D. C., and in a few other Geological Survey offices. Limited distribution reports may be obtained, if still available, from the U. S. Geological Survey, Washington 25, D. C.

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By JANE H. WALLACE and HARRIET B. SMITH

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G E O L O G I C A L S U R V E Y B U L L E T I N 1 0 1 9 - B

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UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1955

UNITED STATES DEPARTMENT OF THE INTERIOR

Douglas McKay, *Secretary*

GEOLOGICAL SURVEY

W. E. Wrather, *Director*

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Washington 25, D. C. - Price 30 cents (paper cover)**

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III

A CONTRIBUTION TO BIBLIOGRAPHY OF MINERAL RESOURCES

BIBLIOGRAPHY OF U. S. GEOLOGICAL SURVEY TRACE ELEMENTS AND RELATED REPORTS, TO JUNE 1, 1954

By JANE H. WALLACE AND HARRIET B. SMITH

INTRODUCTION

Many U. S. Geological Survey Trace Elements reports ¹ and related articles have been made available to the public by open-file release, by reproduction and distribution by the Technical Information Service (referred to as TIS) of the U. S. Atomic Energy Commission, or by publication by the Geological Survey or a scientific journal.

The present list has been compiled as a reference guide to Geological Survey reports on radioactive raw materials that have been made available to the public, to June 1, 1954. These reports are listed by type of publication or release, and are given index numbers. Reports listed under more than one type of publication or release have cross-reference index numbers in parentheses after each listing. The subject and author indexes at the end of the bibliography refer to the reports by index number.

REPORTS AND MAPS RELEASED IN OPEN FILE

The reports released in open file are listed alphabetically by author and, if an author has written more than one report, alphabetically by title. The reports may be consulted at the Geological Survey Library, Room 1033, General Services Administration Building, Washington, D. C., and at various places, whose addresses are indicated after the

¹ Reports prepared by the Geologic Division of the Geological Survey on behalf of the Division of Raw Materials and the Division of Research of the U. S. Atomic Energy Commission. (TEI=Trace Elements Investigations Report; TEM=Trace Elements Memorandum Report; reports with no TE designation are not numbered in the Trace Elements reports series.

date of open file deposit, either by symbol or complete address. Symbols are used for the following places:

- B—Office of the Director, Montana Bureau of Mines and Geology, Butte, Mont.
 BA—Atomic Energy Commission, Butte Suboffice, Butte, Mont.
 D—Geological Survey office, Room 468 New Customhouse, Denver, Colo.
 DA—Atomic Energy Commission, Denver Exploration Branch, Denver Federal Center, Denver, Colo.
 GJ—Geological Survey office, Grand Junction, Colo.
 GJA—Atomic Energy Commission, Grand Junction Operations Office, Grand Junction, Colo.
 H—Atomic Energy Commission, Hot Springs Suboffice, Hot Springs, S. Dak.
 IM—Idaho Bureau of Mines and Geology, Moscow, Idaho
 R—Atomic Energy Commission, Richfield Suboffice, Richfield, Utah
 SF—Geological Survey office, Room 724, Appraisers Building, San Francisco, Calif.
 SL—Geological Survey office, Room 504, Federal Building, Salt Lake City, Utah
 SLA—Atomic Energy Commission, Salt Lake Exploration Branch, Salt Lake City, Utah
 T—Arizona Bureau of Mines, University of Arizona, Tucson, Ariz.
 U—University of Utah, Salt Lake City, Utah
 W—Geological Survey office, S. 157 Howard St., Spokane, Wash.

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- 5 Cressman, E. R., Geology of the Dry Valley quadrangle, Idaho: TEI-258, Aug. 25, 1952. IM, SL, W. (393)
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- 66 ——— Photogeologic map, Carlisle-6 quadrangle, San Juan County, Utah: TEM-587, Oct. 19, 1953. D, GJ, SL.
- 67 ——— Photogeologic map, Moab-10 quadrangle, Grand County, Utah: TEM-616, Sept. 16, 1953. D, GJ, SL.
- 68 ——— Photogeologic map, Moab-11 quadrangle, Grand County, Utah: TEM-652, Dec. 21, 1953. D, GJ, SL.
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- 81 ——— Photogeologic map, Orange Cliffs-4 quadrangle, Wayne County, Utah: TEM-664, Nov. 25, 1953. D, GJ, SL.
- 82 ——— Photogeologic map, Orange Cliffs-9 quadrangle, Garfield and Wayne Counties, Utah: TEM-732, Apr. 26, 1954. D, GJ, SL.
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- 91 ——— Photogeologic map, Clay Hills-14 quadrangle, Navajo Indian Reservation, San Juan County, Utah: TEM-442, Jan. 9, 1953. D, SL.
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SPECIAL PUBLICATION

[For sale by the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at the price indicated.]

Index No.

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7-DAY

Annotated Bibliography and Index Map of Barite Deposits in United States

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GEOLOGICAL SURVEY BULLETIN 1019



GEOLOGY LIBRARY

Annotated Bibliography and Index Map of Barite Deposits in United States

By BASIL G. DEAN *and* DONALD A. BROBST

A CONTRIBUTION TO BIBLIOGRAPHY OF MINERAL RESOURCES

GEOLOGICAL SURVEY BULLETIN 1019-C

*Including references to September
15, 1954*



UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1955

UNITED STATES DEPARTMENT OF THE INTERIOR

Douglas McKay, *Secretary*

GEOLOGICAL SURVEY

W. E. Wrather, *Director*

**For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 45 cents (paper cover)**

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ILLUSTRATION

PLATE 1. Index map of barite deposits in the United States..... In pocket

III

A CONTRIBUTION TO BIBLIOGRAPHY OF MINERAL RESOURCES

ANNOTATED BIBLIOGRAPHY AND INDEX MAP OF BARITE DEPOSITS IN THE UNITED STATES

By BASIL G. DEAN and DONALD A. BROBST

INTRODUCTION

Barite is now ranked as an important non-metallic mineral commodity because of its extensive use in weighting drilling muds and concrete aggregate, in the chemical industry, and in the manufacture of paint, glass, and rubber. According to the U. S. Bureau of Mines, about one million short tons of barite was produced in the United States during 1952. Imports in 1952 totaled three hundred thousand short tons. The United States is the world's leading producer and consumer of barite.

Missouri, Tennessee, and Georgia have been the major sources of barite since mining began there in 1872, 1902, and 1914 respectively. Deposits in Arkansas, Arizona, Idaho, Montana, Nevada, and New Mexico have been developed extensively in recent years. Deposits in Connecticut, Maryland, and Pennsylvania have not been worked for many years, and no production has been recorded from Kentucky since 1926. Deposits in Alabama, Colorado, Illinois, Virginia, and Wisconsin were not mined during 1953, although they were worked between 1923 and 1948. Most of the deposits in California have been worked between 1923 and 1948.

EXPLANATION OF THE ANNOTATED BIBLIOGRAPHY

The work of compiling the preliminary copy of the annotations of the literature cited was done by Basil G. Dean in 1952-53. The material was assembled, brought up to date, and prepared for publication by Donald A. Brobst in 1953-54. The annotated references are listed by authors in alphabetical order. The entries are cross-indexed by two other lists including general references and state references.

The general references, numbered to correspond with the alphabetical list of authors, include general information on occurrence, origin,

production, mining and treatment of ore, as well as some descriptions of deposits that are distributed over large areas involving several states.

State references describe deposits and mining and milling techniques practiced within a particular state. The index by state consists of two parts: a list of general papers arranged by number; a numbered list of districts, mines, and prospects in the state arranged alphabetically. The number for each deposit corresponds to the number of that deposit on the accompanying index map. Letter symbols describing the type of deposit used on the map are repeated in the text; the symbols are explained on the map. The numbers to the right of the names of the deposits correspond to the numbers of the reports in the author index that describe the given deposit.

In a few instances, two references containing essentially the same information have been included for the convenience of the reader who may have access to only one of the references. Some older references which have been superseded by more recent ones have been omitted.

EXPLANATION OF THE INDEX MAP

The index map (Plate 1) gives the location, type of geologic occurrence, and relative production from barite deposits in the United States. The deposits are numbered consecutively in each State on the map; this order is the same as in the list of deposits placed in the State index.

The deposits are classified on the map according to the mode of occurrence as residual (r), bedded or lenticular replacements (b), veins, tabular ore bodies or mineralized breccia zones (v), and other occurrences including disseminated deposits and circle deposits (o). Circle deposits are bell- or cone-shaped masses of lightly brecciated country rock which have been mineralized with barite and small amounts of galena, sphalerite, chalcopyrite, and calcite. Deposits not described in the literature as to type are indicated by a question mark (?).

The symbol for the type of occurrence refers to that part of the deposit which is commercially exploitable, although other types of occurrences may be in the vicinity. In the Cartersville district, Georgia, the deposits are listed as residual because nearly all of the production has been from residual deposits in clay, although the primary deposits of barite occur in noncommercial veins in the bedrock. If more than one type of occurrence is of commercial value, as in the Central district, Missouri, symbols are combined, with the most important type listed first.

Deposits are indicated as either prospects or mines. Prospects include all undeveloped deposits for which there is no record in the

literature of production of barite and the large ore bodies which contain barite as a major gangue constituent. Commercially exploited deposits of barite are associated chiefly with other non-metallic minerals in bedrock and residual clay. Deposits of only mineralogic interest have been omitted.

Production from individual mines or districts is classed as small if the estimated total production has been less than 5,000 tons, and as large if the estimated total production has been more than 5,000 tons. These estimates of production are based largely on incomplete information in the literature cited.

The active or inactive status of mines has not been shown on the index map, for it changes with economic and other conditions. Some barite mines and prospects have not been indicated on the map because of the scale or because of inadequate information in the literature. Some recent discoveries and mining developments, particularly in Nevada, have not been described in the literature as of September 1954.

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AUTHOR INDEX

- 1 Adams, G. I., 1931, Hydrothermal origin of the barite in Alabama: *Econ. Geology*, v. 26, no. 7, p. 772-776.

Small barite veins occurring in shales of the Weisner formation of Lower Cambrian age and in the pre-Cambrian Ashland mica schist, in Cherokee and Cleburne Counties are believed to have been deposited by hydrothermal solutions at the close of the Paleozoic, after formation of the main structural features of the Appalachians. The veins are 12 to 18 inches wide and not considered economic.

- 2 Adams, G. I., and Jones, W. B., 1940, Barite deposits of Alabama: *Ala. Geol. Survey Bull.* 45, 38 p.

The geologic occurrence and origin of barite are discussed, and individual mines and prospects in the nine barite-bearing localities of Alabama described. The major primary deposits occur as irregular veins and replacement bodies in the Knox dolomite of Cambrian and Ordovician age and in the Pelham limestone of Ordovician age. Barite veins also occur in shales of the Weisner formation of Lower Cambrian age and in the pre-Cambrian Ashland [mica] schist. The authors believe that these deposits were formed by mesothermal and epithermal solutions moving along fractures caused by the main deformation of the Appalachians at the close of the Paleozoic. Only residual deposits in red clay derived from weathering of the primary deposits described above have been worked. The most abundant residual deposits are found in Bibb County where barite is associated with fluorite, limonite, calcite, and native sulfur. These deposits are believed by Adams and Jones to offer the best possibilities in the state for mining development. Barite was first produced in 1914; production reached a peak in 1917 and then gradually declined until 1925. Since 1925, production has been intermittent and on a small scale.

- 3 Agnew, Allen F., Flint, Arthur E., Crumpton, R. P., 1954, Geology and zinc-lead-barite deposits in the area east of Cuba City, Wisconsin: *U. S. Geol. Survey Map MF 15.*

A detailed map (scale 1:12,000) shows the geology of the ore deposits east of Cuba City. A marginal text briefly describes the history of the district, the rock units and thin alteration, the structure, and the ore deposits.

- 4 Allen, M. A., and Butler, G. M., 1919, Barytes: *Univ. Bur. Mines Bull.* 99, 18 p.

A general discussion of barite is followed by brief notes on occurrences of barite in Arizona. All known deposits, which occur in veins in igneous or

sedimentary rocks, are small and most veins are less than three feet wide. It is doubtful that many would be of commercial value, even if they were near a market.

- 5 Anderson, A. L., 1943, The antimony and fluorspar deposits near Meyers Cove, Lemhi County, Idaho: Idaho Bur. Mines and Geology Pamph. 62, p. 1, 11, 14-16.

A mineralized fracture zone as much as 20 feet wide in silicic tuff of the Challis volcanics of Oligocene [and early miocene] age contains mostly barite, with considerably less stibnite, fluorite, and chalcedony.

The stibnite content of the deposit is economically unimportant.

- 6 Arkansas Geological Survey, 1942, Mineral resources of Montgomery, Garland, Saline, and Pulaski Counties: County Min. Rept. 3, p. 30.

Small deposits of impure barite have been found in veins with calcite and in limonite deposits in Pulaski, Saline, Garland, and Montgomery Counties. These deposits are not of economic value. The occurrence of commercially exploited barite deposits in Hot Spring County (Magnet Cove) is noted. Additional deposits may occur in Garland County.

- 7 Argall, G. O., Jr., 1949, Industrial minerals of Colorado: Colo. School of Mines Quart., v. 44, no. 2, p. 32-39.

Barite occurrences in Colorado are described. A bibliography and general information on uses, treatment, and marketing of barite are included. Barite occurs as gangue in many base-metal sulfide veins of Colorado, in gold telluride veins at Cripple Creek, in ferberite veins in Boulder County, and in fluorite veins of Boulder and Mineral Counties. In a few localities, barite constitutes the main filling of the vein. Small quantities of barite were mined in Boulder, Fremont, and Custer Counties during World War I and more recently in Park and Custer Counties.

- 8 Arizona Department of Mineral Resources, 1945-1950, Seventh to Eleventh Annual Repts.

These annual reports contain summaries of information on barite mining in the state.

- 9 Averill, C. V., 1937, Mineral resources of Plumas County: Calif. Jour. Mines and Geology, v. 33, no. 2, p. 92.

Barite occurs in lenses in slate at the Savercool and Synthetic Iron Color Co. mines four miles southwest of Almanor, Plumas County. Up to 1936, about 17,000 tons of barite had been mined at the Synthetic Iron Color Co. property. The ore averaging about 94 percent BaSO_4 was mined in open pits and underground. At the Savercool mine, a carload of barite was mined from a barite lens 10 feet wide and shipped as a sample.

- 10 Averill, C. V., 1939, Mineral resources of Shasta County: Calif. Jour. Mines and Geology, v. 35, no. 2, p. 114-115.

Barite occurs in fissure veins in basic igneous rock at the Afterthought prospects, 20 miles north of Redding. The veins range from a few inches to eight feet in width and are reported to contain "quite pure" barite. Barite associated with a small amount of witherite has been exposed in a small open cut (Barite No. 1 and No. 2 claims) in the side of Beegum Creek Canyon about two miles from Platina. A narrow lens or vein of barite has been found on the Bidwell ranch just south of the town of Montgomery Creek. Several thousand tons of barite have been mined east of Castella (Loftus deposit) by the Glidden Co. for the manufacture of lithopone. The

barite occurs as a bedded deposit in nearly horizontal slate and limestone of probable Devonian or Carboniferous age. The average grade of ore was nearly 93 percent BaSO₄; mining was from open pits.

- 11 Averill, C. V., and Norman, L. A., Jr., and others, 1951, Counties of California, mineral production and significant mining activities of 1949: Calif. Jour. Mines and Geology, v. 47, no. 2, p. 338 and 350.

A new barite lens was discovered by diamond drilling at the El Portal barite deposits by the National Lead Co. on the north side of the Merced River, Mariposa County. The company planned to explore the lens with a crosscut and raise in 1950. Colored barite occurs in a lens six feet wide in slate at the Cameron barite mine three miles south of the Almanor Dam, Plumas County. The deposit was mined from an open cut in April and May of 1949.

- 12 Baker, C. L., 1932, Barite in Texas: Texas Univ. Bur. Econ. Geology Min. Res. Circ. 4, 5 p.; 1934, The geology of Texas, v. 2, Structural and economic geology: Texas Univ. Bull. 3401, p. 403-409.

This paper is largely a general discussion of properties, occurrence, production, mining, preparation and uses of barite. Barite occurrences in Texas are briefly described. The barite commonly occurs in small veins or nodules in sedimentary rocks. No production had been recorded from Texas as of 1932.

- 13 Bancroft, Howland, 1911, Reconnaissance of the ore deposits in northern Yuma County, Arizona: U. S. Geol. Survey Bull. 451, p. 123-126.

At the McCracken lead mine in southern Mohave County barite is reported in large quantities in two fissure veins which range in width from 6 to 20 feet. In addition to barite, the vein filling consists of quartz, calcite, siderite, dolomite, and galena.

- 14 Barnes, V. E., 1939, Additional notes on barite: Texas Univ. Bur. Econ. Geology Min. Res. Circ. 11, 4 p.

Three small barite deposits in northeastern Gillespie County, northern Llano County, and near Pandale, Val Verde County are described. Deposits at the first two localities are small veins in pre-Cambrian schist and gneiss. The veins contain impure barite associated chiefly with quartz. Barite occurs near Pandale as cavern fillings in cherty limestone. None of the deposits appears to be large enough to be of economic value.

- 15 Bastin, E. S., 1931, The fluorspar deposits of Hardin and Pope counties, Illinois: Ill. State Geol. Survey Bull. 58, p. 30-31 and 57.

Barite occurs sporadically near the surface where it coats and replaces fluorite in both the vein and blanket-type deposits. The fluorite is considered of hydrothermal origin, but the barite was probably deposited by circulating ground water. The barite is generally not of commercial importance, but it might be recovered as a by-product in mining the fluorspar deposits of the blanket type.

- 16 Bishop, O. M., 1949, The mineral industry of Missouri in 1946 and 1947 with total production summarized: Mo. Geol. Survey and Water Res. Inf. Circ. 4, p. 8-13.

Uses of barite, types of occurrences, production, and mining and milling methods in Missouri are summarized. Annual production and value of barite produced in Missouri from 1872 through 1947 is tabulated. Barite

mining began in pre-Civil War days and has been continuous since 1872, with a total recorded production to 1947 of 4,765,125 tons valued at \$31,774,237. Missouri has produced more barite than any other state.

- 17 Bishop, O. M., 1950, The mineral industry of Missouri in 1948: Mo. Geol. Survey and Water Res. Inf. Circ. 6, p. 6-7.

Barite production in Missouri in 1948 is discussed. In 1948 this totalled 278,071 tons of barite valued at \$2,413,802.

- 18 Bishop, O. M., 1951, The mineral industry of Missouri in 1949: Mo. Geol. Survey and Water Res. Inf. Circ. 7, p. 6-7.

Competition from producers at Magnet Cove, Ark., caused a decline in barite production in Missouri in 1949. Of the total production of 186,891 tons, approximately 78,800 tons were ground for use in drilling muds and 83,300 tons were shipped to the chemical industry. The remaining 25,000 tons was added to stockpiles. All but 3,540 tons was mined in Washington County from residual clays having an average content of 10 percent barite.

- 19 Bradley, W. W., 1930, Barite in California: Rept. 26 of the State Mineralogist, v. 26, no. 1, p. 45-57.

The occurrence and uses of barite in the United States are discussed. Principal barite deposits in California are described by counties. By 1929 production of barite had been reported from Inyo, Los Angeles, Mariposa, Monterey, Nevada, Orange, San Bernardino, Santa Barbara, and Shasta Counties. Commercial production of barite in California began in 1910 and with the exception of 1924 and 1925 some production has been reorded each year since then reaching a total of 86,768 tons at the end of 1929. California barite resources in 1929 were considered ample to meet any considerable increase in Pacific Coast market demands. This is the most complete summary available about deposits of barite in California.

- 20 Bradley, W. W., 1930, Barite in California: Am. Inst. Min. Metall. Engineers. Tech. Pub. 266, 9 p.

Same material as in reference 19 but presented in a slightly condensed version.

- 21 Branner, G. C., 1931, Barite in Arkansas: Eng. and Min. Jour., v. 131, no. 11, p. 512.

The results of prospecting the large Magnet Cove barite deposit during 1930 and 1931 are summarized. The material reviewed here is covered in detail by Norman and Lindsey (1941).

- 22 Branner, G. C., and others, 1940, Polk County: Ark. Geol. Survey County Mineral Rept. 1, p. 18-19 and pl. 7.

The occurrence of six small barite deposits in central Polk County is noted. The barite occurs in thin veins in the Missouri Mountain slate of Silurian age and in small pockets and seams in the overlying Arkansas novaculite of Devonian and Mississippian age. The deposits appear to be too small to be of economic value. Location of deposits is shown on geologic map of Polk County.

- 23 Braun, L. T., 1950, Barite, in Jenkins, O. P., and others, Mineral commodities of California: Calif. Dept. Nat. Res. Div. Mines Bull. 156, p. 130-132.

Occurrences, production, uses, and markets for barite in California are discussed briefly. Occurrences of barite, chiefly as veins or replacements,

are widespread and a total production of more than 500,000 tons from several deposits was recorded between 1910 and 1949. Recent production has been from two properties, a replacement deposit near El Portal, Mariposa County (the principal source) and from a lens near Greenville, Plumas County. California barite is used principally for drilling mud.

- 24 Buckley, E. R., 1909, Geology of the disseminated lead deposits of St. Francois and Washington Counties: Mo. Bur. Geology and Mines, v. 9, pt. 1, p. 223-228 and 238-248.

Lead deposits of southeastern Missouri contain barite associated with galena and other sulfides, sulfates, and carbonates. They occur in irregular vertical and horizontal openings in dolomite and in residual clay derived from dolomite. Barite is most abundant in the Potosi dolomite (Cambrian). The barium is believed to have been carried in solution as BaCO_3 in groundwater and precipitated in solution cavities by reaction with solutions of an alkaline sulfate, probably CaSO_4 . The barium probably was derived originally from the feldspars of igneous rocks from which the sediments of the area were derived. The report includes descriptions and a map indicating the location of 33 barite deposits which were being or had been worked in the area as of 1909.

- 25 Butts, Charles, and Gildersleeve, Benjamin, 1948, Geology and mineral resources of the Paleozoic area in northwest Georgia: Ga. Geol. Survey Bull. 54, p. 83-85.

Although barite is widely distributed in northwest Georgia, important deposits are essentially limited to the Cartersville district. Six other isolated barite localities lie within a belt about 75 miles long and as much as 25 miles wide which extends northeast from the vicinity of Esom Hill, Polk County to Ruralvale in Whitfield County. The principal producers of crude barite in the past three years are listed in a table. The locations of active barite operations in 1946 are indicated on a mineral resource map. Reserves are believed sufficient for many years of continued production.

- 26 California State Mining Bureau, 1910-1948, Mineral production of California: Calif. State Min. Bur. Ann. Bulls. 1910-37; Calif. Dept. Nat. Res. Div. Mines Ann. Bulls. 1938-48.

In this annual publication of the Division of Mines, yearly production of barite by counties in California is tabulated. Tables are included to show annual value and tonnage of barite produced since 1910.

- 27 Clippinger, D. M., 1949, Barite of New Mexico: N. Mex. Bur. Mines and Mineral Res. Circ. 21, 28 p.

All available information on barite in New Mexico up to and including 1948 is summarized. The geology, occurrence, mining, milling, and production of barite is reviewed. Nineteen mines and prospects in Dona Ana, Lincoln, Socorro, and Torrance Counties and 12 other scattered deposits are described briefly. A bibliography is included. Barite occurs chiefly as vein and breccia fillings which may be accompanied by replacement of wall rock. Country rocks include pre-Cambrian granite and schist and quartzite, limestones, and shales of Paleozoic age. The principal minerals associated with the barite are fluorite and quartz, with lesser amounts of calcite, gypsum, and sulfides. Fluorite in varying amounts is present in almost all the deposits. As a result of the recent development of milling methods for separation of barite and fluorite the recovery of both minerals from some deposits is now commercially possible. Recent demands

for heavy drilling muds in the oilfields of New Mexico and west Texas have created a new market nearby.

- 28 Crickmay, G. W., 1935, Origin of barite in the Appalachian Valley: *Econ. Geology*, v. 30, no. 5, p. 563-564.

The paper by Jones and McVay (1934) in which they advocate hydrothermal origin for Alabama barite deposits is discussed. Crickmay believes that both hypogene and supergene deposition of barite occurred in the Cartersville district, Georgia and probably also in Alabama. Massive, white barite at Cartersville is commonly brecciated and Crickmay considers it of hypogene origin. Delicate transparent barite crystals called "flowers of ocher" occur in open cavities in quartzite and may have formed from the earlier veins by solution and subsequent deposition of barite from circulating surface waters.

- 29 Dahners, L. A., 1949, Investigation of the Del Rio and Stackhouse barite deposit, Cocke County, Tenn., and Madison County, N. C.: U. S. Bur. Mines Rept. Inv. 4571, 26 p.

The results of diamond-drilling by the U. S. Bureau of Mines during 1944 on the Moccasin Gap prospect and Krebs property in Cocke County, Tenn., and the Sandy Bottom mine of the Stackhouse group in Madison County, North Carolina are described. Tables of analyses of samples and logs of drill-holes are included. The ore is principally barite associated with fluorite, pyrite, calcite, quartz, and traces of copper. The veins cut by drill holes on the Moccasin Gap property were narrow and low grade. Ore containing 33 to 57 percent barite was intersected by one drill hole on the Krebs property, which was in operation in 1944. At the Sandy Bottom property unconsolidated vein material could not be cored and sludge samples showed only a trace of barite.

- 30 Dake, C. L., 1930, The geology of the Potosi and Edgehill quadrangles: *Mo. Bur. Geology and Mines*, 2d ser., v. 23, 233 p.

Detailed descriptions of stratigraphy, structure, and ore deposits of this area in southeastern Missouri are given. Rocks of the area include pre-Cambrian igneous rocks, chiefly rhyolite porphyry, and sedimentary rocks of Paleozoic age, chiefly dolomites. Beds in this area west of the structural center of the Ozark dome have a westerly regional dip broken by faults and porphyry knobs. Nearly half the total barite produced in the United States in 1927 was from the Washington County district, part of which lies in the Potosi quadrangle. Nearly all of the commercially important barite occurs irregularly disseminated in deep residual clays derived from the weathering of the Potosi and Eminence dolomites of Cambrian age. Silica in the form of chert, chaldony, or quartz universally is associated with barite in the residual clay. Other minerals associated with barite in order of their decreasing abundance are limonite, galena, marcasite, and pyrite. The author suggests that barite was precipitated from sea water in minutely disseminated form in beds of the Potosi and Eminence dolomites. The barite was later concentrated into larger masses by the shallow circulation of groundwater during the weathering process which also formed the residual clay.

- 31 Dunlap, J. C., 1945, Structural control in the eastern belt of the Sweetwater barite district, east Tennessee (abstract): *Econ. Geology*, v. 40, no. 1, p. 82; *Geol. Soc. America Bull.*, v. 56, no. 12, pt. 2, p. 1156.

The Cambrian and Ordovician sedimentary rocks lie in three parallel belts separated by major thrust faults. Barite deposits are restricted to the Beekmantown division [Ordovician] of the Knox group, and occur principally in the limestone member of the lower Kingsport formation. The regional strike of these beds is N. 50° E. and dip is 10° to 20° southeast. Two types of minor structures with axes that strike from N. 70° W. to due west cut across the regional structure. These minor structures "are (1) 'knobs' or sharp flexures caused by abrupt change in strike and (2) very gentle anticlines." Narrow brecciated zones in these minor structures are believed to have admitted rising hydrothermal solutions which spread laterally along the favorable beds in which the barite deposits now occur. These deposits form banded veins in coarse breccia and contain pyrite, fluorite, and barite listed in the order of deposition and increasing abundance. Monthly barite production of 3,400 tons in 1945 was derived entirely from residual deposits.

- 32 Durell, Cordell, 1954, Barite deposits near Barstow, San Bernardino County, California: Calif. Dept. Nat. Res. Div. Mines, Special Report 39, 8 p.

The geology of four barite mines and areas are briefly described: the Ball deposit, the Hansen deposit and vicinity, the deposits in the vicinity of the Barium Queen mine, deposits at the Lead Mountain mine and vicinity. Four detailed geologic maps are included.

- 33 Edmundson, R. S., 1936, Barite deposits of Virginia: Am. Inst. Min. Metall. Engineers Tech. Pub. 725, 17 p.

The descriptions of the individual mines are omitted from this condensed version of a later report (Edmundson, 1938). The occurrence, mineralogy, and origin of the deposits of Virginia are reviewed.

- 34 Edmundson, R. S., 1938, Barite deposits of Virginia: Va. Geol. Survey Bull. 53, 85 p.

The distribution, types of deposits, origin, and probable commercial value of barite deposits is discussed. Individual mines and prospects are described and a section on mining methods and prospecting is included. The deposits are in the Piedmont and Valley and Ridge provinces. Abundant small deposits of barite occur in bedrock in fissure veins, replacement masses, and in breccia zones. The most important of these deposits are lenticular replacement bodies up to 20 feet wide, 100 feet long and 150 feet thick in calcareous rocks. Breccia deposits contain thin seams of barite generally only a few inches wide. Bedrock deposits, because of their small size, are probably not of commercial value. Wall rock of these deposits includes pre-Cambrian marble, schist, and gneiss, Paleozoic limestone and dolomite, and Triassic shale, sandstone, and diabase. The author cites criteria considered indicative of an hydrothermal origin for these deposits. Residual deposits irregularly distributed in red or black clay in Grayson, Botetourt, Campbell, and Pittsylvania Counties might yield small commercial quantities of barite.

- 35 Emmons, W. H., 1910, A reconnaissance of some mining camps in Elko, Lander, and Eureka Counties, Nevada: U. S. Geol. Survey Bull. 408, p. 126.

At the Starr Grove mine about 15 miles southeast of Battle Mountain, barite occurs with quartz and small amounts of disseminated sulfides in a large flat ore body which lies nearly parallel to the enclosing dark gray limestone. In places "there is as much as 10 feet of nearly pure barite".

- 36 Espenshade, G. H., 1952, Manganese, iron, and barite deposits of the James River-Roanoke River district, Virginia: U. S. Geol. Survey Map MF 5.

A geologic map shows the location of barite deposits in the district. Barite has been found at about a dozen localities in the southern part of the district and also south of the Roanoke River in Pittsylvania County. The barite occurs in veins in white marble of Furcron's Mount Athos formation [Paleozoic(?)] and as fragments in overlying surficial and residual clays. Although the Hewitt mine is estimated to have produced about 100,000 tons of barite, most of the deposits in this district are believed to be rather small.

- 37 Evans, G. L., 1946, Barite deposits in Texas, in Sellards, E. H., and others, Texas mineral resources: Univ. Texas Pub. 4301, p. 105-111.

Deposits of barite in Texas occur in thin veins, replacement bodies, and as irregular masses in residual clay. The deposits are in rocks ranging in age from pre-Cambrian to Tertiary. Deposits in 13 counties are described. Only a few hundred tons have been mined from these deposits, many of which are too small to be of commercial value. A replacement deposit of relatively high grade barite in the limestone of the Permian Delaware Mountain formation near Seven Heart Gap, Culberson County, is described as "one of the most promising (deposits) now known in the state from the standpoint of possible commercial development". A large tonnage of low grade barite occurs as filling in limestone caverns near Pandale (Henry Mills ranch deposit), Val Verde County. This is the most complete reference on barite deposits in Texas.

- 38 Ferguson, H. W., and Jewell, W. B., 1951, Geology and barite deposits of the Del Rio district, Cooke County, Tennessee: Tenn. Dept. Conserv., Div. Geology Bull. 57, 235 p.

The barite deposits and geology of the district are described in detail. The district has yielded about 55,000 tons of barite from 12 mines and 5 major prospects since 1880. Geologic conditions indicate reserves of at least four times the amount already mined. The rocks include a clastic group of unknown age, a Lower Cambrian group of clastics, the Cambrian Shady dolomite and Rome formation. The principal barite deposits occur in the immediate vicinity of two prominent low angle thrust faults. High grade but comparatively small deposits of barite are found along a bedding plane fault beneath a prominent coarse-grained quartzite in the upper part of the Cambrian Unicoi formation. In these deposits white, coarsely crystalline barite, commonly containing 95 to 98 percent BaSO_4 , occurs with ankerite in pods, stringers, and veinlets in the fault zone. Mining has been chiefly along weathered portions of the vein where lumps of barite are in reddish-brown sandy clay. Larger low grade deposits containing 60 to 90 percent BaSO_4 are along the Brushy Mountain thrust, a zone of intense shearing with a maximum thickness of nine feet. The sheared granulated material is usually replaced by quartz discolored by blue-black hematite. Workable ore deposits occur where barite is concentrated locally with small amounts of fluorite, hematite, pyrite, and traces of chalcopyrite.

- 39 Fine, M. M., and Kennedy, J. S., 1948, Investigation of ore-dressing methods for barite ores from New Mexico, Missouri, and Arkansas: U. S. Bur. Mines Rept. Inv. 4280, 31 p.

The results of laboratory beneficiation tests on barite samples from five properties are described. Barite-fluorite ore from the Palm Park claims

near Hatch, New Mexico yielded acid-grade fluor spar and drilling-mud-grade barite by flotation and gravity concentration. Recovery of 86 percent of the barite and 76.5 percent of the fluorite was accomplished by flotation. Gravity concentration yielded slightly better recovery of barite but a much poorer recovery of fluorite. Ore with an unusually high content of iron from Washington County, Missouri yielded concentrates by flotation, magnetic separation, and agglomerate tabling. These concentrates contained less than 0.1 percent iron oxide. The flotation of ore with a high content of quartz and iron from central Missouri yielded a concentrate containing 1.1 percent iron oxide, and recovered 95.2 percent of the barite. With tabling and magnetic separation, 86.2 percent of the barite was recovered in a concentrate containing only 0.7 percent iron oxide. Samples from two producing properties at Magnet Cove, Arkansas contained soluble salts detrimental to flotation. Drilling-mud-grade barite was recovered by flotation after removal of most of the soluble salts by leaching and washing.

- 40 Fitch, A. A., 1931, Barite and witherite from near El Portal, Mariposa County, California: *Am. Mineralogist*, v. 16, no. 10, p. 461-468.

The mineralogy of the barite-witherite veins and their wall rocks near El Portal, California are described. A group of north-trending replacement veins up to 20 feet wide occur in the limestone lenses of isoclinally folded Paleozoic sedimentary rocks. These rocks, dominantly argillaceous, have undergone low-grade dynamic metamorphism and local contact metamorphism near the margin of a small granite boss. The veins which terminate at the contact with the intrusive change in composition and texture as the granite is approached. This change may be correlated with the degree of contact metamorphism of the wallrock. Barite and witherite in places occur together and are associated chiefly with quartz and pyrite. As the intrusive is approached, more coarse-grained calc-silicate minerals are developed in the veins with a corresponding decrease of barite and witherite. Barite and witherite are absent from the veins adjacent to the granite. The deposits may have formed by replacement of limestone lenses "by barium solutions given off from the underlying Sierra Nevada granite batholith."

- 41 Fohs, F. J., 1913, Barytes deposits of Kentucky: *Ky. Geol. Survey*, 4th ser., v. 1, pt. 1, p. 441-588.

The geology, mineralogy, mining, milling, production, and prospecting of the barite deposits are reviewed. A general section on the uses and occurrence of barite is also included. Deposits of commercial importance are reported in the Central and Western districts and in Union County where the deposits occur in veins in Ordovician and Carboniferous sedimentary rocks. The important Central district is discussed in detail including brief descriptions of nearly 200 prospects. Barite in the Central district is associated chiefly with calcite, fluorite, sphalerite, and galena in steeply dipping veins and breccia fillings in Ordovician limestone. Replacement of the wall rocks is of minor importance. The veins and breccia fillings are irregularly shaped and average two to four feet in width and 600 feet in depth. Production from the Central district was recorded every year from 1903 to 1911; the most productive year was 1908 when 11,000 tons were mined, ranking Kentucky as the third largest producer in the United States. A small tonnage was produced in the Western district in 1903 and 1907.

- 42 Frommer, D. W., and Fine, M. M., 1952, Experimental treatment of barite ores from Montgomery County, Ark., and Morgan County, Mo.: *U. S. Bur. Mines Rept. Inv.* 4881, 11 p.

Results of ore dressing studies on samples of barite ore from two undeveloped barite deposits in Arkansas and Missouri are described. Ore from Montgomery County, Arkansas consists of barite intimately mixed with finely crystalline quartz. Ore from near Stover and Versailles, Morgan County, Missouri consists of barite with considerable dolomite, sphalerite, chert, and quartz with lesser amounts of fluorite, sulfides, and iron oxides. Ores from both areas are amenable to concentration by fine grinding and froth flotation. The Arkansas ore yields barite concentrate suitably for use in drilling muds and the Missouri ore yields both zinc concentrate and barite concentrate the latter of which is suitable for manufacture of some barium chemicals.

- 43 Galbraith, F. W., 1947, *Minerals of Arizona*: Ariz. Bur. Mines, Geol. Ser. 17, Bull. 153, p. 62.

The location of important barite occurrences in Arizona are listed by counties.

- 44 George, R. D., 1927, *Geology and natural resources of Colorado*: Univ. Colorado, Boulder, Colo., p. 162.

The occurrence of "strong veins of barite in the vicinity of Boulder and Jamestown and near South Boulder Creek in Boulder County" are reported. Several carloads have been shipped from vein deposits in Sunshine Canyon west of Boulder. Barite has also been produced from mines near Aspen.

- 45 Gianella, V. P., 1940, *Barite deposits of northern Nevada*: Am. Inst. Min. Metall. Engineers Tech. Pub. 1200, 6 p.; 1941, *Trans.*, v. 144, p. 294-299.

Barite is widely distributed in at least nine counties. Annual production in 1938 and 1939 was over 15,000 tons and total production to the end of 1938 was 66,424 tons. Production has been principally from the northern part of Lander and Eureka Counties with a smaller amount from Elko County. The barite occurs in veins and replacement deposits. Barite in veins is generally white and is generally associated with sulfides. Most of the barite has been mined from open cuts in replacement deposits of dark barite in limestone beds of probable Carboniferous age. The deposits are believed to be of hydrothermal origin and are probably contemporaneous with some of the hydrothermal metallic ore deposits of the state. Nine principal deposits in northern Nevada are briefly described and located on an index map. This is the most complete reference available concerning barite deposits of Nevada.

- 46 Gildersleeve, Benjamin, 1946, *Minerals and structural materials of east Tennessee*: TVA Regional Products Research Div. Rept. B., p. 3-5.

In the Fall Branch district of Greene, Washington, and Sullivan Counties, workable deposits of barite occur as irregular masses in residual clays in the upper part of the Knox dolomite. The deposits are in a linear belt about 20 miles long. The deposits contain two distinct types of barite, an exceptionally pure black variety and a less pure white variety. There has been no production from the district in many years except for about 168 tons shipped in 1935. Vein deposits in lower Cambrian rocks have been worked intermittently for the past 25 years at several localities in Cocks County. A small deposit of relatively pure white barite in the residuum of the basal part of the Ordovician Murfreesboro limestone on the shore of the Lost Creek area of Norris Lake was developed in 1938. Other occurrences of barite in Johnson, Carter, Sevier, Hamblen, and Hawkins Counties are reviewed briefly.

- 47 Gildersleeve, Benjamin, 1946, Minerals and structural materials of the Watts Bar and Fort Loudon Reservoir areas: TVA Regional Products Research Div. Report No. 5, p. 2-5.

The occurrence and distribution of barite in the Sweetwater district of east Tennessee is described briefly. The location and a brief statement about the history of operation and production of the nine mines that yielded the major production from the district in the early part of 1943 are given. The location of five other mines abandoned or worked intermittently as of 1943 is included. Annual production in the area averaged 20,000 to 30,000 tons prior to 1940 and 60,000 tons in 1941 and 1942. Monroe County yielded 51,501 tons in 1942.

- 48 Gordon, C. H., 1918, Barite deposits of the Sweetwater district, east Tennessee: Tenn. Geol. Survey, Resources of Tenn., v. 8, no. 1, p. 48-82.

The geology and barite deposits of this district in parts of McMinn, Monroe, and Loudon Counties in eastern Tennessee are described in detail. The barite occurs in bedded veins or shattered zones in the Knox dolomite [Upper Cambrian and Lower Ordovician] and as masses in the residual clay derived from weathering of the dolomite. Only the residual deposits are of commercial importance. They occur along three northeastward trending narrow parallel belts about 20 miles long. Workable ore bodies appear only at intervals along the ore belts which are usually from 100 to 300 feet wide. In many places six to eight feet of alluvial red clay overlies the barite-bearing residual clay. The chief impurities in the ore are fluorite, chert, and iron oxide. Small amounts of sphalerite, galena, calcite, and manganese oxide are also found. The primary deposits are believed to have been deposited within breccia zones of the Knox dolomite by solutions that had leached the barium from the dolomite and associated limestones. The principal mines along the three barite belts are described. The history of mining in the district and the mining and preparation of the ore for market are discussed. Only the high grade (98-99% BaSO₄) barite is marketed. A table showing the amount of crude barite marketed in Tennessee from 1903 to 1916 is included.

- 49 Gordon, C. H., 1920, Barite deposits in upper east Tennessee: Tenn. State Geol. Survey Bull. 23 (Pt. 1, Ann. Rept. 1919), p. 65-70.

Barite deposits of upper east Tennessee are of two types—irregular fissure and gash veins in crystalline rocks, and residual deposits in breccia veins in limestones. Vein deposits occur in the vicinity of Del Rio, and residual deposits occur in several places in Greene County. The Del Rio region is underlain by quartzites and slates of Cambrian age. The Pond Ridge prospects about 1½ miles north of Del Rio yielded a small tonnage years ago. Considerable ore was mined from a vein deposit of hard crystalline barite in masses and stringers imbedded in clay at West Meyer 2½ miles east of Bridgeport. At East Meyer pure, hard crystalline barite was mined from a bedding plane vein in quartzite and conglomerate. A vein deposit at Rock Creek, four miles from Del Rio, was worked some years ago. In Greene County, four deposits all in residual clays overlying the Knox dolomite [Upper Cambrian and Lower Ordovician] formerly were worked. These deposits are in the vicinity of Greeneville, Jearoldstown, Midway, and Morristown. Indications appear favorable for the existence of workable bodies of barite in the vicinity of Jearoldstown.

- 50 Hale, D. P., Jr., 1938, Modern mining and beneficiation of barite at Cartersville, Georgia: Am. Inst. Min. Metall. Engineers Tech. Pub. 973, 13 p.; 1942, Trans., v. 148, p. 277-290.

Opencut mining and beneficiation of residual barite ore in the Cartersville district, Bartow County, Georgia are discussed. Overburden averaging 12 to 15 feet thick is removed by stripping. Hydraulic mining has been used successfully for recovery of the fines impounded in old mud ponds and in one mine where large limestone pinnacles were encountered in the residual clay. The chief impurities in the ore are silica and iron oxide. Silica is easily removed by washing and jigging. Manganese, where present, is separated by gravity methods. Since 1931 greater recovery of barite and a final product of higher grade has been made possible by finer crushing, tabling, and use of magnetic separators for removal of iron. Use of these improved methods has permitted mining in large areas previously considered unworkable and had more than doubled the reserves of minable ore as of 1938. Ore from Cartersville has been consumed chiefly by the lithopone and barium chemical industries.

- 51 Ham, W. E., and Merritt, C. A., 1944, Barite in Oklahoma: Okla. Geol. Survey Circ. 23, 42 p.

Barite occurrences in Oklahoma and general information on barite are reviewed. The deposits are either too small or of too low grade to be of commercial value as of 1944. The deposits are of 3 general types: 1) hydrothermal veins, 2) residual deposits and 3) sedimentary deposits. Hydrothermal veins containing small amounts of barite and metallic sulfides cut highly folded shales and quartzitic sandstones of the Stanley [shale of Pennsylvania age] in the Ouachita Mountains in northeastern McCurtain County. Coarsely crystalline masses of barite associated with ocherous limonite are embedded in clays derived from weathering of Cambrian and Ordovician dolomite in the Arbuckle Mountains of south-central Oklahoma. The lower Permian shales and sandstones of central and southwestern Oklahoma contain disseminated grains, concretions, and veins of barite. Some barite may form a cementing agent. Surface concentrations of high grade concretionary nodules in a few localities may offer the possibility for limited production of several thousand tons. The barite in these Permian sedimentary rocks may have been introduced as a secondary concentration from marine water.

- 52 Harding, A. C., 1941, Ground barytes for weighting drilling mud: Eng. and Min. Jour., v. 142, no. 1, p. 33-36.

Barite deposits and mining and milling practices at the National Lead Co. plant near El Portal, Mariposa County, California are reviewed. The deposit has been worked continuously since 1910; in 1941 it was the largest deposit west of the Rockies and yielded the only commercial witherite in the United States. The chief product is ground barite for use in drilling mud. Barite and witherite associated with silica and calcium carbonate occur in vertical shoots or lenses in two distinct belts each about 200 feet wide and 1200 feet apart in steeply dipping metamorphosed sedimentary rocks. Both mineralized belts are cut by the Merced River Canyon. Lenses on the south side of the river contain principally barite and those on the north side contain a higher percentage of witherite. Contacts of the ore with the wall rock of siliceous limestone and schist are generally sharp. The deposits have been worked to a depth of 350 feet without reaching their lower limit. The origin of the deposit is attributed to replacement of limestone lenses by barium sulphate and carbonate.

- 53 Harding, A. C., 1948, Barite production in the United States: Am. Inst. Min. Metall. Engineers Tech. Pub. 2414, 6 p.

The geology and mining and milling operations at the major barite deposits in the United States are described briefly. Production and consumption of barite in 1945 and specifications for the various grades of barite ore used in different industries are listed. It is estimated that inferred reserves at properties now in production or being developed would yield at least a supply for 20 years at the rate of consumption in 1948.

- 54 Harness, C. L. and Barsigian, F. M., 1946, Mining and marketing of barite: U. S. Bur. Mines Inf. Circ. 7345, 78 p.

Information about the geologic occurrence, mining, treatment, and production of barite ore at all major barite mines or districts in the United States is summarized. Mining and methods of preparation of ore for the market are described. Uses of barite, specifications of barite ore for different uses, prices, marketing, and manufacture and utilization of barium chemicals are reviewed.

- 55 Heck, E. T., 1940, Barium in Appalachian salt brines: Am. Assoc. Petroleum Geologists Bull., v. 24, no. 3, p. 486-493.

Appreciable amounts of barium have been found in many [Appalachian] brines from rocks of Silurian, Devonian, Mississippian, and Pennsylvanian age in the Appalachian region. Brines from productive oil and gas areas contain the highest percentage of barium. The barium is believed to have been present in barite in the sediments and was brought into solution by reduction of BaSO_4 , probably by the action of bacteria.

- 56 Hewett, D. F., and others, 1936, Mineral resources of the region around Boulder Dam: U. S. Geol. Survey Bull. 871, p. 149-151.

Occurrences and deposits of barite in the region around Boulder Dam in adjacent parts of California and Nevada are noted briefly. Barite is common particularly as a gangue mineral in Tertiary metal veins in some parts in the region. Five deposits are described in which barite occurs in veins or as replacements. "Most of the deposits are relatively small and of poor quality." Small production has been reported from a few properties and "with sufficient demand a moderate production might be made."

- 57 Hill, J. M., 1917, Barytes and strontium, [in 1915] in Mineral resources of the United States, 1915, pt. 2—nonmetals: U. S. Geol. Survey, p. 161-185.

In addition to the usual statistics on annual production, consumption, and exports and imports of barite, the principal known deposits in the United States as of 1915 are described by States and are shown on a map on which are also indicated the location of plants manufacturing barium products. Methods of mining and preparation of barite for market are discussed. This reference is the most complete summary available as of 1915 concerning the production of barite in the United States.

- 58 Howland, A. L., 1936, An occurrence of barite in the red beds of Colorado: Am. Mineralogist, v. 21, no. 9, p. 584-588.

A small deposit two miles southwest of Hartsel, Park County, is described. In 1932 development work consisted of pits of various size from which some barite had been mined. Further development was done in 1934 and 1935. It is not known whether commercial ore was produced. The barite occurs as a replacement in vertical veins one to two feet wide and in irregular layers six inches to three feet wide in gently dipping beds of a limestone

member of the Maroon formation [of Pennsylvanian and] Permian age. The barium is believed to have been leached from the surrounding sediments by meteoric waters and precipitated by reaction with gypsum in the limestone.

- 59 Hubbell, A. H., 1942, New Riverside - producer of barytes in Georgia: Eng. and Min. Jour., v. 143, no. 10, p. 62-65.

Mining and milling operations of the New Riverside Ochre Co. in Bartow County, Georgia are summarized. Barite occurs irregularly distributed in clay, eight tons of which will yield an average of one ton of washed barite. Concentrations of barite are pockety and hard to find because overburden may be as much as 60 feet thick. The flow sheet of the washing plant is described in detail. The final products are of three grades: 1) drilling mud, 92 percent BaSO_4 with 5 percent iron; 2) lithopone, 96 percent BaSO_4 with not more than 1.0 percent iron; and 3) glass, 98 percent BaSO_4 with not more than 0.3 percent iron.

- 60 Hubbell, A. H., 1943, Barytes—a non-metallic product of eastern Tennessee: Eng. and Min. Jour., v. 144, no. 1, p. 63-65.

Mining and treatment of barite ore from residual deposits in the Sweetwater district of Tennessee and in Bartow County, Georgia are discussed. In the Sweetwater district, overburden as much as 40 feet thick is stripped from the ore-bearing clays which may be as much as 30 feet thick. Each mine generally has its own washing plant. In some operations the washed product may be subsequently cleaned of the remaining iron by tabling, drying, sizing, and magnetic separation. In Bartow County, Georgia, on property operated by the Barytes Mining Co., overburden is 10 to 30 feet thick and the underlying ore-body is over 50 feet thick. Although the barite content of this deposit is slightly less than that of the Tennessee mines, the output is more uniform. Mining and treatment of ore is essentially the same as in Tennessee. A high grade product containing 96 percent BaSO_4 or more and a low grade product containing 92 percent BaSO_4 are produced.

- 61 Hull, J. P. D., 1920, Barytes deposits of Georgia: Ga. Geol. Survey Bull. 36, 146 p.

Occurrence, distribution, origin, production, and mining and milling of barite in Georgia are discussed. The stratigraphy and structure of the Cartersville district are described in detail. More than 60 individual mines and prospects in Bartow, Murray, Whitfield, Gordon, Floyd, Cherokee, and Polk Counties are described. The deposits are of the following types: 1) vein, 2) replacement, 3) breccia, 4) residual, 5) colluvial or residual hillside, and 6) alluvial. The primary deposits (types 1, 2, and 3) occur in pre-Cambrian igneous rocks and Paleozoic sediments. Barium is believed to have been leached from feldspars and mica in the crystalline rocks by circulating meteoric and thermal waters which moved upward along fault and fracture openings to carbonaceous sediments where precipitation of barite occurred. Vein deposits have been worked on a small scale but only the residual and colluvial deposits are of economic importance. The deposits occur almost wholly in the Appalachian Valley region of north-west Georgia in a belt 75 miles long with a maximum width of 25 miles near its center. All the large deposits which have been worked are in the Cartersville district. From 1916 to 1919 Georgia ranked first in production of barite in the United States. Production in 1919 was estimated at 90,000 tons, all from the Cartersville district.

- 62 Hunter, C. E., and Gildersleeve, Benjamin, 1946, *Minerals and structural materials of western North Carolina and north Georgia: TVA Regional Products Research Div. Rept. C*, p. 9-10.

Barite deposits in Gaston and Madison Counties are described briefly. Extensive vein deposits of white barite occur in Gaston County, extending from a point four miles south of Bessemer City to the South Carolina state line. Deposits in the Stackhouse area of northwestern Madison County have intermittently yielded an estimated production of 300,000 tons between the latter part of the nineteenth century and 1927. The barite occurs in veins mainly in a fault zone between the [pre-Cambrian] Max Patch granite and the Cambrian Snowbird [formation]. This area, adjacent to the Del Rio district of Tennessee, is believed to contain large reserves of "rather pure" barite.

- 63 Jenkins, O. P., and others, 1949, *The counties of California—mineral resources and mineral production during 1947: Calif. Dept. Nat. Res. Div. of Mines Bull. 142*, p. 13 and pls. 1 and 4.

The report which in past years has been issued as an annual statistical bulletin known as "Mineral Production of California", has been issued this year with special emphasis on the mineral resources of the counties of California. Production of barite is reported from single properties in Mariposa and Plumas Counties. Barite from Mariposa County was used chiefly for drilling mud and that from Plumas County was used for the manufacture of barium chemicals. A map of California locates barite deposits in 12 counties.

- 64 Jewell, W. B., 1947, *Barite, fluorite, galena, sphalerite veins of Middle Tennessee: Tenn. Dept. Conserv., Div. Geology Bull. 51*, 114 p.

The location, geologic occurrence, and methods of mining small deposits of barite, fluorite, sphalerite, and galena in fissure veins of middle Tennessee are discussed in detail. Mines and prospects also are described. Most of the deposits occur within a 20 mile radius of the intersection of DeKalb, Smith, and Wilson Counties in the Ordovician limestones of the Nashville dome. The veins, which range from a few inches to six feet in width, occur chiefly as fillings in limestone breccia in steeply dipping shear zones which trend northeast. Replacement of the wall rock by barite has been small. Barite is one of the most abundant minerals in the veins; in places it makes up almost the entire vein filling. The barite is generally granular or massive and is often intimately mixed with fluorite and calcite. The vein material is believed to have been deposited from rising magmatic solutions of probable post-Carboniferous age. Only small amounts of lead, zinc, barite, and fluorite have been produced from the area. In 1934 two carloads of barite were shipped from Davidson County and further production may be feasible on a small scale. The veins have not been adequately prospected.

- 65 Johnson, B. L., 1941, *Marketing of barite: U. S. Bur. Mines Inf. Circ. 7149*, 16 p.

General information is presented about the uses, production, markets, and prices of crude barite. Also included is a list of barite producers, buyers, grinders, and producers of barium products, arranged by states.

- 66 Jones, T. A., 1948, *Barite deposits in the Ouachita Mountains, Montgomery, Polk, and Pike Counties, Ark.: U. S. Bur. Mines. Rept. Inv. 4348*, 15 p.

Ten barite deposits in the Ouachita Mountains of western Arkansas, which were investigated by the U. S. Bureau of Mines in 1946 and 1947, are described. The deposits occur as lenticular bodies of impure barite near the contact of the Stanley shale of Pennsylvanian age and Arkansas novaculite of Devonian [and Mississippian] age in beds of both formations. The deposits are associated with the Mazarn syncline. The Bear Creek prospect in Pike County contains boulders of crystalline barite in residual clay of the Stanley shale; it is the only residual deposit known in the area. At the Pigeon Roost Mountain deposit in southeastern Montgomery County, barite occurs in three lenticular bodies near the base of the Stanley shale. This deposit is near the axis of the Mazarn syncline and is the largest yet found in the area. Barite in the deposits of this area would be suitable for use in drilling mud.

- 67 Jones, W. B., and McVay, T. N., 1934, Barite deposits of the Sinks district, Bibb County, Alabama: *Econ. Geology*, v. 29, no. 8, p. 761-766.

Barite deposits in the northeast corner of Bibb County in central Alabama are described. Barite in veins and cavities in Ordovician limestone is associated with fluorite, calcite, limonite, and native sulfur. Hydrothermal origin is advocated because of the intimate association of barite with fluorite. Residual deposits derived from the primary deposits have a much higher content of barite than other deposits mined in the past in Alabama. The authors believe that these deposits may be profitably mined.

- 68 Julihn, C. E., and Horton, F. W., 1940, Mineral industries survey of the United States: *U. S. Bur. Mines. Bull.* 424, pt. II, p. 168-170.

Barite deposits at the El Portal and Egenhoff mines near El Portal, Mariposa County, California are described. Mining and milling at the El Portal mine of the National Lead Co. is summarized. Large quantities of high grade barite and witherite have been developed by crosscuts at the Egenhoff mine.

- 69 Just, Evan, 1943, An Arkansas travelogue: *Eng. and Min. Jour.*, v. 143, no. 12, p. 64-65.

The mining and milling operations at Magnet Cove are described briefly. Barite occurs as a replacement near the base of the Stanley shale (Pennsylvanian) in a syncline plunging southwestward. At the National Lead Co. mine near the eastern end of the syncline, the southern limb of the fold is nearly vertical and the northern limb dips 40° south. At the mine, the barite horizon in the bottom of the fold is 200 feet beneath the surface. The barite deposit, 40-75 feet thick, is mined in an open cut about 500 feet long. After milling, the barite in the ore is then concentrated by flotation to yield a product with a specific gravity of 4.35 used entirely for drilling mud.

The smaller open pit mine of the Magnet Cove Barium Corp. is adjacent to the National Lead Co. mine. The mill is in nearby Malvern where ore is concentrated by a flotation process which floats barite, in contrast to the process used by National Lead Co. in which the barite is depressed.

- 70 Just, Evan, 1948, Barite production upheld by improved equipment: *Eng. and Min. Jour.* v. 149, no. 1, p. 71-73.

The use of modern earthmoving equipment and more efficient beneficiation methods in the old Washington County, Mo. barite district have enabled operators to obtain a greater recovery per acre, and to rework many

areas previously mined by primitive methods. Residual barite occurring with soil and gangue in a ratio of approximately 1 to 10 is dug from pits with diesel power shovels, and hauled by trucks a short distance to movable washing plants. The mill flowsheets of two operations are given.

- 71 Keith, Arthur, 1904, Asheville folio North Carolina-Tennessee: U. S. Geol. Survey Geol. Atlas, folio 116, p. 9.

Small irregular veins of barite generally only a few inches wide occur in a narrow zone extending about five miles northeast from Bluff, Madison County. The veins occur in granite and quartzite near the contact of the two rock types. In 1904 the deposits on Spring Creek were the only ones being mined in the area. Mining was done chiefly in open cuts. A "considerable amount" of barite is reported to have been mined about one mile southeast of Stackhouse.

- 72 Kesler, T. L., 1940, Structure and ore deposition at Cartersville, Georgia: Am. Inst. Min. Metall. Engineers Tech. Pub. 1226, 18 p.; 1941, *Trans.*, v. 144, p. 276-293.

The general geology and ore deposits of the Cartersville district are described, with emphasis on the relation of structure to ore deposition. Deposition of ore was controlled by rock composition and structure. Hydrothermal solutions of magmatic origin ascended to the carbonate rocks of the district along steep oblique fault planes and fractures in a highly folded zone of the Weisner formation and Shady dolomite of Early Cambrian age. Ore deposition occurred chiefly in the carbonate rocks of the Shady dolomite rather than in the quartzites and schists of the underlying Weisner formation. Examples of structural control in four areas in the district are described. The currently mined barite ores are principally surficial weathered products of the primary deposits.

- 73 Kesler, T. L., 1949, Occurrence and exploration of barite deposits at Cartersville, Georgia: Am. Inst. Min. Metall. Engineers *Trans.*, v. 184, p. 371-375.

The geology of the residual barite deposits of the district are described briefly. The primary ore is localized in three differently oriented groups of faults. The search for new ore in the residual clay may be guided by projecting the trend of the fault zones seen in outcrops of the Weisner formation along the ridge crests across the areas of residual clay. Because many of the good deposits on the surface or at shallow depth have been found, prospecting by drilling at greater depths is necessary. The problems of drilling and the methods of interpreting the resulting data compiled by the Paga Mining Company are reviewed.

- 74 Kesler, T. L., 1950, Barite deposits southeast of the Appalachian plateaus, in Snyder, F. G., ed., *Symposium on mineral resources of the southeastern United States*, p. 88-98: Univ. Tenn. Press, Knoxville, Tenn.

The occurrence and origin of the major barite deposits in the southeastern United States are summarized from the reports of recent workers in the region. The areas discussed include the Cartersville district and other areas, Georgia; the Sweetwater and Del Rio-Hot Springs districts, Tennessee; the Central Carolina district in North and South Carolina; and areas in Alabama. Most workers believe that the barite and associated minerals were deposited by hydrothermal solutions of magmatic origin. Laurence and Dunlap attribute ore deposition in the Sweetwater district to thermal

waters but do not specify their source. Although igneous rocks are not obviously associated with most of the deposits, a magmatic source for the ore bearing fluids is suggested by the similarity of their mineralogy to metalliferous deposits of undoubted hydrothermal origin. Evidence suggests that more than one period of barite mineralization occurred. Most investigators believe the deposits are late Carboniferous; Edmundson believes that the deposits in Virginia are Triassic in age.

- 75 Keeler, T. L., 1950, Geology and mineral deposits of the Cartersville district, Georgia: U. S. Geol. Survey Prof. Paper 224, 97 p.

The geology and ore deposits of this district in northwest Georgia are described. By the end of 1943, the district had yielded about 1,830,000 long tons of barite representing 24 percent of the total production of the United States. Rocks of the district are Cambrian metasedimentary rocks of the Weisner, Shady, Rome, and Conasauga formations and feldspathic gneisses derived from them. These rocks are folded into major anticlinoria and synclinoria that extend beyond the limits of the district. The primary ore and gangue minerals were deposited by hydrothermal solutions in steeply dipping faults which trend roughly parallel and oblique to the axis of the major folds. Primary barite occurs as thin veins and irregular bodies principally in carbonate rocks of the Rome formation. The barite which is coarsely crystalline encloses small amounts of pyrite and other sulfides and is associated with quartz and carbonates. Weathering of these primary deposits has freed the barite which remains as fragments $\frac{1}{4}$ to 6 inches across distributed unevenly through the residual clay. Pyrite enclosed by the barite is usually weathered to limonite, and angular boulders of jasperoid commonly accompany barite in the clay. These deposits constitute the barite ore of the district and are mined in open cuts. The average proportion of recoverable barite in clay in large deposits ranges from 11.8 to 17.5 percent. The deposits are believed to be "far from exhausted; but—their recovery will generally involve a gradual increase in mining costs." Nine major barite mines are described and a table summarizes data on 35 barite mines that have been commercially productive.

- 76 Kidwell, A. L., 1946, Blue barite from Texas County, Mo.: Rocks and Minerals, v. 21, no. 12, p. 849-850.

An abandoned open-pit barite mine six miles southwest of Houston, Texas County is the only known commercial barite deposit within a radius of 60 miles. Blue barite associated with limonite and calcite occurs as a filling which cements large blocks of dolomite in a collapsed solution cavity. The country rock is Jefferson City dolomite [Ordovician] containing chert and drusy quartz. This deposit was last operated during 1941 and 1942 by the Murphy Mining Company.

- 77 Knechtel, M. M., and others, 1948, Map showing construction materials and nonmetallic mineral resources of Montana: U. S. Geol. Survey Missouri Basin Studies Map no. 11.

A map shows the location of barite deposits in Glacier National Park and Missoula County. Very little barite has been produced in Montana but occurrences of residual barite in Upper Cretaceous clays are reported in Missoula and Lincoln Counties. Barite deposits are also known in Custer, Wibaux, Dawson, Musselshell, Pondera, Madison, and Phillips Counties.

- 78 Kiilsgaard, T. H., 1950, Geology and ore deposits of the Triumph-Parker mine mineral belt, in Anderson, A. L., and others, Detailed geology of certain areas in the Mineral Hill and Warm Springs mining districts, Blaine County, Idaho: Idaho Bur. Mines and Geology Pamph. 90, p. 60.

The Sun Valley barite mine (Bonnie group) about nine miles northwest of Hailey, has been operated intermittently during recent years, and was under lease to the Simplot Co. in 1950. The barite occurs as a series of lenticular masses in the Wood River formation [Pennsylvanian]. Ore is shipped by rail to the mill in Pocatello where it is prepared for use in drilling mud. Selective mining to control contamination by silica yields an ore containing 84 to 88 percent BaSO_4 with a specific gravity of 4.0 to 4.1. In 1949, 6,700 tons of barite were produced.

- 79 Kottlowski, Frank E., 1953, Geology and ore deposits of a part of the Hansonburg mining district, Socorro County, New Mexico: N. Mex. Bur. Mines and Mineral Res. Circ. 23, 9 p.

Data are supplied to aid exploration of the barite-fluorite-galena ore bodies on the west face of the Oscura Mountains. Stratigraphy, structure, and the nature of the ore deposits are described briefly. The ore is localized in fracture zones and solution cavities in limestones of Paleozoic age.

- 80 Ladoo, R. B., and Myers, W. M., 1951, Nonmetallic minerals: New York, McGraw-Hill Book Co., Inc., p. 67-82.

General information on barite is given: occurrences, production, consumption, mining, milling, ore specifications, marketing, and uses. Short descriptions of principal deposits in the United States and other countries are included. Tables show world production of barite from 1942 to 1948; salient statistics of barite, witherite, and barium chemical industries in the United States from 1944 to 1948; domestic barite sold or used by producers in the United States from 1946 to 1948 by states. A brief section on witherite is included. The bibliography contains 42 references on barite and witherite.

- 81 Larrabee, D. M., and others, 1947, Map showing construction materials and nonmetallic mineral resources of Colorado: U. S. Geol. Survey Missouri Basin Studies Map no. 10.

On the map are indicated the location of barite deposits in Custer, Park, and Lake Counties. The text states that barite occurs in Boulder, Custer, Lake, Las Animas, Park, Pitkin, and Pueblo Counties. Deposits have been developed in Boulder, Custer, and Park counties. Small production from veins and layers in limestone has been recorded in 1915, 1916, and 1939 to 1941.

- 82 Laurence, R. A., 1938, Black barite deposits in upper east Tennessee: Tenu. Acad. Sci. Jour., v. 13, no. 3, p. 192-197.

Deposits of large, crystalline masses of exceptionally pure, dark barite occur in residual clay in the Fall Branch district of upper east Tennessee. The deposits are associated with a thrust fault in the upper Knox dolomite ("Post-Nittany") [Upper Cambrian and Ordovician] and form a long narrow belt extending northeastward through Greene, Washington, and Sullivan Counties. Associated deposits of white barite with sphalerite and galena are found in residual clay and in veins and breccia zones in the underlying dolomite. The black barite, which apparently occurs only in the residual clay, is more pure than the white barite. The dark color and fetid odor are

attributed to small amounts of carbonaceous material on cleavage and fracture planes. The black barite is stable while enclosed in residual clay but will decrepitate readily at low temperatures. Stockpiles exposed to summer sun have disintegrated almost to powder in a short time. White barite was mined in the district in the late 1890's and during World War I. In 1935 about 170 tons of chiefly the black barite were shipped from the district. No production has been recorded since that time. In spite of the purity of the deposits, they are probably not of much commercial value because of their small size and scattered distribution.

- 83 Laurence, R. A., 1939, Origin of the Sweetwater, Tennessee barite deposits: *Econ. Geology*, v. 34, p. 190-200.

This important district had produced about 600,000 tons of barite by 1938. The residual deposits which occur along three parallel belts are underlain by irregular fissure veins in the [Ordovician] Beekmantown limestone. The chief vein minerals, in order of their deposition, are calcite, pyrite, fluorite, and barite. The veins are simple fissure fillings and occur in coarsely crystalline dolomite produced by alteration and recrystallization of limestone. The alinement of the deposits parallel to the regional strike of the country rocks suggests mineralization was restricted to openings created by shattering and brecciation of certain favorable beds. The deposits are believed to have been formed by ascending thermal waters of magmatic or meteoric origin. Igneous rocks are absent from the district.

- 84 Lewis, J. V., 1919, The magmatic origin of barite deposits: *Econ. Geology*, v. 14, no. 7, p. 568-570.

The localization of barite deposits in a disturbed belt extending from southeastern Missouri to north-central New York is noted. The belt is characterized by anticlinal folds, faults which are cut by basic dikes, veins, and breccias containing barite, fluorite, and sulfides. The barite and associated deposits in this belt are believed related to igneous activity which is not necessarily of the same age in all localities. Barite occurrences in Triassic shales and diabase in New Jersey are believed related to the Late Triassic igneous activity in that region.

- 85 Lindgren, Waldemar, 1926, Ore deposits of the Jerome and Bradshaw Mountains quadrangles, Arizona: *U. S. Geol. Survey Bull.* 782, p. 128-129.

A vein reported to be 15 to 20 feet wide containing much barite and manganeseiferous ankerite and minor amounts of galena and sphalerite was worked at the Silver Belt mine in the late 1870's and in 1906 for silver and lead ore.

- 86 Logan, C. A., 1941, Mineral resources of Nevada County: *Calif. Jour. Mines and Geology*, v. 37, no. 3, p. 378-379.

The Democrat barite mine near Alta in Nevada County is reported to have been one of the largest sources of barite in the state between 1919 and 1930. The ore body was 250 feet long and 15 to 24 feet wide near the surface. The mine had not been worked for several years prior to 1941. The Spanish barite deposit about five miles west of Graniteville was being developed in 1940 and was reported to contain several hundred thousand tons of barite. Ore is hauled 20 miles to Emigrant Gap for shipment.

- 87 McCallie, S. W., 1926, Mineral resources of Georgia: *Ga. Geol. Survey Bull.* 23, revised edition, p. 12-15.

The information of reference 61 is briefly summarized. Statistics on production of barite in Georgia from 1919 to 1924 are presented along with a list of producers as of 1926.

- 88 McElwaine, R. B., 1946, Exploration for barite in Hot Spring County, Arkansas: U. S. Bur. Mines Rept. Inv. 3963, 21 p.

The geology and development of Magnet Cove barite deposit are reviewed along with the results of U. S. Bureau of Mines drilling project conducted in 1944 and 1945 to determine reserves and extent of the deposit. A geologic map shows the location of the 10 completed diamond drill holes; The logs of all holes and analyses of barite penetrated are also included. Results of drilling indicate a large tonnage of ore in reserve. Mine workings and mining methods are briefly described.

- 89 McElwaine, R. B., 1946, Exploration of barite deposits in Montgomery County, Ark.: U. S. Bur. Mines Rept. Inv. 3971, 24 p.

The results of exploration of the Gap Mountain, Fancy Hill, and Sulphur Mountain barite deposits by the U. S. Bureau of Mines in 1945 are listed. These deposits occur as lenticular replacement bodies near the base of the highly folded Stanley shale [Pennsylvanian] and in the upper part of the underlying Arkansas novaculite of Devonian [and Mississippian] age. The barite is exposed along the sides of parallel west-trending ridges of the Ouachita Mountains. The barite is similar to that at Magnet Cove and is amenable to concentration by flotation. Exploration indicates the existence of an "appreciable amount of barite suitable for commercial use." The report includes diamond drill core logs, analyses of barite samples, cross sections of trenches, and sketch maps of the deposits. Geologic conditions in the surrounding area indicate that additional deposits may be found. Suggestions for prospecting are given.

- 90 Marbut, C. F., 1907, The geology of Morgan County: Mo. Bur. Geology and Mines, 2d ser., v. 7, p. 86-87.

Brief descriptions of four barite deposits mined in 1907 are presented. The barite, associated with galena, occurs in pocketlike masses in clay derived residually from the Gasconade dolomite [Ordovician].

- 91 Mather, W. B., 1946, The mineral deposits of Morgan County, Missouri: Mo. Geol. Survey and Water Res. Rept. Inv. 2, 207 p.

Barite has been produced intermittently since 1870 from deposits in Morgan County, in the geographic center of the Central Missouri barite district. Greatest activity was between 1935 and 1942. Barite occurs in fissure breccia, circle, and residual deposits. Production has been chiefly from the last two types, the residual deposits yielding the larger amount. Individual mines and prospects are described and located on the map.

- 92 Mather, W. B., 1947, Barite deposits of central Missouri: Am. Inst. Min. Metall. Engineers Tech. Pub. 2246, 15 p.; Trans., v. 173, p. 94-108.

Barite is mined from small, high grade, relatively deep, isolated circle, replacement, and residual deposits. Mining operations are small because the deposits are small and scattered. The ore is mined in open pits and is concentrated by crushing and jigging. Concentrates contain 97 to 98 percent barite. Production from the district in 1946 was less than 10,000 tons. The deposits occur chiefly in the dolomites and limestones of the Gasconade, Roubidoux, and Jefferson City formations of Ordovician age and in the Burlington limestone of Mississippian age. Six transitional types of deposits are recognized: fissure, breccia, circle, solution channel, replacement, and residual. The circle and residual deposits are commercially the most important. The diameter of the circle deposits ranges from 60 to 300 feet. The ore containing from 20 to 30 percent barite by

weight, has been mined to a depth of 100 feet. (See also Mather, 1946.) The richest residual deposits are derived from weathering of circle and replacement deposits. Evidence is cited to support the author's belief that the barite and associated sulfides were deposited from relatively cool hydrothermal solutions.

- 93 Mather, W. B., 1950, Nonmetalliferous mineral resources in Arkansas: Am. Inst. Min. Metall. Engineers Trans., v. 187, p. 582-583.

The deposits of commercial barite and their reserves are reviewed. Arkansas has been the principal barite producer in the United States since 1945. Production has been from a synclinal replacement deposit near Magnet Cove, mined by the National Lead Co. and the Magnet Cove Barium Corp. Barite apparently has replaced carbonate-rich zones at the base of the Stanley shale [Pennsylvanian]. The ore-bearing zone is 35 to 45 feet thick and averages about 67 percent $BaSO_4$. Ore is mined in open pits and underground. Barite is concentrated by flotation and is used almost entirely for drilling mud. This deposit was estimated to contain 8,400,000 tons of reserves as of January 1949. Smaller deposits of similar type have been prospected in Montgomery, Polk, and Pike counties. Reserves for the entire state were estimated to be 15,000,000 tons of ore containing more than 40 percent barite as of January 1949.

- 94 Munyan, A. C., 1951, Geology and mineral resources of the Dalton quadrangle, Georgia-Tennessee: Ga. Geol. Survey Bull. 57, p. 100-101.

A small open pit mine yielded barite for a short time in 1948. The deposit near Camp Ground Mountain, east of Eton, consists of "considerable quantities of small barite nodules" in sandy residuum between pinnacles of Conasauga limestone [Cambrian] which contain thin veinlets of barite. The mine was not successful and has not been operated since 1948. Other barite deposits in this region are described by J. P. Hull (1920). Barite deposits of the Dalton area appear to be small.

- 95 Murdoch, Joseph, and Webb, R. W., 1948, Minerals of California: Calif. Dept. Nat. Res. Div. Mines Bull. 136, p. 64-67.

Occurrences of barite are reported in 29 counties of California. The location and a bibliography are cited, where possible, for each occurrence. The geologic setting of the more important occurrences is briefly reviewed.

- 96 Murdock, T. G., 1950, The mining industry in North Carolina from 1937 to 1945: N. C. Dept. Conserv. Devel., Div. Mineral Res., Econ. Paper 65, p. 22-23.

Activity in the barite areas of North Carolina during 1937-1944 was restricted to the Hot Springs district, where the U. S. Bureau of Mines did core drilling on the Betts property. Small production was reported from a new locality near Stackhouse.

- 97 Norman, James, and Lindsey, B. S., 1941, Flotation of barite from Magnet Cove, Arkansas: Am. Inst. Min. Metall. Engineers Tech. Pub. 1326, 5 p.

Tests on beneficiation of barite ore from Magnet Cove are reviewed. The barite is intimately mixed with quartz, small amounts of iron oxide, and residual shale. Crude ore tested had a specific gravity of 4.03 and assayed 85.1 percent $BaSO_4$, 11.11 percent SiO_2 , and 2.85 percent R_2O_3 . After grinding the ore to 100 percent minus 325 mesh to liberate the barite and siliceous gangue, the minerals were separated by froth flotation, without desliming, using sodium silicate, a fatty acid, and pine oil as reagents. A

concentrate with a specific gravity of 4.395 and containing more than 98 percent BaSO_4 was produced while recovering about 90 percent of the barite in the mill-heads.

- 98 ∇ Northrop, S. A., 1944, Minerals of New Mexico: Univ. of New Mexico Press, p. 79-81.

Barite occurrences in 16 counties are listed. Barite is described as abundant in occurrences in Bernalillo, Dona Ana, Grant, Hidalgo, Sandoval, and Socorro Counties. It has been mined a few miles south of Barton, Bernalillo County, at Devil's Canyon mine, Dona Ana County, and in the Derry district, Sierra County.

- 99 ∇ O'Meara, R. G., and Coe, G. D., 1936, Froth flotation of southern barite ores: Am. Inst. Min. Metall. Engineers Tech. Pub. 678, 6 p.

Results of froth flotation experiments on samples of impure southern barite ores containing iron oxide, quartz, calcite, fluorite, and sulfides indicate that the ores can be beneficiated by flotation. The ores tested are identified only as southern barite ores from properties "either idle or hand-capped in their operations by the lack of satisfactory concentration methods."

- 100 Oriol, S. S., 1950, Geology and mineral resources of the Hot Springs window, Madison County, North Carolina: N. C. Dept. Conserv. Devel., Div. Mineral Res. Bull. 60, p. 48-52.

The occurrence, mineralogy, and origin of the barite deposits of the Hot Springs area are discussed. Descriptions of mines and prospects are included. Production has been largely from the Stackhouse and Gahagan mines and the A. G. Betts Sandy Bottom property. The barite occurs in veins, irregular masses, and small disseminations along thrust faults and in the adjacent wall rocks. Oriol believes that the barite associated with quartz, fluorite, sericite, hematite, pyrite, chalcopyrite, and calcite is of hydrothermal origin. The Stackhouse area is believed to contain large reserves of barite.

- 101 Ostrander, C. W., 1942, Barite prospect near Johnsville, Frederick County, Maryland: The Natural History Society of Maryland Bull., v. 12, no. 3, p. 44.

Small deposits of barite have been prospected and mined. A small lens-shaped deposit in limestone $1\frac{1}{2}$ miles southeast of Johnsville was worked many years ago and is reported to be "the only mine operated for barite in the State of Maryland."

- 102 Pallister, H. D., 1952, Barite in Alabama: Ala. Acad. Sci. Jour., v. 21, p. 45.

Production, location, geology, origin, reserves, and the future of the barite industry in Alabama are summarized briefly. Barite in veins and residual deposits occurs throughout the eastern part of State extending from near Centerville in Bibb County to near the Georgia State line in Cherokee County. Primary deposits occur as veins and breccia fillings and were probably formed by hydrothermal solutions. Residual deposits, some of large extent, were derived by weathering of pre-existing deposits. Although reserves of barite in Alabama are large and widely distributed, their economic value can be determined only by extensive prospecting. In 1952 several deposits were being considered for development, but no barite was produced in the State during the year.

- 103 Parks, Bryan, 1932, A barite deposit in Hot Spring County, Arkansas: Ark. Geol. Survey Inf. Circ. 1, 52 p.

Results of prospecting the Chamberlin Creek valley deposit near Magnet Cove, Hot Spring County are described. The barite occurs near the base of the Stanley shale [Pennsylvanian] in a syncline plunging to the west. The east end of the syncline is closed: the west end is cut by the intrusive rocks of Magnet Cove. The barite is considered a hydrothermal replacement of the porous beds at the base of the Stanley shale. The bed with barite on the north flank of the syncline is 44 feet thick and has been traced for three quarters of a mile. The deposit was estimated to contain at least one million tons of barite within 100 feet of the surface in an area of seven acres. The average of 15 chemical analyses of barite ore show 86.10 percent barium sulfate, 10.29 percent silica, 1.28 percent iron and aluminum oxides and small amounts of magnesia, calcium, and titanium oxides. Concentrates containing 97 percent BaSO_4 were obtained in flotation tests. No barite had been produced from the deposit as of 1932.

- 104 Parks, Bryan, 1932, Great barite deposit of Arkansas: Pan Am. Geologist, v. 57, no. 1, p. 329-332.

The geology and origin of the Magnet Cove barite deposit are discussed. A geologic map and cross section are included. This is a summary of the paper by Parks (1932).

- 105 Penhalegon, W. J., 1938, Barite in the Tennessee Valley region: TVA Geol. Bull. 9, 47 p.

The geology and barite deposits of five major districts and several less important areas in six States of the Tennessee Valley region are described briefly. A summary of the history of barite mining, beneficiation, and production in Tennessee, Georgia, Alabama, Virginia, and Kentucky is given. The Cartersville district, Georgia and the Sweetwater and Pall Mall districts, Tennessee were the chief producing areas in 1936. A table showing production of barite by years from 1882 to 1936 in States of the Valley region is included. Other tables show statistics on barium products sold and used in the United States. Mining and concentration of barite ore, chiefly in the Cartersville and Sweetwater districts, is discussed. A table showing the analyses of a wide variety of samples from five districts in the Valley region is included with a brief statement on buyer's specifications. The manufacture and uses of barium compounds are summarized.

- 106 Prater, L. S., 1948, Beneficiation tests on ore from the Sun Valley Barite mine, Blaine County, Idaho: Idaho Bur. Mines and Geol. Pamph. 81, 11 p.

Tests made on ore from the Sun Valley mine indicate that it may be beneficiated by flotation. Difficulty is experienced in obtaining a wettable product for use in drilling muds because of the film of fatty acid left on particles processed by flotation. The present practice of destroying the film by calcining is expensive. Tests were made to determine the feasibility of flotation at a coarser size followed by grinding to produce sufficient new wettable surfaces. Coarse particles could be floated but beneficiation is much poorer than with fine particles. The best means of obtaining a wettable barite product by flotation, without subsequent calcination, is to depress the barite and float the impurities.

- 107 Rankin, H. S., Laurence, R. A., Davis, F. A. W., Houston, E. C., and McMurray, L. L., 1938. Concentration tests on Tennessee Valley barite: *Am. Inst. Min. Metall. Engineers Tech. Pub.* 880, 13 p.; 1942, *Trans.*, v. 148, p. 291-303.

"Experiments were conducted to determine the application of decrepitation or flotation in simplifying the concentration of barite by removing the iron oxide and silica in one operation. Bleaching studies were made to determine the bleachability" of the off-color ores of the area. A brief description is given of the geology and barite deposits of the Sweetwater, Pall Mall, and Fall Branch districts of Tennessee from which were obtained the samples used in the tests. Ores from the Sweetwater district yield to decrepitation "to give concentrates of commercial quality, but with rather low recoveries". Ores from the other districts "either failed to decrepitate at all or decrepitation was so slight as to be of little interest as a concentrating operation." Froth flotation tests on ore from the Sweetwater district showed that "barite could be floated to a salable concentrate with the feed assay running as high as 9.8 percent iron oxide and 36.7 percent silica." Bleaching by use of acids and calcining gave promising results on most samples. Black barite from the Fall Branch district and barite ore with a rather high silica content from the Sweetwater district were somewhat resistant to bleaching. Few samples attained commercial whiteness without calcining.

- 108 Reyner, M. L., and Trauerman, C. J., 1950, *Directory of Montana mining properties 1949: Mont. Bur. Mines and Geology Memoir* 31, p. 126.

Five barite deposits in Beaverhead, Missoula, Musselshell, and Phillips Counties are indicated on a state map showing areal distribution of mineral resources. No barite properties are listed in the directory.

- 109 Robinson, L. C., 1931, The vein deposits of central Kentucky: *Ky. Geol. Survey*, 6th ser., v. 41, pt. 1, p. 7-127.

The geology of vein deposits in north central Kentucky is described. The veins occur along or near three well defined fault zones in Ordovician limestones and limey shales. The veins of barite, fluorite and calcite average four feet in width, generally trend north, and dip steeply. Barite is most abundant and is the only mineral of economic importance, although the others may be recovered as by-products in the mining of barite. The barite and associated minerals are believed to have been derived from solutions of deep seated igneous origin. Mining, milling, and prospecting are reviewed. Individual deposits are described by counties and located on a sketch map of central Kentucky.

- 110 Ross, C. P., 1941, The metal and coal mining districts of Idaho, with notes on the nonmetallic mineral resources of the state: *Idaho Bur. Mines and Geology Pamph.* 57, p. 101-102.

The occurrence of barite in large veins at the Sun Valley mine near Hailey, Blain County is briefly noted. Another deposit near Muldoon, Blain County is reported. Smaller and less pure deposits are said to occur in Paleozoic and other sedimentary rocks in Custer County and elsewhere.

- 111 Rowe, J. P., 1908, Barytes deposits in Montana: *Mining World*, v. 28, no. 16, p. 637.

A barite deposit two miles southwest of Missoula is described as "the only one of commercial value in the State." A vein from two to three feet wide containing massive, quite pure barite crops out for several hundred

feet. Near the head of Cabin Creek, 23 miles southeast of Ekalaka, Custer County, small spheroidal nodules of barite associated with selenite occur in the residual clay of the Fox Hills formation [Cretaceous]. Layers very rich in nodules have been traced for over one-half mile. Wine colored crystals of barite were found in the Fox Hills formation about 25 miles from mouth of Cedar Creek, Dawson County.

- 112 Rowe, J. P., 1928, Minor metals and non-metallic minerals of Montana: Eng. and Min. Jour., v. 125, no. 20, p. 816.

Commercial deposits of barite were unknown in Montana in 1928. Near Missoula, two deposits (Pattee Canyon and Rattlesnake Creek) of quite pure, massive white barite associated with specular hematite may be of economic importance. A non-commercial occurrence of barite nodules in Upper Cretaceous clays of Wibaux County is noted.

- 113 Santmyers, R. M., 1930, Barite and barium products, part 1, general information: U. S. Bur. Mines Inf. Circ. 6221, 55 p.

Barite deposits in the United States and methods of mining, washing, and milling of barite are described. Domestic and foreign production of barite is discussed. Foreign deposits are briefly described. Imports, exports, consumption, and the condition of the barite industry in 1928 are summarized.

- 114 Santmyers, R. M., 1930, Barite and barium products, part 2, barium products: U. S. Bur. Mines Inf. Circ. 6223R, 26 p.

General information on barium products is given. Preparation, uses, production, markets, imports and exports of ground barite, lithopone, and barium chemicals are discussed. On the map are shown the location of barite deposits and plants making barium products in United States.

- 115 Schrader, F. C., Stone, R. W., and Sanford, Samuel, 1917, Useful minerals of the United States: U. S. Geol. Survey Bull. 624.

The more important occurrences of useful minerals, including barite, are listed by states. Some of the deposits are very briefly described.

- 116 Shannon, E. V., 1926, The minerals of Idaho: U. S. Natl. Mus. Bull. 131, p. 442-444.

Barite occurrences in Idaho are listed and very briefly described. Barite is found principally as a gangue mineral in metallic ore deposits of nine counties. A deposit now known as the Sun Valley barite mine, Blaine County, is the only one of commercial importance.

- 117 Sharp, W. N. and Pray, L. C., 1952, Geologic map of bastnaesite deposits of the Birthday claims, San Bernardino County, California: U. S. Geol. Survey Mineral Investigations Map MF-4.

An area 900 by 1,500 feet is shown on the geologic map of the Birthday claims near Mountain Pass where "considerable quantities" of bastnaesite, a rare-earth mineral, were discovered in 1949. Pre-Cambrian metamorphic rocks are cut by younger shonkinite which forms the host rock for most of the barite-rich carbonate veins. The veins range up to 18 feet in thickness. One vein contains either a new mineral or a variety of barite which is a sulfate of barium and strontium containing rare earths.

- 118 Smith, E. A., and McCalley, Henry, 1904, Index to the mineral resources of Alabama: Ala. Geol. Survey Bull. 9, p. 62-63.

White barite partly stained with iron oxides occurs as irregular masses in residual clay derived from the Trenton limestone [Ordovician] near its con-

contact with the Knox dolomite [of Cambrian and Ordovician] age. Important occurrences are reported near Tampa, Calhoun County, near Greensport, St. Clair County, near Maquire Shoals on the Little Cahaba River, at the "Sinks" on Six Mile Creek, and near Pratt's Ferry in Bibb County. No production was reported from these deposits in 1904.

- 119 Soulé, J. H., 1946, Exploration of Gallinas fluorspar deposits, Lincoln County, N. Mex., U. S. Bur. Mines Rept. Inv. 3854, p. 4-5.

Barite is an important constituent of fluorite veins and mineralized breccia zones in predominantly quartzitic sandstone of Permian age of the the Gallinas Mountains. Some of the deposits contain as much as 37 percent barite.

- 120 Stern, A. G., 1941, Role of clay and other minerals in oil-well drilling fluids: U. S. Bur. Mines Rept. Inv. 3556, 88 p.

The cost, functions, and use of drilling muds are discussed in detail. Tests for evaluating the properties of drilling muds also are given in detail. The operation of a drilling mud system for an oil well and the materials used for drilling muds are described. Weighting materials are used to maintain sufficient hydrostatic pressure in the drill hole to confine gas, oil, and water to the rock strata. Weighting materials should permit the drilling fluid to attain a low viscosity and high specific gravity without being corrosive or toxic. Materials which have been used or considered for weighting muds include barite, celestite, iron oxide, pulverized iron, silica flour, and lead and mercury compounds. Of these materials barite is the most satisfactory; it is insoluble in water, chemically inactive, and makes a low viscosity suspension when mixed with an equal volume of water. The bibliography contains references to 138 papers about drilling mud.

- 121 Stoddard, Carl, 1932, Metal and nonmetal occurrences in Nevada: Nev. Univ. Bull. v. 26, no. 6, p. 93-94.

Ten occurrences of barite in Nevada are listed, but not described. Location and references are given where available.

- 122 Stone, R. W., 1939, Non-metallic minerals: Pa. Geol. Survey Bull. M 18 C, p. 5-9.

In Franklin County near Waynesboro and Chambersburg, barite occurs in small lumps in residual clay derived from limestone, and in thin veins in one limestone outcrop. A few small pits remain where barite was mined years ago. A small amount of barite was mined about 1880 from a deposit near Fort Littleton, Fulton County but it was abandoned because of the high content of iron. A small deposit was reportedly mined near Buckmanville in Bucks County. None of these deposits appears to be of commercial value.

- 123 Stuckey, J. L., 1942, Barite deposits in North Carolina, in Newhouse, W. H., and others, Ore deposits as related to structural features, p. 106-108: Princeton, N. J., Princeton Univ. Press.

The barite deposits and their localization along certain regional structures is discussed. In the Hot Springs district, barite occurs in irregular veins and lenses along two major thrust fault zones between the pre-Cambrian Max Patch granite and the Cambrian Snowbird formation. The faulting took place during the building of the Appalachian mountains in the late Paleozoic. Hydrothermal solutions emanating from granitic intrusions ascended along these fractures and deposited the barite and associated minerals. Highly metamorphosed crystalline rocks of the Kings Mountain and

Hillsboro district have a well defined schistosity which strikes northeast and dips steeply northwest. Barite occurs in veins or elongated lenticular masses parallel to the schistosity. The deposits appear to have been formed by deposition from hydrothermal solutions of magmatic origin which ascended along prominent cleavage planes after the last period of regional metamorphism in the late Paleozoic.

- 124 Stuckey, J. L., and Davis, H. T., 1935, Barite deposits in North Carolina: Am. Inst. Min. Metall. Engineers Trans., v. 115, p. 346-355.

Deposits in the Hot Springs, Kings Mountain, and Hillsboro areas, North Carolina are described. The first two areas had produced about 300,000 tons of barite by 1933 and were estimated to have fairly large reserves. The barite occurs in irregular veins and lenses in pre-Cambrian and Cambrian crystalline rocks. The mineralogy and petrography of the barite veins and lenses is described, and evidence indicates that the deposits were formed by hydrothermal solutions of magmatic origin. Associated minerals include quartz, fluorite, sericite, calcite, pyrite, galena, chalcopyrite, and sphalerite. Mining and reserves in the Hot Springs and Kings Mountain areas are briefly discussed.

- 125 Symons, H. H., and Davis, F. F., 1952, Mineral commodities in California during 1950: Calif. Jour. Mines and Geology, v. 48, no. 4, p. 311.

Properties in Kern and Plumas Counties yielded all of the production of barite in California in 1950. Barite from Kern County was used in oil well drilling, and that from Plumas County for the manufacture of barium chemicals.

- 126 Tarr, W. A., 1918, The barite deposits of Missouri and the geology of the barite district: Univ. Missouri Studies, Science Series, v. 3, no. 1, 111 p.

Barite deposits in the Washington County and Central districts of southeastern and central Missouri are listed. History, geography, geology, occurrence, origin, and economic importance of the deposits are reviewed. The more important Washington County district is discussed in detail and shown on a geologic map. Rocks of the Washington County district are largely dolomites of Cambrian age and dip gently to the north, northwest, and west. The nearly horizontal sedimentary rocks of the Central district are Cambrian, Ordovician, Mississippian and Pennsylvanian in age. Barite in the Washington County district is associated with the Potosi and overlying Proctor dolomites and in the Central district with the Gasconade, Roubidoux, and Jefferson City formations. Four types of deposits are recognized: veins, disseminated deposits, solution cave deposits, and residual deposits. The small veins are closely associated with irregular disseminations of barite in the dolomite. These deposits are not of economic importance. Solution caves or circle deposits are most common in the Central district. Residual deposits derived by weathering of primary deposits in the underlying dolomite are by far the most important commercially. They contain barite fragments associated with limonite and drusy quartz or chert distributed through deep red clay. The barite and associated minerals in the primary deposits are believed to have been deposited at shallow depth by ascending hot waters of magmatic origin. In 1918 all barite mining in Missouri was done by hand from small open pits about 4 or 5 feet deep. Preparation of the barite for market is briefly described.

- 127 Tarr, W. A., 1919, The barite deposits of Missouri: *Econ. Geology*, v. 14, no. 1, p. 46-67.

The geology and origin of the barite deposits of Missouri are discussed. This paper summarizes material presented in detail in Missouri reference 11.

- 128 Tarr, W. A., 1932, A barite vein cutting granite of southeastern Missouri: *Am. Mineralogist*, v. 17, no. 9, p. 443-448.

A small fissure vein in granite near Graniteville, Iron County, Missouri is described. The vein filling consist of barite, pyrite, and fluorite possibly deposited by hydrothermal solutions of magmatic origin which ascended along a fault plane. The discovery of this vein in granite about 20 miles south of the Washington County barite district indicates that the primary barite in the latter region also might have had a magmatic source.

- 129 Tillia, H. J., 1951, Scraper assembly cuts costs at open pit barite mine: *Eng. and Min. Jour.*, v. 152, no. 8, p. 78-79.

The slusher mining plan adopted by Barium Products, Ltd. for developing the Valley View barite claims 28 miles south of Battle Mountain, Nev., is reviewed. This deposit, in production for two years as of 1951, is described as an "erosional remnant of a massive replaced limestone bed, probably of Pennsylvanian age." The operators plan to start production at the larger Mound Springs deposit in the same area after the smaller Valley View deposit has been mined out.

- 130 Tucker, W. B., and Sampson, R. J., 1938, Mineral resources of Inyo County: *Calif. Jour. Mines and Geology*, v. 34, no. 4, p. 481-482.

A considerable tonnage of barite is reported to have been shipped from the Gunter Canyon deposit six miles northeast of Laws in 1928 and 1929. The barite occurs in a series of parallel veins in Cambrian slates and schists. At the Poso Barytes deposit, Tulare County, 15 miles west of Linnie, barite occurs in three parallel veins averaging 20 feet in width and traceable for over 4,000 feet. The veins occur along a shear zone in quartz diorite. In 1938 this deposit was owned and developed with an adit by the Western Barium Corporation. A barite outcrop 6 to 8 feet wide in Warm Springs Canyon 45 miles west of Shoshone was discovered in 1937 and was being developed in 1938.

- 131 Uhley, R. P. and Sharon, Le Roy, 1954, Gravity surveys for residual barite deposits in Missouri: *Am. Inst. Min. Metall. Engineers*, v. 6, no. 1, p. 52-56.

Gravimetric surveying for barite in Washington County is discussed. Large commercial bodies can be outlined and the tonnages of ore computed with an error of 35 percent, or less.

- 132 Ulrich, E. O., and Smith, W. S. T., 1905, The lead, zinc, and fluorspar deposits of western Kentucky: *U. S. Geol. Survey Prof. Paper* 36, p. 135 and 156.

Vein deposits of western Kentucky contain fluorite and calcite with some barite, and smaller amounts of galena and sphalerite and other oxidation products. Few veins consist predominantly of barite: those with predominant barite are generally too small or too intermixed with gangue to be of commercial value.

- 133 Umpleby, J. B., and others, 1930, Geology and ore deposits of the Wood River region, Idaho with a description of the Minnie Moore and nearby mines: *U. S. Geol. Survey Bull.* 814, p. 112-113 and 160-161.

The Bonnie and Barium Sulphate claims (now Sun Valley barite mine), are described. Barite occurs in a series of lenticular masses, at one place over 50 feet thick, trending northwest in calcareous beds of the Wood River formation. [Pennsylvanian]. The barite is generally white, banded, and free from visible impurities except small grains of pyrite and associated stains of iron oxide. In 1923, workings consisted of an 840-foot adit and a shallow open cut from which a carload of barite was shipped in 1922. Barite has not been found in other ore deposits of the region. The source of the barium may have been emanations given off during the last stages of deep seated igneous activity.

- 134 United States Bureau of Mines, 1924-31: Mineral resources of the United States.

These annual publications list statistics on barite production, consumption, uses, prices, imports, and exports. Domestic production is generally reviewed by States. Current developments in the barite industry are noted briefly.

- 135 United States Bureau of Mines, 1932-52: Minerals Yearbook.

These annual publications list statistics on barite production consumption, uses, prices, imports, and exports. Domestic production is generally reviewed by states. Current developments in the barite industry are noted briefly.

- 136 United States Geological Survey, 1882-1923: Mineral resources of the United States.

These annual publications list statistics on barite production, consumption, uses, prices, imports, and exports. Domestic production is generally reviewed by states. Current developments in the barite industry were noted briefly.

- 137 Valentine, G. M., 1949, Inventory of Washington minerals; Part 1, non-metallic minerals: Wash. Dept. Conserv. Dev., Div. Mines and Geology Bull. 37, p. 11.

Twenty-two occurrences of barite are described. Most of these are in Stevens County where several deposits appear to be of commercial value. Production was reported from three mines near Springdale in southern Stevens County in 1938 and 1942. Other occurrences are in Mason, Okanogan, Ferry, and Pend Oreille counties. Deposits are located on a map of the state and briefly described and evaluated.

- 138 Vanderburg, W. O., 1938, Reconnaissance of mining districts in Eureka County, Nevada: U. S. Bur. Mines Inf. Circ. 7022, p. 64.

A barite deposit in Eureka County in the NE¼ of sec. 27, T. 34 N., R. 51E. has been worked since 1938. Massive and relatively pure barite in veins averaging 10 feet in width and dipping 70° east occur in shale. This barite is marketed on the Pacific Coast.

- 139 Vanderburg, W. O., 1939, Reconnaissance of mining districts in Lander County, Nevada: U. S. Bur. Mines Inf. Circ. 7043, p. 53-54 and 79.

Four barite deposits at the northern end of the Shoshone Range and one near Austin are described. The bedded deposit at the Nevada mine four miles southeast of Argenta is at least 60 feet thick. This deposit is mined from an open cut and is probably one of the largest in Nevada; about 6,000 tons were shipped during the summer of 1937. About 4,500 tons were shipped

from the Valley View mine. In the vicinity of Lewis Canyon, barite occurs in a vein up to 20 feet wide. Barite is associated with silver-lead ores at the Starr Grove Mine. In the Reese River district, about $9\frac{1}{2}$ miles south-east of Austin, good quality barite occurs in a series of flat dipping veins in decomposed monzonite. The veins average four feet in width.

- 140 Vanderwilt, J. W., 1947, Metals, nonmetals, and fuels, in Pt. 1 of Mineral resources of Colorado: Colo. Min. Res. Board [Bull.] p. 255-256.

Occurrences of barite in Colorado, most of which are not of economic value, are listed. Barite occurs as a common gangue mineral in many metal mining districts in the state. A small amount was produced from veins in the granite of the Wet Mountains near Ilse, Custer County. Occurrences are reported in Boulder, Custer, Grand, Gunnison, Mesa, Ouray, Park, Pitkin, and San Miguel counties. A bibliography is included.

- 141 Van Horn, E. C., 1949, New barite possibilities revealed in the Carolinas: Eng. and Min. Jour., v. 150, no. 1, p. 76-78.

The material presented in the paper by Van Horn, Le Grand, and McMurray (1949) is reviewed briefly.

- 142 Van Horn, E. C., Le Grand, J. R., and McMurray, L. L., 1949, Geology and preliminary ore dressing studies of the Carolina barite belt: N. C. Dept. Conserv. Devel., Div. Mineral Res. Bull. 57, 25 p.

The geologic occurrence, origin, history of development, and commercial possibilities of the barite deposits of the Kings Mountain-Gaffney area are discussed. Mines and prospects in the area are described and spotted on a map. The deposits form a narrow, irregular belt which extends northeast for about 24 miles from a point about five miles southeast of Gaffney, South Carolina to the northeast slope of Crowder's Mountain four miles east of the town of Kings Mountain, North Carolina. The barite is found only in a zone of quartz-sericite schist near the contact between the Bessemer granite and the Battleground schist and occurs in veins and small lenticular disseminations as much as one inch or more across which are sub-parallel to the foliation of the host rock. Some disseminations form as much as 20 percent of the rock. The barite possibly was deposited by ascending hydrothermal solutions as interstitial fillings along foliation planes and as replacements of quartz and sericite in the schist. Barite has been produced from the veins intermittently since the early 1880's, but the total production has been small. Laboratory tests indicate that the disseminated ore is amenable to concentration by flotation. The Carolina barite belt may contain reserves of commercial importance which can be mined by open-cut methods.

- 143 Watson, T. L., and Grasty, J. S., 1915, Barite of the Appalachian States: Am. Inst. Min. Metall. Engineers Bull. 98, p. 345-390; and 1915, Trans. Am. Inst. Min. Metall. Engineers, v. 51, p. 514-559.

The barite deposits of Alabama, Georgia, Kentucky, Maryland, North Carolina, Pennsylvania, South Carolina, Tennessee, and Virginia are described. The occurrence, mining, beneficiation, production, and uses of barite are discussed. This paper summarizes much of the information available in the literature up to 1914 on deposits in the Appalachian states.

- 144 Weigel, W. M., 1923, Barite and ocher in the Cartersville, Georgia, district: U. S. Bur. Mines Rept. Inv. 2477, p. 1-7.

Ore deposits contain barite imbedded in clay as irregular pieces ranging in size from fine grains to masses weighing several hundred tons. The

barite is concentrated in pockets or steps on hillsides and overlies quartzite or partly weathered limestone from which the deposits have been derived. Methods of prospecting, mining, and milling are described.

- 145 Weigel, W. M., 1929, The barite industry in Missouri: Am. Inst. Min. Metall. Engineers Tech. Pub. 201, 26 p.; Trans. 1929, Year Book, p. 256-279; Pit and Quarry, v. 18, no. 13, p. 87-96.

Production of barite in Missouri and the United States from 1913-1927 and the economic condition of the barite industry in Missouri in 1928 is briefly discussed. A description of the general geology and ore deposits of the Washington County and Central districts is given. Mining, milling, and prospecting methods are also described and a short discussion on reserves, marketing and uses of Missouri barite is included. In Washington County, primary barite in veins, disseminations, and solution cavities occurs chiefly in the Potosi dolomite of Cambrian age. Residual deposits consisting of barite fragments embedded in clay are by far the most important commercially. Similar but smaller and higher grade residual deposits occur in the Central district. Future production of barite in Missouri is predicted to exceed past production which totaled 1,750,000 tons as of 1928. Hand mining in open pits accounted for well over half of the production in 1928. Power shovels and mechanical washing and concentrating methods have been in use for only four or five years. In 1928, most Missouri barite was marketed in St. Louis, Illinois and the Ohio Valley.

- 146 Weissenborn, A. E., 1948, Barite, in Weissenborn, A. E., and Stenzel, H. B., and others, Geological resources of the Trinity River tributary area in Oklahoma and Texas: Tex. Univ. Pub. 4824, p. 67-71.

The uses, specifications, and prices of barite are noted. Occurrences in central and southwestern Oklahoma and the adjacent area in northeastern Texas are described. Barite occurs in thin irregular veins or in scattered nodules in Permian and Triassic shales. Of these deposits, possibly two residual occurrences, in southwestern Oklahoma might be of commercial value. The larger of these is about five miles south of Cache, and is estimated to contain several thousand tons of barite concentrated on gully floors in Permian shale. Residual barite is found in brown clay and limonite derived from weathering of dolomite in the Arbuckle limestone of Cambrian and Lower Ordovician age of the Arbuckle Mountains. Total production of barite in the State to 1948 has amounted to less than 500 tons. A bibliography and a map showing the location of the deposits is included.

- 147 Whitlatch, G. I., 1937, Barite: Tenn. Dept. Conserv. Div. Geology, Markets Circ. 7, 25 p.

The minerals of barium, occurrences in the United States, specification for market, markets, prices and uses are reviewed with emphasis on Tennessee ores. A brief description of barite deposits in Tennessee is given which includes the Sweetwater and Del Rio districts and the Greene County area in east Tennessee; the Pall Mall district in Fentress County and other occurrences in Davidson, De Kalb, Dickson, Smith, Trousdale, and Wilson Counties in middle Tennessee. The history of the barite industry in Tennessee is summarized with a table showing production in selected years between 1903 and 1931. A brief statement on prospecting for barite in Tennessee is included.

- 148 Williams, F. J., 1949, Barium minerals, in *Industrial minerals and rocks*, p. 77-94: Am. Inst. Min. Metall. Engineers, New York.

A summary of general information on barite including occurrence, distribution, production, uses and markets is given. The principal deposits in the United States and foreign countries are briefly described. Mining, prospecting, and concentration methods are listed. Workable deposits are chiefly of two types: veins of total or partial replacement of dolomite and limestone; and residual concentration in clay derived by weathering of preexisting deposits like those of type 1. The principal deposits in the United States are in Arkansas, Missouri, Georgia, Tennessee, California, and Nevada. The principal foreign deposits are in Canada, Germany, Italy, Great Britain, and the U. S. S. R.

- 149 Wilson, E. D., 1933, Geology and mineral deposits of southern Yuma County, Arizona: Ariz. Bur. Mines, Geol. Ser. 7, Bull. 134, p. 42 and 152-153.

Barite is an abundant gangue mineral in veins of the Silver, Castle Dome, Sheep Tanks, and Neversweat districts. Relatively pure veins of barite occur in the Mohawk, Neversweat, and Silver district. At the Renner mine northwest of Mohawk, barite has been mined from an open cut on the widest part of a narrow vein cutting granitic gneiss. The barite is enclosed in mangiferous calcite. Eighteen carloads of barite were shipped from this deposit in 1929 and 1930.

- 150 Wilson, E. D., Moore, R. T., and Roseveare, G. H., 1953, Nonmetallic mineral map of Arizona: Ariz. Bur. Mines.

The map shows the location of barite and other nonmetallic mineral deposits.

- 151 Wilson, E. D., and Roseveare, G. H., 1949, Arizona nonmetallics; a summary of past production and present operations: Ariz. Bur. Mines, Mineral Technology Ser. 42, Bull. 155, p. 10-11.

Barite is a common gangue mineral in veins of metallic ores in Arizona. Deposits of commercial importance occur as veins in which barite is associated chiefly with calcite or fluorite and relatively few other minerals. Total production of barite in Arizona has been small. Figures are available only for 1931-1932 when output was 3,410 tons. Most of the production has been from the Christman property northeast of Mesa now operated by the Arizona Barite Co. A few carloads were shipped in 1929 and 1930 from the Renner deposit and in 1938 from the Ernest Hall property. Both deposits are in Yuma County.

- 152 Winston, W. B., 1949, Barium: Calif. Jour. Mines and Geology, v. 45, no. 1, p. 85-97.

The properties of barium, barium compounds, and barium ores are reviewed. General information is summarized: occurrence and location of deposits, prospecting, mining, preparation for market, uses, marketing, and preparation of barium compounds. Brief notes on barite occurrences in the following counties of California: Inyo, Los Angeles, Mariposa, Monterey, Nevada, Plumas, San Bernardino, Santa Barbara, Shasta, and Tulare. Production of barite in the State in 1945 was from three properties, one each in Mariposa, Nevada, and Plumas Counties. Production during 1944-1945 was about 68,000 tons.

- 153 Woodward, H. P., 1932, Geology and mineral resources of the Roanoke area, Virginia: Va. Geol. Survey Bull. 34, p. 134-135.

A barite vein in pre-Cambrian crystalline rock three miles northwest of Thaxton has been mined in an opencut 20 feet deep and 450 feet long. A barite deposit two miles northeast of Roanoke occurs as a replacement in the Elbrook [formation of Cambrian age] and as irregular nodules in clay residually derived from the limestone. The barite mined from shallow opencuts was shipped for use in the sugar industry.

- 154 Woodward, H. P., 1938, Outline of the geology and mineral resources of Russell County, Virginia: Va. Geol. Survey Bull. 49, p. 69-72.

Deposits in Russell and Tazewell Counties were the chief sources of barite in Virginia in 1906. All of the deposits examined by the writer in 1938 appeared to be exhausted. The barite occurs as veins and replacements in the upper members of the [Ordovician] Beekmantown dolomite or in residually derived clay. The Hubbard, Leonard, and Little River mines are briefly described.

- 155 Wright, L. A., and others, 1953, Mines and mineral deposits of San Bernardino County, California: Calif. Jour. Mines and Geology, v. 49, nos. 1 and 2, p. 155 and nos. 133-135 in tabulated list of mines and mineral deposits included at end of report.

Occurrences of barite, chiefly in veins in igneous and metasedimentary rocks, are widespread in San Bernardino County. Several deposits in the Grapevine, Calico, and Lavic districts, were mined during 1910 to 1912 and 1929 to 1937. Barite has been recovered from mill tailings in the Calico district and interest has been shown recently in recovering barite as a by-product from the rare earth deposit at Mountain Pass. A tabulation at the end of the report includes 13 barite deposits which are briefly described as to location, geology, development, and production. A bibliography is included for each deposit. The three major deposits, the Barium Queen, Hansen, and Lead Mountain mines, are included on a map showing the location of mines and mineral deposits in San Bernardino County.

- 156 Zapp, Alfred, 1941, Barite in northern Llano County: Tex. Univ. Bur. Econ. Geology Min. Res. Circ. 35, 6 p.

A small tonnage of residual barite has been mined from a deposit in northern Llano County. Most of the residual material has been removed, and the underlying primary deposits contain impure barite in a series of irregular thin veins in pre-Cambrian schist and gneiss. The veins are roughly parallel to the foliation of the country rock; they pinch and swell abruptly. The deposits seem to be small.

- 157 Anonymous, 1952, A visit to the Mountain Pass rare-earth enterprise: Eng. and Min. Jour., v. 153, no. 10, p. 87.

The exploration, mining, and milling of the rare-earth deposits at the Sulphide Queen near Mountain Pass, Calif., are described briefly. The deposit is said to cover about 20 acres. The barite forms about 20 percent of the lode, although barite locally constitutes more than 50 percent of some masses. Overburden is negligible; ore is mined in open pits. The flotation mill, opened in February 1952, has a capacity of 100 tons a day and is now daily processing 70 tons of ore containing recoverable rare-earth minerals and barite.

- 158 Anonymous, 1947, Arizona barite: *Mining World*, v. 9, no. 1, p. 20-22.

The mine of the Arizona Barite Co. at Coon Bluff 22 miles northeast of Mesa is described. In 1946, it was producing 100 tons of ground barite per day. Barite occurs in fissure veins in volcanic agglomerate. Production as of January 1947 had been derived solely from the main vein about 15 feet wide and 3,000 feet long that had been opened to a depth of 140 feet. The final product, which contains about 94 percent BaSO_4 and has a specific gravity of 4.0 or higher, is shipped mainly to oil fields of the Southwest and West Coast for use in drilling mud. Plans call for development of other veins in the area. The operators also plan to install flotation equipment to produce a higher grade product and permit recovery of silver, said to run about 3.2 ounces per ton.

- 159 Anonymous, 1953, Socorro County produces barite: *New Mexico Miner*, v. 15, no. 1, p. 2.

Production of barite in 1952 from the Mex-Tex Mining Co. property in Socorro County is discussed. Ore is mined in open pits and trucked 35 miles to a company-owned mill at San Antonio, New Mexico where concentrates are bagged and shipped for use in drilling muds in Texas and New Mexico. The management is considering expanding present operations because of new ore strikes on the property.

- 160 Anonymous, 1952, Southern California's rare-earth bonanza; *Eng. and Min. Jour.*, v. 153, no. 1, p. 100-102.

The recent discovery and exploration of Birthday and Sulphide Queen deposits of rare-earth minerals near Mountain Pass are discussed. Rare-earth values at the Birthday deposits are said to have diminished rapidly at very shallow depth. The Sulphide Queen deposit is described as a "massive lode, about 20 acres in area, of barite-carbonate rock", which in addition to rare-earth carbonates, celestite, calcite, and silica contains barite which locally constitutes the bulk of the rock and averages 20 percent of the entire lode. Successful methods for separating rare-earth material from barite are described.

The Molybdenum Corporation of America, owners of the property, planned to start production about February 1, 1952.

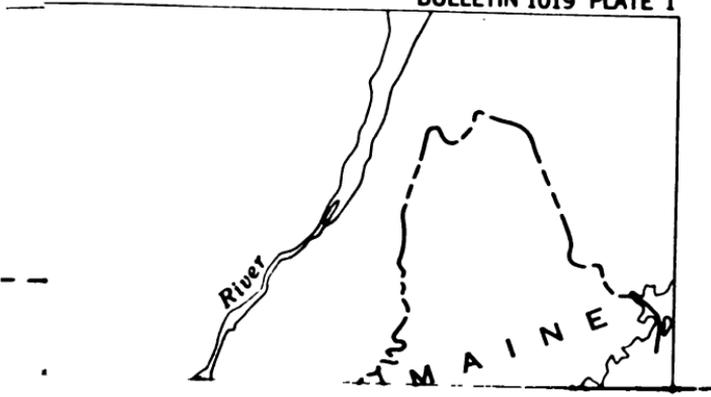
- 161 Anonymous, 1953, This month in mining: *Eng. and Min. Jour.*, v. 154, no. 6, p. 148.

As of April 1951, mining and milling are reported at a high grade barite deposit near Elk Creek in the vicinity of Greenough, Missoula County, Mont. Production is reported to be 12 to 14 cars of pulverized barite and 4 to 6 cars of crushed barite per week.



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Bibliography of Iron Ore Resources of the World (To January 1955)

GEOLOGICAL SURVEY BULLETIN 1019-D



Bibliography of Iron Ore Resources of the World (To January 1955)

by GWENDOLYN W. LUTTRELL

CONTRIBUTIONS TO BIBLIOGRAPHY OF MINERAL RESOURCES

GEOLOGICAL SURVEY BULLETIN 1019-D



UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1957

UNITED STATES DEPARTMENT OF THE INTERIOR

Fred A. Seaton, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

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A CONTRIBUTION TO BIBLIOGRAPHY OF MINERAL RESOURCES

BIBLIOGRAPHY OF IRON ORE RESOURCES OF THE WORLD (TO JANUARY 1955)

By Gwendolyn W. Luttrell

INTRODUCTION

This bibliography contains references to much of the important literature on iron ore deposits of the world. Abstracts of reports and reports that contain little information are omitted. References in foreign languages do not have English summaries unless indicated. The reports are numbered consecutively from 1 to 2732, and these numbers are used for reference in the subject and author indexes.

U. S. Geological Survey professional papers, bulletins, and water-supply papers that are available can be purchased at the prices indicated from the Superintendent of Documents, Government Printing Office, Washington 25, D. C. They may also be purchased on an over-the-counter basis from his authorized agents, Geological Survey offices at 468 New Customhouse, Denver, Colo., 504 Federal Building, Salt Lake City, Utah; 807 Post Office and Courthouse, Los Angeles, Calif.; 724 U. S. Appraisers Building, San Francisco, Calif.; and the E. F. Glover Building, Anchorage, Alaska. Circulars may be obtained free on application to the Geological Survey at Washington 25, D. C. or at the Denver Federal Center, Denver, Colo.

The geologic folios, maps, and charts are sold by the Geological Survey. Remittances for those covering areas east of the Mississippi River may be addressed to the Geological Survey, Washington 25, D. C. Maps of areas west of the Mississippi River may be ordered from the Geological Survey, Denver Federal Center, Denver, Colo., or obtained by over-the-counter sale (but not by mail) from the Geological Survey offices mentioned above. Requests originating in Alaska for maps of Alaska may be ordered from the Geological Survey, P. O. Box 1088, Fairbanks, Alaska.

Those references preceded by an asterisk (*) are out of print, but they can be seen at many public and university libraries. Open-File reports and maps can be seen at the Geological Survey Library, Room 1033, General Services Building, Washington, D. C., and

at various field offices whose addresses can be obtained by writing to the Geological Survey. Preliminary reports and maps can be seen at the Geological Survey Library; some can be obtained from the Geological Survey, Washington 25, D. C.

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Magnesium Resources of the United States— A Geologic Summary and Annotated Bibliography to 1953

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Magnesium Resources of the United States— A Geologic Summary and Annotated Bibliography to 1953

By ROBERT E. DAVIS

CONTRIBUTIONS TO BIBLIOGRAPHY OF MINERAL RESOURCES

G E O L O G I C A L S U R V E Y B U L L E T I N 1 0 1 9 - E



UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1957

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

**For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C.—Price 70 cents (paper cover)**

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 ILLUSTRATION

PLATE 2. Map of the United States showing distribution of magnesium resources and location of magnesium metal plants In pocket

CONTRIBUTIONS TO BIBLIOGRAPHY OF MINERAL RESOURCES

MAGNESIUM RESOURCES OF THE UNITED STATES A GEOLOGIC SUMMARY AND ANNOTATED BIBLIOGRAPHY TO 1953

By ROBERT E. DAVIS

ABSTRACT

Magnesium ranks eighth in order of abundance in the earth's crust and occurs sparsely in sea water and in larger quantities in a wide variety of igneous, sedimentary, and metamorphic rocks. The presently important commercial sources of magnesium metal and magnesium compounds are sea water and sea-water bitterns, dolomite, magnesite, brucite, and inland brines. Brines are only briefly mentioned in this report.

Magnesium and its compounds are used widely in the aircraft, automotive, metallurgical, building, pharmaceutical, agricultural, glass, rubber, paper, textile, and paint industries.

Magnesium is extracted from sea water or sea-water bitterns by the process used by the Dow Chemical Co. at their magnesium plant at Freeport, Tex., or by some variation of the Dow process. In this process lime is used to precipitate magnesium hydroxide from the water; the precipitate is dissolved in hydrochloric acid and magnesium chloride is produced; the magnesium chloride is decomposed in an electrolytic cell into magnesium and chlorine. It is now common practice to substitute dolomite for lime. The dolomite furnishes the necessary lime and additional magnesium to the reaction.

Magnesite, or magnesium carbonate, occurs in commercial quantities in the United States principally as a replacement in dolomite. Its chief use is as a refractory material in the metallurgical industries; it is used to a lesser extent in the fertilizer, rubber, textile, and paper industries; During World War II magnesite was used as a commercial source of magnesium metal.

In the past magnesite has been mined in California, Washington, Nevada, and Texas; at present the only commercial domestic production is from Nye County, Nev., and Stevens County, Wash. Magnesite occurs also in New Mexico, Idaho, Oregon, Utah, Pennsylvania, and Vermont. The occurrence of magnesite in each of these States is discussed briefly.

Brucite occurs in commercial quantities only at Gabbs, Nye County, Nev.

Dolomite, the double carbonate of magnesium and calcium, occurs chiefly as a sedimentary rock, commonly interbedded with limestone. The term "high-grade," as used in the present report, refers to dolomite rock containing more than 40 percent magnesium carbonate and less than about 3 percent noncarbonates. The largest single use of dolomite, where the chemical composition of the rock is important, is as a refractory material. It may be used in either its natural state or calcined. During World War II, and to some extent during the postwar years, dolomite has been used as an ore of magnesium metal.

Dolomite occurs in at least 40 States, but the largest sources of high-grade rock probably underlie parts of Ohio, Indiana, Illinois, Michigan, and Wisconsin. Large reserves also are present in the limestone valleys of the Appalachian Mountains, extending from Alabama to New Jersey. Except for Louisiana and the northern Great Plains States, dolomite occurs in nearly every State west of the Mississippi River. The more important dolomitic formations in each State are described briefly.

INTRODUCTION

PURPOSE AND SCOPE OF REPORT

The present report is a compilation of information on the dolomite, magnesite, and brucite deposits and occurrences in the United States, with a brief section on the use of sea water as a source of magnesium and magnesium compounds. It has been compiled from published literature and data in the files of the U. S. Geological Survey. Many of these data are the result of investigations made by the Geological Survey during Wor'd War II, and this information, particularly that collected by C. F. Deiss on the dolomite deposits of the Western United States, has been drawn on freely in the preparation of the present report.

It is the purpose of this report to present, by means of text and map (pl. 2), a summary of the United States resources of magnesium contained in dolomite, magnesite, and brucite as a general guide to their distribution, geologic environment, purity, and utilization. Owing to their limited use as sources of magnesium and magnesium compounds, olivine, serpentine, and the various saline minerals—kieserite, langbeinite, epsomite, kainite, carnallite, and polyhalite—are considered beyond the scope of the present compilation.

Well brines rich in magnesium are the raw materials for a substantial part of the annual domestic production of certain magnesium compounds. Such brines occur in several areas in the United States but are extracted commercially only in Michigan. Magnesium sulfate is produced from lake brine in the State of Washington. The geologic occurrence and chemical composition of these inland brines are broad subjects, about which relatively little detailed information has been published. The brine resources of the United States are not discussed in this paper.

It is hoped that the information presented will prove useful as a general background of knowledge for field appraisals of areas that might be considered commercial sources of magnesium raw materials. Most of the areas of present and potential commercial importance are considered, most of the pertinent geologic formations within these areas are described, and sample data are at least representative, if not complete. The selected, annotated bibliography is not a complete list of all the literature examined, but it contains the published reports used in preparing this work and the reports considered as most helpful in appraising areas containing magnesium raw materials.

ABUNDANCE, AVAILABILITY, AND USES

Magnesium ranks eighth in order of abundance of the elements in the earth's crust, comprising 2.09 percent by weight of the igneous rocks (Rankama and Sahama, 1950, p. 448) and about 0.13 percent by weight of sea water (Rankama and Sahama, 1950, p. 295). It occurs also in a wide variety of sedimentary rocks. Magnesium is a constituent of at least 150 minerals (Ford, 1932, p. 805-806), but the element and its compounds have been extracted commercially from only a few substances. Magnesium-bearing materials are widespread, and reserves in the United States are virtually inexhaustible. The possible sources of magnesium in the United States and the approximate percentage of magnesium contained in each are listed in the table below.

Magnesium raw materials in the United States

<i>Material</i>	<i>Composition</i>	<i>Percent Mg</i>
Brucite.....	Mg(OH) ₂	42
Magnesite.....	MgCO ₃	29
Serpentine.....	H ₄ Mg ₃ Si ₂ O ₉	26
Olivine (chrysolite).....	(Mg,Fe) ₂ SiO ₄	19
Kieserite.....	MgSO ₄ ·H ₂ O.....	18
Dolomite.....	CaCO ₃ ·MgCO ₃	13
Langbeinite.....	2MgSO ₄ ·K ₂ SO ₄	12
Epsomite.....	MgSO ₄ ·7H ₂ O.....	10
Kainite.....	MgSO ₄ ·KCl·3H ₂ O.....	10
Carnallite.....	MgCl ₂ ·KCl·6H ₂ O.....	9
Polyhalite.....	2CaSO ₄ ·MgSO ₄ ·K ₂ SO ₄ ·2H ₂ O.....	4
Well brines.....	Mg, Ca, K, Na sulfates and chlorides ¹	1
Sea water.....	Mg, etc., chlorides.....	.13

¹ Inland well and lake brines vary widely in composition but generally contain less than 1 percent Mg.

Sea water, well brines, dolomite, magnesite, and brucite are the chief commercial sources of magnesium compounds in the United States. Although each of these is also an ore of magnesium metal by present-day technologies, all are not of economic value commercially under normal competitive conditions.

Enormous quantities of magnesium are in large deposits of olivine and serpentine in the United States. Both materials have been used commercially to a limited extent as fertilizer ingredients and for other purposes (Birch and Wicken, 1949, p. 538-540). Some olivine has been used also in the production of special-use refractories (Gwinn, 1943, p. 2). Adequate resources of other raw materials, technologic problems, and cost of processing have prevented olivine and serpentine from becoming important commercial sources of magnesium and its compounds (Barnes and others, 1950, p. 43-44; Gwinn, 1943, p. 5). They remain, however important potential raw-material sources.

Before World War II sea water was becoming an increasingly important source of magnesium and magnesium compounds. For strategic reasons during the war, however, when rapid expansion of metal-producing facilities became necessary, utilization of inland sources of magnesium raw materials was advisable in order that new plants would not have to be concentrated along sea coasts. New technologies in extractive metallurgy were developed (Ball, 1944; Case and others, 1944; Dungan, 1944; Humes, 1944; Lloyd and others, 1944; Mayer, 1944; Pidgeon and Alexander, 1944; Pierce and others, 1944; Ware, 1944), and, despite higher production costs, magnesium was produced commercially from magnesite and dolomite, materials that had long been commercial sources of certain magnesium compounds.

The most important products derived from magnesium-bearing materials are magnesium metal and magnesium oxide, or magnesia. Magnesium is the lightest of the structural metals in common use. It is about two-thirds the weight of aluminum, and it has become increasingly important in the aircraft and automotive industries for certain items where some strength can be sacrificed in favor of lighter weight. It is used also in the metallurgical industries as a scavenger and deoxidizer. Magnesia is an important refractory material and is used widely in the steel industry. Magnesia and other magnesium compounds, such as magnesium carbonate, magnesium sulfate, and magnesium chloride, are used widely in the building industry, in pharmaceutical preparations, as fertilizer ingredients, and in the glass, rubber, paper, textile, and paint industries.

SEA WATER AND SEA-WATER BITTERNs

Sea water contains approximately 0.13 percent magnesium by weight, or about 6 million tons of magnesium per cubic mile. Reserves of magnesium in sea water are virtually inexhaustible. At present 7 plants in the United States produce magnesium or magnesium compounds, using as raw materials sea water or sea-water bitterns, the saline residue or brine remaining after most of the water has been evaporated and the salt, sodium chloride, extracted. The concentration of magnesium in these bitterns is many times that in normal sea water. As shown in the table below at least 7 magnesium compounds are produced from these raw materials.

The processes by which magnesium and its compounds are derived from sea water and bitterns have been briefly described by Seaton (1942, p. 20-25). Basically, the processes used in the various plants are similar to that used in the plant of the Dow Chemical Co. at Freeport, Tex., for the production of magnesium. Briefly, the Dow process is as follows: the sea water is treated with calcined oyster shell (calcium oxide, or lime) and magnesium hydroxide is precipitated; after most of the excess

water is filtered off, the magnesium hydroxide precipitate is dissolved in hydrochloric acid and magnesium chloride is produced; the remaining water is filtered off and the magnesium chloride dried; the dry magnesium chloride is fed into an electrolytic cell where it is decomposed into chlorine gas and magnesium metal. The procedure is described in somewhat more detail by Gross (1949, p. 29-34).

Manufacturing plants producing magnesium and magnesium compounds from sea water and bitterns

[Data from Irving and Uswald, 1954, p. 4-5]

Company	Location	Products	Raw materials
Kaiser Aluminum & Chemical Corp.	Moss Landing, Calif.	Refractory magnesia..... Caustic-calcined magnesia..... Magnesium hydroxide.....	Sea water and dead-burned dolomite.
Westvaco Chemical Division, Food Machinery & Chemical Corp.	Newark, Calif.....	Refractory magnesia..... Caustic-calcined magnesia..... Magnesium hydroxide.....	Sea-water bitterns, dead-burned dolomite, and magnesite.
Westvaco Chemical Division.	Chula Vista, Calif.....	Magnesium chloride.....	Sea-water bitterns.
Marine Magnesium Division, Merck & Co., Inc.	South San Francisco, Calif.	Magnesium oxides..... Magnesium hydroxide..... Magnesium carbonate.....	Sea water, sea-water bitterns, and dead-burned dolomite.
Northwest Magnesite Co....	Cape May, N. J.....	Refractory magnesia.....	Sea water and calcined dolomite.
Dow Chemical Co.....	Freeport, Tex.....	Caustic-calcined magnesia..... Magnesium chloride ¹ Magnesia..... Magnesium.....	Sea water.
Dow Chemical Co. ²	Velasco, Tex.....	Magnesium chloride ¹ Magnesium.....	Sea water.

¹ Magnesium chloride cell feed for magnesium.

² Government-owned, Dow-operated magnesium plant; not listed in original reference.

At plants producing magnesium compounds, the process described is not carried to completion, and variations in processing depend on the raw materials used and the end product desired. The chief variation in the basic process is the substitution of calcined dolomite for calcined shell or limestone as a source of lime. Dolomite not only furnishes the necessary lime but also increases the yield of magnesium hydroxide by furnishing additional magnesium to the reaction. This substitution is made at most of the plants, as can be seen in the table above.

Theoretically, any place in the United States that borders on the ocean would be a potential plant site for the production of magnesium from sea water. Several factors that affect the number and location of such plants must, however, be considered.

The physical qualifications of a potential plant site are an important factor. The shape of the shoreline and action of the water currents

should be such that the discharge of the large volumes of water from the plant will not be recirculated into the area of intake. The area of sea-water intake should be relatively free from sources of contamination, and an adequate source of fresh water should be available to meet plant requirements. There should also be adequate electric power for plant operations and a nearby source of lime in the form of shells, limestone, or dolomite for use as a precipitant.

An economically suitable plant site should be within a reasonable distance of a ready or potential market for either the main products or one or more of the coproducts that could be recovered from the sea water or bitterns. Coproducts from sea water might include bromine, calcium chloride, and sodium chloride. For the production of magnesium, electric power should be relatively inexpensive because of the large amount used in the electrolysis of magnesium chloride. Of strategic importance is the fact that plants along the coastal areas of the United States would be somewhat more vulnerable than inland plants to possible air or sea attack in case of war. Although sea-water reduction plants are not the least expensive either to build or to maintain, operating costs have been such that other methods of metal production do not compare favorably from an economic standpoint (Surplus Property Administration, 1945, p. 25).

MAGNESITE

DESCRIPTION

Magnesite is the naturally occurring carbonate of magnesium, and its theoretical composition is MgO, 47.8 percent and CO₂, 52.2 percent. Iron may substitute for magnesium to form a complete series from magnesite to siderite, FeCO₃ (Palache and others, 1951, p. 163). Manganese and calcium also may substitute for magnesium to a limited degree. Magnesite is commonly massive, coarse to fine grained or compact and porcelainous; it may also be earthy or chalky (Palache and others, 1951, p. 162). The mineral varies in color but generally is white or grayish; it has a vitreous to dull luster. Although crystalline magnesite may closely resemble limestone or coarse dolomite, it is slightly harder (hardness $3\frac{3}{4}$ – $4\frac{1}{4}$) and heavier (specific gravity 3) and reacts only slightly to cold dilute acids. The crystalline variety is yellowish or brownish white, but it may also be pure white.

MODE OF OCCURRENCE

The four principal modes of occurrence of magnesite, as described by Bain (1924), are (1) as a chemical precipitate in bedded playa-lake deposits, commonly interbedded with limestone, dolomite, clay, or other detrital materials; (2) as a cryptocrystalline replacement product of ser-

pentitized rocks, deposited in veins, pockets, and shear zones by the action of carbonated waters of either magmatic or meteoric origin; (3) as crystalline replacement bodies in limestone and dolomite, formed by the action of magnesium-containing solutions on the preexisting carbonate rocks; and (4) as vein fillings. Other types of occurrence listed by Palache and others 1951, p. 164) include crystalline beds of metamorphic origin associated with schists, cavity minerals in igneous flow rocks, oceanic salt deposits, and as a primary mineral in igneous rocks.

Only the first three types mentioned are of economic interest, and all domestic production at present is from deposits of the third type. Of possible commercial interest is a unique occurrence in eastern Nevada in which magnesite occurs as veins, nodules, and lenses replacing volcanic tuff (Vitaliano, 1951).

USES

Magnesite is used chiefly for refractories, which find their major application in the steel industry in basic open-hearth furnaces and basic converters (Birch and Wicken, 1949, p. 538). The subject has been discussed in some detail by Comber (1937). For refractory use magnesite is dead burned, a process of intense heating which drives off essentially all the carbon dioxide leaving magnesia, which is partly fused or sintered. Granular dead-burned magnesite is used for the building up of furnace bottoms and to some extent for patching; in the form of brick it is used for the lining of furnace walls. Because magnesite contains no lime, it generally is more satisfactory than dolomite, particularly for the manufacture of refractory brick. The presence of lime in dolomite causes difficulties as outlined in the discussion of dolomite refractories (p. 397). However, owing to its relatively low cost and its proximity to markets, dolomite has found much wider use as a patching or repairing material for furnaces than has magnesite (Schallis, 1942, p. 1). Refractory magnesia derived from sea water also is increasing in use as a substitute for dead-burned magnesite.

Caustic-calcined, or light-burned, magnesite is produced at a lower temperature than is required for dead-burned magnesite. Light-burned magnesite is essentially magnesium oxide, but it contains a small quantity, from 0.5 to about 7 percent, of residual carbon dioxide and remains unsintered (Birch and Wicken, 1949, p. 522). This more reactive material is used in the manufacture of magnesium oxychloride cement, for fertilizer, and in the rubber, textile, and paper industries (Ladoo and Meyers, 1951, p. 308-309).

A new use for magnesite in the United States is in the manufacture of magnesium metal. In Nevada, during World War II, magnesite ore from the Gabbs area was used in the large magnesium plant at Henderson. Briefly, the process (Ball, 1944) involved calcining the magnesite and

mixing the resulting magnesia with pulverized coal to form briquettes, which then were charged into an electric furnace in the presence of chlorine gas, producing carbon dioxide and molten magnesium chloride. The magnesium chloride was then reduced in an electrolytic cell to chlorine gas and magnesium metal. The Henderson plant produced more than 81,000 tons of metal from 920,000 tons of magnesite ore quarried from the Gabbs deposits (Callaghan and Vitaliano, 1948, p. 1).

Chemical specifications for magnesite are as varied as its uses and usually are made on the basis of the calcined material, either light burned or dead burned (Birch and Wicken, 1949, p. 535-537). In general, crude magnesite to be marketable should contain a minimum of about 43 percent magnesia (Harness and Jensen, 1943, p. 7). Impurities commonly present in magnesite consist principally of lime, silica, iron, and alumina. The lime content should be at a minimum, being particularly detrimental in light-burned material. Some iron is desirable in magnesite that is to be used for refractories, particularly if the iron is in the form of carbonate. The iron aids the dead-burning process by allowing the magnesia to sinter at lower temperatures (Harness and Jensen, 1943, p. 7).

MINING AND BENEFICIATION

The mining of magnesite is controlled by the geology of the deposit, and it may be by either underground or open-pit methods. Deposits of the California type, which consist of veins and irregular stockworks in the serpentized country rock, generally must be worked by underground methods. One such operation, that of the Bald Eagle mine near Gustine, Calif., has been described by Perry and Kirwan (1938). The Washington and Nevada deposits, which occur as massive crystalline replacements in dolomite, are worked by open-pit methods. The major departure from standard quarry practice is the maintenance of relatively narrow benches and narrow working faces to permit selectivity in quarrying (Parker, 1945). The quarrying methods used in the Nevada deposits are similar to those used in Washington; they have been described briefly by Birch and Wicken (1949, p. 524-527) and in more detail by Parker (1945) and Holmes (1949).

Contaminating materials, the most common of which in the Washington and Nevada deposits are dolomite and magnesium silicates, must be removed before the magnesite is calcined. Before World War II, magnesite ore was brought up to required grade by careful hand sorting or by mechanical classification through screening. Such upgrading was costly and not always as satisfactory as desired, and, about 1941, froth flotation was introduced at the Chewelah, Wash., operation (Seaton, 1942, p. 7). Flotation was used also during World War II at the plant at Gabbs, Nev. Still more recently heavy-media separation has been

utilized to beneficiate ore at Gabbs and Chewelah (Birch and Wicken, 1949, p. 525; Utley, 1952, p. 98).

GENERAL DISTRIBUTION

Commercial deposits of magnesite are not widely distributed in the United States. The only producing mines at present (1954) are those in Stevens County, Wash., and Nye County, Nev. Other States that have produced magnesite during recent years include California and Texas. Relatively small occurrences of doubtful commercial importance occur in New Mexico, Idaho, Oregon, Utah, Pennsylvania, and Vermont.

DISTRIBUTION BY STATES

On the following pages the magnesite deposits of the United States are described briefly by States, which are listed in alphabetical order. Accompanying each State summary is a list of deposits and occurrences, the locations of which are shown on plate 2.

CALIFORNIA

Occurrences of magnesite are numerous throughout the Coast Range and the western Sierra Nevada areas of central and southern California. Many of the deposits and mines have been discussed briefly by Bradley (1925, p. 41-140) and some in more detail by Hess (1908) and Gale (1914). Little is known regarding the magnesite reserves in the State, but according to Vernon (1950, p. 177), reserves of readily accessible, high-grade magnesite are nearly depleted.

Magnesite mined in California in 1886 (Bradley, 1925, p. 37) was the first to be commercially produced in the United States. The State continued as the only domestic producer until operations in the extensive deposits in eastern Washington were initiated in 1916 (Stone, 1918, p. 665). Magnesite was mined in California continuously until 1945 when the Western mine, in the Red Mountain district of Santa Clara and Stanislaus Counties, finally ceased operations (Bodenlos, 1950, p. 227). Since that time the Western mine has been worked intermittently on a small scale. The large-scale production of magnesia from sea water and the high cost of mining, as well as the depletion of reserves, have caused the near-cessation of magnesite mining in California.

Most of the deposits, except for those in San Bernardino County, are associated with serpentized parts of the pre-Cretaceous ultramafic intrusives in the Coast Range and in the western Sierra Nevada (Gale, 1914, p. 486). The magnesite occurs principally as replacements in serpentine and as fissure fillings in zones of fracturing. Most of the deposits were small, and reserves in many totaled only a few thousand tons. A few were considerably larger, the most extensive being those in the Red Mountain district. These deposits have been described in detail by

Bodenlos (1950). The original reserves of the deposit at the Western mine were about 1 million tons, but most of this has been mined out; a recent estimate of reserves of the Western and several other mines in the district totals less than 180,000 tons of measured, indicated, and inferred ore (Bodenlos, 1950, p. 259).

The magnesite is typically cryptocrystalline, massive, brittle, and white, although the color may vary to gray, light green, pink, or even brick red. Its fracture is conchoidal, and freshly broken surfaces resemble unglazed porcelain (Bodenlos, 1950, p. 238). This type of magnesite generally is purer than the more coarsely crystalline varieties that occur as replacements in carbonate rocks; one analysis of material from the Western mine shows a magnesium carbonate content in excess of 99 percent (Bodenlos, 1950, p. 239).

Bodenlos (1950, p. 259-266) believes that the magnesite in the Red Mountain district was formed by the action of ascending hydrothermal solutions, heavily charged with carbon dioxide and carrying magnesium and silica derived from sources at depth. Magnesite, silica, and hydrous magnesium silicate minerals were deposited in fractured zones in the serpentinized country rock. The magnesite occurs both as replacement of serpentine and as fissure-filling material. Earlier theories of origin (Hess, 1908, p. 17-18; Bain, 1924, p. 417-419; Perry and Kirwan, 1938, p. 9-10) suggested the simple alteration of serpentine or of preexisting ultramafic rocks through the action of carbon dioxide-bearing waters. These solutions were regarded by some geologists to be hypogene and by others as supergene.

Crystalline magnesite replacing dolomite occurs near Cima and Lucerne Valley, San Bernardino County. The deposit near Cima has been discussed briefly by Rubey and Callaghan (1936, p. 118-119). The magnesite in these deposits generally is less pure than that in the serpentine replacement deposits; the chief impurities are silica and lime. Mineralization probably is associated with Jurassic igneous activity, which resulted in the replacement of favorable zones in the limestone and dolomite of Paleozoic age.

Sedimentary magnesite, deposited as beds in inland lakes of Tertiary age, occurs near Needles and Kramer, San Bernardino County, and near Bissell, Kern County. The deposits near Needles have been described in detail by Vitaliano (1950) and the one near Bissell by Gale (1914, p. 512-516), Bain (1924, p. 415-416), Bradley (1925, p. 47-50), and Rubey and Callaghan (1936, p. 114-117). The amount of impurities in these deposits is higher than in those of other types, but the magnesite in the Needles deposit is pure enough to have been considered as a possible source of magnesium ore early in World War II (Vitaliano, 1950, p. 365).

Magnesite in California

[M.D.M. indicates Mount Diablo base line and meridian (Calif.-Nev.); S.B.M. indicates San Bernardino base line and meridian (Calif.)]

<i>No. on pl. #</i>	<i>County</i>	<i>Deposit and locality</i>	<i>Reference</i>
6	Mendocino	Southard ranch deposit; 2 miles from Willets.	Bradley, 1925, p. 52.
7	do	Hixon ranch; sec. 11, T. 12 N., R. 11 W., M.D.M., 6 miles by road north of Preston.	Bradley, 1925, p. 52; Hess, 1908, p. 21.
8	Sonoma	Cloverdale area:	
		a. Albertes ranch deposits; 2 miles south- west of Cloverdale.	Bradley, 1925, p. 89.
		b. Battenburg deposit; sec. 32, T. 12 N., R. 10 W., M.D.M.	Bradley, 1925, p. 89; Hess, 1908, p. 22.
		c. Burgans ranch deposit; 1 mile north of Battenburg mine.	Bradley, 1925, p. 91.
		d. Melville ranch deposit; 2 miles south- east of Cloverdale.	Bradley, 1925, p. 92; Hess, 1908, p. 23.
		e. George Hall ranch deposit; 3 miles southeast of Cloverdale.	Hess, 1908, p. 24.
		f. Pat Cummings claim; 2.5 or 3 miles S. 35° W. of Cloverdale.	Do.
9	do	Northwest of Guerneville:	
		a. Madeira deposit (Healdsburg Marble Co.); SW corner sec. 31, T. 9 N., R. 10 W., M.D.M.	Bradley, 1925, p. 91; Hess, 1908, p. 25-26.
		b. Meeker ranch deposit; secs. 2 and 3, T. 8 N., R. 11 W., M.D.M.	Bradley, 1925, p. 91-92.
		c. Snyder ranch; about 12 miles southwest of Healdsburg.	Bradley, 1925, p. 92.
		d. Sonoma Magnesite Co. (Red Slide de- posit); secs. 6, 7, 8, 17, and 20, T. 9 N., R. 11 W., M.D.M.	Bradley, 1925, p. 92-96; Hess, 1908, p. 26-27.
		e. Western Carbonic Acid Gas Co. (Gillam Creek deposit); sec. 8, T. 8 N., R. 10 W., M.D.M.	Bradley, 1925, p. 96-97; Hess, 1908, p. 24-25.
10	Napa	Pope and Chiles Valleys:	
		a. White Rock deposit (Pope Valley or Walters mine); sec. 2, T. 9 N., R. 5 W., M.D.M.	Bradley, 1925, p. 56-58; Hess, 1908, p. 28-29.
		b. Maltby No. 2 mine (Blanco and Snow- flake mines); sec. 28, T. 8 N., R. 4 W., M.D.M.	Bradley, 1925, p. 54-55; Hess, 1908, p. 29-31.
		c. Priest mine; sec. 23, T. 8 N., R. 4 W., M.D.M.	Bradley, 1925, p. 55.
		d. Russell deposit; sec. 24, T. 8 N., R. 4 W., M.D.M.	Hess, 1908, p. 31.
		e. Elder or Detert mine (Matthai or Cleve- land mine); sec. 36, T. 8 N., R. 4 W., M.D.M.	Bradley, 1925, p. 53-54; Hess, 1908, p. 31.
11	Nevada	Deposits at Nevada City and in sec. 22, T. 16 N., R. 8 E., M.D.M.	Bradley, 1925, p. 58.
12	Placer	a. Little Bear mine; sec. 35, T. 16 N., R. 10 E., M.D.M.	Bradley, 1925, p. 59; Gale, 1914, p. 501-503.
		b. Placer County Properties Co.; sec. 13, T. 15 N., R. 10 E., and secs. 7 and 18, T. 15 N., R. 11 E., M.D.M.	Bradley, 1925, p. 59.
		c. Sullivan, et al; sec. 19, T. 16 N., R. 11 E., M.D.M.	Bradley, 1925, p. 59-60.
		d. Towle deposits; sec. 6, T. 15 N., R. 11 E., and secs. 24 and 36, T. 16 N., R. 10 E., M.D.M.	Bradley, 1925, p. 60.
13	Alameda	a. Cedar Mountain Magnesite mine; sec. 27, T. 4 S., R. 3 E., M.D.M.	Bradley, 1925, p. 41.
		b. Hayes ranch deposit; sec. 24, T. 4 S., R. 2 E., M.D.M.	Bradley, 1925, p. 42.

Magnesite in California—Continued

<i>No. on pl. 2</i>	<i>County</i>	<i>Deposit and locality</i>	<i>Reference</i>
13	Alameda—Con.....	c. Winship properties; sec. 25, T. 4 S., R. 3 E., M.D.M.	Bradley, 1925, p. 43.
		d. King claim; 2 miles from Arroyo Mocho and 22 miles southeast of Livermore.	Hess, 1908, p. 37.
		e. Banta's Camp deposit; sec. 16, T. 5 S., R. 4 E., M.D.M.	Do.
14	Santa Clara.....	a. Bradford ranch deposit; small veins 4 miles southeast of Edenvale.	Bradley, 1925, p. 78.
		b. Burnett ranch deposit; 3 miles north-east of Coyote Station.	Bradley, 1925, p. 78-79; Hess, 1908, p. 31-32.
		c. Cochran ranch deposit; 4.5 miles east of Madrone Station and 1.5 miles south of the junction of Coyote and San Felipe Creeks.	Bradley, 1925, p. 79.
		d. O'Connell Bros. ranch (Weber ranch); two groups of deposits: north group is 3 air miles northeast of Madrone, south group is 3.5 road miles east of Madrone.	Bradley, 1925, p. 79-80; Hess, 1908, p. 32-33.
15	....do.....	Red Mountain area:	
		a. Western mine; secs. 18 and 19, T. 6 S., R. 5 E., M.D.M.	Bodenlos, 1950; Bradley, 1925, p. 79-87; Gale, 1914, p. 498-501; Hess, 1908, p. 33-37.
		b. Security deposit; sec. 13, T. 6 S., R. 4 E., M.D.M.	
		c. Standard Magnesite Co.; sec. 18, T. 6 S., R. 5 E., M.D.M.	
		d. Winship properties; secs. 1 and 11, T. 6 S., R. 4 E., and sec. 7, T. 6 S., R. 5 E., M.D.M.	
		e. Fidelity deposit (never operated); sec. 12, T. 6 S., R. 4 E., M.D.M.	
16	Stanislaus.....	Red Mountain area:	
		a. Red Mountain mine (California Magnesite Co. or Patterson mine); sec. 17, T. 6 S., R. 5 E., M.D.M.	Bodenlos, 1950, p. 271-273; Bradley, 1925, p. 98-99.
		b. G. L. Fenster, et al; group of claims in sec. 22, T. 6 S., R. 5 E., M.D.M.	Bradley, 1925, p. 99.
17	....do.....	a. Bald Eagle mine (Gustine Magnesite Co.); sec. 32, T. 8 S., R. 7 E., M.D.M.	Bradley, 1925, p. 99-101; Perry and Kirwan, 1938, p. 3-15.
		b. Howard Cattle Co.; sec. 5, T. 9 S., R. 7 E., M.D.M.	Bradley, 1925, p. 101-102.
18	Tuolumne.....	a. Gray Eagle Magnesite claim; sec. 16, T. 1 S., R. 14 E., M.D.M.	Bradley, 1925, p. 138-139.
		b. Monarch Mine Co.; small body 1.5 miles from Chinese Camp.	Bradley, 1925, p. 139.
		c. Peter Maki claims; sec. 6, T. 1 S., R. 14 E., M.D.M.	Do.
		d. White Rock Magnesite mine; sec. 6, T. 1 S., R. 14 E., M.D.M.	Bradley, 1925, p. 139-140.
19	San Benito.....	a. Bonanza Quicksilver mine; sec. 29, T. 18 S., R. 12 E., M.D.M.	Bradley, 1925, p. 60.
		b. Sampson Magnesite mine (Maltby No. 3); secs. 34, 35, and 36, T. 17 S., R. 11 E., M.D.M.	Bradley, 1925, p. 66-71; Gale, 1914, p. 503-509.
		c. Standard group (Superior Magnesite Co.); secs. 35 and 36, T. 17 S., R. 11 E., M.D.M.	Bradley, 1925, p. 71.
20	Fresno.....	a. Snow Cap and Governor claims; 9 miles east of Sanger.	Hess, 1908, p. 50-51; Gale, 1914, p. 509.
		b. Piedra area; includes several properties.	Bradley, 1925, p. 44-46.

Magnesite in California—Continued

<i>No. on pl. 2</i>	<i>County</i>	<i>Deposit and locality</i>	<i>Reference</i>
20	Fresno—Con.....	c. Piedra Magnesite Co. (Fresno Magnesite Co.); sec. 5, T. 13 S., R. 24 E., M.D.M.	Bradley, 1925, p. 44.
		d. Piedra mine (Ward); sec. 9, T. 13 S., R. 24 E., M.D.M.	Bradley, 1925, p. 44-45.
21	Monterey.....	a. Undeveloped deposits in sec. 28, T. 23 S., R. 15 E., M.D.M.	Bradley, 1925, p. 53.
		b. Kings Magnesite Co.; sec. 26, T. 23 S., R. 15 E., M.D.M.	Do.
22	Kings.....	Kings Magnesite Co.; sec. 20, T. 23 S., R. 16 E., M.D.M.	Bradley, 1925, p. 51.
23	Tulare.....	Hamilton ranch deposit; sec. 22, T. 18 S., R. 27 E., M.D.M.	Bradley, 1925, p. 110; Gale, 1914, p. 509-511; Hess, 1908, p. 39-49.
24	----do.....	a. Cross ranch deposit (Burr Bros. lease); sec. 19, T. 19 S., R. 27 E., M.D.M.	Bradley, 1925, p. 107.
		b. Merryman Magnesite mine; sec. 7, T. 19 S., R. 27 E., M.D.M.	Bradley, 1925, p. 119.
		c. Mitchell deposit; sec. 12, T. 19 S., R. 26 E., M.D.M.	Bradley, 1925, p. 121.
		d. Wood Magnesite mine; sec. 6, T. 19 S., R. 27 E., M.D.M.	Bradley, 1925, p. 137.
		e. Dumont Magnesite; sec. 10, T. 19 S., R. 27 E., M.D.M.	Bradley, 1925, p. 108.
25	----do.....	a. Adeline Magnesite mine (later El Mirador Magnesite Co.); sec. 24, T. 20 S., R. 27 E., M.D.M.	Bradley, 1925, p. 106.
		b. Blue Crystal Magnesite group; sec. 24, T. 20 S., R. 27 E., M.D.M.	Bradley, 1925, p. 106-107.
		c. Fairview Magnesite mines; sec. 30, T. 20 S., R. 28 E., M.D.M.	Bradley, 1925, p. 109.
		d. Headburg Magnesite; sec. 11, T. 20 S., R. 27 E., M.D.M.	Bradley, 1925, p. 118.
26	----do.....	a. DeMoulin mine (Magnesite Refractories Co. or Stewart mine); sec. 12, T. 21 S., R. 27 E., M.D.M.	Bradley, 1925, p. 107-108.
		b. Gill ranch (Sierra Magnesite Co.); secs. 7 and 8, T. 21 S., R. 28 E., M.D.M.	Bradley, 1925, p. 109-110.
		c. Oakland Magnesite Co.; secs. 7 and 8, T. 21 S., R. 28 E., M.D.M.	Bradley, 1925, p. 123.
		d. Harker mine; sec. 17, T. 21 S., R. 28 E., M.D.M.	Bradley, 1925, p. 110-117.
27	----do.....	a. Duncan Magnesite mine; sec. 25, T. 21 S., R. 28 E., and sec. 30, T. 21 S., R. 29 E., M.D.M.	Bradley, 1925, p. 108-109.
		b. Hawley Pulp and Paper Co. (Duncan property); sec. 30, T. 21 S., R. 29 E., M.D.M.	Bradley, 1925, p. 117-118.
		c. Lindsay Magnesite mine; secs. 30 and 31, T. 21 S., R. 29 E., M.D.M.	Bradley, 1925, p. 124-125.
		d. McKiernan mine (west of Lindsay mine).	Bradley, 1925, p. 119.
		e. Rex Plaster mine (Sierra Magnesite Co.); sec. 31, T. 21 S., R. 29 E., M.D.M.	Bradley, 1925, p. 124.
		f. Tulare Mining Co.; secs. 30 and 31, T. 21 S., R. 29 E., M.D.M.	Bradley, 1925, p. 125-129.
28	----do.....	a. Deer Creek mine (Langley-Cook lease); sec. 21, T. 22 S., R. 28 E., M.D.M.	Bradley, 1925, p. 107.
		b. Mentz property (Ravalli lease); sec. 28, T. 22 S., R. 28 E., M.D.M.	Bradley, 1925, p. 119.
		c. Oakland Magnesite Co.; sec. 21, T. 22 S., R. 28 E., M.D.M.	Bradley, 1925, p. 123.

Magnesite in California—Continued

<i>No. on pl. #</i>	<i>County</i>	<i>Deposit and locality</i>	<i>Reference</i>
28	Tulare—Con.....	d. Simmons ranch deposit (Bartlett lease); 8 miles southeast of Porterville.	Bradley, 1925, p. 135.
		e. Tulare Mining Co.; sec. 28, T. 22 S., R. 28 E., M.D.M.	Bradley, 1925, p. 135-137.
29	....do.....	Chamberlain ranch deposits; secs. 3 and 10, T. 23 S., R. 28 E., M.D.M.	Bradley, 1925, p. 107.
30	San Luis Obispo...	Small veins on the Kisar place, 8 or 9 miles northwest of Cambria.	Bradley, 1925, p. 76.
31	Santa Barbara....	Happy Canon claims; sec. 15, T. 7 N., R. 29 W., S.B.M.	Bradley, 1925, p. 77.
32	Los Angeles.....	Magnesite outcrops on properties of Cali- fornia Graphite Co., 18 miles from Saugus.	Bradley, 1925, p. 52.
33	Kern.....	Reported occurrence in Walker's Pass in the Sierra Madre Mountains, east of Bakers- field.	Bradley, 1925, p. 50.
34	....do.....	Near Bissell; sedimentary deposit in the northeastern part of sec. 11, T. 10 N., R. 11 W., S.B.M.	Bradley, 1925, p. 47-50; Gale, 1914, p. 512-516; Rubey and Callaghan, 1936, p. 114-117.
35	San Bernardino....	Kramer Hills; sedimentary deposit in secs. 10, 11, 14, and 15, T. 9 N., R. 6 W., S.B.M.	
36	....do.....	North Lucerne Valley; sec. 15, T. 6 N., R. 1 W., S.B.M., dolomite with veins of mag- nesite.	
37	....do.....	Afton; 1.5 miles east of Afton Station; low grade.	Bradley, 1925, p. 72-75; Rubey and Callaghan, 1936, p. 117-118.
38	....do.....	a. Cima; small deposit about 12 miles northeast of Cima. b. Cima; reported but unconfirmed occur- rence in Providence Mountains, about 12 miles southeast of Cima.	Rubey and Callaghan, 1936, p. 118-119. Bradley, 1925, p. 75; Rubey and Callaghan, 1936, p. 119.
39	....do.....	Needles; 14 miles by road southwest of Needles; two sedimentary deposits: one in secs. 15 and 22, T. 8 N., R. 21 E., S.B.M., the other in the southwestern part of T. 8 N., R. 21 E.	Vitaliano, 1950.
40	Riverside.....	Hemet Magnesite mine; sec. 31, T. 5 S., R. 1 W., S.B.M., about 4 miles by road from Winchester.	Bradley, 1925, p. 61-65.

IDAHO

Surface deposits of hydromagnesite, 2 to 4 feet thick and covering areas of from 2 to 13 acres, occur about 4 miles from Soda Springs, Bannock County (Yale and Stone, 1921b, p. 12-13). The material, although appearing somewhat earthy and impure, consists of about 90 percent hydromagnesite and 10 percent impurities. Reserves of usable material are not known, and the deposits have not been developed (Hodge, 1938, p. 74).

Magnesite in Idaho

<i>No. on pl. #</i>	<i>County</i>	<i>Deposit and locality</i>	<i>Reference</i>
47	Bannock.....	Soda Springs; small deposits of hydromagne- site occur about 4 miles from Soda Springs.	Hodge, 1938, p. 74; Yale and Stone, 1921b, p. 12-13.

NEW MEXICO

Magnesite occurs in the Organ Mountains and San Andres Mountains of Dona Ana County and in the Burro Mountains near Redrock, Grant

County, about 30 miles north of Lordsburg. The deposits in the Organ Mountains are in the southern part of the range, east of Las Cruces, along the southern boundary of T. 23 S., R. 4 E., New Mexico principal meridian. These deposits have been described by Dunham (1935, p. 236). The magnesite replaced certain beds in dolomite inclusions in a quartz monzonite intrusive. Analyses (Dunham, 1935, p. 237) show the magnesite to be of good quality. The deposits have been developed, but resources are not known. A smaller occurrence is reported on the southwest side of the San Andres Mountains north of Organ Pass (Taft, 1936).

A small deposit of magnesite, hydromagnesite, and brucite crops out west of Ash Creek about 2 miles above its junction with the Gila River, near Redrock, Grant County. It has been described briefly by Yale and Stone (1921a, p. 234). The magnesite occurs in lenses in partly serpentinized limestone or dolomite associated mainly with Precambrian intrusives.

Magnesite in New Mexico

<i>No. on pl. #</i>	<i>County</i>	<i>Deposit and locality</i>	<i>Reference</i>
49	Grant.....	Riolite Canyon (near Redrock); small deposit of magnesite, hydromagnesite, and brucite occurs on the west side of Ash Creek, about 2 miles above its junction with the Gila River.	Yale and Stone, 1921a, p. 234.
50	Dona Ana.....	Organ Mountains; magnesite and dolomite occur in South and Target Range Canyons in the southeastern part of T. 23 S., R. 4 E.	Dunham, 1935, p. 236; Talmage and Wootton, 1937, p. 111.
51	.....do.....	San Andres Mountains; occurrence on southwest side of mountain; north of Organ Pass.	Taft, 1936; Talmage and Wootton, 1937, p. 112.

NEVADA

Magnesite, in deposits representing both the carbonate rock replacement and the sedimentary types, occurs in several localities in Nevada. However, only the group of deposits at Gabbs, Nye County, is of commercial importance. The Gabbs area is also the only area in the United States known to contain commercial deposits of brucite. Other magnesite deposits in Nevada are either too small or of too low grade to be of commercial value under present conditions.

GABBS

Although the brucite deposits at Gabbs were discovered in 1927 (Callaghan, 1933, p. 7), very little ore was mined, and that only intermittently, during the next several years. Commercial production began in 1934 (Partridge and Davis, 1935, p. 1168) and, except during 1935, has been continuous up to the present (1954). Nearly the entire production has been shipped to Ohio where it is processed for use in special refractories (Ladoo and Myers, 1951, p. 120). Magnesite has been produced since about 1940 and, from September 1942 to November 1944, it supplied the ore for the world's largest magnesium plant at Henderson, near Las Vegas, Nev. (Callaghan and Vitaliano, 1948, p. 1). At present

two companies are producing refractory magnesia from Gabbs magnesite (Irving and Uswald, 1954, p. 4).

The deposits are on the western slope of the Paradise Range, in the extreme western part of Nye County, approximately 29 miles by road northeast of Luning. The geology of the Gabbs area has been described by Callaghan (1933) and by Callaghan and Vitaliano (1948). The material that follows has been summarized from the latter report, except where noted. Magnesite and brucite occur as replacement deposits in dolomite, the uppermost beds of the Luning formation (Upper Triassic), present here as an overriding plate above a thrust fault. In the mineralized areas the dolomite, which generally is dense, dark gray to black, and fine grained, has been replaced by recrystallized dolomite, magnesite, brucite, and silicate minerals.

The magnesite is coarse to very fine grained, massive, white to gray with a brown-weathering surface, and often is so similar in appearance to the recrystallized dolomite which it replaced that the two cannot readily be distinguished. The brucite, which is massive, has a soapy appearance, and varies from white to yellow or brown, is found in bodies that are distributed along the contact between the magnesitized areas and a granodiorite stock. The mineralization is thought to be associated with the granodiorite.

Impurities contained in various minerals associated with the magnesite include iron, alumina, silica, and lime. Particularly troublesome in mining are the many apophyses from the stock into the mineralized areas, necessitating some selectivity in mining. Beneficiation is accomplished by flotation or heavy-media separation (Utley, 1952, p. 98).

The origin of the magnesite and associated minerals is complex, as several stages probably were involved in the genesis of the present mineral assemblage. Essentially, the process of mineralization involved replacement of the dolomite by magnesite and recrystallized dolomite through the action of hypogene solutions. Igneous intrusive rocks were then emplaced and were accompanied by the introduction of pyrite and silicate minerals. Brucite probably was formed at this time. Later solutions caused magnesite and brucite to be replaced by dolomite.

Callaghan and Vitaliano (1948, p. 17) estimate 27 million tons of magnesite containing less than 5 percent lime and total reserves of magnetitic material at about 52 million tons in the principal ore bodies exposed at the surface.

OVERTON

A large sedimentary deposit of magnesite occurs about 5 miles south-southwest of Overton, Clark County. The geology of the area has been described by Longwell (1928), and Rubey and Callaghan (1936, p. 119-139) have presented detailed descriptions of the deposit, its origin, and mineralogy. This brief summary is taken from the latter report. The

deposit of magnesite occurs in thin beds of varied composition associated with a thick unit of white clayey dolomite belonging to the Horse Spring formation of Tertiary(?) age. The deposit is lenticular and is covered with gravel overburden ranging from 30 to 50 feet in thickness. Resources are estimated to be more than 5 million tons of impure magnesite containing more than 30 percent magnesia and occurring in beds at least 6 inches thick.

CURRENT CREEK

A unique occurrence of magnesite represented in a group of deposits in the Curreant Creek district, about 29 miles by road southwest of Ely, has been described by Vitaliano (1951). The district lies on the boundary between White Pine and Nye Counties. Magnesite occurs as nodules, veins, lenses, and disseminated grains in masses of altered tuff of Tertiary age. Locally the tuffaceous matrix contains a magnesium silicate mineral of the serpentine group. The complex mineralogy of the deposits has been described in detail by Faust and Callaghan (1948). Although much of the magnesian material is quite high in silica and lime, it is amenable to partial beneficiation (Holmes and Matson, 1950, p. 8). Vitaliano (1951, p. 23) estimates that reserves in the district include about 10,000 tons of commercial-grade magnesite and about 350,000 tons of the magnesium silicate-bearing material.

Magnesite in Nevada

<i>No. on pl. 2</i>	<i>County</i>	<i>Deposit and locality</i>	<i>Reference</i>
41	Nye.....	Gabbs; large commercial deposits of brucite and magnesite in secs. 26, 35, and 36, T. 12 N., R. 36 E., M.D.M. ¹	Callaghan and Vitaliano, 1948.
42	Nye and White Pine	Curreant Creek district; two groups of small deposits in the northwestern part of T. 12 N., R. 61 E., and adjoining part of T. 12 N., R. 60 E.; and in T. 12 N., R. 59 E., (unsurveyed) M.D.M.	Vitaliano, 1951.
43	Esmeralda.....	Lone Mountain; reported but unconfirmed occurrence southwest of Tonapah, near Mount Diablo base line, Rs. 39 to 41 E.	Gale, 1912, p. 520; Rubey and Callaghan, 1936, p. 143-144.
44	Nye.....	Payne deposit; small deposit 28.4 miles northwest of Indian Springs, on the Oak Springs Road.	
45	Clark.....	Overton; sec. 2, T. 17 S., R. 67 E., and secs. 34 and 35, T. 16 S., R. 67 E., M.D.M., about 5 miles south-southwest of Overton; large sedimentary deposit.	Rubey and Callaghan, 1936, p. 119-139.
46	do.....	Bauer deposit; 17 miles by road southeast of St. Thomas and 9 miles due north of the former Gold Butte Post Office; somewhat impure sedimentary deposit.	Rubey and Callaghan, 1936, p. 140-141.

¹ Mount Diablo base line and meridian (Calif.-Nev.).

OREGON

Deposits of magnesite, probably similar to those associated with serpentine in California, are reported along the lower Illinois River, on the

Smith River, and on Diamond Creek, Curry County; and near Holland, Josephine County (Hodge, 1938, p. 73-74). Details concerning these deposits are lacking, but it is doubtful that commercial deposits occur in this area (F. G. Wells, 1952, oral communication).

Magnesite in Oregon

<i>No. on pl. #</i>	<i>County</i>	<i>Deposit and locality</i>	<i>Reference</i>
4	Curry.....	Deposits along the lower Illinois River, the Smith River, and on Diamond Creek.	Hodge, 1938, p. 73-74.
5	Josephine.....	Near Holland.....	Hodge, 1938, p. 74.

PENNSYLVANIA

Magnesite occurs in narrow veins and stockworks in the State Line serpentine along the Pennsylvania-Maryland boundary. Deposits along the Chester-Lancaster County line, near where Octoraro Creek crosses the State line, were mined during the last century (Stone, 1922, p. 1). Smaller deposits have been noted also in Fulton and Peach Bottom Townships, Lancaster County (Stone, 1922, p. 2).

Magnesite in Pennsylvania

<i>No. on pl. #</i>	<i>County</i>	<i>Deposit and locality</i>	<i>Reference</i>
54	Chester and Lancaster.	Small deposits near the oxbow of Octoraro Creek on the Pennsylvania-Maryland boundary.	Stone, 1922, p. 1.
54	Lancaster.....	Occurrences in Fulton and Peach Bottom Townships.	Stone, 1922, p. 2.

TEXAS

Magnesite was produced during and immediately following World War II from deposits in the Sharp Mountain area, south of Llano, Llano County, for use principally as fertilizer. The most important deposits are 3 and 6 miles southeast of Llano where they occur as lenses in dolomite marble, part of a Precambrian sequence of metamorphic rocks which has been intruded by granites (Chelf, 1941). Some analyses of the material have been published (Schoch, 1938), but estimates of reserves in the area are not available.

A small deposit of low-grade magnesite occurs with dolomite as a lens in chlorite schist about 3 miles northwest of Mason, Mason County (McCammon, 1941, p. 4). Reserves are estimated to be less than 15,000 tons of mixed magnesite and dolomite (McCammon, 1941, p. 5).

Magnesite in Texas

<i>No. on pl. #</i>	<i>County</i>	<i>Deposit and locality</i>	<i>Reference</i>
52	Mason.....	Mason, 3 miles northwest; low-grade deposit.	McCammon, 1941, p. 4-5.
53	Llano.....	a. Gray Fowler tract (Merameo Minerals Co.); 3 miles by road southeast of Llano. b. Stribling ranch deposit (Texas Mines); 6 miles southeast of Llano.	Chelf, 1941.

UTAH

Small lenses and veins of magnesite occur in the Fish Springs district, about 15 miles east of Callao, Juab County. The deposits have been discussed briefly by Crawford (1941). The magnesite replaces parts of a buff-colored hydrothermally altered dolomite of Cambrian age. The deposits probably are too small to mine for the magnesite alone, but might be recovered in conjunction with quarrying of the enclosing dolomite. Nothing is known, however, of the purity of the dolomite.

Magnesite in Utah

No. on pl. 2	County	Deposit and locality	Reference
48	Juab	Fish Springs deposit; small veins in the Fish Springs district in T. 11 S., R. 14 W.	Crawford, 1941.

VERMONT

Magnesite is associated with talc locally in the belt of ultramafic rocks that extends in a north-south direction through the central part of Vermont. Experiments on flotation of talc-magnesite ores have produced magnesite-rich tailings (Clemmer and Cooke, 1936).

WASHINGTON

Commercial deposits of magnesite are restricted to the so-called "magnesite belt," a narrow, well-defined zone some 30-odd miles long, which is entirely in Stevens County, northeastern Washington. The magnesite is of the carbonate rock replacement variety. Deposits range in size from those of small tonnage to large irregular lenses containing reserves in excess of a million tons, which are adequate to support production for some years.

Production of magnesite on a commercial scale began at the end of 1916, and in 1917, the first full year of production, the new industry supplied more than 100,000 tons of crude magnesite (Tyler, 1931b, p. 24), an amount equal to half that produced the same year by the well-established industry in California. Production has been nearly continuous since that time, and systematic development and exploration, aided by a better understanding of the possible mode of origin of the magnesite, have resulted in the establishment of large reserves during recent years (Bennett, 1943). New methods of beneficiation have been an important factor in increasing the tonnage of usable material.

Much has been written about the Stevens County deposits, and the more important work has been summarized briefly by Bennett (1941, p. 4-6). According to Bennett, the magnesite deposits are confined almost entirely to areas within his Stensgar dolomite, a formation in his Deer Trail group (Precambrian(?)) of argillites, slates, phyllites, quartzites, and dolomites. The Stensgar, generally 300 to 350 feet thick but more than 700 feet thick in its northern area of outcrop, is typically a fine-

grained dense light-bluish or pinkish-gray dolomite. Locally it has been recrystallized into a medium- to coarse-grained dolomite marble. The formation is exposed in a series of outcrops that extends in a south-southwesterly direction from a few miles northwest of Chewelah, along the eastern foothills of the Huckleberry Mountains, to a point within 2 miles of the Spokane River, a total distance of about 31 miles.

According to Campbell and Loofbourow (1942, written communication) and Callaghan (1942, written communication), the so-called Stensgar dolomite changes locally, either gradually or rather abruptly, into magnesite. The magnesite varies from finely to coarsely crystalline and from white through gray to brown and black in color. Where magnesitization of the dolomite has been extensive, the rock tends to stand topographically higher than the surrounding dolomite, because of its greater resistance to weathering. The impurities are chiefly lime, in included dolomite; silica, as quartz or in silicate minerals; and, to some extent, iron carbonate. Flotation and heavy-media separation are used to remove the impurities.

Magnesite in Washington

<i>No. on pl. #</i>	<i>County</i>	<i>Deposit and locality</i>	<i>Reference</i>
1	Skagit.....	Rockport; reported occurrence 0.5 mile from the Great Northern Railway.	Hodge, 1938, p. 73.
2	Okanogan.....	Riverside area; reported occurrence.....	Do.
3	Stevens.....	Magnesite belt; extends from 4 miles northwest of Chewelah to within 2 miles of the Spokane River. a. Finch quarry; sec. 30, T. 32 N., R. 40 E. b. Moss-Allen quarry; secs. 25 and 36, T. 32 N., R. 39 E., and secs. 30 and 31, T. 32 N., R. 40 E. c. Woodbury quarry; sec. 1, T. 31 N., R. 39 E. d. Mountain View deposit; sec. 3, T. 31 N., R. 39 E. e. Nogue deposit; sec. 4, T. 31 N., R. 39 E. f. Phoenix deposit; sec. 3, T. 31 N., R. 39 E. g. Midnight deposit; sec. 7, T. 31 N., R. 39 E. h. Keystone quarry; sec. 9, T. 31 N., R. 39 E. i. Davis deposit; sec. 18, T. 31 N., R. 39 E. j. Double Eagle quarry; sec. 18, T. 31 N., R. 39 E. k. Crosby quarry; sec. 18, T. 31 N., R. 39 E. l. Red Marble quarry; sec. 25, T. 31 N., R. 38 E. m. U. S. Magnesite quarry; sec. 10, T. 30 N., R. 38 E. n. Turk quarry; sec. 1, T. 29 N., R. 37 E., and sec. 36, T. 30 N., R. 37 E.	Bennett, 1941; Bennett, 1943; Campbell and Loofbourow, 1942, written communication.

Magnesite mineralization apparently has been most intense in the north-central part of the belt, and mining operations are centered mainly

in the areas southwest of Chewelah and west of Valley. At least two large deposits occur, however, in the southern part of the belt southeast of Fruitland, in the vicinity of Turk (Bennett, 1943).

The most probable theory of origin, according to Callaghan (1942, written communication), is that the preexisting dolomite was recrystallized or replaced by magnesite through the action of ascending hydrothermal solutions, probably associated with nearby granitic intrusives, which spread through fractures and along bedding planes removing lime and depositing magnesia. Field evidence indicates that deformation of the dolomite preceded the formation of the magnesite and that major shearing and faulting were the controlling factors in the distribution of the magnesite (Bennett, 1941, p. 14).

OTHER STATES

Magnesite, probably of little more than mineralogical interest, occurs in Massachusetts, Maryland, New Jersey, and New York (Harness and Jensen, 1943, p. 2).

RESERVES

Reserves of magnesite are difficult to calculate, because of the irregularities in size and shape of many of the deposits, lack of uniformity in composition of the material, different chemical and physical specifications for various uses, and possibilities for beneficiation. Reserves of usable magnesite readily available for removal by open-pit methods in Washington and Nevada were estimated in 1944 (U. S. Bur. Mines and U. S. Geol. Survey, 1948, p. 128) at about 8 million tons, with an additional 85 million¹ tons of impure material that could be considered inferred ore. At the 1941 rate of consumption, these reserves were considered sufficient for about 250 years, according to the reference cited. Crude magnesite mines in 1941 amounted to about 375,000 tons (Schallis and Warner, 1942, p. 1499). In 1952 approximately 511,000 tons were mined (Irving and Uswald, 1954, p. 1).

DOLOMITE

DESCRIPTION AND DEFINITIONS

The mineral dolomite is the double carbonate of calcium and magnesium, expressed as $\text{CaMg}(\text{CO}_3)_2$ or $\text{CaCO}_3 \cdot \text{MgCO}_3$, and contains approximately 30.4 percent CaO, 21.9 percent MgO, and 47.7 percent CO_2 (Palache and others, 1951, p. 212). Expressed as carbonates the composition is 54.35 percent CaCO_3 and 45.65 percent MgCO_3 (Ford, 1932, p. 516). Bivalent iron or manganese can substitute within limits for magnesium to form other varieties (Palache and others, 1951, p. 211–

¹This figure, as given in the reference, is 85,000 tons. From other data given, it clearly is a typographical error and should be 85 million tons.

213). Dolomite is similar in appearance to calcite (CaCO_3) but is slightly harder (calcite, hardness 3; dolomite, hardness $3\frac{1}{2}$ -4), heavier (calcite, specific gravity 2.71; dolomite, specific gravity 2.85), and reacts very slowly, if at all, with cold dilute acid. Pure dolomite is colorless or white but may vary through shades of red, green, brown, and gray to black. It commonly is massive, finely to coarsely granular, but sometimes is porcelaneous and breaks with a conchoidal fracture.

Dolomite, used as a rock name, generally is applied to carbonate rocks composed of mixtures of dolomite and calcite, and, although massive bodies of pure crystallized dolomite are not common in nature, dolomitic rocks occur extensively. Unfortunately, there is little uniformity in the use of the name, and rocks containing relatively small percentages of magnesium carbonate have been referred to in much of the literature as dolomites. Conversely, in a great deal of the older literature the term "limestone" was applied to rocks that are now called dolomites and magnesium limestones.

It is somewhat difficult to reconcile scientific and industrial definitions of dolomite. Pettijohn (1949, p. 312) defines dolomites as "those varieties of limestones containing more than 50 percent carbonate, of which more than half is dolomite." Following Pettijohn's classification, a rock containing 90 percent or more dolomite in the carbonate fraction would be classed as dolomite; one containing 50 to 90 percent dolomite in the carbonate fraction would be a calcitic dolomite. If the "dolomite" were a pure carbonate rock, in which the carbonate fraction would comprise 100 percent of the total weight, 19.67 to 21.86 percent by weight of the rock would be magnesia. If, on the contrary, only the minimum requirements of the definition are met, that is, if the carbonate fraction constitutes about 50 percent of the total weight, a rock containing as little as 9.84 percent by weight of magnesia also would be classed as dolomite. A dolomite of this composition would not satisfy industrial requirements for a high-magnesia rock.

More useful to industry are those definitions that show relationship between the magnesia content of the total rock and its lithologic designation. Different schemes of classification have been used in the literature, and there seems to be some agreement that to be called a dolomite a rock should contain a minimum of 40 percent magnesium carbonate (about 19.5 percent MgO) (Hatmaker, 1931, p. 2; Hopkins, 1942, p. 3; Weitz, 1942, p. 3). The classification of the carbonate rocks as "natural building stones" on page 392, Part 3 of 1952 Book of American Society for Testing Materials Standards includes the following definitions:

Dolomite—A limestone containing in excess of 40 percent of magnesium carbonate as the dolomite molecule.

Magnesian (Dolomitic) Limestone—A limestone containing not less than 5 nor more than 40 percent of magnesium carbonate.

In the present paper, the terms dolomite and dolomitic or magnesian limestone will be used, insofar as possible, in conformance with the definitions above. In general, the rocks whose localities are shown on the tables accompanying the State summaries contain less than 10 percent noncarbonates. The terms "high-purity" and "high-grade" are used interchangeably to designate rocks containing only a few percent of impurities. If the impurities are in excess of about 3 percent, the rock is designated as "moderately high" in impurities. Rock containing more than about 5 percent impurities is called "high" in impurities.

The writer has found that in the literature little reliability can be placed on the lithologic designation of a rock as a dolomite, unless the report bears specifically on the economic possibilities of a deposit or the description is accompanied by chemical analyses. This is true particularly in older reports. In the descriptions of individual formations in the following pages, the lithologic designations have sometimes been modified by this writer to conform to the definitions above, usually on the basis of the chemical analyses included in the reports studied.

ORIGIN AND MODE OF OCCURRENCE

The origin of dolomite has been the subject of much study. Van Tuyl (1916) presented an excellent review of the various theories of origin and the evidence supporting and opposing each. Pettijohn (1949, p. 316) classifies all the theories of origin under three major categories. These are "(1) primary precipitation of the dolomite, (2) selective leaching of calcite from an original mixture of calcite (or aragonite) and dolomite, and (3) replacement of an original calcitic limestone." Evidence indicates that most dolomites probably are the result of replacement of preexisting sediments, although Stout (1941, p. 9-11) believes that the extensive dolomites of Silurian age of western Ohio are primary precipitates. The time of replacement of the original sediments is problematical. Steidtmann (1911, p. 325-342; 1917, p. 435-445) and Van Tuyl (1916, p. 398-399) have presented evidence indicating that the more extensive dolomites have been formed by the alteration of limestones beneath the sea, probably by the diagenetic replacement of calcium carbonate by dolomite. Miller (1934, p. 51-53) also believes that the dolomites of Pennsylvania have been formed in large part by the same processes. Hewett (1931, p. 57-67), through comprehensive field and laboratory study, has shown that alteration due to the action of magnesia-rich solutions on limestone has formed dolomite in southern Nevada. Pettijohn (1949, p. 317) suggests that dolomitization may take place at several stages in the formation of the final rock.

Dolomites and dolomitic limestones occur chiefly as sedimentary strata associated with limestones and other sedimentary rocks of chemical or detrital origin. They may form thick extensive beds, thin beds, or lenses

and irregular masses. Many formations, some designated "limestone," others "dolomite," are in fact composed of limestone layers, dolomite layers, and layers of dolomitic limestone. In addition to such stratigraphic variations in composition, formations commonly contain beds that vary in composition from limestone to dolomite along their strike. Thus, a certain bed that is limestone in one locality may be represented elsewhere by a bed of dolomitic limestone or dolomite. Less commonly, marbled dolomite occurs as lenses or layers associated with gneisses, schists, or other metamorphic rocks, as typified by occurrences in Massachusetts, North Carolina, and Texas.

Although dolomitic limestones are of widespread occurrence, large deposits of pure dolomite are much more restricted, and many potentially commercial deposits are confined to definitely limited zones within formations of impure carbonate rocks that are unsuitable for chemical or other industrial purposes.

USES

The following reports summarize most of the uses of limestone and dolomite (Miller, 1934, p. 77-111; Lamar and Willman, 1938; Stout, 1941, p. 426-447). Although these summaries are somewhat general, they afford a good background on the uses of the carbonate rocks. More detailed information regarding specifications for specific uses will be found in the literature. Chemical and physical specifications vary widely, not only with the use but also with the user, as technologies have been modified in order to make use of local sources of raw materials. Any given deposit, after it has been thoroughly studied for its size, uniformity, ease of quarrying, and marketability, should be adequately tested to determine whether or not the rock will fulfill requirements of the potential consumer.

The uses of the carbonate rocks can be divided into two broad categories: those in which the physical properties are more important and those in which the chemical composition is more important. The second category can be further subdivided into (a) uses in which limestone is required, (b) uses in which dolomite is required, and (c) uses in which one type can be substituted for the other.

The construction industries annually consume great quantities of limestone and dolomite in the first category. Physical properties of the rock are important, and, in general, the chemical composition of the rock need be considered only insofar as it affects the physical properties. Limestone and dolomite are used interchangeably in the form of dimension stone and as crushed and broken stone for concrete aggregate, railroad ballast, road metal, riprap, and a variety of other purposes.

The agricultural, chemical, and manufacturing industries consume the carbonate rocks for uses in which the chemical composition is more important. Uses that annually require large amounts of reasonably pure

limestone include the manufacture of portland cement, high-calcium lime, alkalies, calcium carbide, mineral feeds, sugar refining, and others. Dolomite is required for refractories, magnesium production, manufacture of technical carbonate, and the milk-of-lime-process for the manufacture of paper. The uses that require dolomite as a raw material have been described by Colby (1941). Substitution of one rock type for the other is permitted when the rock is to be used for agricultural limestone, blast-furnace flux stone, fertilizer ingredient, coal-mine dusting, rock-wool production, whiting substitute, and various fillers.

It is difficult to determine the tonnage of dolomite consumed annually in the United States. Published statistics (Chandler and Jensen, 1954, p. 1205) show that in 1951 more than 5 million tons of dolomite was used as refractories, nearly 364,000 tons for basic magnesium carbonate (including refractory magnesia), and 92,000 tons in the paper industry. In addition to this known amount, an undetermined part of a total of more than 205 million tons of "limestone" was dolomite and dolomitic limestone used as dimension stone and as crushed and broken stone for many purposes.

Of the numerous uses of dolomite that do not permit substitution of limestone, the most important from the tonnage consumed are as refractories and for magnesium production. As noted above, several million tons of dolomite are used annually for refractories. Capacity production of metallic magnesium from plants in the United States that use only dolomite as a raw material would require a total of about 560,000 tons of dolomite per year. These two uses are described in more detail below.

REFRACTORIES

Dolomite and dolomitic limestone containing not less than 35 percent magnesium carbonate have found wide application in the steel industry and in the nonferrous metals industry as a substitute for grain magnesite. The subject of dolomite refractories has been discussed in general terms by Lamar and Willman (1938, p. 18-20) and Colby (1941, p. 3-4) and in more detail by Schallis (1942). The rock is used in the form of crushed raw stone, dead-burned clinker, and as a base for special refractories. It is used chiefly for patching or repairing furnaces and also for building up bottoms and banks of basic open-hearth furnaces and, to a lesser extent, electric furnaces.

Owing to the instability of the lime, dolomite has not proved to be a very satisfactory substitute for magnesite in the form of refractory brick (Schallis, 1942, p. 6). In order to form a stable brick, the dolomite must be processed in such a way as to control hydration and chemical reactivity of the lime. Hydration causes deterioration of the bricks, both in storage and in use, and difficulty in handling. Chemical reaction with

materials in the furnace also decreases the utility of the brick. To impart the necessary refractory properties to dead-burned dolomite the lime must, then, be partly or completely inhibited (semistabilized or stabilized) or must be removed. Several methods for the extraction of magnesia from dolomite have been summarized by Schallis (1943).

Various chemical specifications for dolomite to be used as refractory material have been mentioned in the literature (Lamar and Willman, 1938, p. 19-20; Colby, 1941, p. 3-4). The minimum requirement for magnesium carbonate content is 35 percent. The silica content should be less than 1 percent and the combined alumina and iron oxide less than 1.5 percent. Naturally occurring impurities generally are undesirable because they act as diluents, decreasing the carbonate content, and they do not usually occur uniformly throughout the rock. Impurities, principally iron oxide, may be added to the rock when crushed, however, to facilitate the dead-burning process (Schallis, 1942, p. 4)

MAGNESIUM

Dolomite has been used successfully as a commercial ore of magnesium in several processes, including ferrosilicon reduction (Pidgeon), carbothermic (Hansgirg), and certain of those involving electrolysis of magnesium chloride. During World War II attention was turned to the development of these processes in order to utilize dolomite, the widespread occurrence of which eliminated the necessity for building magnesium plants along sea coasts.

Since World War II the ferrosilicon reduction process is the only one that has attained any importance in the United States, although it is uneconomic under normal competitive conditions. Of the 6 Government-owned plants, 4 are ferrosilicon reduction plants and 2 are electrolytic plants. These facilities are now used only intermittently to supplement production from the single, privately owned sea-water plant. The table below lists the magnesium plants in the United States and also shows the capacity tonnage dependent upon dolomite as a source of raw material.

Despite their higher costs of production, the ferrosilicon reduction plants, according to Comstock (1954, p. 797), have made satisfactory standby facilities because of their simplicity of design and operation, their easily and economically storable equipment, and the comparatively low consumption of electric power per unit of magnesium produced. Approximately 4.5 kwh are needed to produce 1 pound of magnesium (the power is used in the production of the ferrosilicon reducing agent), as contrasted with 10 kwh per pound of magnesium produced by the electrolytic process.

The ferrosilicon reduction process has been described by Pidgeon and Alexander (1944) and by Pidgeon and others (1946). Essentially, this process involves crushing and calcination of the dolomite; grinding, mix-

Magnesium metal plants in the United States

[Data from U. S. Bur. Mines. The plant at Freeport, Tex., is owned by Dow Chemical Corp. All others are Government owned]

Plant	Process	Annual capacity (in short tons)	Raw material and source
Freeport, Tex.	Electrolytic ...	26,000	Sea water; Gulf of Mexico.
Velasco, Tex.	-----do-----	36,000	Do.
Painesville, Ohio ..	-----do-----	18,000	MgCl ₂ cell feed; Ludington, Mich., and Freeport, Tex.
Canaan, Conn.	Ferrosilicon ...	5,000	Dolomite; Canaan, Conn.
Wingdale, N. Y.	-----do-----	5,000	Do.
Spokane, Wash.	-----do-----	20,000	Dolomite; Marble, Wash.
Manteca, Calif.	-----do-----	10,000	Dolomite; Natividad, Calif.

ing, and briquetting the calcine with ground ferrosilicon; and heating in an evacuated nichrome steel retort. By this process the magnesium is vaporized, and the vapor is collected and condensed in the cooler end of the retort to form a cluster of crystalline magnesium. An easily removed residue of unfused dicalcium silicate and iron remains in the retort. The reaction proceeds according to the following equation:



The ferrosilicon reduction process is the only one in which magnesia is reduced directly from calcined dolomite. Other processes using dolomite involve removal of the magnesium from the dolomite, either as the hydroxide or the chloride, preliminary to thermal reduction or electrolysis (Pidgeon and others, 1946).

Purity of the dolomite is important. Pilot plant operations at the beginning of the war showed that dolomite for use in the ferrosilicon reduction process should contain at least 21 percent magnesia and less than 2 percent acid-insoluble material (Mayer, 1944, p. 363). According to Pidgeon and Alexander (1944, p. 338-339), acid insolubles up to about 3 percent were found to be merely diluents, but when present in excess of 3 percent they notably depressed the yield of magnesium. More than a trace of the alkali metals sodium and potassium was found to be particularly undesirable and, in some instances, dangerous (Pidgeon and Alexander, 1944, p. 339-340). As they vaporize and condense along with the magnesium, experience has shown that these metals are likely to ignite spontaneously when the vacuum is broken and the condensate exposed to air.

Although it is desirable to use dolomite containing impurities that are within the tolerances outlined, chemical analyses (Deiss, 1955, p. 133,

136) show that rock slightly below these standards has been used successfully as magnesium ore. Advances in technology eventually may permit the use of dolomite containing alkalis in presently prohibitive amounts or containing impurities in excess of 3 or 4 percent. Such relaxing of specifications would greatly increase the already enormous available tonnage of usable dolomite and considerably broaden the distribution of reserves.

MINING AND BENEFICIATION

As most dolomites and dolomitic limestones for chemical purposes are used in the form of fragments, the rock is obtained by standard crushed-stone quarrying methods. Bowles (1939, p. 452-470) and Goldbeck (1949, p. 269-286) have described the general features of exploiting carbonate rock deposits for crushed stone.

The choice of quarrying methods is determined by the geological and physical characteristics of the deposit. Usually, one of two main methods is employed. Pit quarrying is used when a deposit lies below the adjacent ground surface level; bank or open-cut quarrying is used when the deposit stands at or above the adjacent ground level (Goldbeck, 1949), p. 271). In either method the quarry face may be shot down in benches or as a single face. One or more of several drilling and blasting techniques may be used, depending chiefly upon the physical character of the rock. Various drilling and blasting methods have been described by Bowles (1939, p. 453-459) and by Goldbeck (1949, p. 272-278). Removal of the overburden, which may consist of soil or unmarketable rock or both, usually is necessary before quarrying by either the pit or bank methods.

Not uncommonly, where a deposit contains rock of a particularly desirable quality and the geology of the deposit precludes economical stripping of the overburden, underground quarrying may be employed. This is usually done by the room-and-pillar method or some variation thereof (Bowles, 1939, p. 467-468; Goldbeck, 1949, p. 285-286).

In the production of crushed stone for chemical purposes, it is sometimes necessary to improve the quality of the quarry-run rock. Such upgrading can be accomplished by one or more methods, including hand-sorting, washing, and screening. Recently heavy-media separation has been used commercially to improve the quality of dolomite by removing granite that is associated with the deposit. The process has been described by Utley (1952) and Lenhart (1953).

No one standard procedure for the operation of a crushed stone quarry would be applicable to all deposits. The practicability of the various techniques for stripping, drilling and blasting, loading, hauling, upgrading, and crushing must be determined by the quarry operator, whose major concerns are the cost and quality of his product.

GENERAL DISTRIBUTION

Dolomite and dolomitic limestone are of widespread occurrence in the United States. Enormous quantities of dolomitic limestone are in many geologic formations, ranging in age from Precambrian through Mesozoic. Large, readily accessible supplies of high-purity dolomite are, however, somewhat more limited in occurrence.

Immense tonnages of high-grade dolomite, most of it probably suitable for either refractory or metal production, are in the region around the Great Lakes. These dolomites are principally Ordovician and Silurian in age. In some areas they occur as extensive, near-surface, essentially flat-lying beds; in others they are local facies of extensive limestone or dolomitic limestone beds.

Dolomites occur locally in the great limestone valleys of the Appalachian Mountains, from central Alabama northeastward through southeastern Pennsylvania to New Jersey. Dolomite, some of which has been used as magnesium ore, also occurs in several small areas in southeastern New York and in the western parts of Connecticut, Massachusetts, and Vermont.

In the Western United States dolomite generally does not occur in extensive thick beds but rather as more localized deposits, some of which contain substantial tonnages of high-grade rock. Such deposits are found in nearly every State with the exception of the northern Great Plains States. Dolomite from deposits in Washington and California has been used in the production of magnesium in plants at Spokane, Wash., and Manteca, Calif.

DISTRIBUTION BY STATES

Information pertaining to the dolomite and dolomitic limestone resources of the United States, arranged alphabetically by States, is given in the following pages. Because dolomite is a high-tonnage low-cost commodity and cannot be economically transported great distances, the value of a given deposit is controlled largely by its proximity to transportation facilities and markets. It is thought, therefore, that a summary of the resources of each State might be more useful to a potential quarry operator or consumer than a summary of a larger region or one based on geologic formations alone. The geologic formations known to contain dolomite or dolomitic limestone are mentioned for each State, but only those considered more important as possible commercial sources of these rock types for use in the chemical and manufacturing industries are described in detail.

Accompanying each State summary is a list of known or reported occurrences of dolomite and of dolomitic limestone only slightly less magnesian than dolomite (these contain a minimum of about 39 percent magnesium carbonate). For each occurrence there are listed the location,

the quarry or quarries (active and inactive quarries are not distinguished), and the geologic formation.

In general, the descriptions of geologic formations are composite descriptions based upon information obtained from more than one source. For convenience in reading, the references which were drawn upon for the material in each paragraph are listed at the end of the paragraph, and the reader is advised to consult each of the references listed for more detailed information on a given subject.

ALABAMA

Dolomite occurs in large quantities in northeastern Alabama. The more important deposits are in the area east and northeast of Birmingham, where the rock is used extensively as flux stone in the smelting of iron ore. The dolomites and dolomitic limestones of the series represented by the shaded area on the map (pl. 2) include, in ascending stratigraphic order, the Brierfield, Ketona, Bibb, and Copper Ridge dolomites, of Upper Cambrian age, and the Chepultepec dolomite, of Lower Ordovician (Beekmantown) age. The series has an aggregate thickness of more than 5,000 feet, and the rocks crop out principally in the anticlinal valleys of the northeastern part of the State. High-purity dolomite is, however, limited mainly to the Ketona, and large-scale quarrying is restricted to this formation. (Butts, 1926; Jones, 1926; Smith and others, 1926)

Ketona dolomite.—The Ketona dolomite is primarily a light-gray medium- to coarse-crystalline thick-bedded dolomite. It is nearly free of silica. The formation attains a thickness of from 500 to 600 feet. Its outcrops extend from Vance, Tuscaloosa County, along the Jones River to Bessemer, Jefferson County, thence northward into Opossum Valley, where the formation is typically developed and the rock extensively quarried. The Ketona crops out also from Chepultepec to Remlap in Murphrees Valley, Blount County, and in the Shoal Creek area of Shelby County, north of Montevallo. Chemical analyses indicate that the Ketona dolomite is the most promising source of high-purity dolomite in the State, and

Dolomite quarries and occurrences in Alabama

<i>County</i>	<i>Locality</i>	<i>Formation</i>	<i>Reference</i>
Lee.....	Chewacla; quarry.....	Chewacla marble.....	Jones, 1926.
Jefferson.....	Bessemer; quarries 2 miles west.....	Ketona dolomite.....	Ball and Beck, 1938.
	Birmingham area; quarries.....	do.....	
	a. Dolcito; quarries.....	do.....	
	b. Ketona; quarry.....	do.....	Burchard and Butts, 1910.
	c. Lardona; quarry.....	do.....	Do.
	d. North Birmingham; quarries.....	do.....	Do.
	e. Thomas; quarry.....	do.....	Do.
Shelby.....	Montevallo; quarries 5 miles north.....	do.....	Butts, 1911.
Talladega.....	Talladega.....	Copper Ridge dolomite.....	Weits, 1942.
Tuscaloosa.....	Vance; quarry.....	Ketona dolomite.....	Burchard and Butts, 1910.

available supplies of rock seem to be large in the Birmingham district. (Burchard and Butts, 1910; Butts, 1926; Jones, 1926; Weitz, 1942)

Other formations.—Other known occurrences of high-grade dolomite in Alabama include a lens in the usually cherty Copper Ridge dolomite near Talladega, Talladega County, and portions of the Chewacla marble (Precambrian) near Chewacla, Lee County. The extent and therefore the potential importance of these occurrences is not known. (Weitz, 1942)

ARIZONA

Dolomite and dolomitic limestone occur principally in the central and northwestern parts of Arizona. Smaller occurrences are also in the southeastern part of the State. The dolomites occur predominantly as zones within the Redwall limestone, the Martin formation, and their equivalents. A 60-foot dolomite zone is in the upper part of the Muav limestone of the Grand Canyon area. Many of the deposits are readily accessible to transportation, and some probably would yield considerable tonnages of rock if mined by open-pit methods. Most of the deposits are, however, interbedded or otherwise closely associated with shale, limestone, and sandstone. These probably are not uniformly pure over wide areas and would require selective quarrying or, in a few places, underground quarrying. The most promising deposit of dolomite seems to be that in Tassai Ridge, near Pierce Ferry, Mohave County.

Muav limestone.—The Muav limestone, of Middle Cambrian age, in the Grand Canyon area, is prevailingly a gray and buff mottled limestone overlain by calcareous sandstone and massive magnesian limestone. The magnesian limestone upper member is a hard buff crystalline rock, which forms cliffs upon weathering. Where exposed in the Grand Canyon, its thickness ranges from a thin wedge to about 70 feet. A chemical analysis of a "typical specimen" from Bass Canyon shows the rock to be dolomite, and it is reportedly uniform lithologically over considerable distances in the canyon, despite its markedly varied thickness. (Noble, 1922)

Martin formation.—The Martin formation (Devonian) of the central and southeastern mountain ranges and its Grand Canyon area equivalent, the Temple Butte limestone, contain zones of dolomite or magnesian limestone. The Martin formation, where typically developed, is a series of limestones, sandstones, and shales that grade into one another vertically and laterally and have an aggregate thickness of 300 to 400 feet. The lower part of the formation is the most prevailingly dolomitic. This zone contains dark-brown or black to light-gray, generally fine-grained, irregularly bedded dolomitic limestone beds, from 20 to more than 50 feet thick. The beds commonly contain dark chert nodules and masses and are interbedded with thin layers of green shale. The rock weathers to a characteristic buff color. Chemical analyses of samples of the Temple Butte and descriptions of the Martin indicate that the formations

generally are moderately high in impurities and contain less than 40 percent magnesium carbonate. The poor grade and usually interbedded shales, limestones, and quartzites preclude the use of the rock, in most places, as a source of high-purity dolomite. (Huddle and Dobrovoly, 1952; Wilson, 1942)

Redwall limestone.—The Redwall limestone, of Mississippian age, is predominantly a light-gray to white thin- to very thick-bedded limestone. It ranges in thickness from a few feet in central Arizona to about 800 feet in the Grand Canyon area—perhaps more in the Lake Mead area. Its southern equivalent, the Escabrosa limestone, attains a comparable thickness in the southeastern part of the State. Brief studies of the Redwall in northwestern Arizona around Peach Springs, in Tassai Ridge, and between Chino Valley and Seligman have shown high-purity dolomite to be present. Chemical analyses show some zones of the dolomite to be moderately siliceous, however, and careful detailed sampling would be required to determine the exact areas of high-purity dolomite. (Huddle and Dobrovoly, 1952; Wilson 1942)

Other formations.—Massive light-gray dolomite occurs in lake beds of Tertiary age above the junction of Humbug Creek and the Agua Fria River, near Pleasant Lake, Yavapai County. The dolomite is about 25 feet thick and is present over an area of more than a square mile. An incomplete chemical analysis shows more than 40 percent magnesium carbonate, but no information is available as to the impurity content. (Wilson, 1942)

Dolomite occurrences in Arizona

<i>County</i>	<i>Locality</i>	<i>Formation</i>	<i>Reference</i>
Cochise.....	Biabee; west and southwest.....	Martin formation.....	
Coconino.....	Grand Canyon Station; 15 miles northwest, at Bass Canyon.	Muav limestone, Temple Butte limestone, and Redwall limestone.	Noble, 1922; Wilson, 1942.
Gila.....	Globe; 3 miles northwest.....	Martin formation.....	
Maricopa.....	Roosevelt Dam; southeast wall of canyon.	.....do.....	
Mohave.....	Peach Springs; 2 miles east.....	Temple Butte limestone(?).	
	Tassai Ridge; southwest of Pierce Ferry.	Rocks of Devonian(?) and Mississippian age.	
Pinal.....	Superior; 0.5 mile east.....	Martin formation.....	
Yavapai.....	Chino Valley; 12-15 miles north...	Redwall limestone.....	
	Pleasant Lake.....	Rocks of Tertiary age.	Wilson, 1942.
	Seligman; 6 miles south.....	Redwall limestone(?)..	

ARKANSAS

Dolomite and dolomitic limestone occur in northern Arkansas in several Middle and Lower Ordovician formations. They include the Jefferson City, Cotter, and Powell dolomites, the Smithville and Black Rock formations, and the Everton formation, listed in ascending stratigraphic

order. Chemical analyses indicate that only the Cotter dolomite contains sufficient magnesium carbonate to be considered a potential source of high-grade rock. The other formations listed are dolomitic limestones; they probably contain only minor quantities of dolomite. The extent of outcrop of the Cotter dolomite is shown on the map (pl. 2). (Branner, 1941; Branner, 1942)

Cotter dolomite.—The Cotter dolomite is predominantly a gray cherty dolomite containing a few beds of sandstone and shale. The formation crops out extensively over the northern part of the State and attains a thickness of 500 feet in some places. Available chemical analyses, although showing more than 40 percent magnesium carbonate, show several percent of silica, and it is not known if these analyses are representative of the formation as a whole. Detailed sampling would be necessary to determine what areas might be suitable as sources of high-grade rock. Dolomite has been quarried from the Cotter at 2 localities in Benton County. (Branner and others, 1940; Branner, 1941)

Dolomite quarries and occurrences in Arkansas

<i>County</i>	<i>Locality</i>	<i>Formation</i>	<i>Reference</i>
Benton.....	Sulphur Springs; quarry.....	Cotter dolomite.....	Branner and others, 1940.
	Rogers; quarry.....	.....do.....	Do.
Carroll.....	Leatherwood Switch.....	.....do.....	Branner, 1941.
	Waldon's Switch.....	.....do.....	Do.
Marion.....	Woods mine.....	.....do.....	Do.

CALIFORNIA

Deposits of dolomite in California occur for the most part as more or less isolated or discontinuous masses, blocks, or lenses within rocks of other types and range in age from Precambrian to Mississippian. They are found principally in the southern half of the State, and commercial production has been from Tuolumne, Inyo, Monterey, San Benito, and San Bernardino Counties. Other occurrences have been reported from Los Angeles, San Luis Obispo, Santa Clara, Calaveras, Nevada, Alameda, El Dorado, Orange, Plumas, and Riverside Counties. Because of the nature of the occurrences, no attempt has been made to delineate on the map (pl. 2) the areal extent of the dolomite and dolomitic limestone units. The locations plotted are only those for which adequate information concerning the extent and type of deposit is available, or those for which chemical analyses of samples have been found in the literature. (Logan and Wright, 1950; Pabst, 1938; Weitz, 1942)

Reed dolomite.—The Reed dolomite, of Precambrian age, is exposed in several places in northern Inyo County. In this area the dolomite generally is tan gray or pale gray, finely crystalline, thick bedded, and is interbedded with 2- to 6-foot beds of bluish-gray dolomite. Much of the rock, particularly that in the upper portions of the exposed sections,

contains veins and stringers of calcite and quartz. Probably only the lower 400 to 500 feet of the formation is sufficiently low in silica to be considered a potential source of high-purity dolomite. Outcrops have been studied in Black and Marble Canyons, 12.5 and 14 miles, respectively, southeast of Bishop. Chemical analyses show some of the rock in the lower, less siliceous zone to be of excellent quality. (Jenkins, 1938)

Rocks of Cambrian age.—Dolomite beds tentatively assigned to the Cambrian are in and near the Providence Mountains in the eastern part of San Bernardino County and near Barstow, to the west. Most of the deposits occur as fault blocks or as roof pendants in the Jurassic granitic intrusive rocks. In general, the dolomites are some shade of tan or light gray, although some are white. They are medium to coarse crystalline, thick bedded, and not uncommonly show some degree of metamorphism. Many of the deposits contain masses or stringers of hematite, calcite veins, and might be intruded by plugs and dikes of diorite or granite. Chemical analyses indicate the presence of high-purity dolomite, and some of the rock has been quarried for use as refractory dolomite. (Logan and Wright, 1950)

Rocks of Devonian age.—The dolomites of Devonian(?) age exposed north of Owens Lake near Keeler and Lone Pine, west-central Inyo County, occur in fault blocks of Ordovician, Devonian, and Carboniferous metasediments. The dolomites are usually medium to fine crystalline, thick bedded, predominantly white, and weather buff or pale tan. In some places greenstone dikes and plugs are in the rock, but analyses from certain localities indicate that, in general, the dolomite is of high purity. Dolomite is quarried near Keeler, and it appears likely that sizable reserves of quarriable dolomite are in the area. (Jenkins, 1938)

Sur series.—The Gabilan limestone of the Sur series, a group of metasediments the age of which is uncertain, contains dolomite in Monterey and San Benito Counties. At Pico Blanco, Monterey County, the dolomite occurs as lenses or pods in the sedimentary series; at Natividad, northeast of Salinas, Monterey County, and near Hollister, San Benito County, important deposits occur as roof pendants in the Santa Lucia granite. In the latter two localities the dolomite has been quarried and used for the production of magnesium metal and magnesia. The rock is usually white to bluish gray, medium to coarse crystalline, and is associated with and cut by veins and stringers of granite, chalcedony, and contact-metamorphic minerals. Even though highly selective quarrying and beneficiation have been necessary, a few of the deposits have proved economic, and large reserves of high-purity dolomite are available.

Calaveras formation.—Lenses of dolomite and dolomitic limestone occur in the Calaveras formation, of Mississippian age, in Tuolumne County. Lenses of dolomite occur in a large body of metamorphosed limestone that extends several miles northward from Sonora. The limestone con-

tains some beds of quartzite, conglomerate, and slate; it is intruded by granite and lamprophyre dikes. The dolomite is commonly white, pale gray or dull gray, and is locally streaked with thin dark-gray bands. It is medium crystalline and soft and is cut by and interfingering with irregular masses of limestone. In a few localities the rock has been quarried for building stone; some of the rock may be suitable for refractories, although chemical analyses indicate that its quality is variable. Southeast of Victorville, San Bernardino County, similar good-quality dolomite, thought to be Mississippian in age, is found as roof pendants in the granitic country rock.

Dolomite quarries and occurrences in California

County	Locality	Formation	Reference
Inyo	Ballarat; 8 miles southeast	.....(?).....	Logan, 1947.
	Bishop area:		
	a. Black Canyon	Reed dolomite	
	b. Marble Canyon	.....do.....	
	Keeler:		
	a. quarry 2.5 miles northwest	Rocks of Devonian(?) age.	
	b. quarries 4.5 miles northwest at Dolomite Siding.	.....do.....	Do.
	c. quarry 8 miles northwest at Alico Siding.	Rocks of Devonian age.	Do.
Monterey	Natividad; quarries	Sur series	Do.
	Pico Blanco; 20 miles south of Monterey.	.....do.....	
San Benito	Hollister:		
	a. quarry 11 miles south	.....do.....	Do.
	b. quarries 1.3 miles southeast of locality above.	.....do.....	Do.
San Bernardino	Amboy; 6 miles east	Rocks of Cambrian(?) age.	Do.
	Balch; 5 miles south	.....(?).....	Do.
	Barstow; 5 miles west(?).....	
	Big Bear City; 7 miles south	.....(?).....	Do.
	Cadix; quarry 5.5 miles north	Rocks of Cambrian(?) age.	Do.
	Chubbuck Station; 2 miles southwest.	.....(?).....	Do.
	Cima; 26 miles northwest	.....(?).....	Do.
	Hinkley; quarry 5 miles southwest.	Rocks of Paleozoic(?) age.	Do.
	Ivanpah; 3 miles southeast	.....(?).....	Do.
	Kelso; 9 miles southeast	Rocks of Cambrian age	
	Lucerne Valley; quarry 10 miles north.	Rocks of Paleozoic age.	Do.
	Newberry; 18 miles southeast(?).....	
	Siam; 1.5 miles south	Rocks of Cambrian age	Do.
	Victorville; 15 miles southeast	Rocks of Mississippian(?) age.	Do.
San Diego	Live Oak Springs; 12 miles northeast.	.....(?).....	Do.
San Luis Obispo	Arroyo Grande; 15 miles northeast.	.....(?).....	Franke, 1935.
Santa Clara	San Jose	Sur series	
Tuolumne	Columbia:		
	a. quarry 0.25 mile east	Calaveras formation	
	b. quarries 2.8 miles north	.....do.....	Logan, 1947.
	c. quarries just north of those above.	.....do.....	
	Sonora; 7.6 miles southeast	.....do.....	

COLORADO

Considerable thicknesses of interbedded limestone, dolomitic limestone, and dolomite occur in central and western Colorado. Exposures of dolomitic formations are along the east side of the Front Ranges in parts of Douglas, Teller, El Paso, Fremont, and Pueblo Counties. West of the mountain front, the dolomitic formations crop out in two roughly parallel belts; exposures in the first belt are found principally in parts of Eagle, Lake, Park, Chaffee, and Fremont Counties, those of the second in Eagle, Pitkin, Gunnison, and Saguache Counties. Probably the three most important of the dolomitic formations are the Manitou limestone, the Chaffee formation, and the Leadville dolomite. Several analyses indicate the presence of high-purity dolomite, but little information is available regarding the extent and uniformity of the deposits. The shaded areas on the map (pl. 2) represent the generalization of undivided groups of dolomite and dolomitic limestone of Paleozoic age as shown on U. S. Geological Survey Missouri Basin Studies Map 10 and include rocks ranging in age from Cambrian to Mississippian. (Larrabee and others, 1947; Vanderwilt and others, 1947; U. S. Geol. Survey, 1935)

Manitou limestone.—The Manitou limestone (Ordovician) has been described from several areas in central Colorado and referred to variously as the Yule limestone, White limestone, and Manitou limestone. In general, it is a white, light- to dark-gray, or blue-gray dolomitic limestone, commonly fine grained, thin bedded, and somewhat siliceous. In the Leadville area it contains an abundance of white chert nodules. The formation ranges in thickness from 50 to nearly 400 feet. Chemical analyses show the rock to be a very siliceous dolomitic limestone, and, if these analyses are typical of the formation as a whole, it could not be considered a source of high-grade dolomite. (Emmons and others, 1927; Larrabee and others, 1947)

Chaffee formation.—The Chaffee formation, of Devonian age, comprises two distinct members; the parting quartzite member and the overlying, much thicker Dyer dolomite member. Dolomitic rocks equivalent to the Dyer include the Ouray limestone in the San Juan region of southwestern Colorado. The Dyer member is commonly about 80 feet thick, and the rock is principally a thin-bedded fine-grained dolomite which is locally cherty. It weathers generally to light buff or yellowish gray and not uncommonly contains thin shale partings. Chemical analyses of samples from near Garfield, Chaffee County, show some of the dolomite to be of excellent quality. Earlier writers did not recognize the Dyer member as a distinct unit but, rather, as constituting the lower portion of the Leadville limestone or Blue limestone of local usage. Some of the analyses of the Leadville limestone from Eagle and Lake Counties, therefore, might actually be of the Dyer member. No analyses of the Ouray limestone are available, but it reportedly contains no units of

high-grade dolomite. (W. S. Burbank, 1952, oral communication; Emmons and others, 1927; Tweto, 1949)

Leadville limestone.—The Leadville limestone (Mississippian), overlying the Dyer member, consists of massive gray to blue-black crystalline dolomite or dolomitic limestone. Locally, near mineralized areas, the rock shows coarse recrystallization and at places a striped appearance because of the formation of alternating light and dark bands, which gave rise to the miners' term "zebra rock." Chemical analyses of the Leadville from near Red Cliff and Leadville show the presence of high-purity dolomite. The formation ranges in thickness from about 50 to 375 feet. (Emmons and others, 1927; Tweto, 1949)

Dolomite quarries and occurrences in Colorado

County	Locality	Formation	Reference
Chaffee.....	Garfield area; quarries.....	Chaffee formation....	Crawford, 1913.
Eagle.....	Red Cliff area.....	Leadville limestone (and Chaffee formation?)	Crawford and Gibson, 1925.
Fremont.....	Canon City; quarry 1 mile west...	Manitou limestone(?)	Colo. Bur. Mines, 1945.
El Paso.....	Colorado Springs; quarries.....	Manitou limestone....	Larrabee and others, 1947.
Jefferson.....	Golden; quarry 3 miles south.....	.....(?).....	Colo. Bur. Mines, 1945.
Lake.....	Leadville; quarries.....	Chaffee formation and Leadville limestone.	Emmons and others, 1927.
Park.....	Mount Silverheels.....	.....(?).....	Argall, 1949.
Pitkin.....	Aspen.....	.....(?).....	Do.
Summit.....	Teasdale district.....	.....(?).....	Do.

CONNECTICUT

Limited quantities of high-purity dolomite occur in Connecticut, principally in the northwestern portion, as irregular lenses and layers in the Stockbridge limestone, of Cambrian and Ordovician age. This formation constitutes the marble belt of the western part of the State. The belt is indicated by irregular and discontinuous outcrops through western Litchfield and Fairfield Counties and is a continuation of the marble belt that extends through Vermont and western Massachusetts. The overburden in the region consists of glacial deposits and valley fill, which makes prospecting and quarrying difficult. (Dale, 1923; Moore, 1935)

Stockbridge limestone.—The Stockbridge limestone is generally a white to grayish-white medium- to coarse-grained thin-bedded to massive marble, either calcitic or dolomitic in composition. Detailed studies of the marble area have shown that the calcite and dolomite varieties grade into one another, both vertically and laterally. In general, the northern area of exposure is more dolomitic than the southern area. Dolomite of high quality is, however, found as far south as Redding, central Fairfield County. Much of the dolomite in the belt contains an abundance of irregularly distributed mica and, locally, disseminated sul-

vides. Analyses of the rock, particularly in the vicinity of Canaan and East Canaan, Litchfield County, where quarrying has been extensive, show the presence of high-grade rock. Dolomite from this area supplies the raw material for the Government-owned magnesium (ferrosilicon reduction) plants at Canaan, Conn., and Wingdale, N. Y. (Moore, 1935)

Dolomite quarries and occurrences in Connecticut

[Data from Moore, 1935]

<i>County</i>	<i>Locality</i>	<i>Formation</i>
Fairfield.....	Brookfield; quarries.....	Stockbridge limestone.
	Danbury; quarries.....	Do.
	Redding; quarries.....	Do.
Litchfield.....	Canaan; quarries.....	Do.
	East Canaan; quarries.....	Do.
	Falls Village; quarry 2 miles north.....	Do.
	Gaylordsville.....	Do.
	Lakeville.....	Do.
	New Milford; quarries.....	Do.
	Rattlesnake Hill; quarries.....	Do.

FLORIDA

The occurrences of dolomite in Florida are so sparse as to make them unsuitable as a source of high-grade rock. Considerable quantities of dolomitic limestone are in a narrow belt of discontinuous outcrops and subsurface patches along the west coast of the peninsula from Jefferson County to southern Sarasota County. These rocks from Citrus County northward are restricted principally to the Eocene and Oligocene sediments; those in Manatee and Sarasota Counties occur in sediments of Miocene age. (Hopkins, 1942)

In general, the dolomitic limestones of Eocene and Oligocene age are buff or brown, porous, and they are composed of masses of small dolomite crystals. Because of their crystalline structure and weak cementation, the rocks are friable and can be pulverized easily. Some harder masses occur within the softer portions of the rocks. The dolomitic rocks belonging to the Miocene series are usually light colored, siliceous, and hard on surface exposures. At depth, however, they are gray, softer, clayey in appearance, and contain appreciably less dolomite. (Hopkins, 1942; Vernon, 1951)

Dolomitic limestone quarries and occurrences in Florida

<i>County</i>	<i>Locality</i>	<i>Formation</i>	<i>Reference</i>
Citrus.....	Red Level; quarries.....	Rocks of Eocene age..	Vernon, 1951.
Levy.....	Lebanon; quarry.....	...do.....	Do.
	Yankeetown.....	...(?).....	Hopkins, 1942.
Manatee.....	Samoset; quarries.....	Rocks of Miocene age..	Do.
Sarasota.....	Sarasota; quarry 3.5 miles north-east.	...do.....	Do.

Deposits of dolomitic limestone have been worked at several localities for the production of agricultural lime in the form of soil conditioner and

fertilizer filler. Although these pits are not to be considered as high-grade dolomite quarries, they have been included on the map (pl. 2) along with generalized representations of the areas underlain by dolomite and dolomitic limestone. (Hopkins, 1942; Vernon, 1951)

GEORGIA

Dolomite and dolomitic limestone occur principally in the Paleozoic rocks of northwestern Georgia and in the Precambrian marble belts to the east. Because of their areal extent and chemical composition, the Knox dolomite and the Murphy marble probably are the two most important dolomitic formations. Deposits of lesser importance may occur in the Gainesville and Dahlonega marble belts and in the Shady dolomite. Dolomitic facies are reported also in the Chickamauga limestone, of Ordovician age, and the Fort Payne chert, of Mississippian age, but they are unlikely sources of high-grade dolomite. (Butts and Gildersleeve, 1948; Furcron, 1942)

Talladega slate.—According to Furcron (1942) the marble in the Talladega slate (Precambrian) of the Gainesville belt is somewhat dolomitic, but analyses do not indicate that any of it is high-purity dolomite. The marble crops out in the vicinity of Flowery Branch, Hall County, and northeastward, near the Stephens-Habersham County line, into South Carolina. (Furcron, 1942)

Murphy marble.—The Murphy marble, of Lower Cambrian age, is exposed in several localities in an interrupted belt that enters the State in northeastern Fannin County and extends southwestward through Gilmer and Pickens Counties to a point several miles north of Canton, Cherokee County. This series of outcrops constitutes the Whitestone-Marble Hill belt. Chemically, the Murphy marble varies in composition from almost pure calcite to dolomite containing as much as 43 percent magnesium carbonate. Analyses from Fannin, Gilmer, and Pickens Counties indicate the presence of rather high-purity dolomite in some areas. (Furcron, 1942; Ga. Div. Mines, 1939; Weitz, 1942)

Shady dolomite.—The Shady dolomite, of Cambrian age, is predominantly a bluish-gray medium-crystalline dolomite about 1,000 feet thick. Outcrops of the Shady are rare, being restricted principally to eastern Bartow County in an area extending from southeast of Cartersville northward to a point just north of Pine Log Creek. It crops out also for a distance of about 4 miles along the Southern Railway in the vicinity of Etna, western Polk County. Chemical analyses of samples from the Cartersville area show that dolomite moderately high in silica occurs locally. (Butts and Gildersleeve, 1948; Furcron, 1942)

Knox dolomite.—The Knox dolomite, of Cambrian and Ordovician age, is the most widespread dolomitic formation in Georgia and includes rocks that elsewhere have been separated into the Copper Ridge, Chepultepec,

and Nittany dolomites. The Knox, averaging about 3,500 feet in thickness, is prevailingly a thick-bedded gray dolomite, locally containing an abundance of chert. Fresh outcrops of Knox are rare, but its general distribution is indicated by the residual chert fragments in the overlying soils. It occurs extensively as the bedrock formation in Bartow, Polk, Floyd, and Gordon Counties. The largest area is between Cartersville and Rome, in Bartow and Floyd Counties, where the width of the occurrence is approximately 22 miles. Many quarries have been developed in this formation, and several analyses indicate the presence of high-quality dolomite. No information on the reserves of high-grade material is available. (Butts and Gildersleeve, 1948; Furcron, 1942)

Dolomite quarries and occurrences in Georgia

County	Locality	Formation	Reference
Bartow	Adairsville; quarry 3 miles south-east.	Knox dolomite	Furcron, 1942; Butts and Gildersleeve, 1948.
	Cartersville	Shady dolomite	Furcron, 1942.
	a. barite mine 1.5 miles southeast	do.	Do.
	b. quarry 2 miles southwest	Knox dolomite	Furcron, 1942; Butts and Gildersleeve, 1948.
	Cassville; 3.7 miles northeast	Shady dolomite	Furcron, 1942.
Oatoosa	Graysville:		
	a. quarry 0.5 mile east	Knox dolomite	Do.
	b. quarry 1.5 miles southeast	do.	Do.
Chatooga	Trion; quarry 1.5 miles north	do.	Do.
Fannin	Mineral Bluff; 1 mile east	Murphy marble	Weits, 1942.
Floyd	Cave Spring	Knox dolomite	Do.
	Vans Valley	do.	Furcron, 1942.
Gilmer	Northcutt	Murphy marble	Do.
Habersham	Turnerville area; quarry	Talladega slate	Do.
Pickens	Jaaper; quarry 2 miles east	Murphy marble	Do.
Polk	Youngs Station	Knox dolomite	Weits, 1942.
Whitfield	Dalton:		
	a. quarry 0.5 mile west	do.	Furcron, 1942.
	b. quarry 4 miles east	do.	Do.

IDAHO

Dolomite deposits of any potential commercial importance are restricted mainly to south-central and southeastern Idaho in Lemhi, Custer, Butte, Bannock, Caribou, and Bear Lake Counties. The dolomitic formations range in age from Precambrian to Carboniferous, but only about half are worthy of mention. Deposits of high-grade rock are very scarce, the largest and purest occurring in the Fish Haven and Laketown dolomites. Other formations known to contain small, local deposits of high-grade rock, probably of no economic importance, include the Blacksmith and Nounan limestones, of Cambrian age, the Garden City limestone, of Ordovician age, and the Jefferson limestone, of Devonian age.

Fish Haven dolomite.—The Fish Haven dolomite, of Late Ordovician age, is generally a fine-textured medium-bedded dark-gray to blue-black

dolomite, locally containing chert. The formation is about 500 feet thick. It is well exposed along the Portneuf River from Topaz to the ridge west of Bancroft, Bannock County; along the southwest side of the Lost River Range east of Mackay and northeast of Arco, Butte County; and probably along the crest of the Lemhi Range south of Gilmore, Lemhi County. A promising dolomite deposit east of the mouth of Elbow Canyon in the Mackay district is in the Fish Haven. Chemical analyses show that the formation contains dolomite of excellent quality in several localities.

Laketown dolomite.—The Laketown dolomite, of Silurian age, overlies the Fish Haven and is exposed in the same general areas. The formation is more than 500 feet thick, and the rock is predominantly a massive light-gray to whitish dolomite, locally containing lenses of calcareous sandstone. It forms the upper part of the ridge west of Lava Hot Springs, the ridge south of Topaz, and probably is exposed east of Mackay and along the crest of the Lemhi Range. Chemical analyses indicate that some of the purest dolomite in the State occurs in the Laketown dolomite.

Because outcrops of the dolomitic formations are few and discontinuous, and because most of them are grouped on the Idaho State geologic map (Ross and Forrester, 1947) as undifferentiated Paleozoic sedimentary rocks, no attempt has been made to delineate their areal extent on the map (pl. 2).

Dolomite occurrences in Idaho

<i>County</i>	<i>Locality</i>	<i>Formation</i>
Bannock.....	Bancroft; 2 miles west.....	Laketown dolomite(?).
	Blaser; 1 to 4 miles north.....	Garden City formation.
	Lava Hot Springs:	
	a. 2 miles west.....	Fish Haven dolomite and Laketown dolomite.
	b. 0.5 to 1 mile northeast.....	Fish Haven dolomite.
Bear Lake.....	Pebble; 1.4 miles south.....	(?).
	Topaz; south.....	Laketown dolomite.
	Paris; 6.6 miles west.....	Blacksmith limestone.
Butte.....	St. Charles; 4.5 miles west.....	Nounan limestone.
	Arco; 4 miles east.....	Fish Haven dolomite.
Caribou.....	Mackay; 10 miles east.....	Do.
	Monroe Canyon.....	Laketown dolomite.
Custer.....	Challis; 13 miles southeast.....	Jefferson limestone.
Lemhi.....	Gilmore; 6 miles south.....	Fish Haven dolomite and Laketown dolomite.

ILLINOIS

Extensive deposits of dolomite occur in Illinois, principally in the northern third of the State. Chemical analyses indicate that high-purity rock in commercial quantities generally is restricted to the Platteville to Galena sequence, of Ordovician age, in the north-central region and the four formations constituting the Niagara group (Silurian) in the northwestern and northeastern areas. Smaller quantities of dolomite are in other formations; these are included in the shaded area on

the map (pl. 2). Although much of northern Illinois is covered by glacial drift, in many areas this overburden is only a few feet thick, and exposures of the dolomite bedrock are not uncommon. Many of the deposits are very pure, readily accessible, and extensive enough to be of potential importance as sources of high-grade material. Many areas in northern Illinois have already been extensively developed. (Weitz, 1942; Willman, 1943)

Platteville and Decorah formations.—The Platteville and Decorah formations, of Middle Ordovician age, consist of a series of interbedded limestone, dolomite, and beds of intermixed limestone and dolomite, having an average total thickness of 100 to 150 feet. The proportions of limestone and dolomite vary widely both vertically and laterally, as does the character of the beds; some are sandy, some cherty, and others shaly. Dolomite deposits moderately high in impurities are near Ashton, Lee County, Rockton, Winnebago County, and Winslow, Stephenson County. Outcrops of these formations occur as far south as southern La Salle County. (Willman, 1943)

Galena dolomite.—The Galena dolomite, which overlies the Decorah formation, comprises three members having an aggregate thickness of 200 to 250 feet. The lowest member, the Prosser, is made up of 20 to 40 feet of high-purity chert-free dolomite, 80 to 100 feet of generally cherty but locally high-purity dolomite, and about 30 feet of high-purity dolomite. The overlying Stewartville member consists of 40 feet of chert-free dolomite lithologically similar to the upper 30 feet of the Prosser. The Dubuque member, overlying the Stewartville, consists of shaly dolomite. The Galena is in parts of Boone, Carroll, De Kalb, Jo Daviess, Lee, Ogle, Stephenson, Whiteside, and Winnebago Counties. Chemical analyses of samples from several of these counties show that the rock is dolomite, usually with a moderately high impurity content. (Weller, 1945; Willman, 1943)

Joliet limestone.—The Joliet limestone, of Niagaran age, is composed of five dolomitic members of varied degrees of purity. At Joliet, the formation attains a thickness of approximately 75 feet, the upper 25 feet of which commonly is high-purity dolomite. The formation is exposed mainly in Du Page County and western Will County in the northeastern part of the State, and in western Carroll County and southern Jo Daviess County in the western part of the State. Chemical analyses show that high-grade dolomite is present in the Joliet and Du Page and Will Counties. (Willman, 1943)

Waukesha limestone.—The Waukesha limestone, of Niagaran age, is present in the same general areas as the Joliet. In northeastern Illinois, the rock is a dense fine-grained dolomite, usually highly argillaceous and approximately 25 to 30 feet in thickness. In this region it is exposed along the Des Plaines Valley from Joliet to Sag Bridge, along the Kanka-

kee River northwest of Kankakee, and in quarries at Hillside and Elmhurst. The Waukesha in the northwestern region is a highly porous high-purity dolomite, about 50 feet thick. It is well exposed in Whiteside County and western Carroll County in the vicinity of Savanna, Fulton, and Morrison. (Willman, 1943)

Racine dolomite.—The Racine dolomite, of Niagaran age, generally contains many coral reefs. The reef rock is usually a very high-purity dolomite, but the interreef strata commonly are quite impure. In the northeastern region the formation attains a maximum thickness of 250 to 300 feet; it is exposed in Cook, Du Page, Will, and Kankakee Counties. In the northwestern area it is exposed in parts of Whiteside, Rock Island, and Carroll Counties. Chemical analyses indicate that the high-purity rock occurs in several of these counties. (Willman, 1943)

Dolomite quarries in Illinois

[Data from Krey and Lamar, 1925, and Willman, 1943]

County	Locality	Formation
Boone	Belvidere	Galena dolomite.
Carroll	Lanark	Do.
	Mount Carroll	Waukesha limestone.
	Savanna	Do.
Cook	Chicago	Racine dolomite.
	Chicago Heights	Do.
	Gary	Rock of the Niagara group.
	Hawthorne	Do.
	Hillside	Racine dolomite.
	La Grange	Do.
	McCook	Do.
	Riverside	Do.
	Thornton	Do.
Du Page	Elmhurst	Do.
	Naperville	Joliet limestone.
Jersey	Grafton	Rock of Silurian age.
Jo Daviess	Elisabeth	Galena dolomite.
	Galena Junction	Do.
	Warren	Do.
Kankakee	Kankakee	Rock of the Niagara group.
	Manteno	Racine dolomite.
Kendall	Plano	Galena dolomite.
Lee	Ashton	Decorah formation.
	Dixon	Galena dolomite.
	Palmyra	Do.
Ogle	Mount Morris	Do.
	Polo	Do.
Rock Island	Cordova	Port Byron limestone of Savage (1926).
Stephenson	Freeport	Galena dolomite.
	Ridott	Do.
	Rock City	Do.
	Winslow; 1 mile north	Platteville formation.
Whiteside	Albany	Racine dolomite.
	Fulton	Racine dolomite and Waukesha limestone.
	Morrison	Racine dolomite.
Will	Joliet	Joliet limestone.
	New Lenox	Racine dolomite.
	Romeo	Joliet limestone.
	Symerton; 3 miles east	Platteville formation.
Winnebago	Rockford	Galena dolomite.
	Rockton	(?).
	Seward	Galena dolomite.

Port Byron limestone of Savage (1926).—The Port Byron limestone, of Niagaran age, is lithologically similar to the rocks of the Racine, containing reefs of high-purity dolomite and averaging 50 to 75 feet thick. It is exposed in northern Rock Island County, where analyses show that high-grade rock is present. (Willman, 1943)

The shaded area on the map (pl. 2) represents the areal distribution of the Ordovician and Silurian carbonate rocks and, in addition, the Wapsipinicon and Cedar Valley limestones, of Devonian age. The latter formations, dolomitic in Iowa, are along the Mississippi River in Rock Island and Mercer Counties. Because of the many occurrences of dolomite in Illinois, only quarries in dolomite that are listed by Willman (1943) and not occurrences and road cuts, have been plotted on the map. Additional locations are listed in the report by Krey and Lamar (1925).

INDIANA

Dolomite and dolomitic limestone occur in the strata of Silurian and Devonian age which form the bedrock principally in the northwestern, east-central, and southeastern parts of Indiana. In the northwestern and east-central parts, where these rocks underlie extensive areas, outcrops are scarce and potential quarry sites limited because of the heavy overburden of glacial drift. Exposures are confined chiefly to the major drainage channels. In southeastern Indiana, however, where the formations are in a relatively narrow southward-trending belt and are generally not so dolomitic, overburden is thin or absent and exposures are numerous. Several formations have been described in the literature as being dolomitic; these include the Laurel and Louisville limestones, the Geneva dolomite, and the Jeffersonville limestone in the southeastern area, and parts of the Mississinewa shale, the Liston Creek formation, the Huntington dolomite and the Jeffersonville limestone (?) in the area to the north. Of these, however, as indicated by chemical analyses, only the Huntington and Geneva and the Jeffersonville appear to contain any quantity of high-grade dolomite. (Cumings and Shrock, 1928; Dawson, 1941; Deiss, 1952b; Esarey and Bieberman, 1948; Patton, 1949)

Huntington dolomite.—The Huntington dolomite, of Silurian age, is generally a massive to slabby evenly bedded yellowish, gray, or pinkish granular dolomite. Most exposures originally identified as Huntington are reefs and associated beds, some of which are now considered parts of the underlying Liston Creek formation. It has been suggested that all exposures called Huntington actually are reefs in older strata and that the Huntington is not a separate formation. Exposures of this dolomite are found in two general areas: one includes parts of Randolph, Jay, Adams, Wells, and Huntington Counties, and the second includes parts of Cass, Carroll, White, Pulaski, and Jasper Counties. Chemical analyses indicate that the dolomite is generally of good quality. The rock

has been quarried in many localities in northern Indiana. (Cumings and Shrock, 1928; Patton, 1949)

Geneva dolomite.—The Geneva dolomite, of Devonian age, is predominantly a buff and chocolate-colored, calcareous, generally massive but sometimes thin-bedded dolomite. The formation ranges from a thin wedge to about 40 feet in thickness. It occurs as bedrock in a narrow belt extending from southern Rush County and Shelby County southward to the vicinity of Charlestown, Clark County, beyond which it generally is absent. Chemical analyses show that at least locally the Geneva dolomite contains rock of good quality. (Dawson, 1941; Patton, 1949)

Jeffersonville limestone.—The Jeffersonville limestone (Devonian), in its lower portion, consists of brown dolomitic limestone. The formation overlies the Geneva, and it is in the same general area, extending from eastern Bartholomew County southward to southern Clark County. One analysis of a sample from Jasper County, thought to be from the Jeffersonville limestone or its equivalent, indicates a dolomite having a high silica content. Another analysis of a sample from near Logansport, Cass County, shows a dolomite of excellent quality thought to be of Devonian (Jeffersonville?) age. (Dawson, 1941; Patton, 1949)

Dolomite quarries in Indiana

[Data from Cumings and Shrock, 1928, and Patton, 1949. Quarries marked with an asterisk (*) are listed by Patton as active]

County	Locality	Formation
Adams	Decatur	Huntington dolomite.
	*Geneva; 4.5 miles southeast	Do.
	*Linn Grove; 1.5 miles northwest	Do.
	*Pleasant Mills; 3 miles southeast	Do.
Blackford	*Montpelier	Do.
Carroll	*Delphi	Do.
Cass	*Logansport; 2.5 miles east	Jeffersonville limestone(?)
Delaware	*Eaton	Huntington dolomite.
Huntington	*Huntington	Huntington dolomite and Liston Creek formation.
Jasper	*Rensselaer	Jeffersonville limestone(?)
Jay	*Portland; 1.5 miles west	Huntington dolomite.
Jefferson	*Wirt; 3 miles northwest	Geneva dolomite.
Pulaski	Franceville; 2.5 miles south	Huntington dolomite.
Randolph	Deerfield	Do.
	*Fairview; 1.5 miles southeast	Do.
	Maxville	Do.
	*Ridgeville; 0.5 mile southeast	Do.
Rush	*Millroy; 4 miles west	Geneva dolomite.
	*Moscow	Do.
Shelby	*Geneva; 1 mile west	Do.
	*Norristown	Do.
Wells	*Bluffton; 1.5 miles north	Liston Creek formation.
White	*Monon; 1 mile south	Huntington dolomite.

IOWA

Several formations of Paleozoic age in Iowa are dolomites or dolomitic limestones, but little information is available regarding deposits of high-

grade dolomite. The dolomites are confined geographically to the east-central and northeastern parts of the State and occur principally in the Galena dolomite and in rocks of Early Silurian age. Chemical analyses indicate that dolomite occurs at least locally also in the Oneota and Shakopee dolomites and in the Wapsipinicon and Cedar Valley limestones. Although surficial material, both windblown and glacial in origin, covers much of the area underlain by dolomite, exposures are plentiful, particularly along drainage channels. Quarrying in this area has been extensive. Because of the many quarries, only those for which chemical analyses of the rock quarried are available have been plotted on the map (pl. 2). (Beyer and Wright, 1914; Hershey, 1947; Smith, 1926; Tester, 1937)

Galena dolomite.—The Galena dolomite, of Ordovician age, may contain sizable deposits of high-grade rock. Of a total thickness of approximately 240 feet, only the lower 40 feet and the upper 100 feet are generally free of chert and relatively pure. The color of the rock varies but in general is buff or bluish. The Galena dolomite crops out along the Mississippi River and its tributaries from Jackson County northward into Alamakee and Winneshiek Counties, where it is less magnesian than to the south. Available analyses show the presence of dolomite containing more than 3 percent of impurities near Beulah, Clayton County, and Dubuque, Dubuque County. (Beyer and Wright, 1914; Smith, 1926; Tester, 1937)

Hopkinton dolomite.—The Silurian consists of two formations—the Hopkinton and Gower dolomites—and appears to offer the best possibilities as a potential source of high-grade dolomite. The Hopkinton comprises a sequence of dolomites that vary considerably in character and composition. The rock generally is light buff to yellow, thick bedded but sometimes finely laminated, hard to soft and earthy, and contains cherty zones. The Hopkinton attains its maximum thickness of about 220 feet in Dubuque and adjacent counties. It is in a rather broad belt extending from Clinton County northwestward to Fayette and Bremer Counties. Analyses show that high-grade dolomite is present in parts of Clinton, Delaware, and Jackson Counties. (Beyer and Wright, 1914; Smith, 1926; Tester, 1937)

Gower dolomite of Norton (1899).—The overlying Gower dolomite includes the LeClaire and Anamosa dolomites of Calvin (1895), which are perhaps reef and interreef facies, respectively, of the Gower. Rock of the LeClaire generally is bluish gray, grayish yellow, yellow or buff, hard, vesicular dolomite. The Anamosa is typically a thin- to medium-bedded dolomite, soft, laminated, and light buff or yellow. The total thickness of the Gower dolomite is about 80 feet. The formation is present in an area southwest of that underlain by the Hopkinton, principally in Scott, Clinton, Cedar, Jones, and Linn Counties. Analyses show the presence

of high-grade dolomite in the latter three counties mentioned. (Beyer and Wright, 1914; Smith, 1926; Tester, 1937)

Wapsipinicon and Cedar Valley limestones.—The Wapsipinicon and Cedar Valley limestones, of Devonian age, range from limestone to dolomite. The basal portion of the Wapsipinicon, the Coggan member of Stainbrook (1944), is predominantly dolomite, which locally is cherty. Analyses of this member in Linn County show some excellent-quality dolomite. One analysis of the Cedar Valley limestone in Bremer County indicates dolomite with a high percentage of impurities. These formations form a belt from 25 to 75 miles in width extending from Scott and Muscatine Counties northwestward to Mitchell and Howard Counties. (Beyer and Wright, 1914; Norton, 1920; Smith, 1926; Stainbrook, 1944; Tester, 1937)

Dolomite quarries and occurrences in Iowa

<i>County</i>	<i>Locality</i>	<i>Formation</i>	<i>Reference</i>
Bremer	Plainfield; 3 miles north	Cedar Valley limestone	Beyer and Wright, 1914.
	Tripoli; 3.5 miles west	Hopkinton dolomite	Do.
Cedar	Cedar Valley; quarry	Gower dolomite	Do.
	quarry 6 miles west	Wapsipinicon limestone(?)	Beyer and Wright, 1914; Smith, 1926.
	Lime City; quarries	Gower dolomite	Do.
	Rock Creek; quarries	do	Beyer and Wright, 1914.
Clayton	Beulah; quarry	Galena dolomite	Smith, 1926.
Clinton	Clinton; quarry	Hopkinton dolomite	Do.
	Elwood; 2 miles east	do	Do.
Delaware	Delaware; quarry 2.5 miles west	do	Do.
	Earlville; quarry	do	Do.
	quarry 6 miles east	do	Do.
	Greeley; quarry 1.75 miles north-east	do	Do.
Dubuque	Dubuque; quarries	Galena dolomite	Beyer and Wright, 1914.
	Eagle Point; quarry	do	Do.
	Peosta; quarry 0.75 mile northeast	Hopkinton dolomite	Smith, 1926.
Fayette	Postville; quarry 6 miles south-west	do	Beyer and Wright, 1914; Smith, 1926.
Jackson	Maquoketa; quarries	do	Smith, 1926.
Jones	Anamosa; quarries	Gower dolomite	Beyer and Wright, 1914.
	Stone City; quarries	do	Beyer and Wright, 1914; Smith, 1926.
Linn	Bertram	Wapsipinicon limestone	Norton, 1920.
	Big Creek	do	Do.
	Indian Creek	do	Do.
	Mount Vernon; quarry	Gower dolomite	Do.
	Springville	Wapsipinicon limestone	Do.
Scott	LeClaire; quarry	Gower dolomite	Smith, 1926.
Winnebiek	Fort Atkinson; quarry 1.5 miles northwest	do(?)	Do.

KANSAS

Deposits of dolomitic limestone in Kansas are restricted to two formations, the Stone Corral dolomite and the Day Creek dolomite, both Permian in age. Outcrops of these formations are scant, and available

analyses of the rocks do not indicate that any dolomite is in the areas examined. It is doubtful that these deposits constitute a potential source of dolomite. It has been suggested that these rocks might be used in conjunction with waste oilfield brines for the extraction of magnesium or magnesium compounds. (Jewett and Schoewe, 1942; Weitz, 1942)

Stone Corral dolomite.—The Stone Corral dolomite forms a massive ledge of hard cellular gray dolomitic limestone. Below the surface the rock is a mixture of dolomite and anhydrite, but where exposed the anhydrite has been removed by the action of surface water. In some places, the cells remaining have been filled with calcite, thereby raising the calcium carbonate content of the rock. At its maximum development, in eastern Rice County, the formation attains a thickness of about 6 feet. It crops out in parts of Rice, Reno, Kingman, and Harper Counties, in south-central Kansas. (Jewett and Schoewe, 1942; Norton, 1939)

Day Creek dolomite.—The Day Creek dolomite is a single bed of fine-grained dense dolomitic limestone, locally siliceous, attaining a thickness of 2.5 feet. It is exposed near Ashland, Clark County. It is higher in impurities and lower in magnesium carbonate than rock of the Stone Corral. (Jewett and Schoewe, 1942; Norton, 1939)

Dolomitic limestone occurrences in Kansas

[Data from Jewett and Schoewe, 1942]

County	Locality	Formation
Clark.....	Ashland.....	Day Creek dolomite.
Rice.....	T. 20 S., R. 6 W.....	Stone Corral dolomite.

KENTUCKY

No extensive deposits of dolomite are known in Kentucky. Dolomitic limestones occur in certain of the Ordovician, Silurian, and Devonian formations on both the east and west sides of the Cincinnati Arch in north-central Kentucky and, locally, in rocks of Mississippian age. Formations that have been described as containing more than 30 percent of magnesium carbonate include the Oregon limestone, of Ordovician age; the Bisher formation of Foerste (1923), Laurel dolomite, Lilley dolomite of Rogers (1936) and Peebles dolomites of Foerste (1929), of Silurian age; and the Silver Creek limestone member, of Devonian age. Many other formations have been described as magnesian limestones containing less than 30 percent of magnesium carbonate. Of the formations named, probably only the Laurel limestone need be considered as a potential commercial source of dolomite. (McFarlan, 1943; Stokley, 1949; Stokley and McFarlan, 1952; Stokley and Walker, 1953)

Laurel dolomite.—The Laurel is predominantly a fine-grained light- or bluish-gray dolomitic limestone or dolomite. The thickness of the formation ranges from 35 to 45 feet. The Laurel crops out in a southward-trending belt that extends from southern Indiana through parts of

Oldham, Jefferson, Bullitt, and Nelson Counties. Chemical analyses of samples of the Laurel dolomite show that the rock contains less than 40 percent of magnesium carbonate on the average and excessive silica. The Laurel has been quarried at several localities in Jefferson County. (McFarlan, 1943; Stokley, 1949; Stokley and Walker, 1953)

Ste. Genevieve limestone.—Thin beds of dolomite occur locally in the Ste. Genevieve limestone (Mississippian), generally a good-quality limestone, in Breckenridge and Meade Counties. (Stokley and McFarlan, 1952)

The shaded area on the map (pl. 2) represents a generalization of the outcrop areas of the more important dolomitic formations of Silurian age east and west of the Cincinnati Arch, which are shown on the State geologic map. (Ky. Geol. Survey, 1954)

Dolomite and dolomitic limestone quarries and occurrences in Kentucky

County	Locality	Formation	Reference
Breckenridge.....	Webster; quarry.....	Ste. Genevieve limestone.	Stokley and McFarlan, 1952.
Fayette.....	Grimes Mill; quarry.....	Oregon limestone.....	Richardson, 1923.
Jefferson.....	Avoca; quarry.....	Laurel dolomite.....	Stokley, 1949.
	Fern Creek; quarry 3 miles southwest.	.....do.....	Do.
	Louisville; quarry 1.2 miles northeast.	Louisville limestone...	Stokley and McFarlan, 1952.
	Middletown; quarry 3.5 miles northeast.	Laurel dolomite.....	Stokley and Walker, 1953.
Meade.....	Brandenburg; quarry 7 miles northwest.	Ste. Genevieve limestone.	Stokley and McFarlan, 1952.
Nelson.....	Bardstown; quarry 7 miles west...	Laurel dolomite.....	Stokley and Walker, 1953.
Oldham.....	La Grange; 2 miles east.....	Osgood formation.....	Richardson, 1923.

MAINE

Dolomite deposits in Maine are limited, so far as is known, to Knox County. The deposits generally are small and occur as elongate lenses or belts of dolomite marble in the Rockland formation, of Cambrian or Ordovician age, in areas near Rockport, Thomaston, and Warren. Because of their limited extent, the deposits probably are not potentially important sources of high-grade dolomite. (Bastin, 1906; Allen, 1951)

Rockland formation.—Dolomite marble deposits occur in the Rockport limestone member of the Rockland formation southwest of Rockland. The dolomites are in lenses that crop out southeast of the main limestone belt that extends from Thomaston to a point about 1.5 miles north of Rockland. These lenses, as much as 1.5 miles in length, are from 100 to 200 feet wide, and chemical analyses of the rock from 2 quarries show high-magnesia rock moderately high in silica. The country rock is shown on the State geologic map as quartzite and slate of Cambrian and Ordovician age. (Bastin, 1906; Allen, 1951; Keith, 1933)

An important occurrence of dolomite is about 2 miles northwest of Warren, where it is in a lens similar to those in the Rockland-Thomaston

area but wider and probably extending to greater depth. The dolomite is surrounded by schist, and in places it has been cut through by granite dikes. The metamorphism that accompanied the emplacement of the granite recrystallized and purified the dolomite to a greater degree than in the Rockland area, which resulted in a rock of better quality than that near Rockland. (Bastin, 1906; Keith, 1933; Trefethen, 1945)

Dolomite quarries and occurrences in Maine

County	Locality	Formation	Reference
Knox.....	Rockland area:		
	a. quarry 1 mile southwest.....	Rockland formation...	Bastin, 1906.
	b. quarry 2 miles southwest.....	.....do.....	Do.
	Warren; quarry 2 miles northwest..	.....do.....	Do.
	Warren Station; 2.25 miles north..	.....do.....	Trefethen, 1945.

MARYLAND

The dolomite deposits of Maryland are restricted to the limestone formations of Cambrian and Ordovician age in Washington County and the Cockeyville marble, of Precambrian(?) age, in Baltimore County. Little detailed information is available regarding the size and purity of most of the deposits, although nearly pure dolomite is known to occur in some localities. (Mathews and Grasty, 1910; Weitz, 1942)

Cockeyville marble.—The Cockeyville marble is a white crystalline marble of varied grain size. The formation is about 400 feet thick, but by repeated folding it locally attains thicknesses approaching 1,000 feet. It occurs in central Baltimore County, and it has been quarried in the vicinity of Cockeyville and Texas. Chemically the rock ranges from calcitic to highly dolomitic and contains silica in quantities ranging from less than 1 to more than 5 percent, sometimes showing both extremes in the same quarry. For this reason, it seems doubtful that the formation could be used as a source of high-purity dolomite, even with selective quarrying. (Mathews and others, 1929; Weitz, 1942)

Tomstown dolomite.—The Cambrian and Ordovician formations include the Tomstown dolomite, the Waynesboro formation, and the Elbrook and Conococheague limestones, all of Cambrian age, and the Beekmantown and Stones River groups, of Ordovician age. These formations, together with the overlying Martinsburg shale, crop out across Washington County in a broad northeastward-trending belt the width of which extends from the vicinity of Harpers Ferry, W. Va., on the southeast to McCoys, Md., on the northwest. Each of these formations is more or less dolomitic in part, but chemical analyses indicate that the Tomstown is probably the most promising potential source of high-grade dolomite. The Tomstown is a massive drab dolomitic limestone, generally high in magnesium carbonate and cherty near the top. Certain beds, however, approach pure dolomite in composition and contain less than 1 percent of silica. The Tomstown is about 1,000 feet thick, and it occupies a

belt about 1.5 miles wide in the eastern part of Washington County. (Mathews and Grasty, 1910; Weitz, 1942)

Dolomite quarries and occurrences in Maryland

County	Locality	Formation	Reference
Baltimore.....	Cockeyville; quarries.....	Cockeyville marble....	Weitz, 1942; Mathews and others, 1929.
	Loch Raven.....	...do.....	Weitz, 1942.
	Summerfield.....	...do.....	Do.
	Texas; quarries.....	...do.....	Weitz, 1942; Mathews and others, 1929.
Washington.....	Cavetown; quarry.....	Tomstown dolomite....	Mathews and Grasty, 1910.
	Eakles Mill; quarry.....	...do.....	Do.
	Hagerstown Valley.....	...do.....	Do.

MASSACHUSETTS

Deposits of dolomite in Massachusetts are confined chiefly to the Stockbridge limestone, of Cambrian and Ordovician age. This formation, which occurs in a belt of discontinuous outcrops in western Berkshire County, is the extension of the Stockbridge limestone belt of western Connecticut. Because of the heavy cover of glacial drift over much of the area, the interbedding of limestone and dolomite facies, and the irregular distribution of impurities, it is not possible to obtain detailed information regarding the extent of high-purity deposits. (Dale, 1923; Weitz, 1942)

Stockbridge limestone.—The Stockbridge limestone ranges from a gray mottled limestone to a white highly crystalline marble, which at some places is very coarse grained. Chemically the rock varies from nearly pure calcite to dolomite, the dolomitic phase predominating, and generally has an abundance of secondary minerals. The formation may be divided into two, perhaps three, members: a lower member comprising dolomite marble 500 to 800 feet thick, an upper member principally of calcite marble 200 to 400 feet thick, and, at least locally, a middle member composed of quartzite. (Apfel, 1944; Dale, 1923; Emerson, 1917)

Recent studies of the area around Lee, where quarrying of rock from the Stockbridge has been extensive, have shown that the faulting and complex folding in the formation make difficult the tracing of favorable beds over more than short distances. Some of the examined quarry areas contain high-grade dolomite in rather large quantities, but chemical analyses do not show the amount of potassium that the reportedly abundant mica would furnish. Excessive quantities of the alkali metals would preclude the use of the dolomite in the production of magnesium by the ferrosilicon reduction process. (Apfel, 1944)

Other formations.—At places in southern and eastern Worcester County and in central Middlesex County, thin limestone beds, generally coarsely

marbleized, occur interbedded with mica gneiss. Most of these limestones contain many secondary minerals and probably contain no high-purity dolomite in commercial quantities. One analyses of white marble from Webster shows dolomite containing less than 2 percent of impurities. (Emerson, 1917)

Dolomite quarries and occurrences in Massachusetts

County	Locality	Formation	Reference
Berkshire.....	Adams area:		
	a. 0.5 mile west.....	Stockbridge limestone.	Dale, 1923.
	b. 0.5 mile north.....	.....do.....	Do.
	c. 1.5 miles north.....	.....do.....	Do.
	Lee area:		
	a. quarries 0.5 mile south.....	.....do.....	Apfel, 1944.
	b. quarries 1 mile south.....	.....do.....	Do.
	c. quarry 0.45 mile west-south-west of "b".	.....do.....	Do.
	d. 0.7 mile south of "c".....	.....do.....	Do.
	South Egremont; 0.5 mile north-east.	.....do.....	Dale, 1923.
Stockbridge; 1 mile north at Rattlesnake Hill.	.....do.....	Do.	
West Stockbridge; 2 miles south....	.....do.....	Do.	
Worcester.....	Webster; quarries.....	Bolton gneiss (as used by Emerson, 1917).	Emerson, 1917.

MICHIGAN

Practically unlimited supplies of high-purity dolomite occur in Michigan, principally in the Niagaran series (Silurian) of limestones and dolomites of the northern peninsula. The reserves of dolomite probably are measurable in billions of tons. Dolomites occur also in rocks of Precambrian, Ordovician, and Devonian ages. In addition to the deposits of the northern peninsula, chiefly in the southeastern part, dolomite is found also in the extreme northwestern and southeastern parts of the southern peninsula. Much of the high-purity dolomite of the State is accessible to roads, railroads, and harbors, and in many places the usually heavy overburden of glacial drift is thin or absent. (Smith, 1916; Weitz, 1942)

Lower Huronian group.—The Lower Huronian group (Precambrian), present in the iron-bearing districts of the northern peninsula, contains dolomitic limestones that sometimes approach the composition of true dolomite. The formations generally are interbedded with quartzite and slate and contain chert and other impurities. Thick pure dolomite beds are reported to occur locally. Because of the large amounts of high-grade dolomite in other formations, these rocks are not important as a source of high-grade dolomite. Their areal extent is not shown on the map (pl. 2). (Martin, 1936; Smith, 1916)

Hermansville limestone.—Dolomite occurs locally in the Hermansville limestone, of Late Cambrian and Early Ordovician age. The Hermans-

ville is composed of white dolomite that is generally sandy and white sandstone, and gradations between the two. Because of its sandy nature, the Hermansville probably is not a potential source of high-grade dolomite and therefore it is not shown on the map (pl. 2). It occurs in Menominee, Marquette, Alger, Schoolcraft, Luce, and Chippewa Counties. (Martin, 1936; Smith, 1916)

Black River-Trenton rocks.—The Black River-Trenton sequence, of Middle Ordovician age, is composed of a series of limestones, ranging from low- to high-magnesian, variably colored, and generally argillaceous. The thickness varies from about 250 feet in the vicinity of Green Bay to 100 feet or less along the St. Marys River. The broad belt occupied by these formations is represented on the map (pl. 2) by the shaded area that extends along the west side of Green Bay and Little Bay de Noc, through central Menominee County and parts of Delta, Schoolcraft, Luce, and Chippewa Counties to the St. Marys River. Analyses do not confirm the presence of high-purity dolomite, although in Wisconsin this sequence is the source of some dolomite. (Martin, 1936; Smith, 1916; Steidtmann, 1924)

Manistique and Engadine formation of Smith (1916).—The Niagara group consists of the Mayville formation, the Burnt Bluff formation as used by Ver Wiebe (1928), the Manistique series of Smith (1916), and the Engadine formation of Smith (1916). These formations range from high-calcium limestone to very high-purity dolomite. The important dolomite formations are the Manistique and Engadine. The Manistique comprises a thick succession of dolomite and magnesian limestone, ranging from 150 to 275 feet, and varying widely in color and degree of bedding. Some of the beds contain cherty bands and nodules. The Engadine is a hard bluish crystalline dolomite, about 55 feet thick, and nearly free from impurities. The extremely massive beds are uniformly high-purity dolomite both vertically and laterally. This is the most important potential source of high-purity dolomite in the State. The dolomites of Niagaran age are in the northern peninsula in a belt along the north shores of Lakes Michigan and Huron, extending from Big Bay de Noc, Delta County, through Schoolcraft County, southern Chippewa County, and Mackinac County to the easternmost point of Drummond Island in Lake Huron. Analyses show that high-purity dolomite is present in many localities in the northern peninsula. (Martin, 1936; Smith, 1916; Weitz, 1942)

Bass Island dolomite.—The overlying Bass Island dolomite, of Silurian age, consists of four members: the Greenfield dolomite member, the Tymochtee shale, the Put-in-Bay dolomite member, and Raisin River dolomite member. These members generally are too impure to be used as a source of high-grade dolomite, although high-grade deposits occur locally. The Bass Island is absent in the northern peninsula. The

Raisin River member is exposed in Monroe County, southeastern Michigan. (Landes, 1951; Martin, 1936; Smith, 1916)

Detroit River group.—The Detroit River group, of Middle Devonian age, consists of two formations—the Amherstberg and Lucas—which are magnesian limestone or dolomite, gray to brown, and generally moderately impure. This group occurs in parts of Wayne and Monroe Counties; it is exposed along the Detroit River and in several localities in western Monroe County. (Landes, 1951; Martin, 1936; Smith, 1916)

Traverse group.—The Traverse group, of Devonian age, generally is high-calcium limestone. In the area around Little Traverse Bay in Emmet and Charlevoix Counties, however, it contains a 40-foot layer of almost completely dolomitized rock, analyses of which indicate some high-grade dolomite. The areal extent of the Traverse group is represented on the map (pl. 2) in the northwestern part of the southern peninsula. (Martin, 1936; Smith, 1916)

Dolomite quarries and occurrences in Michigan

County	Locality	Formation	Reference
Alger	Munising	Hermansville limestone	Smith, 1916.
Arenac	Umstead; quarry	.....(?).....	Do.
Charlevoix	Norwood; 1 mile north	Traverse group	Do.
Chippewa	Detour area; quarries	Engadine formation of Smith (1916).	Do.
	Drummond Island; quarries mainly in south and west parts:	.....do.....	Do.
	Goetsville:	.....do.....	
	a. 3 miles southeast	.....do.....	
	b. 5 miles west	.....do.....	
	Lime Island; quarry	Mayville formation or Burnt Bluff formation as used by Ver Wiebe (1928).	Do.
	Osark; 2 miles north	Engadine formation of Smith (1916).	
	Pickford; 5 miles south	.....do.....	
	Trout Lake; 4 miles east	.....do.....	Do.
	West Neebish Rapids on St. Marys River.	Hermansville limestone	Do.
Delta	Burnt Bluff; sec. 24, T. 38 N., R. 19 W.	.....(?).....	Do.
Emmet	Petosky; quarry	Traverse group	Do.
Gogebic	Ross; northwest	Bad River dolomite	Do.
Jackson	Jackson; southwest	Rock of Mississippian age.	Do.
Mackinac	Caffey	Engadine formation of Smith (1916).	
	Cedarville area:		
	a. 1.5 miles east	.....do.....	
	b. 3 miles east	.....do.....	
	c. 4.5 miles northeast	.....do.....	
	d. 5 miles northeast	.....do.....	
	Charles area:		
	a. 1 mile north	Rock of Upper Monroe age of Smith (1916).	Do.
	b. 6.5 miles north	Engadine formation of Smith (1916).	

County	Locality	Formation	Reference
Mackinac—Con.	Cordell area:		
	a. 3.5 miles southeast.....	Engadine formation of Smith (1916).	
	b. 5 miles southeast.....	do.....	
	c. 5 miles south.....	do.....	
	Corinne; 5.5 miles east.....	do.....	
	East Lake; 3 miles south.....	do.....	
	Engadine area:		
	a. 1 mile west.....	do.....	Smith, 1916.
	b. 2 miles west.....	do.....	
	Garnet area:		
	a. 1 mile northwest.....	do.....	
	b. 1 mile south.....	do.....	
	Hendricks Quarry; quarry.....	Burnt Bluff formation as used by Ver Wiebe (1928).	Do.
	Hessel.....	Engadine formation of Smith (1916).	
	a. 2 miles northwest.....	do.....	
	Kenneth.....	do.....	Do.
	a. 1 mile south.....	do.....	
	b. 2 miles east.....	do.....	
	c. 3 miles southwest.....	do.....	
	Mackinac Island; east side.....	Rock of Upper Monroe age of Smith (1916).	Do.
Ozark; quarry.....	Engadine formation of Smith (1916).	Do.	
a. 1 mile south.....	do.....		
Pike Lake area:			
a. 5 miles southeast.....	do.....		
b. 6 miles southeast.....	do.....		
c. 6 miles east.....	do.....		
Secs. 9 and 28, T. 43 N., R. 2 W.....	do.....		
Secs. 2, 7, and 10, T. 42 N., R. 2 W.....	do.....		
Menominee.....	Menominee; quarry 2 miles north.....	Trenton limestone.....	Do.
Monroe.....	Carleton.....	Rock of Upper Monroe age of Smith (1916).	Do.
	Lulu; quarry.....	Detroit River group.....	Do.
	Monroe; quarries.....	Raisin River dolomite member.	Do.
	a. quarry 2 miles north.....	do.....	Do.
	Raisinville; quarries.....	Detroit River group.....	Do.
	Scotfield; quarry.....	do.....	Do.
Schoolcraft.....	Blaney Jct.; quarry 2.5 miles north.....	Mayville formation.....	Do.
	Cooks.....	Burnt Bluff formation as used by Ver Wiebe (1928).	Do.
	Manistique; quarry.....	Manistique series of Smith (1916).	Do.
	a. quarry 6 miles northeast.....	do.....	Do.
	b. 11 miles northeast.....	Burnt Bluff formation as used by Ver Wiebe (1928).	Do.
Wayne.....	Gibraltar; quarry.....	Detroit River group.....	Do.

MINNESOTA

Dolomites and dolomitic limestones are restricted to southeastern Minnesota. Although the rock in many of the deposits contains enough magnesium carbonate to allow it to be classified as dolomite, in most places the high silica content makes it unsuitable as a commercial source of high-purity dolomite. Dolomite and dolomitic limestone are found in the St. Lawrence formation, the Oneota and Shakopee dolomites, the

Platteville and Galena formations, and the Cedar Valley limestone. In the eastern part of the area of occurrence (pl. 2), principally in Winona and Houston Counties and in eastern Fillmore County, the overburden of glacial drift is negligible or absent, but it thickens to the west where outcrops generally are restricted to drainage cuts. (Stauffer and Thiel, 1933; Stauffer and Thiel, 1941; Weitz, 1942)

Oneota and Shakopee dolomites.—The Oneota and Shakopee dolomites, of Early Ordovician (Beekmantown) age, probably are the most important sources of high-purity dolomite. The Oneota is primarily a thick-bedded, drab to buff and in places pink dolomite, sometimes sandy or shaly, and commonly cherty, especially in the upper part. The thickness varies from 45 to more than 150 feet. The Shakopee, overlying the Oneota and separated from it by the Root Valley sandstone of Stauffer and Thiel (1941), is less dolomitic, much of the rock being a drab massive dolomitic limestone. Locally it closely resembles the Oneota and crops out over much the same area. The average thickness is less than 60 feet. These formations form a northeastward-trending belt extending from southeast of Mankato, Blue Earth County, through parts of Nicollet, Le Sueur, Sibley, Scott, Carver, Hennepin, Ramsey, Washington, and Dakota Counties. They are present also to the east in parts of Goodhue, Wabasha, Olmsted, Winona, Fillmore, and Houston Counties. Chemical analyses show that, although many samples contain excessive silica, high-purity dolomite occurs at least in Fillmore, Goodhue, and Scott Counties. (Stauffer and Thiel, 1933; Stauffer and Thiel, 1941)

Platteville formation and Galena dolomite.—Certain beds in both the Platteville and Galena formations, of Ordovician age, are dolomitic limestones. The McGregor (middle) member of the Platteville contains 8 to 10 feet of thin-bedded gray to bluish-gray brittle dolomitic limestone having a high impurity content. The Stewartville (upper) member of the Galena formation is a mottled gray to yellow or tan, thick-bedded dolomitic limestone, usually about 50 feet thick. These formations occur in parts of Faribault, Waseca, Rice, Goodhue, Dodge, Olmsted, and Fillmore Counties. Neither appears to offer any possibilities as a potential source of high-grade rock. Their areal distribution has been represented on the map (pl. 2) to show their extension from northeastern Iowa. (Stauffer and Thiel, 1933; Stauffer and Thiel, 1941)

Cedar Valley limestone.—The Cedar Valley limestone, of Devonian age, is extremely variable lithologically. The rock ranges from high calcium to high magnesium; it is hard to soft and earthy and usually heavy bedded. The total thickness in Minnesota is about 130 feet. It occurs in parts of Fillmore, Mower, Freeborn, and Faribault Counties. Chemical analyses of samples from Fillmore and Mower Counties show the presence of some high-purity dolomite. (Stauffer and Thiel, 1933; Stauffer and Thiel, 1941)

Dolomite quarries and occurrences in Minnesota

<i>County</i>	<i>Locality</i>	<i>Formation</i>	<i>Reference</i>
Blue Earth.....	Mankato; quarries.....	Oneota and Shakopee dolomites.	Stauffer and Thiel, 1933; Stauffer, 1950.
Dakota.....	Hastings; quarry 4 miles down-river.....	.....do.....	Do.
Fillmore.....	Choice; quarry 0.5 mile south.....	Oneota dolomite.....	Stauffer and Thiel, 1933.
	Etna; quarry.....	Cedar Valley limestone	Stauffer, 1950.
	Lanesboro; quarry.....	Oneota and Shakopee dolomites.	Stauffer and Thiel, 1933; Stauffer, 1950.
	Rushford; quarry.....	Oneota dolomite.....	Stauffer and Thiel, 1933.
	a. quarry 2.5 miles north.....	.....do.....	Stauffer, 1950.
	Spring Valley; quarry.....	Cedar Valley limestone	Stauffer and Thiel, 1933; Stauffer, 1950.
	Tawney; 1.5 miles south.....	Shakopee dolomite.....	Stauffer and Thiel, 1933.
Goodhue.....	Cannon Falls; quarry.....	.....do.....	Stauffer and Thiel, 1933; Stauffer, 1950.
	Frontenac; quarries.....	Oneota dolomite.....	Do.
	Red Wing; quarries.....	.....do.....	Stauffer, 1950.
Houston.....	Egbert.....	.....do.....	Do.
	La Crescent; quarry 1.5 miles north-west.	.....do.....	Do.
	Spring Grove; quarry.....	Shakopee dolomite.....	Do.
Le Sueur.....	Kasota; quarries.....	Oneota dolomite.....	Stauffer and Thiel, 1933; Stauffer, 1950.
	Ottawa; quarry.....	.....do.....	Stauffer and Thiel, 1933.
Mower.....	Lyle; quarry 3 miles west.....	Cedar Valley limestone	Stauffer, 1950.
	Racine; 2.5 miles south.....	.....do.....	Stauffer and Thiel, 1933.
Nicollet.....	Judaon; across river.....	St. Lawrence formation.	Do.
	North Mankato; quarry.....	Oneota dolomite.....	Stauffer, 1950.
Olmsted.....	Oronoco.....	Shakopee dolomite.....	Do.
Scott.....	Merriam Junction; quarry.....	Oneota dolomite.....	Stauffer and Thiel, 1933; Stauffer, 1950.
	St. Lawrence; quarries.....	St. Lawrence formation.	Stauffer and Thiel, 1933.
	Shakopee; quarries.....	Oneota and Shakopee dolomites.	Do.
Wabasha.....	Lake City; 4 miles south.....	Oneota dolomite.....	Stauffer, 1950.
	Wabasha; 2 miles southeast.....	.....do.....	Do.
	Zumbro Falls.....	Oneota and Shakopee dolomites.	Do.
	a. quarry 4.5 miles east.....	Oneota dolomite.....	Do.
Washington.....	Gray Cloud Island.....	.....do.....	Stauffer and Thiel, 1933.
	Stillwater; quarry.....	.....do.....	Stauffer, 1950.
Winona.....	Dresbach; quarry.....	.....do.....	Do.
	Elba; quarry 4 miles southeast.....	.....do.....	Do.
	Winona; quarries.....	.....do.....	Stauffer and Thiel, 1933; Stauffer, 1950.

MISSOURI

Dolomites and dolomitic limestones underlie large areas in central and southeastern Missouri. From the few chemical analyses given in the literature, it seems probable that sizable reserves of dolomite are available in the region. Much of the dolomite in the thick sequence of Cambrian and Ordovician rocks is, however, known to be too cherty or otherwise

unsuitable as a source of high-grade rock. The more important dolomite formations, as indicated by chemical analyses, are the Bonneterre and Eminence dolomites and, perhaps, parts of the Potosi and Gasconade dolomites. Dolomite and dolomitic limestone containing some impurities occur at least locally also in the Derby and Doe Run dolomites, of Cambrian age, and in the Van Buren formation, Jefferson City (Cullison's (1944) Rich Fountain and Theodosia formations), Cotter, Powell, and Joachim dolomites, of Ordovician age.

Bonneterre dolomite.—The Bonneterre dolomite (Cambrian), oldest of the dolomite formations, is generally a massive gray to buff crystalline dolomite, essentially chert free, but containing varying amounts of silica in the form of sand or in clay, glauconite, and other silicates. The formation underlies the greater part of the Ozark uplift, but outcrops are confined principally to the vicinity of the St. Francois Mountains in Washington, St. Francois, Ste. Genevieve, Iron, and Madison Counties. Chemical analyses of samples from Washington County indicate a fairly high grade dolomite containing about 2.5 percent or less of silica. Analyses from Madison County, representative of a 150-foot zone in the vicinity of Fredericktown, show a high-grade rock with a lower silica content. Sizable reserves probably are in the Fredericktown area. (Bridge, 1930; Dake, 1930; McQueen, 1943; Mo. Geol. Survey, 1939)

Potosi dolomite.—The Potosi dolomite, of Cambrian age, is characteristically a massive fine- to medium-crystalline light to dark chocolate-brown dolomite or dolomitic limestone. It generally contains abundant quartz and chalcedony druses, and its thickness varies from a thin wedge up to about 400 feet. The formation forms the bedrock over large areas in and around the St. Francois Mountains. Analyses of the Potosi dolomite from Washington County show that it is a high-purity dolomite at least locally, but the general abundance of quartz and chalcedony throughout much of the formation probably precludes its use as a source of high-grade rock in most areas. (Bridge, 1930; Dake, 1930; Mo. Geol. Survey, 1939)

Eminence dolomite.—The Eminence dolomite, of Cambrian age, is essentially a massively bedded gray moderately crystalline dolomite or dolomitic limestone. The formation averages about 300 feet thick and is divided into a lower cherty member and an upper noncherty member (Josiah Bridge, 1952, oral communication). The upper noncherty zone is still officially designated the Proctor dolomite by the U. S. Geological Survey. The Eminence crops out mainly in the valleys of each of the drainage systems radiating from the St. Francois Mountains. It appears in St. Francois, Ste. Genevieve, Madison, Iron, Wayne, Carter, Shannon, Reynolds, Washington, Crawford, and Franklin Counties. It underlies most of the Ozark region and appears at the surface again to the west in Morgan and Camden Counties. Analyses from Shannon, Washington,

Camden, and Morgan Counties show the presence of high-purity dolomite through at least the upper 30 feet of the noncherty zone (Proctor). It seems probable that large reserves of high-grade rock are available. (Bridge, 1930; Dake, 1930; Mo. Geol. Survey, 1939; Weitz, 1942)

Gasconade dolomite.—The Gasconade dolomite, of Ordovician age, is essentially a well-bedded light-gray medium- to coarse-crystalline very

Dolomite quarries and occurrences in Missouri

County	Locality	Formation	Reference
Benton	Warsaw; quarry 1.5 miles north	Jefferson City dolomite	Buehler, 1907.
Bollinger	Lutesville; quarries	do.	Buckley and Buehler, 1904.
Camden	Camdenton	Eminence dolomite	Weitz, 1942.
Cole	Elston; quarries 2.5 miles west	Jefferson City dolomite	Buckley and Buehler, 1904.
	Jefferson City; quarries	do.	Do.
Douglas	Ava; quarry 0.5 mile east	Rock of Cambrian age.	Buehler, 1907.
Franklin	Union; quarry 1 mile east	Jefferson City dolomite	Buckley and Buehler, 1904.
Greene	Aah Grove; quarry	Burlington limestone	Buehler, 1907.
Jefferson	DeSoto; quarry	Jefferson City dolomite	Buehler, 1907; Buckley and Buehler, 1904.
	Hematite; quarry 0.25 mile south	do.	Buckley and Buehler, 1904.
Madison	Fredericktown; quarry	Bonnetterre dolomite	Buckley and Buehler, 1904; McQueen, 1943.
Miller	Eldon; quarry 3 miles east	Jefferson City dolomite	Buckley and Buehler, 1904.
Morgan	Proctor	Eminence dolomite(?)	Weitz, 1942.
Osage	Koeltstown; quarry 0.75 mile east	Jefferson City dolomite	Buckley and Buehler, 1904.
Pbelps	Rolla; quarries	do.	Do.
Polk	Bolivar; quarries	do.	Do.
Shannon	Eminence	Eminence dolomite	Bridge, 1930.
	a. 3 miles north	Van Buren formation	Do.
	b. 4 miles southeast	Eminence dolomite	Do.
	Round Spring	Eminence and Gasconade dolomites.	Do.
St. Francois	Bonnetterre; quarry	Bonnetterre dolomite	Mo. Geol. Survey, 1944.
	Desloge; quarry 2 miles north	do.	Buehler, 1907.
	Farmington; quarries	do.	Buckley and Buehler, 1904.
St. Louis	Glencoe	Joachim dolomite	Hinchey and others, 1947.
Washington	Caledonia area:		
	a. 2 miles south	Bonnetterre dolomite	Dake, 1930.
	b. 3 miles west	Derby dolomite	Do.
	Irondale area:		
	a. south	Bonnetterre dolomite	Do.
	b. 6 miles southwest	do.	Do.
	Potosi; 7 miles northwest	Potosi dolomite	Do.
	Shirley	Gasconade dolomite	Do.
	a. 4 miles north	Potosi dolomite	Do.
	b. 5 miles north	Eminence dolomite	Do.
	c. 2 miles east	Van Buren formation	Do.
Wayne	Patterson; quarry	Eminence dolomite(?)	Mo. Geol. Survey, 1944.
	Piedmont; quarry	Eminence dolomite	Do.

cherty dolomite. The Gasconade is present over much of the Ozark region, although its outcrops are confined principally to stream channels where the rock sometimes forms large cliffs. Analyses from Shannon and Washington Counties show a dolomite moderately high in impurities. (Bridge, 1930; Dake, 1930; Mo. Geol. Survey, 1939)

Other formations.—The other Cambrian and Ordovician formations mentioned contain dolomite locally, much of it with excessive impurities, and in all probability none of these would contain large deposits of uniformly pure dolomite. The shaded portion on the map (pl. 2) shows the general distribution of all the formations named, except that of the Joachim dolomite, in the eastern part of the State. (Bridge, 1930; Buckley and Buehler, 1904; Buehler, 1907; Dake, 1930; Hinchey and others, 1947; Mo. Geol. Survey, 1939)

MONTANA

Dolomite and dolomitic limestone occur principally in the Upper Cambrian rocks, extensively exposed in western and southwestern Montana, and in certain of the Ordovician rocks in the Bighorn and Little Rocky Mountains. The more important dolomitic formations include the Hasmark formation, the Pilgrim limestone, the Bighorn dolomite, and the Jefferson formation. Of these formations, the Hasmark probably is the most important as a potential source of high-grade dolomite, although each of the other formations mentioned may contain local deposits of high-grade rock. Other formations, of doubtful value because of the limited extent of the dolomite, the impurity content, or relative inaccessibility, include certain of the Precambrian limestones, the Devils Glen dolomite, of Cambrian age, and the Hannan limestone, of Mississippian age.

Hasmark formation.—The Hasmark formation, of Late Cambrian age, contains probably the most promising dolomite deposits in the State. The general sequence of the Hasmark consists of a lower unit of interbedded limestone and dolomite, a middle unit of calcareous shale, and an upper unit of dolomite and dolomitic limestone. The formation has been studied in the Phillipsburg quadrangle in parts of Powell, Deer Lodge, and Granite Counties, and it is considered to be the approximate equivalent of the Pilgrim limestone. A series of exposures along the highway 7 to 13 miles west of Anaconda total 350 feet in thickness; this series may contain several million tons of readily accessible dolomite. Similar deposits may be present elsewhere in the Phillipsburg quadrangle. Southwest of Helena, Lewis and Clark County, a coarsely crystalline marbleized dolomite (Pilgrim? or Hasmark?), ranging in thickness from 360 to 450 feet, also contains a large tonnage of high-purity rock. Dolomite has been quarried in this area as a source of lime. (Emmons and Calkins, 1913; Perry, 1949)

Pilgrim limestone.—The Pilgrim limestone contains a middle member consisting of dolomitic limestone and dolomite interbedded with purer limestones. The formation crops out in south-central Montana, and it has been examined in the vicinity of Three Forks, western Gallatin County, and south of Livingston, central Park County. These rocks are more dolomitic in the Livingston area. Although no analyses are available, the dolomites probably are too impure to be useful as a source of high-grade material. (Deiss, 1936)

Bighorn dolomite.—The Bighorn dolomite, of Ordovician age, consists generally of light-colored massive rough-weathering dolomite, interbedded with pale-gray and buff, mottled dolomite. Its thickness ranges from about 100 to nearly 300 feet. The Bighorn crops out in the Little Rocky Mountains to the north, in the Pryor Mountains, and along the flanks of the Absaroka Range and Beartooth Mountains in the south-central part of the State. No chemical analyses are available, but the dolomite may be moderately siliceous. The Bighorn in Montana, because of its impurity content or its unfavorable locations, probably is not as promising a source of rock as it is in Wyoming. (Blackwelder, 1913)

Jefferson formation.—The Jefferson formation, of Devonian age, contains thick beds of dolomitic limestone and dolomite usually too arenaceous or argillaceous to be considered as a source of high-grade dolomite. The dolomites are exposed in the Lewis and Clark and Sawtooth Ranges of northwestern Montana and near Logan, Three Forks, and in the Bridger Range of south-central Montana. The Jefferson also may contain dolomite beds in the central part of the State. No representative analyses are available. (Deiss, 1933; 1943)

The shaded areas shown on the map (pl. 2) represent the general areal extent of the "dolomite, or dolomite and limestone undivided" as taken from Knechtel's map. (Knechtel and others, 1948)

Dolomite occurrences in Montana

<i>County</i>	<i>Locality</i>	<i>Formation</i>
Carbon.....	Red Lodge; south and southwest.....	Bighorn dolomite.
Deer Lodge.....	Anaconda; 7.5 miles west.....	Hasmark formation.
	Foster Gulch; mouth of.....	Do.
	Silver Lake; 0.25 mile east.....	Do.
Gallatin.....	Logan; north.....	Pilgrim limestone and Jefferson formation.
	Manhattan; 8 miles north.....	Do.
Lewis and Clark.	Helena area:	
	a. south at Grizzly Gulch.....	Hasmark formation.
	b. 6 miles west at Colorado Gulch....	Do.
	c. 6 miles west at Nelson Gulch.....	Do.
Park.....	Livingston; 5 miles south in Yellowstone Canyon.	Pilgrim limestone, Bighorn dolomite, and Jefferson formation.

NEVADA

Dolomites and dolomitic limestones, ranging in age from Cambrian to Tertiary, occur at several localities in Nevada. However, because

the reports in which the rocks are described do not include many chemical analyses, little is known of their extent and uniformity of chemical composition. The dolomites of economic importance occur in the Monte Cristo dolomite in Clark County where, in the Sloan area, both dolomite and limestone are produced commercially. Dolomites of good quality are found also in the Goodsprings dolomite, the Luning formation, and the Horse Spring formation. Other formations, analyses of which indicate a relatively high percentage of impurities or for which no analyses are available, include the Highland Peak and Mendha limestones and the Ely Springs and Silverhorn dolomites of the Pioche district of Lincoln County, and the Sultan limestone, Muddy Peak limestone, and Bird Spring formation of Clark County. (Callaghan and Vitaliano, 1948; Deiss, 1952a; Hewett, 1931; Longwell, 1928; Muller and Ferguson, 1939; Roberts, 1943; Spurr, 1906; Westgate and Knopf, 1932)

Goodsprings dolomite.—The Goodsprings dolomite, containing beds ranging in age from Late Cambrian to Devonian(?), is composed principally of light- and dark-gray mottled thin-bedded dolomite and magnesian limestone. The formation attains a maximum thickness of approximately 2,450 feet. It is widely distributed throughout the Goodsprings quadrangle, in southwestern Clark County, extending in a broad belt along the west side of the Spring Mountains. Chemical analyses indicate that dolomite of excellent quality occurs at least locally in the formation. (Hewett, 1931)

Monte Cristo dolomite.—The Monte Cristo dolomite, of Mississippian age, comprises a series of limestones and dolomites. It has been divided into five members in the Goodsprings quadrangle; three of these members have been recognized in the Sloan area. Of these units, which include the Dawn and Anchor limestone members, the Bullion dolomite member, and the Arrowhead and Yellowpine limestone members, only the Bullion, because of its thickness, uniformity of composition, and accessibility, particularly at Sloan, is a potentially important source of high-grade dolomite. In the Sloan area the Bullion member is a thick (445 feet) dolomite, the lower 350 feet of which is pale gray, cream gray, and white, coarse crystalline, thick bedded, massive, and essentially chert free. The upper 100 feet contains more silica and limestone, and it is thought to be equivalent to the Arrowhead and Yellowpine members. Chemical analyses show that dolomite is in all the members, although many of the samples represent relatively pure areas in otherwise cherty zones and are not representative of the member as a whole. The Bullion member reportedly contains many millions of tons of readily accessible high-grade dolomite in the Sloan area. Both limestone and dolomite are produced commercially at Sloan. (Deiss, 1952a; Hewett, 1931)

Luning formation.—Dolomite of the Luning formation (Triassic) occurs in association with brucite and magnesite in the Paradise Range near

Gabbs, Nye County. In this area the uppermost of the three members of the formation is a dark-gray to black fine-grained dense dolomite, containing minor amounts of tremolite and talc. Chemical analyses of the recrystallized dolomite in this member show that some of the rock is of excellent quality. Only magnesite and brucite have been produced commercially from the area, and during World War II magnesite from these deposits supplied raw material for the magnesium plant near Las Vegas. (Callaghan and Vitaliano, 1948; Muller and Ferguson, 1939)

Horse Spring formation.—The Horse Spring formation, of Tertiary(?) age, comprises a thick, varied succession of limestone, dolomite, sandstone, clay, magnesite, and gypsum. The formation occurs in the ranges in southeastern Clark County. Pale-gray finely crystalline thick-bedded dolomite and dolomitic limestone, containing considerable iron stain and some chert nodules, form an isolated hill in the vicinity of Glendale. One chemical analysis shows that part of the rock is a good-quality dolomite, but the composition of the rock probably is not consistent throughout the deposit. (Longwell, 1928)

Dolomite quarries and occurrences in Nevada

County	Locality	Formation	Reference
Clark	Apex area:		
	a. quarry 1.5 miles north	Monte Cristo dolomite	
	b. 1.5 miles southwest	do	
	Glendale; 2.5 miles southeast	Horse Spring formation.	
	Goodsprings quadrangle	Goodsprings dolomite, Monte Cristo dolomite, and Bird Spring formation.	Hewett, 1931.
Jean	east	Monte Cristo dolomite	
	Las Vegas; 10 miles east	do	
	Sloan; quarry	Monte Cristo dolomite and Sultan limestone.	Deiss, 1952a.
Emeralda	Silver Peak district; northwest part of T. 2 S., R. 39 E.	Rocks of Cambrian age	Spurr, 1906.
Eureka	Eureka district	(?)	Weitz, 1942.
Lincoln	Pioche district	Highland Peak and Mendha limestones, Ely Springs and Silverhorn dolomites.	Weitz, 1942; Westgate and Knopf, 1932.
Nye	Gabbs	Luning formation	Callaghan and Vitaliano, 1948; Callaghan, 1933.
Perishing	Rose Creek	Rock of Triassic age	Roberts, 1943.

NEW JERSEY

Dolomite occurs locally in two formations in northwestern New Jersey: the Franklin limestone, of Precambrian age, and the Kittatinny limestone, of Cambrian and Ordovician age. Although high-grade deposits have been reported from several localities, commercial deposits are not known to be present. (Weitz, 1942)

Franklin limestone.—The Franklin limestone is predominantly a coarse white marble, usually high in calcite and silica, but in some places dolomitic. The dolomites probably are too local and irregular in distribution to be considered a potential source of high-grade rock. The Franklin crops out in an interrupted belt trending northeastward through Warren and Sussex Counties. Small isolated occurrences are found also in Morris and Passaic Counties. Some dolomite of excellent quality occurs at Franklin Furnace, as shown by chemical analyses of samples from the area. (Kummel and Gage, 1906; Lewis and Kummel, 1912; Weitz, 1942)

Kittatinny limestone.—The Kittatinny limestone consists primarily of massive blue-gray magnesian limestone, sometimes cherty, and scattered thin beds of shale and sandstone. Dolomite occurs in the upper portion of the formation, the total thickness of which is 2,500 to 3,000 feet. The Kittatinny crops out in several belts that trend northeastward through Warren and Sussex Counties and in small areas in Hunterdon, Morris, and Passaic Counties. Although many chemical analyses show a high magnesium carbonate content, the impurity content usually is moderately high. (Lewis and Kummel, 1912; Weitz, 1942)

Dolomite occurrences in New Jersey

<i>County</i>	<i>Locality</i>	<i>Formation</i>	<i>Reference</i>
Hunterdon.....	Vernoy.....	Kittatinny limestone..	Lewis and Kummel, 1912; Weitz, 1942.
Morris.....	Montville.....	.....(?).....	Do.
Passaic.....	Macopin.....	.....(?).....	Do.
	West Milford.....	Kittatinny limestone..	Do.
Sussex.....	Franklin Furnace; quarry.....	Franklin limestone....	Kummel and Gage, 1906.
	Hamburg.....	Kittatinny limestone(?)	Do.
	Newton.....	.....do.....	Lewis and Kummel, 1912; Weitz, 1942.
	Ogdensburg.....	Franklin and Kitta- tinny limestones.	Do.
	Vernon Township.....	Kittatinny limestone..	Do.
	Wantage Township.....	.....do.....	Do.
Warren.....	Belvidere.....	.....do.....	Do.
	Bushkill.....	.....do.....	Do.
	Columbia.....	.....do.....	Do.
	New Hampton.....	.....do.....	Do.
	Phillipsburg.....	.....do.....	Do.

NEW MEXICO

High-magnesian limestones are reported to be widespread in central and southern New Mexico. It is not known if commercial deposits of high-purity dolomite occur, although chemical analyses indicate that such rock might possibly be found in some localities. The formations containing beds of dolomite or dolomitic limestone include the El Paso, Montoya, and Fusselman limestones, and the Chupadera formation of former usage. (Talmage and Wootton, 1937; Weitz, 1942; Wells, 1937)

El Paso limestone.—The El Paso limestone, of Early Ordovician age, is primarily a thin-bedded limestone that contains some dolomitic beds. Some beds in the formation are sandy or cherty. At the type locality, in the Franklin Mountains near El Paso, Tex., the El Paso attains a thickness of about 1,000 feet. One analysis shows that the rock is magnesian limestone containing a high percentage of impurities. (Darton, 1928a; Dunham, 1935)

Montoya limestone.—The Montoya limestone, of Late Ordovician age, is predominantly a light- to dark-colored limestone, in places sandy or cherty, which attains a thickness of about 300 feet in the vicinity of Silver City. East of Silver City, in the vicinity of Hanover and Santa Rita, the basal member of the Montoya consists of quartzitic sandstone, and the upper member of massive beds of gray to pink and white dolomite that becomes cherty near the top. Available analyses are of magnesian limestone with a high-impurity content. (Darton, 1928a; Dunham, 1935; Lasky, 1936)

Fusselman limestone.—The Fusselman limestone, Silurian in age, consists generally of a lower member of compact fine-grained gray limestone that weathers nearly white and an upper member of hard dark massive dolomite. The formation ranges in thickness from 40 to about 1,000 feet. Analyses indicate a rock low in magnesium carbonate and high in impurities. (Darton, 1928a; Dunham, 1935)

This group of limestones occurs principally along the west side of the Sacramento Mountains southeast of Alamogordo, in the San Andres Mountains of Socorro and Dona Ana Counties, and in the Franklin Mountains extending from southern Dona Ana County southward to El Paso, Tex. The group occurs also in some of the smaller ranges of southwestern New Mexico. (Darton, 1928b)

Chupadera formation of former usage.—The Chupadera formation of former usage, of Permian age, consists principally of a thick series of limestone, gypsum, and red and gray sandstone. The formation contains a large amount of magnesia, and many oil wells in Chaves and

Dolomite and dolomitic limestone occurrences in New Mexico

County	Locality	Formation	Reference
Dona Ana	San Andres Canyon ¹	Fusselman limestone	Wells, 1937.
Eddy	Carlsbad area:		
	a. 13 miles north	Chupadera formation (?) of former usage.	Weits, 1942.
	b. 18 miles northwest	do.	Do.
	c. 20 miles west	Rock of Permian age	Wells, 1937.
	Queen; northwest ¹	Chupadera formation of former usage.	Do.
	Government test hole 18 (Carlsbad area?)	Carlsbad limestone	Do.
Socorro	Prairie Spring; 10 miles north ¹	Chupadera formation of former usage.	Do.

¹ Dolomitic limestone containing more than 38 percent magnesium carbonate.

Eddy Counties have encountered thick dolomitic beds close to the surface. Several analyses indicate the presence of dolomite, although the impurity content is moderately high in all the samples. The Chupadera extends over large areas in southern and central New Mexico; it is represented on the map (pl. 2) by the large shaded area and the two smaller areas to the northwest. (Darton, 1928a, 1928b; Talmage and Wootton, 1937; Weitz, 1942; Wells, 1937)

NEW YORK

Dolomites are not widespread in New York. They are confined chiefly to the southeastern part of the State, to the west in the counties bordering the southern shore of Lake Ontario, and to the north, principally in St. Lawrence County. The more important dolomitic units include the Grenville series and Inwood limestone, of Precambrian age, the Stockbridge limestone, of Cambrian and Ordovician age, and the Lockport dolomite, of Silurian age. Descriptions and chemical analyses of Cambrian and Ordovician dolomitic limestones north, east, and south of the Adirondack Mountains show the rocks generally to be siliceous and to contain little dolomite; these rocks probably are of no potential value as sources of high-grade dolomite. Quarrying of the dolomite has been most extensive in the southeastern New York area, and high-purity dolomite from Dutchess County has furnished raw material for the magnesium plant at Wingdale, N. Y. (Ries, 1901; Dale, 1923)

Inwood limestone.—The Inwood limestone is essentially a white coarse-crystalline marble high in magnesia. The formation underlies Manhattan Island and extends northward into Westchester County. The dolomite has been quarried in the vicinity of Ossining, Pleasantville, and Tuckahoe. Chemical analyses show that the Inwood at these localities is a fairly good dolomite, although moderately siliceous at places notably at Ossining. (Ries, 1901)

Grenville series.—Dolomite marbles occur in the Grenville series of St. Lawrence County. These marbles vary from snow white to bluish gray and are rather coarsely crystalline. They vary considerably in purity because of the presence of grains and masses of serpentine, tremolite, and other minerals. The distribution of these deposits is very irregular, outcrops are scarce, and some of the probable deposits are likely to be rather inaccessible. A very pure deposit about 3 miles north of Gouverneur contains many millions of tons of uniformly high-purity, dolomite. The deposit has been quarried in a small way. (Prucha, 1953; Ries, 1901)

Stockbridge limestone.—The Stockbridge limestone of southeastern New York is lithologically similar to that in Massachusetts and Connecticut. It ranges from almost pure limestone to equally pure dolomite, is highly marbled locally, and generally is light colored. The Stockbridge

crops out along the east boundary of New York in Rensselaer, Columbia, Dutchess, Putnam, and Westchester Counties and in several smaller belts extending southwestward across Dutchess, Putnam, and Westchester Counties. Small areas of dolomite in southwestern Orange County probably are extensions of the Kittatinny limestone of New Jersey, of equivalent age. Dolomite has been quarried from the Stockbridge chiefly in the vicinity of South Dover and Dover Furnace, Dutchess County, and has been used as an ore of magnesium at the Wingdale magnesium plant. Several chemical analyses show that this high-grade dolomite in places contains small quantities of the alkali metals, which are detrimental if magnesium is to be produced by the ferrosilicon reduction process. (Dale, 1923; Ries, 1901)

Lockport dolomite.—The Lockport dolomite contains zones that are at least locally a good grade of dolomite. The Gasport limestone member has a fairly low silica content but generally is dolomitic limestone rather than dolomite. Overlying the Gasport member is a 30- to 35-foot section of massive heavy-ledged dolomite that usually is of good grade and fairly low in silica. The upper portion of the Lockport, that part containing Guelph fauna, is a brown partly thin bedded dolomite about 45 feet of which is exposed at Shelby, Orleans County. Exposures of this zone are rare, but analyses indicate that the rock is consistently a dolomite with a low silica content. The Lockport dolomite occurs in a belt extending from the Niagara River eastward through Niagara, Orleans, Monroe, Wayne, and Cayuga Counties. A thin strip continues east as far as Utica, Oneida County. (Ries, 1901)

Dolomite quarries and occurrences in New York

County	Locality	Formation	Reference
Dutchess	Dover Plains; quarries	Stockbridge limestone	Ries, 1901; Dale, 1923.
	Wingdale; quarries 2 miles north-east.	do.	
Lewis	Sterlingbush (Lewisburg); quarries 1.5 miles northeast.	Grenville series	
Monroe	East Penfield; quarries	Lockport dolomite	Ries, 1901.
	Penfield; quarries	do.	Do.
	Rochester and vicinity; quarries	do.	Do.
Niagara	Lockport; quarry 1.5 miles east	do.	
	Niagara Falls; quarry south	do.	Do.
St. Lawrence	Gouverneur; quarries 3 miles north	Grenville series	Prucha, 1953.
Westchester	Ossining; quarries	Inwood limestone	Ries, 1901.
	Pleasantville; quarries	do.	Do.
	Tuckahoe; quarries	do.	Do.

NORTH CAROLINA

Dolomitic rocks are confined to the western part of North Carolina and occur in the Shady dolomite, of Early Cambrian age, and its approximate equivalents, the Murphy marble in the extreme southwest and the Gaffney marble, some distance to the east. Lenses of dolomite marble occur also in the Carolina gneiss. Chemical analyses of samples

from several localities show that dolomite occurs in each of these formations, although no information is available regarding its extent and uniformity in composition. It seems probable, however, that potentially commercial deposits of high-grade rock in the State are few. (Loughlin and others, 1921; Weitz, 1942)

Carolina gneiss.—The Bandana dolomite marble of Hunter and Gildersleeve (1946) occurs as a lens in the Carolina gneiss. It is a white extremely coarsely crystalline marble exposed in a railroad cut approximately 3.5 miles from Toecane (or 1.25 miles north of Bandana Station) along the Toe River, Mitchell County. The deposit is not particularly large, but chemical analyses indicate that it is an exceptionally pure dolomite. (Hunter and Gildersleeve, 1946; Loughlin and others, 1921)

Murphy marble.—The Murphy marble is a coarse- to fine-grained rock, ranging from a high-calcite to a high-dolomite marble, and varying in thickness from 150 to nearly 500 feet. It is predominantly white, but not uncommonly dark gray or blue, and contains layers of banded or mottled blue and white rock. The formation is present nearly the entire length of Cherokee County, extending as a narrow band along the valleys of the Nottely and Valley Rivers. It occurs also between Nantahala and Hewitt along the valley of the Nantahala River, Swain County, and as a group of narrow areas in the vicinity of Peachtree and Brasstown, Clay County. Outcrops of the Murphy marble generally are scarce, but analyses show the presence of dolomite locally. (Loughlin and others, 1921; Van Horn, 1948)

Gaffney marble.—The Gaffney marble is predominantly a fine-grained bluish-gray to white marble, ranging from 30 to about 120 feet thick, and usually has a banded or schistose appearance due in part to impurities. The white beds of the Gaffney generally are the more highly dolomitic, but the content of impurities commonly is somewhat higher than desirable. The formation forms a linear group of narrow bands extending across the southeastern part of Cleveland County into Gaston County. Minor occurrences of similar nature, in Catawba and Lincoln Counties, are presumably continuations of the Gaffney belt. Outcrops are principally along stream valleys and generally are obscure. It seems doubtful that commercial deposits of dolomite occur in the Gaffney marble. (Loughlin and others, 1921)

Shady dolomite.—The Shady dolomite, although sometimes a limestone, is almost wholly a dolomite in most areas. It is fine grained, somewhat crystalline, commonly gray, bluish gray, or white in color, and not uncommonly weathers to a dull gray or black. This formation occurs near Hot Springs, Madison County, where it has an apparent thickness of nearly 2,000 feet, and along the North Fork of the Catawba River from near Linville Falls southward to the vicinity of Sevier, McDowell

County. The rock has been quarried in the vicinity of Hot Springs and near Ashford, a few miles south of Linville Falls. Chemical analyses show that the Shady is a high-grade dolomite in these areas. (Loughlin and others, 1921; Oriol, 1950)

Dolomite quarries and occurrences in North Carolina

County	Locality	Formation	Reference
Catawba.....	Catawba area:		
	a. quarry 5 miles south.....	Gaffney marble.....	Loughlin and others, 1921.
	b. quarry 8 miles south.....	..do.....	Do.
Cherokee.....	Andrews.....	Murphy marble.....	Do.
	Tomata; 1 mile northeast.....	..do.....	Do.
Madison.....	Hot Springs; quarries 1 mile north- west.	Shady dolomite.....	Do.
Mitchell.....	Toecane; 3.5 miles southwest.....	Carolina gneiss.....	Do.
McDowell.....	Ashford area; quarry.....	Shady dolomite.....	Do.
	Avery.....	..do.....	Do.
	Woodlawn; quarry.....	..do.....	Do.
Swain.....	Hewitt; quarries.....	Murphy marble.....	Do.
Yancey.....	Burnsville.....	..(?).....	Weitz, 1942.

OHIO

Very large quantities of high-purity dolomite are in surface or near-surface deposits in the western half of Ohio, where many thousands of square miles are underlain by carbonate rocks ranging in age from Ordovician to Devonian. Development of these resources has been extensive, and for many years Ohio has led in domestic production of lime. Nearly half the production from Ohio has been as refractory (dead-burned) dolomite, representing more than half the total quantity of refractory dolomite produced in the United States in recent years. (Stout, 1941; Chandler and Jensen, 1951)

The dolomites and dolomitic limestones are principally in the upper part of the Niagara group, of Silurian age. The dolomitic formations include the Euphemia dolomite of Foerste (1917), the Springfield, Cedarville, and Lockport dolomites. The overlying Bass Island, Amherstburg, and Lucas dolomites and parts of the Columbus limestone also are dolomitic. Chemical analyses show that several of these formations are uniformly pure dolomite over large areas. The beds are nearly flat lying, and most of the structural features are small and cause little difficulty for quarry operators. Although the overburden of glacial drift that covers most of the region ranges from 25 to 75 feet in thickness over large areas, it is thin or absent locally, and its removal apparently presents no great problem. Even where overburden is heavy and outcrops scarce, quarrying operations are carried out on a large scale. (Stout, 1941)

Euphemia dolomite of Foerste (1917).—The Euphemia dolomite, at the base of the dolomite sequence in the upper part of the Niagara group, is an irregularly bedded porous somewhat mottled dolomite averaging

about 6 feet in thickness. It occurs principally in Preble, Montgomery, Greene, Clark, and Miami Counties and, where samples have been analyzed, is a high-purity dolomite. (Stout, 1941)

Springfield dolomite.—The Springfield dolomite is a uniformly bedded dull earthy dolomite having a porous texture and varying from buff to light brown. The formation averages about 10 feet in thickness. It is exposed in Preble, Montgomery, Miami, Clark, Greene, Clinton, Highland, and Adams Counties. Chemical analyses of the rock show that, although the magnesium carbonate content is nearly always high, the silica content also is moderately high. (Stout, 1941)

Cedarville dolomite.—The overlying Cedarville dolomite is a highly crystalline generally massive dolomite, open textured and varying from a light buff through light gray and bluish gray. Its thickness averages about 50 feet. The Cedarville occurs in southwestern Ohio in at least parts of the following counties: Adams, Highland, Clinton, Greene, Fayette, Clark, Champaign, Logan, Montgomery, Miami, Shelby, Auglaize, Preble, Darke, Mercer, and Van Wert. The chemical composition of the rock generally is that of a high-purity dolomite. In Adams and Highland Counties, this formation is the approximate correlative of the Peebles dolomite of Foerste (1929). (Stout, 1941; Wilmarth, 1938)

Dolomite of Niagaran age.—Dolomite of Niagaran age (the Guelph dolomite of former usage) is very similar to the Cedarville both physically and chemically, but it has been distinguished from it on the basis of certain faunal differences. The dolomite is highly crystalline, open and porous in texture, and varies from nearly white to light gray or bluish gray. The thickness ranges from 50 to 80 feet, and, locally, chert is in the lower portion. The unit is confined to northwestern Ohio, cropping out in parts of Marion, Hardin, Wyandot, Hancock, Seneca, Wood, Sandusky, and Ottawa Counties. This dolomite of Niagaran age (the Guelph of former usage) is an unusually pure dolomite, analyses often showing less than 1 percent total impurities. In western Sandusky County and southwestern Ottawa County, however, it contains from 1 to 4 percent celestite occurring as disseminated grains and in cavity fillings. Commercially this unit is the most important dolomite in Ohio. It has been used as a raw material in both the electrolytic and ferrosilicon reduction processes for the production of magnesium; it is also used extensively in the manufacture of refractory dolomite. Large reserves of very high-purity dolomite are present throughout the area underlain by this dolomite. (Stout, 1941)

Bass Island dolomite.—The Bass Island dolomite, of Silurian age, overlies the Niagara group and consists of four members, which are, in ascending order, the Greenfield dolomite, Tymochtee shale, Put-in-Bay dolomite, and Raisin River dolomite members. The Bass Island has an

average thickness of about 570 feet, and the rock is generally a fair grade of dolomite but tends to be slightly siliceous. The formation ranges from thin bedded to massive, dense and hard to coarsely crystalline and open in texture, and generally is some shade of brown or dark bluish gray. It is in at least 23 counties in the western part of the State, but it does not occur in the southwest corner or the extreme northwest corner. The rock has been quarried in many localities. (Landes, 1951; Stout, 1941)

Amherstburg and Lucas dolomites.—The Detroit River group, of Devonian age, consists of two formations, the Amherstburg and Lucas dolomites. The Amherstburg is an open-textured dolomite, usually massively bedded, and varies from drab to brownish gray. Exposures are scarce because of the heavy drift cover, but the thickness apparently ranges from 50 to 75 feet. The formation is confined to two areas, one east of Cincinnati Arch in Ottawa, Erie, and Sandusky Counties and another west of the arch in Lucas, Wood, and Henry Counties. One analysis indicates that the rock is relatively free from impurities but slightly low in magnesium carbonate. The Lucas dolomite, although locally somewhat calcareous, is predominantly a light-blue to drab bedded dolomite, attaining a maximum thickness of 140 feet but usually ranging from 30 to 75 feet. This formation is coextensive with the Amherstburg. Chemical analyses show that the Lucas varies in composition, ranging from a magnesian limestone moderately high in silica to a high-purity dolomite. (Landes, 1951; Stout, 1941)

Monroe formation of former usage.—In some reports the Bass Island dolomite and the Detroit River group have been called the Monroe formation. The term has persisted to some extent, and analyses of samples shown as being from the Monroe formation could be from any one of the dolomites stratigraphically between the Niagara group and the Columbus limestone.

Columbus limestone.—The Columbus limestone (Middle Devonian), uppermost of the thick series of dolomites in Ohio, is a light-gray to light-brown massively bedded rock, rather earthy in appearance. It varies in composition both vertically and laterally, but generally it is a limy dolomite in the lower portion and a low-magnesium limestone in the upper. The thickness ranges from 80 to 125 feet where the formation is normally developed, and layers of chert are present locally. The formation is in three general areas. The first is a broad belt 10 to 15 miles wide extending northward from Pickaway County to Kelleys Island, in Lake Erie. The second, heavily drift covered, is a crescent-shaped area on the rim of the Michigan Basin, reaching from northern Paulding County through parts of Defiance, Putnam, Henry, and Wood Counties into western Lucas County. The third area is in eastern Logan County and north-central Champaign County. Several analyses, notably those

of samples from Logan and Wood Counties, indicate the local presence of a good grade of dolomite with about 2 percent of silica. (Stout, 1941)

The shaded area on the map (pl. 2) shows the general distribution of the Niagara group, the Monroe formation of former usage, and the Columbus limestone as taken from the geologic map of Ohio. Because of the many quarries and sample localities in the dolomite, it is impracticable to show on the map or to list in the accompanying table anything but active or recently active quarries for which there are analyses, either specific or representative, showing high-grade dolomite. For a more complete listing of quarries and sample localities, special reference should be made to Stout's (1941) paper. (Bownocker, 1947; Stout, 1941)

Dolomite quarries in Ohio

[Data from Stout, 1941; all quarries in this reference are listed as active or recently active. Except for those localities marked with an asterisk (*), chemical analyses are available for locality shown or for representative area]

County	Locality	Formation
Adams	Locust Grove; quarry	Peebles dolomite.
	Lynx; quarry 1.25 miles east	Do.
Allen	Bluffton; quarry	Monroe formation (of former usage). ¹
	*Elida; quarry	Do.
	Herrod; quarry 1.75 miles south	Do.
	Lafayette; quarry	Do.
	Lima; quarry	Do.
	*Southworth; quarry	Do.
	*Westminster; quarry	Do.
Auglaise	*Buckland; quarry	Do.
Champaign	Salem Township; quarry	Do.
Clark	Springfield; quarry 4 miles west	Cedarville dolomite.
Clinton	Melvin; quarry 1 mile east	Niagara group.
	New Vienna; quarry 1.25 miles northwest	Do.
Darke	Greenville; quarry 4.5 miles east	Cedarville dolomite.
	Weavers; quarry	Do.
Fayette	Greenfield; quarry 2.75 miles north	Monroe formation (of former usage).
	Rock Mills; quarry	Do.
Greene	Cedarville; quarry	Cedarville dolomite.
	Jamestown; quarry 1.75 miles west	Niagara group.
Hancock	Arlington area:	
	a. quarry 3 miles south	Monroe formation (of former usage).
	b. quarry 2 miles east	Do.
	Findlay; quarry	Do.
	*Williamstown; quarry	Do.
Hardin	Ada; quarry 1.5 miles north	Do.
	Blanchard; quarry	Do.
	Dunkirk; quarry	Do.
	Kenton; quarry	Do.
	McVittys; quarry	Dolomite of Niagaran age (Guelph dolomite).
Highland	Highland; quarry 2 miles south	Bas Island dolomite.
	Hillboro; quarry	Lilley dolomite of Foerste (1917) and Peebles dolomite of Foerste (1929).
	*Marshall; quarry	Niagara group.
	*New Market; quarry	Do.
	Samantha; quarry 2 miles west	Peebles dolomite of Foerste (1929).
	Sinking Spring area:	
	a. quarry 1.5 miles northwest	Lilley dolomite of Foerste (1917).
	b. quarry 1 mile north	Peebles dolomite of Foerste (1929).
	Willettville; quarry 1.25 miles southeast	Cedarville dolomite(?).

¹ Monroe formation includes Bas Island, Amherstburg, and Lucas dolomites.

<i>County</i>	<i>Locality</i>	<i>Formation</i>
Logan.....	Belle Center; quarry.....	Monroe formation (of former usage).
	Bellefontaine; quarry.....	Columbus limestone.
	*Big Springs; quarry.....	Monroe formation (of former usage).
	East Liberty; quarry 1.25 miles west.....	Columbus limestone.
	*Huntsville; quarry.....	Monroe formation (of former usage).
	Northwood; quarry.....	Do.
Lucas.....	Ruhsylvania; quarry 2 miles southeast.....	Columbus limestone.
	West Liberty; quarry 2 miles east.....	Lucas dolomite.
	*Holland; quarry.....	Monroe formation (of former usage).
	*Maumee; quarry.....	Do.
	Monclova; quarry 1.75 miles north.....	Basin Island dolomite.
	*Silica; quarry.....	Lucas dolomite.
Marion.....	Sylvania; quarry 2.5 miles southwest.....	Do.
	Waterville; quarry 1 mile south.....	Monroe formation (of former usage).
	*Whitehouse; quarry.....	Columbus limestone.
	*Hepburn; quarry 3 miles east(?).....	Niagara group.
	Marseilles; quarry 2 miles southwest.....	Monroe formation (of former usage).
	Mercer.....	Celina; quarry 4.5 miles southwest.....	Niagara group.
Rockford; quarry 1.5 miles northwest.....		Do.
Miami.....	Ludlow Falls.....	Euphemia dolomite of Foerste (1917).
	West Covington; 1 mile southwest.....	Springfield dolomite.
Ottawa.....	Clay Center; quarry.....	Dolomite of Niagaran age (Guelph dolomite).
	*Elmore; quarry.....	Do.
	Genoa; quarry.....	Do.
	*Port Clinton; quarry.....	Monroe formation (of former usage).
Paulding.....	Grover Hill; quarry 2.5 miles east.....	Do.
Preble.....	Lewisburg; quarry 1.25 miles northwest.....	Euphemia dolomite of Foerste (1917), and Springfield and Cedarville dolomites.
	New Paris; quarry.....	Euphemia dolomite of Foerste (1917) and Cedarville dolomite.
Putnam.....	*Cloverdale; quarry.....	Monroe formation (of former usage).
	*Fort Jennings; quarry.....	Do.
	*Ottawa; quarry.....	Do.
	Pandora; quarry.....	Do.
Ross.....	Rimer; quarry.....	Do.
	Greenfield; quarry.....	Basin Island dolomite.
Sandusky.....	Fremont; quarry.....	Niagara group.
	Gibsonburg area; quarries.....	Dolomite of Niagaran age (Guelph dolomite).
	*Millersville; quarry.....	Do.
Seneca.....	Woodville area; quarries.....	Do.
	Bacom; quarry 1.5 miles east.....	Monroe formation (of former usage).
	Maple Grove-Bettsville area; quarries.....	Dolomite of Niagaran age (Guelph dolomite).
Shelby.....	Kirkwood; 1 mile northwest.....	Cedarville dolomite.
Union.....	*Watkins; quarry.....	Monroe formation (of former usage).
	York Center; quarry.....	Do.
Van Wert.....	*Convoy; quarry.....	Do.
	Delphos; quarry.....	Do.
	Middlepoint; quarry 1 mile west.....	Do.
	Scott; quarry 3.5 miles southwest.....	Do.
Wood.....	Fostoria; quarry.....	Dolomite of Niagaran age (Guelph dolomite).
	Luckey; quarry.....	Do.
	North Baltimore; quarry.....	Monroe formation (of former usage).
	Portage; quarry.....	Dolomite of Niagaran age (Guelph dolomite).
	Rising Sun; quarry.....	Do.
	*Rudolph; quarry.....	Monroe formation (of former usage).
	West Millgrove; quarry.....	Do.
	Weston; quarry.....	Columbus limestone.

Dolomite quarries in Ohio—Continued

County	Locality	Formation
Wyandot.....	Carey; quarry.....	Guelph dolomite and Monroe formation (of former usage).
	Upper Sandusky area:	
	a. quarry 2.5 miles northeast.....	Monroe formation (of former usage).
	b. quarry 4.5 miles southeast.....	Do.

OKLAHOMA

Deposits of dolomite occur in several localities in Oklahoma in formations ranging in age from Cambrian to Permian. Large quantities are available in the Arbuckle and Wichita Mountains, in south-central and southwestern Oklahoma. The principal dolomitic formations belong to the Arbuckle group, of Cambrian and Ordovician age, and include, in ascending order, the Royer and Butterly dolomites and the Strange formation of Decker (1939). The Kindblade and West Spring Creek formations also contain some dolomite. Of these formations, the Royer is the only one that has been quarried on a large scale.

Royer dolomite.—The Royer dolomite, of Late Cambrian age, generally is a coarsely crystalline marblelike dolomite, which attains a thickness of more than 700 feet in the Arbuckle Mountains and about 200 feet in the Wichita Mountains. The formation is more widespread in the Arbuckles than in the Wichitas, where it occurs only in the northwestern part. In the Arbuckle Mountains the Royer is typically a thick-bedded gray locally brecciated dolomite, free of sand and chert. It contains several discontinuous beds of fine-grained light-gray limestone, but these beds constitute only a minor part of the total thickness. Chemical analyses of samples from Atoka, Johnston, Murray, and Kiowa Counties show that the Royer is in general a moderately good grade of dolomite. Locally the quality is excellent, notably in the Mill Creek-Ravia area, Johnston County, where quarrying operations were started in 1948 and large reserves of high-grade dolomite are readily accessible. (Decker, 1939; Ham, 1949)

Butterly dolomite.—The Butterly dolomite, overlying the Royer and separated from it by the Signal Mountain limestone, is a coarse- to fine-crystalline partly laminated rock, containing large quartz grains and thin layers of quartz conglomerate in the upper part. It is predominantly gray, although in places it is pink to yellow. Owing to the resistance of the rock to weathering, rough masses stand out in relief 4 to 6 feet above the general surface level. So far as is known, the formation occurs only in the Arbuckle Mountains, where it ranges in thickness from 150 feet in the western part to 365 feet in the east. One analysis of the Butterly dolomite from Murray County shows that the rock is of fairly high purity, but another from the same locality shows that it is somewhat low in magnesium carbonate and contains more than 10 percent impurities. (Beach and English, 1940; Decker, 1939)

Strange dolomite of Decker (1939).—The Strange dolomite of Decker (1939), of Early Ordovician age, is a massive coarse-grained pink to gray dolomite. It has been recognized only in the Wichita Mountains northwest of Lawton, Comanche County, where about 80 feet is exposed. Several analyses of the rock show that it is generally a good-quality dolomite, and large quantities of the rock are readily accessible. (Beach and English, 1940; Decker, 1939)

Kindblade and West Spring Creek formations.—The overlying formations, particularly the Kindblade and West Spring Creek formations, forming the upper part of the Arbuckle group, are predominantly limestone throughout most of the Arbuckle Mountain area. They tend to be more dolomitic in the eastern part of the mountains, however, particularly in the areas adjacent to faults. No analyses of samples from the Arbuckle Mountains are available, but it is reported that large quantities of dolomite may be obtained from the upper part of the West Spring Creek formation in the vicinity of Hickory, eastern Murray County. A few analyses of rocks from the Kindblade of the Wichita Mountains, in eastern Kiowa County, show that the rock is moderately high in impurities. (Beach and English, 1940; Decker, 1939)

Other formations.—Thin but widespread beds of generally impure dolomite and dolomitic limestone are in western Oklahoma. The beds are part of the Permian sequence of shales, sandstones, limestones, and gypsum. Among these dolomitic limestones are the Mangum dolomite

Dolomite quarries and occurrences in Oklahoma

<i>County</i>	<i>Locality</i>	<i>Formation</i>	<i>Reference</i>
Atoka.....	Coleman; 3.5 miles east.....	Royer dolomite.....	Ham, 1949.
Blaine.....	Greenfield.....	Relay Creek dolomite beds.....	Beach and English, 1940.
	a. 6 miles northwest.....	.....do.....	Suffel, 1930.
	Watonga; 6 miles east.....	Blaine gypsum.....	Beach and English, 1940.
Comanche.....	Lawton area:		
	a. 6 miles northwest.....	Strange dolomite of Decker (1939).....	Ham, 1949.
	b. 7 miles northwest.....	.....do.....	Do.
Delaware.....	Eucha; 2 miles southeast.....	Cotter dolomite.....	Beach and English, 1940.
	Flint.....	.....do.....	Do.
	Sycamore; 6 miles northeast.....	.....do.....	Do.
Jackson.....	Creta area:		
	a. 2 miles northwest.....	Mangum or Creta member.....	Do.
	b. 2 miles southwest.....	.....do.....	Do.
Johnston.....	Mill Creek-Ravia area; quarry.....	Royer dolomite.....	Ham, 1949.
	Wapanucks; 3 miles south.....	.....do.....	Do.
Kiowa.....	Gotebo; 9 miles south.....	Kindblade formation..	Beach and English, 1940.
	Sedan; 6 miles east.....	Royer dolomite.....	Do.
Murray.....	Davis area:		
	a. 7 miles south.....	.....do.....	Ham, 1949.
	b. 8 miles south.....	Royer and Butterly dolomites.....	Do.

member, the Creta and Jester dolomite members (Suffel, 1930) of the Blaine gypsum, and the Relay Creek and Day Creek dolomites. Because of the variability in composition, the general impure nature, and the thinness of the beds, it is unlikely that any of these formations could be used for high-grade dolomite. Dolomite occurs in northeastern Oklahoma in the Cotter dolomite. (Beach and English, 1940; Ham, 1949; Okla. Geol. Survey, 1944; Suffel, 1930)

PENNSYLVANIA

Dolomites and dolomitic limestones are confined principally to southeastern Pennsylvania in several northeast-trending belts of Cambrian and Ordovician carbonate rocks. High-purity dolomite in these belts does not persist either vertically or laterally, and intricate structure often disrupts the normal sequence to such an extent that several formations may appear in the same quarry. This condition necessitates careful selective quarrying in order to recover rock of the desired composition. Dolomites of varied quality have been quarried in many areas. The dolomitic formations include the Tomstown dolomite, which, in the York, Lancaster, and Chester Valleys, has been subdivided into the Vintage dolomite, Kinzers formation, and Ledger dolomite; the Conococheague limestone, which is the Allentown limestone of Berks, Lehigh, and Northampton Counties, and the Gatesburg formation and Mines dolomite of Blair and Huntingdon Counties; the Beekmantown limestone, which is the Larke and Nittany dolomites, Axemann limestone, and Bellefonte dolomite in Blair and Huntingdon Counties; and the Conestoga limestone. Although these formations commonly are siliceous, intimately inter-layered with low-magnesium limestone, or are otherwise impure, large reserves of high-purity dolomite probably exist in certain areas, notably in Chester and Montgomery Counties. Of the formations mentioned, the Ledger is perhaps the most nearly uniform in composition and generally contains the least amount of impurities. (Butts and others, 1939; Miller, 1934; Stose and Stose, 1944)

Tomstown dolomite.—The Tomstown dolomite, of Early Cambrian age, is predominantly a dolomitic limestone with varied quantities of silica and magnesia. In many places the formation contains considerable quantities of interbedded shaly material, which renders the rock undesirable for many uses. It is generally blue, but sometimes gray, quite massive and hard, and the thickness is about 1,000 feet. Outcrops of the Tomstown form a discontinuous belt extending through parts of Franklin, Adams, Cumberland, Lebanon, Berks, Lehigh, Northampton, and Bucks Counties. Chemical analyses show that the rock is generally moderately siliceous, although near Clayton, Berks County, and East Allentown, Lehigh County, some of the dolomite is of good quality. (Miller, 1934; Stose and Ljungstedt, 1931)

Vintage dolomite.—The Vintage dolomite which, in the York, Lancaster, and Chester Valleys, is equivalent to the lower part of the Tomstown, is rather poorly exposed. Its presence generally is indicated by the characteristic weathering product, a dark-red or maroon, granular soil. In addition to a basal unit of white quartzose marble, the formation consists of two major units, a lower one principally of dark-blue or gray, heavily bedded to massive, knotty dolomite and an upper one of mostly pure fine-grained limestone. The thickness of the formation varies considerably but probably never exceeds 1,000 feet. The Vintage is present in narrow interrupted belts that extend through parts of Adams, York, Lancaster, Berks, and Chester Counties. Analyses from Lancaster County, probably from the Vintage, show some dolomite of excellent quality. (Miller, 1934; Stose and Ljungstedt, 1931; Stose and Stose, 1944)

Kinzers formation.—The Kinzers formation, equivalent to the middle part of the Tomstown, is varied in character, but generally can be separated into three distinct members: a lower member of dark-colored argillaceous shale or argillite, a middle member that is predominantly a limestone of varied composition but locally a good-quality coarse-grained dolomite, and an upper member of earthy or fine-grained quartzose limestone containing dark argillaceous layers. The thickness of the formation varies with the locality and ranges from perhaps 150 feet or less in Lancaster County to about 500 feet in York County. The Kinzers is in the same general areas as the Vintage, and analyses of samples from York County, thought to be from the Kinzers formation, indicate the presence of some high-purity dolomite. (Miller, 1934; Stose and Ljungstedt, 1931; Stose and Stose, 1944)

Ledger dolomite.—The Ledger dolomite, equivalent to the upper part of the Tomstown, generally is a white to light-gray pure dolomite, which may be mottled with dark-gray or blue spots. It is thick bedded or massive, coarse grained, and in some places may merge laterally into high-calcium marble. The thickness of the Ledger is about 1,000 feet, and in many places, although poorly exposed, its presence is marked by the deep-red granular soil into which the rock weathers. The distribution is approximately the same as the Vintage dolomite and Kinzers formation, and in Chester, Lancaster, and Montgomery Counties good-quality rock has been quarried for use in magnesian products. (Miller, 1934; Stose and Ljungstedt, 1931; Stose and Stose, 1944)

Conococheague limestone.—The Conococheague limestone, of Late Cambrian age, generally is a dense massive or thick-bedded dolomite or dolomitic limestone, usually some shade of blue or light gray. This formation, having a maximum thickness of about 1,500 feet, comprises a series of alternating beds of limestone and dolomite and in places contains black chert layers, shaly beds, wavy argillaceous partings, and thin sandstone layers. Differential weathering causes the more highly

magnesian beds to turn whiter than the others and the sandy layers to stand out in relief, thus imparting a banded appearance that is an excellent, almost diagnostic, criterion for recognizing the formation. The Conococheague and the underlying Elbrook limestones are combined as a single unit on the State geologic map and are shown in parts of Franklin, Cumberland, Lebanon, Berks, Lehigh, Northampton, Lancaster, Chester, Montgomery, and Bucks Counties. Although the rock from this formation commonly is moderately high in silica, some dolomite of good quality has been quarried in the areas south of Centerville, Lancaster County, and east of Bethlehem, Northampton County. (Miller, 1934; Miller and others, 1939; Stose and Ljungstedt, 1931)

Beekmantown limestone.—The Beekmantown limestone, of Early Ordovician age, ranges in composition from rather pure limestone to dolomite. The rock is dark blue to light blue and gray, and in many places the limestones and dolomites occur as alternating beds. The silica content of the rock is quite varied. The thickness of the formation approximates 1,000 feet. The Beekmantown occurs in the same general areas as the Conococheague, usually north and northwest of the older formation. It occurs also in Dauphin County, where the Conococheague apparently is absent. The silica content of the rock commonly is higher than desirable for most purposes, but good-quality dolomite has been quarried from the Beekmantown(?) in Blair and Montgomery Counties. (Gray, 1951; Miller, 1934; Miller and others, 1939; Stose and Ljungstedt, 1931)

Conestoga limestone.—The Conestoga limestone, of Cambrian(?) and Early Ordovician age, is principally a blue argillaceous limestone. It is thick bedded, blue to light gray in the lower part and thin bedded and dark blue in the upper part. In many localities a coarse limestone conglomerate or breccia occurs at the base of the formation. The Conestoga forms a broad belt through central Lancaster County, with narrower extensions through York and Adams Counties to the southwest and Chester and Montgomery Counties to the east. Chemical analyses show that good-quality dolomite occurs a short distance southeast of Columbia, Lancaster County. (Miller, 1934; Stose and Ljungstedt, 1931)

Dolomite quarries and occurrences in Pennsylvania

<i>County</i>	<i>Locality</i>	<i>Formation</i>	<i>Reference</i>
Adams	Bittinger area; quarries	Ledger dolomite	Miller, 1934.
Bedford	Colerain Township	Rocks of Cambrian and Ordovician age.	Do.
Berks	Bechtelsville area; quarries	Tomstown dolomite(?)	Do.
	Clayton; quarry	do	Do.
	Dale; quarry	do	Do.
	Earlville; quarries	do	Do.
	Greshville; quarry	do	Do.
	Rabbit Hill	do	Do.
	Reading; quarry	Conococheague lime- stone(?)	Do.
	Seisholtzville; quarries 2 miles east.	Tomstown dolomite(?)	Do.

<i>County</i>	<i>Locality</i>	<i>Formation</i>	<i>Reference</i>
<i>Blair</i>	Birmingham; quarries.....	Beekmantown lime- stone(?)	Miller, 1934.
	Roaring Spring; quarries south....	.....do.....	Do.
<i>Becka</i>	Durham area; quarries.....	Tomstown dolomite and Conococheague limestone.	Do.
	New Hope; quarries 2.5 miles north- west.	Beekmantown lime- stone.	Do.
<i>Chester</i>	Cedar Hollow; quarries.....	Ledger dolomite(?)	Do.
	Mill Lane area; quarries.....	.....do.....	Do.
	Planebrook; quarry.....	.....do.....	Do.
<i>Franklin</i>	Mont Alto; quarry.....	Tomstown dolomite...	Do.
	a. quarry 1.5 miles northeast....	.....do.....	Do.
<i>Fulton</i>	McConnellsburg area; quarries....	Beekmantown lime- stone.	Do.
<i>Huntingdon</i>	Spruce Creek; quarries.....	Beekmantown (Nit- tany) limestone.	Do.
	Union Furnace; quarries.....	Beekmantown (Belle- fonte) limestone.	Do.
<i>Lancaster</i>	Billmeyer; quarries.....	Ledger dolomite.....	Do.
	Centerville; 0.5 to 0.75 mile south.	Conococheague lime- stone.	Do.
	Chickies area; quarries.....	Ledger dolomite.....	Do.
	Columbia; quarry 1 mile southeast.	Conestoga limestone..	Do.
	Glenmanor; quarry.....	Ledger dolomite(?)	Do.
	Lancaster area; quarries.....	Ledger dolomite.....	Do.
	Landis Valley; quarry 0.5 mile southeast.	.....do.....	Do.
	Leaman Place—Kinsers area; quarries.	Vintage dolomite.....	Do.
	Newtown; quarry 0.75 mile south- west.	Ledger dolomite.....	Do.
	Rowena P. O.....	Ledger dolomite(?)	Do.
<i>Lehigh</i>	Alburtis area: a. quarry 0.75 mile northwest....	Beekmantown lime- stone.	Do.
	b. quarry 1 mile north.....	Allentown limestone..	Do.
	Allentown; quarries.....	Allentown limestone..	Do.
	Catasauqua; quarry across river....	Beekmantown lime- stone.	Do.
	East Allentown; quarries.....	Tomstown dolomite...	Do.
	Friedensville; quarry 0.5 mile north	Beekmantown lime- stone.	Do.
	Ormrod; quarry 0.5 mile south....	Beekmantown lime- stone(?).	Do.
	Trexlertown; quarry 1.5 miles northeast.	Beekmantown lime- stone.	Do.
	Whitehall; quarry 0.75 mile west..	.....do.....	Do.
<i>Mifflin</i>	Reedsville.....	(?)	Do.
<i>Montgomery</i>	Bridgeport-Shainline area; quarries.	Ledger dolomite.....	Do.
	Fitswatertown; quarries.....	.....do.....	Do.
	Mogee; quarries.....	.....do.....	Do.
	Plymouth Meeting area; quarries..	Beekmantown lime- stone(?)	Do.
	Port Kennedy; quarry.....	Ledger dolomite(?)	Do.
	a. quarry 1.5 miles southwest....	Ledger dolomite.....	Do.
	Williams; quarries.....	Beekmantown lime- stone(?)	Do.
<i>Northampton</i>	Bethlehem area; quarries.....	Conococheague lime- stone.	Do.
	a. quarry 2 miles east.....	.....do.....	Do.
	Bingen; quarry.....	.....do.....	Miller and others, 1939.
	Brodhead; quarry.....	Beekmantown lime- stone.	Do.

Dolomite quarries and occurrences in Pennsylvania—Continued

County	Locality	Formation	Reference	
Northampton— Continued	Easton; quarry.....	Conococheague lime- stone.	Miller, 1934.	
	Freemansburg; quarry.....	do.....	Do.	
	Hellertown; quarry 0.5 mile south- west.	do.....	Do.	
	Island Park; quarry.....	Tomstown dolomite..	Do.	
	Portland; quarry.....	Allentown and Beek- mantown limestones.	Miller and others. 1939.	
	Redington; quarry.....	Tomstown dolomite..	Miller, 1934.	
	York.....	Menges Mills; quarries.....	(?).....	Do.
		Saginaw; quarry.....	(?).....	Do.
		Thomasville; quarries.....	Kinzers formation(?)..	Do.
		York area:		
a. 1 mile west.....		do.....	Do.	
b. 2 miles west.....		do.....	Do.	
c. quarry 1.5 miles southwest... d. 2 miles north.....		do..... do.....	Do. Do.	

SOUTH CAROLINA

Little information is available regarding dolomite in South Carolina. A few chemical analyses indicate the presence of dolomite in Cherokee, Laurens, and Oconee Counties, but practically nothing is known of the extent or average composition of the deposits. The best known dolomite deposits occur near Gaffney, Cherokee County, in the Gaffney marble; the occurrence northwest of Laurens, Laurens County, has not been assigned to a stratigraphic unit; and the occurrences northwest of Walhalla, Oconee County, have been assigned, at least tentatively, to the Brevard schist. It appears doubtful that any commercial deposits of high-purity dolomite occur in South Carolina. (Keith and Sterrett, 1931; Sloan, 1908)

Brevard schist.—Details concerning the dolomite in the Brevard schist sequence, in Oconee County, are lacking. Two analyses of samples from the area northwest of Walhalla, from "limestone" beds 3.5 and 6.5 feet thick associated with slates, are of dolomite, but they show that the silica content is higher than desirable. (Sloan, 1908)

Gaffney marble.—The Gaffney marble, of Cambrian age, is predominantly a fine-grained bluish-gray to white crystalline rock having a banded appearance due to impurities. The whiter beds generally overlie the gray ones and are more highly magnesian. The thickness of the Gaffney, usually poorly exposed, probably does not exceed about 120 feet. These outcrops extend in interrupted belts from the quarries south

Dolomite quarries and occurrences in South Carolina

[Data from Sloan, 1908]

County	Locality	Formation
Cherokee.....	Gaffney; quarries 1 mile south.....	Gaffney marble.
Laurens.....	Laurens; quarry 7.5 miles northwest.....	(?).
Oconee.....	Walhalla area:	
	a. 8.1 miles northwest.....	Brevard schist(?).
	b. 9 miles northwest.....	Do.

of Gaffney northeastward through Blacksburg and into North Carolina. One analysis from a quarry south of Gaffney shows that the rock is a dolomite moderately high in silica. (Keith and Sterrett, 1931; Sloan, 1908)

SOUTH DAKOTA

Dolomite and dolomitic limestone are restricted to the Black Hills region of South Dakota in parts of Custer, Fall River, Lawrence, Meade, and Pennington Counties. The dolomites occur in three formations ranging in age from Late Ordovician to Permian(?) and include the Whitewood dolomite and Pahasapa and Minnekahta limestones. These formations are predominantly limestones that locally contain high concentrations of magnesium carbonate. Of these formations, the Pahasapa limestone and, possibly, the dolomitic sands derived from it probably are the most important potential sources of dolomite. Few analyses and no details concerning the extent of these localized deposits are available, but it is possible that large quantities of dolomite are in this region. (Darton and Paige, 1925; Rothrock, 1944)

Whitewood dolomite.—The Whitewood dolomite, of Late Ordovician age, is predominantly a hard massive limestone, generally buff colored or pinkish with pale-brownish spots. The maximum thickness is about 80 feet. The formation is principally in the northern part of the Black Hills uplift. One analysis of a sample from near Deadwood, Lawrence County, shows a dolomitic limestone. (Darton and Paige, 1925; Rothrock, 1944)

Pahasapa limestone.—The Pahasapa limestone, of Mississippian age, is a fine-grained massively bedded limestone, ranging from pale buff to light gray or white. It ranges in thickness from 300 to more than 600 feet, and it is reported to be highly magnesian locally. No analyses of the rock are available. Large deposits of dolomitic sand derived from the weathering of the Pahasapa limestone are reported at several places in the Black Hills, and an analysis from the largest deposit, near Piedmont, southwestern Meade County, shows a magnesium carbonate content approaching that of a pure dolomite. The Pahasapa is the most widespread of the formations mentioned. It surrounds almost completely the central part of the Black Hills uplift and forms the greater part of the broad limestone plateau on the west side of the uplift. Commercial deposits of dolomite may be available in the Pahasapa limestone. (Bryson and others, 1947; Darton and Paige, 1925; Rothrock, 1944)

Minnekahta limestone.—The Minnekahta limestone, of Permian(?) age, is a light-gray rock, usually exhibiting a pinkish or purplish tinge. Its average thickness is less than 40 feet, and it varies from limestone to dolomite. An analysis of a sample from near Hot Springs, Fall River County, shows that the rock is dolomite. The Minnekahta crops out in a narrow band that forms the front of the limestone ridge around the

periphery of the Black Hills uplift. (Bryson and others, 1947; Darton and Paige, 1925; Rothrock, 1944)

Dolomite and dolomitic limestone occurrences in South Dakota

County	Locality	Formation	Reference
Fall River.....	Hot Springs.....	Minnekahta limestone.	Darton and Paige, 1925.
Lawrence.....	Deadwood.....	Whitewood dolomite..	Rothrock, 1944.
Meade.....	Piedmont.....	Pahasapa limestone...	Do.

TENNESSEE

Dolomites and dolomitic limestones of Cambrian and Ordovician age extend through eastern Tennessee in several northeast-trending belts that are northward continuations of those that begin in northeastern Alabama and northwestern Georgia. The dolomitic strata include the Shady dolomite, of Cambrian age, and the Knox group, of Cambrian and Ordovician age. The Knox group consists of the Copper Ridge, Chepultepec, and Longview dolomites, the Kingsport limestone, and the Mascot dolomite. It is doubtful that the rocks of the Longview, Kingsport, and Mascot should be considered as sources of high-grade dolomite, owing to the general abundance of sand, chert, and limestone in the formations, although chemical analyses show that moderately siliceous dolomite may occur locally. (Oder, 1934; Pond, 1933; Rodgers, 1948, 1953; Rodgers and Kent, 1948)

Shady dolomite.—The Shady dolomite, of Early Cambrian age, is characteristically a dolomite with some interbedded limestone. The dolomite is white to light gray or blue gray, massive to well laminated, fine grained, and locally contains a little chert. The rock not uncommonly exhibits alternating bands or ribbons of light and dark dolomite. The thickness of the formation averages about 1,000 feet. Outcrops are not common, but they occur in parts of Blount, Monroe, Carter, Johnson, Cocke, Unicoi, and Washington Counties. Chemical analyses of samples from Johnson and Washington Counties indicate that the rock generally is moderately siliceous but that some good-quality dolomite occurs locally, notably near Wills Station and Erwin. (Pond, 1933; Rodgers, 1948, 1953; Secrist, 1924)

Knox group.—The Knox group comprises a thick series of limestones and dolomites, with dolomites predominating, in several northeast-trending belts that extend through the Great Valley region of eastern Tennessee. The group averages about 2,600 to 3,000 feet in thickness, and the rocks generally are dolomitic in the northwest side of the Valley, becoming progressively more calcareous toward the southeast. The Knox contains five formations where completely subdivided, but only the two lower formations—the Copper Ridge and Chepultepec dolomites—probably have any possibilities as sources of high-grade dolomite. (Josiah

Bridge, 1952, oral communication; Rodgers, 1953; Rodgers and Kent, 1948)

Copper Ridge dolomite.—The Copper Ridge dolomite, of Late Cambrian age, consists of two members. The lower one is massive knotty dark-gray asphaltic crystalline dolomite interbedded with light-gray silty dolomite and marked at the base by a striking black and white coarse-grained dolomitic oolite. The upper member is light-gray slightly silty dolomite having an exceptionally coarse oolite at the base, arenaceous zones at many levels, and marked near the top by prominent oolitic chert layers and beds of sandstone. The average total thickness of the Copper Ridge is about 900 feet, approximately 225 feet of which is represented by the upper member. Chemical analyses representing parts of the so-called lower Knox or of the Copper Ridge dolomite show that the rock generally is a siliceous dolomite or, more frequently, a siliceous dolomitic limestone. A moderately siliceous dolomite has been quarried at Norris Dam, Anderson County. (Oder, 1934; Benjamin Gildersleeve, 1946, written communication; Rodgers, 1953; Rodgers and Kent, 1948)

Chepultepec dolomite.—The overlying Chepultepec dolomite, of Ordovician age, also contains two rather distinct members. The lower member is generally sandy and is composed of interbedded sandstone or chert and light-gray to dark-gray fine-grained dolomite, which is in places silty or cherty. The upper member is predominantly dolomite, light gray to

Dolomite quarries and occurrences in Tennessee

County	Locality	Formation	Reference
Anderson	Norris Dam; quarry	Copper Ridge dolomite.	Benjamin Gildersleeve, 1946, written communication.
	Offрутt	do.	Do.
Hamilton	Chattanooga; quarry	Knox group	Do.
	Soddy; 2.5 miles east	do.	Do.
Jefferson	Dandridge; quarry	do.	Do.
Johnson	Doe Valley	Shady dolomite	Jenkins, 1916.
	Mountain City area:		
	a. 3.5 miles north	do.	Do.
	b. 4 miles north	do.	Do.
	c. east of Wills Station; quarry	do.	Do.
	d. Silver Lake	do.	Do.
	Roane Creek Valley; quarries 0.75 miles east of Shouns, near Forge Creek.	do.	Do.
	Shady Valley; quarry 0.5 mile northwest.	do.	Do.
Roane	Harriman; quarry	Knox group	Benjamin Gildersleeve, 1946, written communication.
	Kingston	do.	Do.
Union	Maynardsville; quarry 8.5 miles northwest.	(?)	Do.
	Sharpe Chapel	Knox group	Do.
Washington	Bumpass Cove; quarries northwest of Erwin.	Shady dolomite	Rodgers, 1948.
	Erwin; 0.5 mile northwest	do.	Do.

medium gray, although some dark beds are present, usually fine grained, and contains some silty layers. The average thickness of the formation is about 700 feet. Details concerning the chemical composition of the rock are not available. (Oder, 1934; Rodgers, 1953; Rodgers and Kent, 1948)

TEXAS

The dolomites of Texas range in age from Precambrian to Cretaceous and occur in several areas. The more important localities include the Central Mineral region, north-central Texas, and parts of western Texas. The formations that appear, from chemical analyses, to contain the best quality dolomite are the Tanyard, Gorman, and Honeycut formations of the Ellenburger group in the central region. These formations and the dolomite facies in them attain considerable thickness in certain areas. Other dolomites that may have commercial possibilities include lenses in the Packsaddle schist and, perhaps, parts of the Wilberns and Rustler formations. Dolomite belonging to the lower part of the Ellenburger group has been quarried as a source of magnesium. (Barnes and others, 1947; Cloud and Barnes, 1946; Warren, 1943)

Packsaddle schist.—Dolomite marble, associated with magnesitic dolomite and magnesite, occurs as lenses in the Packsaddle schist, of Precambrian age. The dolomite is coarsely crystalline, predominantly white, although in places cream colored, and contains varied amounts of silicate minerals. In the vicinity of Llano, Llano County, parts of one lens, more than one-half mile long and about 200 feet thick, have been quarried as a source of terrazzo chips. Chemical analyses of samples from several of these lenses in the same general area show the presence of good-quality dolomite, but they probably are not representative of the average composition of each lens. (Barnes and others, 1947)

Wilberns formation.—The Pedernales dolomite member of the Wilberns formation, of Late Cambrian age, is a fine- to medium-grained, medium- or brownish-gray dolomite, which contains some interstitial glauconite and is locally cherty. The member ranges in thickness from 70 to 150 feet. The Pedernales crops out in Blanco, Burnet, and Llano Counties. Analyses of samples of the dolomite from north of Johnson City, Blanco County, show the rock to range from high-silica to excellent-quality dolomite. (Barnes and others, 1947; Cloud and Barnes, 1946)

Ellenburger group.—The Ellenburger group, of Early Ordovician age, consists of three formations—the Tanyard, Gorman, and Honeycut—each of which contains some dolomite. In general, the Ellenburger group crops out around the periphery of the Llano uplift in Mason, Llano, and adjoining Counties.

Tanyard formation.—The Tanyard formation comprises the Threadgill member and the overlying Staendebach member. The Threadgill, 91

to 313 feet thick, is principally limestone in its western area of outcrop, grading eastward into dolomite. Locally there are abrupt lateral transitions between the two rock types. The dolomite is medium to coarse grained, locally cherty, and usually some shade of gray. Analyses of samples from the dolomitic parts of the Threadgill show that it ranges from dolomitic limestone to excellent-quality dolomite. It has been quarried in the vicinity of Sudduth, Burnet County, as a source of magnesium. The Staendebach member, ranging in thickness from 205 to 456 feet, also contains limestone and dolomite, the dolomites predominating in the western and southeastern areas of outcrop. This member generally is similar in appearance to the Threadgill; it has been distinguished from the Threadgill largely on its higher chert content and finer grained texture. Owing to its cherty nature, the silica content of the dolomite is somewhat higher than in the Threadgill member. (Barnes and others, 1947; Cloud and Barnes, 1946)

Gorman formation.—The Gorman formation is from 426 to 498 feet thick, where typically formed. The lower part generally is dolomitic, the upper calcitic with local interbedded dolomites. The lower dolomitic zone is as much as 230 feet thick. It consists of very fine grained to microgranular dolomite with yellowish, pinkish, and brownish hues predominating. A group of analyses of the dolomite in the vicinity of Johnson City, Blanco County, shows the rock to have a high average silica content. (Barnes and others, 1947; Cloud and Barnes, 1946)

Honeycut formation.—The overlying Honeycut formation is roughly divisible into three units. The lower unit is an alternation of limestone and dolomite, the middle predominantly microgranular dolomite, and the upper part is predominantly limestone. The maximum total thickness of the formation is 678 feet. The formation closely resembles the Gorman except that the light- or yellowish-gray colors generally are not so vivid. Silica sand is common in the lower 50 feet of the Honeycut formation, and siliceous limestone and chert also are common. Chemical analyses indicate that it is slightly low in magnesium carbonate and high in silica. (Barnes and others, 1947; Cloud and Barnes, 1946)

El Paso, Montoya, and Fusselman limestones.—Dolomites of Ordovician age occur in the Franklin Mountains of El Paso County. These include the El Paso and Montoya limestones which, together with the Fusselman limestone, of Silurian age, comprise the summit of the range. These limestones have been described in the section on New Mexico (p. 437), and the same lithologic character prevails in the Franklin Mountains.

Alibates dolomite lentil.—The Alibates dolomite lentil of the Quartermaster formation, of Permian age, occurs in Potter and Moore Counties, where it forms bluffs along the Canadian River. It is a massive white crystalline dolomite, usually separated by a shale member into 2 layers,

2 and 9 feet thick. Although the dolomite is locally cherty, analyses show that some good-quality dolomite is present. (Warren, 1943)

Other formations.—Certain of the limestones of Permian age in the northwestern part of Culberson County contain dolomite locally. A few of the available chemical analyses of the Victorio Peak member of the Bone Spring limestone, the Goat Seep limestone, and the Carlsbad limestone are of high-grade dolomite. The extent of the rock of this quality is not known, however. (King, 1948)

Thin, widespread dolomites of Permian age, similar in occurrence and character to those of western Oklahoma, occur in north-central Texas.

Dolomite quarries and occurrences in Texas

County	Locality	Formation	Reference	
Blanco	Johnson City area:			
	a. 1 mile north	Wilberns and Tanyard formations.	Cloud and Barnes, 1946.	
	b. 5 miles east	Gorman and Honeycut formations.	Do.	
	c. quarry 7.7 miles west	Wilberns formation	Barnes and others, 1947.	
	Round Mountain area:			
	a. 0.6 mile west	do	Do.	
	b. 7 miles northwest	do	Do.	
	Burnet	Burnet; quarry	(?)	Do.
		a. 1 mile south	Rocks of Cambrian(?) age.	Do.
		Fairland; 5 miles east	Ellenburger group	Do.
Kingland; 7 miles northeast		Rocks of Precambrian age.	Do.	
Lake Victor; quarry, 2.5 miles north-northwest.		Gorman formation	Do.	
Marble Falls; 2 miles south		Honeycut formation	Do.	
Sudduth; quarry		Tanyard formation	Do.	
a. quarries 1 mile north		do	Do.	
b. quarry 3.1 miles south		Gorman formation	Do.	
Culberson		Pine Springs area:		
	a. 4 miles west	Bone Spring limestone.	King, 1948.	
	b. 6 miles west	Goat Seep limestone	Do.	
Gillespie	Fredericksburg area:			
	a. 7 miles east	Tanyard formation	Barnes and others, 1947.	
	b. 9.5 miles east	Wilberns formation	Do.	
Llano	Llano; quarry	Packsaddle schist	Do.	
	a. quarry 3 miles southeast	do	Do.	
	b. 1.5 miles south-southeast	do	Do.	
	c. quarry 6 miles southeast	do	Do.	
	Oxford area:			
	a. 2 miles southeast	do	Do.	
	b. 3 miles southeast	do	Do.	
	Moore	Fritch; 3.5 miles southwest	Alibates dolomite lentil	Warren, 1943.
		Potter	Fritch; 8 miles southwest	Do.
	San Saba	Cherokee area:		
a. 3 miles northeast		Tanyard formation	Cloud and Barnes, 1946.	
b. 9 miles east-northeast		Ellenburger group	Do.	
Harkeyville; 14 miles south-southwest.		Gorman formation	Barnes and others, 1947.	
Richland Springs; 2 miles south-southwest.		Ellenburger group	Do.	

They are interbedded with gypsum, shale, sandstone, and limestone. They include the Merkel dolomite member of the Choza formation, and dolomites of the Blaine gypsum and the Dog Creek formation. Chemical analyses are not available, but, if the dolomites are similar in composition to those in western Oklahoma, they probably are not suitable as sources of high-grade rock. The Edwards limestone (Cretaceous) in the central region, although dolomitic in part, probably need not be considered as a source of dolomite, because of the thick beds of pure limestone with which the thin dolomites are interbedded. (Barnes and others, 1947; Cloud and Barnes, 1946; Weissenborn and Stenzel, 1948)

UTAH

Dolomites and dolomitic limestones occur principally in the western half of Utah in the Paleozoic sections exposed in the Wasatch Range and in the fault-block mountains of the Basin and Range province. They range in age from Cambrian to Mississippian, and they are best known in the mineralized areas such as the Tintic, Gold Hill, Oquirrh Mountain, San Francisco, and Cottonwood-American Fork mining districts. The formations have not been correlated between districts; this has resulted in different nomenclature for equivalent geologic sections in each of the districts. The dolomite deposits in these mining districts, those in Cache and Rich Counties, and several examined briefly during the war probably represent most, if not all, the more important deposits in Utah. In most of the areas, little information is available regarding the chemical composition, uniformity, or extent of the dolomite.

Dolomites and dolomitic limestones of Cambrian age have been described at many localities in northern and western Utah. These formations include the Langston, Blacksmith, Nounan, and St. Charles limestones in the Bear River Range and in the Blacksmith Fork area, eastern Cache County; the Bluebird and Cole Canyon dolomites, and the Opex formation in the Tintic district, Juab County; the Maxfield limestone in the Cottonwood-American Fork area, Salt Lake County; the Young Peak dolomite, Trippe limestone, Lamb dolomite, and Hicks formation in the Gold Hill district, western Tooele County; the lower part of the Grampian limestone in the San Francisco district, Beaver County; and the Lynch dolomite of the Oquirrh Mountain district (Stockton-Fairfield quadrangles), near Ophir, Tooele County. (Butler, 1913; Calkins and Butler, 1943; Deiss, 1938; Eardley, 1944; Gilluly, 1932; Lindgren and Loughlin, 1919; Nolan, 1935; Richardson, 1913)

Dolomites and dolomitic limestones of Ordovician age occur also in most of the districts mentioned. These formations include the Ajax limestone and Bluebell dolomite in the Tintic district; the Chokecherry dolomite in the Gold Hill district; the Fish Haven dolomite in the Gold Hill district, Blacksmith Fork area, Bear River Range, and probably

south of Laketown, Rich County; and the upper part of the Grampian limestone in the San Francisco district. (Butler, 1913; Nolan, 1935; Lindgren and Loughlin, 1919)

Younger dolomitic rocks include the Laketown dolomite, of Silurian age, in the Gold Hill district, in the area south of Laketown, Rich County, and in the Bear River Range; the Red Warrior limestone, of Silurian(?) and Devonian(?) age, in the San Francisco district; the Sevy and Simonson dolomites, and the Guilmette formation, of Devonian age, in the Gold Hill district; the Jefferson dolomite (Devonian) in the Bear River Range, in eastern Rich County, in the Oquirrh Mountain area, and in the Cottonwood-American Fork district; the Gardner dolomite of Mississippian age, in the Tintic district; and the Madison and Deseret limestones, of Mississippian age, in the Cottonwood-American Fork district. (Butler, 1913; Calkins and Butler, 1943; Gilluly, 1932; Lindgren and Loughlin, 1919; Nolan, 1935; Richardson, 1913)

Of these 27 formations that have been described as dolomite or dolomitic limestone, 7 are shown to be dolomites by available chemical analyses. Brief descriptions of these rocks follow.

Grampian limestone.—The Grampian limestone, of Cambrian(?) and Ordovician age, occurs in the San Francisco district of north-central Beaver County. It consists of about 4,000 feet of heavy-bedded blue dolomitic limestone, with some beds of light-gray limestone and thin shales. Locally the dolomitic limestone is siliceous or cherty, but one analysis shows a "gray dolomitic limestone" that is high-grade dolomite. (Butler, 1913)

Blacksmith limestone.—The Blacksmith limestone, of Middle Cambrian age, consists predominantly of white-gray to dull steel-gray fine- to medium-grained thick-bedded dolomite and interbedded dolomitic limestone. Many of the beds are banded and contain irregular markings of white dolomite. In the Blacksmith Fork area, Cache County, the formation is about 450 feet thick. Chemical analyses of the rock in this locality show that it is a dolomite of excellent quality locally. (Deiss, 1938)

Nounan limestone.—The Nounan limestone, of Middle Cambrian age, consists of light-gray and some dark-gray, medium-grained, thin- and thick-bedded dolomite with about 150 feet of white-gray limestone in the lower part. The formation is about 900 feet thick in the Blacksmith Fork area. One chemical analysis of the rock shows that the sample is a dolomite of excellent quality. (Deiss, 1938)

Bluebird dolomite.—The Bluebird dolomite, of Middle Cambrian age, is typically a dark bluish-gray fine-grained dolomite that is characteristically spangled with short white calcite rods. The thickness of the formation is 175 to 200 feet, and it occurs in several places in the Tintic district, southwestern Utah County and northeastern Juab County. One

chemical analysis shows the presence of good-quality dolomite in the area west of Eureka. (Lindgren and Loughlin, 1919)

Cole Canyon dolomite.—The Cole Canyon dolomite, of Middle Cambrian age, overlies the Bluebird and consists of a series of alternating beds, from 10 to 25 feet thick, with nearly white and dark-gray weathered surfaces. The white-weathering beds are medium gray to light gray on the fresh surface; some are dense and finely banded; others are very finely crystalline. The dense variety usually is rather argillaceous, and the finely crystalline variety reportedly is nearly pure dolomite. A few thin shale beds occur in the series. One chemical analysis shows that the darker beds are highly dolomitic, siliceous limestone. No analyses of the light-colored beds are available. (Lindgren and Loughlin, 1919)

Lynch dolomite.—The Lynch dolomite, of Middle(?) and Late Cambrian age, comprises the dolomite sequence of Cambrian age in the Oquirrh Mountains of eastern Tooele County. The formation consists of thick-bedded light-gray dolomite, the lower part of which contains layers of the distinctive dolomite that is characteristic of the Bluebird dolomite. A few limestone beds also occur in the lower part of the formation. The thickness of the Lynch ranges from 825 to 1,000 feet. One analysis of a sample from near Ophir shows that the dolomite has a moderately high silica content. (Gilluly, 1932)

Jefferson dolomite.—The Jefferson dolomite, of Devonian age, occurs in the Bear River Range, west of Garden City, where it is chiefly a massive fine-grained dark dolomite weathering with a brownish tint. The thickness of the formation here is 1,200 feet. A partial analysis shows more than 19 percent magnesia, but nothing is known of the purity

Dolomite quarries and occurrences in Utah

County	Locality	Formation	Reference
Beaver	San Francisco district	Grampian limestone	Butler, 1913.
Cache	Hyrum; 12 miles east, at Blacksmith Fork Canyon.	Blacksmith limestone	
	a. 1 mile west of above	Nounan limestone	
	Logan; east in Logan Canyon	(?)	
Juab	Eureka; west	Bluebird and Cole Canyon dolomites.	
	Leamington; 5 miles east	Rocks of Cambrian(?) or Mississippian(?) age.	
Rich	Laketown; 3 miles south	Laketown and Jefferson dolomites.	Richardson, 1913.
Salt Lake	Alta	Maxfield limestone and Jefferson dolomite(?)	Calkins and Butler, 1943.
Tooele	Dolomite; quarry	Jefferson dolomite(?)	
	Ophir	Lynch and Jefferson(?) dolomites.	
Utah	Santaquin area:		
	a. quarry 3 miles west	Rocks of Devonian(?) or Mississippian(?) age.	
	b. quarry 2 miles northwest	Bluebird(?) and Cole Canyon dolomites.	

of the rock. The formation tentatively identified as Jefferson in the Cottonwood-American Fork area is a thick-bedded light- to medium-gray dolomite, in places faintly mottled. Near the base and near the middle of the formation are layers of thin-bedded impure dolomite with a little shale and chert. It is about 150 feet thick. No analyses of the rock are available. Chemical analyses of rock from formations identified as Jefferson(?) near Ophir and Dolomite, Tooele County, show the presence of some good-quality dolomite. (Calkins and Butler, 1943; Richardson, 1913)

VERMONT

The dolomitic formations in Vermont are mainly in the partly metamorphosed Cambrian and Ordovician sedimentary rocks that occur in north-south belts in the extreme western part of the State. These rocks are west of the Green Mountain front where, in northern Vermont, they occupy the eastern part of the Champlain lowland. The belts extend from the Canadian border southward through Addison County, the narrow Rutland Valley east of the Taconic Range, and into northwestern Massachusetts. The geology is complicated by thrusting, folding, varied degrees of metamorphism, and lack of uniformity in the formations both vertically and laterally. Metamorphism has been greater in the southern part of the belt, and the areas around Proctor, Rutland, and Danby, all in Rutland County, contain the high-grade marbles of the State. The dolomitic formations worthy of mention include the Dunham dolomite of Clark (1934), Winooski marble, Rutland dolomite, the Danby formation, and the Clarendon Springs dolomite. Owing to the lack of uniformity and the siliceous nature of the rocks, the extent of high-purity dolomite seems to be small. Commercial deposits of dolomite are not known. (Cady, 1945; Prindle and Knopf, 1932)

Dunham dolomite of Clark (1934).—The Dunham dolomite of Clark (1934), of Early Cambrian age, is mainly a buff-weathering siliceous dolomite with well-rounded sand grains irregularly distributed throughout. North of Malletts Bay, the upper part of the Dunham is represented by the Mallett member of Cady (1945), typically a smooth gray sandy dolomite interbedded with buff dolomite having siliceous partings and several flaggy, shaly dolomite beds. The thickness of the Dunham varies from 1,700 to 2,000 feet. Commercial quantities of high-grade dolomite may be present in the Dunham(?) in the gorge of Mill River just east of Clarendon, Rutland County. (Cady, 1945)

Winooski marble.—The Winooski marble, of Early Cambrian age, is separated from the underlying Dunham dolomite of Clark (1934) by the Monkton quartzite in west-central Vermont. The rock typically is pink on the fresh surface, becoming less so upward in the section and finally becoming buff or gray. The beds, usually less than 1 foot thick, are

separated by siliceous partings. The thickness of the formation ranges from about 100 feet on Snake Mountain, west-central Addison County, to at least 800 feet in the vicinity of Pittsford, north-central Rutland County. No analyses of the dolomites in the formation are available. (Cady, 1945; Keith, 1932)

Rutland dolomite.—The Rutland dolomite, of Early Cambrian age, is composed of a series of heavy-bedded snow-white dolomite; gray dolomite; thin-bedded white grayish-streaked dolomite interbedded with quartzose and shaly layers; and dark-blue to gray carbonaceous dolomite, the uppermost beds of which contain considerable chert. The formation occupies the southern part of the narrow valley bounded on the east by the Green Mountains and on the west by the Taconic Range. South of Pittsford, where the Monkton quartzite apparently pinches out, the Rutland probably is the formational equivalent of the Dunham-Monkton-Winooski sequence. (Cady, 1945; Prindle and Knopf, 1932)

Danby formation.—The lower part of the Danby formation, of Late Cambrian age, contains protruding beds of sandstone separated by beds of dolomite 10 to 12 feet thick. The thickness of this unit is from 400 to 800 feet. The upper part of the Danby is represented by the Wallingford member of Cady (1945). It consists of dark iron-gray magnesian limestone, somewhat siliceous, with some of the beds approaching the composition of sandstone. The thickness of the Wallingford is about 300 to 400 feet where typically formed. (Cady, 1945)

Clarendon Springs dolomite.—The Clarendon Springs dolomite, which overlies the Wallingford member of Cady (1945), is a rather uniform massive smooth-weathering gray dolomite, containing numerous geodes and knots of white quartz. Locally, near the top of the formation, sandy beds and masses of black chert occur. The thickness of the formation varies from 50 to 200 feet and generally is greater to the west. (Cady, 1945; Keith, 1932)

Other formations.—At many places in the eastern part of the State, lenses of calcite marble or dolomite marble occur in the schists and gneisses. These masses are not continuous nor are they uniform in composition from one locality to another. An analysis of a sample from one such lens, near Plymouth, Windsor County, shows that the rock is excellent-quality dolomite, but this is by no means typical of the dolomite in these areas. (Dale, 1915)

Dolomite quarries in Vermont

[Data from Dale, 1915]

County	Locality	Formation
Windsor.....	Plymouth; quarry.....	(?)

VIRGINIA

Dolomite and dolomitic limestone in Virginia are in the Cambrian and Ordovician carbonate rocks that occur in nearly continuous northeast-

trending belts throughout the length of the Appalachian Valley. The principal dolomitic formations include the Tomstown and Shady dolomites, Honaker dolomite, Elbrook limestone, Copper Ridge dolomite, and the Beekmantown dolomite. Northwest of Clinch Mountain in Tazewell, Russell, and Scott Counties, the Copper Ridge and Beekmantown, together with the intervening Chepultepec dolomite, constitute the Knox dolomite. Dolomite also occurs locally in the Rome formation. The Honaker appears to be the most promising source of high-purity dolomite, and large quantities are reported to occur in Tazewell and Russell Counties. (Cooper, 1944; Cooper, 1945; Edmundson, 1945)

Tomstown and Shady dolomites.—Dolomite of Early Cambrian age is represented by the Tomstown dolomite northeast of Roanoke and by its equivalent, the Shady dolomite, to the southwest. The upper part of the Tomstown in the northern part of the Valley is predominantly a light- to dark-gray fine- to medium-grained dolomite or dolomitic limestone; some of the beds are cream colored and saccharoidal. The lithologic character of the lower part is less well known. The formation generally is poorly exposed but crops out in parts of Clarke, Rockbridge, and Botetourt Counties. The thickness ranges from 1,000 to 1,500 feet in Clarke County, where large reserves of dolomite may be present along the Shenandoah River. Chemical analyses of samples from near Berryville and Shepherd Ford show the presence of good- to excellent-quality dolomite. The Shady dolomite occupies parts of the Valley southwest of Roanoke. The formation has been divided into three members: the Patterson limestone member, Austinville dolomite member of Butts (1940), and Ivanhoe limestone member. The Austinville is probably the only member that need be considered a potential source of dolomite. It is composed principally of gray and white, usually saccharoidal dolomite, containing some thin limestone beds. Its thickness ranges from perhaps 600 to more than 1,000 feet. It is exposed south of Roanoke and in a nearly continuous belt extending from near Allisonia, Pulaski County, southwestward to Damascus, Washington County. (Butts, 1933; Butts, 1940; Currier, 1935; Edmundson, 1945)

Rome formation.—The Rome formation, of Early Cambrian age, is principally a series of shales, siltstones, and limy sandstones, but it contains local beds of dolomite, one of which is prominent in the vicinity of Roanoke. In this area the dolomite member consists of medium-bedded fine-grained dark-gray dolomite, ranging in thickness from 135 to 155 feet. Chemical analyses show that the rock normally averages about 5 percent impurities, but that some of the dolomite, notably at Roanoke, is of excellent quality. (Cooper, 1944)

Honaker dolomite.—The Honaker dolomite, of Middle Cambrian age, is predominantly dark bluish-gray dolomite, usually finely granular but in places medium grained. The formation contains a few intercalated

zones of brecciated dolomite and, locally, minor quantities of limestone and shale. The Honaker crops out in narrow, nearly continuous, northeast-trending belts that extend through parts of Giles, Bland, Tazewell, Russell, Wythe, Smyth, Scott, and Washington Counties. South of Castlewood, Russell County, the dolomite gives way to an equally thick succession of dark bluish-gray limestone (Maryville limestone). The maximum thickness of the Honaker is about 1,400 feet. Analyses show that deposits of excellent-quality rock are in Russell and Tazewell Counties. Large reserves of high-grade dolomite are reported between Carterton and Honaker, Russell County, in the southern part of Cedar Bluff, and in the vicinity of Wittens Mills, both in Tazewell County. (Butts, 1933; Butts, 1940; Cooper, 1944; Cooper, 1945)

Elbrook limestone.—The Elbrook limestone, of Middle and Late Cambrian age, is in part equivalent to the Honaker dolomite and somewhat resembles the Honaker. The formation generally is composed of limestone and dolomitic limestone, but it contains zones of medium- to dark-gray dolomite. Locally these zones attain a thickness of more than 80 feet. Dolomite of good quality is restricted principally to zones of this type. The Elbrook occurs on either side of the Shenandoah Valley and in counties to the south, which include Botetourt, Roanoke, and Montgomery. In Wythe County the formation crops out in a belt that extends from the vicinity of Pierce Mill northeastward nearly to Bertha. The dolomites of the Elbrook have been sampled in several counties, and chemical analyses show them to range from high-silica rock in Augusta County to good-quality rock in Rockingham and Shenandoah Counties. (Butts, 1940; Cooper, 1944; Currier, 1935; Edmundson, 1945)

Copper Ridge dolomite.—The Copper Ridge dolomite, of Late Cambrian age, is equivalent to the lower part of the Knox dolomite northwest of Clinch Mountain and to the Conococheague limestone in the southeastern half of the Valley. It is separated from the underlying Honaker by the Nolichucky shale. The rock is coarser in texture than the Honaker, prevailingly medium gray but varying from bed to bed. The thickness of the formation is from 1,400 to 1,650 feet in Giles County and is probably somewhat less in Clinch Valley. Locally sandstone beds as much as 70 feet in thickness, along with thin layers of chert and silty material, occur. The Copper Ridge crops out in discontinuous belts paralleling the trend of the Valley in parts of Roanoke, Botetourt, Montgomery, Giles, Bland, Wythe, Smyth, Tazewell, Russell, Washington, Scott, and Lee Counties. Chemical analyses show that some of the rock is dolomite but that the content of silica generally is greater than 3 percent. (Butts, 1933; Butts, 1940; Cooper, 1944; Cooper, 1945)

Beekmantown dolomite.—The Beekmantown dolomite, of Early Ordovician age, is predominantly rather fine-grained pearl-gray very compact

dolomite containing beds of light- or bluish-gray limestone associated with, or grading into, beds of coarse-grained dolomite. Chert, occurring as masses or beds, is common locally. The thickness of the formation is varied, attaining a maximum of about 3,000 feet. It occurs in belts that extend through nearly every county in the Appalachian Valley.

Dolomite quarries and occurrences in Virginia

<i>County</i>	<i>Locality</i>	<i>Formation</i>	<i>Reference</i>
Augusta.....	Churchville; 1.25 miles northwest..	Elbrook limestone.....	Edmundson, 1945.
	Staunton; quarry.....	Beekmantown dolomite.	Do.
Clarke.....	a. 6 miles west.....	Elbrook limestone(?)..	Do.
	Berryville area:		
	a. 3.5 miles southeast.....	Tomstown dolomite...	Do.
Frederick.....	b. 5.5 miles east, or 1.5 miles northeast of Castleman Ferry.	.....do.....	Do.
	Shepherd Ford; 1.5 miles west.....	.....do.....	Do.
Giles.....	Meadow Mills.....	Beekmantown dolomite.	Do.
	Winchester; 0.5 mile south.....	.....do.....	Do.
	Berton; along Norfolk & Western Railroad.	Copper Ridge dolomite	Cooper, 1944.
	Bluff City; east, along Norfolk & Western Railroad.	Beekmantown dolomite.	Do.
	Eggleston.....	Copper Ridge dolomite.	Do.
	Goodwins Ferry; along Virginian Railroad.	Copper Ridge and Honaker dolomites.	Do.
	Klots; quarry 0.5 mile northwest..	Beekmantown dolomite.	Do.
Montgomery....	Narrows; northwest, along Norfolk & Western Railroad.	Copper Ridge dolomite	Do.
	Pembroke; quarry 1 mile southwest	Beekmantown dolomite.	Do.
	Montgomery Station.....	Copper Ridge dolomite	Do.
Page.....	Radford-Peppers Ferry area.....	.....do.....	Do.
	Yellow Sulphur; 0.75 mile southeast.	.....do.....	Do.
Roanoke.....	"along Shenandoah River".....	.....(?).....	Basler, 1909.
Rockingham....	Roanoke; quarry.....	Rome formation.....	Cooper, 1944.
	Rockydale; quarry.....	.....do.....	Do.
Russell.....	Cootes Store area:		
	a. quarry 1.5 miles northeast...	Elbrook limestone.....	Edmundson, 1945.
	b. 3 miles southwest.....	.....do.....	Do.
	Mount Clinton; 2.5 miles north	.....do.....	Do.
Scott.....	Mount Crawford.....	Beekmantown dolomite.	Do.
	Boody; quarry.....	Honaker dolomite.....	Cooper, 1945.
	Cleveland area:		
	a. 1 mile southeast.....	.....do.....	Do.
	b. 2 miles southeast.....	.....do.....	Do.
	Honaker; 1 mile southeast.....	.....do.....	Do.
	Hubbard Junction; along Norfolk & Western Railroad.	Knox dolomite.....	Do.
Shenandoah....	Clinchport.....	Honaker dolomite(?)..	Basler, 1909.
	Glenita; quarry.....	Knox dolomite.....	Cooper, 1945.
	Spears Ferry; north.....	.....do.....	Do.
Smyth.....	Mount Clifton; 3.5 miles southwest.	Elbrook limestone....	Edmundson, 1945.
	Strausburg; 2 miles northeast.....	Beekmantown dolomite.	Do.
	Glade Spring; northeast, at Lyon Gap.	Knox dolomite.....	Basler, 1909.

County	Locality	Formation	Reference
Tazewell.....	Cedar Bluff; south, along State Route 4. Wittens Mills area:	Honaker and Knox dolomites.	Cooper, 1945.
	a. north.....	Honaker dolomite.....	Do.
	b. south.....	Knox dolomite.....	Do.
Wythe.....	Wytheville.....	Beekmantown dolomite.	Basler, 1909.

Northeast of Augusta County the formation becomes more dominantly limestone. The Beekmantown has been quarried at many places, and chemical analyses show that the silica content generally is higher than desirable for a high-grade dolomite. (Butts, 1933; Cooper, 1944; Cooper, 1945; Edmundson, 1945)

WASHINGTON

Commercially important dolomite deposits are restricted to northeastern Washington in Okanogan, Stevens, Pend Oreille, and Lincoln Counties. The deposits in Stevens County have been the most important. The dolomitic formations include the Stensgar dolomite of Weaver (1920), which is the host rock of the magnesite deposits, the Old Dominion limestone of Weaver (1920), the Metaline and Northport limestones (perhaps equivalent in age), and the limestone at Riverside. Each of these formations varies in composition, ranging from dolomitic limestone to high-purity dolomite. Much of the dolomite is readily accessible for quarrying, and the Northport limestone northeast of Marble, Stevens County, has been used as the raw material for the production of magnesium at the ferrosilicon reduction plant at Spokane, Spokane County.

Stensgar dolomite of Weaver (1920).—The Stensgar dolomite of Weaver (1920), of Paleozoic(?) age, is predominantly thin-bedded bluish- or pinkish-gray dolomitic limestone and dolomite, which weathers to medium gray or light buff. It generally is fine grained to dense, but in places it is a medium- to coarse-grained marble. Chert, as lenses or nodules, is not uncommon. The formation ranges from 300 to 350 feet in thickness, except in its northern exposures where the apparent thickness is more than 700 feet, due probably to repetition of beds by faulting. The Stensgar crops out in many places in a belt that extends from northwest of Chewelah, Stevens County, southwestward nearly to the Spokane River. Chemical analyses indicate that the impurity content is too high for the rock to be used as a source of high-purity dolomite. (Bennett, 1941; Weaver, 1920)

Old Dominion limestone of Weaver (1920).—The Old Dominion limestone of Weaver (1920), of Paleozoic(?) age, varies considerably in composition and appearance locally. It ranges from nearly pure limestone to white or black coarse-crystalline dolomite that is commonly strongly marbled and somewhat thick bedded. Near Dunn Mountain, north-

west of Addy, Stevens County, dolomite and dolomitic limestone comprise all but the lower 400 feet of the 4,000-foot section. The formation crops out intermittently in a belt extending from Addy northwestward for 5 miles along the Stranger Creek Valley, and then northeastward, passing east of Colville, to a point north of Aladdin. The dolomite in the Miles area, northern Lincoln County, probably is part of the Old Dominion. Chemical analyses show the presence of some excellent-quality dolomite, perhaps in large quantities, in the Addy district, the Miles area, and east of Colville, although the impurity content may be moderately high, generally. (Bennett, 1944; Valentine, 1949; Weaver, 1920)

Northport limestone.—The Northport limestone, of Middle Cambrian(?) age, generally is massive, fine-grained although in places rather coarse, usually white limestone, which is dolomitic locally. The dolomite phase northeast of Marble is light gray and has large areas that are banded or mottled dark gray or black, hard, dense, and finely crystalline. In this area the exposed dolomite section is about 725 feet in thickness. The formation crops out in a belt along the Columbia River Valley, from the mouth of Kettle River northeastward nearly to the Canadian border. Analyses of the dolomite from the Marble deposit show that the rock ranges from dolomitic limestone to excellent-quality dolomite. The rock has been quarried from this deposit for use as magnesium ore at the Spokane plant. (Deiss, 1955)

Metaline limestone.—The Metaline limestone, of Middle Cambrian age, has a total thickness of about 3,000 feet, of which approximately 1,200 feet is dolomitic. The base of the dolomitic zone is 1,200 feet above the base of the formation. The upper part of the dolomite generally is fine grained, massive, cream colored to gray, and contains a few intercalated layers of black dolomite with white spots. Lower in the section the texture becomes coarser, and the black layers become more plentiful until, near the base of the dolomite, they constitute perhaps 50 percent of the section. The black layers are usually 5 feet or less in thickness. The general lithologic character of the dolomite is similar to that of the dolomite in the Northport, which is one of the bases for the tentative correlation of the two formations. The Metaline is exposed only in northern Pend Oreille County, extending from Ione northward through the Pend Oreille Valley to the Canadian border. Chemical analyses of the dolomite in the vicinity of Crescent Lake (sec. 12, T. 40 N., R. 44 E.) show that both the light- and dark-colored rock is excellent-quality dolomite. (Park and Cannon, 1943)

Unnamed limestone.—Dolomite and dolomitic limestone of Carboniferous(?) or Triassic age occur in the unnamed unit at Riverside, Okanogan County. These rocks are part of a 10,000-foot succession of limestones, dolomites, and subordinate amounts of shaly limestone, sandstone, conglomerate, quartzite, and siltstone. The main body of dolomite

appears to form a stratigraphic zone more than 500 feet thick at or near the base of the series. This rock is mostly white to gray, fine grained, and thick bedded to massive; it contains a few thin interbeds of buff dolomitic limestone. Sand or silt and thin veinlets of quartz occur locally. The dolomitic zone extends from sec. 36, T. 35 N., R. 26 E., southwest of Riverside, northwestward to sec. 3 of the same township. It becomes less evident toward the north, due to folding, faulting, and lateral gradation into sandy and limy phases. Chemical analyses show that the rock ranges from dolomitic limestone to excellent-quality dolomite. (Bennett, 1944)

Dolomite quarries and occurrences in Washington

<i>County</i>	<i>Locality</i>	<i>Formation</i>	<i>Reference</i>
Lincoln.....	Miles area.....	Old Dominion limestone(?) of Weaver (1920).	Bennett, 1944.
Okanogan.....	Riverside area:		
	a. 0.5 mile southwest.....	Unnamed limestone at Riverside.	Do.
	b. quarry 1.25 miles west.....	do.....	Do.
	c. 1.5 miles west.....	do.....	Do.
	d. 2.5 miles northwest.....	do.....	Do.
	e. 2 miles northwest.....	do.....	Do.
	f. north of "e".....	do.....	Do.
	g. 3 miles northwest.....	do.....	Do.
	h. 1.25 miles northwest.....	do.....	Do.
	i. 3.5 miles northwest.....	do.....	Do.
	j. 4.5 miles southwest.....	do.....	Do.
Pend Oreille....	Metaline Falls; 11 miles north.....	Metaline limestone...	Park and Cannon, 1943.
Stevens.....	Addy area:		
	a. just northwest.....	Old Dominion limestone of Weaver (1920).	Bennett, 1944.
	b. quarry 11 miles west-northwest, at Dunn Mt.	do.....	Do.
	Chewelah; 4.7 miles northwest....	Stensgar dolomite of Weaver (1920).	Do.
	Colville area:		
	a. quarry 4.6 miles east.....	Old Dominion limestone of Weaver (1920).	Do.
	b. just west of "a".....	do.....	Do.
	c. 6.5 miles east.....	do.....	Do.
	Fruitland; 5 miles east.....	Stensgar dolomite(?) of Weaver (1920).	Do.
	Marble; quarry 2 miles northeast...	Northport limestone...	Deiss, 1955.
	Valley area:		
	a. quarry 1 mile southwest.....	(?).....	Stebbins, 1951.
	b. 7 miles west.....	Old Dominion limestone(?) of Weaver (1920).	Bennett, 1944.
	c. quarry 10.6 miles west.....	Stensgar dolomite of Weaver (1920).	Do.
	d. 14.5 miles west.....	do.....	Do.

WEST VIRGINIA

Dolomite and dolomitic limestone are restricted principally to relatively small areas in the extreme southeastern and northeastern parts of

West Virginia. They occur chiefly in the Cambrian sequence of carbonate rocks, although dolomitic limestone and some dolomite occur also in the Lower Ordovician strata. The dolomitic formations include the Tomstown dolomite, perhaps parts of the Waynesboro formation, the Beekmantown limestone, and lower Stones River limestone (Murfreesboro limestone). Quarrying has been rather extensive in the areas around Millville, Jefferson County, and Martinsburg, Berkeley County. The Tomstown probably contains the only deposits of high-grade dolomite that might be of commercial interest. (Grimsley, 1916; McCue and others, 1939)

Tomstown dolomite.—The Tomstown dolomite, of Cambrian age, is composed mainly of light blue-gray to white fine-grained splintery dolomite, medium bedded and weathering to dark brown. The formation contains some zones of limestone and shale. The total thickness of the formation is about 1,000 feet. The only exposures of the Tomstown are in eastern Jefferson County, and a belt of high-purity dolomite has been quarried about 1 mile east of Bakerton. Chemical analyses show that the dolomite in this area, although low in impurities, contains more than 0.5 percent sodium and potassium oxides, the presence of which might prove deleterious in some processes. It is probable that most of the rock quarried in the Millville area and assigned questionably to the Waynesboro formation is of Tomstown age. The division between the two formations is not clearly marked in this area. (Grimsley, 1916; McCue and others, 1939; Stose and Ljungstedt, 1932)

Copper Ridge dolomite and Beekmantown limestone.—Dolomitic limestone of Cambrian and Ordovician age is present in southeastern and northeastern West Virginia. In the southeast, in Mercer and Monroe Counties, they are represented by a lower division—the Copper Ridge dolomite—consisting of medium- to massive-bedded dolomitic limestone that weathers into red soil containing small blocks of sandstone; and an upper division—the Beekmantown limestone—consisting of irregularly to massively bedded gray and light-blue magnesian limestones that are dense, hard, and commonly cherty. This sequence in adjoining parts of Virginia contains dolomite that is moderately high in silica, but analyses of the rock in Mercer and Monroe Counties do not show the presence of rock of comparable quality. (McCue and others, 1939)

Conococheague and Chepultepec limestones and Nittany and Bellefonte dolomites.—In northeastern West Virginia the series described above is represented by the Conococheague and Chepultepec limestones and the Nittany and Bellefonte dolomites (Beekmantown). The group comprises a succession of massive dark-blue limestones with dark dolomitic lenses; fairly pure dove-colored to dark-gray limestone; medium- to thick-bedded fine-grained light-blue to dove-colored magnesian limestone; and dark-blue to bluish-gray thick-bedded magnesian limestone

and dolomite. The aggregate thickness varies, and its maximum is about 3,600 feet. These rocks crop out in two broad, northeast-trending belts in western Jefferson County and eastern Berkeley County. The Beekmantown has been quarried in the Martinsburg area, and chemical analyses show that it contains some dolomite that is moderately high in silica. (Grimsley, 1916; McCue and others, 1939)

Murfreesboro limestone.—The Murfreesboro limestone probably is not a potential source of dolomite, although it has been quarried in the Martinsburg area, and analyses show that it contains some high-silica dolomite. (Grimsley, 1916)

Dolomite quarries and occurrences in West Virginia

County	Locality	Formation	Reference
Berkeley.....	Martinsburg area; quarries.....	Beekmantown lime- stone and Murfrees- boro limestone.	Grimsley, 1916.
Jefferson.....	Bakerton; quarry 1 mile east.....	Tomstown dolomite....	Grimsley, 1916; McCue and others, 1939.
	Millville area; quarries.....	Waynesboro forma- tion(?).	Do.
	a. 2.25 miles north.....	.....do.....	Do.
	b. south of town.....	.....do.....	Do.
	c. quarry 1 mile east.....	.....(?).....	Do.

WISCONSIN

Dolomitic rocks, ranging from dolomitic sandstones, shales, and limestones to high-purity dolomites, are in the formations of Ordovician and Silurian ages that crop out in an arcuate pattern extending through western, southern, and eastern Wisconsin. The most important source of high-purity dolomite probably is the Niagara dolomite, which crops out along the eastern margin of the State. Older rocks, including those of the Prairie du Chien and Black River groups and the Galena dolomite, vary considerably in composition, are generally impure, and probably contain only very local areas in which high-grade rock is to be found. Owing to overburden, exposures of the dolomites are mostly confined to hill and ridge tops, bluffs, and stream valleys. Quarrying has been relatively widespread, and most of the rock has been used locally. Because the dolomitic rocks are not uniform chemically, only those quarries represented by chemical analyses showing dolomite are located on the map (pl. 2). (Steidtmann, 1924)

Prairie du Chien group.—The Prairie du Chien group or Lower Magnesian of former usage, of Early Ordovician age, consists of the Oneota dolomite, a series of shaly, sandy, cherty, gray and light-buff dolomitic limestones; the New Richmond sandstone; and the Shakopee dolomite, which is locally cherty and resembles the lower part of the Oneota. The thickness of the group is about 250 feet where typically formed. These formations crop out in a U-shaped area that extends from Polk County on the west, southward through the southern counties

then northeastward to the west of Lake Winnebago and Green Bay, into Marinette County. Chemical analyses indicate that the dolomites of the group generally contain excessive silica, although some good-quality rock occurs in Grant, Outagamie, and Polk Counties. (Behre and others, 1948; Kay, 1935; Powers, 1935; Steidtmann, 1924)

Black River group.—The Black River group, which includes the Platteville and Decorah formations, overlies the Prairie du Chien group and is separated from it by the St. Peter sandstone. The Platteville is principally a limestone and shale series, but one member, the Pecitonica dolomite, is composed of heavy ledges of rather dense blue or gray buff-weathering dolomite. Pecitonica attains a maximum thickness of about 30 feet. The overlying Decorah formation also is a shale and limestone series. Its uppermost member, the Ion dolomite member, is composed of gray argillaceous dolomite. These formations, together with the overlying Galena dolomite, are shown on the State geologic map as a single unit present in the following counties: Grant, Iowa, Lafayette, Green, Rock, Walworth, Dane, Jefferson, Waukesha, Columbia, Dodge, Washington, Green Lake, Fond du Lac, Winnebago, Calumet, Outagamie, Brown, Oconto, and Marinette. They occur also in the western part of the State in parts of Pierce and St. Croix Counties. Generally these formations are too high in impurities, usually silica, to be considered a source of high-purity dolomite. (Behre and others, 1948; Kay, 1935; Steidtmann, 1924)

Galena dolomite.—The Galena dolomite, of Middle Ordovician age, consists of three members: the Prosser cherty member, the Stewartville massive member, and the Dubuque shaly member. The Prosser generally makes up the bulk of the formation; it is a white to gray-buff rather fine-textured cherty dolomitic limestone or dolomite, the thickness of which is commonly more than 125 feet. The Stewartville is composed of buff or gray, mottled thick-bedded dolomite or dolomitic limestone, usually about 80 feet thick. The Dubuque member is composed of thin-bedded ledges of yellow or light-buff dolomite with interbedded shale. Analyses indicate that the Galena generally also is too high in impurities to be considered a source of high-purity dolomite, except possibly in the Watertown area, Dodge County. (Bays and Raasch, 1935; Behre and others, 1948; Kay, 1935; Steidtmann, 1924)

Niagara dolomite.—The Niagara dolomite, of Silurian age, is the most promising source of high-purity dolomite in Wisconsin. The rocks generally are light colored, fine to coarse grained, thin to thick bedded, sometimes cherty, and attain a maximum thickness of about 700 feet. The formation occurs along the eastern margin of the State in a broad belt that extends from the Illinois border northward to the tip of the peninsula separating Green Bay from Lake Michigan. Analyses show that the silica content of the dolomite varies from more than 8 percent

to 0.24 percent. It seems likely that large quantities of high-purity dolomite are available from the Niagara. (Behre and others, 1948; Steidtmann, 1924; Sutton, 1935)

Waubakee dolomite.—The Waubakee dolomite (Silurian), which crops out only in Milwaukee and Ozaukee Counties, contains some good-quality dolomite in the vicinity of Wauwatosa, although the impurity content generally is moderately high. The rock is a hard brittle thin-bedded dolomite and usually light gray. The formation is 10 to 12 feet thick. (Steidtmann, 1924; Sutton, 1935)

Dolomite quarries and occurrences in Wisconsin

[Data from Steidtmann, 1924]

County	Locality	Formation
Brown	Duck Creek; quarries	Galena dolomite.
Buffalo	Alma; quarries	Prairie du Chien group, (the Lower Magnesian dolomite of former usage).
	Cochrane; quarry	Do.
	Fountain City; quarries	Do.
Calumet	Brillion; quarries	Niagara dolomite.
	Hayton; quarries	Do.
	High Cliff; quarries	Do.
Columbia	Columbus; quarries	Galena dolomite.
Crawford	DeSoto; quarry	Prairie du Chien group (the Lower Magnesian dolomite of former usage).
	Soldiers Grove; quarry	Do.
Dane	Oregon; quarry 2 miles west	Galena dolomite.
	Sun Prairie; quarries 2 miles northeast	Do.
Dodge	Iron Ridge; quarry	Niagara dolomite.
	a. quarry 3 miles north	Do.
	Knowles	Do.
	Mayville; 2 miles southwest	Do.
	Nasbro; quarry	Do.
	Richwood; quarry	Galena dolomite.
	Watertown area; quarries	Do.
Door	Sturgeon Bay area; quarries	Niagara dolomite.
Fond du Lac	Hamilton; quarries	Do.
	Marblehead; quarries	Do.
	Oakfield; quarry	Do.
	Ripon; quarry	Prairie du Chien group (the Lower Magnesian dolomite of former usage) and Black River group.
	Taycheedah	Niagara dolomite.
Grant	Woodman	Prairie du Chien group (the Lower Magnesian dolomite of former usage).
Jefferson	Fort Atkinson; quarry 2 miles southeast	Black River group and Galena dolomite.
	Jefferson; quarry 4 miles northwest	Do.
	Milford; quarry 3 miles northwest	Do.
Kewaunee	Kewaunee; quarry 2 miles west	Niagara dolomite.
La Crosse	La Crosse; quarries 2 miles east	Prairie du Chien group (the Lower Magnesian dolomite of former usage).
Lafayette	Darlington; quarry	Black River group and Galena dolomite.
Manitowoc	Cooperstown; quarry	Niagara dolomite.
	Grimms; quarry	Do.
	Quarry; quarry	Do.
Milwaukee	Milwaukee	Waubakee dolomite.
	Wauwatosa; quarry	Waubakee and Niagara dolomites.
Oconto	Oconto Falls	Prairie du Chien group (the Lower Magnesian dolomite of former usage).
		Do.
Outagamie	Black Creek; quarry 3 miles north	Do.
	Kaukauna; quarries	Black River group and Galena dolomite.

Dolomite quarries and occurrences in Wisconsin—Continued

<i>County</i>	<i>Locality</i>	<i>Formation</i>
Osaukee.....	Druecker; quarry.....	Niagara dolomite.
	Fredonia; 1 mile west.....	Waubakee dolomite.
	Grafton; quarry.....	Niagara dolomite.
Pierce.....	Elmwood; quarry 2 miles west.....	Prairie du Chien group (the Lower Mag- nesian dolomite of former usage).
	Prescott; 6 miles north.....	Do.
Polk.....	Little Falls.....	Do.
Racine.....	Ives; quarry.....	Niagara dolomite.
	Racine; quarries.....	Do.
Rock.....	Beloit; quarry.....	Black River group and Galena dolomite.
	a. quarry 1 mile west.....	Do.
	b. quarry 2 miles north.....	Do.
	Janesville; quarry.....	Do.
St. Croix.....	New Richmond; quarry 2 miles north- west.....	Prairie du Chien group (the Lower Mag- nesian dolomite of former usage).
	Wilson; quarry.....	Do.
Sauk.....	Sauk City area:	
	a. 5 miles west.....	Do.
	b. 5 miles southwest.....	Do.
Sheboygan.....	Sheboygan; quarries 1 mile northwest....	Niagara dolomite.
	Sheboygan Falls; quarry.....	Do.
Walworth.....	Whitewater; quarry.....	Black River group and Galena dolomite.
Waukesha.....	Delafield; quarry 1 mile southeast.....	Niagara dolomite.
	Genesee; quarry 1 mile northeast.....	Do.
	Lannon; quarry.....	Do.
	Pewaukee; quarry.....	Do.
	a. quarry 2 miles northeast.....	Do.
	Templeton; quarry.....	Do.
Winnebago.....	Waukesha; quarry 0.5 mile north.....	Do.
	Mehasha; quarry 2 miles northwest.....	Black River group and Galena dolomite.
	Oshkosh; quarry.....	Do.

WYOMING

Dolomites and dolomitic limestones occur rather extensively in the Absaroka, Wind River, Owl Creek, and Bighorn Mountains of west-central and north-central Wyoming and, to a lesser extent, in the south-eastern part of the State. Potentially the most important of the dolomitic formations is the Bighorn dolomite, although it is not everywhere a high-purity dolomite. Other dolomitic formations include those of the Whalen group, the Darby formation, the Madison limestone, and the Amsden, Casper, and Phosphoria formations. These formations locally contain dolomite, but deposits of high-grade rock in commercial quantities probably are few. The Wyoming dolomites have not been exploited; many of the deposits are somewhat inaccessible and rather distant from marketing areas.

Whalen group.—The dolomites of the Whalen group, of Precambrian age, are maroon and salmon pink to tan gray, fine grained, thick bedded, and siliceous and contain bands and nodules of chert in the lower part. In the upper part the colors change to dull gray and white, and the dolomite becomes extremely siliceous. These rocks have been studied in the vicinity of Guernsey, Platte County. South and southwest of Guernsey, dolomite, which might belong to the same group, occurs as isolated masses, probably roof pendants, partly surrounded by granite. The dolomite is coarsely crystalline, nearly pure white, thick and thin

bedded, and contains abundant tremolite. Chemical analyses of these dolomites are not available, but they are reported to range from slightly magnesian limestone to nearly pure dolomite. (Clabaugh and others, 1946; Osterwald and Osterwald, 1952)

Bighorn dolomite.—The Bighorn dolomite (Ordovician), most widespread of the dolomites, is generally tan-gray or gray, usually strongly mottled, fine- to medium-grained, very thick bedded dolomite which weathers to extremely rough surfaces. The formation generally is from 150 to 300 feet thick, but thins rapidly to the south and, consequently, is not present in the mountains in southern Wyoming. The most favorable areas of the Bighorn are in the Absaroka, Wind River, and Owl Creek Mountains. Chemical analyses indicate that the Bighorn is consistently a dolomite of moderately good quality, except in the Bighorn Mountains where limestone and shale are more common than elsewhere. One deposit of the Bighorn dolomite at the south end of Wind River Canyon, about 20 miles south of Thermopolis, appears to be a promising source of excellent-quality dolomite. (Blackwelder, 1913; Osterwald and Osterwald, 1952)

Darby formation.—The Darby formation, of Devonian age, is principally a drab-brown impure dolomitic limestone, locally containing dolomite, with interbedded limestones and shale partings. The formation is chiefly in the Wind River Mountains. Although some good-quality dolomite has been examined in the area west of Lander, Fremont County, the Darby probably does not contain commercially important deposits of high-purity dolomite. (Osterwald and Osterwald, 1952)

Madison limestone.—The Madison limestone, of Mississippian age, comprises a limestone series, but in certain areas it contains dolomite and dolomitic limestone, either as a basal zone or as lenticular masses. In Wind River Canyon south of Thermopolis, in the area southwest of Lander, and in Shoshone Canyon west of Cody, the basal zone of dolomite and dolomitic limestone is present in thicknesses as much as 200 feet. In the area south of Thermopolis the dolomites so closely resemble the underlying Bighorn dolomite that separation of the two formations is extremely difficult. Chemical analyses indicate that the dolomites of the Madison are, in a few localities, of good quality. (Osterwald and Osterwald, 1952)

Casper formation.—The Casper formation, of late Pennsylvanian and Permian(?) age, equivalent in part to the Amsden, is principally in the Laramie Range and the Casper Mountains, southeastern Wyoming. It is predominantly an alternating series of limestones, dolomites, sandstones, and shales. The dolomite beds in the lower part of the formation are usually 5 to 20 feet thick in the vicinity of Casper, and analyses indicate the presence of some good-quality dolomite in this area. In the Laramie Mountains, however, the dolomites probably are too siliceous

and calcareous to be considered high-purity dolomite. (Osterwald and Osterwald, 1952)

Phosphoria formation.—The Phosphoria formation, of Permian age, contains beds of dolomite that range from 3 to 16 feet in thickness separated by considerably thicker units of cherty limestones, sandstones, and sandy shales. The formation is in the Bell Springs and Casper Mountain areas, the Owl Creek Mountains, the Lovell area, and west of Cody. Chemical analyses show that the rock is a dolomitic limestone generally, although some good-quality dolomite occurs south of Thermopolis and west of Cody. (Osterwald and Osterwald, 1952)

Dolomite occurrences in Wyoming

[Except for Casper area (a), data taken from Osterwald and Osterwald, 1952]

County	Locality	Formation
Albany	Boaler; 12 miles east	Precambrian rocks.
	Centennial; 8 miles northwest	Ranger marble of Blackwelder.
	Laramie; 8.5 miles northeast, in Rogers Canyon.	Casper formation.
Bighorn	Greybull; 21.8 miles east, in Shell Creek Canyon.	Bighorn dolomite.
	Lovell area:	
	a. 5 miles east	Phosphoria formation.
Carbon	b. 29 miles by road east	Bighorn dolomite.
	Bell Springs	Phosphoria formation.
Fremont	a. 2 miles south	Amsden formation.
	Bull Lake	Bighorn dolomite.
	Lander area:	
Hot Springs	a. 10 miles southwest	Bighorn dolomite, Darby formation, and Madison limestone.
	b. 36 miles by road west, at Bald Mountain.	Bighorn dolomite and Darby formation.
	Thermopolis; 20 miles south	Bighorn dolomite and Madison limestone.
	Thermopolis area:	
Johnson	a. 5 miles south	Phosphoria formation.
	b. 6 miles south	Embar formation.
	c. 9 miles south	Bighorn dolomite.
	d. 13 miles south	Do.
Johnson	Buffalo; 7.5 miles west	Do.
Natrona	Casper area:	
	a. 5.5 miles south	Madison limestone.
	b. 10.5 miles southwest, in Jackson Canyon.	Casper formation and Madison limestone.
	c. 40 miles southwest, in Platte Canyon.	Casper formation.
Park	Cody area:	
	a. 4 miles west	Bighorn dolomite.
	b. 7 miles west	Phosphoria formation.
	c. west of Shoshone Dam	Bighorn dolomite.
Platte	Guernsey; 2 miles northeast	Whalen group.
	Wheatland area:	
	a. 18.5 miles by road west	Do.
	b. 16.3 miles southwest	Do.
	c. 26 miles southwest	Do.
d. 30.4 miles by road southwest	Do.	
Sheridan	Dayton; 14 miles by road west	Bighorn dolomite.
Sublette	Gros Ventre Range:	
	a. Lebarge Mountain	Do.
	b. Shoal Creek, upper falls	(?).
Teton	Teton Mountains; Leigh Creek	(?).

RESERVES

Very little information has been published regarding reserves of dolomite in the United States. For this and many other reasons any attempt to record an estimate of reserves in a report of this type would be futile. To determine with any degree of accuracy the reserves of even a single deposit would require systematic drilling and sampling, because of the common vertical and lateral variations in chemical composition of the rocks. This fact must be kept in mind by a potential quarry operator in his appraisal of an otherwise desirable quarry site.

A figure representing tons of available dolomite in the United States would be astronomical. A tonnage estimate of inferred "ore" in 125 deposits in California, Wyoming, Idaho, Montana, Washington, Arizona, Nevada, and Utah, examined by the U. S. Geological Survey during World War II, amounts to nearly 2 billion tons of dolomite available by open-pit quarrying (Deiss, 1945, p. 1). This figure by no means represents the total quantity of dolomite available in these States, but it conveys some idea of the order of magnitude of reserves. For all practical purposes, it appears that reserves of dolomite in the United States are unlimited, or at least inexhaustible for any foreseeable time.

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- 18 Beyer, S. W., and Wright, H. F., 1914, Road and concrete materials in Iowa: Iowa Geol. Survey, v. 24, p. 33-685

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- 26 Branner, G. C., 1941, Limestones of northern Arkansas: Little Rock, Ark., Ark. Geol. Survey, 24 p.

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Gives general descriptions, including measured sections, of the rocks, structure, and geologic history of the Appalachian Valley, also descriptions of the Shady and Tomstown dolomites, the Honaker and Elbrook dolomites, the Conococheague limestone, and the Copper Ridge dolomite. No analyses are included. For geologic map, see Butts, 1933.
- 39 Butts, Charles, and Gildersleeve, Benjamin, 1948, Geology and mineral resources of the Paleozoic area in northwest Georgia: Ga. Geol. Survey Bull. 54, 176 p.

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Presents the geology, including stratigraphic descriptions and structure, and a summary of the mineral resources of northwest Georgia. Includes for each mineral a description, along with sections on uses, location of deposits, character of the ores, and remarks on production and reserves. Section on limestone and dolomite (p. 127-137) includes brief descriptions of the formations and 21 analyses. Maps, scale 1 inch = about 4 miles, show the geology of the area and mine, quarry, and prospect locations.

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Gives detailed description of the stratigraphy, structure, geologic history, and mineral resources of the Tyrone quadrangle, covering parts of Blaire, Centre, and Huntingdon Counties, and a few analyses. Report is of interest principally for the descriptions of the formations equivalent to the Elbrook, Conococheague, Beekmantown, and Conestoga limestones. Includes geologic map, scale 1 inch = 1 mile.

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- 44 Callaghan, Eugene, and Vitaliano, C. J., 1948, Magnesite and brucite deposits at Gabbs, Nye County, Nev.: U. S. Geol. Survey open-file rept., 18 p.

Brief preliminary report of the deposits at Gabbs summarizes the general geology and occurrence of the ore deposits, including their distribution, composition, origin, and reserves of magnesite. Reserves are estimated to be 27 million tons of magnesite containing less than 5 percent CaO. Includes 10 analyses of magnesite, brucite, and associated rocks, and geologic map, scale 1 inch = 100 feet, showing distribution of dolomite, magnesian dolomite, magnesite, hydro-magnesite, and brucite.

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- includes brief description of beds of the Anamosa stage, which overlies the Leclaire.
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Gives brief summary of improvements in pellet mixing, metal handling, and metallurgical recovery and of production from September 1942 to July 1944 at the Basic Magnesium, Inc., plant near Las Vegas, Nev.
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Summarizes general statistics of the stone industry in 1951. Data on dolomite generally included with those on limestone. Table (p. 1205) shows quantity of dolomite used for basic magnesium carbonate, refractory uses, dead-burned dolomite, and paper mills during 1950-51.
- 48 Chelf, Carl, 1941, Magnesite mining in Llano County, Tex.: *Tex. Univ. Bur. Econ. Geology, Min. Res. Survey Circ.* 40, 6 p.
Describes briefly the magnesite deposits at the Texas Mines and Meramec mines, southeast of Llano. Includes cross-section sketches of the mines, brief summary of the uses and consumption of magnesite, and a bibliography.
- 49 Clabaugh, S. E., and others, 1946, Construction materials and nonmetallic mineral resources of Wyoming: *U. S. Geol. Survey Missouri Basin Studies Map* 9.
Map, scale 1:500,000, shows areal distribution of rock types and nonmetallic minerals, including dolomite and dolomitic limestone. Brief explanatory text lists the following units as containing dolomite: Whelan, Bighorn, Madison, Darby, Amsden, Casper, and "Permian." States that "reserves are almost inexhaustible."
- 50 Clark, T. H., 1934, Structure and Stratigraphy of southern Quebec: *Geol. Soc. America Bull.*, v. 45, p. 1-20.
Uses the term Dunham dolomite to identify certain dolomite beds of Early Cambrian age in the Sutton quadrangle, Quebec and Vermont.
- 51 Clemmer, J. B., and Cooke, S. R. B., 1936, Flotation of Vermont talc-magnesite ores: *U. S. Bur. Mines Rept. Inv.* 3314, 12 p.
Talc concentrates and tailings rich in magnesite were obtained in experimental concentration of the ores. Describes results of batch-tests; magnesite, containing 8 to 14 percent impurities, comprised the tailings. Concludes that this material might be suitable for some uses and constitute a source of extra income for talc producers.
- 52 Cloud, P. E., Jr., and Barnes, V. E., 1946, The Ellenburger group of central Texas: *Tex. Univ. Bur. Econ. Geology Pub.* 4621, 473 p. [1948].
Describes in detail the stratigraphy, including measured sections, general geology, and structure of central Texas and discusses the lithologic character, facies changes, and thicknesses of the formations ranging in age from Precambrian to Pennsylvanian. Includes analyses of 113 samples of limestone and dolomite from Johnson City and Cherokee areas, analyses of samples from 32 drill holes on the Victoria Gravel Co. properties near Sudduth, small-scale index map

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- showing where Ellenburger was mapped, and large-scale (1 in. = about 800 ft.) geologic maps of these areas.
- 53 Colby, S. F., 1941, Occurrences and uses of dolomite in the United States: U. S. Bur. Mines Inf. Circ. 7192, 21 p.
Discusses briefly the composition, properties, and uses of dolomite, and gives a very brief survey of occurrence and uses of dolomite by States. Includes a small-scale map showing "location of high-grade dolomite quarries in the U. S." and a bibliography.
- 54 Colorado Bureau of Mines, 1945, 1945 list of operating mines, mills, smelters, quarries, etc.: Colo. State Bur. Mines, 14 p.
- 55 Comber, A. W., 1937, Magnesite as a refractory: Philadelphia and New York, J. B. Lippincott Co., 114 p.
Presents a general discussion of magnesite, its composition and properties, sources, methods of calcination, the chemical and physical properties of refractory magnesite, manufacture of refractory brick, and the industrial application of refractory magnesite. Includes a bibliography.
- 56 Comstock, H. B., 1954, Magnesium: U. S. Bur. Mines Minerals Yearbook, 1951, p. 791-800.
Reviews the magnesium industry for 1951. Summarizes status of Government-owned magnesium plants and the ferrosilicon reduction process; points out the advantages of this type of plant for standby production facilities.
- 57 Cooper, B. N., 1944, Industrial limestones and dolomites in Virginia, New River—Roanoke River district: Va. Geol. Survey Bull. 62, 98 p.
Describes in detail limestone and dolomite occurrences in parts of Giles, Montgomery, Pulaski, Roanoke, and Botetourt Counties. Includes columnar sections, about 90 analyses of limestones and dolomites, and brief descriptions of some quarries and potential quarry sites. Maps (scales range from 1 in. = 250 ft. to 1 in. = 1 mi.) show quarry locations and geology of some of the areas discussed.
- 58 ——— 1945, Industrial limestones and dolomites in Virginia; Clinch Valley district: Va. Geol. Survey Bull. 66, 259 p.
Describes in detail the limestone and dolomite formations in Tazewell, Russell, and Scott Counties, also quarries and potential quarry sites. Includes 144 geologic sections and 241 analyses of limestones and dolomites. Maps show the distribution of the carbonate rocks in the 3 counties.
- 59 Crawford, A. L., 1941, Magnesite—a new economic mineral for Utah [abs.]: Utah Acad. Sci. Proc., v. 18, p. 18.
Brief note on geology of magnesite deposit in the Fish Springs district, Juab County, Utah.
- 60 Crawford, R. D., 1913, Geology and ore deposits of the Monarch and Tomichi districts, Colorado: Colo. Geol. Survey Bull. 4, 317 p.
Describes the stratigraphy, structure, lithologic character of the formations, and economic geology of the area, in southwestern Chaffee County. Most important to a dolomite study is the description of the Ouray limestone, nine analyses from the vicinity of Garfield, and a geologic map, scale 1:62,500.
- 61 Crawford, R. D., and Gibson, Russell, 1925, Geology and ore deposits of the Red Cliff district, Colorado: Colo. Geol. Survey Bull. 30, 89 p.

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Describes the stratigraphy, structure, and mineral deposits of the district, in southeastern Eagle County. Gives a lithologic description of the Leadville limestone, which here includes the dolomite portion (Dyer dolomite) assigned to the Chaffee formation of later reports, and six analyses of the limestone.

- 62 Cullison, J. S., 1944, The stratigraphy of some Lower Ordovician formations of the Ozark uplift: Mo. Univ. School Mines and Metallurgy Bull. Tech. Ser., v. 15, no. 2, 112 p.

Discusses in detail the areal distribution, thickness, lithologic character, and paleontology of the Jefferson City-Cotter-Powell sequence in central and south-central Missouri. The Jefferson City is raised to group status with two formations, the Rich Fountain and Theodosia, on the basis of its lithologic character and fauna. Includes a geologic map, scale 1 inch = about 16 miles, of the area studied and 18 measured sections. No analyses of the limestone and dolomite are given.

- 63 Cumings, E. R., 1922, Nomenclature and description of the geological formations in Indiana, in Handbook of Indiana geology: Ind. Dept. Conserv. Pub. 21, p. 403-570.

Gives a summary of the stratigraphy, including general descriptions of the formations, their distribution, fauna, and historical sketches of the nomenclature. Small-scale maps, 1 inch = about 43 miles, show the distribution of the formations. No analyses are included.

- 64 Cumings, E. R., and Shrock, R. R., 1928, The geology of the Silurian rocks of northern Indiana: Ind. Div. Geology, Conserv. Comm. Pub. 75, 226 p.

Discusses in detail the physiography, stratigraphy, structure, and economic geology of the Silurian area of northern Indiana. Describes lithologic character, thickness, general outcrop area, and quarries and outcrops of each formation. Of particular interest is the discussion of the Huntington dolomite. Includes geologic and outcrop maps, scale 1 inch = about 5 miles, and 8 analyses of the Huntington.

- 65 Currier, L. W., 1935, Zinc and lead region of southwestern Virginia: Va. Geol. Survey Bull. 43, 122 p.

Presents a general description of the stratigraphy, structure, economic geology, and occurrences of lead and zinc and a rather detailed description of the Shady dolomite, which is divided into three members in this region. No analyses are given. Includes geologic map, scale 1:62,500.

- 66 Dake, C. L., 1930, The geology of the Potosi and Edgehill quadrangles: Mo. Bur. Geology and Mines, 2d ser., v. 23, 233 p.

Includes a detailed report on the stratigraphy, structure, and economic geology of the area, which comprises parts of Washington, Iron, and Reynolds Counties; detailed discussions of the Bonnetterre dolomite, Derby-Doerun formation, Potosi and Eminence dolomites, and the Van Buren and Gasconade formations; 11 analyses of limestone and dolomite; and a geologic map, scale 1:62,500.

- 67 Dale, T. N., 1912, The commercial marbles of western Vermont: U. S. Geol. Survey Bull. 521, 170 p.

Discusses limestones, dolomites, marble, also general geology of the marble belt; describes individual quarries and the character of the marbles. Includes some analyses and geologic maps, scales 1:125,000 and 1:31,250.

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- 68 Dale, T. N., 1915, The calcite marble and dolomite of eastern Vermont: U. S. Geol. Survey Bull. 589, 67 p.

Describes occurrences of calcite and dolomite marbles in the eastern part of the State. The term "dolomite" is used in a rather broad sense and is not restricted to the rocks approaching the theoretical composition of dolomite. Includes 4 analyses. Small-scale map, 1:750,000, shows the location of the deposits.

- 69 ——— 1923, The lime belt of Massachusetts and parts of eastern New York and western Connecticut: U. S. Geol. Survey Bull. 744, 71 p.

Briefly describes the general geology and areal distribution of the limestones and dolomites in the area. Includes many of the structural details of the quarries and textural and mineralogical descriptions of thin sections, chemical analyses of 13 samples, and geologic maps, scale 1:62,500.

- 70 Darton, N. H., 1928a, "Red Beds" and associated formations in New Mexico, with an outline of the geology of the State: U. S. Geol. Survey Bull. 794, 356 p.

Summarizes the geology of the State, giving descriptions of the principal formations, including their general features, lithologic character, and distribution. Discusses in more detail the stratigraphy and structure of several regions and gives brief summaries of the geology of many more. Of particular interest are the general and local descriptions of the El Paso, Montoya, and Fusselman limestones and of the Chupadera formation.

- 71 ——— 1928b, Geologic map of New Mexico: U. S. Geol. Survey, scale 1:500,000.

- 72 Darton, N. H., and Paige, Sidney, 1925, Description of the central Black Hills [with contributions by J. D. Irving]: U. S. Geol. Survey Geol. Atlas, folio 219, 34 p.

Discusses the geology of the central Black Hills, including general and local descriptions of the dolomitic Whitewood, Pahasapa, and Minnekahta limestones. Includes analysis of one sample of the Minnekahta limestone from near Hot Springs.

- 73 Dawson, T. A., 1941, The Devonian formations of Indiana; Pt. 1, Outcrop in southern Indiana: Ind. Dept. Conserv., Div. Geology, 48 p.

Describes in detail the Devonian formations of southern Indiana, including history of names, lithologic character, distribution, and discussion of age. Of interest are the descriptions of the Geneva formation and Jeffersonville limestone. No analyses are included.

- 74 Decker, C. E., 1939, Progress report on the classification of the Timbered Hills and Arbuckle group of rocks, Arbuckle and Wichita Mountains, Okla.: Okla. Geol. Survey Circ. 22, 62 p.

Gives a detailed discussion of the stratigraphy of the Timbered Hills and Arbuckle groups and brief discussion of the structure and economic features of the areas studied. Includes 17 detailed columnar sections and geologic map of the Wichita Mountains, scale 1 inch = about 2 miles.

- 75 Deiss, C. F., 1933, Paleozoic formations of northwestern Montana: Mont. Bur. Mines and Geology Mem. 6, 51 p.

Gives detailed descriptions of 10 measured stratigraphic sections, in parts of the Swan, Flathead, and Lewis and Clark Ranges and a tentative correlation

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of the sections. The sections lie stratigraphically between the top of the Precambrian Missoula group and the top of the Mississippian Madison limestone. Also gives summary descriptions of the formations and their type localities.

- 76 Deiss, C. F., 1936, Revision of type Cambrian formations and sections of Montana and Yellowstone National Park: Geol. Soc. America Bull., v. 47, p. 1257-1342.

Includes detailed descriptions of 11 measured stratigraphic sections in central and southern Montana just west of the central part of the State and in the northwestern part of Yellowstone Park; historical summary of Cambrian stratigraphic nomenclature in the area; original and emended definitions and general descriptions of the Cambrian formations, and a tentative correlation of the 11 sections.

- 77 ——— 1938, Cambrian formations and sections in part of Cordilleran trough: Geol. Soc. America Bull., v. 49, p. 1067-1168.

Gives detailed descriptions of 7 measured sections of the Cambrian in the Cordilleran region, 2 of which, the Blacksmith Fork and House Range areas, are in Utah. Summarizes the previous studies in each area. Describes and, in some instances, redefines the Langston, Blacksmith, Nounan, and St. Charles limestones; each of these formations are reportedly dolomitic. No analyses are included.

- 78 ——— 1943, Stratigraphy and structure of southwest Saypo quadrangle, Montana: Geol. Soc. America Bull., v. 54, p. 205-262.

Includes a general description of the sedimentary and igneous rocks and of the structure of the area, which covers parts of the Sawtooth and Lewis and Clark Ranges, and a few measured sections. General descriptions of the Devils Glen, Devonian (Jefferson age) limestones and dolomites, and Hannan limestone are of interest.

- 79 ——— 1945, Distribution of dolomite deposits in the Western States: U. S. Geol. Survey Prelim. Rept. and Map, 4 p.

Summarizes very briefly the geologic and geographic distribution of dolomite deposits and describes the 10 most important ones. Index map shows the location of 125 deposits in the Western United States.

- 80 ——— 1952a, Dolomite deposit near Sloan, Nev.: U. S. Geol. Survey Bull. 973-C, p. 107-141.

Gives a detailed study of the stratigraphy and structure at Sloan Hill, Clark County, Nev., and a description of the dolomite deposit and the formations involved, including the Sultan limestone, Monte Cristo dolomite, and Bird Spring formation. Estimated reserves of dolomite total about 70 million tons. Includes an annotated bibliography and a geologic map, scale 1 inch = 400 feet.

- 81 ——— 1952b, Geologic formations on which and with which Indiana's roads are built: Ind. Dept. Conserv. Geol. Survey Circ. 1, 17 p.

Gives a general outline of geologic history, distribution of limestones, glacial drift, potential quarry sites, and types of road subgrades in Indiana. Small-scale maps, 1 inch = about 42 miles, show distribution of crushed rock quarries, sand and gravel areas, and bedrock formations. No analyses are included.

- 82 ——— 1955, Dolomite deposit near Marble, Wash.: U. S. Geol. Survey Bull. 1027-C, p. 119-141.

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- Includes detailed description of the dolomite deposit in the Northport limestone, about 2 miles northeast of Marble, Stevens County; descriptions of quarrying operations; estimate of reserves; analyses of 53 samples, and a geologic map, scale 1 inch = 400 feet.
- 83 Dow, D. H., and others, 1945, Mineral resources of the Missouri Valley region; Pt. 4, Construction materials: U. S. Geol. Survey Missouri Basin Studies Map 1, 4 sheets.
The map, scale 1:2,500,000, outlines the general areal distribution of the "sedimentary rocks of Paleozoic age" in the Black Hills region. These rocks include the dolomitic Whitewood, Pahasapa, and Minnekahta limestones. The map does not indicate any dolomite occurrences in this area.
- 84 Dungan, T. A., 1944, Production of magnesium by the carbothermic process at Permanente: Am. Inst. Min. Metall. Eng. Trans., v. 159, p. 308-314.
Describes the process used by Permanente Metals Corp. at their plant at Permanente, Calif. The process involved reduction of magnesium oxide obtained from dolomite by carbon (coke) in electric furnaces.
- 85 Dunham, K. C., 1935, The geology of the Organ Mountains, with an account of the geology and mineral resources of Dona Ana County, N. Mex.: N. Mex. School Mines Bull. 11, 272 p.
Includes detailed description of the geology and mineral deposits of the Organ Mountains; outline of the geology of Dona Ana County, along with brief discussions of the geology of other mountain ranges in the county, mineral districts, and mines; 6 analyses of dolomitic limestones, and geologic maps of Dona Ana County, scale 1 inch = 5 miles, Organ Mountains, scale 1 inch = 1 mile, and Organ mining district, scale 1:24,000.
- 86 Eardley, A. J., 1944, Geology of the north-central Wasatch Mountains, Utah: Geol. Soc. America Bull., v. 55, p. 819-894.
Contains general description of the stratigraphy, structure, and physiography of the Wasatch Range east and southeast of Ogden; very brief description of a sequence of more than 1,300 feet of Cambrian limestone and dolomite, mentioning the occurrence of rocks of the "Bluebird type" and "Lynch type". No analyses are given. Includes a geologic map, scale 1 inch = about 2 miles.
- 87 Edmundson, R. S., 1945, Industrial limestones and dolomites in Virginia, northern and central parts of Shenandoah Valley: Va. Geol. Survey Bull. 65, 195 p.
Includes general discussion of the geology of the Valley from Augusta County northward; more detailed descriptions of the limestone and dolomite areas in parts of Frederick, Shenandoah, Rockingham, Augusta, Page, Warren, and Clarke Counties; descriptions of 130 sections and 224 analyses of limestones and dolomites; and geologic maps, scale 1 inch = 2 miles.
- 88 Emerson, B. K., 1917, The geology of Massachusetts and Rhode Island: U. S. Geol. Survey Bull. 597, 289 p.
Discusses in general the sedimentary and igneous rocks, their distribution, character, and geologic relationships. Mentions several localities where the "Bolton" gneiss contains lenses of marbleized magnesian limestone (p. 83-84). Includes analysis of dolomite marble from near Webster, Mass., and a geologic map, scale 1:250,000, of the States.

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- 89 Emmons, S. F., Irving, J. D., and Loughlin, G. F., 1927, *Geology and ore deposits of the Leadville mining district, Colorado*: U. S. Geol. Survey Prof. Paper 148, 368 p.
Gives a comprehensive treatment of the stratigraphy, petrology, structure, and ore deposits of the district. Of particular interest are lithologic descriptions of the "White" limestone (now Manitou limestone) and the Leadville limestone (including Dyer dolomite member of the Chaffee formation) and 6 analyses of the Leadville limestone.
- 90 Emmons, W. H., and Calkins, F. C., 1913, *Geology and ore deposits of the Philipsburg quadrangle, Montana*: U. S. Geol. Survey Prof. Paper 78, 271 p.
Describes in detail the sedimentary and intrusive rocks, structure, mineralogy, ore deposits, and mines of the area. Of particular interest to dolomite study is the original description of the Hasmark formation (p. 57-61). Includes a geologic map, scale 1:125,000.
- 91 Esarey, R. E., and Bieberman, D. F., 1948, *Correlation of the Waldron and Mississinewa formations [Indiana]*: Ind. Dept. Conserv., Div. Geology Bull. 3, 38 p.
Contains a brief description of the physiography and regional structure of Indiana; more detailed descriptions of the rocks and faunal assemblages upon which the formation correlations are made; and a discussion of geologic history. No analyses are included. Small-scale map, 1 inch = 40 miles, shows Silurian outcrop areas.
- 92 Faust, G. T., and Callaghan, Eugene, 1948, *Mineralogy and petrology of the Curren Creek magnesite deposits and associated rocks of Nevada*: Geol. Soc. America Bull., v. 59, p. 11-74.
Gives a detailed discussion of the megascopic and microscopic character of the rocks of the area, their mineralogy and chemistry, and the origin of the magnesite deposits.
- 93 Foerste, A. F., 1917, *Notes on Silurian fossils from Ohio and other central States*: Ohio Jour. Sci., v. 17, p. 17, 201-202.
Proposes the name Euphemia dolomite for the lowest of the beds that make up the dolomitic Niagaran series north of Cedarville, Ohio; formerly regarded as the Mottled Zone of Prosser and, to the south, as part of the West Union formation.
- 94 ——— 1923, *Notes on Medina, Niagaran, and Chester fossils*: Denison Univ., Sci. Lab. Jour., v. 20, p. 41-43.
Discusses very briefly the Bisher formation, formerly treated as the Bisher member of the West Union formation.
- 95 ——— 1929, *Correlation of the Silurian section of Adams and Highland Counties with that of the Springfield area [abs.]*: Ohio Jour. Sci., v. 29, p. 168-169.
States that the Peebles dolomite is equivalent to the Guelph of Canada and belongs above the Cedarville of the Springfield, Ohio, area.
- 96 Ford, W. E., 1932, *Dana's textbook of mineralogy*: New York, John Wiley & Sons, Inc., p. 516-518, 805-806.
Describes the physical and chemical characteristics of dolomite and magnesite. Lists about 150 minerals of which magnesium is a basic constituent.

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- 97 Franke, H. A., 1935, Mines and mineral resources of San Luis Obispo County: Calif. Jour. Mines and Geology, v. 31, p. 402-461.
Presents a survey of the mineral resources of the county, listed alphabetically and including metals and nonmetals, with specific mines and occurrences for each mineral. Includes a very brief description of each locality and state of activity at the time of compilation. Lists one occurrence and one analysis for dolomite.
- 98 Furcron, A. S., 1942, Dolomites and magnesian limestones in Georgia: Ga. Geol. Survey Inf. Circ. 14, 30 p.
Outlines the general distribution of the dolomites and magnesian limestones and describes in some detail outcrops of the Talladega(?) marble in the Gainesville belt, the Murphy marble of the Whitestone-Marble Hill belt, the general occurrence of the Shady and Knox dolomites, the Chickamauga formation, and the magnesian limestones of the Coastal Plain area. Includes chemical analyses of 76 samples, some of which are not precisely located.
- 99 Gale, H. S., 1914, Late developments of magnesite deposits in California and Nevada: U. S. Geol. Survey Bull. 540-S, p. 483-520.
Gives summary descriptions of certain magnesite deposits in Sonoma, Santa Clara, Placer, San Benito, Fresno, Tulare, Kern, and Riverside Counties, Calif.; mentions reported occurrences in Nye and Esmeralda Counties, Nev.; and includes 18 chemical analyses and small-scale maps showing location of the deposits.
- 100 Georgia Division Mines, Mining, and Geology, 1939, Geologic map of Georgia, prepared in cooperation with the U. S. Geological Survey: Atlanta, Ga. Geol. Survey, scale 1:500,000.
- 101 Gibbs, Ralph, 1949, Manufacturing refractory dolomite: Rock Products, v. 52, no. 4, p. 129-131, 161-163.
Summarizes the requirements of refractory dolomites; outlines the steps in production—quarrying, crushing and grinding, sizing, storage, kiln feeding, burning, screening; and considers plant and manufacturing costs.
- 102 Gilluly, James, 1932, Geology and ore deposits of the Stockton and Fairfield quadrangles, Utah: U. S. Geol. Survey Prof. Paper 173, 171 p.
Discusses in detail the stratigraphy, structure, rock alteration, mineralogy, ore deposits and mines of the area, which covers parts of Tooele, Utah, and Salt Lake Counties. The dolomitic formations described include the Lynch and Jefferson dolomites. Includes 2 analyses of dolomitic limestone and a geologic map, scale 1:62,500.
- 103 Goldbeck, A. T., 1949, Crushed stone, in Industrial minerals and rocks: New York, Am. Inst. Min. Metall. Eng., 2d ed., p. 245-293.
Presents a general discussion of crushed stone, including classification of rocks, mineral composition, physical properties, uses, production and consumption, prospecting, stripping, quarrying, crushing, etc. Includes a bibliography.
- 104 Gray, Carlyle, 1951, Preliminary report of certain limestones and dolomites of Berks County, Pa.: Pa. Topog. and Geol. Survey, 4th ser., Progress Rept. 136, 85 p.
Contains detailed descriptions of the Ordovician formations, including the Beckmantown limestone and dolomite, Annville limestone, and Jacksonville

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formation; summaries of the structure and economic possibilities of the limestones; brief descriptions of 81 quarries and outcrops; and analyses of 378 samples. Dolomite, usually siliceous, occurs locally in the Beekmantown. Index map, scale 1 inch = 2 miles, shows principal limestone areas and sample localities.

- 105 Grimsley, G. P., 1916, Jefferson, Berkeley, and Morgan Counties: W. Va. Geol. Survey, 644 p.

Includes general treatment of the history, industrial development, physiography, climate, general geology, structure, and mineral deposits of the eastern panhandle counties; general lithologic descriptions; measured sections; and many analyses of limestones and dolomites. The dolomitic formations include the Stones River limestones, Beekmantown limestone, Conococheague limestone, Waynesboro formation, and Tomstown limestone. Briefly describes many of the quarry operations.

- 106 Gross, W. H., 1949, The story of magnesium: Cleveland, Ohio, Am. Soc. Metals, 260 p.

Gives a nontechnical summary of the sources, methods of production, alloying and refining, casting, fabrication, machining, jointing, finishing, physical metallurgy, and uses of magnesium. Of particular interest are the brief, clear outlines (with flow sheets) of the more important methods of metal production.

- 107 Gwinn, G. R., 1943, Olivine: U. S. Bur. Mines Inf. Circ. 7239, 11 p.

Summarizes briefly the occurrence and use of olivine, particularly in refractories, and the properties of forsterite refractories.

- 108 Ham, W. E., 1949, Geology and dolomite resources, Mill Creek-Ravia area, Johnston County, Okla.: Okla. Geol. Survey Circ. 26, 104 p.

Describes in detail the stratigraphy of the area, giving distribution of the formations, their general character, origin, and their characteristics helpful for field identification. Includes detailed columnar sections. Discusses physical and chemical properties of the Royer dolomite and shows that it compares favorably with the best dolomites of northwestern Ohio. Briefly mentions other dolomite occurrences in Oklahoma and shows their location on small-scale map. Gives analyses of 22 samples. Reserves are estimated to be at least 150 million tons of readily accessible dolomite. Includes a geologic map, scale 1 inch = $\frac{1}{2}$ mile.

- 109 Harness, C. L., and Jensen, N. C., 1943, Marketing magnesite and allied products: U. S. Bur. Mines Inf. Circ. 7269, 25 p.

Summarizes magnesia raw materials, mining methods, calcination, specifications for crude, dead-burned, and caustic-calcined magnesia, uses, and mineral industry statistics (to 1941).

- 110 Hatmaker, Paul, 1931, Utilization of dolomite and high-magnesium limestone: U. S. Bur. Mines Inf. Circ. 6524, 18 p.

Includes a brief description of the uses of dolomite, some production statistics for 1920-29, general chemical requirements for dolomite, and a bibliography. Contains substantially the same information as in the later paper by Colby (1941).

- 111 Hershey, H. G., and others, 1947, Mineral resources of Iowa: Iowa Geol. Survey, index map, scale 1:500,000.

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- 112 Hess, F. L., 1908, The magnesite deposits of California: U. S. Geol. Survey Bull. 355, 67 p.

Contains brief descriptions of magnesite occurrences in several counties, and brief sections on uses, markets, and the origin of the magnesite. Small-scale map, 1 inch = about 60 miles, shows location of deposits.

- 113 Hewett, D. F., 1931, Geology and ore deposits of the Goodsprings quadrangle, Nevada: U. S. Geol. Survey Prof. Paper 162, 172 p.

Describes in detail the stratigraphy, structure, rock alteration, ore deposits, and mines in this part of Clark County. Discusses the lithologic character and distribution of the dolomite and dolomitic limestone formations which include the Goodsprings dolomite, the Sultan and Monte Cristo limestones, and the Bird Spring. Includes a good, detailed discussion on dolomitization, analyses of 42 limestone and dolomite samples, and a geologic map, scale 1:62,500.

- 114 Hinchey, N. S., Fisher, R. B., and Calhoun, W. A., 1947, Limestones and dolomites in the St. Louis area: Mo. Geol. Survey and Water Res. Rept. Inv. 5, 80 p.

Gives brief descriptions of 17 selected limestone and dolomite deposits, including location, transportation facilities, stratigraphic position, measured section, and analyses of representative samples. Only one locality, that near Glencoe, contains dolomite (more than 40 percent magnesium carbonate).

- 115 Hodge, E. T., 1938, Market for Columbia River hydroelectric power using northwest minerals; Sec. 1, Northwest magnesia ores: War Dept., Corps of Engineers, U. S. Army, Office of Div. Engineer, North Pacific Div., Portland, Ore., v. 1, Pt. 2, p. 33-131.

Presents a brief survey of areas of magnesite occurrence, both United States and foreign, with particular emphasis on the Washington deposits, and a brief description of the deposits, including economic considerations, such as transportation facilities and estimates of mining costs. Paper is principally a survey of the available literature on the subject.

- 116 Holmes, G. H., Jr., 1949, Mining methods at the brucite deposit, Basic Refractories, Inc., Gabbs, Nye County, Nev.: U. S. Bur. Mines Inf. Circ. 7543, 10 p.

Describes briefly the plant operations and mining methods at the brucite deposit, which is the only commercial deposit in production in the United States.

- 117 Holmes, G. H., Jr., and Matson, E. J., 1950, Investigation of the magnesite deposit of the Ala-Mar Magnesium Co., Inc., and Nevada Magnesite Co., White Pine County, Nev.: U. S. Bur. Mines Rept. Inv. 4608, 13 p.

Includes a summary discussion of the deposits, an account of the exploratory drilling program carried on by the Bureau of Mines in 1942, sample analyses from 13 drill holes, and 196 analyses of trench samples.

- 118 Hopkins, R. H., 1942, The dolomitic limestones of Florida: Fla. Geol. Survey Rept. Inv. 3, 105 p.

Presents a summary of the properties, modes of occurrence in Florida, and uses of dolomite and dolomitic limestone. Gives locations, drill-hole logs, drill-core analyses (at about 5-ft. intervals), and brief descriptions of the rocks for about 80 test holes which were drilled to determine the character of the dolomites in Taylor, Dixie, Levy, Citrus, Pasco, Manatee, and Sarasota Counties.

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- 119 Huddle, J. W., and Dobrovolsky, Ernest, 1952, Devonian and Mississippian rocks of central Arizona: U. S. Geol. Survey Prof. Paper 233-D, p. 67-112.
Gives a detailed description of the Martin formation (Devonian) and Redwall limestone (Mississippian), including descriptions of facies and their distribution and correlation with formations to the north and south. Includes several detailed stratigraphic sections, a bibliography, an index map (scale 1 in. = approx. 35 mi.) of area studied, and an outline map of the State (scale 1 in. = about 50 mi.) showing the general distribution of outcrops of Devonian and Mississippian rocks.
- 120 Humes, W. B., 1944, Vacuum engineering as related to the dolomite ferrosilicon process: Am. Inst. Min. Metall. Eng. Trans., v. 159, p. 353-362.
Describes in detail vacuum technology as applied to the retorts used in the ferrosilicon reduction process for producing magnesium from dolomite.
- 121 Hunter, C. E., and Gildersleeve, Benjamin, 1946, Minerals and structural materials of western North Carolina and north Georgia: Tenn. Valley Authority, Commerce Dept., Regional Products Research Div., Rept. C, p. 23-29.
Presents brief descriptions and several chemical analyses of some dolomites in North Carolina and Georgia; includes description of the Bandana dolomite marble at Bandana Station, N. C.
- 122 Irving, D. R., and Uswald, F. P., 1954, Magnesium compounds: U. S. Bur. Mines Minerals Yearbook, 1952, preprint, 16 p.
Presents a general summary and statistics of domestic and foreign industry.
- 123 Jenkins, O. P., 1916, Phosphates and dolomites of Johnson County, Tenn.: Tenn. Geol. Survey, Res. Tenn., v. 6, p. 51-106.
Describes in general the geology and mineralogy of the phosphate deposits. Briefly mentions the formations in the area, including the Shady limestone. Includes 19 analyses of dolomitic limestones, along with more detailed descriptions of the occurrences from which the samples were taken.
- 124 ——— 1938, Geologic map of California: Calif. Div. Mines, six sheets, scale 1:500,000.
- 125 Jewett, J. M., and Schoewe, W. H., 1942, Kansas mineral resources for wartime industries: Kans. Geol. Survey Bull. 41, pt. 3, p. 69-180.
Summarizes the mineral resources of the State, with brief statements concerning occurrence, uses, production and reserves. Section on magnesium (p. 104-112) discusses the possibility of producing magnesium from oilfield brines, listing several specific fields and the magnesium content of the brines. Discusses briefly the occurrence of the Stone Corral and Day Creek dolomites and gives 6 analyses from Clark and Rice Counties. Reserves are estimated to be about 16 million tons of readily accessible dolomite in these counties.
- 126 Jones, W. B., 1926, Index to the mineral resources of Alabama: Ala. Geol. Survey Bull. 28, 256 p.
Presents a survey of the mineral resources of the State, with sections on the location of each of the minerals. Of interest to the subject of dolomite are 2 analyses of the Chewacla dolomite from Chewacla, Lee County, and the section on fluxing materials, page 49 and pages 120-128. Describes the lithologic character and areal distribution of the Ketona dolomite.

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- 127 Kay, G. M., 1935, Ordovician system in the upper Mississippi Valley: *Kans. Geol. Soc. Guidebook, 9th Ann. Field Conf.*, p. 281-295.
Describes briefly the Ordovician formations in the upper Mississippi Valley. Of interest are the descriptions of the dolomite units in the Prairie du Chien group, Platteville formation, and Galena group. No analyses are included.
- 128 Keith, Arthur, 1932, Stratigraphy and structure of northwestern Vermont: *Washington Acad. Sci. Jour.*, v. 22, p. 357-379; v. 22, p. 393-406.
Discusses in detail the Cambrian and Ordovician rocks that occur in three sequences in northwestern Vermont and correlates them. No analyses are included. Outline map shows the distribution of the rocks in the region. [Some of the stratigraphy has since been revised.]
- 129 ——— 1933, Preliminary geologic map of Maine: *Maine Geol. Survey*, scale 1:100,000.
- 130 Keith, Arthur, and Sterrett, D. B., 1931, Description of the Gaffney and Kings Mountain quadrangles: *U. S. Geol. Survey Geol. Atlas*, folio 222, 13 p.
Describes the general and economic geology of the area. Of interest is the general description of the Gaffney marble, which in places is highly magnesian. Includes topographic, areal geology, and economic geology maps, scale 1:62,500.
- 131 Kentucky Geological Survey, 1954, Geologic map of Kentucky, prepared in cooperation with Ky. Agr. Indus. Devel. Board: *Lexington, Ky. Geol. Survey*, scale 1:1,000,000.
- 132 King, P. B., 1948, Geology of the southern Guadalupe Mountains, Tex.: *U. S. Geol. Survey Prof. Paper* 215, 183 p.
Describes in detail the Permian stratigraphy, structure, and Cenozoic deposits of the area. Includes descriptions of the dolomites of the Bone Spring, Goat Seep, and Carlsbad limestones, a few analyses, and a geologic map, scale 1:48,000.
- 133 Knechtel, M. M., and others, 1948, Map showing construction materials and nonmetallic mineral resources of Montana: *U. S. Geol. Survey Missouri Basin Studies Map* 11, 2 sheets.
Map outlines the general areal distribution of dolomite and limestone in the State. Brief text on map gives very general description of the geographic and geologic distribution of the carbonate rocks and mentions a few of the more important limestone formations. Scale 1:750,000 or about 1 inch = 12 miles.
- 134 Krey, Frank, and Lamar, J. E., 1925, Limestone resources of Illinois: *Ill. Geol. Survey Bull.* 46, 392 p.
Contains sections on limestone and dolomite for road materials, properties of Illinois limestone and dolomite, quarry practice, a comprehensive survey of the resources (by counties) that describes the quarries and outcrops in each county, and a table of about 300 analyses, most of which are well located. Page-size county maps show the locations of quarries and sample sites.
- 135 Kummel, H. B., and Gage, R. B., 1906, The chemical composition of the white crystalline limestones of Sussex and Warren Counties: *N. J. Geol. Survey Ann. Rept. State Geologist*, 1905, p. 173-191.
Describes the distribution, lithologic character, and chemical composition of the "white limestone" (Franklin limestone). Includes 108 analyses of limestones and dolomites, many of which represent drill-hole samples. Map, scale 1 inch = 1 mile, shows the distribution of the limestone in Sussex County.

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- 136 Ladoo, R. B., and Meyers, W. M., 1951, *Nonmetallic minerals*: New York, McGraw-Hill, 2d ed., 605 p.
Catalogs commercial nonmetallic minerals. The summary of each mineral includes brief sections on composition, description, physical properties, occurrence, production, uses, and a bibliography. Describes dolomite on pages 194-202 and magnesite and magnesium compounds on pages 298-311.
- 137 Lamar, J. E., and Willman, H. B., 1938, *A summary of the uses of limestone and dolomite*: Ill. Geol. Survey Rept. Inv. 49, 50 p.
Summary of more than 50 uses of limestone and dolomite, briefly describes how the material is used and outlines the general chemical and physical requirements of the rock for each use. Gives a bibliography.
- 138 Landes, K. K., 1951, *Detroit River group in the Michigan basin*: U. S. Geol. Survey Circ. 133, 12 p.
Discusses in detail the nomenclature and stratigraphy of the Detroit River group. Presents revised section of the type locality and correlates it with the subsurface strata explored by wells in the Michigan basin. Includes stratigraphic column, cross sections, and isopach maps, scale about 1:2,500,000, of Detroit River formations as they occur in the southern peninsula of Michigan.
- 139 Larrabee, D. M., and others, 1947, *Map showing construction materials and nonmetallic mineral resources of Colorado*: U. S. Geol. Survey Missouri Basin Studies Prelim. Map 10.
Shows the general areal distribution of dolomite and dolomitic limestone in Colorado. Text briefly mentions the Manitou, Ouray, Leadville, and Madison limestones as containing dolomite. Also briefly describes the general areas of outcrop of the dolomite and summarizes quarrying activity and uses of Colorado dolomite.
- 140 Lasky, S. G., 1936, *Geology and ore deposits of the Bayard area, Central mining district, New Mexico*: U. S. Geol. Survey Bull. 870, 144 p.
Describes in detail the stratigraphy, igneous rocks, and structure of this area, about 9 miles east of Silver City, Grant County. Discusses rock alteration and ore deposits, giving descriptions of individual mines and prospects. Also briefly describes on page 17 the Montoya and Fusselman limestones. No dolomite analyses are given. Includes a geologic map, scale 1:12,000.
- 141 Lenhart, W. B., 1953, *Heavy media separation removes friable granite from dolomite*: *Rock Products*, v. 56, no. 2, p. 89-93, 152.
Presents a general description of the heavy media separation process used by Kaiser Aluminum & Chemical Corp. at their Natividad, Calif., plant to upgrade quarry-run dolomite by removing granite.
- 142 Lewis, J. V., and Kummel, H. B., 1912, *Geologic map of New Jersey, 1910-1912*: N. J. Geol. Survey, scale 1:250,000.
- 143 Lindgren, Waldemar, and Loughlin, G. F., 1919, *Geology and ore deposits of the Tintic mining district, Utah*: U. S. Geol. Survey Prof. Paper 107, 282 p.
Describes in detail the stratigraphy, structure, ore deposits, and mines of the district. Formations described as being dolomites or dolomitic limestones include the Bluebird, Cole Canyon, and Opex dolomites, the Ajax limestone, and the Bluebell and Gardner dolomites. Gives 4 carbonate rock analyses; 1 is of dolomite. Includes a geologic map, scale 1:62,500.

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- 144 Lloyd, R. R., Rawles, W. T., and Knickerbocker, R. G., 1944, Pilot-plant production of magnesia from Sloan dolomite: *Am. Inst. Min. Metall. Eng. Trans.*, v. 159, p. 296-307.

Describes in detail the pilot-plant operation for producing cell-grade magnesia from dolomite quarried at Sloan, Nev. Pilot plant was at U. S. Bureau of Mines experiment station at Boulder City, Nev.

- 145 Logan, C. A., 1947, Limestone in California: *Calif. Jour. Mines and Geology*, v. 43, p. 175-357 [1948].

Summarizes the uses of lime and limestone (including dolomite) and describes, by counties, limestone and dolomite deposits, which are precisely located. Includes brief summary of production from each deposit, many analyses, and a brief description of the controlling structure for most of the more important deposits. A map, scale 1 inch = about 34 miles, shows locations of 307 limestone and dolomite deposits.

- 146 Logan, C. A., and Wright, L. A., 1950, Dolomite, *in* Mineral commodities of California: *Calif. Dept. Nat. Res., Div. Mines Bull.* 156, p. 155-158.

The report comprises a summary of the mineral resources of the State, including fuels, metallics, and nonmetallics, and describes their geographic and geologic occurrence, economic development, and uses. The section on dolomite briefly summarizes some of the more important occurrences. No analyses are given. Small-scale map, 1:5,000,000, shows distribution of the principal mineral resources.

- 147 Longwell, C. R., 1928, Geology of the Muddy Mountains, Nev.: *U. S. Geol. Survey Bull.* 798, 152 p.

Discusses in general the physiography, structure, and stratigraphy of the Muddy Mountains and parts of the Virgin Mountains and Grand Wash Cliffs. Dolomite occurs in the Muddy Peak limestone; magnesite occurs with limestone, dolomite, and other sediments in the Horse Spring formation (Tertiary) near Overton. Also discusses the origin of the magnesite and gives 2 magnesite analyses.

- 148 Loughlin, G. F., Berry, E. W., and Cushman, J. A., 1921, Limestones and marls of North Carolina: *N. C. Geol. and Econ. Survey Bull.* 28, 211 p.

Includes general descriptions of the limestone, dolomite, and marl formations of the State; more detailed descriptions of specific occurrences in quarries and outcrops; and summaries of the uses, character, and production of limestones and marls. The principal formations that contain dolomite include the Murphy and Gaffney marbles and the Shady limestone. Gives analyses of 36 limestone and dolomite samples. Maps of specific areas (scale, generally 1 in. = 1 mi.) show areal distribution of the carbonate rocks.

- 149 McAllister, J. F., 1952, Rocks and structure of the Quartz Spring area, northern Panamint Range, Calif.: *Calif. Dept. Nat. Res., Div. Mines Special Rept.* 25, 38 p.

Describes in general the stratigraphy and structure of the area, which covers about 50 square miles in east-central Inyo County. Dolomite occurs in the Racetrack dolomite, Nopah formation, Pogonip limestone, Ely Springs and Hidden Valley dolomites, and Lost Burro formation. Does not mention the quality of the dolomite, although much of it apparently is siliceous or cherty. Includes a geologic map, scale 1 inch = about 2,700 feet.

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- 150 McCammon, J. H., 1941, Report on tin and magnesite deposits in Mason County, Tex.: Tex. Univ. Bur. Econ. Geology, Min. Res. Survey Circ. 32, 8 p.
Gives a description and 1 analysis of the small magnesite deposit 3 miles northwest of Mason. Map, scale 1 inch = 660 feet, shows location of the deposit.
- 151 McCue, J. B., Lucke, J. B., and Woodward, H. P., 1939, Limestones of West Virginia: W. Va. Geol. Survey, v. 12, 560 p.
Includes general descriptions of the limestone formations in West Virginia, discussion of the geographic distribution of the formations, along with brief descriptions of quarries and outcrops, section on quarrying and grinding methods and on uses of limestone, and nearly 1,500 chemical analyses. Accompanying map, scale 1:500,000, shows the areal distribution of the Cambrian and Ordovician limestones and of sample localities.
- 152 McFarlan, A. C., 1943, Geology of Kentucky: Lexington, Ky., Ky. Univ., 531 p.
Presents a comprehensive treatment of the geology of the State, including stratigraphy, regional geology, and mineral resources. Includes a very general reference to resources of "limestone (including dolomite)." Of interest are the lithologic descriptions in the section on Ordovician-Devonian stratigraphy (p. 8-55). Small-scale map, 1 inch = about 97 miles, shows general geology.
- 153 McQueen, H. S., 1943, Occurrence of dolomite in the Fredericktown area, Madison County, Mo.: Mo. Geol. Survey and Water Res. 62d Bienn. Rept., App. 2, 16 p.
Describes briefly the Bonneterre dolomite near Fredericktown and includes 18 analyses and descriptions of the samples. The dolomite is appraised as being suitable for the production of magnesium by the ferrosilicon reduction process. Geologic map, scale 1 inch = about $\frac{3}{4}$ mile, shows distribution of the various zones of the Bonneterre.
- 154 Martin, H. M., 1936, Geologic maps of the southern and northern peninsulas of Michigan: Mich. Dept. Conserv., Geol. Survey Div. Pub. 39, Geol. ser. 33.
- 155 Mathews, E. B., and Grasty, J. S., 1910, The limestones of Maryland with special reference to their use in the manufacture of lime and cement: Md. Geol. Survey Special Pub., v. 8, pt. 3, p. 227-484.
Discusses the uses of limes and cements, and describes the geology and distribution of lime and cement materials as they occur in the Piedmont Plateau, Frederick Valley, and in Washington, Allegany, and Garrett Counties. Includes many analyses of limestones and dolomites and a map, scale 1 inch = 3 miles, showing the distribution of the limestones in the State and sample localities.
- 156 Mathews, E. B., and others, 1929, Baltimore County: Md. Geol. Survey, 420 p.
Presents a report on the physical features of Baltimore County, including physiography, geology, mineral resources, soils, climate, and forests. Describes the lithologic character and areal distribution of the Cockeysville marble. Includes three analyses and descriptions of quarrying operations in the Cockeysville-Texas area. Map, scale 1 inch = 3 miles, shows location of "quarries and open workings" in the county.
- 157 Mayer, Andrew, 1944, Plant for production of magnesium by the ferrosilicon process: Am. Inst. Min. Metall. Eng. Trans., v. 159, p. 363-376.

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Gives a summary description of the plant operated by National Lead Co. at Luckey, Ohio.

- 158 Miller, B. L., 1934, Limestones of Pennsylvania: Pa. Geol. Survey, 4th ser., Bull. M 20, 729 p.
- Discusses the composition, mineral associations, physical properties, origin, weathering, uses, and distribution of limestones, dolomites, and marbles. Describes in some detail the occurrences, in outcrops and quarries, of limestone and dolomite by counties. Gives many analyses, some of which are not precisely located. County maps, scale, generally about 1 inch = 9 miles, show distribution of the limestones. State map, scale 1 inch = about 26 miles, shows the general areal distribution of the limestones.
- 159 Miller, B. L., Fraser, D. M., and Miller, R. L., 1939, Northampton County, Pa.: Pa. Geol. Survey, 4th ser., Bull. C 48, 496 p.
- Gives a detailed description of the geography and geology of the county, including sections on stratigraphy, structure, and economic geology; analyses of limestones and dolomites from many localities; an annotated bibliography; and a geologic map, scale 1 inch = 1 mile.
- 160 Missouri Geological Survey, 1939, Geological map of Missouri: Rolla, Mo. Geol. Survey and Water Res., scale 1:500,000.
- 161 ——— 1944, Mineral resources of Missouri: Rolla, Mo. Geol. Survey and Water Res., map, scale 1:600,000.
- 162 Moore, F. H., 1935, Marbles and limestones of Connecticut: Conn. Geol. Nat. History Survey Bull. 56, 56 p.
- Describes in detail the marbles of western Connecticut, by areas of occurrence, giving their general distribution, structural relations, and physical character. Mentions localities where marble is quarried, and includes 18 analyses of the calcite and dolomite marbles. Summarizes the requirements of marble for its varied uses.
- 163 Moore, R. C., Frye, J. C., Jewett, J. M., Lee, Wallace, and O'Connor, H. G., 1951, The Kansas rock column: Kans. Geol. Survey Bull. 89, 132 p.
- Contains brief, general descriptions of the lithologic character, thickness, and distribution of the formations of Kansas; generalized columnar sections; and small-scale maps showing areal distribution of the formations. Of interest are the descriptions of the Day Creek and Stone Corral dolomites.
- 164 Muller, S. W., and Ferguson, H. G., 1939, Mesozoic stratigraphy of the Hawthorne and Tonopah quadrangles, Nevada: Geol. Soc. America Bull., v. 50, p. 1573-1624.
- Describes in detail the stratigraphy and paleontology of the Triassic and lower Jurassic formations in the mountain ranges in these quadrangles. Of particular interest is the description of the Luning formation, the dolomite host rock for the magnesite and brucite deposits at Gabbs. Map, scale 1:125,000, shows the distribution of the formations in the area.
- 165 Noble, L. F., 1922, A section of the Paleozoic formations of the Grand Canyon at the Bass Trail: U. S. Geol. Survey Prof. Paper 131-B, p. 23-73.
- Gives a detailed stratigraphic section at Bass Trail, Grand Canyon, and general descriptions of the lithologic character and distribution of each of the

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Paleozoic formations. Correlates the section with other Grand Canyon sections. Includes 10 analyses. Of interest are the descriptions of the Muav, Temple Butte, and Redwall limestones.

- 166 Nolan, T. B., 1935, The Gold Hill mining district, Utah: U. S. Geol. Survey Prof. Paper 177, 172 p.

Describes in detail the stratigraphy, structure, ore deposits, and mines of the district. No analyses are included, but the lithologic descriptions of the Young Peak, Trippe, Lamb, Hicks, Chochecherry, Fish Haven, Laketown, Sevy, Simonson, and Guilmette indicate that each of these formations are dolomite, at least in part. Includes a geologic map, scale 1:62,500.

- 167 Norton, G. H., 1939, Permian red beds of Kansas: Am. Assoc. Petroleum Geologists Bull., v. 23, p. 1751-1819.

Describes in detail the Permian red bed formations of Kansas. Of interest are the descriptions of the Stone Corral and Day Creek dolomites. No analyses are included. Small-scale map, 1 inch = about 23 miles, shows the distribution of the red beds in Kansas and northern Oklahoma.

- 168 Norton, W. H., 1899, Geology of Scott County: Iowa Geol. Survey, v. 9, p. 422-440.

Refers the beds of Niagaran age in Scott County to a single formation—the Gower stage; treats the Le Claire and Anamosa beds as members—or substages—of approximately equivalent ages. Includes measured sections and brief descriptions of Le Claire and Anamosa beds at several quarries.

- 169 ——— 1920, Wapsipinicon breccias of Iowa: Iowa Geol. Survey, v. 27, p. 355-547.

Describes in detail the lithologic character and the breccias of the several subdivisions (which have since been revised) of the Wapsipinicon limestone. Includes a discussion of the origin of the breccias, several measured sections, and 12 analyses of the limestones and dolomites.

- 170 Oder, C. R. L., 1934, Preliminary subdivision of the Knox dolomite in east Tennessee: Jour. Geology, v. 42, p. 469-497.

Subdivides the Knox dolomite and describes each of the proposed formations. Includes the Maynardville limestone at the base. [The subdivisions above the Chepultepec have since been revised.] Includes two detailed sections and a small-scale map showing the areal distribution of the Knox dolomite.

- 171 Oklahoma Geological Survey, 1944, Minerals of Oklahoma: Norman, Okla. Geol. Survey, index map with text, scale about 1:554,000.

Outlines the distribution of minerals by colors, patterns, and symbols. Text very briefly summarizes areas of occurrence of each mineral. Shows distribution of dolomite in the State in a very general way.

- 172 Oriol, S. S., 1950, Geology and mineral resources of the Hot Springs window, Madison County, N. C.: N. C. Dept. Conserv. Devel., Div. Min. Res. Bull. 60, 70 p.

Discusses the name, limits and thickness, distribution, character, and correlation of the rocks in the area, also the structure and mineral resources. Describes the Shady dolomite (p. 9-12) and briefly discusses quarrying operations in the Shady near Hot Springs (p. 52-54). Lists 7 chemical analyses of the Shady. Includes a geologic map, scale 1:24,000.

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- 173 Osterwald, F. W., and Osterwald, D. B., 1952, Wyoming mineral resources: Wyo. Geol. Survey Bull. 45, 215 p.

Catalogs minerals of Wyoming, listing producing areas, plants, prospects, and reported occurrences for each mineral. Lists prospects and occurrences of dolomite by section, township, and range (p. 50-56). Includes analyses for 16 of the localities.

- 174 Pabst, Adolph, 1938, Minerals of California: Calif. Dept. Nat. Res., Div. Mines Bull. 113, 344 p.

Catalogs minerals of California, giving their physical properties, descriptions, and general modes of occurrence. Lists occurrences of dolomite in 14 counties, including minor, uneconomic deposits, and 1 analysis of a sample from San Bernardino County.

- 175 Palache, Charles, Berman, Harry, and Frondel, Clifford, 1951, Dana's system of mineralogy: New York, John Wiley & Sons, Inc., v. 2, p. 162-166.

- 176 Park, C. F., Jr., and Cannon, R. S., Jr., 1943, Geology and ore deposits of the Metaline quadrangle, Washington: U. S. Geol. Survey Prof. Paper 202, 81 p.

Describes in detail the general geology, stratigraphy, structure, and ore deposits of the quadrangle, northern Pend Oreille County. Of interest is the detailed description of the Metaline limestone, including 4 analyses of dolomite samples from Crescent Lake. Includes a geologic map, scale 1:96,000.

- 177 Parker, J. L., 1945, Open-pit mining of magnesite ore: Explosives Engineer, v. 23, p. 9-11.

Describes in general the Anaconda operations at Gabbs, Nev.

- 178 Partridge, E. P., and Davis, A. E., 1935, Magnesium and its compounds: U. S. Bur. Mines Minerals Yearbook, 1935, p. 1165-1176.

Presents a general summary and statistics of foreign and domestic industry.

- 179 Patton, J. B., 1949, Crushed stone in Indiana: Ind. Dept. Conserv. Div. Geology, Rept. Progress 3, 47 p.

Describes the lithologic character of 29 formations quarried in Indiana for use as crushed stone. Includes brief descriptions of 92 quarries, giving their locations, geologic formation quarried, and the quarry products; analyses of 103 samples from 32 quarries; and a map, scale 1 inch = about 10 miles, showing the locations of the quarries and the rock quarried.

- 180 Pennsylvania Department Internal Affairs, 1944, Pennsylvania's mineral heritage: Pa. State Coll., Bur. Statistics, Topog. and Geol. Survey, 248 p.

Summarizes the mineral resources of the State, both by commodity and by counties. Includes production statistics and general section on technology, trends, and possibilities for future development of the industries. Mentions briefly magnesite and dolomite and their use in the production of magnesium.

- 181 Perry, E. S., 1949, Gypsum, lime, and limestone in Montana: Mont. Bur. Mines and Geology Mem. 29, 45 p.

Contains brief summary discussions of the preparation and uses of lime, the limestone formations, and production of limestone and lime in Montana; description of quarrying of the Pilgrim limestone in the vicinity of Helena, with a generalized geologic map of the Helena area, scale 1 inch = 1 mile; a few lime-

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stone analyses; and a page-size map of Montana showing exposures of Madison limestone.

- 182 Perry, J. B., and Kirwan, G. M., 1933, The Bald Eagle magnesite mine, California: *Am. Inst. Min. Metall. Eng. Tech. Pub.* 861, p. 1-15.

Describes briefly the geology of the deposit, the mining methods used, and the plant of the Bald Eagle mine, about 20 miles southwest of Gustine. Magnesite occurs as a blanket deposit in an accumulation of serpentine breccia, rather than in association with solid serpentine as in the typical "California type" deposits.

- 183 Pettijohn, F. J., 1949, *Sedimentary rocks*: New York, Harper & Bros., 526 p.

Textbook deals with the properties, composition, descriptions, etc., of sedimentary rocks. Brief section on dolomites (p. 312-317) defines dolomite in terms of percent of dolomite in the carbonate fraction, describes general characteristics, and outlines theories of origin.

- 184 Pidgeon, L. M., and Alexander, W. A., 1944, Thermal production of magnesium—pilot-plant studies on the retort ferrosilicon process: *Am. Inst. Min. Metall. Eng. Trans.*, v. 159, p. 315-352.

Gives a detailed discussion of the ferrosilicon reduction process for producing magnesium from dolomite, including discussions of the character of the dolomite, the retorts used, and the effects of varying conditions of time, temperature, grade of ferrosilicon, etc.

- 185 Pidgeon, L. M., and others, 1946, *Magnesium*: Cleveland, Ohio, Am. Soc. Metals, 265 p.

Contains a series of five papers covering (1) extractive metallurgy, (2) magnesium structural design, (3) magnesium castings, (4) wrought magnesium alloy fabrication, and (5) corrosion protection of magnesium. Paper on extractive metallurgy contains summary descriptions of the several methods of metal production including electrolytic, carbothermic, and ferrosilicon processes as they are used in various installations. Includes a bibliography.

- 186 Pierce, W. M., Waring, R. K., Fetterolf, L. D., and Mahler, G. T., 1944, Some developments in the production of magnesium from dolomite by the ferrosilicon process: *Am. Inst. Min. Metall. Eng. Trans.*, v. 159, p. 377-391.

Discusses the advantages and disadvantages of wet and dry briquetting and the effect of time, temperature, and grade of ferrosilicon on the efficiency of the ferrosilicon reduction process.

- 187 Pond, W. F., 1933, *Geologic map of Tennessee*: Tenn. Dept. Education, Div. Geology, 4th ed., scale 1:500,000.

- 188 Powers, E. H., 1935, *Stratigraphy of the Prairie du Chien [upper Mississippi Valley]*: *Kans. Geol. Soc. Guidebook*, 9th Ann. Field Conf., p. 390-394.

Discusses in general the Prairie du Chien group and its subdivisions. Treats the Prairie du Chien here as a formation with 3 members—the Oneota, New Richmond, and Willow River. Small-scale map, 1 inch = about 37 miles, shows the areal distribution of the Prairie du Chien.

- 189 Price, P. H., Tucker, R. C., and Haight, O. L., 1938, *Geology and natural resources of West Virginia*: *W. Va. Geol. Survey*, v. 10, 462 p.

Contains a brief discussion of the general geology and stratigraphy of the State, a catalog of the mineral resources, briefly outlining their character, uses,

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- occurrence in the State, and production, a section on dolomite (p. 330-331) which states that it occurs in Monroe, Jefferson, Berkeley, and Morgan Counties, and a geologic map, scale 1 inch = about 16 miles. No analyses are included.
- 190 Prindle, L. M., and Knopf, E. B., 1932, Geology of the Taconic quadrangle: *Am. Jour. Sci.*, 5th ser., v. 24, p. 257-302.
- Discusses in general the stratigraphy and structure of the Taconic quadrangle, which includes the southwest corner of Vermont, the northwest corner of Massachusetts, and the adjoining portion of eastern New York. Of interest is the description of the Rutland dolomite in the vicinity of Bennington, Vt. Includes a geologic map, scale 1 inch = about $4\frac{1}{2}$ miles. No analyses are given.
- 191 Prucha, J. J., 1953, The White Crystal dolomite deposit near Gouverneur, N. Y.: *N. Y. Univ., N. Y. State Sci. Service Rept. Inv.* 9, 13 p.
- Includes a general description of the dolomite deposit about 3 miles north of Gouverneur, St. Lawrence County; a summary of chemical analyses of composite chip samples and of uses of dolomite; and a geologic map, scale 1 inch = 600 feet. Reserves are estimated at 68 million tons.
- 192 Rankama, Kalervo, and Sahama, T. G., 1950, *Geochemistry*: Chicago, Ill., Univ. of Chicago Press, 911 p.
- Surveys in general the broad science of geochemistry. Discusses on pages 448-456, the abundance, geochemical character, minerals, occurrence in igneous rocks, biogeochemistry, and cycle of magnesium.
- 193 Richardson, C. H., 1923, The building stones of Kentucky: *Ky. Geol. Survey*, ser. 6, v. 11, 355 p.
- Contains discussion, by counties, of the building stones of the State, which include limestone, dolomite, marble, and sandstone; brief descriptions of stone found in quarries and in outcrops that might have potential value; about 100 analyses of building stones of all types, listing location, description of the rock, and original source of the information.
- 194 Richardson, G. B., 1913, The Paleozoic section in northern Utah: *Am. Jour. Sci.*, 4th ser., v. 36, p. 406-416.
- Gives a general description of the Paleozoic section in the Blacksmith Fork area; more detailed descriptions of the Fish Haven, Laketown, and Jefferson dolomites; and 1 partial analysis.
- 195 Ries, Heinrich, 1901, Lime and cement industries of New York: *N. Y. State Mus. Bull.*, v. 8, p. 641-968.
- Includes a detailed discussion of the origin, properties, uses, geology, and occurrence of New York limestones, and the cement industry in New York, and nearly 1,000 analyses of limestones and dolomites in the United States. Maps (1) scale 1 inch = about 12 miles, shows locations of limestone and marl deposits, limestone quarries, and cement plants; and (2) scale 1 inch = about 24 miles, shows areal distribution of limestone in the State.
- 196 Roberts, R. J., 1943, The Rose Creek tungsten mine, Pershing County, Nev.: *U. S. Geol. Survey Bull.* 940-A, p. 1-14.
- Describes briefly the geology, structure, ore deposits, and mine workings in the area, 11 miles southwest of Winnemucca, Nev.; also describes downfaulted blocks of generally silicified dolomite, indicating from its lithologic character

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that the dolomite is Triassic in age. Geologic map, scale 1 inch = 2,000 feet, shows the distribution of the dolomite.

- 197 Rodgers, John, 1948, Geology and mineral deposits of Bumpass Cove, Unicoi, and Washington Counties, Tenn.: Tenn. Dept. Conserv., Div. Geology Bull. 54, 82 p.

Describes in general the geology and mineral deposits of the area. Of interest is the description of the Shady dolomite, which was studied in greater detail than the other formations because the Shady and the residual clay derived from it contain all the commercial ore deposits. Gives two chemical analyses of the dolomite. Mentions several flux-stone quarries.

- 198 ——— 1953, Geologic map of East Tennessee with explanatory text: Tenn. Dept. Conserv., Div. Geology Bull. 58, pt. 2, 168 p.

Includes general descriptions of the rock units of the Unaka Mountains and the Valley of East Tennessee and of the larger structural features, descriptions of the Shady dolomite (p. 42-43) and the Knox dolomite (p. 53-64), and geologic maps, scale 1:125,000. No analyses are given.

- 199 Rodgers, John, and Kent, D. F., 1948, Stratigraphic section at Lee Valley, Hawkins County, Tenn.: Tenn. Dept. Conserv., Div. Geology Bull. 55, 47 p.

Describes in detail the geologic section at Lee Valley; section extends from the Rome formation to the Martinsburg shale. Treats the Knox as a group, including in it the Copper Ridge, Chepultepec, and Longview dolomites, the Kingsport limestone, and Mascot dolomite. Index map shows location of the section and the generalized geology.

- 200 Rogers, J. K., 1936, Geology of Highland County: Ohio Geol. Survey, 4th ser., Bull. 38, 148 p.

Describes the general and economic geology of Highland County; treats the Lilley dolomite as a formation rather than as a member of the West Union formation. Includes also descriptions of the Bisher, Peebles, and Greenfield dolomites. Gives several chemical analyses of these dolomites and mentions localities where sizable quarries have been operated.

- 201 Ross, C. P., and Forrester, J. D., 1947, Geologic map of the State of Idaho: U. S. Geol. Survey, scale 1:500,000.

- 202 Rothrock, E. P., 1944, Mineral resources, Pt. 3 of A geology of South Dakota: S. Dak. Geol. Survey Bull. 15, 255 p.

Briefly mentions the Whitewood, Pahasapa, and Minnekahta limestones as being dolomites locally and therefore a potential source of magnesium. Mentions dolomite sands near Piedmont. Includes the analysis of the Minnekahta given in U. S. Geological Survey Geologic Atlas, folio 219.

- 203 Rubey, W. W., and Callaghan, Eugene, 1936, Magnesite and brucite, in Hewett, D. F., and others, Mineral resources of the region around Boulder Dam: U. S. Geol. Survey Bull. 871, 93 p.

Bulletin 871 summarizes metallic and nonmetallic mineral occurrences in the Boulder Dam area. The section on magnesite and brucite (p. 113-144) describes in some detail the magnesite deposit near Overton, Nev., with detailed discussion of the mineralogy and probable origin of the deposit. Reserves are estimated

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- to be greater than 5 million tons. Includes a geologic map, scale 1 inch = about 2,000 feet, and several analyses. Briefly mentions the occurrences near Bauer, in the Currant Creek district, and near Gabbs.
- Section on limestone and dolomite (p. 163-165) gives a very brief summary of a few of the occurrences in the region.
- 204 Savage, T. E., 1926, Silurian rocks of Illinois: Geol. Soc. America Bull., v. 37, p. 525-526, 531-533.
- Defines and briefly describes the Port Byron limestone, of Niagaran age, which overlies the Racine dolomite in northern Illinois.
- 205 Schallis, Alvin, 1942, Dolomite-base refractories: U. S. Bur. Mines Inf. Circ. 7227, 11 p.
- Describes briefly some of the chemical and physical properties of and methods of producing calcined and stabilized dolomite refractories. Briefly touches on the separation of lime and magnesia in dolomite. Small-scale map of the United States shows general distribution of high-purity dolomite.
- 206 ——— 1943, Economic considerations in the recovery of magnesia from dolomite: U. S. Bur. Mines Inf. Circ. 7247, 53 p.
- Discusses briefly the thermal decomposition of dolomite and methods of producing half-burned dolomite. Includes brief descriptions of mechanical and chemical methods by means of which magnesia can be separated from dolomite, short general section on cost and applicability of certain processes in the production of magnesia for selected end uses, and a bibliography.
- 207 Schallis, Alvin, and Warner, K. G., 1942, Magnesium compounds and miscellaneous salines: U. S. Bur. Mines Minerals Yearbook, 1941, p. 1497-1508.
- Presents a general review of the industry in 1941, giving statistics on the magnesite industry in particular. States that crude magnesite mined amounted to nearly 375,000 tons.
- 208 Schlocker, J., 1942, Magnesium-bearing minerals in the Boulder Dam area for the production of magnesium metal: U. S. Bur. Mines Inf. Circ. 7216, 15 p.
- Summarizes the magnesite deposits at Bissell, Afton, Needles, and Cima, Calif., and at Overton and Indian Springs, Nev. Mentions some of the dolomite occurrences in the area.
- 209 Schoch, E. P., 1918, Chemical analyses of Texas rocks and minerals: Tex. Univ. Bull. 1814, 256 p.
- Contains several analyses of Texas dolomites (p. 60-61, 182). Most locations are not given exactly.
- 210 ——— 1938, High magnesia marble from Sharp Mountain area of Llano County, Tex.: Tex. Univ., Div. Nat. Res., Min. Res. Circ., 5 p.
- Gives chemical analyses of high-magnesia rock samples collected in Llano County, Tex.
- 211 Seaton, M. Y., 1942, Production and properties of the commercial magnesias: Am. Inst. Min. Metall. Eng. Tech. Pub. 1496, 21 p.
- Includes a general discussion of the production of magnesia from its several sources, which include magnesite, silicates, natural brines, sea water, and sea-water bitterns, and descriptions of the magnesite industries in California, Washington, and Nevada.

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- 212 Secrist, M. H., 1924, Zinc deposits of east Tennessee: Tenn. Dept. Education, Div. Geology Bull. 31, 165 p.
Includes brief descriptions of the stratigraphy and structure of the Great Valley area of eastern Tennessee and of districts and of the mines and prospects within them, discussions of chemistry and genesis of the ores, and a geologic map, scale 1:500,000, of eastern Tennessee.
- 213 Shreve, R. N., 1945, The chemical process industries: New York, McGraw-Hill Book Co., Inc., 1st ed., 957 p.
Textbook gives somewhat detailed summaries of many of the more important chemical processes used in industry. Each summary outlines the chemical and physical changes and how they are brought about, physical chemistry, economics, and energy and power requirements. Of interest are the sections on magnesium compounds (p. 209-216) and magnesium (p. 306-311), which briefly outline magnesium chloride electrolysis, carbon reduction, and ferrosilicon reduction processes for magnesium production, and present several flow sheets illustrating production of magnesium compounds from sea water, bitterns, sea water and dolomite, and dolomite.
- 214 Sloan, Earle, 1908, Catalogue of the mineral localities of South Carolina: S. C. Geol. Survey, 4th ser., Bull. 2, 505 p.
Lists mineral localities and includes brief description of each deposit. Delineates the so-called petrographic zones and briefly describes the geology of each. Gives column of "tentative sub-divisions" of geologic formations in the State. Map, scale about 1 inch = 15 miles, shows mineral localities. Includes analyses of 20 limestone samples.
- 215 Smith, E. A., and others, 1926, Geologic map of Alabama, prepared in cooperation with the U. S. Geological Survey, scale 1:500,000: Ala. Geol. Survey.
- 216 Smith, J. E., 1926, The fertilizer materials of Iowa: Iowa Geol. Survey, v. 31, p. 91-151.
Discusses the fertilizer resources of Iowa, which include salt, gypsum, marl, pyrites, phosphates, peat, limestone, and dolomite. Contains brief notes on quarries in and outcrops of limestone and dolomite suitable for use as a fertilizer. Small-scale maps, 1 inch = about 12 miles, show the location of quarries and outcrops. Gives about 160 analyses, along with several measured sections.
- 217 Smith, R. A., 1916, Limestones of Michigan: Mich. Geol. Biol. Survey Pub. 21, pt. 2, p. 109-311.
Presents a general summary of the origin, classification, and uses of limestone and descriptions of the lithologic character and distribution of the limestone and dolomite formations in the State. Includes a more detailed discussion of their character, development, and distribution by counties and descriptions of occurrences as seen in quarries and outcrops. Outline map, scale 1 inch = about 26 miles, shows distribution of formations and location of limestone quarries. Gives analyses of 724 samples.
- 218 Spurr, J. E., 1906, Ore deposits of the Silver Peak quadrangle, Nevada: U. S. Geol. Survey Prof. Paper 55, 174 p.
Gives a very general reference to dolomitic limestone and marble occurring in the Cambrian sequence in this portion of Esmeralda County. Includes 4 analyses, 2 of which are dolomite, from "lower Cambrian carbonate rocks," and a geologic map, scale 1:125,000.

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- 219 Stainbrook, M. A., 1944, The Devonian system in Iowa, in *Symposium on Devonian stratigraphy*: Ill. Geol. Survey Bull. 68, p. 182-188.
Summarizes Iowa Devonian stratigraphy, including brief lithologic descriptions of the formations. Discusses general outcrop areas. Of interest are the descriptions of the Wapsipinicon and Cedar Valley limestones.
- 220 Stauffer, C. R., 1950, The high magnesium dolomites and dolomitic limestones of Minnesota: Minn. Geol. Survey Summary Rept. 4, 27 p.
Describes briefly the dolomites, which include the Nicollet Creek member of the St. Lawrence formation, Oneota dolomite, Shakopee dolomite, Stewartville member of the Galena formation, and the Cedar Valley limestone, and 36 sample localities, usually accompanied by measured sections. Gives 196 chemical analyses of the dolomites.
- 221 Stauffer, C. R., and Thiel, G. A., 1933, The limestones and marls of Minnesota: Minn. Geol. Survey Bull. 23, 193 p.
Summarizes the nature and origin of limestones, dolomites, and marls, and their occurrence in Minnesota in quarries and outcrops. Contains many measured sections, 160 analyses of limestones and dolomites including location, geologic formation, and, in some instances, a brief description of the rock sampled.
- 222 ——— 1941, The Paleozoic and related rocks of southeastern Minnesota: Minn. Geol. Survey Bull. 29, 261 p.
Describes in detail the stratigraphy of southeastern Minnesota, including descriptions of the lithologic character, general distribution, and measured sections of the formations. Includes about 90 selected analyses taken from Minnesota Bulletin 23, well records, small-scale county index maps, and faunal lists; also small-scale, 1 inch = about 35 miles, geologic map of southeastern Minnesota.
- 223 Stebbins, R. H., 1951, Directory of Washington mining operations, 1951: Wash. Dept. Conserv. and Devel., Div. Mines and Geology Inf. Circ. 19.
Lists all active mines and quarries and products of each, including 2 dolomite quarries active in 1951.
- 224 Steidtmann, Edward, 1911, The evolution of limestone and dolomite: Jour. Geology, v. 19, p. 323-345, 392-428.
Discusses in detail the decrease in proportion of dolomite to limestone going up the geologic time scale. Presents evidence for the origin of dolomite in the sea, evidence for the origin of dolomite by the alteration of limestones after their emergence from the sea, discusses calcium and magnesium in the products of metamorphism, and presents the conclusion that most dolomites are formed in the sea and that changes in life processes and changes in the chemical composition of the sea are the two factors primarily responsible for a decrease in the quantity of dolomite with the advance of geologic time.
- 225 ——— 1917, Origin of dolomite as disclosed by stains and other methods: Geol. Soc. America Bull., v. 28, p. 431-450.
Discusses the principles and methods of distinguishing calcite and dolomite by stains and of the time and manner of dolomitization as disclosed by direct observation. Staining shows that pure limestones and dolomites predominate over mixed beds of limestone and dolomite. Concludes that most dolomites

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were formed in the sea and that replacement of lime carbonate is an important process in the formation of dolomite.

- 226 Steidtmann, Edward, 1924, Limestones and marls of Wisconsin: Wis. Geol. and Nat. Hist. Survey Bull. 66, 208 p.

Discusses in general the occurrence of limestone, dolomite, and marl, arranged by counties. Includes many sections, quarry locations, and characteristics of the deposits, brief discussions of origin and uses of limestones and marls and of the general geology of Wisconsin; 225 analyses of limestones and dolomites; also analyses of marls, clays, slates, and shales. Geologic map of Wisconsin, scale 1:1,000,000, shows general geology and sample localities.

- 227 Stokley, J. A., 1949, Industrial limestones of Kentucky: Ky. Geol. Survey Rept. Inv. 2, 51 p.

Summarizes the uses of limestone and dolomite, along with approximate specifications for each use; briefly describes distribution, thickness, and character of the carbonate rocks. Includes sets of chemical analyses representing 30 quarries. At only one locality, Avoca, Jefferson County, does the magnesium carbonate content exceed 39 percent.

- 228 Stokley, J. A., and McFarlan, A. C., 1952, Industrial limestones of Kentucky, no. 2: Ky. Geol. Survey Rept. Inv. 4, 95 p.

Includes brief notes on the stratigraphy of the middle and upper Mississippian beds and summaries of several areas that seem favorable for the production of high-calcium limestone. Lists 23 quarries, drill holes, and road cuts with logs, analyses, and lithologic descriptions of the more important limestone units. The analyses indicate that in the quarries examined, dolomite exists only locally, mainly in the Ste. Genevieve limestone.

- 229 Stokley, J. A., and Walker, F. H., 1953, Industrial limestones of Kentucky no. 3: Ky. Geol. Survey Rept. Inv. 8, 62 p.

Includes brief notes on areas favorable for the production of high-calcium limestone and near high-magnesium dolomite, description of the formations involved, and discussion of quarrying conditions. Lists 12 quarries with logs, chemical analyses, and lithologic descriptions of the quarryable units. Magnesian limestone and dolomite occur principally in the Laurel dolomite in Jefferson, Oldham, Bullitt, and Nelson Counties.

- 230 Stone, R. W., 1918, Magnesite deposits of Washington: Eng. Min. Jour., v. 105, p. 665-668.

Includes a description of magnesite quarries and plant facilities in Stevens County, Wash., production figures, and a brief note on uses. Map, scale about 1 inch = 3 miles, shows location of deposits.

- 231 ——— 1922, Magnesite in Pennsylvania: Pa. Bur. Topog. and Geol. Survey Bull. 28, 3 p.

Presents a brief treatment of the history, description, and evaluation of the small magnesite deposits in Chester and Lancaster Counties, near the Pennsylvania-Maryland State line. The deposits are too small to be considered commercial.

- 232 Stose, A. J., and Stose, G. W., 1944, Geology of the Hanover-York district, Pennsylvania: U. S. Geol. Survey Prof. Paper 204, 84 p.

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Gives a detailed account of the stratigraphy and structure of the area, which lies in York County, and a brief section on the mineral resources of the district. No analyses of the carbonate rocks. Includes a geologic map, scale 1 inch = 1 mile. Paper is of particular interest for the descriptions of the Vintage, Kinzers, Ledger, and Conestoga formations.

- 233 Stose, G. W., and Ljungstedt, O. A., 1931, Geologic map of Pennsylvania: Pa. Geol. Survey, scale 1 inch = 6 miles.

- 234 ——— 1932, Geologic map of West Virginia, by the West Virginia Geological Survey, James D. Sisler, State geologist. Scale 1:500,000.

- 235 Stout, W. E., 1941, Dolomites and limestones of western Ohio: Ohio Geol. Survey, 4th ser., Bull. 42, 468 p.

Discusses the general features of western Ohio geology and describes in detail the formations, including lithologic character, thickness, areal distribution, and commercial importance. Discusses in detail the carbonate rocks by counties and gives chemical and mineralogical data on samples obtained from quarries and outcrops. Includes chapter on utilization, a list of operators, and analyses of about 300 well-located samples.

- 236 Suffel, G. G., 1930, Dolomites of western Oklahoma: Okla. Geol. Survey Bull. 49, 155 p.

Discusses in detail the dolomites of the Blaine gypsum and the Permian dolomites overlying the Blaine. Describes the lithologic character and distribution of the dolomites, giving detailed descriptions of individual occurrences. Includes only a few analyses. Small-scale maps show distribution of the Day Creek dolomite, the Blaine escarpment in northwestern Oklahoma, and the dolomite members of the Blaine in southwestern Oklahoma.

- 237 Surplus Property Administration, 1945, Magnesium plants and facilities: Rept. to Congress, Washington, D. C., 48 p.

Report discusses the magnesium industry and the Government's investment therein and outlines the economic problems involved in the disposition of the Government-owned magnesium plants.

- 238 Sutton, A. H., 1935, Stratigraphy of the Silurian system of the upper Mississippi Valley: Kans. Geol. Soc. Guidebook, 9th Ann. Field Conf., p. 268-280.

Discusses the Alexandrian and Niagaran series of Illinois, Iowa, and Wisconsin. Of interest are the brief descriptions of the Mayville and Byron formations of the Alexandrian, the Waukesha formation, Coral beds, and Racine-Guelph formation of the Niagaran, and the Waubakee formation. Includes correlation charts and a sketch map showing general distribution of these formations.

- 239 Taft, H. H., 1936, Magnesite in Dona Ana County, N. Mex.: Eng. Min. Jour., v. 137, p. 137.

Describes magnesite locality.

- 240 Talmadge, S. B., and Wootton, T. P., 1937, The nonmetallic mineral resources of New Mexico and their economic features (exclusive of fuels): N. Mex. School Mines Bull. 12, 159 p.

Presents a brief summary of the geologic history of the State and a survey of the nonmetallic minerals, including their general features, occurrences, and uses. Section on magnesite and dolomite (p. 110-112) mentions that the El

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Paso, Montoya, and Fusselman limestones contain many dolomite and dolomitic beds and that the Chupadera formation contains a large amount of magnesia. Briefly describes 3 magnesite deposits, giving 5 analyses of magnesite.

- 241 Tester, A. C., 1937, Geologic map of Iowa: Iowa Geol. Survey, scale 1:500,000.

- 242 Trefethen, J. M., 1945, Report of the State Geologist 1943-44: [Maine Devel. Comm.], 64 p.

Section on limestone and dolomite (p. 13-18) gives brief description of the dolomite around Warren, Knox County, with suggestions for utilization. Two maps, scale 1 inch = 4/5 mile; 1 inch = about 3/7 mile, show general distribution and sample localities. Six partial analyses show high magnesia content but do not indicate amount or type of impurities present.

- 243 Tucker, W. B., and Sampson, R. J., 1943, Mineral resources of San Bernardino County [Calif.]: Calif. Jour. Mines and Geology, v. 39, p. 427-549 [1944].

Sections on limestone, dolomite, and magnesite (p. 516-535) give locations of deposits by section, township, and range. Includes brief descriptions of each deposit and analyses of samples from a few of the deposits.

- 244 Tweto, O. L., 1949, Stratigraphy of the Pando area, Eagle County, Colo.: Colo. Sci. Soc. Proc., v. 15, p. 149-235.

Includes detailed description of the stratigraphy of the area and measured sections. Of interest are the descriptions of the dolomite members of the Chaffee formation (Dyer dolomite member), the Leadville dolomite, and the Minturn formation (Wearyman, Hornsilver, and Resolution dolomite members).

- 245 Tyler, P. M., 1931a, Magnesium compounds (other than magnesite): U. S. Bur. Mines Inf. Circ. 6406, 19 p.

Summarizes the uses and methods of production and presents statistical data for magnesium carbonate, magnesium sulphate, magnesia, and magnesium chloride. Includes a list of manufacturers of these compounds.

- 246 —1931b, Magnesite: U. S. Bur. Mines Inf. Circ. 6437, 53 p.

Describes magnesite, its geologic occurrence, methods of mining, calcining, and brickmaking, and gives summary descriptions of domestic and foreign sources of supply. Includes export, import, and consumption statistics, a bibliography, and lists of producers, brick manufacturers, importers, and dealers.

- 247 United States Bureau of Mines and United States Geological Survey, 1948, Mineral resources of the United States: Washington, D. C., Public Affairs Press, p. 127-129.

Gives a summary appraisal of the United States resources of magnesium raw materials. Section on reserves of sea water, brines, magnesite, dolomite, olivine, and serpentine is very general. States that magnesite reserves are adequate for 250 years at 1941 rate of consumption.

- 248 United States Geologic Survey, 1935, Geologic map of Colorado, in cooperation with the Colorado State Survey Board and Colorado Metal Mining Fund, compiled by W. S. Burbank and others, edited by G. W. Stose. Scale 1:500,000.

- 249 Utley, H. F., 1952, Wartime Nevada brucite plant now producing dead-burned magnesite: Pit and Quarry, v. 44, no. 9, p. 96-98.

Describes briefly the new dead-burning operations of Basic Refractories, Inc., at Gabbs, Nev.

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- 250 Valentine, G. M., 1949, Inventory of Washington minerals; Part 1, Nonmetallic minerals: Wash. Dept. Conserv. and Devel., Div. Mines and Geology Bull. 37, 113 p.

Shows the general distribution and specific locations of the nonmetallic minerals of Washington, using maps of the State (scale 1 in. = about 24 mi.) and brief descriptive texts, along with a key for each map giving specific localities by section, township, and range. Includes a separate map for each mineral or group of related minerals and lists the source of information for each location.

- 251 Vanderwilt, J. W., Burbank, W. S., and Traver, W. M., Jr., 1947, ¹Mineral resources of Colorado; foreword by W. E. Scott, Jr., Pt. 1, Metals, nonmetals, and fuels, by J. W. Vanderwilt; Pt. 2, Summaries of mining districts and mineral deposits, by W. S. Burbank and others; Pt. 3, Investigations of strategic mineral resources, by W. M. Traver, Jr.: Colo. Min. Res. Board [Bull.], 547 p.

Report summarizes the occurrences of metallic and nonmetallic minerals, outlines their general distribution and geology, and gives brief descriptions of many of the mining districts. Small- and large-scale maps show mineral resources of the State and the geology of the mining districts described. Brief section on dolomite mentions only general areas of occurrence. No analyses are given.

- 252 Van Horn, E. C., 1948, Talc deposits of the Murphy marble belt: N. C. Dept. Conserv. Devel., Div. Min. Res. Bull. 56, 54 p.

Includes a general description of the stratigraphy, structure, geology of the talc deposits, and of the individual talc deposits and a general discussion of the distribution, extent, and character of the Murphy marble (p. 8-13). Of interest is the concept of zoning of lithologic character in the marble. Also includes geologic maps, scale 1:24,000.

- 253 Van Tuyl, F. M., 1916, The origin of dolomite: Iowa Geol. Survey, v. 25, p. 251-421.

Gives an excellent summary of the various theories of origin of dolomite. Presents theories in three groups: (1) primary deposition theories, (2) alteration theories, and (3) leaching theories. Cites positive and negative evidence—experimental, field and chemical, and petrographic—bearing on the various theories. Concludes that the majority of stratified dolomites have resulted from the alteration of limestones before their emergence from the sea.

- 254 Vernon, J. W., 1950, Magnesite, magnesium, and magnesium compounds, *in* Mineral commodities of California: Calif. Dept. Nat. Res., Div. Mines Bull. 156, p. 177-184.

Summarizes the status of production of magnesium compounds in California, history of production, raw materials (mentioning the larger magnesite deposits), uses, and markets.

- 255 Vernon, R. O., 1951, Geology of Citrus and Levy Counties, Fla.: Fla. Geol. Survey Bull. 33, 256 p.

Describes in detail the physiography, structure, and stratigraphy of Citrus and Levy Counties. Summary of economic geology includes brief section on dolomite (p. 221-224); 1 analysis of sample from near Lebanon, Levy County; brief discussion of mining methods, uses of the dolomite, and reserves. Includes

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- geologic map, scale 1 inch = 1.5 miles, and small-scale map, scale 1 inch = about 14 miles, showing distribution of the dolomite.
- 256 Ver Wiebe, W. A., 1928, Stratigraphy of Chippewa County, Mich.: Mich. Acad. Sci. Papers, v. 9, p. 309-331.
Presents general descriptions of the strata, consisting in part of the rocks of Niagaran age, which include the Engadine, Manistique, and Burnt Bluff formations.
- 257 Vitaliano, C. J., 1950, Needles magnesite deposit, San Bernardino County, Calif.: Calif. Jour. Mines and Geology, v. 46, p. 357-382.
Describes in detail the geology, structure, and mineral deposits of 2 magnesite areas near Needles. Reserves of indicated and inferred ore are estimated to be 521,000 tons of magnesite containing less than 10 percent lime at 1 deposit. Includes analyses and a geologic map, scale 1 inch = about 400 feet.
- 258 ——— 1951, Magnesium-mineral resources of the Currant Creek district, Nevada: U. S. Geol. Survey Bull. 978-A, 25 p.
Gives a general description of the geology, petrology, structure, and occurrence of magnesite and more detailed descriptions of the several individual deposits. Reserves are estimated to be 10,000 tons of commercial-grade magnesite and 350,000 tons of magnesium silicate-bearing material. Includes a geologic map of the district, scale 1 inch = 1 mile, and geologic maps of individual deposits, scale generally 1 inch = 200 feet.
- 259 Ware, Louis, 1944, Magnesium from potash ores: Am. Inst. Min. Metall. Eng. Trans., v. 159, p. 280-284.
Summarizes the process for extraction of magnesium from magnesium chloride discharge liquor from Carlsbad, N. Mex. Process involved magnesium chloride liquor and treated, calcined dolomite to produce magnesium chloride cell feed for electrolytic cells. Plant was located near Austin, Tex., and operated by International Minerals & Chemical Co.
- 260 Warren, L. E., 1943, Notes on dolomite in Potter and Moore Counties, Tex.: Tex. Univ. Bur. Econ. Geology Pub. 4301, p. 258-264 [1946].
Includes a detailed description of the Alibates dolomite lentil which is exposed along the bluffs of the Canadian River in Potter and Moore Counties; descriptions of 4 measured sections, and 8 analyses of the dolomite. Accompanying the publication is an index map, scale 1:1,000,000, that shows metallic and non-metallic mineral localities of the State.
- 261 Watkins, D. G., 1951, Ohio's lime industry: Ohio Chamber of Commerce, Indus. Devel. Dept. [Rept.] no. 12, 9 p.
Gives a summary of the lime industry, including uses, production, consumption, location of resources, production methods, and future possibilities for the industry. A map, scale 1 inch = about 32 miles, shows the areal distribution of the limestone formations.
- 262 Weaver, C. E., 1920, The mineral resources of Stevens County: Wash. Geol. Survey Bull. 20, 350 p.
Presents general descriptions of the geography, stratigraphy, structure, and economic geology of the county; includes brief descriptions of the Stenagar dolomite member of the Deer Trail argillite and of the old Dominion limestone,

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both of the Stevens series of Paleozoic(?) age. Includes also general descriptions of the magnesite mines and a geologic map of the county, scale 1:125,000.

- 263 Weissenborn, A. E., and Stenzel, H. B., eds., 1948, Geological resources of the Trinity River tributary area in Oklahoma and Texas: Tex. Univ. Bur. Econ. Geology Pub. 4824, 252 p.

Includes brief summary of the geology of the area; catalog of metallic and nonmetallic mineral deposits, with maps (scale 1 in. = about 75 mi.) showing the general distribution of these resources; and general discussion of dolomite and magnesian limestone on pages 93-99. Mentions the dolomite beds of the Permian in north-central Texas. Gives 8 analyses of the dolomite in Potter and Moore Counties and 15 analyses of Oklahoma dolomites.

- 264 Weitz, J. H., 1942, High-grade dolomite deposits in the United States: U. S. Bur. Mines Inf. Circ. 7226, 86 p.

Includes a compilation of information from published and unpublished sources, summarizing dolomite occurrences by States; brief descriptions, including some structural details, of some of the deposits in each State; tables containing nearly 1,000 analyses; a bibliography; and a small-scale map showing distribution of high-purity dolomite in the United States.

- 265 Weller, J. M., 1945, Geologic map of Illinois: Ill. Geol. Survey, scale 1:500,000.

- 266 Wells, R. C., 1937, Analyses of rocks and minerals from the laboratory of the U. S. Geological Survey, 1914-1936: U. S. Geol. Survey Bull. 878, 134 p.

Catalogs more than 1,500 chemical analyses of rock and mineral samples made by the chemistry laboratory, arranged by composition. Gives analyses of carbonate rocks of New Mexico on page 57.

- 267 Westgate, L. G., and Knopf, Adolph, 1932, Geology and ore deposits of the Pioche district, Nevada: U. S. Geol. Survey Prof. Paper 171, 79 p.

Describes in detail the stratigraphy, structure, and ore deposits of this section of Lincoln County. The lithologic descriptions indicate that the following formations are dolomites or dolomitic limestones: the Highland Peak, and Mendha limestones and the Ely Springs and Silverhorn dolomites. No analyses are included. Includes a geologic map, scale 1:62,500.

- 268 Whitlatch, G. I., 1948, Minerals, in Forests, agriculture, and minerals, industrial resources of Tennessee: Tenn. State Plan. Comm., revised ed., v. 2, p. 61-100.

Brief section on limestone and dolomite (p. 81-83) includes general comments on the distribution and quality of carbonate rocks of Tennessee; the dolomites include the "Knox" and Shady. Gives 1 dolomite analysis (average of 5 "Knox" samples) from TVA quarry at Norris, Anderson County.

- 269 Whitwell, G. E., and Patty, E. N., 1921, The magnesite deposits of Washington; their occurrence and technology: Wash. Geol. Survey Bull. 25, 194 p.

Briefly discusses the geologic occurrence and origin of the magnesite and describes individual deposits, mining methods, and the occurrence of dolomite. Includes sections dealing with world occurrences, production, uses, technology, and research for new uses of magnesite and a geologic map, scale 1 inch = about 1½ miles, of the magnesite area.

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- 270 Willman, H. B., 1943, High-purity dolomite in Illinois: Ill. Geol. Survey Rept. Inv. 90, 89 p.

Includes general descriptions of the high-purity dolomites in the Chicago, Savanna-Port Byron, Rockford, and Grafton-Hardin regions; detailed descriptions of each of the dolomite formations in each region, along with small-scale index maps showing the general distribution of the dolomite quarries and outcrops; and analyses of 58 samples, well located both as to geography and stratigraphy.

- 271 Wilmarth, M. G., 1938, Lexicon of geologic names of the United States (including Alaska): U. S. Geol. Survey Bull. 896, pt. 1, A-L, pt. 2, M-Z, 2396 p.

Lists and defines geologic names.

- 272 Wilson, E. D., 1942, Magnesium: Ariz. Bur. Mines, Ariz. Univ., Circ. 11, 9 p.

Summarizes dolomite occurrences in Arizona. Primary emphasis is on northwestern Arizona where, in general, "portions of the lower Redwall and underlying limestone formations are dolomitic." Cites several localities and gives partial analyses; also cites the occurrence of Tertiary dolomite in the Agua Fria-Humbug area. Mentions the dolomitic portions of Martin, Mescal, and Abrigo limestones and includes a few representative analyses.

- 273 Yale, C. G., and Stone, R. W., 1921a, Magnesite: Min. Res. U. S., 1919, pt. 2, p. 227-234 [1922].

Presents a general review of industry with production and import statistics, general discussion of deposits in California and Washington, and a brief note on the geology of an undeveloped deposit 30 miles north of Lordsburg, N. Mex.

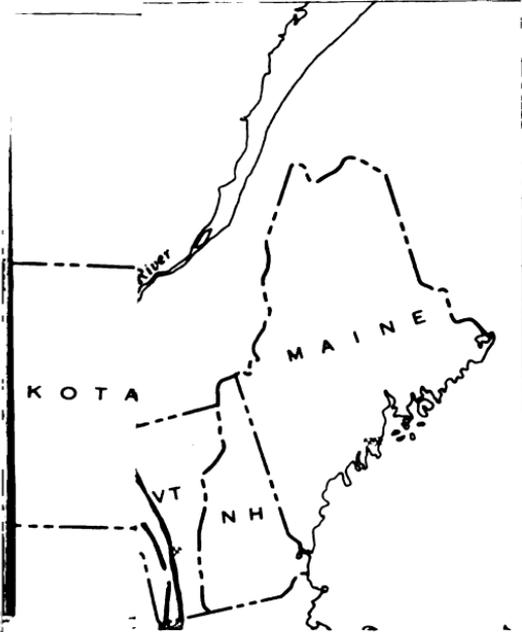
- 274 ——— 1921b, Magnesite: Min. Res., U. S. 1920, pt. 2, p. 1-16 [1923].

Presents a general review of industry with production, consumption, and import statistics, discussions on deposits in California, Washington, and Nevada, and a brief description of undeveloped hydromagnesite deposits in Idaho, near Soda Springs, Bannock County, with one analysis.

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Selected Annotated Bibliography of Thorium and Rare-Earth Deposits in the United States Including Alaska

U.S.

GEOLOGICAL SURVEY / BULLETIN 1019-F

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Selected Annotated Bibliography of Thorium and Rare-Earth Deposits in the United States Including Alaska

KATHARINE L. BUCK

CONTRIBUTIONS TO BIBLIOGRAPHY OF MINERAL RESOURCES

GEOLOGICAL SURVEY BULLETIN 1019-F

Including references to September 1954.

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the U. S. Atomic Energy Commission
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UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1957

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

**For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 40 cents (paper cover)**

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CONTRIBUTIONS TO BIBLIOGRAPHY OF MINERAL RESOURCES

SELECTED ANNOTATED BIBLIOGRAPHY OF THORIUM AND RARE-EARTH DEPOSITS IN THE UNITED STATES INCLUDING ALASKA

By KATHARINE L. BUCK

INTRODUCTION

Thorium and rare-earth metals have come into strategic importance in this country in the last few years with the potential use of thorium in the production of atomic power and the development of new uses for the rare earths in the aircraft industry. The United States was thought to be dependent upon foreign sources of these elements because its entire supply from 1910 to 1950 was imported, principally from India and Brazil. By 1951 the foreign supplies of monazite, the main ore of thorium and the rare earths, were seriously curtailed because of restrictions imposed by the producing countries on the exportation of fissionable materials and their ores. In order to develop sources of these elements within the United States, a search has been made which has resulted in a significant increase in the known reserves (U. S. Congress Documents, 1953, p. 211-219).

The rare-earth metals are the elements ranging in atomic number from 57 to 71; they include lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutecium. Yttrium, atomic no. 39, and scandium, no. 21, occur almost inseparably with the rare earths proper and are usually included in the group. Thorium, no. 90, also occurs with the rare earths in nature.

USES

The principal early use of rare earths and thorium was in the manufacture of incandescent gas mantles. Monazite was mined in the United States for this purpose from the 1890's until 1911, when the tungsten lamp largely replaced the gas mantle. The manufacture of

gas mantles is, however, still the main use of thorium, although the amount consumed in such manufacture is decreasing. Thorium is now used in the filaments of tungsten lamps, in radio tubes, in refractories, and in the chemical and medical industries. Pure thorium has recently been produced for experimental purposes and would probably have industrial use if it were in sufficient supply (U. S. Congress Documents, 1952, p. 112-113). The use of thorium in the manufacture of atomic energy is now in the planning stage (U. S. Atomic Energy Commission, 1954, p. 25), and it takes precedence over the development of other new uses.

The rare earths are more widely used than thorium in industry. Cerium compounds are used in the carbon-arc electrode cores of searchlights and motion-picture projectors. Mischmetal, a mixture of rare earths, is used in the sparking elements of cigarette lighters and, alloyed with copper, nickel, zinc, aluminum, and magnesium, in aircraft parts, gas turbines, and jet engines. Some of the rare earths are used in waterproofing, mothproofing, and mildew-proofing fabrics, in printing and dyeing, in the glass industry as coloring agents, polishing agents, and in the manufacture of certain special-purpose glasses.

THE INDUSTRY AND ITS PROBLEMS

The main ore mineral of thorium and the rare earths, monazite, occurs primarily in beach and river placer concentrations. In this country domestic placers have been mined for their monazite content alone only in the last 5 years and in the period 1893-1911. The monazite produced between these two periods has been a byproduct of the mining of other minerals, such as ilmenite or gold, and even now the economics of producing monazite are complicated by the problem of marketing the byproduct minerals in order to reduce the overall cost of mining.

Large deposits of bastnaesite, which have recently been discovered and may become the main source of rare earths in this country, interject another factor into the economics of production and use of rare earths and thorium. Bastnaesite contains an amount of thorium that is insignificant at current prices so that, if bastnaesite, instead of monazite, were to dominate as the rare-earth ore, byproduct production of thorium would drop considerably.

There is a ready market for rare earths in this country, but domestic mining operations are insecure because of the threat of the return of foreign imports which would place the price below the domestic cost of mining. The profitable mining of monazite is dependent on the market for byproduct heavy minerals. This factor is especially important in the Idaho field. The market for thorium as such is limited.

Thorium is purchased in the mineral monazite, which is sold for and graded on its combined rare-earth and thorium content.

ORE DEPOSITS

Monazite is the principal ore mineral of both thorium and the rare earths. In this country, thorite is an important potential ore mineral of thorium, and bastnaesite is an important ore mineral of the rare earths. Monazite is essentially a phosphate of cerium and lanthanum and contains small variable quantities of the other rare earths, thorium, silicon, uranium, and other elements. It commonly contains from a few percent to 10.6 percent thorium. Movable monazite deposits are found generally in placers, but monazite also occurs as an accessory mineral in many granitic rocks, which are the ultimate source of the placer concentrations. Commercial monazite contains from 55 to 65 percent total rare-earth oxides plus thoria.

Thorite is a silicate of thorium and contains from 25.2 to 62.7 percent thorium and as much as 9.0 percent uranium. Thorite or a hydrated thoritelike mineral is the main ore mineral of some of the vein deposits recently discovered in this country, notably those in the Westcliffe and Powderhorn districts of Colorado and the Lemhi Pass district of Idaho. It also occurs along with bastnaesite in similar deposits in the Mountain Pass district of California.

Bastnaesite was a mineralogic curiosity until early in this decade when a large bastnaesite-barite deposit was discovered at Mountain Pass, Calif., and production began from a bastnaesite-fluorite deposit in the Gallinas Mountains of New Mexico. Bastnaesite is a fluocarbonate of the rare earths, primarily cerium and lanthanum, and contains less than 1 percent uranium and thorium.

Monazite is now being produced in the United States from the placers of the central Idaho region (Anonymous, 1949a, 1950a, 1952b, 1954a, 1954e) and from the placer deposit of the National Lead Co., Jacksonville, Fla. (Mertie, 1953, p. 15), where it is produced as a by-product of ilmenite mining. Monazite was mined from stream placers in western North and South Carolina in the late nineteenth and early twentieth centuries for use in gas mantles. It has also been produced from a beach placer near Mineral City, Fla. (Santmyers, 1930, p. 11), and as a byproduct of the Climax molybdenum deposit of the Tenmile district, Colo. (Carlson and others, 1953, p. 11). Potential regions of monazite production are the drainage areas of the Idaho batholith in Idaho and Montana, the drainage areas of the western and eastern monazite belts of the southeastern States as outlined by Mertie (1953, p. 15, 24-30), and the drainage areas of the Tuscaloosa formation of the southeastern States (Mertie, 1953). Other districts

which may produce thorium and the rare earths from monazite are the Mineral Hill district, Idaho and Montana, where monazite and allanite occur in marble layers in Precambrian metamorphic rocks, and the Palmer area, Marquette County, Mich., where monazite occurs in ancient placers of the upper Huronian Goodrich quartzite. Monazite may also contribute to the radioactivity of the beach sands of the southeastern Atlantic and Gulf coasts, and it is possible that a commercial deposit may be found in such sands (Anonymous, 1954a, 1954d).

No mines in this country are producing thorite or thorumite (hydrothorite) at present. However, the Westcliffe and Powderhorn districts of Colorado (Christman and others, 1953; Burbank and Pierson, 1953, p. 2, 3 and the Lemhi Pass district of Idaho (Trites and Tooker, 1953, p. 191-205) are potential sources of thorite or thorumite. Thorium occurs in the thorumite (Th, U) $\text{SiO}_4 \cdot 6\text{H}_2\text{O}$, and thorium-bearing zircon in the Wausau area, Wisconsin.

Bastnaesite is currently being produced from the Mountain Pass district, California (Carlson, Keiser, and Sargent, 1953; Olson and others, 1954), and the Gallinas Mountains district of New Mexico (Anonymous, 1952a). No other potential producers of bastnaesite are known in this country at present.

The Baringer Hill district, Llano County, Tex., produced, in the early 1900's, a few hundred pounds of rare earths a year from a pegmatite intruded into Precambrian granite. The principal rare-earth-bearing minerals mined were gadolinite, $\text{Be}_2\text{FeY}_4\text{Si}_2\text{O}_{18}$; allanite, $(\text{Ca,Ce,Th})_2\text{Al,Fe,Mg}_3\text{Si}_5\text{O}_{12}(\text{OH})$; cyrtolite, an altered zircon containing uranium, thorium, yttrium, and other rare earths; fergusonite, $(\text{Y,Er,Ce,Fe})(\text{Nb,Ta,Ti})\text{O}_4$; and polycrase, $(\text{Y,Ca,Ce,U,Th})(\text{Ti,Nb,Ta})_2\text{O}_8$ (Hess, 1908).

Potential areas of production of rare earths and thorium from minerals other than monazite, thorite, or bastnaesite are the Bear Lodge Mountains district, Wyoming, where the thorium-, rare-earth-bearing minerals have not yet been identified; the Mineville district of New York where rare earths and thorium occur in fluorapatite and might be recovered as a byproduct of magnetite mining; and the St. Peters Dome district, El Paso County, Colo., where several rare-earth- and thorium-bearing minerals occur in pegmatites.

There are no deposits in Alaska that have produced thorium or the rare earths, and the possibility of such production is small. In Alaska, thorium-bearing minerals have been recognized at 47 locali-

ties which are described in U. S. Geological Survey Circular 202 (Bates and Wedow, 1953); deposits which might, with a change in economic conditions, come into production or byproduct production of thorium-bearing minerals, are also indicated.

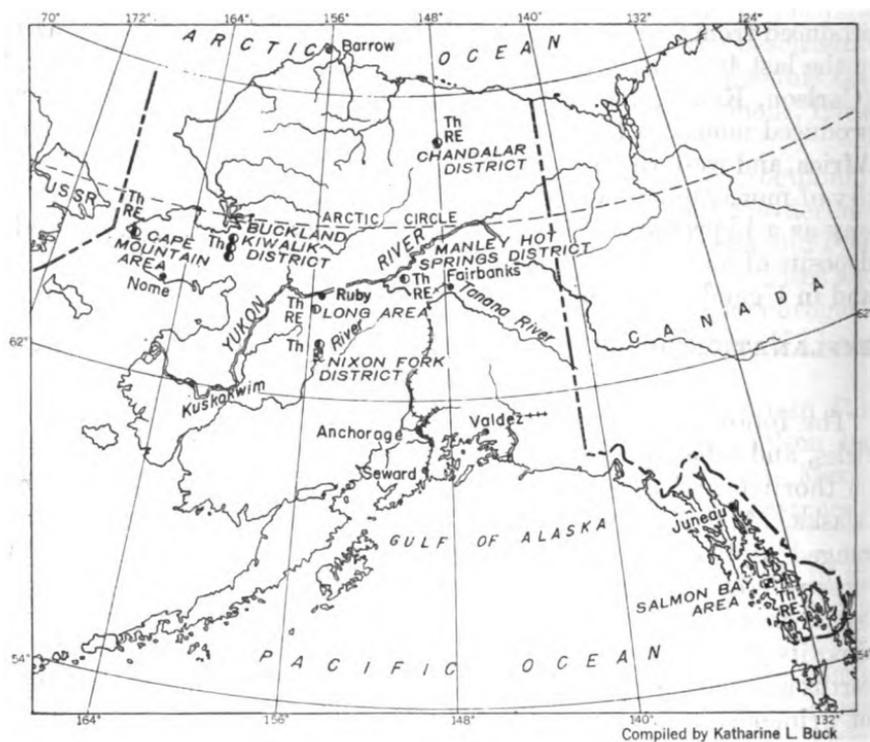
Monazite has been the principal ore of thorium and the rare earths produced from foreign deposits. The main world sources of monazite in the last 40 years have been the beach deposits of India and Brazil (Carlson, Keiser, and Sargent, 1953, p. 9). Other areas that have produced monazite from beach placers are Ceylon, Malaya, parts of Africa, and western Australia (Petar, 1935, p. 16, 17). A small quantity of monazite has been produced from pegmatites in southern Norway as a byproduct of feldspar mining (Petar, 1935, p. 18). Lode deposits of monazite have been reported in the Union of South Africa and in Uganda (Carlson, Keiser, and Sargent, 1953, p. 9).

EXPLANATION OF SELECTED ANNOTATED BIBLIOGRAPHY, INDEX, AND INDEX MAP

The following selected annotated bibliography includes books, articles, and other publications generally available in September 1954, on thorium and rare-earth deposits in the United States including Alaska. Many general papers are also included. Entries are arranged alphabetically by author. The index to the bibliography cross-references the authors' listing by locality and subject. An effort has been made to include in the bibliography references to those deposits which produce or may produce thorium and (or) the rare earths and to exclude those references dealing with minor occurrences of primarily mineralogic interest; however, the extensive Bibliography and Index of Literature on Uranium and Thorium and Radioactive Occurrences in the United States by Margaret Cooper (1953, 1954) does include references to such minor occurrences of thorium-bearing minerals and many rare-earth-bearing minerals.

The index maps (pl. 3 and fig. 1) show those deposits in the United States including Alaska for which information was available in September 1954 and which may produce, or have produced, thorium and (or) rare-earth-bearing minerals either as principal products or byproducts. The type of deposit is indicated by symbol, and the presence of important amounts of thorium or the rare earths is indicated by letters. The name of the mining district or area of the deposits is included on the map.

This report was prepared on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.



Production category	Type of deposit	
	Vein	Modern placer
Potential producer of thorium and (or) rare earths as the principal product	☐	
Potential producer of thorium and (or) rare earths as a byproduct		●

Abbreviations beside the map symbols indicate the commodities as follows:

Th Thorium and rare earths, Th Thorium only
 RE thorium predominating

FIGURE 1.—Index map of thorium and rare-earth deposits in Alaska.

SELECTED ANNOTATED BIBLIOGRAPHY

Abbott, A. T., 1954, Monazite deposits in calcareous rocks, northern Lemhi County, Idaho: Idaho Bur. Mines and Geology Pamph. 99, 24 p.

Between North Fork and Shoup, Idaho, immediately north of the Salmon River, several thin beds of marble are interbedded with the paragneisses and schists that belong to the vast assemblage of metamorphic rocks derived from the pre-Cambrian Belt series. Crystalline aggregates and disseminated crystals of the radioactive phosphate mineral monazite occur sporadically within the beds of marble. Other minerals commonly associated with the monazite are actinolite, barite, siderite, apatite, ilmenite and magnetite. A genetic interpretation involves the migration of rare earth elements during metamorphism of sandy, argillaceous sediments of the Belt series to a more compatible environment of phosphatic limestone in which porphyroblasts of monazite were formed. Although relatively little is known at the present time concerning the value of these deposits, results of this investigation should encourage further exploration and development.—*Author's abstract*

Argall, G. O., Jr., 1954, New dredging techniques recover Idaho monazite: *Min. World*, v. 16, no. 2, p. 28-30.

Dredging operations for monazite begun in Idaho in 1950 and now carried on by Baumhoff-Marshall, Inc., Idaho-Canadian Dredging Co., and the Warren Dredging Corp. are described in detail and are contrasted with dredging operations for gold.

The main recovery problem in dredging for monazite is caused by the irregularity and wide variation in heavy-mineral content of the sand which do not allow the jigs to be set for a uniform feed. Test drilling and sampling are used to block out areas for dredging, and churn drilling is operated directly ahead of the dredges.

This newly created mining industry has made the United States independent of imports of monazite.

Atkinson, A. S., 1910, Mining for the rare minerals: *Min. Sci.*, v. 61, p. 76-77.

Gadolinite from Llano County, Tex., and from Henderson County, N. C., has been mined and used for gaslight mantles. Gadolinite used in the Nernst lamp contains 40 to 45 percent yttria.

Bates, R. G., and Wedow, Helmuth, Jr., 1953, Preliminary summary review of thorium-bearing mineral occurrences in Alaska: *U. S. Geol. Survey Circ.* 202, 13 p.

Of the forty-seven known thorium-bearing mineral localities in Alaska, only a very few may have commercial possibilities. These are the Salmon Bay area, Prince of Wales Island; the Tofty tin belt in the Manley Hot Springs district, central Alaska; the Long area in the Ruby-Poorman district, central Alaska; the Nixon Fork area, central Alaska; the Buckland-Kiwalik district, eastern Seward Peninsula; the Cape Mountain area, western Seward Peninsula; and the Chandalar district, northeastern Alaska.

The thorium-bearing minerals at each locality are listed in the text and indicated on a map. Published and unpublished references are cited.

Burbank, W. S., and Pierson, C. T., 1953, Preliminary results of radiometric reconnaissance of parts of the northwestern San Juan Mountains, Colorado, U. S. Geol. Survey Circ. 236, 11 p.

Radiometric reconnaissance survey of parts of the San Juan Mountains resulted in the discovery of thorium-bearing quartz-carbonate-sulfide deposits in the Cebolla (Powderhorn) district, Gunnison County, Colo., uranium-bearing ores in several districts in Ouray and San Juan Counties. The pre-Jurassic thorium-bearing veins of the Cebolla district cut Precambrian schists and greenstone. The veins, which are not of economic significance at this time, have been subjected to several cycles of erosion and leaching. Locally they are jasperized. Leaching of uranium disintegration products in the Cebolla district is in progress. (See p. 2, 3.)

Cannon, H. B., 1950, Economic minerals in the beach sands of the southeastern United States, in Snyder, F. G., ed., Symposium on mineral resources of the southeastern United States: Knoxville, Tenn., Univ. of Tenn. Proc., 1950, p. 202-210.

According to present practice, an economically workable beach sand deposit in the southeastern United States must have a reserve of a million tons of minerals heavier than 3.0 specific gravity making up 4 or 5 percent of the sand. Smaller deposits must be of higher grade. The main ore mineral of beach sand deposits is ilmenite, and a deposit to be workable must contain two or three hundred thousand tons of this mineral. Ilmenite is used chiefly in the production of white pigment. Changes in the several variable characteristics of the mine often require costly changes in the processing plant. Therefore, ilmenite is usually purchased by the titanium pigment industry in large lots of known characteristics rather than in small odd lots.

Only two beach sand deposits are being worked in the southeastern United States, one 9 miles east of Jacksonville, Fla., and the other at Trail Ridge, 10 miles southwest of Jacksonville. Other deposits worked in the past in Florida were at Pablo Beach, Vero Beach, 2 miles inland from Vero Beach, and the west shore of Indian River lagoon.

It is probable that there are still undiscovered large high-grade economic ore bodies in the southeastern United States. Because of high water table, thick vegetation, and low-grade sand cover, discovery of such deposits requires systematic exploration programs using mechanical drills. The best deposits now known are in the old raised beaches, with only small deposits having been found in the modern beaches.

The sources of beach sand deposits of the southeastern States are the crystalline rocks of the southeastern Piedmont province. The heavy minerals have been concentrated, after erosion from the original rock and transportation by streams and rivers to the sea, into "stormline" deposits of heavy minerals on the active beaches or in lagoons and dunes.

The heavy minerals of Florida are divided into two assemblages, the Gulf coast assemblage and the Atlantic coast assemblage. Staurolite and kyanite are the main constituents of the Gulf assemblage. The Gulf assemblage also includes zircon with few inclusions, ilmenite containing 64 to 65 percent titanium oxide and no hornblende or epidote. In the Atlantic coast assemblage there is little staurolite and kyanite; hornblende and epidote are the main constituents. The zircon contains many inclusions, and the ilmenite contains only 52 to 56 percent titanium oxide. Other heavy minerals likely to occur in both assemblages are leucosene, rutile, monazite, tourmaline, pyroxene, garnet, andalusite, spinel, corundum, colophane, and limonite.

Carlson, E. J., Keiser, H. D., and Sargent, J. D., 1953, *Minor metals: Minerals Yearbook*, 1952, v. 1, p. 1178-1180 [preprint, p. 7-9].

The activities and success of the U. S. Bureau of Mines in searching for monazite in the Carolinas, Georgia, Florida, Idaho, Montana, and Wyoming are mentioned. The United States may soon become independent of foreign sources of rare earths because of the recent discoveries of monazite and bastnaesite deposits in this country. The principal producers of monazite in this country in 1952 are three Idaho companies—Baumhoff Marshall, Inc., the Warren Dredging Corp., and the Idaho-Canadian Dredging Co. Monazite is also produced by the Humphreys Gold Corp. of Jacksonville, Fla., and bastnaesite by the Molybdenum Corp. of America at Mountain Pass, Calif. Processors of monazite ores are Lindsay Chemical Co., which also processes bastnaesite concentrates; Rare Earths, Inc.; and Maywood Chemical Works.

The price of monazite in 1952 is quoted as 16½ cents per pound for 55 percent total rare-earth oxides plus thoria, f. o. b. domestic mill; 18¾ cents per pound for 64 percent; and 19 cents per pound for 65 percent. The price of mischmetal is \$4.50 and ferro-cerium \$8.00 per pound. Cerium metal of high purity is \$18.00 per pound. Rare-earth chlorides are quoted at 45 to 50 cents per pound.

A brief world review states that lode deposits of monazite have been found in the Union of South Africa and Uganda. Monazite sand discoveries are reported from Madagascar, Brazil, and Argentina.

Carlson, E. J., Kauffman, A. J., Jr., Keiser, H. D., and Needleman, Stanley, 1953, *Minor metals: Minerals Yearbook*, 1951, p. 1361-1363 [preprint p. 11-13].

The activities of the U. S. Bureau of Mines in searching for monazite in Idaho, Montana, and the Carolinas, are mentioned. Climax Molybdenum Co., Leadville, Colo., is listed as a producer of monazite. Purchasers, uses, and prices of monazite are listed along with a brief world review.

Christman, R. A., Heyman, A. M., Dellwig, L. F., and Gott, G. B., 1953, *Thorium Investigations, 1950-52, Wet Mountains, Colo.*: U. S. Geol. Survey Circ. 290, 40 p.

In the Wet Mountains, Colo., thorium-bearing minerals, principally thorite, occur in an area 20 miles long by 10 miles wide. The minerals occur in barite-sulfide veins in northwest-trending shear zones that cut a Precambrian igneous and metamorphic complex. The largest ore body is 300 feet long, 26 feet wide, and 400 feet deep. Some of the veins contain as much as 4.5 percent equivalent thorium oxide. Descriptions of the rock units and the deposits studied, geologic maps, logs of the 11 diamond-drill holes, and analyses of samples are included.

Cooley, C. M., 1953, *Storke level—Key to \$25 million Climax project*: Min. Eng., v. 5, no. 1, p. 36-41.

The flow sheet on page 41 shows clean monazite as a final product.

Cooper, Margaret, 1953 and 1954, *Bibliography and index of literature on uranium and thorium and radioactive occurrences in the United States*: Geol. Soc. America Bull., v. 64, p. 197-234, 1103-1172; v. 65, p. 467-590.

This extensive bibliography will cover uranium, thorium, and radioactive occurrences throughout the United States, although to date only the sections for Arizona, Nevada, and New Mexico (pt. 1); California, Idaho, Montana, Oregon, Washington, and Wyoming (pt. 2); and Colorado and Utah (pt. 3) have been published. The bibliography contains a listing of articles by author, a gazetteer by States, a geographical index, and a subject index. Geologic and mining

literature has been reviewed through 1949 and a few standard publications through early 1952.

Day, D. T., and Richards, R. H., 1906, Useful minerals in the black sands of the Pacific slope: *Min. Res. U. S.*, 1905, p. 1175-1258.

Heavy-mineral analyses of various black sands obtained from placer mines throughout the western States are presented in tabular form by locality. Descriptions of the methods by which the sands were concentrated, methods of testing and examining the sands, results of concentration, and a bibliography are included.

Fron del, J. W., and Fleischer, Michael, 1952, A glossary of uranium- and thorium-bearing minerals: *U. S. Geol. Survey Circ.* 194, 25 p.

This glossary contains a compilation of (1) minerals containing uranium and thorium as major constituents, (2) minerals containing uranium and thorium as minor constituents, (3) minerals that might show uranium or thorium content, and (4) minerals that often contain uranium, thorium, or the rare earths as impurities or intergrowths. Formulas but not properties are given for most of the minerals, and their relations to other minerals are indicated. The uranium and thorium content of each mineral is listed by percent.

Gillson, J. L., 1949, Titanium, in *Industrial minerals and rocks*: New York, Am. Inst. Min. Metall. Eng., 2d ed., p. 1042-1073.

The geologic history common to most commercial beach-sand deposits includes a source area of crystalline rocks, a period of deep-soil formation and the decomposition of magnetite, a period of uplift and rapid erosion of the soil zone, heavy-mineral deposition in coastal-plain sediments, subsidence and straightening of the coast, and, finally, elevation and erosion of the coast.

Glass, J. J., and Smalley, R. G., 1945, Bastnäsite: *Am. Mineralogist*, v. 30, p. 601-615.

Bastnaesite, a fluorocarbonate of cerium metals, occurs in the fluorspar deposits of the Gallinas Mountains, N. Mex., where the two minerals are associated with barite, barytecelestite, calcite, goethite, hematite, orthoclase, pyrite, quartz, and limonitic material along fissures and faults near the contacts of intrusive porphyritic quartz-monzonites, rhyolites, and syenites with Permian sediments that overlie Precambrian granites. The physical, optical, and chemical properties of bastnaesite specimens from this locality are described and compared with the properties of bastnaesite from five other localities. This comparison suggests that bastnaesite has a constant chemical composition. The comparison also indicates that most of the known occurrences of bastnaesite are in contact with metamorphic rocks. A bibliography is included.

Hess, F. L., 1908, Minerals of the rare-earth metals at Baringer Hill, Llano County, Tex.: *U. S. Geol. Survey Bull.* 340, p. 286-294.

A few hundred pounds per year of rare earths, mainly yttrium, and zirconium have been produced from this area for use in the Nernst lamp. The principal rare-earth minerals of the deposit are gadolinite, alanalite, cyrtolite, fergusonite, and polycrase containing the elements yttrium, beryllium, cerium, praseodymium, neodymium, lanthanum, zirconium, niobium, and uranium. The minerals occur in a pegmatite that has been intruded into Precambrian granite.

Houk, L. G., 1943, Monazite sand: *U. S. Bur. Mines Inf. Circ.* 7233, 19 p.

This report includes analyses of foreign and domestic monazite sands, world-production figures for the period 1893-1938, a review of tariff history, domestic

production and imports figures, a description of the uses of monazite, and a list of importers and consumers of monazite sands.

Kithil, K. L., 1915, Monazite, thorium, and mesothorium: U. S. Bur. Mines Tech. Paper 110, 32 p.

This paper presents the history of world production of monazite, including the German thorium conventions; descriptions of domestic and Brazilian deposits; methods of mining and milling monazite; a description of the separation, determination, and uses of mesothorium; and a selected bibliography on monazite, thorium, and mesothorium.

Kremers, H. E., 1949, The rare earth industry: Jour. of the Electrochem. Soc., v. 96, no. 3, p. 152-157.

The industrial treatment of monazite sand for the extraction of cerium and other rare earths and the uses of the rare earths are described briefly. A bibliography is included.

Levy, S. I., 1915, The rare earths, their occurrence, chemistry and technology: London, Edward Arnold, 345 p.

This well-documented older book includes descriptions of the minerals, the mode of occurrence, chemistry, and technology of the rare earths. The incandescent mantle industry, the chemical treatment of monazite, artificial silk and its application to the mantle industry, and other early technological and industrial uses of the rare earths are described.

Lindgren, Waldemar, 1898, The mining districts of the Idaho Basin and the Boise Ridge, Idaho: U. S. Geol. Survey 18th Ann. Rept., pt. 3, p. 677-679.

The heavy minerals derived from the granites of the Idaho Basin are found in the sand of the gravels and lake beds of the region. Throughout the basin, monazite forms a large percentage of the heavy minerals. Samples of monazite from 3 miles east of Idaho City and from Wolf Creek near Placerville are described. This is the first report of monazite placers in Idaho.

Mertle, J. B., Jr., 1949, Monazite, in Industrial minerals and rocks: New York, Am. Inst. Min. Metall. Eng., 2d ed., p. 629-636.

The characteristics, occurrence, production, economic control, and uses of monazite, the rare earths, and thorium are described. A bibliography is included.

——— 1953, Monazite deposits of the southeastern Atlantic States: U. S. Geol. Survey Circ. 237, 31 p.

Monazite, the principal ore mineral of thorium and the rare earths, was mined from fluviatile placers in the Piedmont province of the Carolinas from 1887 to 1917 with some interruptions. From 1917 to 1946 monazite was imported from India and Brazil; since 1946 the embargoes on exportation of foreign monazite have made it a scarce commodity in this country. Monazite is now being produced in Idaho as well as in Florida, where it is a byproduct of the ilmenite mining near Jacksonville.

New deposits of monazite have been discovered in the southeastern Piedmont, and the placers which were formerly mined have been re-evaluated. The latter were not exhausted by mining and many of the deposits have been rejuvenated. Mining in the area is complicated by the predominance of farming and by the uncertainty of the future value of monazite. These deposits are, however, a reserve which could be invaluable in a time of emergency.

Monazite in the southeastern Piedmont province of complex metamorphic and igneous rocks occurs in two belts, a western belt that is traced from east-central

Virginia southwestward into Alabama and an eastern belt from near Fredericksburg, Va., south-southwestward into North Carolina. These monazite belts may have been the sites of Precambrian valleys where detrital monazite was concentrated and later reconstituted into gneisses or remelted into intrusives.

The western monazite belt includes the area of placers formerly mined in the Carolinas. Results of sampling of the early headwater placers show as much as 8.4 pounds of monazite per cubic yard and a mean content of 5.7 percent thorium oxide. These placers do not contain enough yardage to be mined by large-scale methods.

The principal source rocks in the monazite belts are certain granitic intrusives, granitized and pegmatized country rock, and certain granitic phases of the Carolina gneiss. There is a mean tenor of 0.006 percent monazite in the bedrock.

Moxham, R. M., 1954, Reconnaissance for radioactive deposits in the Manley Hot Springs-Rampart district, east-central Alaska, 1948: U. S. Geol. Survey Circ. 317, 6 p.

The radioactive minerals eschynite, ellsworthite, columbite, monazite, and zircon have been found in the gold-tin placer deposits of the Tofty area, east-central Alaska. The bedrock source of these minerals was not found, although monazite is present in the granite country rock; geologic data suggest a common local bedrock source for both the cassiterite and the radioactive minerals of the Tofty tin placers.

Under present conditions the radioactive minerals of the Tofty placers are probably not sufficiently concentrated to be recovered as a byproduct of the gold and tin mining.

Murata, K. J., Rose, H. J., Jr., and Carron, M. K., 1953, Systematic variation of rare earths in monazite: *Geochim. et Cosmochim. Acta*, v. 4, p. 292-300.

Ten monazite samples from scattered localities have been analyzed for the individual rare-earth elements by a combined chemical and emission spectrographic method. Rules are given for the variation in the proportions of the rare-earth elements. Variation trends are explained by fractional precipitation and deviations from the trends by abnormally high or low temperatures.

Nininger, R. D., 1954, *Minerals for atomic energy*: New York, Toronto, London, D. Van Nostrand Co., Inc., 367 p. (See especially p. 16, 17, 87, 89, 91-100, 116, 128-131, 133-139, 142, 172-176, 213, 218, 219, 228, 229, 242, 243.)

Uranium, thorium, and beryllium minerals are discussed in this useful book according to their mineralogy and deposits, to the possibility of their occurrence in various broad geographic and geologic settings, and according to the equipment used in prospecting. Also discussed in detail are regulations pertinent to prospecting for these metals, along with the evaluation of discoveries, and a review of services available to the prospector by governmental and private agencies for sample examination and assay, property examination, and financial aid. Generalized maps of the United States and of the world show occurrence of these elements and their relation to various geologic features. Selected references are listed.

Marketing of the minerals is discussed, and a list of companies that may be interested in the purchase of monazite and rare-earth ores is found on page 309.

The mineralogy of thorium is described in some detail, and tables of the characteristics and tests for the identification of the various minerals are included. The productive deposits of monazite and significant deposits of other thorium minerals in Brazil, India, Ceylon, Indonesia, Malaya, Australia, the Union of South Africa, and the United States are briefly described.

The edges of the Precambrian shield areas of the world have produced the important primary deposits of uranium, but thorium minerals occur only as minor disseminated constituents of these old masses. The concentration of thorium minerals into placer deposits is aided by the mechanical and chemical breakdown of the parent rocks which is carried on most rapidly and to the greatest degree in those shields found in warm climates, such as the Brazilian and Indian shields.

Massifs or roughly equidimensional mountainous areas, seem to be favorable for primary uranium deposits but less so for thorium and beryllium. Examples of massifs which are source areas for placer deposits of monazite are the mid-African Highlands which contribute to the beach placers of Sierra Leone, to the river placers of the Gold Coast, and to the tin placers of central and southern Nigeria which also contain monazite and thorite, and the Korean Highlands which are a source of commercial monazite deposits.

The great linear mountain systems of the world with their large areas of crystalline rocks and their associated basins and plateaus of sedimentary rocks have produced great amounts of metals and offer many possibilities for primary and secondary deposits of uranium and thorium. The principal mountain chains of North and South America, the Alpine-Himalayan system, and the East-Australian Cordillera, are described in detail.

The broad plains areas of sedimentary rocks offer little possibility for primary deposits of uranium and thorium but may contain some secondary deposits of these metals. Local areas of igneous and metamorphic rocks within the plains may contain primary deposits of thorium minerals, and there may be secondary deposits near these source rocks.

Coastal lowlands near granitic source rocks may contain placers of monazite or of other minerals from which monazite may be obtained as a byproduct. Such deposits occur in the southeastern United States.

Nitze, H. B. C., 1895a, Monazite and monazite deposits in North Carolina: N. C. Geol. Survey Bull. 9, 47 p.

Monazite is briefly described and its history, nomenclature, and crystallography are reviewed. Chemical analyses of monazite from various localities are given. The geologic and geographic occurrence of monazite is described. Also covered are the uses, methods of extraction and concentration, and the production and value of monazite. A bibliography is included.

——— 1895b, Monazite: U. S. Geol. Survey 16th Ann. Rept., pt. 4, p. 667-693.

The mineralogical and chemical nature of monazite is described and a brief sketch is given on the history and nomenclature of the mineral. The methods of analysis are presented. Geologic and geographic occurrence of monazite is presented in tabular form. The uses, methods of extraction and concentration, production and value are described. A good early bibliography is included.

Olson, J. C., Shawe, D. R., Pray, L. C., and Sharp, W. N., 1954, Rare-earth mineral deposits of the Mountain Pass district, San Bernardino County, Calif: U. S. Geol. Survey Prof. Paper 261, 75 p.

Bastnaesite, a rare-earth fluorocarbonate, was discovered in the Mountain Pass district in April 1949. Geologic mapping has shown that rare-earth mineral deposits occur in a belt about 6 miles long and $1\frac{1}{2}$ miles wide. One deposit, the Sulphide Queen carbonate body, is the greatest concentration of rare-earth minerals now known in the world. The report describes the district, the history of

the discovery, the rare-earth and thorium deposits, and the alkalic igneous rocks with which the deposits are associated. Geologic maps of the district and of selected mineral deposits accompany the report.

The radioactive minerals occur in mineralized shear zones characterized by abundant hematite and goethite and in the carbonate rocks. The radioactivity is due almost entirely to thorium and its decay products. The uranium content of vein samples, determined chemically, is low, the highest value being 0.020 percent uranium. Thorium oxide, however, is more than 2 percent of some selected samples. The strongest radioactivity is attributable chiefly to thorite and thorumgumite and, to a lesser extent, to monazite which occurs in and near the Sulphide Queen carbonate body.

Parks, R. D., 1949, Source materials for nuclear power, in Goodman, Clark, ed., *The science and engineering of nuclear power*; Cambridge, Mass., Addison-Wesley Press, Inc., v. 2, p. 1-18.

Thorium is not a particularly scarce element in the earth's crust; it is found in about the same quantity as tin, cobalt, zinc, or lead. Economically workable concentrations of thorium are, or have been, less common than those of tin, cobalt, zinc, or lead.

Monazite, for all practical purposes, has been the only commercial source of thorium, and it is generally considered to have been derived from pegmatite sources. Economic deposits have been concentrated into placers by the weathering of such pegmatites.

The monazite mining capacity of India is about 7,000 tons per year, which could be increased by shifting operations from low-monazite high-ilmenite sands to sands richer in monazite. The monazite mining capacity of Brazil is about 1,500 tons per year, which could be increased by adding equipment or going on two shifts. Australia's capacity is about 100 tons per year.

The monazite reserves of India were estimated 25 years ago to be over 2 million tons on a basis of beds 2 feet thick containing 10 percent monazite. They have not been seriously depleted. Brazilian deposits are thought to be of similar magnitude. Ceylon deposits are stated to be very rich but not extensive.

Petar, A. V., 1935, *The rare earths*: U. S. Bur. Mines Inf. Circ. 6847, 46 p.

This is a general paper, with a good bibliography, on the rare earths. A description and list of properties of the individual elements by family are included, and the history of their discovery is reviewed. Tables are presented of the abundances of rare earths in the earth and of rare-earth-bearing minerals and their occurrence. The chemical separation of these elements and the rare-earth industry, both foreign and domestic, are described. Tables of imports and exports, a discussion of tariff regulations, markets and prices, and a list of producers, dealers, and possible buyers of rare earths are included.

Pratt, J. H., 1916, Zircon, monazite, and other minerals used in the production of chemical compounds employed in the manufacture of lighting apparatus: N. C. Geol. and Econ. Survey Bull. 25, p. 19-69.

This is an excellent report on monazite and the rare earths. A description of the yttrium minerals is given with special attention to gadolinite. Thorium-bearing minerals are also described. Monazite is described as a source of thorium and cerium for use in incandescent lamp mantles, and its occurrence is covered thoroughly by a table of foreign and domestic localities, which lists the country rock and minerals associated with each locality. The uses of

lanthanum are reviewed. The Carolina and Idaho areas are described in more detail. Production in North Carolina from 1893 to 1915 is reviewed. A full description is given of the mining and cleaning of the Carolina monazite sands, including an attempt at mining saprolite. A description of the Brazilian deposits, the history of foreign trade in monazite, and import and export data on monazite and thoria are included.

Pratt, J. H., 1917, Monazite in the United States: Mineral Foote-Notes, v. 1, no. 10, p. 3-15.

A table of occurrences of monazite lists for each locality the country rock and associated minerals. The Carolina and Idaho deposits and the types of rock in which they occur are discussed. A description of monazite and a brief discussion of its uses are included.

Pratt, J. H., and Sterrett, D. B., 1910, Monazite and monazite-mining in the Carolinas: Am. Inst. Min. Eng. Trans., v. 40, p. 313-340.

Monazite and its occurrences in the United States are described along with the geology and deposits of the Carolina monazite region. A description of the separation and uses of monazite is included.

Roots, E. F., 1946, Cerium and thorium: Western Miner, v. 19, no. 8, p. 50-56.

Minerals carrying cerium and thorium (particularly monazite, thorite, auelite, thorianite, and xenotime) are described, and placer and lode deposits of cerium- and thorium-bearing minerals, both foreign and domestic, are reviewed. Other items covered are the production and consumption of cerium and thorium; mining and milling; marketing, shipping, and duties; extraction of cerium and thorium compounds from monazites; byproducts and utilization; and grades, prices, and buyers of cerium and thorium products and ores.

Santmyers, R. M., 1930, Monazite, thorium, and cerium: U. S. Bur. Mines Inf. Circ. 6321, 43 p.

Thorium- and cerium-bearing minerals and ores, especially monazite, are reviewed, and tests for their identification, history of their discovery, and brief descriptions of their mode of occurrence and geographical distribution are given. Other topics especially well covered are domestic and world production, imports, exports, trade, and the tariff history of monazite, thorium, and cerium. The incandescent gas-mantle industry is described and other uses of thorium and cerium are discussed. Mesothorium is described and imports listed. A good bibliography is included.

At Mineral City, Fla., 4 miles south of Jacksonville Beach, monazite, along with zircon and rutile, was recovered as a byproduct of ilmenite mining (see p. 11). In 1925 there was a reported production of 2,000 pounds of monazite from this deposit.

Schaller, W. T., 1922, Thorium, zirconium, and rare-earth minerals: Min. Res. U. S., 1919, pt. 2, p. 1-32.

This report includes a review of the thorium and rare-earth industry with production and import data, both foreign and domestic; foreign and domestic producing localities; uses; and a review of the sources of ore. Monazite, thorite, auelite, and thorianite are described; analyses of foreign and domestic monazites with percentage of thoria are given. A good selected general bibliography covering foreign and domestic occurrences is included.

Schrader, F. C., 1910, An occurrence of monazite in northern Idaho: U. S. Geol. Survey Bull. 430, p. 184-191.

Occurrences of monazite are reported in Idaho on Mussel Shell Creek, Nez Perce (now Clearwater) County, near Dent, and in the Pierce district, Idaho. The Mussel Shell Creek deposit is described, and analyses of the monazite from this locality are given.

The origin and distribution of monazite in Idaho are discussed and related to the Idaho batholith. A bibliography is included.

Sharp, W. N., and Pray, L. C., 1952, Geologic map of bastnaesite deposits of the Birthday claims, San Bernardino County, Calif.: U. S. Geol. Survey Min. Inv. Field Studies Map MF 4.

The Precambrian metamorphic complex, country rock in the Birthday claims area, is intruded at the Birthday claims by a body of shonkinite which contains most of the bastnaesite veins in the area. The shonkinite and enclosing gneiss are cut in turn by fine-grained granite bodies and other intrusives.

The barite-rich bastnaesite-bearing carbonate veins follow a west- to north-west-trending fracture system which cuts the Precambrian metamorphic complex as well as the intrusive sequence. The veins have been divided into six types on the basis of mineral content.

The main minerals of the veins are bastnaesite, calcite and other carbonates, barite, quartz, and fluorite. The paragenesis of the minerals, at least locally, is bastnaesite, barite, and the carbonates. Quartz and fluorite may have been deposited later.

Thorium is the main radioactive element in the veins and in the shonkinite, which is more radioactive than the country rock. The largest concentrations of thorium and uranium are in limonitic alteration products found in the weathered veins. Small amounts of these elements occur in the bastnaesite.

Sloan, Earle, 1908, Catalogue of the mineral localities of South Carolina: S. C. Geol. Survey, 4th ser., Bull. 2, p. 129-142.

The geographic limits of monazite zones in South Carolina are described, and detailed locations of monazite gravels in the State are given.

Soulé, J. H., 1946, Exploration of Gallinas fluorspar deposits, Lincoln County, N. Mex.: U. S. Bur. Mines Rept. Inv. 3854, 25 p.

Bastnaesite was discovered in the Gallinas deposits during the Bureau of Mines drilling program in 1943-44. Methods for separating the bastnaesite are discussed. Analyses of bastnaesite are included.

Staley, W. W., 1948, Distribution of heavy alluvial minerals in Idaho: Idaho Bur. Mines and Geology Min. Res. Rept. 5, 12 p.

The mineralogical and chemical composition of black sands, their commercial use, and the distribution of such sands in Idaho are described. Assay results on Idaho heavy sands are given by localities along with chemical and spectrographic analyses. The estimated tonnages of monazite, zircon, and ilmenite available in Idaho are listed; the amount of monazite is 181,500 tons.

Staley, W. W., and Browning, J. S., 1949, Preliminary investigation of concentrating certain minerals in Idaho placer sand: Idaho Bur. Mines and Geology Pamph. 87, 23 p.

Increasing interest in certain heavy minerals accumulated in placer deposits led to this study on the methods of concentrating monazite, zircon, ilmenite, and magnetite in material obtained primarily from dredging operations in the

Boise Basin, Idaho. The experimental method found successful in separating these minerals is a combination of screening, flotation, and magnetic separation.

Sterrett, D. B., 1907, Monazite and zircon: Min. Res. U. S., 1906, p. 1195-1209.

The monazite industry as a whole is reviewed, and the geology of monazite deposits and the mining and cleaning of the monazite sand in North Carolina, South Carolina, and Georgia are described. The deposits in Idaho and in foreign countries are reviewed. Figures are given on price, production, imports and exports of monazite.

— 1911, Monazite and zircon: Min. Res. U. S., 1909, pt. 2, p. 897-905.

The monazite deposits near Centerville, Idaho, the operation of the Centerville Mining and Milling Co. along Grimes and Quartz Creeks, Idaho, and the methods of mining and concentrating are described. Estimates of the monazite and thoria content of the deposits are given.

Trites, A. F., and Tooker, E. W., 1953, Uranium and thorium deposits in east-central Idaho and southwestern Montana: U. S. Geol. Survey Bull. 988-H, p. 157-209.

Monazite occurs in Precambrian pegmatites of the Deer Creek district, Montana (p. 184-191), at the Divide nos. 1 and 2 claims and at the Gray Goose claims where allanite also occurs in the pegmatite. The Lookout no. 3 claim in the same district contains an hydrothermal carbonate vein, a sample of which contained 0.24 percent thorium oxide and 2.71 percent rare earths, cutting Precambrian (?) gneissic hornblende diorite.

The 11 deposits examined in the Lemhi Pass district (p. 191-208) contain thorium. Thorite is the main thorium-bearing mineral and occurs in quartz-hematite veins which fill fractures in the Precambrian Belt series and which measure from less than 1 foot to 50 feet in width and from 10 to more than 700 feet in length. Other minerals in the veins are goethite, chalcedony, and barite. Samples from the veins contain as much as 6.6 percent calculated thorium oxide, and spectrographic analysis indicates the presence of yttrium, cerium, samarium, neodymium, gadolinium, and lanthanum.

Copper veins also occur as fracture fillings in the Belt series in the Lemhi Pass district. The radioactivity of these veins is similar to that of the quartz-hematite veins, and it is thought to be caused by thorium.

The claims and mines checked in the Lemhi Pass district are the Wonder Lode mine, the Buffalo nos. 1 and 2 claims, the Wonder Lode no. 18 claim, the Lucky Strike nos. 1 and 2 claims, the Trapper nos. 1 and 4 claims, the Radio claim, the Brown Bear claim, the Last Chance claim, and the Shady Tree claim.

United States Atomic Energy Commission, 1954, Sixteenth semiannual report of the Atomic Energy Commission: Washington, D. C., U. S. Govt. Printing Office, p. 25.

The Atomic Energy Commission now has an homogeneous thorium reactor in the planning stage. This reactor will use thorium as a blanket from which uranium 233 will be produced. Construction of the reactor is planned to begin in the fiscal year 1957 and to be completed in the fiscal year 1959.

United States Congress Documents, 1952, 82d Cong., 2d sess., H. Doc. 527, v. 4, p. 22, 23, 112-114.

The current need to increase domestic supplies of thorium and the rare earths has led to the discovery of deposits of monazite in Idaho and bastnaesite in New Mexico and California. New techniques for separating the rare earths will

make it possible to develop new individual uses for these elements, which are now often used in the mixture known as mischmetal.

Embargoes on the exportation of monazite from Brazil and India have raised the price of domestic monazite. The development of new uses for the rare earths has been discouraged because the supply has been considered limited and the price, even of foreign ore, has been unstable. The recent bastnaesite discoveries could supply all the current requirements for rare earths for many years, and monazite mining could be abandoned if bastnaesite had a higher thorium content. Hence the thorium content of monazite continues to make it a mineral essential to our nation, and it is estimated that the probable production of monazite from Idaho will be from 3,000 to 5,000 tons a year for the years 1952 to 1955.

Experiments with pure thorium are being carried on, and they indicate that the properties of the metal are such that there will be a continuing demand for thorium, even outside the field of atomic energy.

United States Congress Documents, 1953, 83d Cong., 1st-2d sess., Hearings on S. R. 143, pt. 1, p. 211-219.

The United States is now becoming self-sufficient in rare-earth metals, largely through the intense search made for rare-earth-bearing minerals since 1950. Promising deposits and adequate reserves of monazite have been found in South Carolina and in Idaho, and a large deposit of bastnaesite has been found at Mountain Pass, Calif. Foreign supplies have been seriously curtailed since January 1951, although there is a possibility that these sources might be reopened to the United States. Shipments of monazite have been contracted for from Africa for a 3-year period.

Substitutes are available for the rare earths in certain of their uses, such as in carbon-arc electrodes and in flints for lighters.

Recommendations made to assure adequate supplies of rare earths are:

1. A stockpile sufficient for a 5-year emergency.
2. Continued exploration for new placer deposits of monazite and byproduct minerals.
3. Development of markets for the byproduct minerals of monazite placer mining.
4. Continued studies to improve recovery of monazite and heavy minerals from placers and to improve extraction of rare earths from the ore.
5. Extensive study of the treatment of bastnaesite and its separation from gangue minerals.
6. Studies of the separation of individual rare-earth elements from their ores.
7. Research in metallurgy on the value and uses of the individual rare-earth metals.

West, W. S., and Matzko, J. J., 1953, Buckland-Kiwalik district, 1947, in Gault, H. R., and others, Reconnaissance for radioactive deposits in the northeastern part of the Seward Peninsula, Alaska, 1945-47 and 1951: U. S. Geol. Survey Circ. 250, p. 21-27.

Uranothorianite and thorite are the most important of the radioactive minerals found widely distributed in the Buckland-Kiwalik district. These minerals occur mainly in well-defined placer zones within areas of granitic rock and are thought to be concentrated accessory minerals from the differentiate phases of certain of the granitic rocks. It is possible, however, because of the presence of metallic sulfides, that some of the uranium was introduced during a period of hydrothermal alteration of the granitic rocks. Concentrations of uranothorianite are found in the headwaters of the Peace River and Quartz and Sweepstakes

Creeks on Granite Mountain; in the Hunter Creek-Connolly Creek area; and on Clem Mountain. The Peace River placer locality may be a lead to a high-grade uranium lode.

White, M. G., and Stevens, J. M., 1953, Reconnaissance for radioactive deposits in the Ruby-Poorman and Nixon Fork districts, west-central Alaska, 1949: U. S. Geol. Survey Circ. 279, 19 p.

In the Long area of the Ruby-Poorman district are two small granite bodies with an average equivalent uranium content of 0.005 percent. This radioactivity is due largely to uranorthorite(?) disseminated throughout the granite. No high concentrations of the mineral were found.

In the Nixon Fork district uraniferous thorianite, allanite and other radioactive minerals whose radioactivity is principally due to thorium, were found in the placers of Hidden, Ruby, and Eagle Creeks. Bedrock occurrences are found at the Whalen mine where the rare-earth mineral parisite is found along with allanite, radioactive hematite and sphene, and zircon; in the monzonite of the Ruby Creek area which contains zircon and sphene; and the Nixon Fork mine.

Anonymous, 1949a, Monazite production: Min. Cong. Jour., v. 35, no. 7, p. 71.

Rare Earths Mineral Co., McCall, Idaho, is extracting monazite from Idaho sands and is contracting to ship 16,000 tons of concentrated sand during the next 10 years.

——— 1949b, Monazite research: Min. Cong. Jour., v. 35, no. 9, p. 82.

University of Idaho School of Mines is conducting a research program on the rare earths recovered as byproducts in the milling of monazite sand.

Idaho placer gravels are being treated for monazite content at a plant at McCall, Idaho.

——— 1950a, Idaho—Operation of a bucket-line dredge on Big Creek: Eng. Min. Jour., v. 151, no. 11, p. 130.

A bucket-line dredge on Big Creek, Idaho, is producing monazite and gold and is handling 5,000 to 6,000 yards of gravel daily.

——— 1950b, Wyoming—Atomic energy representatives investigating the uranium deposits reported at Sundance: Eng. Min. Jour., v. 151, no. 6, p. 128.

The uranium deposits at Sundance, Wyo., contain low-grade uranium and rare-earth oxides.

——— 1952a, Companies join with Heim to develop bastnasite: Eng. Min. Jour., v. 153, no. 1, p. 108.

The Gallinas district, Lincoln County, N. Mex., produces each month several carloads of rare-earth ore which is shipped to Lindsay Light & Chemical Co.

——— 1952b, Fred Baumhoff, Centerville, Idaho: Eng. Min. Jour., v. 153, no. 2, p. 168-169.

Fred Baumhoff, operating near Cascade, Idaho, has shipped 1,000 tons of monazite to Lindsay Light & Chemical Co.

——— 1952c, Southern California's rare-earth bonanza: Eng. Min. Jour., v. 153, no. 1, p. 100-102.

The massive bastnaesite-barite veins of the Mountain Pass district are described, and an estimate of their size and grade is given. The ore-dressing problem is discussed. A history of the discovery and development of the district is presented.

Anonymous, 1954a, Atlantic beaches radioactive: *Min Cong. Jour.*, v. 40, no. 1, p. 63.

The U. S. Geological Survey has released maps showing the location of radioactivity anomalies detected along parts of the Atlantic Ocean beach from Cape Henry, Va., to Cape Fear, N. C., and from Savannah Beach, Ga., to Miami Beach, Fla. These anomalies may or may not indicate the presence of uranium or thorium.

——— 1954b, Dredges work Idaho sand: *Eng. Min. Jour.*, v. 155, no. 3, p. 190.

Dredges operating in the Long Valley, Idaho, area are recovering monazite from gravels which contain about 15½ pounds per cubic yard of black sand which in turn contains about 7½ percent monazite. The black sand is separated at Boise in the Baumhoff-Marshall, Inc. plant. Half of the monazite, which contains about 60 percent rare-earth metals, is purchased by Lindsay Light & Chemical Co. and half by the Government for stockpiling.

Bear Valley, Idaho, is reported to be a new source of radioactive elements, including thorium and rare earths. Production in Bear Valley is scheduled to begin by September 1954.

——— 1954c, Idaho dredge plans: *Min. Cong. Jour.*, v. 40, no. 8, p. 127.

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Bibliography of Titanium Deposits of the World

GEOLOGICAL SURVEY BULLETIN 1019-G



Bibliography of Titanium Deposits of the World

by ROBERT LAWTHERS *and* HELEN R. MARK

CONTRIBUTIONS TO BIBLIOGRAPHY OF MINERAL RESOURCES

GEOLOGICAL SURVEY BULLETIN 1019-G

Including references published through December 31, 1955



UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON: 1957

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

**For sale by the Superintendent of Documents, U. S. Government Printing Office
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1. 凡欲求學問者，必先求其心。心者，身之主也。心正則身正，心邪則身邪。故曰：心正體直。

2. 心之動也，有善有惡。善者，天理也；惡者，人欲也。天理者，性之德也；人欲者，情之動也。

3. 性者，天之賦也；情者，天之動也。性本善，情本惡。性之善也，猶天之有日月也；情之惡也，猶天之有風雷也。

4. 天之有日月也，不可一日無之；天之有風雷也，不可一日無之。性之善也，不可一日無之；情之惡也，不可一日無之。

5. 性之善也，猶天之有日月也；情之惡也，猶天之有風雷也。性之善也，不可一日無之；情之惡也，不可一日無之。

6. 性之善也，猶天之有日月也；情之惡也，猶天之有風雷也。性之善也，不可一日無之；情之惡也，不可一日無之。

7. 性之善也，猶天之有日月也；情之惡也，猶天之有風雷也。性之善也，不可一日無之；情之惡也，不可一日無之。

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10. 性之善也，猶天之有日月也；情之惡也，猶天之有風雷也。性之善也，不可一日無之；情之惡也，不可一日無之。

CONTRIBUTIONS TO BIBLIOGRAPHY OF MINERAL RESOURCES

BIBLIOGRAPHY OF TITANIUM DEPOSITS OF THE WORLD

By ROBERT LAWTHERS and HELEN R. MARK

INTRODUCTION

Since early 1951, when the U. S. Geological Survey issued Circular 87, "Bibliography on titanium," by J. R. Carpenter and G. W. Luttrell, the titanium industry has continued to expand. Not only has the production of titanium metal advanced from the experimental stages to become a new and important industry, but the production of titanium pigments has increased. As a result of this expansion, new sources of titanium ore have been developed. This bibliography has been prepared, therefore, to fulfill the need for a comprehensive, up-to-date compilation of the literature on raw materials used by this important industry.

The preparation of the bibliography was facilitated by consulting references given in Circular 87, and by using articles obtained during the senior author's studies of the worldwide resources of titanium (manuscript in preparation).

The authors acknowledge with thanks the assistance given by A. P. Cerkel during initial phases of the compilation.

EXPLANATION OF THE BIBLIOGRAPHY

This bibliography contains about 600 references selected to provide information on the resources and utilization of titanium deposits; it includes articles on the geology, resources, exploration, mining methods, and beneficiation of deposits. Because some general background information is necessary for a proper evaluation and understanding of the economics of titanium, a few articles are included on the mineralogy of titanium minerals, the geology of rocks in which titanium deposits occur, and the petrology and geochemistry of mineral assemblages that are common to both titaniferous and other deposits.

The utilization of a deposit depends, in part, on mining and ore-dressing techniques, hence articles on these subjects relevant to certain deposits are included.

Production and consumption statistics, information on uses of titanium

compounds, methods of producing metal and pigments, and other data on various phases of the titanium industry are of secondary importance in this bibliography. Such material has been treated comprehensively in other reports. (See, for example, Archer and Gibson, 1953; Brophy, Archer, and Gibson, 1952; and DuMont, 1947).

The bibliography has been compiled from domestic and foreign publications available through December 31, 1955, in libraries in the Washington, D.C., area. Most of the entries were obtained from publications in the U. S. Geological Survey Library and the Central Library of the Department of the Interior.

Individual references are given in the language that appears on the title page of the publication. Exceptions are references by Japanese and Chinese publications, which are given in English. A translation, within the citation, of the title and publication of some foreign entries, particularly Russian, is inclosed in brackets. In some instances brief notes have been added at the end of the citation, and where there were no titles, brief bracketed titles have been supplied.

Much information published as short articles in the "current events" sections of technical journals is of interest only for a short time. However, all such articles that contain material believed to be of permanent value have been included in the bibliography.

Annual summaries of developments in the titanium industry appear in many technical journals and publications of State and Federal geological surveys and mining bureaus. Although many of these reports give excellent annual summaries, the references included in this bibliography are those which contain information on titanium deposits that has not been published elsewhere. Exceptions are the issues of the Minerals Yearbook from 1940 to the present, which are included because they provide excellent summaries of the years of greatest development of the domestic titanium industry. The annual volumes of the Minerals Yearbook have been published for the years 1932-33 to the present by the U. S. Bureau of Mines. They were preceded by the annual volumes of the Mineral Resources of the United States, issued for the years 1924 through 1931 by the Bureau of Mines, and from 1882 through 1923 by the U. S. Geological Survey.

The references in this bibliography are listed by authors in alphabetical order; those by anonymous authors are at the end. All citations are cross-indexed, and the index is subdivided to include such topics as location of deposit, geology, resources, mineralogy, petrology, and mining activities. Information pertaining to production, consumption, trade statistics, metal technology, uses of titanium products, and related subjects is not indexed completely, because the principal purpose of the bibliography is to provide references on deposits of titanium.

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Ural Mountains.

General:

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Europe—Continued

Union of Soviet Socialist Republics—Cont.

Ural Mountains—Continued

- Barksdale 1949
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- Gorskly 1939
- Hess and Gillson 1937
- Lawthers 1954
- Malyshev 1936
- Panteleyev and Malyshev 1934
- Shimkin 1953
- Suirokovski 1926
- Vogel, F. 1950

Kusa deposit:

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- Gmelin-Institut 1951
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- Shimkin 1953
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- Warren 1918

Exploitation and utilization of titaniferous deposits.

General:

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- Singewald 1913b

Development plans.

Maryland.

- Cove Point: Anonymous 1955g

Mexico.

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Possibilities of utilization.

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- Buenos Aires Province coastal sands: Lannefors 1929

New Zealand.

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California.

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New York.

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Possibilities of utilization—Continued

United States—Continued

Virginia.

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Wyoming.

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Hawaii.

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Florida.

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- Folkston area: Moxham 1954

South Carolina.

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- Hammond 1952
- McDonald 1951

United Nations 1955

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- Ivry deposit: Osborne 1936

- Natashkwan sand deposits: United Nations 1955

- St. Urbain: Gillson 1932

Norway.

- Ekersund-Soggedal area: Anonymous 1955u, w

United States.

New York.

- Lake Sanford area: Balsley 1943

Oregon.

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Wyoming.

- Laramie Range: Dempsey 1955

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Methods of test-drilling.

Florida.

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Idaho.

- Long Valley area, Cascade: Argall 1954

Virginia.

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Results of test-drilling.

Arkansas.

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- Magnet Cove area: Dupuy 1949

Exploration—Continued

Results of test-drilling—Continued

Arkansas—Continued

Magnet Cove area—Continued

Fryklund and others 1954

Magnet Cove Rutile Co. deposit:

Reed 1949b

Spencer 1946

Florida.

Buried heavy mineral sands, central and northeast part of state:

Thoenen and Warne 1949

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Mina Podesta: Bassi 1952

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New South Wales:

Poole 1939

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Beach deposits—Continued

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Fróes Abreu 1933, 1936a
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Jobim 1941
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Alberta.

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Quebec.

General: Dulleux 1915

Allard Lake:

Bateman 1951
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Illingworth 1952
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Bay of Seven Islands area:

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Faessler and Schwartz 1941
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Degrosbols deposit:

Dulleux 1913, 1915
Osborne 1936

Geology—Continued

Canada—Continued

Quebec—Continued

Ivry deposit:

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Osborne 1928, 1936
Robinson 1922

St. Charles prospect, Chicoutimi county:

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MacKenzie 1912b

St. Urbain:

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Attia 1950, 1952
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England.

Cornwall.

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French West Africa—Continued
Senegal.

Coastal beach deposits:

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la Rüe 1932
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Germany.

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Gold Coast:

- Junner 1950

Greenland.

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Hungary.

Szarvasko, Bükk Mountains:

- Pantó 1952
Szentpetery 1937

India.

Titaniferous magnetite deposits:

- Dunn and Dey 1937
Fox 1926
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Swanmathan 1928
Tipper 1936

Travancore.

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Chambers 1939
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Krishnan and Roy 1942
Tipper 1914
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Japan.

Fukuahima Prefecture.

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- Andrews 1947
Kikuchi and others 1955
Maeda 1935
Mitsuchi 1952
Staatz 1947, 1948

Korea.

Kyonggi-do—Porum-do:

- Gallagher and others 1946

Shoenpeito deposit: Ichimura 1931

Madagascar:

- Gulgues 1951
Lacroix 1920

*Malaya.*Tin-bearing placer deposits: Scriver
nor 1928*Mexico.*

Guerrero.

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jorada 1952

Oaxaca.

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Mejorada 1952

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Mexico—Continued

Oaxaca—Continued

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1952

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1952

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- Kakanga: Legraye 1940

- Mawili: Legraye 1940

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Kemp 1899b
Wylie 1937

Norway.

Ekersund-Soggendal area:

- Bugge 1953
Dulleux 1915
Evrard 1944
Gillson 1949
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Kemp 1899b
Michot 1939

Kragerø rutile deposit:

- Barksdale 1949
Lawthers 1954
Thornton 1927
Watson 1915
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Portugal.

Sines.

- São Torpes beach: Castro 1947

Sierra Leone.

Freetown norite deposit:

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Junner 1930b, 1950
Lawthers 1954
Pollett 1951

Sweden.

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- Gmelin-Institut 1951
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Taberg:

- Bateman 1951
Dulleux 1915
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Hjelmqvist 1949
Kemp 1899b
Kuhn 1927
Lawthers 1954

Taiwan.

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Tanganyika.

Liganga deposits:

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Stockley 1945

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Thailand.

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1951

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Istanbul.

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1950

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Survey 1940
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Gmelin-Institut 1951

Union of Soviet Socialist Republics.

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General:

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Panteleyev and Malyshev 1934

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Surokomski 1926
Vertushkov 1949

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Yavapai County titaniferous magnetite deposit: Ball and Broderick 1919

Arkansas.

Magnet Cove area.

General:

Fryklund, Harner 1954
Fryklund and Holbrook 1950

Geology—Continued

*United States—Continued**Arkansas—Continued**Magnet Cove Area—Continued*

General—Continued

Lawthers 1954
Ross 1941
Vogel, F. A. 1944

Christy deposit:

Fryklund and others 1954
Fryklund and Holbrook 1950
Holbrook 1947
Reed 1949a

Hardy-Walsh or Kilpatrick brook-ite deposit:

Fryklund and others 1954
Fryklund and Holbrook 1950

Magnet Cove Rutile Company deposit:

Fryklund and others 1954
Fryklund and Holbrook 1950
Kinney 1949
Reed 1949b
Spencer 1946

Mo-Tl deposit:

Fryklund and others 1954
Fryklund and Holbrook 1950

Southern Howard County.

Titaniferous sands:

Holbrook 1948

California.

San Gabriel Mountains:

Higgs 1954a, b
Moorehouse 1938
Oakeshott 1937, 1948, 1950,
1954
Tucker 1927

Colorado.

Caribou Hill: Singewald 1913b

Cebolla Creek-Iron Hill:

Larsen 1942
Singewald 1912, 1913b

Iron Mountain, Fremont County:

Kemp 1899b
Singewald 1913b

Florida.

Beach deposits, modern and buried:

Cannon 1950
Lawthers 1954
MacNeil 1950
Martens 1935
Phelps 1941
Thoenen and Warne 1949
Vernon 1943

Highland mine, Lawtey: Roberts
1955

Pablo Beach mine, Mineral City:

Liddell 1917

Trall Ridge area:

Spencer 1948
Thoenen 1950

Trall Ridge mine, Starke:

Carpenter and others 1953
Anonymous 1952d

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Georgia.

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Watson 1915

Watson and Taber 1913

Watson and Watson 1912

Idaho.

Long Valley area, Cascade: Argall 1954

Titanium-bearing, high-alumina clay deposits:

Scheid 1952

Scheid and Hosterman 1951

Scheid, Hosterman 1951a, b

Scheid and Sohn 1945

Scheid, Sohn 1952

Maryland.

Cove Point beach placer: Anonymous 1953d

Harford County rutile deposits:

Ostrander 1942

Tomlinson 1946

Minnesota.

Titaniferous deposits in Duluth gabbro:

Broderick 1917

Emmons and Grout 1943

Grout 1926, 1949-1950

Kemp 1899b

Lawthers 1954

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Van Hise and Leith 1911

Montana.

Titaniferous sandstones:

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Wimmler 1946

Nevada.

Corral Canyon mine: Ferguson 1939

New Jersey.

Titaniferous magnetite deposits:

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Singewald 1913b

Smith 1933

New York.

Adirondack Mountains:

Balk 1931

Buddington 1939

Evrard 1947

Newland 1908

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Dulleux 1915

Kemp 1899a

Osborne 1928

Singewald 1913b

Lake Sanford area.

General:

Balsley 1943

Dulleux 1915

Geology—Continued

United States—Continued

New York—Continued

Lake Sanford area—Continued

Gmelin-Institut 1951

Herres and others 1943

Kemp 1899a

Newland 1908

Osborne 1928

Calamity-Mill Pond deposit:

Singewald 1913b

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Singewald 1913b

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Bateman 1951

Gillson 1949

Lawthers 1954

Stephenson, R. C. 1945, 1948

Sanford Hill deposit (At present, MacIntyre mine): Singewald 1913b

North Carolina.

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Knob Creek monazite placer: Griffith 1953b

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Cross 1949

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Pennsylvania.

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Rhode Island.

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South Carolina.

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Tennessee.

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Texas.

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1908

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County: Vogel, F. A. 1942

Virginia.

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Thornton 1927
Watson 1907a, b, 1915
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Youngman 1930b

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Cross 1949
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County:

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Hess 1910
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Iron Mountain deposit:

Ball 1907
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Lawthers 1954
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Frederickson 1948
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Strauss 1947

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Youngman 1930a

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Coll 1933
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Edwards 1942
Frederickson 1948
Gillson 1949
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Murphy and Houston 1955
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- Occurrence of titanium minerals.
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 New South Wales:
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 Whitworth 1931
 Anonymous 1939
 Queensland:
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 New Plymouth:
 Fyfe 1952
 Hutton 1945a
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 states: Martens 1935
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 Beach sands, modern and buried:
 Cannon 1950
 Miller 1945
 Phelps 1941
- Idaho.**
 Placer deposits: Shannon 1922

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 Texas.
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Anonymous 1953j, 1955r

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Detweiler 1952

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Humphreys 1945

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Lenhart 1949

Michell 1952

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Robinson 1922

Youngman 1930a

Riz Mineral Co. mine, Melbourne:

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Trall Ridge mine, Starke:

Carpenter and others 1953

Cross 1949

Mining Activities—Continued

United States—Continued

Florida—Continued

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Dennis 1953

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Lawthers 1954

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Anonymous 1950a, 1952d

Idaho.

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Kearney and Lutjen 1953

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ley 1950

Matthews 1943a

Matthews and Bryson 1947

Merritt 1952

Milliken 1948

Oldham 1952

Stephenson, R. C. 1945, 1948

Tumin and Cservenyak 1955

Anonymous 1943, 1951e

North Carolina.

Yadkin Mica and Ilmenite Company
mine:

Cross 1949

Lawthers 1954

Oregon.

Placer mines along coast: Pardee
1934

Virginia.

Piney River mine:

Cross 1949

Cservenyak and Tumin 1956

Hubbard and others 1953

Lawthers 1954

Anonymous 1942b

Roseland rutile mine:

Bevan 1942b

Hess and Gillson 1937

Robinson 1922

Thornton 1927

Watson 1907a

Watson and Taber 1913

Youngman 1930b

North America.

*Canada.**Alberta.*

- Burmis titaniferous sandstone:
 Goodwin, W. L. 1919
 Imperial Min. Res. Bur. 1922b
 Lawthers 1954
 Robinson 1922
 Youngman 1930b

Newfoundland:

- Gmelin-Institut 1951
 Imperial Min. Res. Bur. 1922b
 Lawthers 1954
 Youngman 1930b

Nova Scotia.

- Rutile occurrences:
 Robinson 1922
 Watson and Taber 1913

Ontario.

- Miscellaneous deposits:
 Gmelin-Institut 1951
 Goodwin, W. L. 1919
 Hurst 1932
 Kemp 1899b
 Lawthers 1954
 Robinson 1922

- Pine Lake deposit, Halliburton
 County:
 Dulleux 1915
 Imperial Min. Res. Bur. 1922b
 Kemp 1899b

- Seine Bay and Bad Vermillion Lake:
 Barksdale 1949
 Lawthers 1954
 Parsons and others 1934
 Robinson 1922
 Tucker 1927
 Youngman 1930b

Quebec.

- Allard Lake and Sorel:
 Barksdale 1949
 Bateman 1951
 Bourret 1949
 Brown, D. I. 1951
 Buisson 1952, 1954
 Cross 1949
 Cservenyak 1953
 Cservenyak and Tumin 1954,
 1956
 Dennis 1953
 Dunn and Morgan 1955a
 Faessler 1950
 Frankel and others 1951
 Gillson 1949
 Gmelin-Institut 1951
 Goodwin, W. M. 1953
 Hammond 1949, 1952
 Illingworth 1952
 Knoerr 1952
 Lawthers 1954
 McDonald 1951
 Maillet 1950
 Matthews 1948b
 Meyer 1950, 1951
 Oldham 1952

North America—Continued

*Canada—Continued**Quebec—Continued*

Allard Lake and Sorel—Continued

- Retty 1942, 1944
 Tumin 1955
 Tumin and Cservenyak 1955
 United Nations 1955
 U. S. Bur. Mines 1955b
 Wilson, H. D. B. 1953
 Anonymous 1948b, 1951a, d
 1955f

Bay of Seven Island area:

- Buisson 1952
 Dulleux 1912b, 1915
 Faessler and Schwartz 1941
 Gmelin-Institut 1951
 Imperial Institute 1917a
 Kemp 1899b
 Lawthers 1954
 Robinson 1922
 Tumin and Cservenyak 1955

Degrosbois deposit:

- Dulleux 1913, 1915
 Imperial Min. Res. Bur. 1922b
 Osborne 1936
 Robinson 1922

Ivry deposit:

- Barksdale 1949
 Buisson 1954
 Dulleux 1913, 1915
 Gmelin-Institut 1951
 Hess and Gillson 1937
 Lawthers 1954
 Osborne 1928, 1936
 Robinson 1922
 Tucker 1927
 Tumin and Cservenyak 1955
 Vogel, F. 1950
 Youngman 1930b
 Anonymous 1951b

Miscellaneous deposits:

- Dulleux 1913, 1915
 Girault 1953
 Goodwin, W. L. 1919
 Imperial Min. Res. Bur. 1922b
 Kemp 1899b
 Lawthers 1954
 Robinson 1922
 U. S. Bur. Mines 1955b
 Watson and Taber 1913
 Youngman 1930b
 Anonymous 1955f

St. Charles prospect, Chicoutimi

- County:
 Barksdale 1949
 Denis 1925
 Dulleux 1913, 1915
 Gmelin-Institut 1951
 Imperial Institute 1917b
 Imperial Min. Res. Bur. 1922b
 Kemp 1899b
 Lawthers 1954
 Robinson 1922, 1926
 Stansfield 1916

North America—Continued

Canada—Continued

Quebec—Continued

St. Lawrence River sand deposits,
including Moisie and Natashk-
wan:

Dulieux 1912a, b, 1915
Gmelin-Institut 1915
Imperial Min. Res. Bur. 1922b
Kemp 1899b
Lawthers 1954
MacKenzie 1912a, b
United Nations 1955

St. Urbain:

Barksdale 1949
Bulsson 1954
Dulieux 1912b, 1915
Gillson 1932, 1949
Gmelin-Institut 1951
Hess and Gillson 1937
Imperial Institute 1917a
Imperial Min. Res. Bur. 1922b
Karpoff 1953
Kemp 1899b
Lawthers 1954
Mawdsley 1927
Osborne 1928
Robinson 1922
Ross 1941
Thornton 1927
Tucker 1927
Vogel, F. 1950
Warren 1912, 1918
Watson 1915, 1917
Watson and Taber 1913
Youngman 1930b
Anonymous 1951d

Yukon Territory.

Rutile occurrences:

Robinson 1922
Watson and Taber 1913

Greenland:

Lawthers 1954
Moos 1938
Ramberg 1948
Vincent and Phillips 1954

Mexico.

Miscellaneous deposits:

Lawthers 1954
Meyer 1949
Sánchez Mejorada 1952
U. S. Bur. Mines 1947a
U. S. Tariff Comm. 1946
Youngman 1930b
Anonymous 1952i

Oaxaca.

Pluma Hidalgo deposit:

Gmelin-Institut 1951
Lawthers 1954
Meyers 1949
Sánchez Mejorada 1952
Anonymous 1955a, b, c, d, e

United States.

Alabama:

Watson and Taber 1913
Youngman 1930b

North America—Continued

United States—Continued

Arizona.

General: Day and Richards 1906
Hackberry: Palmer 1909
Yavapai County titaniferous mag-
netite deposit: Ball and Brod-
erick 1919

Arkansas.

Christy deposit:

Falconer and Crawford 1944
Fine and Frommer 1952
Fryklund and others 1954
Fryklund and Holbrook 1950
Holbrook 1947
Reed 1949a
Tumin and Cservenyak 1955

Hardy-Walsh or Kilpatrick brook-
ite deposit:

Fryklund and others 1954
Fryklund and Holbrook 1950

Magnet Cove area, general:

Barksdale 1949
Cservenyak and Tumin 1956
Dupuy 1949
Fine and others 1949
Fryklund and others 1954
Fryklund and Holbrook 1950
Gmelin-Institut 1951
Hess and Gillson 1937
Lawthers 1954
Matthews 1943b, 1945
Matthews and others 1947
Nighman and Bryson 1946
Ross 1941
U. S. Bur. Mines 1938b
U. S. Senate, Comm. Interior
and Insular Affairs 1954
Vogel, F. A. 1944
Warren 1918
Watson and Taber 1913
Youngman 1930b

Magnet Cove Rutile Company de-
posit:

Fryklund and Holbrook 1950
Fryklund and others 1954
Kinney 1949
Reed 1949b
Spencer 1946

Mo-Ti deposit:

Fryklund and others 1954
Fryklund and Holbrook 1950
Holbrook 1948a

Southern Howard County titani-
ferous sands:

Holbrook 1948b
Lawthers 1954

Titanium in bauxite:

Calhoun 1950
Cservenyak and Tumin 1956

California: Matthews and others 1947

Aptos, Santa Cruz County:

Barksdale 1949
Gary 1942
Youngman 1930b

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North America—Continued

United States—Continued

California—Continued

Hermosa and Redondo beaches:

Barksdale 1949
 Baughman 1927
 Gary 1942
 Gmelin-Institut 1951
 Lawthers 1954
 Tucker 1927
 Youngman 1930a, b

Los Angeles County: Mulryan 1951

San Gabriel Mountains:

Barksdale 1949
 Baughman 1927
 Gary 1942
 Gillson 1949
 Gmelin-Institut 1951
 Hess and Gillson 1937
 Higgs 1954a, b
 Lawthers 1954
 Meyer 1950
 Moorehouse 1938
 Oakeshott 1927, 1948, 1950,
 1954
 Tucker 1927
 United Nations 1955
 Youngman 1930b

Colorado.

Caribou Hill:

Barksdale 1949
 Jennings 1913
 Kemp 1899b
 Lawthers 1954
 Singewald 1913b

Cebolla Creek—Iron Hill:

Barksdale 1949
 Brunton 1913
 Gmelin-Institut 1951
 Larsen 1942
 Lawthers 1954
 Singewald 1912, 1913b

El Paso County rutile occurrences:

Watson and Taber 1913

Iron Mountain, Freemont County:

Barksdale 1949
 Dulleux 1915
 Kemp 1899b
 Lawthers 1954
 Singewald 1913b

Italian Mountain, Gunnison County:

Cross and Shannon 1927

Florida.

Beach deposits, modern and buried:

Gmelin-Institut 1951
 Lynd and others 1954
 MacNeill 1950
 Martens 1928, 1935
 Matthews 1934b
 Matthews and others 1947
 Meuschke and others 1953
 Moxham 1954
 Moxham and Johnson 1953
 Phelps 1941
 Thoenen and Warne 1949

North America—Continued

United States—Continued

Florida—Continued

Beach deposits, modern and buried—Continued

Vernon 1943
 Youngman 1930b
 Anonymous 1955e, m, o, s

Highland mine, Lawtey:

Roberts 1955
 Tumin 1955
 Anonymous 1953j, l, n, 1955e, r

Jacksonville mine:

Cannon 1950
 Cross 1949
 Detweller 1952
 Gillson 1949
 Hubbard and others 1953
 Humphreys 1945
 Lawthers 1954
 Lenhart 1949
 Matthews 1945
 Michell 1952
 Miller 1945
 Anonymous 1951d

Pablo Beach, Mineral City:

Barksdale 1949
 Gillson 1949
 Lawthers 1954
 Liddell 1917
 Martens 1928
 Robinson 1923
 Thornton 1927
 Tucker 1927
 Youngman 1930a, b

Pensacola Bay area:

Gmelin-Institut 1951
 Lawthers 1954
 Matthews 1945
 Miller 1945

Trail Ridge area:

Cannon 1950
 Creitz and McVay 1948
 Lawthers 1954
 Spencer 1948
 Thoenen 1950
 Thoenen and Warne 1949

Trail Ridge mine, Starke:

Cannon 1950
 Carpenter and others 1953
 Cross 1949
 Cservenyak and Tumin 1956
 Dennis 1953
 Gillson 1949
 Hubbard and others 1953
 Lawthers 1954
 Lenhart 1949, 1951
 Meyer 1949, 1951
 Michell 1952
 Anonymous 1950a, 1952d,
 1955i

Vero Beach deposits:

Lawthers 1954
 Matthews 1945
 Miller 1945

North America—Continued

United States—Continued

Georgia.

- Coastal beach deposits:
 Lawthers 1954
 McKelvey and Balsley 1948
 Martens 1928, 1935
 Moxham and Johnson 1953
 Teas 1921
 Youngman 1930b

Graves Mountain:

- Lawthers 1954
 Watson 1915
 Watson and Taber 1913
 Watson and Watson 1912
 Youngman 1930b

Miscellaneous deposits:

- Lawthers 1954
 MacNell 1950
 Moxham 1954

Idaho.

Long Valley area, Cascade:

- Argall 1954
 Banning and others 1955
 Cservenyak and Tumin 1954,
 1956
 Shelton and Stickney 1955
 Anonymous 1954c

Miscellaneous placer deposits:

- Lawthers 1954
 Shannon 1922
 Shelton and Stickney 1955
 Anonymous 1954c

Titanium-bearing high-alumina clay deposits:

- Scheid 1952
 Scheid and Hosterman 1951
 Scheid, Hosterman 1951a, b
 Scheid and Sohn 1945
 Scheid, Sohn 1952

Maryland.

Cove Point beach placer: Anonymous 1953d, 1955g

Harford County rutile deposits:

- Lawthers 1954
 Ostrander 1942
 Tomlinson 1946

Miscellaneous deposits:

- Miller 1945
 Youngman 1930b

Michigan.

Copper district: Cornwall 1951

Minnesota.

Titaniferous deposits in Duluth gabbro:

- Barksdale 1949
 Broderick 1917
 Clements 1903
 Emmons and Grout 1943
 Gmelin-Institut 1951
 Grout 1926, 1949-50
 Kemp, 1899a, b
 Lawthers 1954
 Schwartz 1930
 Singewald 1913b

North America—Continued

United States—Continued

Minnesota—Continued

Titaniferous deposits in Duluth gabbro—Continued

- Tucker 1927
 Van Hise and Leith 1911
 Youngman 1930b

Missouri.

Fredericktown-Einstein Silver mine:
 Youngman 1930b

Montana.

Teton County titaniferous sandstone: Barksdale 1949

- Gmelin-Institut 1951
 Wimmeler 1946
 Anonymous 1952c

Titaniferous sandstone:

- Lawthers 1954
 Stebinger 1914
 Youngman 1930b

Nevada.

Blue Metal corundum property:

- Binyon 1946
 Lawthers 1954

Corral Canyon mine:

- Ferguson 1939
 Lawthers 1954
 U. S. Bur. Mines 1938b

New Jersey.

Titaniferous magnetite deposits:

- Bayley 1910
 Dulleux 1915
 Kemp 1899b
 Singewald 1913b
 Smith 1933
 Youngman 1930b

New Mexico.

Hidalgo County: Coulter 1939

New York.

Adirondack Mountains:

- Balk 1931
 Buddington 1939
 Evrard 1947, 1949

Essex County titaniferous magnetite deposits (exclusive of Lake Sanford area):

- Dulleux 1915
 Gmelin-Institut 1951
 Imperial Min. Res. Bur. 1922f
 Kemp 1899a, b
 Lawthers 1954
 Newland 1908
 Osborne 1928
 Singewald 1913b
 Anonymous 1943

Lake Sanford area, general:

- Brunton 1913
 Dulleux 1915
 Hess and Gillson 1937
 Kemp 1899a
 Lawthers 1954
 Matthews and others 1947
 Newland 1908
 Newland and Hartnagel 1939

North America—Continued

United States—Continued

New York—Continued

Lake Sanford area, general—Con.

Osborne 1928
 Singewald 1913b
 Tucker 1927
 United Nations 1955
 Warren 1918
 Watson 1917
 Youngman 1930b
 Anonymous 1943

Lake Sanford area deposits, exclu-

sive of MacIntyre mine:
 Balsley 1943
 Gmelin-Institut 1951
 Singewald 1913b
 Stephenson, R. C. 1945, 1948

MacIntyre mine, Tahawus:

Balsley 1943
 Barksdale 1949
 Bateman 1951
 Cross 1949
 Cservenyak and Tumin 1956
 Dennis 1953
 Frankel and others 1951
 Gillson 1949
 Gmelin-Institut 1951
 Hagar 1942
 Herres 1946
 Herres and others 1943
 Kearney and Lutjen 1953
 Lawthers 1954
 MacMillan, Dinnin 1950
 MacMillan, Heindl 1952
 Maillet 1950
 Matthews 1943a, b, 1945
 Matthews and Bryson 1947
 Meyer 1951
 Mitchell 1952
 Milliken 1948
 Oliver 1942
 Stephenson, R. C. 1945, 1948
 Tumin and Cservenyak 1955
 Tyler 1941
 Anonymous 1950o, 1951d, e,
 1955h, s

Miscellaneous deposits:

Ellison 1950
 Kemp 1899b
 Lawthers 1954
 Newland 1908
 Singewald 1913b

North Carolina.

Beach placer deposits:

Lawthers 1954
 Lynd and others 1954
 McKelvey and Balsley 1948
 Moxham and Johnson 1953

Rutile deposits:

Gillson 1949
 Hess and Gillson 1937
 Matthews 1943b
 Murdock 1950(?)
 Watson and Taber 1913
 Youngman 1930b

North America—Continued

United States—Continued

North Carolina—Continued

Stream placer deposits:

Griffith and Overstreet 1953a, b
 Hansen and Cuppels 1954

Titaniferous magnetite deposits:

Bayley 1923a, b, c
 Dulleux 1915
 Gmelin-Institut 1951
 Kemp 1899b
 Lawthers 1954
 Matthews and others 1947
 Murdock 1950(?)
 Singewald 1913b

Yadkin Mica and Ilmenite Company,

Caldwell County:
 Barksdale 1949
 Cross 1949
 Cservenyak and Tumin 1956
 Frankel and others 1951
 Gillson 1949
 Gmelin-Institut 1951
 Greaves-Walker 1945
 Lawthers 1954
 McMurray 1944
 Maillet 1950
 Murdock 1950(?)
 Singewald 1913b
 Tumin and Cservenyak 1955
 Anonymous 1951d

Oklahoma.

Wichita Mountains, placer deposits:

Chase 1952
 Youngman 1930b

Wichita Mountains, titaniferous

magnetite deposits:
 Barksdale 1949
 Gmelin-Institut 1951
 Lawthers 1954
 Merritt 1938, 1939, 1940

Oregon.

Coastal placer deposits:

Dasher and others 1942
 Gmelin-Institut 1951
 Griggs 1945
 Lawthers 1954
 Pardee 1934
 Stephenson, E. L. 1945
 Twenhofel 1943, 1946a, b

Ferruginous bauxite deposits:

Bell 1945
 Lawthers 1954
 Libbey and others 1945, 1946

Pennsylvania:

Bayley 1941
 Lawthers 1954
 Watson 1915
 Watson and Taber 1913
 Youngman 1930b

Rhode Island.

Iron Mine Hill, Cumberland:

Barksdale 1949
 Brunton 1913
 Driver 1953
 Dulleux 1915

North America—Continued**United States—Continued****Rhode Island—Continued****Iron Mine Hill, Cumberland—
Continued**

Gmelin-Institut 1951
 Imperial Min. Res. Bur. 1922f
 Johnson and Warren 1908
 Kemp 1899b
 Lawthers 1954
 MacMillan and Heindl 1952
 Singewald 1912b
 Tucker 1927
 Tumin and Cservenyak 1955
 Warren 1918
 Warren and Powers 1914
 Youngman 1930b

South Carolina.**Coastal placer deposits:**

McKelvey and Balsley 1948
 Martens 1935
 Meuschke 1955

**Marine Minerals, Alken: Anony-
mous 1955e****Rutile occurrences:**

Watson 1915
 Watson and Taber 1913
 Youngman 1930b

South Dakota:**Custer County area:**

Watson and Taber 1913
 Youngman 1930b

Tennessee.**Titaniferous magnetite deposits:**

Bayley 1923a, b, c
 Gmelin-Institut 1951

Texas.**Baringer Hill, Llano County:**

Hess 1908
 Lawthers 1954
 Youngman 1930b

Gulf Coast: Bullard 1942**Marfa rutile deposit, Jeff Davis
County:**

Gmelin-Institut 1951
 Lawthers 1954
 U. S. Bur. Mines 1942
 Vogel, F. A. 1942

Virginia.**Amherst-Nelson Counties area:**

Barksdale 1949
 Bevan 1942b
 Brunton 1913
 Cservenyak and Tumin 1956
 Gillson 1949
 Gmelin-Institut 1951
 Hess and Gillson 1937
 Imperial Institute 1917a
 Lawthers 1954
 Matthews and others 1947
 Merrill 1902
 Meyer and Bryson 1948
 Moore 1940
 Pegau 1950
 Robnson 1922
 Ross 1932, 1936, 1941, 1942, 1947

North America—Continued**United States—Continued****Virginia—Continued****Amherst-Nelson Counties area—
Continued**

Ryan 1933
 Thornton 1927
 Tucker 1927
 Tyler 1941
 Warren 1918
 Watson 1907a, b, 1915, 1917
 Watson and Taber 1909, 1913
 Youngman 1930b
 Anonymous 1942b

**Bush-Hutchins deposit, Roanoke
County:**

Hickman 1947
 Lawthers 1954
 Steldtmann 1931
 Watson 1907a
 Watson and Taber 1913

Goochland and Hanover Counties:

Brown, C. B. 1937
 Hess 1910
 Hess and Gillson 1937
 Lawthers 1954
 Pegau 1950
 Watson 1915, 1917
 Watson and Taber 1913
 Youngman 1930b
 Anonymous 1942b

Miscellaneous deposits:

Bevan 1942b
 Bloomer and DeWitt 1941
 Gmelin-Institut 1951
 Lawthers 1954
 Moxham and Johnson 1953
 Pegau 1950
 Steldtmann 1931
 Watson 1922
 Watson and Taber 1913

Piney River deposit:

Cross 1949
 Davidson 1948
 Davidson and others 1947
 Hubbard and others 1953
 Maillet 1950
 Matthews 1943b

Roseland rutile deposit:

Cross 1949
 Hess 1909
 Meyer 1950 1951
 Ross 1932
 Youngman 1930b

Washington.**Excelsior clay deposit:**

Lawthers 1954
 Scheld 1945
 Scheld, Hosterman 1945

Other deposits:

Glover 1942
 Huntting 1943
 Lawthers 1954
 Tucker 1927
 Youngman 1930b

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North America—Continued

United States—Continued

Wisconsin.

N.W. of Wausau: Youngman 1930b
Wyoming.

Iron Mountain deposit:

Back and others 1952
Ball 1907
Barksdale 1949
Birch 1955
Brunton 1913
Cservenyak and Tumin 1954
Dempsey 1955
Diemer 1941
Diets 1929, 1932
Dulieux 1915
Frey 1946b
Gillson 1949
Gmelin-Institut 1951
Herres 1946
Hess and Gillson 1937
Kemp 1899a, b
Lawthers 1954
Meyer and Bryson 1948
Newhouse and Hagner 1951
O'Dea 1946
Osterwald and Osterwald 1952
Pinnel 1954
Singewald 1913b
Tucker 1927
Tumin and Cservenyak 1955
United Nations 1955
Warren 1918
Watson 1917
Youngman 1930b
Anonymous 1954d

Shanton deposit:

Diemer 1941
Frey 1946a
Gmelin-Institut 1951
Hild 1953
Newhouse and Hagner 1951
Osterwald and Osterwald 1952
Singewald 1913b
Tumin 1955

Taylor deposit:

Diemer 1941
Osterwald and Osterwald 1952

Titaniferous sandstones: Murphy
and Houston 1955

Hawaii.

Titaniferous soils:

Sherman 1952, 1954
Anonymous 1953m

Oceania.

Australia.

Placer deposits of east coast:

Blaskett 1950
Dunn and Morgan 1955a
Fisher 1948
Gillson 1949
Gmelin-Institut 1951
Hess and Gillson 1937
Raggatt 1953
Anonymous 1952g, 1953f, 1955f,
l, k, l, t

Oceania—Continued

Australia—Continued

New South Wales.

Rutile-bearing placers of east coast:
Blaskett and Dunkin 1948
Dunkin 1953
Fisher 1949
Gardner 1951
Lawthers 1954
Lyons 1954
Meyer 1950
Poole 1939
Raggatt 1953
Tumin 1955
Tumin and Cservenyak 1951
U. S. Bur. Mines 1935, 1948
1953a
Whitworth 1931
Anonymous 1934, 1939

Titaniferous magnetite deposit
near Williams and Karu

Rivers:
Gardner 1951
Imperial Min. Res. Bur. 1921
Lawthers 1954
United Nations 1955
Youngman 1930b

Northern Territory:

Fisher 1949
Gardner 1951
Lawthers 1954

Queensland.

Rutile-bearing placers of east coast:

Beasley 1948, 1950
Blaskett and Dunkin 1948
Carlson 1944
Connah 1948
Cservenyak and Tumin 1955
Dunkin 1953
Fisher 1949
Gardner 1951
Lawthers 1954
Lyons 1954
Meyer 1950
Morton 1948
Nighman and Bryson 1946
Raggatt 1953
Tumin 1955
Tumin and Cservenyak 1955
U. S. Bur. Mines 1948c, 1955
Watson and Taber 1913
Youngman 1930b
Anonymous 1952j

Titaniferous deposits other than
placers of east coast:

Cribb 1943
Fisher 1949
Gardner 1951
Lawthers 1954

South Australia.

General:

Fisher 1949
Gardner 1951
Lawthers 1954
U. S. Bur. Mines 1953a

- Oceania—Continued**
- Australia—Continued**
- South Australia—Continued
- Miscellaneous deposits:
- Alderman 1925
- Hess and Gillson 1937
- Mount Crawford area:
- Fisher 1949
- Gardner 1951
- Imperial Institute 1917a, 1938
- Lawthers 1954
- Thornton 1927
- Watson 1915, 1917
- Watson and Taber 1913
- Tasmania.**
- King Island:
- Barksdale 1949
- Fisher 1949
- Gardner 1951
- Gmelin-Institut 1951
- Hess and Gillson 1937
- Lawthers 1954
- U. S. Bur. Mines 1948c
- Youngman 1930b
- Anonymous 1928
- Miscellaneous deposits:
- Fisher 1949
- Gardner 1951
- Imperial Institute 1917a
- Anonymous 1928
- Victoria:**
- Edwards 1942
- Fisher 1949
- Gardner 1951
- Lawthers 1954
- U. S. Bur. Mines 1953a
- Youngman 1930b
- Western Australia.**
- Coastal placer deposits:
- Fisher 1949
- Gardner 1951
- Lawthers 1954
- McMath 1951
- McMath and de la Hunty 1951a, b
- Tumin and Cservenyak 1955
- U. S. Bur. Mines 1948c, 1953a
- Anonymous 1953f, 1955h
- Titaniferous deposits other than coastal placers:**
- Fisher 1949
- Gardner 1951
- Imperial Min. Res. Bur. 1922d
- Lawthers 1954
- Tumin and Cservenyak 1955
- Youngman 1930b
- New Zealand.**
- Titaniferous iron sands.**
- General:**
- Aubel 1920
- Barksdale 1949
- Fyfe 1952
- Gillson 1949
- Imperial Institute 1917a
- Oceania—Continued**
- New Zealand—Continued**
- Titaniferous iron sands.**
- General—Continued**
- Imperial Min. Res. Bur. 1922d
- Kemp 1899b
- Lawthers 1954
- Mason 1945
- Meyer 1949
- United Nations 1955
- Wylie 1938
- Youngman 1930b
- Anonymous 1953i, 1955q
- New Plymouth deposits:**
- Beck 1947
- Gmelin-Institut 1951
- Hutton 1945a, b
- Wylie 1937
- Patea deposits:**
- Donovan 1916
- Gmelin-Institut 1951
- Hutton 1940
- Wylie 1937
- Wanganui deposits:**
- Finch 1947
- Fleming 1946
- Gmelin-Institut 1951
- South Island:**
- Hutton 1950
- Mason 1945
- Petrology.**
- Titaniferous deposits.**
- (General: Lawthers 1954
- Anorthositic and gabbroic deposits.**
- Argentina.**
- Mina Podesta, Catamarca: Bassi 1952
- Canada.**
- St Urbain area, Quebec: Ross 1941
- Greenland.**
- General: Ramberg 1948
- India.**
- Mayurbhanj and Singhbhum: Dunn and Dey 1937
- United States.**
- California.**
- San Gabriel Mountains:
- Higgs 1954a, 1954b
- Moorehouse 1938
- Minnesota.**
- Duluth gabbro: Grout 1949-50
- New York.**
- Adirondack Mountains:**
- Balk 1931
- Buddington 1939
- Rhode Island:**
- Iron Mine Hill, Cumberland: Johnson and Warren 1908
- Virginia.**
- Amherst-Nelson Counties area:
- Davidson and others 1946
- Moore 1940
- Ross 1926, 1941, 1947
- Watson 1907b
- Watson and Taber 1909, 1913

Petrology—Continued

Anorthositic and gabbroic deposits—Con.
United States—Continued

Wyoming.

Laramie Range: Newhouse and
Hagner 1951

Ferromagnesian deposits.

Sweden.

Taberg: Hjelmqvist 1949

Iron oxides associated with titanium
minerals.

General:

Bateman 1951
Brunton 1913
Buddington and others 1955
Evrard 1944
Kemp 1899a
Osborne 1928
Ramdohr 1926, 1939
Rechenberg 1955
Singewald 1913a, 1913b
Warren 1918
Wilson, H. D. B. 1953

Australia.

General: Edwards 1938

Canada.

Allard Lake, Quebec:

Hammond 1949

Retty 1944

Bay of Seven Islands area, Quebec:

Faessler and Schwartz 1941

Degrosbols deposit, Quebec: Os-
borne 1936

Ivry, Quebec: Osborne 1936

St. Urbain, Quebec:

Gillson 1932

Mawdsley 1927

Warren 1912

Egypt.

Abu-Ghalqua (Wadi El Ranga):
Amin 1954

Finland.

Attu: Pehrman 1927

Otanmäki: Vaasjoki 1947

Greenland.

Skergaard complex:

Chevallier and others 1954

Vincent and Phillips 1954

Hungary.

Szarvasko: Pantó 1952

India.

Dhalbum and Mayurbhanj: Tipper
1936

Norway.

General: Bugge 1953

Union of South Africa.

Bushveld complex:

Schwellnus and Willemsse 1943

Wagner 1928

Natal—Tugela and Mambula Riv-
ers deposit: Du Toit 1918

Union of Soviet Socialist Republics.

Ural Mountains: Malyshev 1936

Petrology—Continued

Iron oxides associated with titanium
minerals—Continued

United States.

Arizona.

Western Yavapai County: Es-
and Broderick 1919

California.

San Gabriel Mountains: Oak
shott 1948

Michigan.

Copper district lavas: Cornwell
1951

Minnesota.

Duluth gabbro: Schwartz 1933

New Jersey: Bayley 1910

New York.

Adirondacks, General:

Buddington 1939

Evrard 1947, 1949

Lake Sanford area:

Balsley 1943

Newland, D. H. 1908

Stephenson, R. C. 1945, 1947

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- Gillson 1949, 1951
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By MARION C. JASTER

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UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1957

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

**For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C.—Price 25¢ (paper cover)**

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SELECTED ANNOTATED BIBLIOGRAPHY OF HIGH-GRADE SILICA OF THE UNITED STATES AND CANADA, THROUGH DECEMBER 1954

By MARION C. JASTER

ABSTRACT

This bibliography consists of about 282 annotated references concerned with high-silica (minimum SiO_2 content, 95 percent) raw materials in the United States and Canada. The annotations, arranged alphabetically by author, contain information on geology, geographic distribution, physical and chemical properties, mining, processing, and uses of high-grade materials, the more important of which are sand, sandstone, and quartzite.

Canadian and United States entries are cross indexed. The United States index is divided into two parts, a general list and a State list. In both parts, references are arranged in alphabetical order by author under each type of high-grade silica material.

INTRODUCTION

Silica occurs in many forms and associations. The term "high-grade silica," as used in this bibliography, is restricted to naturally occurring materials containing a minimum of 95 percent SiO_2 . These materials include chert, "chert-clay," conglomerate, flint, gravel, quartz-mica schist, novaculite, massive quartz, quartzite, sand, "sand-clay," sandstone, and tripoli. "Chert-clay" is used here for a high-silica material in Illinois in preference to the end-use term "ganister" (Lamar, 1953); and for a natural mixture of high-silica material and clay occurring in California, the term "sand-clay" is used in preference to "Livermore ganister" (Turner, 1950; Wright, 1948).

Although high-grade silica raw materials enter principally into the metallurgical, glass, and abrasives industries, some are used for the same purposes as materials of lower grades, such as aggregate and building stone. Annual production data are not published separately for high- and low-grade silica materials.

EXPLANATION OF THE BIBLIOGRAPHY

This bibliography contains annotations on publications of the U. S. Geological Survey, U. S. Bureau of Mines, and State organizations; scientific, professional, and trade journals; and a few publications of the Ontario Department of Mines and the Canada Department of Mines. Some older references that have been superseded by more recent ones have been omitted. Reports that contain little information on high-grade silica are excluded. Material through December 1954, is included.

The annotated references are listed by authors in alphabetical order; anonymous references are listed at the end. All entries are cross indexed according to United States and Canadian references. The United States references are divided into two categories, general and States.

In the index to general references, lists of authors are arranged alphabetically under each type of high-grade silica material. The general references include information on geology, geographic occurrence, physical and chemical properties, production, mining, processing, analyses, and uses of high-grade silica materials. Also included are descriptions of several deposits distributed over large regions in several States.

State references describe deposits within a particular State and include much of the information given in general references. The State references appearing under each type of high-grade silica material are grouped according to the following categories: (a) general references for the State, (b) references concerned with particular areas within the State, (c) references concerned with counties, and (d) references concerned with independent cities. In each category, authors are listed alphabetically.

The Canadian references are listed under each types of silica material and are arranged according to area and provinces.

Listed under "silica" are those references in which the type of siliceous material is not identified.

The stratigraphic nomenclature in this report is that of the various authors and does not necessarily correspond to U. S. Geological Survey usage.

BIBLIOGRAPHY

Adams, G. I., 1929, Molding sands of Alabama: Ala. Geol. Survey Bull. 35, p. 30.

The Hartselle sandstone, which crops out in Jefferson County in the northeastern suburbs of Birmingham, has been quarried and crushed near Irondale. It is very friable, and has been used in steel foundries and in the manufacture of glass. A sand bed in the Citronelle formation crops out in a railway cut near the waterworks siding northwest of Mobile. The sand has been used in steel foundries. In the Greeley opencut brown iron ore mines, near Woodstock station, Bibb County, is a bed of sand that is also used in steel foundries.

American Foundrymen's Association, 1925, Report of certain molding sand resources of Iowa, Kentucky, New Jersey, Pennsylvania, and Wisconsin: Preprint 492, p. 4-16.

Gives location, producer, formation, physical properties, grade, and use of samples from Kentucky, New Jersey, and Pennsylvania. Some of the deposits in New Jersey yield sand that is used for steel molding. Deposits listed in Iowa and Wisconsin are not of high-purity grade.

Anderson, R. J., 1942, Pulaski, Saline, Garland, and Montgomery Counties [Ark.]: Ark. Geol. Survey County Mineral Rept. 3, p. 66-74, 87-90.

Novaculite is a hard, highly siliceous, compact material of almost pure silica content. Two commercial types are identified. The Arkansas stone is very fine grained, commonly white, has a waxy luster, is translucent on thin edges, and breaks with a conchoidal fracture. This type is valuable for the manufacture of oilstones, whetstones, and abrasives in general. The Ouachita stone is much more porous and resembles unglazed porcelain; its composition is the same as the Arkansas stone. It has fewer joints and quartz veins than the Arkansas stone but contains more cavities. It is not damaged by freezing, but, on long drying, loses its easy fracture and becomes much tougher; this type is used for railroad ballast, road metal, and, in pebbles of 2 to 4 inches in diameter, for tube mill grinding. Analyses and location of quarries and deposits are given.

Tripoli occurs in the Arkansas novaculite in Garland and Montgomery Counties. The tripoli ranges in color from white to red, is soft, fine textured, and friable. Beds range from 2 to 50 feet in thickness, and they have an overburden ranging from 2 to 6 feet in thickness. Descriptions of the occurrences are given.

Argall, G. O., Jr., 1949, Industrial minerals of Colorado: Colo. School Mines Quart., v. 44, no. 2, p. 354-361.

Gives the locations of high silica sandstone deposits, production, treatment, and marketing. These deposits are in Chaffee, Douglas, El Paso, Fremont, Jefferson, Pueblo, and Prowers Counties. The silica deposits in Jefferson and

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Douglas Counties occur in the Dakota and Lykins formations. Four silica deposits in Fremont County also yield ganister. Analysis of El Paso County sand is given.

Averill, C. V., and Norman, L. A., Jr., 1951, Counties of California—Mineral production and significant mining activities, 1949: Calif. Jour. Mines and Geology, v. 47, p. 319, 344–345, 351, 357.

Foundry sand was produced from beds of Eocene sandstone south of Antioch and at Nortonville, Contra Costa County. Dune sands at Moss Beach, Monterey County, yield high-quality white sand for the foundry and glass industries. The dune deposit covers about 12 square miles. Glass sand has been produced near Corona, Riverside County. Various grades of silica and quartzite were quarried about 3 miles east of Oro Grande, San Bernardino County. This material has been used as a refractory and in the manufacture of sulfate-resistant cements.

Bain, H. F., 1907, Analysis of certain silica deposits: Ill. Geol. Survey Bull. 4, p. 185–186.

Gives analyses of silica taken from deposits at Anna and Reynoldsville, Union County, and from Thebes and McCotridge prospect, Alexander County. All material came from surface pits.

Baldwin, W. B., 1949, A preliminary report on the Sioux quartzite: S. Dak. Geol. Survey Rept. Inv. 63, 34 p.

Discusses the Sioux quartzite, also known as the Sioux Falls "granite," in the southeastern corner of South Dakota; in southwestern Minnesota, and minor occurrences in northwest Iowa, south of Rowena, S. Dak. Four quarries produce quartzite in South Dakota. Describes outcrops in Minnehaha, Turner, McCook and Hanson Counties, which may be of commercial value. Analyses and map (scale 1 in. = 5 mi.), showing outcrops in eastern South Dakota, are included.

Barrell, Joseph, and Loughlin, G. F., 1910, The lithology of Connecticut: Conn. Geol. Nat. History Survey Bull. 13, p. 199–201.

Lantern Hill quartz deposit is between Ledyard and North Stonington. It is slightly more than a mile long and, in most places, several hundred feet wide. The geology of the area is described.

Barrett, Edward, 1914, Glass sands of Indiana—Industries: Ind. Dept. Geology Nat. Res. 38th Ann. Rept., 1913, p. 41–59.

Discusses glass sand deposits and includes some analyses of the sands, qualities of Mansfield sandstone (texture, color, thickness, and workability), preparation of glass sand, Indiana limestone as an ingredient for glassmaking, and general aspects of the glass and industry. Dune sands of the lakefront at Michigan City are described as an excellent glass sand source; the sands also can be used as core sand in steel foundries.

Bascom, Florence, Clark, W. B., Darton, N. H., and others, 1909, Description of the Philadelphia district [Pennsylvania-New Jersey-Delaware]: U. S. Geol. Survey Geol. Atlas, folio 162, p. 21.

Sand (Magothy), along the south bank of Pensauken Creek in New Jersey, consists of fine to coarse angular quartz grains. Pockets or lenses of sand ranging from a few to 20 feet in thickness are distributed over an area of

several acres. It is used for filter material and in the manufacture of fire brick. Southeast of the Philadelphia district, glass sand (Cohansey) is dredged.

Bascom, Florence, Darton, N. H., Kummel, H. B., and others, 1909, Description of the Trenton quadrangle [New Jersey-Pennsylvania]: U. S. Geol. Survey Geol. Atlas, folio 167, p. 23.

Fine and coarse clean quartz sand (Magothy) occurs near Florence. It is used in steel molding and for other foundry purposes.

Bastin, E. S., 1911, Geology of the pegmatites and associated rocks of Maine: U. S. Geol. Survey Bull. 445, p. 133-137.

Describes the processing, uses, marketing, and production of quartz and other pegmatite minerals in general, and lists States where massive crystalline quartz is found. Map, scale 1:1,000,000, shows location of pegmatites.

Bayley, W. S., Salisbury, R. D., and Kummel, H. B., 1914, Description of the Raritan quadrangle [New Jersey]: U. S. Geol. Survey Geol. Atlas, folio 191, p. 30-31.

At Carey, N. J., the Green Pond conglomerate occurs in deeply disintegrated ledges, which is quarried for furnace-bottom and core sands.

Beach, J. O., 1939, Glass sands: Okla. Geol. Survey Mineral Rept. 3, 7 p.

Discusses briefly the Oklahoma glass sand deposits that have not been exploited commercially in Woods, Jefferson, and Major Counties. Also mentions that quarries near Roff, Pontotoc County, and near Mill Creek, Johnston County, are yielding high-grade silica sandstone.

Bengston, R. J., Moore, D. D., Ramsey, R. H., and Lund, R. J., 1950, Mineral resources of southeastern Ohio: Ohio Geol. Survey, Dept. Nat. Res. (Battelle Mem. Inst.), p. 59-76.

The Sharon conglomerate contains members of sandstone and quartz pebble conglomerate in Jackson and Pike Counties. It is an almost inexhaustible source of high-silica raw material. Because of its location to markets, it is not used for glass sand. To compete with West Virginia plants it must be acid treated and washed. Chemical analyses, sketch map, and bibliography on this area are included.

Beyer, S. W., 1897, Sioux quartzite and certain associated rocks: Iowa Geol. Survey, v. 6, p. 71-112.

The Sioux quartzite is a southwestward prolongation of Minnesota Point. It extends across the northwest corner of Iowa and underlies about equal areas in South Dakota and Minnesota. Its extreme eastern limit of outcrop is marked approximately by Redstone, at the junction of the Cottonwood and Minnesota Rivers; its most western exposure is near Mitchell on the James River. Its maximum width is 60 miles, extending from Flandreua northerly to Canton. It probably extends over an area of more than 6,000 square miles, and is from 3,000 to 4,000 feet thick. Sketch map is included.

Bieber, C. L., and Smith, N. M., 1952, Industrial sands of the Indiana dunes: Ind. Geol. Survey Bull. 7, 31 p.

Beaches formed during several stages of glacial Lake Chicago and Lake Michigan are sources of commercial sand. The commercial operations are

described. Samples were taken for laboratory determination of particle size, density separation, and chemical analysis. Composition and roundness of sand grains, as well as details of bedding, weathering, porosity, bonding, and moisture content, were studied.

The general requirements of each of the uses of dune sand are summarized. Although it is used extensively for molding sand for some types of large castings, most of it has been used as fill; smaller amounts have been utilized for asphalt paving sand, core sand, fire and furnace sand, engine sand, and glass sand. If the present supply and demand are maintained, sand operations will be possible for 50 to 100 years.

Map, scale about 1 inch = 2 miles, showing industrial sand deposits south of Lake Michigan is included.

Born, K. E., 1936, Summary of the mineral resources of Tennessee: Tenn. Div. Geol., Res. Tenn., 2d ser., p. 82, 85.

The geologic formations considered favorable for producing glass sands are the Bon Air and Sewanee (Pennsylvanian) of the Cumberland Plateau, the Clinch sandstone (Silurian) of East Tennessee, and possibly certain formations in the Tertiary and Cretaceous of West Tennessee. Glass sand is produced from the Sewanee conglomerate, 3 miles east of Sewanee. In East Tennessee, sand has been used from the Holston River; sands from the Bays Mountain area were used for experimental purposes only.

The most extensive development of tripoli is in the Collinwood district, Wayne County, in the southern part of the western Highland Rim region. It varies from a few to 60 feet thick. The deposit is in the Fort Payne and Warsaw formations (Mississippian). Tripoli is also reported in Dickson, Hickman, Johnson, and Bradley Counties.

Map, scale about 1 inch = 15 miles, showing localities of deposits is included.

Boswell, P. G. H., 1917, Notes on American high grade glass sands: Soc. Glass Tech. Jour. 1, p. 147-152.

Gives a brief description and chemical analysis of sand deposits at Ottawa, Ill., Cheshire, Mass., Berkeley Springs, W. Va., Baltimore, Md., and St. Louis, Mo.

Bowdish, F. W., and Runnels, R. T., 1952, Experimental production of feldspar and silica from several river sands in Kansas: Kans. Geol. Survey Bull. 96, pt. 6, p. 279-300.

Six river and flood-plain sand samples from the vicinity of Kansas City, Wichita, Concordia, and Salina were treated by flotation methods to determine the feasibility of producing feldspar and silica concentrates for use in glass, glass fiber, ceramic, and allied industries. The silica and residue after flotation of the feldspar is amenable to concentration to a ferric oxide content of less than 0.03 percent. These tests show that both a silica sand and feldspar product of commercial grade can be produced from the sand samples at three of the localities. Chemical and sieve analyses and flow sheets are included.

Bowen, C. H., 1953, Petrology and economic geology of the Sharon conglomerate in Geauga and Portage Counties, Ohio: Ohio State Univ. Eng. Expt. Sta. Bull. 153, 58 p.

The area is roughly triangular, and extends from Thompson in the north-

eastern part of Geauga County to Lake Geauga on the west, and to Windham, Portage County on the east. The Sharon conglomerate is the lowermost member of the Pottsville series (Pennsylvanian). The general areal characteristics, geologic history, and economics are discussed, and many mechanical and chemical analyses are given.

Bowles, Edgar, 1941, The geology and mineral resources of Cherokee County, Ala.: Ala. Geol. Survey Circ. 15, p. 29.

Extremely high-grade quartzite is produced from the Weisner formation (lower Cambrian), which yields material of nearly pure silica. This formation crops out extensively through the southern part of the county where it maintains a fairly uniform composition. Typical analyses are:

SiO ₂	98.1 percent	97.75 percent
R ₂ O ₃	1.3 do	1.62 do

The metal present may be aluminum, iron, or manganese.

Bownocker, J. A., 1921, Steel molding sand in Ohio: Ohio Jour. Sci., v. 21, p. 249-266.

Steel molding sands of Ohio occur in the Pottsville and Allegheny formations (Pennsylvania). The Sharon conglomerate of the Pottsville group is the larger source. It attains a thickness of 225 feet. The Allegheny formation is quarried for steel molding sands only at Strasburg, Tuscarawas County.

Many foundries, quarry locations, and chemical analyses of the sandstone, a map showing the outcrop of the Pottsville formation, and location of plants are included.

——— 1939, Glass sands and molding sands: Ohio Geol. Survey Repr. Ser. 2, p. 1-37.

Gives the age, specifications, locations, and many analyses of glass and steel molding sands of Ohio.

Branner, G. C., 1940a, Polk County [Ark.]: Ark. Geol. Survey County Mineral Rept. 1, p. 4-5, 22-23, 36-37.

Novaculite in Polk County occurs in the Arkansas novaculite formation as two types: the Arkansas stone which on the broken surface is smooth, compact, and hard; and the Ouachita stone, the surface of which is rough and porous. Most of the stone is white, although it varies in color.

Arkansas novaculite (Devonian) is divided into three lithologic units. The lower unit is almost wholly compact massive novaculite, even bedded in layers 2 to 10 feet thick, white or bluish white, with a manganiferous horizon at the top. This unit ranges from 10 to 410 feet in thickness. The middle unit is dark-colored dense novaculite in layers 1 to 5 inches thick interbedded with black cleavable shale, in beds ranging from an inch to 100 feet in thickness. Novaculite and sandstone pebble conglomerate occur at the base of this 75- to 525-foot unit. The upper unit is mostly massive light-gray to bluish-black calcareous novaculite, which, upon weathering, becomes porous, lighter colored and also yields manganese. This unit is 20 to 125 feet thick. The whole formation ranges from 250 to 950 feet in thickness.

Chemical analysis of novaculite near Hot Springs, Garland County, is given; this is believed to be representative of the Polk County novaculite.

Tripoli in Polk County is white and compact, but some is stained along joints by iron and manganese oxides. It is in the Arkansas novaculite forma-

tion and probably was formed by the leaching of the lime from the rocks. At Hot Springs, about 20 feet of tripoli is exposed in the upper unit of the Arkansas novaculite. Other occurrences also are given.

——— 1940b, Mineral resources of Benton, Carroll, Madison, and Washington Counties [Ark.]: Ark. Geol. Survey County Mineral Rept. 2, p. 19-24.

Tripoli has been mined since 1929 and the industry centers around Rogers, Benton County. Fourteen deposits have been investigated but not all have been exploited. Two deposits in Washington County and one in Madison County are reported. The tripoli at these localities is in the Boone formation (Mississippian), derived from the original cherts and cherty limestones by leaching. The deposits are generally flat lying and from 5 to 30 feet thick; the largest deposit is 30 feet thick over an area of 60 acres. Most of the tripoli is lightweight, snow white, fine grained, firm, and in places entirely free of chert inclusions and limy fragments; it generally contains more than 98 percent SiO₂.

The developed deposits contain large reserves. Many undeveloped deposits appear to be of good quality and contain large tonnages. Chemical analyses and production figures of Benton County are included.

——— 1942, Mineral resources of Arkansas: Ark. Geol. Survey Bull. 6, p. 58-60, 67-68, 78-79.

Glass sand is produced in Arkansas from the St. Peter sandstone (lower Ordovician) in Madison, Carroll, Newton, Boone, Searcy, Marion, Baxter, Stone, IZard, Sharp, and Independence Counties. It is well exposed along the White and Buffalo Rivers and many of their tributaries, where it occurs in bluffs about 40 feet high. It varies in thickness from 40 to 100 feet, with an average of about 60 feet.

Calico Rock formation (Ordovician) is an equally good glass sand exposed over a large area in southern Baxter, northern Stone, northern and western IZard, and central Fulton Counties. The formation ranges in thickness from 50 to 150 feet.

Kings River sandstone (Ordovician), also a good glass sand, crops out in the valleys of streams that have cut their channels through overlying strata of later rocks in Carroll, Madison, eastern Marion, and southern Baxter Counties. This sandstone is widely distributed. Thickness in IZard County is 80 feet, but it is less to the north and west.

Reserves of glass sand in northern Arkansas are very large.

Novaculite (Devonian) is widely distributed in the Ouachita Mountains of southwestern Arkansas. Between 200 to 300 miles of narrow belts of novaculite crop out from Pulaski County westward to Polk County. The novaculite occurs in layers from 2 to 10 feet thick.

Tripoli has been quarried and reported in Benton, Garland, Hot Spring, Pike, Baxter, Montgomery, Polk, and Washington Counties. Tripoli in north and northwestern Arkansas apparently was derived from siliceous limestone, whereas that from the west-central part of the State was derived from novaculite. It is mined both by underground and by opencut methods.

Broadhurst, S. D., 1949, A general survey of some high silica materials in North Carolina: N. C. Dept. Conserv. Devel., Div. Min. Res. Inf. Circ. 7, 34 p.

High-silica rocks in North Carolina include quartzites, quartz veins, sand,

and gravel. The higher grade quartzites occur in the mountainous area. There are a few sizable quartz veins which are quite pure, some containing 98 percent SiO_2 . High-grade quartz also occurs as cores in the pegmatites of western North Carolina.

Sand and gravel of the Coastal Plain seem to be the most important silica resources. Although some treatment is necessary to bring them up to specifications, there are sizable deposits which approach general chemical requirements of the glass and refractory industries. Some of these deposits are very thin whereas others are 30 feet or more thick.

Descriptions of the rocks and localities, with analyses from each location, are included.

——— 1954, A report on the high-silica sand resources of North Carolina: N. C. Dept. Conserv. Devel., Div. Min. Res. Inf. Circ. 11, 35 p.

An appraisal of potential raw materials for the manufacture of high-silica products in North Carolina. Their physical, mineralogical, and chemical qualities are equal to other eastern United States coastal sands. For potential use as glass sand, they are favorably located with respect to markets and transportation to make them economically feasible. Tests have shown that with beneficiation they meet specifications required for high-grade glass manufacture.

Chemical and mechanical analyses and a map, scale about 1 inch = 40 miles, showing silica deposits in eastern North Carolina, are included.

Brown, G. G., 1936, Molding sands of Michigan and their uses: Mich. Dept. Conserv., Geol. Survey Div. Pub. 41, Geol. Ser. 35, 262 p.

The first part of this publication includes a discussion of the physical and chemical properties of sand and the results of the investigation of the cause of bond in naturally bonded sands. The second part is a detailed description of the sand areas and deposits throughout the State, with a table giving all the properties of the sands which have been tested. Maps of sand areas of the northern and southern peninsulas of Michigan are included.

Bryson, H. J., 1937, The mining industry in North Carolina from 1929 to 1936: N. C. Dept. Conserv. Devel., Div. Min. Res. Econ. Paper 64, p. 93.

Vein quartz occurs in Anson, Montgomery, Moore, and Harnett Counties. In places, it is found in its original position cutting the old slates; elsewhere it occurs as pebbles in the Lafayette formation of the Coastal Plain. Quartz production comes chiefly from the feldspar mines of Mitchell, Avery, and Yancey Counties. Important deposits of quartz are in Buncombe and Transylvania Counties. The Tusquitee (lower Cambrian) quartzite has been mined in Cherokee County.

Bryson, R. P., Fox, E. L., Larrabee, D. M., and others, 1947, Map showing construction materials and nonmetallic mineral resources of South Dakota: U. S. Geol. Survey Missouri Basin Studies Map 12, scale 1:500,000.

Soft white sandstone (Unkpapa) in the southeastern part of the Black Hills is pure enough to be used for glass sand. In many places, this sandstone is red or variegated and of lower purity. In places, layers of shale are interbedded.

Buckley, E. R., 1898, On the building and ornamental stones of Wisconsin: Wis. Geol. Nat. History Survey Bull. 4, Econ. Ser. 2, p. 164-254.

Discusses the Precambrian quartzite outcrops, Potsdam and St. Peter sandstones, and gives descriptions of individual quarries, with a few chemical analyses.

Buie, B. F., 1949, Industrial minerals and rocks, in Shiver, H. E., and others, South Carolina raw materials: Columbia, S. C., Univ., South Carolina Press, p. 116-119.

The glass sand deposits of South Carolina are in the Coastal Plain. The chemical and screen analyses indicate an abundance of glass sand suitable for use in all except the highest quality crystal and optical glass.

The Nichols deposit, Marion County, is favorably located for rail transportation. The glass sand is reported to contain 0.025 to 0.035 percent Fe_2O_3 and about 99.50 percent SiO_2 . This deposit has yielded about 400 tons of sand per week for the manufacture of soft-drink bottles.

Burchard, E. F., 1905, The requirements of sand and limestone for glass making: U. S. Geol. Survey Bull. 285-N, p. 452-455.

The chemical and physical properties of certain sandstones and sand of the middle Mississippi River basin, including general proportions by weight, of various components of glass, requirements for glass sand, and chemical analyses of glass sand, are given.

——— 1906, Glass sand of the middle Mississippi basin: U. S. Geol. Survey Bull. 285-N, p. 459-472.

Geologic descriptions, quarry locations, sample descriptions, and analyses for some possible sources of glass sand in Arkansas, Illinois, Kansas, Missouri, and Wisconsin are discussed.

——— 1907a, Glass-sand industry of Indiana, Kentucky, and Ohio: U. S. Geol. Survey Bull. 315-376.

Geologic formations, quarries, utility, and analyses of samples from deposits in Indiana, Kentucky, and Ohio are described in detail.

——— 1907b, Notes on various glass sands, mainly undeveloped: U. S. Geol. Survey Bull. 315-K, p. 377-382.

Geologic details, quarry descriptions, analyses of samples, and utility are given for various sources of glass sand in Alabama, Arkansas, Florida, Georgia, Iowa, Kansas, Missouri, and Nebraska.

Burchfiel, B. M., 1936, Ceramic materials other than clays abundant in California: Mining and Metallurgy, v. 17, no. 357, p. 441-443.

High-grade silica occurs in many places in California. In general the quartz is simply quarried from the vein. Considerable quartz occurs with feldspar in the deposit at Campo, San Diego County. This deposit is in Hauser Canyon, 6 miles northeast of the mill, which is 2 miles west of Campo. Chemical analysis of typical silica from Campo shows 99.65 percent SiO_2 , with 0.02 percent Fe_2O_3 , and a trace of Al_2O_3 .

Burwell, A. L., and Ham, W. E., 1945, New facts regarding Oklahoma raw materials for the ceramic industries: Am. Ceramic Soc. Bull., v. 24, p. 293-295.

Glass sand deposits occur in the north-central Arbuckle Mountain district.

The principal deposits are in the Oil Creek and McLish formations (Ordovician). Chemical and sieve analyses of the glass sand and a map showing geographic distribution of Oklahoma deposits are included.

Butler, P. B., 1928, Tripoli: Mining and Metallurgy, v. 9, no. 264, p. 527-531.

Discusses briefly the properties, occurrence, history, preparation, and uses of tripoli.

Buttram, Frank, 1913, The glass sands of Oklahoma: Okla. Geol. Survey Bull. 10, p. 42-91.

Glass sand deposits occur in the Arbuckle Mountains and in northeastern Oklahoma near Tahlequah. The general features, occurrence, and character of the sands are described. Analyses of the deposits, geologic map of the Arbuckle Mountains, and maps showing distribution of the Simpson formation, the Trinity sand, and the Burgen sandstone are included.

Beds of almost pure white sand are reported near Tulsa, Bartlesville, Claremore, Ramona, Cleveland, Catoosa, Muskogee, and Holdenville. Analyses show that these beds contain large amounts of ferric oxide and other impurities, making the sand suitable only for bottle glass.

Butts, Charles, 1945, Description of the Hollidaysburg and Huntingdon quadrangles [Pennsylvania]: U. S. Geol. Survey Geol. Atlas, folio 227, p. 18-19 [1946].

Stone suitable for ganister occurs in the Tuscarora quartzite. This formation is 400 to 600 feet thick and extends through the mountainous region of central Pennsylvania. It is a compact light-gray to white quartzite with a vitreous luster, and is used to make refractory brick and furnace linings. Analyses of this stone from Lock Mountain near Point View are given.

A good glass sand occurs in the Ridgeley sandstone formation at Mapleton, a few miles southeast of Huntingdon.

Butts, Charles, and Gildersleeve, Benjamin, 1948, Geology and mineral resources of the Paleozoic area in northwest Georgia: Ga. Geol. Survey Bull. 54, p. 155-156.

Most tripoli deposits occur as irregular beds from a few inches to several feet thick associated with chert layers in residuum of the Knox dolomite formation. In Chattooga County near Harrisburg, tripoli deposits are associated with the Bangor limestone formation. Small deposits near Cartersville, Bartow County, occur in areas underlain by the Shady dolomite formation. Geologic and index maps, scale 1 inch = 4 miles, are included.

California Division of Mines Mineral Information Service, 1954, Glass sand in California: v. 7, no. 6, 4 p.

Sand mined from the Ione formation (Eocene), Amador County, containing 94 percent SiO_2 was used for glassmaking before 1922.

Glass sand has been produced from the Tesla formation (middle Eocene), near Tesla, Alameda County.

Almost white fine-grained sand used for foundry sand and bottles is quarried from the middle Eocene sandstone, exposed in a 20-mile area on the northeast side of Mount Diablo in the Brentwood area, Contra Costa County.

Glass sand is produced for bottles from the lowermost sandstone of the Paleocene Silverado formation in the Corona area, Riverside County.

Sandstone layers as much as 40 feet thick are quarried for the bottle

industry from the Tejon formation (Eocene) east of Oceanside, San Diego County. The sand is fine to coarse grained and contains a moderate amount of feldspar.

A white beach and dune sand deposit (Quaternary) containing little clay and used for bottles is near Pacific Grove. It extends about 6 miles along the coast and about 1 mile inland, Monterey County. Chemical analysis of this deposit is included.

Cameron, E. N., Larrabee, D. M., McNair, A. H., and others, 1954, Pegmatite investigations 1942-45 New England: U. S. Geol. Survey Prof. Paper 255, 352 p.

Detailed geologic maps of pegmatites show small deposits of quartz as cores. Quartz also is recovered from the flotation of feldspar from a mixture of the two minerals.

Campbell, M. R., 1902, Description of the Masontown and Uniontown quadrangles [Pennsylvania]: U. S. Geol. Survey Geol. Atlas, folio 82, p. 21.

The Homewood sandstone is exposed along the Youghiogheny River west of Connellsville; also in the Chestnut-Laurel Ridge area where it is quarried on the north side of the valley. Some glass sand has been obtained from abandoned channels of the Monongahela River.

——— 1903, Description of the Brownsville and Connellsville quadrangles [Pennsylvania]: U. S. Geol. Survey Geol. Atlas, folio 94, p. 19.

Glass sand is produced from river sand near Bellevernon and at Perryopolis. It also is produced from the Homewood sandstone (Pottsville) on the east side of the Youghiogheny River about 1 mile north of Layton.

——— 1904, Description of the Latrobe quadrangle [Pennsylvania]: U. S. Geol. Survey Geol. Atlas, folio 110, p. 15.

Glass sand is quarried from the Homewood sandstone (Pottsville) half way up the western slope of Chestnut Ridge, near the town of Derry.

Carman, J. E. 1936, Sylvania sandstone of northwestern Ohio: Geol. Soc. America Bull., v. 47, p. 253-265.

Gives the distribution of the Sylvania sandstone (Devonian) and discusses its characteristics, stratigraphic relation to underlying formations, fauna, and origin. Map, scale 1 inch = 20 miles, showing the distribution of the sandstone and the location of several exposures in Lucas and part of Wood Counties, and columnar sections of the sandstone are included.

Chelf, Carl, 1941, The crushed quartz industry of Llano County [Tex.]: Tex. Univ. Min. Res. Survey Circ. 37, 2 p.

Half a mile northwest of Packsaddle Mountain, and 9 miles from the railway at Kingsland, in the Llano region, quartz is quarried from pegmatite dikes which cut the pre-Paleozoic schists, gneisses, and granites. Most dikes contain feldspar and smaller amounts of accessory materials, but some pegmatites contain clear to dark smoky quartz crystals. The most common occurrence is well-consolidated milky-colored "sugar" quartz. One outcrop is 150 yards wide and about 300 yards long. Concentrations of large tonnages are rare. The quartz is used for roofing granules.

Chicago and North Western Railway Company, 1942, Preliminary outline of mineral resources, State of Wyoming: p. 27, 60, 78.

Deposits of fine-grained tough sandstone occur near Rawlins, Carbon County, and on Baldwin Creek near Lander, Lander County. It is used for grindstones. A bedded sand deposit, 3 feet thick, covering a large area, is in the Casper formation, east of Laramie, Albany County.

Occurrence of tripoli is reported in Laramie County and at Sunrise, Platte County.

Clabaugh, S. E., Larrabee, D. M., Griffiths, W. R., and others, 1946, Map showing construction materials and nonmetallic mineral resources of Wyoming: U. S. Geol. Survey Missouri Basin Studies Map 9, scale, 1:500,000.

High-purity silica sandstone occurs in Wyoming, but due to its remoteness from markets, it has been produced only at Lovell, Big Horn County, and at Laramie, Albany County. Both quarries were inactive in 1946.

Glass sand has been produced from the Casper formation (Pennsylvanian), east of Laramie. Operation is now idle because of inaccessibility to markets.

Cleaves, A. B., 1939, The Oriskany group in The Devonian of Pennsylvania: Pa. Geol. Survey Bull. G 19, ser. 4, p. 92-130.

An extensive study of the Oriskany sandstone (Devonian) in Pennsylvania, together with the Oriskany of adjacent States, is discussed. Formations, thickness, and fossil representatives are given, and a correlation chart of the Oriskany group in Pennsylvania is included.

Cole, L. H., 1923, Silica in Canada, part 1, Eastern Canada: Canada Dept. Mines, Mines Br. Pub. 555, 126 p.

Comprehensive report on deposits in eastern Canada discusses types of occurrence, structural and geologic features, localities, method of testing, and uses. Maps showing the distribution of sandstone and quartzite are included.

— 1928, Silica in Canada, part 2, Western Canada: Canada Dept. Mines, Mines Br. Pub. 686, 59 p.

Comprehensive report on deposits in western Canada discusses structural and geologic features and occurrences. Chemical analyses, mechanical tests, and an appendix on recent developments in the silica industry in eastern Canada to 1928, are included.

Cole, S. S., 1932, Effect at 1500° C. on the porosity and specific gravity of quartzites: Am. Ceramic Soc. Jour., v. 15, p. 87-106.

Quartzites from deposits commercially utilized for the manufacture of silica brick in the United States, Canada, and Europe were tested for 2 hours for porosity and apparent specific gravity before and after firing at 1500° C. Petrographic examinations were made of several of the raw quartzites, and the differences in crystalline structure are shown by photomicrographs. The rate of conversion of quartz was not constant for the quartzites reported. The porosity, after firing, ranged from 2 to 30 percent, and the apparent specific gravity ranged from 2.30 to 2.44. A fine-grained quartzite tends to give lower porosity after firing than does a coarse-grained one.

Colony, R. J., 1919, High-grade silica materials for glass, refractories, and abrasives: N. Y. State Mus. Bulls. 203-204, p. 5-31.

Lithologic character, general geology, chemical analyses, and locality of

each of the following formations are given: Poughquag, quartzite, Shawangunk conglomerate, Oriskany sandstone, Potsdam sandstone, and Oneida glass sands. Suggestions are made as to operating facilities, transportation, and various specific industries in which rock from the different formations might be used. Physical tests are reported.

Crickmay, G. W., 1937, Tripoli deposits of Georgia: Ga. Div. Geol. Inf. Circ. 9, p. 3-7.

The tripoli deposits of Georgia have not been fully developed. Comparison is made with Missouri-Oklahoma and Illinois-Tennessee tripoli. It has been shown that Georgia tripoli of the amorphous type is not inferior to tripoli found elsewhere. Chemical composition, description of properties, and a spot map showing locations of tripoli deposits are included.

Dake, C. L., 1921, The problem of the St. Peter sandstone: Mo. Univ., School Mines and Metallurgy Bull., Tech. Ser., v. 6, no. 1, 228 p.

Gives a description of the St. Peter sandstone, paleogeographic interpretations, and the stratigraphy of the areas in which it occurs.

Dale, Phyllis, and Beach, J. O., 1951, Mineral production of Oklahoma 1885-1949: Okla. Geol. Survey Circ. 29, p. 21, 32.

Presents a table showing production, tonnage, and value of glass sand in Oklahoma from 1920 to 1930. Sand and gravel are included in the figures from 1931 to 1949. Tripoli production in Oklahoma and Missouri is briefly discussed.

Damon, H. G., 1943, The origin and distribution of spiculite near Lampasas, Lampasas County, Tex., in Texas mineral resources: Tex. Univ. Pub. 4301, p. 271-282 [1946]. See also Sellards and others, 1944.

Spiculite (tripoli) beds occur in the Marble Falls formation (Pennsylvania), where it crops out west and southwest of Lampasas. Outcrops of pure silica may grade into limestone, or unaltered limestone beds may alternate with beds of spiculite. Description of deposits, composition, and physical properties in Lampasas and Burnet Counties are given. A geologic map, scale about 1 inch = 1,800 feet, showing outcrops of spiculite in parts of Burnet and Lampasas Counties is included.

Darton, N. H., 1939, Gravel and sand deposits of eastern Maryland: U. S. Geol. Survey Bull. 906-A, p. 31, 34-39.

Discusses sand for glass, molding, and other uses and the requirements of the sands. Gives some localities of glass and molding sand in the area and the results of sieve tests of steel molding sands from various localities for comparison with materials from the Baltimore-Washington region.

The Brennan pit, one of the largest producers, is on the west side of Forked Creek, 2 miles west of Round Bay station; it was active from 1906 to 1920. Considerable stripping was necessary to uncover the sand, much of which was regarded as suitable for glassmaking. Borings showed it was 30 feet or more thick. Map, scale 1:62,500, showing distribution of sand and gravel in the area is included.

Darton, N. H., Bayley, W. S., Salisbury, R. D., and Kummel, H. B., 1908, Description of the Passaic quadrangle [New Jersey-New York]: U. S. Geol. Survey Geol. Atlas, folio 157, p. 26.

Molding sand has been quarried near Montville and south of Morris Plain

railroad station. Chemical analysis of the best grade of this sand underlying the Woodbridge fire clay is from 92.5 to 98 percent SiO_2 , and from 1.45 to 6.55 percent Al_2O_3 , and Fe_2O_3 . The sand is used in foundries.

Darton, N. H., and Smith, W. S. T., 1904, Description of the Edgemont quadrangle [South Dakota-Nebraska]: U. S. Geol. Survey Geol. Atlas, folio 108, p. 10.

A deposit of Dakota sandstone suitable for grindstones is $3\frac{1}{2}$ miles north-northeast of Edgemont. It is of excellent quality and uniform grain size, but the overburden is thick.

Dasher, John, Rough, R. R., and Bacon, F. L., 1943, Beneficiation of Del Monte, Calif., sand: U. S. Bur. Mines Rept. Inv. 3740, 10 p.

Gives methods of removing objectionable impurities, largely oxides of iron and aluminum, from west coast sand that otherwise would be suitable for use in the glass container industry.

Davis, F. A. W., and Johnson, Martin, 1938, Technology of the western Tennessee tripoli in Tripoli deposits of western Tennessee and Mississippi: Knoxville, Tenn. Valley Authority, Water Control Plan. Dept., Geol. Div., Geol. Bull. 8, p. 13-17.

Discusses the processing of tripoli from the Warsaw formation in western Tennessee Valley area. Tests have shown this tripoli is comparable to the Missouri tripoli in its high-oil absorption. Mechanical tests are included, and a table shows the comparative screen analysis and oil absorption for Tennessee tripoli, with standard commercial grades of Missouri tripoli, Illinois "soft" silica, and Black Fox (East Tennessee) "soft" silica.

Davis, F. F., and Vernon, J. W., 1951, Mines and mineral resources of Contra Costa County [Calif.]: Calif. Jour. Mines and Geology, v. 47, p. 580-584.

Locations of glass and foundry sand deposits in Contra Costa County are described. A map, scale about 1 inch = 80 miles, showing mineral distribution is included.

Dorisy, C. E., 1935, Index of mineral occurrences in the State of Washington: Wash. Plan. Council Pub. 3, p. 30.

Glass sand, 96 percent SiO_2 , occurs near Newport, Pend Oreille County. Silica suitable for making glass is found 2 miles east of Kettle Falls, Stevens County. Reserves of high-grade sandstone in the vicinity of Denison, Spokane County, are reported to be 7 million tons.

Dunkin, D. D., 1928, Mining and preparation of St. Peter sandstone in Arkansas: Am. Inst. Min. Metall. Eng. Tech. Pub. 55, 10 p.

The St. Peter sandstone (lower Ordovician) is widely distributed in north-central Arkansas and is exposed most prominently along the slopes of the White River valley and its tributaries. The greatest thickness is at the southeastern end where it is more than 100 feet thick in many places. The deposit and methods of operations at Guion, Izard County, are described, and chemical and sieve analyses are included.

Edwards, A. C., 1926, Pioneer in the silica sand industry keeps plant abreast of times: Pit and Quarry, v. 13, no. 1, p. 58-60.

For several miles along the Illinois River, sand is mined from the St.

Peter sandstone, and is used for the manufacture of iron, steel, and glass, sandblasting, and chemical purposes. It extends into the high ground bordering the Illinois River on the north, and about 4 miles west of Ottawa. Overburden consists of 10 to 12 feet of earth and shale, a 22-inch seam of coal, and a second layer of shale. No material is stored at the plant; production is moved direct from the pit to railway cars. No attempt is made to produce molding sand during the winter because the frozen sandstone does not break as desired. However, a small amount is mined by hand during this period.

Ehlers, G. M., Stumm, E. C., and Kesling, R. V., 1951, Devonian rocks of southeastern Michigan and northwestern Ohio: Ann Arbor, Mich., Edwards Bros., Inc., 40 p.

Discusses the lithology, succession, and relationship of the Devonian strata of southeastern Michigan and northwestern Ohio. Comparison of the Devonian strata of northern Michigan and New York is made in relation to the deposition of the rocks and the chief diagnostic fossils of the various formations. A brief description of the Sylvania sandstone is given.

Geologic map, scale about 1 inch = 1 mile, showing distribution of Devonian rocks and drawing showing distribution of Sylvania sandstone and quarries in which it is exposed are included.

Emerson, B. K., 1899, The geology of eastern Berkshire County, Mass.: U. S. Geol. Survey Bull. 159, p. 78-79, 100.

Cheshire quartzite (Cambrian) suitable for the glass industry extends approximately from north of Dalton southward to Washington. At Coltsville station, the deposits are 180 feet thick. The quartzite has been quarried for glass sand in the mountains of Washington Township at Dalton. The geology and topography of the area are discussed. Buhrstone also has been quarried in the mountains in Washington Township.

Geologic map, scale about 2 inches = 1 mile, showing Cheshire quartzite at Ferncliff and East Lee, and a geologic map, scale 1 inch = 2¼ miles, showing Cheshire quartzite in the eastern half of the Housatonic quadrangle are included.

——— 1917, Geology of Massachusetts and Rhode Island: U. S. Geol. Survey Bull. 597, p. 74-75.

Discusses the Quabbin quartzite of Carboniferous age. The quartzite, which is pure, white, and sugary, in many places flaggy, makes up a great part of Quabbin and Felton Mountains. It was formerly used as hearthstones for iron furnaces and firestone. At Chaffee's Place, 4 miles south of Peaked Mountain, Stafford, Conn., are large quarries of quartzite and a mill where it was sawed 50 years ago.

Emmons, W. H., and Grout, F. F., 1943, Mineral resources of Minnesota: Minn. Geol. Survey Bull. 30, p. 78-89, 111-112, 134.

Grinding pebbles derived from the Sioux quartzite, which compare favorably with the Danish, Belgian, and French flint pebbles, are found on the shores of Lake Superior between Grand Portage and Pigeon Point. Recent deposits in the Lake Superior area also are used in making cores. Sioux quartzite is quarried at Pipestone, Jasper, Luverne, and formerly was produced at New Ulm. It is used for refractory molds and sandblast castings. Some screenings are sold as refractory sand for foundry use and some as ganister used in the manufacture of silica brick or furnace lining. At Pipestone, sized chips are used for roofing granules.

Jordan sandstone (upper Cambrian) is mined near Ottawa, Jordan, and other localities along the Minnesota River. It is a white to yellow medium-grained friable high-grade silica sandstone. It ranges from about 100 to 200 feet in thickness, and is exposed along the St. Croix, Minnesota, and Mississippi Rivers. It is used for sandblasting, stone sawing, other abrasive purposes, in foundries, for filter beds, and for making glass. St. Peter sandstone (lower Ordovician) is exposed in the Minneapolis-St. Paul area. It is a weakly cemented white medium- to fine-grained rock, whose sand grains are well rounded and frosted. It contains some clay and silt. It is used for rough finishing of stone, as a core sand, in foundry work, and also for making glass.

Tripoli was quarried at Stillwater. It is believed to be a silt partly inter-laminated with clay that was deposited in a glacial lake.

Evans, G. L., 1943, Mineral abrasive and polishing material in Texas, *in* Texas mineral resources: Tex. Univ. Pub. 4301, p. 245-248 [1946]. See also Sellard and others, 1944.

Grinding pebbles occur in large thin deposits on interstream divides and in river terraces of the Gulf Coastal Plain between Guadalupe River and the Rio Grande. Pebbles also have been produced in many counties. The milled pebbles are equal in quality to foreign pebbles.

A small quantity of flint-tube-mill liner stock has been produced from the Edward formation in western Travis County. Flint occurs as thin beds and lenses as well as nodules in this formation.

Sandblast sand (rice sand) occurs mainly near the base of the Catahoula formation and in later deposits derived therefrom. The sand grains are sub-rounded to sharp and range from fine to coarse.

Tripoli (spiculite) deposits occur in the Pennsylvanian Marble Falls formation in Lampases and Burnet Counties.

Massive quartz occurs as vein deposits in the Precambrian rocks in the Llano region and in the Carrizo Mountains of Culberson and Hudspeth Counties. The Texas deposits are of sufficient size and quality to meet industrial requirements.

Novaculite formation (Caballos) forms prominent and extensive outcrops in the Marathon uplift in Brewster County. The strata of the novaculite have been intensely folded and fractured. Value of the novaculite is impaired if blocks are cracked and filled with material of different hardness.

Distribution map, scale about 1 inch = 75 miles, is included.

Fettke, C. R., 1918, Glass manufacture and the glass sand industry of Pennsylvania: Pa. Topog. Geol. Survey Rept. 12, 278 p. [1919].

Comprehensive report on the glass sands of Pennsylvania gives composition of glass, classification of glasses, chemical and mechanical analyses, raw materials for glass manufacture, statistics of the glass industry, location of glass sand deposits and factories.

The Oriskany glass sand deposits are in Huntingdon, Mifflin, Bedford, Blair, Carbon, Centre, and Monroe Counties. The Pottsville glass sand deposits are in Clearfield, Elk, Fayette, Forest, Jefferson, McKean, Venango, Warren, and Westmoreland Counties. Other glass sand deposits occur in river terraces. The Tuscarora sandstone, or quartzite, may also be a possible source of glass sand.

Small maps showing outcrops in specific counties and a map, scale about 1 inch = 15 miles, showing location of glass plants and glass sand quarry are included.

Fettke, C. R., 1926, American glass sands, their properties and preparation: *Am. Inst. Min. Metall. Eng. Trans.*, v. 73, p. 398-423.

Report on the technology of glass manufacture gives specifications and procedures of processing. Includes short discussion on prices and production and geographic location of raw materials in the mid-West and Eastern States.

Flint, N. K., 1951, Geology of Perry County [Ohio]: *Ohio Geol. Survey*, 4th ser., Bull. 48, p. 122-123.

The only sandstone presently used for glass is the Massillon. Operations in the vicinity of Glenford and Glassrock in Hopewell Township are briefly described. Analyses are given.

Frederick, C. L., 1932, Properties of silica brick manufactured from Sharon conglomerate: *Am. Ceramic Soc. Jour.*, v. 15, p. 61-67.

Silica refractories are discussed, and a résumé of materials utilized in the manufacture of silica brick in the United States is given. Comparative tests were made on brick manufactured from Medina (Tuscarora) quartzite, Oriskany sandstone, and Sharon conglomerate of Pennsylvania. Final conclusion was that bricks made from Sharon conglomerate are equal in quality to the average silica brick. Analyses of Pennsylvania quartzite and Sharon conglomerate are included.

Frye, J. C., 1942, Kansas mineral resources for wartime industries: *Kans. Geol. Survey Bull.* 41, pt. 3, p. 168-169.

Short discussion on Mississippian tripoli in Cherokee County.

Fuller, J. O., 1947, Sharon conglomerate, a source of high silica raw material: *Ohio State Univ. Eng. Expt. Sta. News*, v. 19, no. 2, p. 48-55.

The Sharon conglomerate (Pennsylvanian) averages 95 to 99 percent SiO_2 , as rounded pebbles ranging in diameter from one-eighth of an inch to 3 inches. The pebbles are generally white, but pink, rose, gray, and black are fairly common. The thickness in northeast Ohio is 175 feet, whereas in the southern part of the State it is 200 feet. Total production for industrial uses is well over 700,000 tons a year.

Chemical analyses giving locations where the samples were obtained and an outcrop map, scale about 1 inch = 64 miles, are included.

Fulton, J. A., and Smith, A. M., 1932, Nonmetallic minerals in Nevada: *Pit and Quarry*, v. 24, no. 11, p. 37.

Large quantities of silica associated with alunite and sulfur were quarried in the Cuprite district, Esmeralda County, from 1914 to 1918. No production in recent years has been reported.

Glass sand was mined in 1931 at Steamboat Springs, Washoe County, 10 miles south of Reno. Analysis of the sand show 99 percent SiO_2 , 0.6 percent Al_2O_3 , and about 0.04 percent Fe_2O_3 .

Silica is mined at Overton, Clark County. This mine produces 30,000 tons of washed silica annually.

Many large deposits of silica sand occur in Clark County. Two deposits are 7 and 11 miles, respectively, northwest of Crystal; another occurs in the White Basin district, about 12 miles southeast of Crystal. Near Apex, 12 miles north of Las Vegas, hard white sandstone, interbedded with limestone, crops out, and on the Union Pacific Railroad, 30 miles south of Las Vegas, a large deposit of loosely consolidated sandstone has yielded glass sand.

Furcron, A. S., and Teague, K. H., 1943, Mica-bearing pegmatites of Georgia: Ga. Geol. Survey Bull. 48, 192 p.

Discusses quartz occurring in the mica-bearing pegmatites. Description of the deposits and a map, scale about 1 inch = 65 miles, showing five principal areas are included.

Gildersleeve, Benjamin, 1946a, Minerals and structural materials of the Pickwick, Wilson, and Wheeler reservoir areas (revised): Knoxville, Tenn. Valley Authority Rept. 2, p. 33-35.

Tripoli occurs in the Stout district, in the southwest corner of Wayne County, Tenn., and adjoining parts of Hardin County, Tenn., and Lauderdale County, Ala. The average analysis of this deposit shows 96 percent SiO_2 , 1 percent Fe_2O_3 , and 3 percent Al_2O_3 . In the Bear Creek district, it occurs from Riverton, Colbert County, Ala., southward along the east side of Bear Creek to about 2 miles north of Margerum. On the west side of Bear Creek, the most important deposits are in the vicinity of Eastport, Tishomingo County, Miss.

The tripoli ranges in thickness from a few feet to 60 feet, the larger deposits averaging about 25 feet. No tripoli has been produced in this area since 1912. Geologic and location maps, scale about 1 inch = 7 miles, are included.

——— 1946b, Minerals and structural materials of southwest Virginia (revised): Knoxville, Tenn. Valley Authority Rept. A, p. 34-35.

Gives locations of outcrops of the Erwin, Clinch, Oriskany, Price, and Gladeville sandstones and quartzites. The above formations have been cited as typical of the sandstones and quartzites of the area. In some places they have been used as a source of glass sand. Attention is called to the fact that sodium carbonate and other essential ingredients for glass manufacture are produced in this area. Map, scale 1 inch = 8 miles, shows location of deposits.

——— 1946c, Minerals and structural materials of the Hales Bar and Chickamauga reservoir areas [Tennessee] (revised): Knoxville, Tenn. Valley Authority Rept. 4, p. 49, 54.

Glass sand is produced from the Sewanee conglomerate (Pennsylvanian) about 3 miles east of Sewanee, Franklin County, Production in 1943 averaged about 3,500 tons per month.

Bon Air formation is a possible potential resource of glass sand.

Map, scale about 1 inch = 9 miles, showing locations is included.

Tripoli formerly was produced from a dense chert horizon of the lower Knox dolomite at Black Fox, $3\frac{1}{2}$ miles south of Cleveland, Bradley County. This operation was abandoned about 1932.

Giles, A. W., 1930, St. Peter and older Ordovician sandstones of northern Arkansas: Ark. Geol. Survey Bull. 4, 187 p.

Presents a comprehensive report on the Kings River, Calico Rock, and St. Peter sandstones. The Kings River and Calico Rock sandstones are members of the Everton formation (lower Ordovician). The Kings River sandstone ranges from 2 to 40 feet in thickness, and averages about 25 feet. It is chemically pure and averages above 99 percent SiO_2 . Calico Rock sandstone ranges from 50 to 150 feet in thickness, and averages about 100 feet. The SiO_2 content averages above 98 percent. St. Peter sandstone (Ordovician) ranges in thickness from 10 to 200 feet. The grains are generally frosted and pitted. The SiO_2 content exceeds 98 percent.

These sandstones are widely distributed, but the St. Peter is the only sandstone being exploited at present. Sieve analyses; map, scale about 1 inch = 13 miles, showing outcrops of Calico Rock sandstone; and maps, scale 1 inch = 1 mile, showing location and surface outcrop of St. Peter sandstone are included.

Glenn, L. C., 1914, A tripoli deposit near Butler, Tenn.: *Tenn. Geol. Survey, Res. Tenn.*, v. 4, no. 1, p. 29-35.

Tripoli occurs on the Matherley farm at Cobb Creek, 2½ miles northwest of Butler, Johnson County. It occurs in the Watauga formation (Cambrian) where it is interbedded with shale and limestone more than 800 feet thick. Most of the particles range from 0.0015 mm to 0.16 mm in diameter. Analysis, origin, mining, and uses are included.

Glover, S. L., 1936, Nonmetallic mineral resources of Washington: *Wash. Div. Geology Bull.* 33, p. 12-13, 94-96.

Sandstone suitable for abrasives occurs in the Eocene rocks of the Puget Sound area and in Chelan and Kittitas Counties. The Miocene and Oligocene rocks in the Olympic Mountains are possible sources of abrasive sandstones. Pulpstone has been quarried from a deposit at Wilkerson, Pierce County, and in Skagit County. Whetstones were quarried from an 8-foot bed in Skamania County between White Salmon and Stevenson. Sandstone with a high percentage of silica but which would require beneficiation before it could be of commercial use as high-purity silica occurs in Stemilt Canyon, south of Wenatchee, Chelan County. The Swauk sandstone, after beneficiation, contains 98 to 99 percent SiO_2 ; it occurs 3 miles south of Wenatchee, Chelan County. Sands of the Hammer Bluffs formation in King County overlies Eocene rocks a few miles east of Auburn, and crop out in the Hammer Bluffs and Green River region. Some samples, after washing, were satisfactory for glass. Green glass was produced from the Kummer sandstone in northwestern Washington.

A dike of white quartz, 50 feet wide and 96.6 percent pure, is near Wenatchee. A large quartz vein occurs near Merritt, Chelan County. Vein quartz is mined at Rockport, Skagit County. The Denison (Latshaw) pegmatitic quartz deposit is about 7 miles south of Denison and 13 miles north of Spokane, Spokane County. This deposit extends over an area of 3½ acres. The stained surface quartz averages about 95 percent SiO_2 , and the fresher rock about 98 percent SiO_2 . Quartz in the Chuckanut formation in Whatcom County is found on the northeast shore of Samish Lake in the NE1/4 sec. 26, T. 37 N., R. 3 E., on the Saar Creek, southeast of Sumas, and in the NW1/4 sec. 17, T. 40 N., R. 5 E.; the latter deposit, which is 80 feet thick, is reported to contain 98 percent SiO_2 and very little Fe.

Quartzite occurs at Kettle Falls, Stevens County, and south of Spokane near the north center of NE1/4 sec. 15, T. 24 N., R. 43 E., Spokane County. It also is reported 8 miles east of Enumclaw.

Goldstein, August, Jr., and Hendricks, T. A., 1953, Siliceous sediments of Ouachita facies in Oklahoma: *Geol. Soc. America Bull.*, v. 64, p. 428-430.

Certain sedimentary rocks crop out in the Ouachita Mountains; these contain large amounts of silica disseminated through a relatively thick series of novaculite beds. Four lithologic types, including novaculite and spiculite chert, are present. The stratigraphy and petrography of these types are given in detail, with extracts from other authors.

Gould, C. N., 1908, Glass sand *in* Preliminary Report on the mineral resources of Oklahoma: Okla. Geol. Survey Bull. 1, p. 44-46.

Glass sand in Oklahoma occurs in three regions, near Tahlequah, in the Arbuckle Mountains, and north of the Red River in southern Oklahoma. The glass sand at Tahlequah is in the Bergen sandstone, which is a massive moderately fine grained light-brown rock. The formation ranges from a thin stratum to beds more than 100 feet in thickness. The Arbuckle Mountain glass sand occurs in the Simpson formation, which is composed of three members. Some limestone is interbedded with the sandstone, which in places is 100 feet thick. In southeastern Oklahoma, glass sand occurs in the Trinity sandstone which crops out as a band ranging in width from 5 to 15 miles along the southern base of the Arbuckle and Ouachita Mountains, extending from Marietta to the Arkansas line. Localities near Marietta, Atoka, and Antlers are said to yield good glass sand.

——— 1910, Brief chapters on Oklahoma's minerals: Okla. Geol. Survey Bull. 6, pt. 2, p. 94-96.

Gives a brief discussion on the tripoli industry of Oklahoma. Tripoli occurs in the Boone formation in the vicinity of Seneca, Mo., and in the area of Spring and Grand Rivers and north of the Arkansas River. Small amounts occur near Tahlequah and near Spavinaw Creek. Oklahoma tripoli is not suitable for filters.

Novaculite occurs in the eastern part of the Ouachita Mountains, near Hot Springs, Ark. The same formation passes westward into Oklahoma where it is exposed near Talihina and Otoka. Possible potential resources are east of the Missouri-Kansas-Texas Lines between Stringtown and Otoka and in the Potatoe Hills east of Talihina and north of Tuskahoma.

Gould, C. N., and Beach, J. O., 1930, Oklahoma glass sands: Okla. Geol. Survey Mineral Rept. 3, 12 p.

Sands suitable for the manufacture of various grades of glass occur in three localities in Oklahoma: in the Simpson formation in the Arbuckle Mountain region of Pontotoc, Johnston, Murray, and Carter Counties, in the Trinity sandstone north of the Red River in south-central and southeastern Oklahoma, and in a small area in the Burgen sandstone near Tahlequah in northeastern Oklahoma. Brief description is given of the locality and deposits. A map, scale 1 inch = 43 miles, showing distribution of glass sands in Oklahoma is included.

Grimshaw, R. W., 1953, The quantitative estimation of silica minerals: Clay Mineral Bull., v. 2, no. 9, p. 2-7.

Discusses the importance of silica and siliceous materials for refractory purposes. Analyses of samples from various localities are included.

Grimsley, G. P., 1909, History of the glass sand industry in West Virginia: W. Va. Geol. Survey, v. 4, p. 375-390.

Gives a description of the glass sand producing plants as they existed in 1909, a classification of glass, location of deposits, list of companies, and many analyses.

——— 1916, Jefferson, Berkeley, and Morgan Counties [W. Va.]: W. Va. Geol. Survey County Repts., p. 222, 224, 313, 321-344.

Discusses the Oriskany sandstone at Berkeley Springs and the properties

of the Antietam sandstone in Jefferson County. Describes the glass sand resources, glass plants, mining, milling, economical features, and companies engaged in the glass sand industry of the eastern Panhandle counties. A few chemical analyses are given. Maps, scale 1:62,500, showing the topography and general and economic geology are included.

Griswold, L. S., 1892, Whetstones and the novaculites of Arkansas: *Ark. Geol. Survey Ann. Rept. for 1890, v. 3, 443 p.*

Presents a comprehensive report on deposits of whetstones and novaculites known before 1892. Localities are listed in Arkansas, Georgia, Oklahoma, Maine, Maryland, Massachusetts, and New Hampshire. Deposits in Arkansas are described in detail. Chemical analyses and analyses of tripoli from Seneca, Mo., and of novaculite from Marquette, Mich., are included. Geologic map, scale 1 inch = 3 miles, of the novaculite region in Arkansas accompanies the report.

Ham, W. E., 1945, Geology and glass sand resources, central Arbuckle Mountains, Okla.: *Okla. Geol. Survey Bull. 65, 103 p.*

Describes the glass sand deposits in the Arbuckle Mountains. These deposits are in the Oil Creek and McLish formations of the Simpson group (Ordovician). They range in thickness from 150 to 400 feet and in width from 500 feet to 1½ miles, and have an overburden 3 to 20 feet thick of loose iron-stained sandy soil or clay.

Crude sands contain 97.82 to 99.57 percent SiO₂, 0.09 to 0.40 percent Fe₂O₃, 0.04 to 1.16 percent Al₂O₃, and very little CaO and MgO. Sieve analyses show 83 to 90 percent fine to very fine sand (Wentworth scale). The average median diameter of the sands is 0.142 mm, and the average sorting coefficient is 1.20.

Map showing localities of glass sand in Oklahoma is included.

Hanley, J. B., Heinrich, E. W., and Page, L. R., 1950, Pegmatite investigations in Colorado, Wyoming, and Utah, 1942-1944: *U. S. Geol. Survey Prof. Paper 227, 125 p.*

Discusses quartz occurring in pegmatites in Colorado, Wyoming, and Utah, which might be a possible source of glass sand, and includes 17 plates, 34 figures, and 7 tables.

Harris, G. D., 1941, Report on the geology of Lee County, Tex.: *Tex. Univ. Min. Res. Survey Circ. 33, p. 4-5, 6-8.*

The Carrizo sand crops out in Lee County. The area of outcrop is about 1 mile wide in the northeast corner and is at least 5 miles wide in the southwest part of the county. Thickness exceeds 200 feet. The lower part of the Carrizo consists of tan and white medium-grained sands, with one or two layers of bluish sand or siltstone. The upper part of the formation consists of iron-stained massive sandstone, with a conglomerate ironstone cap. The Queen City sand is exposed in Lee County in an outcrop that ranges in width from 1 to 3 miles.

Harton, B. H., 1953, Ouachita chert facies, southeastern Oklahoma: *Am. Assoc. Petroleum Geologists Bull., v. 37, p. 788-796.*

The Arkansas novaculite includes three divisions, lower, middle and upper. It not only is related to faulting but also to widespread solution and redeposition of silica. The lower and upper divisions, originally shale and shaly limestone, have been altered chemically by replacement of clay minerals by silica

through action of ground waters. In the middle division, the process of segregation of silica within the belt of deformation was aided and controlled by conditions developed during overthrusting. The age of the middle division is Devonian and lower Mississippian. Specific locations are given for those divisions where novaculite occurs. The theory is advanced that the excessive deposition of silica in the Ouachita region was produced by alteration during the orogenic process.

Havell, R. F., and McVay, T. N., 1939, Beneficiation of some Alabama glass sands: *Am. Ceramic Soc. Bull.*, v. 18, p. 429-431.

Studies were made on the beneficiation of beach sands southeast of Mobile, on the Gulf of Mexico. Tests have shown the following: Iron content may be lowered by tabling from 0.093 to 0.169 percent Fe_2O_3 , to 0.057 to 0.066 percent Fe_2O_3 . Grain-size distribution of the sands is satisfactory for glass manufacture. It might be possible to recover small amounts of zircon, kyanite, ilmenite, and rutile as byproducts.

Proposed flow sheet for possible treatment of sands, mechanical and chemical analyses, and tables giving percentage grain counts of heavy minerals are included.

Heinz, C. E., 1937, Tripoli, in *Industrial Minerals and Rocks*: New York, Am. Inst. Min. Metall. Eng., 1st ed. p. 911-922.

Discusses the properties, origin, and mining of tripoli in the United States and lists five districts where it occurs. Missouri-Oklahoma district includes Racine and Seneca, Newton County, Mo., and Peoria, Ottawa County, Okla.; Illinois district includes Alexander and Union Counties; Tennessee-Georgia-Alabama district; Tennessee Valley district, where Tennessee, Alabama, and Mississippi join; and Arkansas 6 miles from Rogers, Benton County.

Hewett, D. F., Callaghan, Eugene, Moore, B. N., and others, 1936, Mineral resources of the region around Boulder Dam: *U. S. Geol. Survey Bull.* 871, p. 169-170.

A 300-foot crossbedded sandstone member of the Supai formation forms a cliff along the mountain front several miles west of Bard. Because of the crossbedding, there is a great variation in composition and size of grains. The sandstone, which contains a small amount of iron and some lime, is used for molding sand. The reserves are said to be inexhaustible.

Extensive deposits of quartz sand crop out northeast and southwest of the Muddy Mountains. In the northeastern area, large sand deposits occur in the Jurassic(?) sandstone and in dunes. Silica is quarried from the Overton fanglomerate, 5 miles south of Overton. Some of the deposits are reported to average 99.2 percent SiO_2 . Other analyses included show a slightly lower percentage.

Dune sand in Magnesite Wash, 2 miles south of Overton, is suitable for making colored bottle glass.

Exploratory work is being done in the Overton fanglomerate, southwest of Muddy Mountains.

Chemical analyses are included.

Hewitt, D. F., 1951, Silica in Ontario: *Ont. Dept. Mines Indus. Mineral Circ.* 2, 16 p.

This report gives a brief discussion of the occurrences, characteristics, and uses of silica deposits in Ontario. Mining, milling, beneficiation, and market-

ing are also mentioned. Workable deposits consist of unconsolidated silica sand, sandstone, quartzite, and pegmatitic quartz. The main silica resources in Ontario are the Lorrain quartzite (Precambrian), Potsdam sandstone (Cambrian), Medina sandstone (Silurian), Sylvania sandstone (Devonian), and the unconsolidated sands (Quaternary and Recent).

Chemical analyses of samples from most deposits are given. Map, scale 1 inch = about 25 miles, showing the distribution of quartzite deposits and a map, scale 1 inch = about 38 miles, showing the location of sandstone deposits are included.

Hickok, W. O., IV, and Moyer, F. T., 1940, Geology and mineral resources of Fayette County, Pa.: Pa. Geol. Survey, 4th ser., Bull. C 26, p. 53-59, 299, 311, 487-488, 492-494.

Discusses the Connoquenessing and Homewood sandstones (Pottsville). Several quarries and one mine are on Chestnut Ridge, along the Youghiogheny River and Dunbar Creek, where 40 to 50 feet of the Upper Connoquenessing sandstone and about 40 to 50 feet of Homewood sandstone have been worked. Both formations are composed of light-buff to white coarse-grained heavy-bedded sandstone. Sands from these formations must be washed to be suitable for the better grades of glass. Silica refractories are produced from these sands. Geologic and topographic maps, scale 1:62,500, of Fayette County, are included.

Hodge, E. T., 1938, Northwest silica minerals, in Market for Columbia River hydroelectric power using northwest minerals: Portland, Oreg., War Dept., Corps of Engineers, U. S. Army, North Pacific Div., sec. 2., v. 1, 175 p., v. 2, p. 177-189.

Discusses the silica deposits of Idaho, Washington, and Oregon and localities other than the Pacific Northwest; gives a detailed discussion on the technology of silica. Maps showing location, topography, and geology are included.

Hoeman, E. C., and Redfield, R. C., 1943, Industrial sand from the Eocene Rockdale formation in Texas, in Texas mineral resources: Tex. Univ. Pub. 4301, p. 283-300 [1946]. See also Sellards and others, 1944.

Sand strata in the Simsboro member of the Rockdale formation (Eocene) crop out in many counties in the Texas Coastal Plain. Geologic and geographic description, properties, and analyses of the deposits are given. After beneficiation this sand may be used for foundry, molding, filter and engine sands, flint glass, abrasives, sand-lime and silica brick, sodium silicate, and silicon carbide.

Holmquist, P. J., 1947, Details of the quartz transformation in silica bricks: Ingeniörs vetens. akad. Handl. 192 (The Royal Swedish Academy of Eng. Sci. Proc.), 19 p.

Several observations indicate that the transformation of quartz in bricks may be essentially accelerated by subordinate admixed substances. Even very small quantities of alkali metals are highly active in the formation of easily fusible mixtures of alkali silicates and fluid eutectics.

Petrographic examinations have shown that burning gives rise to two products in the silica bricks. One consists of a fine grained mixture of tridymite and glassy slag (sometimes also containing slag minerals) of the groundmass; the other consists of coarser grains, mainly composed of

heterogenous cristobalite which often contains remnants of nontransformed quartz.

Hones, C. W., 1923, *Geology of the southern Ouachita Mountains of Oklahoma*, part 1, Stratigraphy, structure, and physiographic history, p. 19-139; part 2, Geography and economic geology, p. 54-58: Okla. Geol. Survey Bull. 32.

Discusses the general features of the Arkansas novaculite formation, which has three lithologic units. The lower consists of massive white novaculite; the middle contains thin layers of dense dark novaculite interbedded with shale; and the upper is chiefly massive calcareous novaculite. The maximum thickness does not exceed 600 feet.

Two types of commercial material are the Arkansas stone and the Ouachita (Washita) stone. The Arkansas stone, a true novaculite, is homogeneous, gritty, fine-grained, has low porosity (0.25 percent) and a conchoidal fracture. Chemical analyses indicate a content of 99 percent SiO_2 . The Ouachita stone is chemically similar to the Arkansas stone, but its dull luster and porosity of 5 percent exclude it from the classification of a true novaculite. The cryptocrystalline silica of the Ouachita stone is denser around the rims of minute rhombohedral cavities; the rims of these cavities accomplish the sharpening of tools rubbed across the stone. The Arkansas stone is better adapted for fine finish work done on whetstones, whereas the Ouachita stone is better for the coarse cutting as done on scythestones. Reserves are large. Geologic map, scale 1 inch = 1 mile, of the southern Ouachita Mountains is included.

Hudson, W. C., 1946a, *Investigation of the Miami-West Palm Beach belt of silica sand in Florida*: U. S. Bur. Mines Rept. Inv. 3865, 5 p.

The Miami-West Palm Beach belt of silica sand extends 65 miles northward from Miami to West Palm Beach. The width of the belt is more than a mile and the deposits range from 4 to more than 7 feet in thickness. The long, narrow sand terrace is 10 to 30 feet above sea level. Most of it is flat but sand dunes occur near the northern end. The possible glass sand is believed to end a few miles north of West Palm Beach because of the increased content of black sands, especially near Stuart. Overburden is about 1 foot thick. Chemical and mechanical analyses of the sand and a map, scale about 1 inch = 11 miles, showing the glass sand belt are included.

——— 1946b, *Investigation of the McLeod glass-sand pits Wheeler County, Ga.*: U. S. Bur. Mines Rept. Inv. 3859, 3 p.

The McLeod pits are on the southeast side of the Little Ocmulgee River, Wheeler County. They are about 1 mile long and one-fourth mile wide. Overburden is about 6 to 11 feet thick. Thickness of sand is about 5 feet. Chemical and mechanical analyses of sample are given, and location map, scale 1 inch = 19 miles, is included.

Huey, A. S., 1948, *Geology of the Tesla quadrangle, California*: Calif. Div. Mines Bull. 140, p. 61.

Abandoned glass sand prospects of the Tesla formation are in San Joaquin and Alameda Counties. The mining of glass sand in the Tesla area has been limited by the more ready accessibility and higher quality of the white sands near Mount Diablo, Contra Costa County. "Livermore ganister," a natural mixture of silica sand and clay, occurs in Alameda County. It is confined to a

single stratigraphic unit and is used in foundries as a ladle-patching and furnace-lining material. Geologic map, scale 1:62,500, is included.

Huttl, J. B., 1937, A glass sand enterprise on the Pacific Coast: *Eng. Min. Jour.*, v. 138, no. 12, p. 29-31.

The report describes operations of the Silica Co. of California, about 3 miles southeast of Brentwood, a station on the Santa Fe Railway. The deposit is of Eocene age and consists of compact sandstones in which a workable bed of amber-colored sand occurs, ranging in thickness from 30 to 40 feet. The mining and processing of the sand are discussed, illustrated by a flow sheet.

Jahns, R. H., Griffiths, W. R., and Heinrich, E. M., 1952, Mica deposits of the southeastern Piedmont; part 1, General features: U. S. Geol. Survey Prof. Paper 248-A, 102 p. *See also* Prof. Papers 248-B, C, D, E, F.

Discusses quartz occurring in pegmatites in Virginia, North Carolina, Georgia, South Carolina, and Alabama. Includes 1 plate, 31 figures, and 14 tables.

Jensen, N. C., 1942, Marketing silica (Quartz, tripoli, diatomite, etc.): U. S. Bur. Mines Inf. Circ. 7202, 39 p.

Describes various forms of silica, discusses their occurrence, properties, and uses, and gives production and prices. Includes list of buyers.

Jewell, W. B., 1931, Geology and mineral resources of Hardin County, Tenn.: *Tenn. Geol. Survey Bull.* 37, p. 80-85.

Tripoli occurs in the Fort Payne and Warsaw formations. Descriptions of the occurrences and chemical analyses are given.

Flint for tube-mill lining has been produced on a small scale in Wayne County, but none has been exploited in Hardin County. Map, scale 1 inch = 1 mile, showing areal geology of Hardin County is included.

Jillson, W. R., 1938, The Saint Peter sandstone in Kentucky: Louisville, Ky., Standard Printing Co., Inc., 46 p.

Discusses the occurrence of St. Peter sandstone in Franklin, Gallatin, Harrison, Menifee, Estill, and Madison Counties, giving the regional geology and outline of its stratigraphic correlatives.

Johnson, J. H., 1934, Paleozoic formations of the Mosquito Range, Colo.: U. S. Geol. Survey Prof. Paper 185-B, p. 20-21.

The Sawatch quartzite lies directly upon the eroded surface of the Precambrian rocks. Generally the formation consists of hard, massive bedded grayish-white quartzite. Locally there are thin basal conglomerate beds composed of well-rounded and polished grains of bluish-gray quartz, about pea size, well cemented with silica. The quartzite differs considerably in thickness in different localities. Near Trout Creek it is absent or very thin; at Weston Pass, about 60 feet of it appears to be present; and, in the Leadville and Alma districts, it is about 120 to 130 feet thick.

Little information from adjoining areas indicates Upper Cambrian age, probably middle Upper Cambrian, for the quartzite.

Cross sections showing the thickness of the quartzite throughout the area are given, but no analyses as to the purity of the rock are included.

Johnson, M. E., 1935, The mineral industry of New Jersey for 1933: N. J. Dept. Conserv. Devel. Bull. 42, p. 13.

A quartzite deposit about 1½ miles west of Wharton, adjacent to the Delaware, Lackawanna and Western Railroad, is quarried for use in foundries, filters, and cement flux. Most of the rock, part of the Green Pond conglomerate, is white but some is iron stained. Random and grab samples showed 95.78 percent SiO₂ and 0.68 percent Fe₂O₃.

Jones, W. B., 1938, Glass sands of Alabama: Am. Ceramic Soc. Bull., v. 17, p. 327-328.

The Mohawk deposit of the Shades formation (lower Pottsville) near Ohatchee, Calhoun County, is a massive bedded sandstone and conglomerate, ranging in thickness from 40 to 80 feet. The texture ranges from a medium fine-grained sandstone to a conglomerate consisting of small water-worn pebbles. The sandstone is almost pure white. There is little overburden. The tract is 1 mile square and about 3 miles northwest of Ohatchee, near rail and water transportation. Outcrops and test pits have disclosed tonnage calculated at 100 million tons. Chemical and mechanical analyses from the deposit are given.

The Gulf Beach sands of southern Baldwin County exceed 20 feet in thickness. Most of the deposit is 5 feet above and 15 feet below sea level. Production is done by dredging. It is somewhat higher in ferric oxide and lower in silica than the Mohawk deposit. It has good transportation facilities. A chemical analysis is given.

The author believes that the materials of these two deposits are the only ones in the State suitable for supplying glass sand of high quality.

Keith, M. L., 1946, Sandstone as a source of silica sands in southeastern Ontario: Ontario Dept. Mines 55th Ann. Rept., pt. 5, 36 p.

This area is in parts of Frontenac, Leeds, and Lanark Counties, extending from Kingston to Brockville along the St. Lawrence River and from the St. Lawrence River northward beyond Perth and Smiths Falls. The sandstone is in the Potsdam formation (Precambrian). The thickness ranges from less than 72 feet to 280 feet. This sandstone is used for foundry work, blast sand, and for the manufacture of silicon carbide; it could be used for glass sand if demand required. Each area is described, giving chemical and mechanical analyses. The Kingston Silica Mines deposit is reported to contain about 10 million tons of sandstone. A mill flow sheet and histograms showing the size analysis of a sandstone sample of the deposit and a map, scale 1:126,720, showing the distribution of the Potsdam sandstone of part of southeastern Ontario are included.

Kinney, D. M., 1948, Glass sand and other special sands, in Geological resources of the Trinity River tributary area in Oklahoma and Texas: Tex. Univ. Pub. 4824, p. 143-147.

Sands suitable for glass are found in the Arbuckle Mountains near Tahlequah in northeast Oklahoma, southeast Oklahoma, north-central Texas, and the Gulf Coastal Plain of Texas. The sands of the Arbuckle Mountains occur in the Oil Creek and McLish formations of the Simpson group (Ordovician). The Oil Creek sand is the base of the Simpson group and ranges from 150 to 400 feet in thickness. The McLish sand is about 165 feet thick and overlies the Oil Creek sand. Sands near Tahlequah occur in the Burgen sandstone (Ordovician). Sands in southeast Oklahoma and north-

central Texas occur in the Trinity sand (Lower Cretaceous). The outcrop is from 5 to 20 miles wide. Sources for glass sand are rare. However, south of the main body of the Trinity sand in Texas, a sand deposit in the lower Trinity is being mined for making bottle and glass containers. The Gulf Coastal Plain of Texas yields the Carrizo, Queen City, and Sparta sands (Eocene). These sands may be suitable for glass, but, for the most part, they contain too much iron and are too fine grained. The Trinity, Carrizo, Queen City, and Sparta sands cross the Trinity River basin, but deposits of sufficient purity for the manufacture of common bottle glass are rare.

Production figures are not available, but reserves of the Oil Creek and McLish formations are said to be very large. Reserves at Santa Anna, Tex., are also large.

Map, scale about 1 inch = 70 miles, showing distribution of glass sand and other special sands in the Trinity River tributary area is included.

Knapp, G. N., 1923, The foundry sands of Minnesota: Minn. Geol. Survey Bull. 18, p. 17-22, 62-65.

Describes the sands in Minnesota, giving the best use of each, localities where they occur, and some chemical and mechanical analyses of the sands. Coarser quartz sand is sometimes desired for cores in heavy work in gray iron and steel foundries. This material is obtained from the Jordan formation (Cambrian). The material preferred for core work is a quartz sand with the least possible amount of silt and with little or no clay. The St. Peter sandstone (lower Ordovician) is well suited for this work. Sioux quartzite (upper Huronian) withstands attrition and abrasion to a remarkable degree and is in demand as pebbles for ball mills.

Knechtel, M. M., Larrabee, D. M., Fischer, E. C., and others, 1948, Map showing construction materials and nonmetallic mineral resources of Montana: U. S. Geol. Survey Missouri Basin Studies Map 11, scale 1:750,000.

Rock that probably forms part of the Tertiary "lake beds," 15 miles southwest of Dillon, Beaverhead County, is used for fluxing and silica brick in copper converter work, and might be used for the manufacture of glass. A quarry at Columbus, Stillwater County, has produced material for grindstones.

Knight, Nicholas, 1926, Iowa glass sand [abs.]: Pan-Am. Geologist, v. 46, p. 402-403.

At several points in Linn County, along the Chicago, Milwaukee, St. Paul and Pacific Railroad between Marion and Cedar Rapids; and also along the old county highway sandstone occurs in marked unconformity upon limestone of Devonian age. Fossils clearly indicate that this sandstone is of Carboniferous age. Analyses show this material to be nearly 99 percent SiO_2 . The several exposures seem to warrant a moderate glass industry.

Krynine, P. D., Klepper, M. R., and Glasser, M., 1940, Mineralogy of the Mapleton glass sand: Pa. State College, Mineral Industries Expt. Sta. Tech. Paper 51, p. 88-94.

Report on the technology of the Oriskany sandstone in a quarry at Mapleton and at Mount Union. Mechanical analyses and histograms are included.

Krynitsky, A. I., and Raring, F. W., 1951, Sieve analyses of silica sands: Am. Foundrymen's Soc. Trans., v. 59, p. 117-120.

A study of sieve analyses of silica sand was undertaken to determine the

precision of the American Foundrymen's Society fineness test for foundry sands. The primary purpose of the investigation was to determine whether the type of sieve shaker used has any significant effect on the analytical results for a given sample and the reproductibility of a sampling technique. Conclusions were that, under the conditions of the analyses made in the study, the vibratory and rotary type sieve shakers will yield approximately the same results on a given sample with the same set of sieves.

Kummel, H. B., and Gage, R. B., 1907, The glass-sand industry of New Jersey: N. J. Geol. Survey Ann. Rept., 1906, p. 77-96.

Sands along the Maurice River below Millville, in the region around Vine-land and Williamstown, may be a source of glass sand. Glass sand has been mined at Egg Harbor and west of Salem.

Description of the deposits, method of mining, and physical properties are described; chemical analyses of 13 washed glass sands from New Jersey and 1 from Pennsylvania are given; a few mechanical analyses are included.

Ladoo, R. B., and Myers, W. M., 1951, Nonmetallic minerals: New York, McGraw-Hill Book Co., Inc., 2d ed., p. 423-431, 561-566.

Gives a general description of the geographic distribution, physical properties, mining, milling, specifications and tests, production, consumption, grades and prices, utilization of silica, and contains a bibliography.

Lamar, J. E., 1928, Geology and economic resources of the St. Peter sandstone of Illinois: Ill. Geol. Survey Bull. 53, 175 p.

Describes the distribution, lithology, thickness, structure, origin, and geologic history of St. Peter sandstone in Illinois. Discusses in detail its structural, physical, and compositional features, giving special attention to the impurities, and production methods of local quarries; lists and specifies requirements for more than 100 uses of sand; describes methods of sampling and testing and tabulates the results of these tests. Mentions briefly undeveloped deposits of possible commercial value.

——— 1953, Siliceous materials extreme southern Illinois: Ill. Geol. Survey Rept. Inv. 166, 39 p.

Most silica produced in southern Illinois is from the Clear Creek formation. Recently silica also has been produced from the Grassy Knob formation at Olive Branch. All mines currently producing tripoli from the Clear Creek formation are west of Elco and Mill Creek. Specific gravity, weight per cubic foot, and porosity of silica are given, along with character of deposits of commercial silica, mining, processing, uses, and resources.

Novaculite Gravel Co. pit near Tamms, Alexander County, is described as to character, occurrence, resources, mining, processing, uses; chemical and sieve analyses are included.

It is thought that ganister deposits in southern Illinois occur in the Hartline formation, although some may have been formed also from calcareous siliceous beds of the Springville formation. Chemical analyses of ganister from the Hartline formation are given. Ganister in Alexander County is discussed as to character of the deposits, mining, processing, uses, resources, and origin.

Larrabee, D. M., Clabaugh, S. E., Griffiths, W. R., and others, 1947, Map showing construction materials and nonmetallic mineral resources of

Colorado: U. S. Geol. Survey Missouri Basin Studies Prelim. Map 10, scale 1:500,000.

Silica sand has been produced from white sandstones and quartzite in Douglas, El Paso, Fremont, and Pueblo Counties. These sandstones crop out along the mountain front, and similar sandstones and quartzites crop out in a belt from Orient, Saguache County, northwestward to Leadville and Aspen. Among the formations that contain white sandstone and quartzite are the Uncompahgre formation, the Sawatch and Ignacio quartzites, and the Lyons sandstone.

Le Chatelier, H., and Bogitch, B., 1918, Manufacture of silica brick: *Am. Inst. Min. Metall. Eng. Trans.*, v. 60, p. 134-161.

Discusses the methods of investigation, the tridymite network, independent variables, and manufacturing operations of silica brick.

Leith, Andrew, 1935, The Pre-Cambrian of the Lake Superior region, the Baraboo district, and other isolated areas in the upper Mississippi Valley: *Kans. Geol. Soc. 9th Ann. Field Conf.*, p. 329-331.

The Baraboo quartzite is massive, well cemented, almost pure, and about 4,000 feet thick. Some thin beds of slate occur between the layers of quartzite. Geologic map, scale about 1 inch = 4 miles, of the Baraboo district is included.

Levings, G. V. B., 1923, Marketing of tripoli: *Eng. Min. Jour.-Press*, v. 116, p. 631-632.

Gives a brief discussion of tripoli, including its properties, uses, and location of producing areas—stressing tripoli from Seneca, Mo.—and marketing.

Libbey, F. W., 1950, Oregon's mineral industry in 1950: *Ore.-Bin*, v. 13, no. 1, p. 4.

Metallurgical silica is mined and processed at Rogue River, Jackson County, Oreg.

Littlefield, M. S., 1925, Natural-bonded molding sand resources of Illinois: *Ill. Geol. Survey Bull.* 50, p. 100, 122-125.

Describes a deposit of weathered chert mined and shipped as ganister near Elco and the occurrences of high-purity silica in Kandall, Lake, and La Salle Counties.

Loughlin, G. F., 1912, The gabbros and associated rocks at Preston, Conn.: *U. S. Geol. Survey Bull.* 492, p. 24, 53, 106, 110, 135-146.

The Lantern Hill quartz deposit forms a high narrow ridge $1\frac{1}{4}$ miles long and about 1,000 feet wide along the west boundary of North Stonington. Analyses show pulverulent quartz is 98 to 99.4 percent SiO₂.

Another quartz mass similar to the Lantern Hill occurs a mile north of Glasgo village in Griswold. The origin and geology of the quartz mass and a complete petrographic description of the quartz and wall rock are discussed.

Maps, scale 1:62,500, showing location and geology of deposits are included.

Lowe, W. B., 1926, The phenomena of the Sioux quartzite: *Pit and Quarry*, v. 12, no. 8, p. 82-84.

Sioux quartzite (Huronian) occurs along the Big Sioux River: it is the

only quartzite of any commercial value in South Dakota. Maximum width is believed to be 60 miles, extending across the northwestern corner of Iowa. It underlies about equal areas in South Dakota and Minnesota. The formation probably extends over an area of 6,000 square miles. It is fine grained and friable. Thickness is estimated to be from 1,500 to 4,000 feet.

Density and acid tests are given. The fusion point is very high. This quartzite has many uses; among them is furnace converter linings for steel mills.

Lowry, W. D., 1947, Foundry sand produced near Eugene, Oreg.: Am. Inst. Min. Metall. Eng., v. 173, p. 532-541.

Report on the steel foundry sands near Eugene, Oreg., includes the history, geology, properties, and a map, scale about 1 inch = 50 miles, showing the location of deposits. Gives a flow sheet of a current operation and references.

——— 1954, Silica sand resources of western Virginia: Va. Polytech. Inst., Eng. Expt. Sta. Ser. Bull., 96, 62 p.

This report describes the geology of the silica sand deposits, giving descriptions of the deposits and mechanical and chemical analyses. Map, scale about 1 inch = 25 miles, showing localities is included.

McAllister, H. E., and Bartram, J. W., 1947, Handmade glass tableware, a potential new industry for Colorado: Colo. Univ., Bur. Business Research, p. 12, 17-20.

A sand deposit meeting all the requirements of glass sand is being worked in a hogback west of Denver. Sand deposits near Colorado Springs are also found suitable for the glass industry. Other deposits near Pueblo have been analysed and found suitable, after beneficiation, for glassmaking.

Analysis of sand produced near Denver: SiO₂—99.5 percent, Fe₂O₃—0.029 percent, Al₂O₃—0.261 percent, CaO—0.00 percent, MgO—0.03 percent, loss on ignition—0.18 percent.

Analyses of 2 potential glassmaking sands of Colorado Springs:

	1	Percent		2	Percent
SiO ₂		98.56	SiO ₂		97.98
Al ₂ O ₃ -TiO ₂		.85	Al ₂ O ₃ -TiO ₂		1.55
Al ₂ O ₃		.81	Fe ₂ O ₃		.068
Fe ₂ O ₃		.038	Ignition loss		.40
MgO		.02			
CaO		.06			
K ₂ O		.05			
Na ₂ O		.04			
Ignition loss		.34			

The deposit from which sample 1 was taken yields washed sand possibly suitable for making flint glass, containers and tableware. However, it exceeds 0.003 percent Fe₂O₃ standards set up by the American Society for Testing Materials.

Samples of sand from deposits near Pueblo were submitted to Colorado University for analyses. They were adequately high in silica, but the iron content was too high, running 0.059 percent. With beneficiation, this sand might be suitable for glassmaking.

McGrain, Preston, 1952, Recent investigations of silica sands of Kentucky: Ky. Geol. Survey, ser. 9, Rept. Inv. 5, 14 p.

Gives requirements, specifications, chemical, and physical analyses of glass

sand. Hardinsburg sandstone near Marion, Crittendon County, and Bethel sandstone near Princeton, Caldwell County, seem to offer the best possibilities for sources of sand for high-grade glass in the State. Map showing sources of analyzed sands is included.

Machin, J. S., and Tooley, F. V., 1937, Decolorization of southern Illinois silica: Ill. Geol. Survey Rept. Inv. 47, p. 5-35.

Possible methods of decolorizing silica are classified roughly as high-temperature methods, wet bleaching with acids alone or in the presence of reducing agents, and electrical or magnetic separation of iron compounds. Experimental investigations of three wet leaching methods employing first, hydrochloric acid; second, sulfuric acid; and third, a combination of an active metal with sodium bisulfite and sulfuric acid, indicate that it is technically feasible to bleach by any of the three methods investigated.

McNamara, E. P., 1938, Introduction to ceramics: Pa. State Coll., School Mineral Industries, v. 2, p. 79-95.

Describes forms of silica: quartz, tridymite, and cristobalite, their formation and occurrence, Oriskany and St. Peter sandstone occurrences, the commercial forms of silica. Chemical analyses of some American sands, sandstones, and quartzites are given; also a table showing ferric oxide in different types of glass sand and screen analyses of glass sands.

Metcalf, R. W., 1940a, Grinding pebbles: Stone, v. 61, p. 468, 470.

Describes the resources of quartzite pebbles and silex liners and summarizes foreign sources, namely Denmark and France, markets for export, and the domestic supply situation.

——— 1940b, Grinding pebbles and tube-mill liners: U. S. Bur. Mines Inf. Circ. 7139, 5 p.

Artificially rounded grinding pebbles have been produced from quartzite deposits near Jasper, Minn., and from the Sioux quartzite near East Sioux Falls, S. Dak. No production has been reported for 15 years. Before 1936, pebbles were used from the beaches between Oceanside and Encinitas, Calif. Although somewhat harder than Danish flint pebbles, the California pebbles wore out faster on hard material, being coarser grained and rougher than the Danish pebbles. However, their cost is less than one-half the price of Danish pebbles.

Various types of stream or beach pebbles have been produced locally in the Rocky Mountain region for use in metallurgical mills.

Tube-mill liners, and possibly artificially rounded-grinding pebbles, formerly were supplied from the Ocala limestone beds in Florida and from the Fort Payne chert near Iron City, Tenn.; they also were obtained from a quartzite belt of central and southeast Pennsylvania, and in Calhoun, Talladega, Cherokee, Clay, and Cleburne Counties, Ala.

——— 1949, Tripoli, in *Industrial Minerals and Rocks*: New York, Am. Inst. Min. Metall. Eng., 2d ed., p. 1074-1101.

Discusses tripoli with respect to composition, physical properties, mining, milling, specifications, uses, marketing, and deposits in Alabama, Arkansas, Georgia, Illinois, Mississippi, Missouri, Oklahoma, Pennsylvania, Tennessee, and some foreign deposits. Chemical analyses, production data, and a bibliography are included.

Meyers, T. R., 1941, Some New Hampshire quartz deposits, preliminary report: N. H. State Plan. Devel. Comm., Mineral Resources Survey, pt. 7, 21 p. Rept. N. H. Plan. Devel. Comm., pt. 6, 21 p.

Discusses only the larger deposits of quartz in New Hampshire. The deposits are grouped into three types; silicified zones, quartzites and quartz conglomerates, and pegmatites. Emphasis is placed upon the study of silicified zones. Geology and some chemical analyses of the deposits examined are given; also a map, scale about 1 inch = 20 miles, showing distribution and types of quartz deposits examined.

Miser, H. D., 1943, Quartz veins in the Ouachita Mountains of Arkansas and Oklahoma (their relations to structure, metamorphism, and metalliferous deposits): Econ. Geology, v. 38, p. 105-106.

Quartz veins are hydrothermal deposits of probable magmatic origin, and novaculite is the result of progressive metamorphism. Dynamic metamorphism had produced fracturing, shearing, and preferred orientation of the grains in some novaculites. The oilstone quarries in the Arkansas novaculite near Hot Springs, Ark., are in an area that has been metamorphosed to a greater extent than elsewhere in the Ouachita Mountains, except in the mountains a few miles north of Broken Bow, Okla.

Miser, H. D., and Purdue, A. H., 1929, Geology of the De Queen and Caddo Gap quadrangles, Arkansas: U. S. Geol. Survey Bull. 808, p. 162-166, 178-180.

Discusses the Arkansas novaculite deposits which occur in three lithologic units. The novaculite for the most part is massive, breaks with a conchoidal fracture, and ranges in color from yellow to white. It occurs in beds of a maximum thickness of almost 1,000 feet. At Hot Springs, two commercial types are mentioned. The Arkansas stone is fine grained and suitable for sharpening fine edges of tools. The Ouachita (Washita) stone is porous. Novaculite pebbles range from a fraction of an inch to 10 inches in diameter. Most of the pebbles are white with a bluish tint, but many are red, gray, green, yellow, brown, and black. They are comparatively brittle, which may hinder the economic use in tube mills. The basal part of the Arkansas novaculite is composed almost wholly of silica, which is white, free from impurities, and is used for pottery. The purest grade might be used for making optical glass. Tripoli deposits occurring in the Arkansas novaculite are described.

Modes, C. H., 1932, Sand supply and the glass industry on the Pacific Coast: Ceramic Industry, v. 18, p. 254, 266, 268, 270.

Gives locations, sources, production, and chemical analyses of glass sand in California, and analyses of glass sand from Missouri, Pennsylvania, Illinois, and New Jersey for comparison. Data on Belgian sand imports are included.

Moore, E. S., and Taylor, T. G., 1924, The silica refractories of Pennsylvania: Pa. Geol. Survey, 4th ser., Bull. M 3, 100 p.

Gives a detailed description of the Tuscarora and Chickies quartzite. Chemical analyses and map, scale about 1 inch = 15 miles, showing localities of quartzites used as ganister for silica brick are included.

Murphy, T. D., 1954, Silica, in Mineral resources of Clark County, Nev.: Nev. Bur. Mines Bull. 55, 6 p.

The Eureka quartzite, the Supai, Aztec, and Baseline sandstones, and

certain deposits of eolian sand are of sufficient purity to be potentially commercial in Clark County. Although practically all of these materials have been exploited, only the Baseline sandstone and eolian sand are currently used. Four companies in the Overton area ship both crude and dry finished products that are used by the foundry, glass, and chemical industries.

Market specifications favor the present utilization of the sands from Clark County for glass melting, but a substantial tonnage is consumed by the West Coast foundry trade. The Eureka quartzite may be considered a potential resource for refractory and metallurgical use.

Raw material resources of most type of silica seem to be substantial but not inexhaustible. Finished products shipped from the Overton area to West Coast industries must always compete with sources of supply in southern California.

Murray, H. H., and Patton, J. B., 1953, Preliminary report on high-silica sand in Indiana: Ind. Geol. Survey Progress Rept. 5, 35 p.

From 1850 to 1910, high-silica sands were produced in Indiana from dunes along the Lake Michigan shores; the Pendleton sandstone (Devonian) at Pendleton, Madison County; the Mansfield formation (Pennsylvanian) near Loogootee, Martin County; the Linton (Staunton) formation (Pennsylvanian) near Coxville, Parke County; the Ohio River formation (Tertiary) in eastern Harrison County and southeastern Washington County. At present, all high-silica sand used by the glass industries is imported from other States.

The report gives stratigraphic units sampled, descriptions of selected exposures, and chemical and spectrographic analyses. Map, scale 1:1,000,000, showing location of samples of sand and sandstones is included.

Nevin, C. M., 1929, The sand and gravel resources of New York State: N. Y. State Mus. Bull. 282, p. 116-117.

Glass, core, and blast sands have been produced at Cleveland, Oswego County. This deposit is a continuation of the large sand plain between Rome and Oneida Lake. Thickness is about 15 feet; overburden, 2 feet. Chemical and mechanical analyses are given.

Another extensive area of beach and dune sands suitable for core work occurs in Oswego County, along the east shore of Lake Ontario near Selkirk. Sieve tests are given for samples of this sand.

New Hampshire State Planning and Development Commission, 1949, Mineral resources in the Lakes region: p. 3.

Quartz used for glass and abrasives had been mined near Sandwich and Stafford in the Lakes region. Most of the material came from pegmatite deposits and from large silicified or fault zones. Map, scale 1 inch = 8 miles, showing distribution of deposits is included.

Newland, D. H., 1919, The mineral resources of the State of New York: N. Y. State Mus. Bull. 223-224, p. 154-156, 220-221, 241, 272-276.

The Shawangunk conglomerate, a hard, firmly cemented pebbly light-gray sandstone ranges from 50 to 300 feet in thickness, thinning northeastward. Millstones are quarried in the Shawangunk Mountain area, from the vicinity of High Falls, near Kingston, southwestward into New Jersey and Pennsylvania. Extensive quarrying has been done near Kyserike, St. Josen, Granite, and Kerhonkson. In the past it was quarried for glass sand at Ellenville.

Beach sand from the Oneida Lake region has been used for glass, fire, and core sand.

Potsdam sandstone crops out on the northern, eastern, and southern borders of the Adirondacks. The beds range from a few inches to more than 2 feet in thickness. Deposits in the vicinity of Moira and Bangor, Franklin County, have been worked for glass sand.

Quartzite of high quality occurs at Port Henry and Fort Ann. White granular sandstone 96 to 99 percent SiO_2 at Keck Center, Fulton County, is used for ferrosilicon manufacture. Poughquag quartzite occurs in the Highland region. It is very hard and tough, suitable for tube-mill lining, and probably for chemical and metallurgical purposes.

The Oriskany sandstone crops out at Oriskany Falls, Oneida, and near Union Springs, Cayuga County.

Vein quartz, used for abrasives, was quarried near Fort Ann and Port Henry.

Nixon, E. K., Runnels, R. T., and Kulstad, R. O., 1950, The Cheyenne sandstone of Barber, Comanche, and Kiowa Counties, Kans., as raw material for glass manufacture: Kans. Geol. Survey Bull. 86, pt. 3, p. 43-84.

Results of chemical, mineralogical, mechanical and spectrographic analyses show that Cheyenne sandstone (lower Cretaceous), which crops out in southern Kansas, is suitable for both glass and foundry sands. All data indicate that reserves are adequate for commercial operation of sands amenable to standard methods of beneficiation established by the American Ceramic Society and the National Bureau of Standards.

Nordberg, Bror, 1954, Producing high-grade silica from sandstone: Rock Products, v. 57, no. 4, p. 126-127, 130, 180, 182.

Sand for all grades of glass except optical is obtained from the Hardinsburg sandstone, 1 mile east of Marion, Ky. Daily production includes 12 carloads of glass and foundry sand. Includes description of plant and sieve analyses.

Oregon Department of Geology and Mineral Industries, 1951, State of Oregon map showing principal mineral deposits, scale 1:100,000; Key to Oregon mineral deposits map, by R. S. Mason: Oreg. Dept. Geology and Mineral Industries (Misc. paper no. 2).

Shows location of the following silica deposits:

Owen: T. 33 S., R. 12 W., Powers District, Curry County.

Bristol: sec. 30, T. 36 S., R. 3 W., Gold Hill District, Jackson County.

Hugo: sec. 5, T. 35 S., R. 6 W., Grants Pass District, Josephine County.

Hauser: T. 24 S., R. 13 W., Coos Bay District, Coos County.

Eugene: sec. 34, 35, T. 17 S., R. 4 W., Lane County.

Luckiamute: sec. 30, T. 9 S., R. 4 W., Polk County.

Oklahoma Geological Survey, 1942, Utilization of glass sand: Director's Bienn. Rept. 1941-42, p. 29-31.

Deposits of sand suitable for glass manufacture occur in Pontotoc, Johnston, Murray, Carter, Cherokee, and Love Counties. Analyses are given.

Page, L. R., and others, 1953, Pegmatite investigations 1942-1945, Black Hills, S. Dak.: U. S. Geol. Survey Prof. Paper 247, 228 p.

Discusses quartz occurring in pegmatite dikes in the Black Hills. Report includes 45 plates, 37 figures, and 4 tables.

Parker, J. M., III, 1952, Geology and structure of part of the Spruce Pine district, North Carolina: N. C. Dept. Conserv. Devel. Bull. 65, p. 21.

Discusses high-grade quartz occurring as cores or pods in pegmatites suit-

able for the manufacture of glass, and also fairly high silica quartz recovered as a byproduct from the froth-flotation production of feldspar. Geologic map, scale 1 inch = 2,000 feet, is included.

Parkinson, G. A., and Barnes, V. E., 1943, Grinding pebbles deposits in western Gulf Coastal Plain of Texas, *in* Texas mineral resources: Tex. Univ. Pub. 4301, p. 47-54 [1946].

Numerous deposits of flint suitable for grinding pebbles occur west of the Guadalupe River. The gravels of the Colorado and Brazos Rivers contain abundant flint pebbles unsuitable for grinding purposes. The stratigraphy, lithologic character, and source of many of the deposits are given. Map, scale about 1 inch = 75 miles, showing distribution by counties is included.

Parmelee, C. W., 1932, Progress report on the study of southern Illinois silica as a pottery material: Ill. Geol. Survey Rept. Inv. 24, p. 3-7.

Tripoli, locally called "silica," occurs in deposits that range in thickness from a few feet to almost 50 feet in the Clear Creek formation (Devonian). Results of investigations of southern Illinois tripoli for pottery manufacture are given. Tests show that quartz sand, "flint," and French pebble flint are superior to tripoli for this purpose.

Parmelee, C. W., and Harman, C. G., 1946, Southern Illinois novaculite and novaculite gravel for making silica refractories: Ill. Geol. Survey Rept. Inv. 117, 55 p.

Extensive deposits of novaculite and of novaculite gravel occur in Alexander and Union Counties. The novaculite is a cryptocrystalline material containing approximately 97 percent silica; novaculite gravel contains a small amount of clay. The character and properties of the novaculite when properly crushed, graded, bonded with lime, and fired correspond closely with commercial refractory silica brick. Better brick can be obtained by mixing with the novaculite a certain proportion of extremely fine grained silica or tripoli obtainable in the same area as the novaculite and novaculite gravel.

Patty, E. N., and Glover, S. L., 1921, The mineral resources of Washington with statistics for 1919: Wash. Geol. Survey Bull. 21, p. 111-113, 132-133.

Pegmatitic quartz deposit estimated to contain several million tons of almost pure quartz occurs as a hill, 650 feet in diameter, in sec. 14, T. 27 N., R. 42 E., 12 miles north of Spokane and 6 miles from the Great Northern Railway. The quartz is used chiefly to make silica brick.

The Denny-Renton Co. deposit on McClellan Pass Highway, east of Enumclaw, King County, and a deposit on the Siegmund ranch, 1 mile north of Clay City, Pierce County, supply material for use in the manufacture of silica brick.

Some molding sand has been produced in King, Spokane, and Pierce Counties.

Phalen, W. C., 1910, Description of the Johnstown quadrangle [Pennsylvania]: U. S. Geol. Survey Geol. Atlas, folio 174, p. 14.

Gives chemical analysis of glass sand from the Pottsville formation on the west flank of Laurel Ridge, near Seward.

Plummer, F. B., 1942?, A new quartz sand horizon in the Cambrian of Mason County, Tex.: Tex. Univ. Circ. 22, 2 p.

Erna sand (upper Cambrian) crops out along the valley of Leon Creek,

southeast of Erna. It is a pure very friable sand. Mechanical and chemical analyses and a sketch map, scale about 1 inch = 1 mile, showing sand localities are included.

Popoff, C. C., 1949, Investigation of silica deposits near the Skagit River, Skagit County, Wash.: U. S. Bur. Mines Rept. Inv. 4472, 16 p.

Describes three large vein quartz deposits near Marblemount. Analyses are included.

Price, P. H., 1929, Pocahontas County [W. Va.]: W. Va. Geol. Survey County Rept., p. 346-348.

Discusses the Droop sandstone, which covers several hundred acres on Droop Mountain. This sandstone meets the requirements of glass sand. The White Medina sandstone near Minnehaha Springs also offers possibilities for glass sand. Chemical analyses of the sand are given. Geologic and topographic maps, scale 1:62,000, are included.

——— 1938, Geology and natural resources of West Virginia: W. Va. Geol. Survey Repts., v. 10, p. 291, 335, 380-384.

Presents a general discussion on occurrences of high-grade silica sand and uses, production from 1902-23, and occurrences of "grindstone." Geologic map, scale 1 inch = 16 miles, is included.

Purdue, A. H., and Miser, H. D., 1923, Description of the Hot Springs district [Arkansas]: U. S. Geol. Survey Atlas, folio 215, p. 10-11.

Novaculite is quarried at several places on the mountain ridges northeast of Hot Springs. Two commercial types are described. The Arkansas stone is a homogeneous gritty stone, fine grained and siliceous. This type is used in the manufacture of oilstones, but it is best adapted to finishing the sharpening of tools that have had a preliminary sharpening with a coarser abrasive. The Ouachita (Washita) stone resembles the Arkansas stone but it is more porous, and has the appearance of unglazed porcelain. It is used mainly for making whetstones for larger tools.

The basal part of the Arkansas novaculite is composed almost wholly of silica, some of which may be suitable for making optical glass. The middle part of the formation has weathered to a soft porous fine-grained white to cream-colored tripoli.

Purdy, C. P., Jr., 1953, Directory of Washington mining operations, 1953: Wash. Dept. Conserv. Devel. Inf. Circ. 21, p. 4-5, 48, 50-53, 56, 59-60, 63.

Gives a list of the active mining operations in Washington and the current status of activities. Map, scale 1 inch = about 40 miles, shows silica deposits.

Quinn, Alonzo, Ray, R. G., and Seymour, W. L., 1948, Bedrock geology of the Pawtucket quadrangle, Rhode Island and Massachusetts, in The geology and ground-water resources of the Pawtucket quadrangle, Rhode Island: R. I. Indus. Comm. Geol. Bull. 3, p. 11-12, 18-19, 25.

Westboro quartzite occurs along the Blackstone River between Albion and Berkeley; although predominantly massive, thin beds of quartz-mica schist occurs throughout the formation. The thickness ranges from about 1,000 feet near Lonsdale to about 3,000 feet northwest of Ashton.

Vein quartz more than 1,000 feet wide and a mile long makes up the western face of Diamond Hill. Numerous quartz veins cut the Grant Mills

granodiorite west of Thompson Hill. Chemical analysis shows the quartz to be 98.7 percent SiO₂.

Ralston, O. C., 1937, Quartz and silica in Washington, *in* Annual report of the nonmetals division, fiscal year, 1937: U. S. Bur. Mines Inf. Circ. 6974, p. 11-13.

Vein quartz near Mica, Spokane County, can be used for glass, potter's flint, and ceramic glazes. The cost of mining and beneficiation of vein quartz in this area prevents it from competing with the Belgian sand.

Quartzites in Stevens County and the Wenatchee sands of the Swauk formation can be used for amber and colored glasses and possibly for abrasives in steel foundries.

Tertiary sandstones of Washington might be used for amber glass, where the feldspar content is low.

Richardson, C. H., 1920, The glass sands of Kentucky: Ky. Geol. Survey, ser. 6, v. 1, 149 p.

Gives a comprehensive discussion of sandstones, including the history of glass in the United States, classification of sands, raw materials, location of deposits, and analyses.

Ries, Heinrich, 1949, Special sands, *in* Industrial Minerals and Rocks: New York, Am. Inst. Min. Metall. Eng., 2d ed., p. 965-979.

The report gives the distribution, properties, mining methods, and specifications for preparation of sands for commercial use of glass, filter, abrasive, blasting, and steel molding sands. A bibliography is included.

Roalfe, G. D., 1937, New silica sand plant in Nevada: Rock Products, v. 40, no. 8, p. 86-87.

Describes silica deposits about 4 miles northwest of Arden on Salt Lake Route of Union Pacific Railroad. The silica is used in steel foundries. Estimated reserves are 25 million tons.

Rose, K. E., 1950, Silica sand from south-central Kansas for foundry use: Kans. Geol. Survey Bull. 86, pt. 4, p. 89-104.

Cheyenne sandstone of Barber, Comanche, and Kiowa Counties is said to be a satisfactory source of silica sand for preparing molding sand and cores. The Cheyenne sands are characterized by a low percentage of minus 140-mesh particles and by a broad grain-size distribution. Chemical and sieve analyses, cumulative curves, and a map, scale about 1 inch = 2 miles, showing localities are included.

Ross, D. W., 1919, Silica refractories—Factors affecting their quality and methods of testing the raw materials and finished ware: Bur. Standards Tech. Paper 116, 84 p.

Discusses the properties of silica refractories and the preparation necessary to obtain the best silica brick. The harder parts of the Medina formation in Blair and Huntingdon Counties, Pa., have proved particularly suited for steel furnace work. About 60 percent of the silica brick manufactured in the United States is made from this formation. The remainder comes largely from the Baraboo formation of Wisconsin. A table showing the geologic column with reference to commercial quartzites for silica refractories is included.

Rothrock, E. P., 1944, Mineral resources, part 3 of A geology of South Dakota: S. Dak. Geol. Survey Bull. 15, p. 147-154, 207.

Quartzites of the Sioux formation are in the valley of the Big Sioux River at Dell Rapids, Sioux Falls, East Sioux Falls, in the valley of the Vermillion River at Parker, in Wolf Creek at Salem, Pierre Creek at Alexandria, and in the James Valley south of Mitchell. The quartzite is more than 97 percent SiO_2 . Chemically, the stone could be used for refractories, ganister, and silica brick. Tests and chemical analyses of the quarries at Sioux Falls and Dell Rapids are included.

Sampson, R. J., and Tucker, W. B., 1931, Feldspar, silica, andalusite, and cyanite deposits of California: Calif. Dept. Nat. Res., Div. Mines, Mining in California, v. 27, p. 432-450.

Describes the occurrence of silica deposits in California, giving some mechanical and chemical analyses. Map, scale 1 inch = 80 miles, shows location of the principal deposits.

Santmyers, R. M., 1931a, Quartz and silica—part 1, General summary: U. S. Bur. Mines Inf. Circ. 6472, 15 p.

Presents material introductory to three reports relative to occurrence and uses of quartz and silica. It also contains a flow sheet from deposit to consumer.

——— 1931b, Quartz and silica, part 2, Quartz, quartzite, and sandstone: U. S. Bur. Mines Inf. Circ. 6473, 20 p.

Presents data on uses, markets, prices and producers of optical quartz, piezoelectric quartz, fused quartz glass, agate, ferrosilicon, fluxing quartz, quartz for acid towers, fillers, refractories, ceramics, the abrasive industry, and dimension stone.

——— 1931c, Quartz and silica, part 3, Sand and miscellaneous silicas: U. S. Bur. Mines Inf. Circ. 6474, 17 p.

Gives uses, market prices, and other information on fused silica glass and silicon carbide; building, paving, molding, glass, fire or furnace, abrasive, filter, and engine sands; and roofing granules, sand-lime brick, tripoli, and diatomite.

Schafer, G. H., 1942, Rice sands in Polk and adjoining counties [Texas]: Tex. Univ. Circ. 41, p. 1-3.

"Rice sand," which contains a high percentage of quartz, occurs in Polk, Trinity, Tyler, and Walker Counties in the Jackson (Eocene), Catahoula (Oligocene), and Willis (Pliocene) formations. Deposits are briefly described and screen analyses of some of the deposits are given. This sand is suitable for molding sand.

Schrader, F. C., 1908, Description of the Independence quadrangle [Kansas]: U. S. Geol. Survey Geol. Atlas, folio 159.

Sandstone about 10 feet thick and suitable for making glass occurs in the Buxton formation 4 miles northwest and 2 miles north of Caney. Other exposures are farther north. A noteworthy deposit is in the SE $\frac{1}{4}$ sec. 22, Fall River Township, about 4 miles southwest of Fredonia. The rock is exposed over an area of 10 to 15 acres and is about 12 feet thick.

648. CONTRIBUTIONS TO BIBLIOGRAPHY OF MINERAL RESOURCES

Schrader, F. C., Stone, R. W., and Sanford, Samuel, 1917, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, 412 p.

The more important occurrences of useful minerals including silica are listed by States. Some of the deposits are briefly described.

Searle, A. B., 1923, Sands and crushed rocks; their uses in industry: London, Oxford Tech. Pubs., v. 2, p. 192-205.

Discusses silica glass, alkali glasses, purpose served by sand in glass, sources of sands, chemical and mineral composition, shape and size of grains, specification of sand for glass manufacture, preparation of glass sands, and testing.

Sellards, E. H., and Evans, G. L., 1943, Index to Texas mineral resources, in Texas mineral resources: Tex. Univ. Pub. 4301, p. 359-383, pl. 1 [1946]. See also Sellards and others, 1944.

Résumé of occurrence of silica in the State.

Sellards, E. H., Evans, G. L., and Hendricks, Leo, 1944, Mineral locality map of Texas, scale 1:1,000,000, in Texas mineral resources, 1943: Tex. Univ. Pub. 4301, pl. 1 [1946].

Map shows occurrence of minerals, rocks, oil and gas.

Shaw, E. W., and Munn, M. J., 1911, Description of the Foxburg and Clarion quadrangles [Pennsylvania]: U. S. Geol. Survey Geol. Atlas, folio 178, p. 17.

The Connoquenessing and Homewood sandstones are quarried near Upper Hillville and north of Foxburg. The rock is almost pure silica. Near Upper Hillville it is treated as ganister and made into silica brick. North of Foxburg it is used for molding sand, for grinding plate glass, and as engine traction sand.

Shaw, Edmund, 1937, Mining and milling methods and costs at the glass sand plant of P. J. Weisel, Inc., Corona, Calif.: U. S. Bur. Mines Inf. Circ. 6937, 16 p.

Includes a good description of marine sand deposits in an area about 25 miles long and 4 miles wide, sieve and chemical analyses, a flow sheet of the silica plant, and a locality map.

Shed, A. C., 1928, Chemical analyses of Oklahoma mineral raw materials: Okla. Univ. Bull. 14, p. 25-27, 80-83.

Gives location, description, and chemical analyses of the Burgen sandstone (lower Ordovician), Cherokee County; Silo sandstone (upper Cretaceous), Bryan County; Simpson sands (lower and upper Ordovician), Murray and Johnston Counties; and Trinity sands (lower Cretaceous), Johnston, Marshall, Carter, and Love Counties.

Sheakley, H. L., and Coolidge, D. J., 1942, Use of silica sand in the glass industry in Missouri: Am. Inst. Min. Metall. Eng. Tech. Pub. 1538, 6 p.

Describes in general the occurrence and distribution of the St. Peter sandstone in Missouri. Properties, mining methods, and comparative analyses of St. Peter sandstone from Crystal City are given.

Sherzer, W. H., 1917, Description of the Detroit district [Michigan]: U. S. Geol. Survey Geol. Atlas, folio 205, p. 18.

Sylvania sandstone, 7 miles northwest of Monroe, Monroe County, has been

mined for a number of years for glass and abrasive purposes. East of Rockwood, Wayne County, a pit opened through more than 15 feet of till has reached 75 feet of sand, and is said to be available for the same purposes. Analyses of both deposits are given.

Siebenthal, C. E., and Mesler, R. D., 1908, Tripoli deposits near Seneca, Mo.: U. S. Geol. Survey Bull. 340-J, p. 429-437.

Tripoli occurs in the Boone formation in the vicinity of Seneca and Racine. The deposits range in thickness from 4 to more than 12 feet, and overburden from 2 to more than 3 feet.

Analyses of tripoli near Seneca and a sketch map, scale 1 inch = about 2½ miles, showing location of deposits are included.

Singewald, J. T., Jr., 1928, Notes on feldspar, quartz, chrome, and manganese in Maryland: Md. Geol. Survey, v. 12, p. 131-157.

Gives production, uses, occurrences, distribution, quarrying, milling, and economic aspects of the Maryland flint industry. Map, scale 1 inch = 1 mile, showing locations of quarries in Harford County, and map, scale 1 inch = 3 miles, showing locations of quarries in Baltimore, Carroll, and Howard Counties, are included.

Smith, E. A., 1884, List of the ores and minerals of industrial importance occurring in Alabama: [Ala. Geol. Survey], p. 10.

Friable quartz rock occurs in T. 22 N., R. 16 E., in Chilton County, and also in Randolph, Tallapoosa, northwest Macon, Lee, Chambers, and other counties.

In the Tennessee Valley the siliceous cherty rocks of the lower Carboniferous period at many places yield a fine white friable silica that may be used for making glass.

Smith, W. H., 1949, Sand and gravel resources in northern Ohio: Ohio Geol. Survey Rept. Inv. 6, p. 20.

Describes production of silica and silica pebbles from the Sharon conglomerate which occurs in the western part of Jackson County, and in parts of Summit, Portage, and Geauga Counties. Outliers extend into parts of Medina, Cuyahoga, and Lake Counties. The Sharon is a medium- to coarse-grained sandstone containing scattered thin pebble beds. The parts most extensively quarried are the zones of true conglomerate containing large quantities of pebbles. These pebble zones form long, narrow north-south bands which represent deposition in channels cut into the underlying Mississippian rocks.

Sosman, R. B., 1927, The properties of silica: Am. Chem. Soc. Mon. Ser. 37, 885 p.

Discusses the fundamentals, phases and their transformations, symmetry and structure, thermal and mechanical energy, and applications of silica; also silica in the electric and magnetic fields and in the periodic electromagnetic field.

Spain, E. L., Jr., 1936, Tripoli deposits of the western Tennessee Valley: Am. Inst. Min. Metall. Eng. Tech. Pub. 700, 17 p.

The deposits described occur over the greater part of Wayne County and the southeast part of Hardin County, Tenn., and in the northeast and northwest part of Mississippi and Alabama, respectively. Origin and stratigraphy

are discussed. Analyses of tripoli from Hardin County, Tenn., and a map showing location of deposits of the western Tennessee Valley are included.

Stead, F. W., and Stose, G. W., 1943, Manganese and quartzite in the Lick Mountain district, Virginia: Va. Geol. Survey Bull. 59, p. 15-16.

Gives locations of Erwin quartzite deposits in the Lick Mountain district. Description of 3 quartzite workings and 7 analyses of quartzite ranging from 97.63 percent to 99.37 percent SiO₂ are listed.

Reserves for the Lick Mountain district are estimated at about 2 million tons of metallurgical grade quartzite.

Map, scale 1 inch = 200 feet, showing plan and sections of quartzite workings at the west end of Sand Mountain and map, scale 1:31,250, showing geology and structure sections of the Lick Mountain area are included.

Stenzel, H. B., 1938, Glass sands in Leon County, Tex.: Tex. Univ. Bur. Econ. Geology Circ. 9, 1 p.

Outcrops of the Carrizo, Queen City, and Sparta formations in Leon County furnish glass sand. Some beds are 40 feet thick. Sand soil produced by weathering from these beds is also suitable for glassmaking. These soils reach a thickness of more than 8 feet.

Stenzel, H. B., Fountain, H. G., Jenke, A. L., and Weissenborn, A. E., 1948, Natural abrasives, in Geological resources of the Trinity River tributary area in Oklahoma and Texas: Tex. Univ. Pub. 4824, p. 56-57, 60-61, 65.

Grinding pebbles occur in the gravel deposits of the major stream valleys in Texas. All production is in Bastrop, Frio, Llano, and Travis Counties. Texas produced 5,341 short tons in 1943.

Rice sand deposits occur in lenticular bodies near the base of the Catahoula formation (Tertiary) in Trinity, Polk, Walker, and San Jacinto Counties. It is believed reserves are large. Producers, localities, and mechanical analyses are listed. Map, scale 1 inch = 70 miles, showing occurrences is included.

Fine-grained quartzites and quartzitic sandstones of the Stanley and Jackfork (Pennsylvanian) formations in the Ouachita Mountain region of Oklahoma may be suitable for the manufacture of millstones and buhrstones.

Oklahoma novaculite (Devonian) occurs in central McCurtain County. Smaller exposures are known in the Potatoe Hills area in southeastern Latimer and northern Pushmataha Counties, and near Atoka and Stringtown, Atoka County. Map, scale 1 inch = 70 miles, shows outcrops.

Stoll, W. C., 1950, Mica and beryl pegmatites in Idaho and Montana: U. S. Geol. Survey Prof. Paper 229, 64 p.

Discusses quartz occurring in pegmatites in Idaho and Montana. Includes 9 plates, 25 figures, and 25 tables.

Stone, R. W., 1919, Sand and gravel, in Our mineral supplies: U. S. Geol. Survey Bull. 666-G, p. 47-49.

Gives a brief history of glass, molding, and abrasive sands, the productive States, and production figures.

——— 1925, Molding sands of Pennsylvania (preliminary report): Pa. Topog. Geol. Survey Bull. 87, 20 p.

The location of high-purity silica deposits in Butler, Elk, Erie, Jefferson, Lycoming, Mercer, Mifflin, and Venango Counties are listed. Mechanical tests of molding sands are included.

Stone, R. W., 1928, Molding sands of Pennsylvania: Pa. Geol. Survey, 4th ser., Bull. M 11, 94 p.

Deposits and operations are classified and described either as natural-bonded (low silica) molding sand or as silica and core sand. Mechanical analyses and resulting histograms are furnished on a large and representative list of samples. Map showing location of sand is included.

——— 1939, The minerals of Pennsylvania—Non-metallic minerals: Pa. Geol. Survey, 4th ser., Bull. M 18-C, p. 32-35.

Summarizes the occurrence, distribution, and development of vein quartz deposits in Adams, Chester, and Cumberland Counties, Pa.

Stose, G. W., 1932, Geology and mineral resources of Adams County, Pa.: Pa. Geol. Survey, 4th ser., Bull. C 1, p. 129-13.

Describes the occurrence, development, and utilization of vein quartz, Adams County, Pa. Geologic map, scale 1:125,000, and topographic map, scale 1:62,500, are included.

——— 1946, Structure of Lick Mountains, Va.: Am. Jour. Sci., v. 244, p. 189-199.

The Lick Mountains are a small isolated group of mountains in the Appalachian Valley about 8 miles north of the main front range. They are in an anticline exposing thick resistant Lower Cambrian quartzites in parallel south-dipping plates which are upthrust on their north sides. The Erwin quartzite is the most important formation in the study of the structure of the area. The main body of the formation is a massive resistant quartzite about 350 feet thick. Analyses of selected beds 60 to 80 feet thick are given.

Stose, G. W., and Jonas, A. I., 1933, Geology and mineral resources of the Middletown quadrangle, Pennsylvania: U. S. Geol. Survey Bull. 840, p. 12-17, 69-71.

Describes the occurrence and character of the Chickies quartzite in the Middleton quadrangle. Analysis and geologic map, scale 1:62,500, are included.

Stose, A. J., and Stose, G. W., 1944, Geology of the Hanover-York district, Pennsylvania: U. S. Geol. Survey Prof. Paper 204, p. 81.

Gives locations of quarries in Chickies quartzite, Chickies slate, and Antietam quartzite. Geologic map, scale 1:62,500, shows outcrops.

Stose, G. W., and Swartz, C. K., 1912, Description of the Pawpaw and Hancock quadrangles [Maryland-West Virginia-Pennsylvania]: U. S. Geol. Survey Atlas, folio 179, p. 21.

The Oriskany sandstone crops out in many places in the Pawpaw and Hancock quadrangles, but it is only pure enough for glass sand in the Warm Spring Ridge, which extends southwest in West Virginia from the Potomac River opposite Hancock, Md. The sandstone is pure quartz, white, medium to fine grained, and free from silt and other fine debris, except particles of milky cryptocrystalline silica. The oldest mine is 2 miles from Hancock, on top of Warm Spring Ridge. Several quarries are in operation. The sand is reported to contain 98 to 99.8 percent SiO₂.

Stout, Wilber, 1946, Mineral resources of Ohio: Ohio Geol. Survey Inf. Circ. 1 (revised), ser. 4, p. 20-23, 27-28, 31.

Summarizes the occurrence and distribution, and describes the mineralogy of sandstone, conglomerate, flint, and ganister in the State.

Stow, M. H., 1938, Conditions of sedimentation and sources of the Oriskany sandstone as indicated by petrology: *Am. Assoc. Petroleum Geologists Bull.*, v. 22, p. 541-564.

Exposures of the Oriskany formation were examined, and samples collected between Monroe County, N. Y., and Monroe County, W. Va. The lithologic character of the Oriskany and adjacent formations at 10 localities is described. Samples were studied by the usual methods of sedimentary petrography.

Two distinctly different heavy mineral suites were found. The assemblage of tourmaline, zircon, rutile, leucosene, indicative of derivation from sedimentary rocks, was characteristic of the Oriskany south of New York. The assemblage of garnet, hypersthene, kyanite, biotite, and amphiboles, in addition to those minerals just mentioned, is indicative of derivation from crystalline rocks as well as sedimentary rocks. This assemblage was confined to the Oriskany of New York.

The minerals indicate that south of New York the Oriskany sediments were derived from sedimentary formations exclusively, probably from Cambrian and Silurian sandstones, and that in the New York area they were derived from crystalline rocks of the Adirondacks as well as from sedimentary formations.

Map, scale about 1 inch = 100 miles, showing the generalized outcrop of Oriskany sandstone from Genessee County, N. Y., to Giles County, Va., is included.

Symons, H. H., 1946, California mineral production and directory of mineral producers, 1945: *Calif. Div. Mines Bull.* 137, p. 102-103.

Silica suitable for glass occurs in Contra Costa, Monterey, Riverside, and San Bernardino Counties. The industry is of limited importance because much of the available material is not of the quality to produce first-grade colorless glass. Total silica production in California since the beginning of the industry in 1899 is given.

Teas, L. P., 1921, Preliminary report on the sand and gravel deposits of Georgia: *Ga. Geol. Survey Bull.* 37, 392 p.

Includes a general discussion of classification, properties, uses, prospecting, production and marketing of sand and gravel; detailed descriptions of deposits by counties; chemical and screen analyses; map, scale 1:1,500,000, showing distribution of deposits; and bibliography.

Thiel, G. A., 1935, Sedimentary and petrographic analysis of the St. Peter sandstone: *Geol. Soc. America Bull.*, v. 46, p. 559-613.

The St. Peter sandstone in Illinois, Missouri, Arkansas, and Oklahoma is a composite marine sandstone formed in a shallow sea characterized by retreats and readvances of the marine environment. The upper 6 or 8 feet of the St. Peter sandstone in the upper Mississippi Valley is much coarser grained than the lower levels. The sands 10 to 40 feet from the top of the formation are more rounded and frosted in the area of the upper Mississippi Valley; however, there is a decrease in grain size from north-central Illinois northward to the present margin of the formation. The sands of the St. Peter are too well sorted and rounded to have been derived directly from an area of maturely weathered granite.

Samples of the St. Peter sandstone were collected in Arkansas, Oklahoma, Missouri, Illinois, Iowa, Wisconsin, and Minnesota and were subjected to

uniform laboratory tests and methods of calculating textural analysis, heavy residuals, and other characteristics of correlative value.

Thiel, G. A., and Schwartz, G. M., 1932, *Geology and development of Minnesota's nonmetallic-mineral resources: Pit and Quarry*, v. 24, no. 6, p. 24-28.

Describes quarries in Sioux quartzite (upper Huronian) in Nicollet, Pipestone, Cottonwood, Rock, and Watonwan Counties. Quartzite also occurs north of the Mesabi range in St. Louis County. Much of this material is used for ball-mill liners and grinding pebbles.

The Jordan (upper Cambrian) sandstone crops out along the Minnesota River and the Mississippi River below Red Wing. The sandstone is almost pure silica and is used in the glass industry. The St. Peter (lower Ordovician) sandstone is exposed in Minneapolis and St. Paul; it consists of about 200 feet of almost pure silica sand, but the iron content is too high for making cores.

Formations that are used for foundry sands are the Sioux quartzite, Jordan sandstone, Kettle River sandstone, and St. Peter sandstone.

Trainer, D. W., Jr., 1927, *The geology of molding sand deposits: Am. Foundrymen's Assoc. Repr.* 428, 11 p.

Discusses types of molding sand deposits: lake, commonly of glacial origin, terrace; deposits along abandoned drainage lines, those of estuarine character; deposits associated with terminal moraine material; those in terraces of outwash material; marine; those along the shores of present lakes, and dunes.

——— 1928a, *The molding sands of Maryland: Md. Geol. Survey*, v. 12, p. 29-89.

Discusses the requisite properties of molding sands; permeability, bond strength, general geology of molding sand deposits, occurrence and properties of the deposits. Describes occurrences in the State.

——— 1928b, *Molding sands of Wisconsin: Wis. Geol. Nat. History Survey Bull.* 69, p. 21-22, 23, 43, 55, 78-93.

No steel molding sands are produced in Wisconsin. Blast sand, known as "Red flint" because of its red color, is produced for cleaning castings. Deposit in SW1/4 NW1/4 sec. 15, T. 17 N., R. 13 E., Green Lake County, 1 mile south of Chicago, Milwaukee, St. Paul and Pacific Railroad may be a possible source for steel molding sands. Samples taken from this deposit are steel sand grade.

Possible sources for steel molding sands are in Fond du Lac, Green Lake, Columbia, Sauk, La Crosse, and Buffalo Counties. The St. Peter sandstone is in general too fine for steel sands but excellent for core sand.

Future prospecting of outwash terraces or sand plains for sources of coarse molding sand and of glacial lake deposits of the Berlin district for sources of fine molding and core sands may prove profitable. Samples from Cambrian sandstone are of steel sand grade.

Mechanical analyses are included.

Tuck, Ralph, 1930, *Classification and specifications of siliceous sands: Econ. Geology*, v. 25, p. 57-64.

Gives definitions of sand from various sources. The properties are the

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amount of clay, mineralogic composition, purity, size of grain, distributed grading, uniformity of grain size, and the angularity of the individual grains. Classifying sands according to uses cannot be done successfully, because the same sand may be adapted to several uses. Table of classification and specifications of siliceous sands, some sieve tests, and a selected bibliography are included.

Tucker, W. B., and Sampson, R. J., 1931, Nonmetallic minerals; Calif. Dept. Nat. Res., Div. Mines, Mining in California, v. 27, p. 376-377.

Emsco ganister deposits are approximately 2½ miles northeast of Wilde siding on the Santa Fe Railway, about 20 miles northeast of Oro Grande. The entire upper part of the cone-shaped hill is composed of quartzite, about 200 feet thick. This property is abandoned, and operations have been transferred to a similar deposit approximately 9 miles east and slightly north of Victorville. Here the quarry face is 300 feet long and 20 feet high. The quarry is about 1 mile from the railroad.

The Kennedy, or Atlas Fire Brick Co. deposit, is about 4 miles northwest of Wilde siding on the Santa Fe Railway. The deposit is similar to the Emsco deposit and is probably a continuation of the same quartzite belt.

Turner, M. D., 1950, Sand and gravel, in Mineral commodities of California: Calif. Div. Mines Bull. 156, p. 254-258.

Descriptive report giving the geologic formation, mining methods, and locations of foundry sand, ganister, and glass sand in California.

Twenhofel, W. H., 1946, Mineralogical and physical composition of the sands of the Oregon coast from Coos Bay to the mouth of the Columbia River: Oreg. Dept. Geology and Mineral Industries Bull. 30, 65 p.

Describes the beach sands of the area and includes many chemical and mechanical analyses.

Tyler, P. M., 1950, Special methods for the beneficiation of glass sand: Am. Inst. Min. Metall. Eng. Trans., v. 187, p. 1139-1142.

Methods are given for the beneficiation of the poorer quality glass sand deposits.

United States Bureau of Mines, 1924-31: Mineral resources of the United States.

These annual publications list statistics on silica production, consumption, uses, prices, imports, and exports. Domestic production generally reviewed by States. Includes brief statements on annual developments in the silica industry.

——— 1932-52: Minerals Yearbook.

These annual publications list statistics on silica production, consumption, uses, prices, imports, and exports. Domestic production generally reviewed by States. Includes brief statements on annual developments in the silica industry.

United States Geological Survey, 1882-1923: Mineral resources of the United States.

These annual publications list statistics on silica production, consumption, uses, prices, imports, and exports. Domestic production generally reviewed by

States. Includes brief statements on annual developments in the silica industry, with certain volumes going into more detail on occurrence and resources.

Utley, H. F., 1942, Crude silica-sand output doubled to meet war demands of foundries: *Pit and Quarry*, v. 35, no. 2, p. 41-44.

Outcrops of St. Peter sandstone in the vicinity of Ottawa, Ill., provide practically pure silica sand, most of which is sold to steel foundries as molding sand and for core making. Best exposed in the bluffs along the Illinois and Fox Rivers. Maximum overburden 38 feet. Analyses of seven types of crude sand produced at Ottawa are included.

Valentine, G. M., 1949, Inventory of Washington minerals, part 1, Non-metallic minerals: Wash. Dept. Conserv. Devel., Div. Mines and Geology Bull. 37, p. 73, 75, 89-91, 93-94.

Résumé of occurrence and economic uses of deposits of vein quartz, silica sand, sandstone, and quartzite in the State. Map, scale about 1 inch = 23 miles, shows occurrences.

Vanderwilt, J. W., 1947, Mineral resources of Colorado, part 1, Metals, non-metals, and fuels: Colo. Min. Res. Board [Bull.], p. 262-264.

Describes three sandstone beds about 3 miles southeast of Waterton in Douglas County and another bed about three-fourths of a mile north of Waterton in Jefferson County.

The Molding Sand Quarry, Helmer Quarry, Kassler Quarry, Little Quarry, and Roxborough Park deposit are discussed, giving location and chemical analysis for each deposit. Location map, scale about 1 inch = 40 miles, is included.

Vernon, R. O., 1943, Florida mineral industry: Fla. Geol. Survey Bull. 24, p. 121-139.

Subrounded quartz and quartzite pebbles, together with minor amounts of chert, limonitic sandstone, and limestone occur as stream deposits in the Escambia, Apalachicola, Flint, and Chattahoochee Rivers. These deposits might be of commercial value. Mining of sand and gravel in Florida is done by dredging; some small operations are roadside pits. The sand industry is in Polk, Hillsborough, Orange, Putnam, and Dade Counties. The high-grade sand is used for blasting, glass sand, and filter aggregates.

Vestal, F. E., 1938, Tripoli deposits of Mississippi, in Tripoli deposits of western Tennessee and Mississippi: Knoxville, Tenn. Valley Authority, Water Control Plan. Dept., Geol. Div., Geol. Bull. 8, p. 8-12.

The best known tripoli deposits is about 1 mile southwest of Eastport. The tripoli deposits in Mississippi are part of the Iuka formation of the lower Iowa series of the Mississippian system. Appreciable quantities of tripoli have been shipped from a mine in the SW1/4 sec. 26, T. 2 S., R. 11 E.

— 1950, Carroll County geology [Mississippi]: Miss. Geol. Survey Bull. 67, p. 55, 61, 93.

Sand in the channel of Palusha Creek, sec. 35, T. 19 N., R. 3 E., near the southern boundary, and sands from the Coila Creek, NE1/4 sec. 4, T. 17 N., R. 2 E., might be used for the manufacture of green or amber glass.

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Voskull, W. H., and Sweeny, A. R., 1936, Illinois mineral industry in 1934: Ill. Geol. Survey Rept. Inv. 39, p. 40-48.

Treats briefly the economic possibilities of the uses of glass sand in Illinois, distribution of glass manufacturing industry in the United States, and the glass market.

Wadell, Hakon, 1935, Volume, shape, and roundness of quartz particles: Jour. Geology, v. 43, p. 250-280.

The report discusses the methods of measuring the volume, shape, and roundness of sedimentary quartz particles.

Watson, T. L., 1907, Mineral resources of Virginia: Lynchburg, Va., J. P. Bell Co. (Virginia-Jamestown Exposition Comm.), p. 216, 392-396.

Glass sand is derived from the Potsdam sandstone along the eastern edge of the Middle Valley region. Deposits of high grade sand occur at Balcony Falls, Rockbridge County; at Stapleton Mills, Amherst County; about 9 miles northwest of Salem, Roanoke County; at the foot of Potsdam Mountain, southeast of Greenville, Augusta County; and in the vicinity of Waynesboro. Includes analyses.

Molding sands of superior quality, strength, and a certain degree of fineness are found in the Coastal Plain. Chemical analyses and physical tests are given on molding sands in the vicinity of Richmond, Petersburg, and Fredericksburg.

Quartz has been mined from large pegmatite dikes near Amelia Court House, Amelia County, and from a bedded deposit in crystalline schists near Falls Church, Fairfax County. White pure crystalline quartz occurs three-fourths of a mile west of Wirtz Post Office, Franklin County.

——— 1919, Glass-sand resources of Virginia: Am. Ceramic Soc. Jour., v. 2, p. 794-803.

Summarizes the occurrence and stratigraphic distribution of sands, sandstones, and quartzites considered sources of silica raw material suitable for glassmaking in the State. Analyses are included.

Weidman, P. A., 1942, The Berea sandstone of the Cleveland area: Ohio State Univ. Eng. Expt. Sta. News, v. 14, no. 5, p. 14-21.

The Berea sandstone of the Waverly series (Mississippian) occurs as an irregular band in the southeastern part of Ashtabula County. It crops out westward through Lake, Geauga, Cuyahoga, Lorain, and Erie Counties, and then turns southward at Norwalk to form a broad north-south belt extending to the Ohio River. Thickness varies from 50 to more than 225 feet. A description of the geology, physical character, and mineralogy of the sandstone is given, including some chemical analyses.

Weidman, Samuel, 1904, The Baraboo iron-bearing district of Wisconsin: Wis. Geol. Nat. History Survey Bull. 13, Econ. Ser. 8, p. 1-2, 22-46.

The Baraboo district in Sauk and Columbia Counties, Wis., is about 28 miles long, and ranges from 2 to 12 miles in width. The area is about 225 square miles. The Baraboo quartzite occurs throughout the largest part of the district. This quartzite is hard, brittle, vitreous, and consists of rounded medium-sized grains of quartz cemented by secondary quartz.

Massive beds of quartzite vary in thickness and at many places are inter-

leaved with quartz schist. Describes the structure of the Baraboo quartzite localities.

Geological map, scale 1 inch = 1 mile, of the district is included.

——— 1907, The geology of north-central Wisconsin: Wis. Geol. Nat. History Survey Bull. 16, Sci. Ser. 4, p. 41-53, 82-84, 366-408, 560-563, 600-603.

Discusses the Rib Hill and Powers Bluff quartzites, giving their occurrence and petrographic character. Analysis of the Rib Hill quartzite shows 99.07 percent SiO_2 . Thin sections of the Powers Bluff quartzite closely resemble sections of the medium-grained Rib Hill quartzite. The Potsdam sandstone and its conglomeratic beds are described. Geologic map, scale 1 inch = 3 miles, and outcrop maps, scale about 1 inch = $1\frac{1}{2}$ miles, are included.

Weigel, W. M., 1926, Preparation and use of industrial special sands: Am. Inst. Min. Metall. Eng. Trans. 1569-H, 14 p.

Special sands are those classified as filter, sand blast, potter, flooring, fire or engine, standard, burnishing sands, sand for magnesium oxychloride cement-plasters, and sand for chemical and metallurgical uses. New Jersey, Pennsylvania, West Virginia, Ohio, Illinois, Minnesota, and Missouri produce some of these sands. Mining methods, some uses and properties of the sands, and possible fields for research are discussed.

——— 1927, Technology and uses of silica and sand: U. S. Bur. Mines Bull. 266, 204 p.

Summarizes mining and quarrying methods and uses of silica and sand in the United States and foreign countries. Chemical and screen specifications used by manufacturers are included.

Wells, F. G., Gates, G. O., Grantham, R. M., and others, 1940, Preliminary geologic map of the Grants Pass quadrangle, Oregon: Oreg. Dept. Geology and Mineral Industries, scale 1:125,000.

Discusses silica deposit of very pure quality is in the SE $\frac{1}{4}$ sec. 30, T. 36 S., R. 3 W., Jackson County. The deposit occurs as a lens-shaped body about 1,000 feet long and 200 feet wide. The silica generally is pure and white but is impure along the western edge of the lens.

Whitlatch, G. I., 1937, Tripoli: Tenn. Dept. Conserv., Div. Geology Markets Circ. 1, p. 3-12.

Occurrence and general uses of tripoli in the Missouri-Oklahoma and Illinois-Tennessee areas are described. Analyses are included.

——— 1938, The ceramic resources of Tennessee: Am. Ceramic Soc. Bull., v. 17, p. 290-291.

Glass sand and potter's flint, 99 percent SiO_2 , occur in the Sewanee conglomerate, of the Cumberland Plateau area.

Molding sand is mined from the Ripley formation (Cretaceous) in Benton and Carroll Counties. The annual production is estimated to be 30,000 tons.

Tripoli occurs in extensive deposits along the western valley of the Tennessee River. It is milled at Collinwood, and analyses show more than 99 percent SiO_2 and less than 0.02 percent Fe_2O_3 .

Whittemore, J. W., and Dear, P. S., 1940, Ceramic silica possibilities in Virginia: Va. Polytech. Inst., Eng. Expt. Sta. Ser. Bull. 43, 23 p.

Requirements of silica sand for the ceramic industries are discussed, publications on ceramic silica in Virginia are reviewed, and ceramic silica plants in Virginia are described.

Petrographic examinations and mechanical and chemical analyses have been made on many samples from different parts of the State. The results are discussed with reference to ceramic silica possibilities. These studies indicate that many silica deposits suitable for use as ceramic raw materials are favorably located for quarrying with respect to transportation and abundant fuel supplies.

Wilkerson, A. S., and Comeforo, J. E., 1948, Some New Jersey glass sands: Rutgers Univ. Bur. Mineral Research Bull. 1, 155 p.

The field relations, mineral and chemical composition, and results of laboratory beneficiation of 24 silica sand samples are described. The samples were collected in central and southern New Jersey, south and east of New Brunswick and Trenton. Of the 24 samples collected, 19 were found suitable, after treatment, for use as high-quality glass sand. The mineralogy, methods of treatment, and uses of the sands are discussed. Map, scale 1 inch = 27 miles, showing locations is included.

Willman, H. B., and Payne, J. N., 1942, Geology and mineral resources of the Marseilles, Ottawa, and Streater quadrangles [Illinois]: Ill. Geol. Survey Bull. 66, p. 71-80, 234-243, 344-348.

The St. Peter sandstone crops out along the Illinois valley west from Fox River to the west side of the Ottawa quadrangle and forms high bluffs along both sides of the valley west of Buffalo Rock. It also is exposed in the eastern part of the LaSalle quadrangle, west of the Ottawa quadrangle, and along Fox River Valley, with small outcrops along Indian, Buck, and Crooked Leg Creeks in the Ottawa quadrangle, and Brumbach and Mission Creeks in the Marseilles quadrangle.

The mineralogical and chemical composition of the deposits are described. Many chemical analyses show SiO₂ content greater than 97 percent; average SiO₂ content after beneficiation, 99 percent. Maps included are geologic map of Ottawa and Marseilles quadrangles, scale 1:62,500; bedrock topographic maps, Ottawa and Marseilles quadrangles, scale 1:62,500; isopach maps showing thickness of St. Peter-Glenwood formations, scale 1 inch = 5 miles; and map showing graphic logs of deep wells in north-central Illinois, scale 1 inch = 5 miles.

Wilson, E. D., and Roseveare, G. H., 1949, Arizona nonmetallics; a summary of past production and present operations (revised): Ariz. Bur. Mines Bull. 155, Mineral Tech. Ser. 42, v. 20, no. 2, p. 41, 44.

Quartzite for reverberatory furnace lining has been produced from a deposit west of Douglas. A few thousand tons of silica was mined from the Dixie claims, 40 miles northeast of Phoenix. Sand from the Coconino sandstone (Permian) at Meteor Crater, 18 miles west of Winslow, is used for the manufacture of glass and in the foundry industry.

Wilson, Hewitt, Skinner, K. G., and Couch, A. H., 1942, Silica sands of Washington: Wash. Univ. Eng. Expt. Sta. Bull. 108, p. 21-22, 32, 45-46, 48, 52-53.

Many silica deposits occur in Washington, but most are not high enough in silica content, or contain too many impurities, to be used in the glass and steel industries. Vein deposits in Eocene sandstone may be developed if factors other than quality are favorable.

The Brown deposit is in the Swauk formation, 2 miles from Appleyard, Chelan County. Thickness ranges from 150 to 200 feet and estimated reserves are 430,000 tons. Sample of this deposit showed 99.4 percent SiO_2 and 0.1 percent Fe.

Brooke deposit, at Hammer Bluff, King County, contains 97.2 percent SiO_2 and 0.1 percent Fe.

Siegmund deposit is in sec. 30, T. 17 N., R. 4 E., Pierce County. The SiO_2 content is 95.1 percent and Fe is 0.6 percent.

Stoner deposit is three-fourths of a mile north of the Jennings and Nestes bridge, Skagit County. The SiO_2 content is 99.6 percent and Fe is 0.13 percent.

Scheel deposit is in sec. 16, T. 36 N., R. 11 E., Skagit County. The SiO_2 content is 99 percent and Fe is 0.47 percent.

Sample of vein quartz in NW $\frac{1}{4}$ sec 17, T. 40 N., R. 4 E., Whatcom County, showed 99.3 percent SiO_2 and 0.3 percent Fe.

Map showing localities of sampled sand deposits is included.

Wilson, Hewitt, and Zvanut, F. J., 1936, Properties of quartz sands washed from kaolins of the Pacific Northwest: Wash. Univ. Eng. Expt. Sta. Bull. 88, 42 p.

Studies were made of the purification of quartz sand and the removal of muscovite mica and heavy iron minerals in the Spokane district of eastern Washington and in Latah County, Idaho. After beneficiation, colored glass is made from sands at Troy, Idaho, and Mica, Wash. These studies were made to determine the possibility of utilizing the quartz recovered from the purification of kaolin. Tests and sieve analyses and suggested flow sheet for kaolin washing and sand concentration are included.

Witherow, C. N., 1933, Silica as a refractory material: Brick and Clay Record, v. 82, p. 123-124, 137, 164-165, 171, 208-209.

Discusses the properties of silica, silica in special refractories, its physical and chemical nature, its reaction to heat, physical forms of silica, silicate minerals, and properties of fused silica. Types of sandstones and quartzites and sillimanite and mullite refractories are also discussed. Chemical analyses are included.

Woodward, H. P., 1932, Geology and mineral resources of the Roanoke area, Virginia: Va. Geol. Survey Bull. 34, p. 136-137.

Sands from the Clinch and Clinton sandstones near Roanoke and deposits in the Catawba Valley, about 9 miles northeast of Salem, were used for making glass. In general, the sandstones of the Price formation are too clayey and carbonaceous for making glass.

Analyses of sand and sandstone from Catawba Mountain and Catawba Valley are given. Map, scale 1:125,000, showing the geology of the Roanoke area and map, scale 1 inch = 1 mile, showing geologic structure sections across the Roanoke area are included.

Woodward, T. P., and Guena, A. J., Jr., 1941, The sand and gravel deposits of Louisiana: La. Geol. Survey Bull. 19, 365 p.

Report consists mainly of data sheets for each locality, listed alphabetically by parish. Many sieve and some chemical analyses are included. In most places the silica content is high, but the iron content is also somewhat high for use in the glass industry.

Map, scale 1 inch = 12 miles, showing localities and map, scale 1 inch = 4 miles, showing general geology are also included.

Wright, L. A., 1948, California foundry sands: Calif. Jour. Mines and Geology, v. 44, p. 37-72.

California is self-sufficient in foundry sands of all general types except high-grade silica sands. Five dune areas along the California coast, at San Francisco, Lapis, Del Monte (Moss Beach), Oceano Beach, and El Segundo Beach are contributing clay-free felspathic sands. These sands are suitable for cores.

Three foundry sands produced in California have silica contents high enough to meet steel-casting requirements. Two of these are obtained from the Eocene sediments west of Mount Diablo in Contra Costa County; the third is a machine-crushed silica rock from a deposit near Montrose in southern California.

Two natural mixtures of refractory clay and high silica sand, are used as patching materials and to a lesser degree, in synthetic sand mixes. Both are from Eocene sediments, one from the Livermore area, the other from the vicinity of Trabuco Canyon in the Santa Ana Mountains.

Many sieve analyses and a few chemical analyses are included.

Wright, L. A., Stewart, R. M., Gay, T. E., Jr., and Hazenbush, G. C., 1953. Mines and mineral deposits of San Bernardino County, Calif.: Calif. Jour. Mines and Geology, v. 49, p. 4-5, 196-197.

Silica (quartz) recently has been produced in San Bernardino County. The principal sources are quartzite beds and lenses in the Paleozoic metamorphic series near Oro Grande and Barstow. Felsite from the Ivanpah deposit in the Castle Mountains also is marketed as a silica rock. It is used chiefly in refractories and in sulfate-resistant cement. Map, scale 1 inch = 80 miles, showing distribution of silica is included.

Wyer, S. S., 1922, The Smithsonian Institution's study of natural resources applied to Pennsylvania's resources: U. S. Natl. Mus., p. 86-91, 109-112.

Discusses glass sand and the manufacture of glass. The glass industry is confined to the western and central part of the State; the latter area is more important in production and quality of sand.

Deposits occur at Falls Creek, Clearfield County; Daguscahonda, Elk County; at Dunbar and along the Monongahela River near Belle Vernon, Fayette County; in the vicinity of Mapleton, Huntingdon County; in Jefferson County; in the vicinity of Vineyard and at Granville along the main line of the Pennsylvania Railroad between Huntingdon and Lewistown, Mifflin County; at Kennerdell and Rockmere station near Oil City, Venango County; in Warren County; and in Westmoreland County. Map, scale 1 inch = 28 miles, showing glass sand quarries and plants is included.

Cambrian sandstone, quarried for whetstone, occurs in the South Mountains near Allentown, Lehigh County.

Ganister is mined for silica brick at Pattonville, Bedford County; McKee

Gap and Point View, Blair County; Water Street Gap, Huntingdon County; Beartown, Lancaster County; Edge Hill, Montgomery County; and near Bowmans, Carbon County.

Millstone occurs at East Earl and Lincoln, Lancaster County.

Crushed quartzite is produced at Exton and Honeybrook, Chester County, for fire sand.

Quartz-mica schist is quarried at Edge Hill and Glenside, Montgomery County. It is used for the manufacture of cupola blocks, furnace bricks, silica bricks, and fire mortar.

Anonymous, 1926a, Nevada Pacific Company plans extensive operations: Pit and Quarry, v. 13, no. 1, p. 92-93.

Deposit of 640 acres of silica sand occurs near Las Vegas on the Salt Lake Route of the Union Pacific Railroad. The sand grains are round and compare in quality to the Ottawa silica. Used in foundries and for glass manufacture. The exposed deposit is estimated to contain 100 million tons.

——— 1926b, New modern silica sand operation opens up in Wisconsin: Pit and Quarry, v. 12, no. 4, p. 103-104.

A sandstone deposit occurs on a 35-acre tract 5 miles north of Westfield, Marquette County. Tests show that the sandstone averages 99 percent SiO_2 and is very low in impurities. The sand grains are sharp, and the fusion point is $3,128^\circ\text{F}$.

The report describes the operation of the plant, which has a crushing capacity of 150 to 200 tons per hour, with a drying and screening capacity of 50 tons per hour.

——— 1926c, New plant makes sand-lime brick from pure silica deposit: Rock Products, v. 29, no. 14, p. 53-55.

In Florida, sand containing 99.6 percent SiO_2 and practically free from iron occurs 7 miles from Lakeland, near Galloway. The deposit is 13 feet deep; the lower half is below the water table. Brick is now being made from this sand. Because of its purity, it would also make excellent glass sand.

——— 1926d, Possibilities for the glass industry in the South: Glass Worker, v. 45, no. 19, p. 15.

Glass sand occurs in three areas in Oklahoma; the most extensive is in the Arbuckle Mountains. The Trinity sandstone occurs in the southeastern part of the State. In the northeastern part of the State, the Bergen sandstone is 50 to 100 feet thick.

The St. Peter sandstone (Ordovician) is exposed in Missouri and Arkansas. It is composed of very pure quartz sand, averaging more than 99 percent SiO_2 and less than 0.10 percent Fe. The formation averages 80 feet in thickness and crops out in a belt 150 miles long and as much as 15 miles wide. The sand is uniform in grain size, averaging about 0.154 mm. The maximum thickness is 200 feet. In the past 2 years nearly 90,000 yards of sand were produced at one of three exposures. Some of the glass sand used in Arkansas comes from Oklahoma.

Of the southern States east of the Mississippi, West Virginia has the most important glass sand deposits. The Piedmont province contains deposits of pure quartzite used for making glass. The Cambrian and Silurian formations in the mountain province are the most important sources of glass sand. The Clinch sandstone (Silurian) is exceptionally pure and may be used for

optical glass. The same formation in Tennessee is reported to have favorable outcrops for furnishing good glass sand. Glass is also made from the sands dredged from the St. Johns River, Fla.

Anonymous, 1926e, Silica sand taken out by dredging: *Rock Products*, v. 29, no. 15, p. 48-49.

Chemical analyses of silica sand near Millville, N. J., is about 99.5 percent SiO_2 . Some of the unwashed sand was used for chemical glassware. All the sand can be washed to an exceptionally pure grade or glass and silicate of soda. The deposit contains some gravel and large amounts of molding sand.

——— 1926f, Underground mining protects purity: *Pit and Quarry*, v. 12, no. 9, p. 93-95.

The St. Peter sandstone mined at Pacific, Mo., is known locally as the Pacific, Crystal City, and Cap au Gres sandstone. The formation is massive and shows indistinct bedding. It averages more than 99.0 percent SiO_2 and less than 0.01 percent Fe_2O_3 .

——— 1932, Shenandoah Silica Company builds new mill: *Ceramic Age*, v. 20, no. 5, p. 181-182.

Silica deposit on Cold Run Ridge near Gore, Va., has the same pure quartz sand as other deposits in the Oriskany sandstone and is similar to the deposit at Berkeley Springs, W. Va. The sandstone crops out on the side of the ridge in beds 4 to 7 feet thick, which dip about 45° toward the base of the mountain. Drilling and blasting are necessary in quarrying. The deposit is near rail transportation.

——— 1944, Alabama today and tomorrow: *Manufacturers Record*, v. 113, no. 8, p. 87.

Molding sand is obtained at several localities near the foundry industries of Birmingham, Gadsden, and Anniston. Production of molding sand in 1942 was 105,371 tons. Deposits of glass sand occur in Baldwin County near the Gulf Coast and in Calhoun County in northeast Alabama. These sands are of the highest grade used by the glass industry, including sand for plate and optical glass.

——— 1946, Sand and gravel covers coastal plain: *Rock Products*, v. 49, no. 5, p. 78, 82.

Glass sand (99 percent SiO_2) is obtained at Gate City, Ala., from sandstone of lower Carboniferous age.

The Tuscaloosa formation (Cretaceous) contains a practically unlimited supply of all grades of sands, and some parts of the Ripley formation (upper Cretaceous) has some excellent sands, including glass sand.

Map showing distribution of silica sand, Gate City, Jefferson County, and Ohatchee, Calhoun County, is included.

——— 1953a, Jeanette Creek Mining and Development Co.: *Eng. Min. Jour.*, v. 154, p. 140.

A large silica deposit is being developed about a mile north of Bergdorf, Idaho County, Idaho.

——— 1953b, *Min. World*, v. 15, no. 2, p. 103.

Four companies in the Northwest obtain silica from a quarry at Denison, Wash. In 1952, this quarry produced 140,000 tons of silica.

Anonymous, 1953c, Processing silica for refractory brick: Rock Products, v. 56, no. 9, p. 114, 116, 118, 120.

The Sharon conglomerate (Pennsylvanian) is quarried 6 miles north of Windham near Nelson's Ledges, Ohio. This very friable quartz conglomerate average 60 feet in thickness. The overburden is 5 to 20 feet thick.

Two types of refractory silica brick are made from this rock. One consists of about 96 percent SiO_2 ; 1-2 percent oxides, in which Al_2O_3 and Fe_2O_3 predominate; and 2-3 percent lime which is added as a bond. The second type, used in higher temperature furnaces, is quality controlled so that the total content of alumina, titania, and alkalis does not exceed 0.5 percent.

A flow sheet of operations in the manufacture of refractory brick accompanies the article.

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 Witherow 1933
Tripoli:
 Butler 1928
 Dale and Beach 1951
 Gildersleeve 1946
 Gould 1910
 Heinz 1937
 Levings 1923
 Metcalf 1949
 Spain 1936
 Whitlatch 1937
Alabama.
Chert.
 Area, Tennessee Valley: Smith, E. A.
 1884
Conglomerate.
 County, Calhoun: Jones 1938
Massive quartz.
 Area, general: Jahns and others 1952
Quartzite.
 County:
 Calhoun, Talladega, Cherokee, Clay,
 and Cleburne: Metcalf 1940b
 Cherokee: Bowles 1941
Sand.
 County:
 Baldwin: Jones 1938
 Baldwin and Calhoun: Anonymous
 1944
 Bibbs and Mobile: Adams 1929
 Mobile: Havell and McVay 1939
Sandstone.
 County:
 Calhoun: Jones 1938
 Calhoun, Etowah, and Jefferson:
 Anonymous 1944

Alabama—Continued

Sandstone—Continued

County—Continued

Calhoun and Jefferson: Anonymous 1946

Chilton, Randolph, Tallapoosa, Macon, Lee, and Chambers: Smith, E. A. 1884

Jefferson: Adams 1929; Burchard 1907b

Tripoli.

Area, Tennessee Valley: Heinz 1937

County:

Colbert and Lauderdale: Gildersleeve 1946a; Spain 1936

Colbert, Lauderdale, and Calhoun: Metcalf 1949

Arizona.

Quartzite.

County, Cochise and Maricopa: Wilson and Roseveare 1949

Sandstone.

County, Coconino: Wilson and Roseveare 1949

Arkansas.

Chert.

Area, southwest Arkansas: Goldstein and Hendricks 1953

Novaculite.

Area:

Ouachita Mountains: Miser 1943

Southwest Arkansas: Goldstein and Hendricks 1953

County:

Clark, Hempstead, Howard, Montgomery, Pike, Polk, and Sevier: Miser and Purdue 1929

Garland and Hot Spring: Purdue and Miser 1923

Garland, Hot Spring, Howard, Montgomery, Pike, Polk, Pulaski, and Saline Counties: Griswold 1892

Garland, Montgomery, Pulaski, and Saline: Anderson 1942

Polk: Branner 1940a

Polk and Pulaski: Branner 1942

Sandstone.

Area:

General: Thiel 1935

Northern Arkansas: Giles 1930

County:

Baxter, Boone, Carroll, Fulton, Independence, Izard, Madison, Marion, Newton, Searcy, Sharp, and Stone: Branner 1942

Boone: Burchard 1906

Izard: Burchard 1907b; Dunkin 1928

Silica.

County, Garland: Purdue and Miser 1922

Miser and Purdue 1929

Tripoli.

County:

Baxter, Benton, Garland, Hot Spring, Madison, Montgomery, Pike, Polk, and Washington: Metcalf 1949

Arkansas—Continued

Tripoli—Continued

County—Continued

Baxter, Benton, Garland, Hot Spring, Montgomery, Pike, Polk, and Washington: Branner 1942

Benton: Heinz 1937

Benton, Madison, and Washington: Branner 1940b

Garland: Purdue and Miser 1922

Garland and Montgomery: Anderson 1942

Montgomery, Pike, and Polk: Miser and Purdue 1929

Polk: Branner 1940a

California.

Massive quartz.

County:

Eldorado, Los Angeles, and Stanislaus: Sampson and Tucker 1931

San Bernardino: Symons 1946

San Diego: Burchfiel 1936

Quartzite.

County:

San Bernardino: Averill and Norman 1951; Sampson and Tucker 1931;

Tucker and Sampson 1931; Wright and others 1953

San Diego: Metcalf 1940b

Sand.

County:

Alameda, Amador, Los Angeles, Monterey, Orange, Placer, Riverside, Sacramento, San Diego, San Francisco, San Mateo, and Ventura: Turner 1950

Contra Costa, Monterey, Riverside, and San Diego: Symons 1946

Imperial and Riverside: Sampson and Tucker 1931

Los Angeles, Monterey, San Diego, and San Francisco: Wright 1948

Monterey: Averill and Norman 1951; Calif. Div. Mines Inf. Service 1954;

Dasher and others 1943

"Sand-clay."

County:

Alameda: Huey 1948

Alameda and Orange: Wright 1948

Alameda, Orange, San Diego, San Mateo, and Ventura: Turner 1950

Sandstone.

County:

Alameda, Amador, Contra Costa, Riverside, and San Diego: Calif. Div. Mines Inf. Service 1954

Alameda, Contra Costa, and San Joaquin: Huey 1948

Contra Costa: Davis and Vernon 1951; Huttel 1937

Contra Costa and Los Angeles: Wright 1948

Contra Costa and Riverside: Averill and Norman 1951; Turner 1950

Riverside: Shaw 1937

California—Continued

Silica.

County:

Amador, Contra Costa, El Dorado, Inyo, Kern, Monterey, Placer, Riverside, and San Diego: Modes 1932
San Bernardino: Averill and Norman 1951

Canada.

Massive quartz.

Province:

British Columbia and Manitoba: Cole, L. H. 1928
Maritime, Ontario, and Quebec: Cole, L. H. 1923
Ontario: Hewitt 1951

Quartzite.

Province:

Alberta, British Columbia, and Manitoba: Cole, L. H. 1928
Ontario: Hewitt 1951

Sand.

Province:

Alberta, Manitoba, and Saskatchewan: Cole, L. H. 1928
Maritime and Ontario: Cole, L. H. 1923
Ontario: Hewitt 1951

Sandstone.

Area, southeast Ontario: Keith 1946

Province:

Alberta, Manitoba, and Saskatchewan: Cole, L. H. 1928
Maritime, Ontario, and Quebec: Cole, L. H. 1923
Ontario: Hewitt 1951

Colorado.

Massive quartz.

County, Boulder, Chaffee, Douglas, El Paso, Fremont, Gunnison, Jefferson, Larimer, and Park: Hanley and others 1950

Quartzite.

Area:

Missouri River basin: Larrabee and others 1947
Mosquito Range: Johnson, J. H. 1934
County, Fremont: Argall 1949

Sandstone.

Area, Missouri River basin: Larrabee and others 1947

County:

Chaffee, Douglas, El Paso, Fremont, Jefferson, Pueblo and Prowers: Argall 1949
Denver, El Paso, and Pueblo: McAllister and Bartram 1947
Douglas and Jefferson: Vanderwilt 1947

Connecticut.

Massive quartz.

County, New London: Barrell and Loughlin 1910; Loughlin 1912

Quartzite.

County, Tolland: Emerson 1917

Florida.

Flint.

Area, general: Metcalf 1940b

Gravel.

Area, Apalachicola, Chattahoochee, Escambia, and Flint Rivers: Vernon 1943

Sand.

Area, Miami to West Palm Beach: Hudson 1946a

County:

Dade, Hillsborough, Orange, Polk, and Putnam: Vernon 1943
Escambia: Burchard 1907b
Polk: Anonymous 1926c

Georgia.

Gravel.

Area, general: Teas 1921

Massive quartz.

Area, general: Furcron and Teague 1943; Jahns and others 1952

Novaculite.

County, Heard, Lincoln, McDuffie, Meriwether, Oglethorpe, and Troup: Griswold 1892

Sand.

Area, general: Teas 1921

County:

Richmond: Burchard 1907b
Wheeler: Hudson 1946b

Tripoli.

County:

Bartow, Catoosa, Chattooga, Floyd, Gilmer, Gordon, Murray, Polk, Walker, and Whitfield: Crickmay 1937
Bartow, Catoosa, Chattooga, Floyd, Gilmer, Murray, Polk, Walker, and Whitfield: Metcalf 1949
Bartow and Chattooga: Butts and Gildersleeve 1948

Idaho.

Massive quartz.

County, Adams, Idaho, and Latah: Stoll 1950

Sand.

County, Latah: Wilson and Zvanut 1936

Silica.

Area, general: Hodge 1938
County, Idaho: Anonymous 1953a

Illinois.

"Chert-clay."

County:

Alexander: Lamar 1953
Alexander, Kendall, and Lake: Littlefield 1925

Gravel.

County, Alexander and Union: Parmelee and Harman 1946

Novaculite.

County:

Alexander: Lamar 1953
Alexander and Union: Parmelee and Harman 1946

Illinois—Continued

Sand.

County, La Salle: Weigel 1926

Sandstone.

Area, general: Thiel 1935; Voskull and Sweeney 1936

County:

Calhoun, La Salle, Ogle, and Winnebago: Lamar 1928

Grundy, Kendall, La Salle, and Livingston: Willman and Payne 1942

La Salle: Boswell 1917; Burchard 1906; Edwards 1926; Littlefield 1925; Utley 1942

Tripoli.

General: Machin and Tooley 1937; Whitlach 1937

County, Alexander and Union: Bain 1907; Heinz 1937; Lamar 1958; Metcalf 1949; Parmelee 1932; Parmelee and Harman 1946

Indiana.

Sand.

Area, general: Bieber and Smith 1952

County:

Harrison, Madison, Martin, Parke, and Washington: Murray and Patton 1953

La Porte: Barrett 1914

Sandstone.

County:

Clay, Crawford, Dubois, Fountain, Greene, Martin, Owen, Parke, Perry, and Putnam: Barrett 1914

Parke, Martin, and White: Burchard 1907a

Iowa.

Quartzite.

Area:

General: Beyer 1897
Northwest Iowa: Baldwin 1949

Sandstone.

Area, general: Thiel 1935

County:

Linn: Knight 1926

Woodbury: Burchard 1907b

Kansas.

Sand.

County, Cloud, Saline, Sedgwick, and Wyandotte: Bowdish and Runnels 1952

Sandstone.

County:

Barber, Comanche, and Kiowa: Nixon and others 1950; Rose 1950

Chautauqua, Montgomery, and Wilson: Burchard 1906

Greenwood: Burchard 1907b

Wilson and Montgomery: Schrader 1908

Tripoli.

County, Cherokee: Frye 1942

Kentucky.

Sand.

Area, general: Richardson 1920

Kentucky—Continued

Sand—Continued

County, Boyd, Carroll, and Greenup: Am. Foundrymen's Assoc. 1925

Sandstone.

Area, general: Richardson 1920

County:

Caldwell and Carter: Am. Foundrymen's Assoc. 1925

Caldwell and Crittenden: McGrain 1952

Crittenden: Nordberg 1954

Estill, Franklin, Gallatin, Harrison, Madison, and Menifee: Jillson 1933

Hardin: Burchard 1907a

Louisiana.

Sand.

Area, general: Woodward and Gueno 1941

Maine.

Massive quartz.

Area, general: Bastin 1911

Novaculite.

Counties, Franklin, Hancock, and York: Griswold 1892

Maryland.

Massive quartz.

County, Baltimore, Carroll, Cecil, Harford, Howard, and Montgomery: Singewald 1928

Novaculite.

County, Anne Arundel and Prince George: Griswold 1892

Sand.

Area, general: Trainer 1928a

County, Anne Arundel and Prince George: Darton 1939

City, Baltimore: Boswell 1917

Massachusetts.

Novaculite.

County, Essex: Griswold 1892

Quartzite.

County:

Berkshire: Boswell 1917; Emerson 1899

Franklin, Hampden, and Hampshire: Emerson 1917

Michigan.

Sand.

Area, general: Brown 1936

Sandstone.

Area, southeast Michigan: Ehlers and others 1951

County, Monroe and Wayne: Sherzer 1917

Tripoli.

County, Marquette: Griswold 1892

Minnesota.

Quartzite.

Area:

General: Beyer 1897

Southwest Minnesota: Baldwin 1949

County:

Brown, Cook, Pipestone, and Rock: Emmons and Grout 1943

Minnesota—Continued**Quartzite—Continued****County—Continued**

Cottonwood, Nicollet, Pipestone, Rock, St. Louis, and Watonwan: Thiel and Schwartz 1932

Nicollet, Pipestone, and Rock: Knapp 1923

Pipestone and Rock: Metcalf 1940b

Sand.

Area, general: Weigel 1926

Sandstone.

Area, general: Thiel 1935

County:

Fillmore, Goodhue, Hennepin, Le Sueur, Pine, Ramsey, Rice, and Wabasha: Knapp 1923

Goodhue, Hennepin, and Ramsey: Thiel and Schwartz 1932

Hennepin, Lake, Le Sueur, and Ramsey: Emmons and Grout 1943

Tripoli.

County, Washington: Emmons and Grout 1943

Mississippi.**Sand.**

County, Carroll: Vestal 1950

Tripoli.

Area, Tennessee Valley: Heinz 1937

County, Tishomingo: Gildersleeve 1946a; Metcalf 1949; Spain 1936; Vestal 1938

Missouri.**Sand.**

County, Franklin, Jefferson, and St. Louis: Weigel 1926

Sandstone.

Area, general: Thiel 1935

County:

Barry, Cape Girardeau, Franklin, Jefferson, St. Charles, St. Louis, and Ste. Genevieve: Burchard 1906

Cape Girardeau, Jefferson, and Montgomery: Sheakley and Coolidge 1942

Franklin: Anonymous 1926f

Morgan: Burchard 1907b

City, St. Louis: Boswell 1917

Tripoli.

Area, general: Whitlatch 1937

County, Newton: Dale and Beach 1951; Gould 1910; Griswold 1892; Heinz 1937; Levings 1923; Metcalf 1949; Siebenthal and Mesler 1908

Montana.**Massive quartz.**

County, Madison: Stoll 1950

Sandstone.

County, Beaverhead and Stillwater: Knechtel and others 1948

Nebraska.**Sandstone.**

County, Burt, Dakota, Dixon, Gage, Jefferson, Lancaster, and Saunders: Burchard 1907b

Nevada.**Quartzite.**

County, Clark: Murphy 1954

Sand.

County Clark: Hewett and others 1936; Murphy 1954

Sandstone.**County:**

Clark: Hewett and others 1936; Murphy 1954; Roalfe 1937; Anonymous 1926a

Clark, Esmeralda, and Washoe: Fulton and Smith 1932

New Hampshire.**Massive quartz.****Area:**

General: Meyers 1941

Lakes region: N. H. State Plan. Devel. Comm. 1949

Novaculite.

County, Carroll: Griswold 1892

Quartzite.

County, Grafton and Sullivan: Meyers 1941

New Jersey.**Conglomerate.**

Area, general: Newland 1919

Gravel.

County, Cumberland: Am. Foundrymen's Assoc. 1925

Quartzite.

County, Morris: Johnson, M. E. 1935

Sand.

Area, general: Weigel 1926

County:

Burlington: Bascom and others 1908; Bascom and others 1909

Cumberland: Am. Foundrymen's Assoc. 1925; Anonymous 1926e

Cumberland and Gloucester: Kummel and Gage 1907

Mercer and Middlesex: Wilkerson and Comeforo 1948

Morris: Darton and Kummel 1904

Sandstone.

County, Morris: Bayley and Kummel 1914

New York.**Conglomerate.**

General: Colony 1919

County, Ulster: Newland 1919

Massive quartz.

County, Essex and Washington: Newland 1919

Quartzite.

General: Colony 1919

Area, Highland region: Newland 1919

County, Essex, Fulton and Washington: Newland 1919

Sand.

General: Colony 1919

Area, Oneida Lake region: Newland 1919

County, Oswego: Nevin 1929

Sandstone.

General: Colony 1919

New York—Continued

Sandstone—Continued

Area: Stow 1938

County, Cayuga, Franklin, and Madison:
Newland 1919

North Carolina.

Gravel.

Area, Coastal Plain: Broadhurst 1949;
Bryson 1937

Massive quartz.

Area.

General: Jahns and others 1952

Spruce Pine district: Parker 1952

Western North Carolina: Broadhurst
1949County, Anson, Avery, Harnett, Mitchell,
Montgomery, Moore, and Yancey:
Bryson 1937

Novaculite.

County, Anson, Chatham, Orange, Per-
son, and Randolph: Griswold 1892

Quartzite.

Area, Mountainous region: Broadhurst
1949

County, Cherokee: Bryson 1937

Sand.

Area:

General: Broadhurst 1954

Coastal Plain: Broadhurst 1949

Ohio.

Conglomerate.

Area, general: Fuller 1947

County:

Cuyahoga, Geauga, Jackson, Lake,
Medina, Portage, and Summit:
Smith, W. H. 1949

Gauga and Portage: Bowen 1953

Jackson and Pike: Bengston and
others 1950Jackson, Perry, Pike, Portage, Scioto,
Stark, Summit, and Trumbull: Stout
1946Jackson, Perry, Portage, Summit,
Trumbull, and Wayne: Bownocker
1921

Portage: Anonymous 1953c

Flint.

County, Coshocton, Hocking, Licking,
Muskingum, Perry, and Vinton: Stout
1946

Sand.

County, Stark and Wood: Weigel 1926

Sandstone.

Area:

General: Bownocker 1939; Stout 1946
Northwest Ohio: Ehlers and others
1951

County:

Ashtabula, Cuyahoga, Erie, Geauga,
Huron, Lake, and Lorain: Weid-
men, P. A. 1942Coshocton, Hocking, Holmes, Jackson,
Knox, Licking, Lucas, Mahoning,
Muskingum, Perry, Stark, Summit,
Trumbull, Tuscarawas, and Wayne:
Burchard 1907a

Ohio—Continued

Sandstone—Continued

County—Continued

Lucas and Wood: Carman 1936

Muskingum, Scioto, Stark, and Tus-
carawas: Bownocker 1921

Perry: Flint 1951

Oklahoma.

Chert.

Area, Southeast Oklahoma: Goldstein
and Hendricks 1953

Novaculite.

Area:

General: Honess 1923

Ouachita Mountains: Miser 1943

Southeast Oklahoma: Goldstein and
Hendricks 1953; Harton 1953

County:

Atoka, Garland, Latimer, and Le Flore:
Gould 1910Atoka, Latimer, McCurtain, and Push-
mataha: Stenzel and others 1948

Choctaw: Griswold 1892

McCurtain: Miser and Purdue 1929

Quartzite.

Area, Ouachita Mountain region: Stenzel
and others 1948

Sand.

Area:

Arbuckle Mountain region: Burnwell
and Ham 1945

Southeast Oklahoma: Kinney 1948

County:

Carter, Johnston, Love, Marshall, and
Murray: Shead 1928Hughes, Muskogee, Pawnee, Rogers,
Tulsa, and Washington: Buttram
1913

Sandstone.

General: Dale and Beach 1951

Area:

General: Thiel 1935

Ouachita Mountain region: Stenzel
and others 1948Arbuckle Mountain region: Kinney
1948Southeast Oklahoma and Arbuckle
Mountain region: Gould 1908

County:

Bryan and Cherokee: Shead 1928

Carter, Cherokee, Johnston, Love,
Murray, and Pontotoc: Okla. Geol.
Survey 1942Carter, Cherokee, Johnston, Murray,
and Pontotoc: Gould and Beach
1930

Cherokee: Kinney 1948

Cherokee: Gould 1908

Cherokee and Murray: Buttram 1913
Jefferson, Johnston, Major, Pontotoc,
and Woods: Beach 1939Johnston, Murray, and Pontotoc: Ham
1945

Tripoli.

Area, general: Whitlach 1937

Oklahoma—Continued

Tripole—Continued

County:

- Beaver and Ottawa: Metcalf 1949
 Cherokee and Ottawa: Gould 1910
 Ottawa: Heinz 1937

Oregon.

Sand.

- Area, Oregon coast: Twenhofel 1946
 County, Lane: Lowry 1947

Silica.

- Area, general: Hodge 1938

County:

- Coos, Curry, Jackson, Josephine, Lane,
 and Polk: Oreg. Dept. Geology and
 Mineral Industries 1951
 Jackson: Libbey 1950; Wells and
 others 1940

Pennsylvania.

Conglomerate.

- General: Frederick 1932
 Area, General: Newland 1919

Massive quartz.

County:

- Adams: Stose 1932
 Adams, Chester, and Cumberland:
 Stone 1939

Quartz-mica schist.

- County, Montgomery: Moore and Taylor
 1924; Wyer 1922

Quartzite.

- General: Frederick 1932

Area:

- General: Stone 1928
 Central and southeast Pennsylvania:
 Metcalf 1940b; Moore and Taylor
 1924

County:

- Adams and York: Stose and Stose
 1924
 Bedford, Blair, Carbon, Chester, Hunt-
 ington, Lancaster, and Montgomery:
 Wyer 1922
 Blair: Butts 1945
 Blair and Huntingdon: Ross 1919
 Lancaster: Stose and Jonas 1933

Sand.

Area:

- General: Bascom and others 1908
 Monongahela and Youghiogheny
 Rivers: Fettke 1918

County:

- Cleveland, Elk, Jefferson, and Venan-
 go: Am. Foundrymen's Assoc. 1925
 Fayette: Campbell 1902
 Fayette and Washington: Campbell
 1903
 Huntingdon: Weigel 1926
 Washington: Wyer 1922

Sandstone.

- General: Cleaves 1939; Frederick 1932
 Area, general: Stone 1928

Pennsylvania—Continued

Sandstone—Continued

County:

- Bedford, Blair, Carbon, Centre, Clear-
 field, Elk, Fayette, Forest, Hunting-
 don, Jefferson, McKean, Mifflin,
 Monroe, Venango, Warren, and
 Westmoreland: Fettke 1918
 Butler, Elk, Erie, Jefferson, Lycoming,
 Mercer, Mifflin, and Venango: Stone
 1925
 Clarion: Shaw and Munn 1911
 Clearfield, Elk, Fayette, Huntingdon,
 Jefferson, Lehigh, Mifflin, Venango,
 Warren, and Westmoreland: Wyer
 1922
 Clearfield, Jefferson, and Mercer: Am.
 Foundrymen's Assoc. 1925
 Fayette: Campbell 1902a, b; Hickok
 and Moyer 1940
 Huntingdon: Butts 1945; Krynine
 and others 1940
 Lancaster: Stose and Jonas 1933
 Westmoreland: Campbell 1904; Phalen
 1910

Tripoli.

- County, Lycoming: Metcalf 1949

Rhode Island.

Massive quartz.

- County, Providence: Quinn and others
 1948

Quartzite.

- County, Providence: Quinn and Seymour
 1948

South Carolina.

Massive quartz.

- Area, general: Jahns and Heinrich 1952
 Sand.
 Area, Coastal Plain: Buie 1949

South Dakota.

Massive quartz.

- Area, Black Hills: Page and others
 1953

Quartzite.

- Area, general: Beyer 1897

County:

- Davison, Hanson, McCook, Minnehaha,
 and Turner: Rothrock 1944
 Hanson, McCook, Minnehaha, and
 Turner: Baldwin 1949
 Minnehaha: Knapp 1923; Lowe 1926;
 Metcalf 1940b

Sandstone.

- Area, southeast Black Hills: Bryson and
 others 1947
 County, Fall River: Darton and Smith
 1904

Tennessee.

Chert.

County:

- Hardin: Jewell 1931
 Lawrence: Metcalf 1940b

Conglomerate.

- County, Franklin: Born 1936; Gilder-
 sleeve 1946c

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Tennessee—Continued

- Flint.
County, Wayne: Jewell 1931
- Sand.
County, Benton and Carroll: Whitlatch 1938
- Sandstone.
Area, Bays Mountain: Born 1936
- Silica.
Area, Chattanooga region: Whitlatch 1938
- Tripoli.
Area, Tennessee River Valley: Davis and Johnson 1938; Heinz 1937; Whitlatch 1938
- County:
Bradley: Gildersleeve 1946c
Bradley, Dickson, Greene, Hardin, Humphreys, Johnson, Lewis, Perry, and Wayne: Metcalf 1949
Bradley, Decatur, Dickson, Hardin, Humphreys, Johnson, Lewis, Perry, and Wayne: Whitlatch 1937
Bradley, Decatur, Dickson, Hickman, Johnson, and Wayne: Born 1936
Hardin: Jewell 1931
Hardin and Wayne: Gildersleeve 1946a; Spain 1936
Johnson: Glenn 1914

Texas.

- Flint.
Area, Coastal Plain: Evans 1943; Park-
inson and Barnes 1943
County, Bastrop, Frio, Llano, and
Travis: Stenzel and others 1948
- Massive quartz.
County:
Culberson and Hudspeth: Evans 1943
Llano: Chelf 1941
- Novaculite.
County, Brewster: Evans 1943
- Sand.
Area:
Coastal Plain: Hoeman and Redfield 1948
North-central Texas and Gulf Coastal
Plain: Kinney 1948
- County:
Lee: Harris 1941
Leon: Stenzel 1938
Mason: Plummer 1942
Polk: Evans 1943
Polk, Trinity, Tyler, and Walker:
Schafer 1942
- Sandstone.
County:
Leon: Stenzel 1938
Polk, San Jacinto, Trinity, and Walker:
Stenzel and others 1948
- Silica.
Area, general: Sellards and Evans 1943;
Sellards and others 1944
- Tripoli.
County, Burnet and Lampasas: Damon
1943; Evans 1943

Utah.

- Massive quartz.
County, Tooele: Hanley and others 1950
- Virginia.
Massive quartz.
Area, general: Jahns and Heinrich 1952
County, Amelia: Watson 1907
- Quartzite.
Area:
General: Whittemore and Dear 1940
Northern Virginia: Watson 1919
Western Virginia: Lowry 1954
- County:
Amherst: Watson 1919
Fairfax and Franklin: Watson 1907
Smyth and Wythe: Gildersleeve 1946b
Wythe: Stead and Stose 1943; Stose
1946
- Sand.
Area, Coastal Plain: Watson 1907
County, Princess Anne: Watson 1919
- Sandstone.
Area:
General: Watson 1919; Whittemore
and Dear 1940
Western Virginia: Lowry 1954
- County:
Amherst, Augusta, Roanoke, and
Rockbridge: Watson 1907
Frederick: Anonymous 1932
Roanoke: Woodward 1932
Russell, Scott, and Tazewell: Gilder-
sleeve 1946b
City, Waynesboro: Watson 1907
- Washington.
Massive quartz.
County:
Chelan, Pierce, Skagit, and Spokane:
Glover 1936
King, Pierce, and Spokane: Patty and
Glover 1921
Pierce, Skagit, Spokane, and Stevens:
Valentine 1949
Skagit: Popoff 1949
Spokane: Purdy 1953; Ralston 1937;
Anonymous 1953b
- Quartzite.
County:
King, Spokane and Stevens: Glover
1936
Pend Oreille: Purdy 1953
Stevens: Dorisy 1935; Ralston 1937
Stevens and Whitman: Valentine 1949
- Sand.
County:
Clark, King, and Stevens: Purdy 1953
King: Glover 1936
King, Spokane, and Stevens: Valentine
1949
Pend Oreille: Dorisy 1935
Spokane: Wilson and Zvanut 1936
- Sandstone.
Area, Olympic Mountains: Glover 1936
- County:
Chelan: Ralston 1937

- Washington—Continued
 Sandstone—Continued
 County—Continued
 Chelan, King, Pierce, Skagit and
 Whatcom: Wilson and others 1942
 Chelan, King, and Whatcom: Valentine
 1949
 Chelan, Kittitas, Pierce, Skagit, Ska-
 mania, and Whatcom: Glover 1936
 Spokane: Dorisy 1935
 Silica.
 Area, general: Hodge 1938
 County, Chelan and Skagit: Purdy 1953
 West Virginia.
 Sand.
 County, Morgan: Weigel 1926
 Sandstone.
 Area:
 General: Price 1938; Stow 1938
 Droop Mountain: Price 1929
 County:
 Berkeley, Jefferson, and Morgan:
 Grimsley 1916
 Morgan: Boswell 1917; Stose and
 Swartz 1912
 Morgan, Preston, Monongalia, and
 Upshur: Grimsley 1909
 Pocahontas: Price 1929
 Wisconsin.
 Conglomerate.
 County, Marathon, Portage, and Wood:
 Weidman, Samuel 1907
 Quartzite.
 General: Ross 1919
- Wisconsin—Continued
 Quartzite—Continued
 Area, general: Leith 1935
 County:
 Barron, Chippewa, Dodge, Jefferson,
 Juneau, and Sauk: Buckley 1898
 Columbia and Sauk: Weidman, Samuel
 1904
 Marathon and Wood: Weidman, Samuel
 1907
 Sand.
 County, Green Lake, Waushara, and
 Winnebago: Trainer 1928b
 Sandstone.
 Area, general: Buckley 1898; Thiel
 1935; Trainer 1928b
 County:
 Grant: Burchard 1906
 Marathon, Portage, Taylor and Wood:
 Weidman, Samuel 1907
 Marquette: Anonymous 1926b
 Wyoming.
 Massive quartz.
 County, Fremont and Goshen: Hanley
 and others 1950
 Sandstone.
 County:
 Albany and Big Horn: Clabaugh and
 others 1946
 Albany, Carbon, and Lander: Chicago
 and North Western Ry. Co. 1942
 Tripoli.
 County, Laramie and Platte: Chicago
 and North Western Ry. Co. 1942

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*References on geology, areal distribution,
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mining, utilization, reserves, and
potential resources*



UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1957

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

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CONTRIBUTIONS TO BIBLIOGRAPHY OF MINERAL RESOURCES

ANNOTATED BIBLIOGRAPHY OF HIGH-CALCIUM LIMESTONE DEPOSITS IN THE UNITED STATES INCLUDING ALASKA, TO APRIL 1956

by G. C. GAZDIK and KATHLEEN M. TAGG

ABSTRACT

This bibliography of 226 annotated references lists publications that appeared before May 1956. Annotations emphasize geology, areal distribution, results of chemical and physical tests on samples, mining, utilization, reserves, and potential resources of high-calcium limestone. The index forms a cross-reference system to the literature cited.

INTRODUCTION

Preparation of this bibliography was begun by the United States Geological Survey early in 1954 as the result of numerous requests for information concerning high-grade limestone. Most of the bibliography was compiled by the junior author between March 1954 and September 1955. The annotation was done by the senior author during the period September 1955–June 1956. New publications were added until May 1, 1956. Many of the references contain further bibliographic information. All references in this report are published and can be obtained either from or through any major library. Stratigraphic nomenclature used in the annotations is that of the original authors and is not necessarily that of the Geological Survey.

At present there is no universally accepted definition of high-calcium limestone. A calcium carbonate content greater than 95 percent seems to be the most generally used figure for high-calcium limestone, although many authors use a figure as high as 98 percent. In this bibliography, references to any limestone having a calcium carbonate content greater than 90 percent are included. It was thought that by so doing the bibliography would find a broader use because many large consumers of high-calcium limestone do not require an extremely

high degree of purity. A few references included describe limestones that just approach 90 percent calcium carbonate; these references are only for areas deficient in high-grade limestone.

The chemical composition of a limestone may change from one locality to another; consequently it would be presumptuous to assume that a formation known to be a high-calcium limestone in one locality is consistently a high-calcium limestone throughout its extent. For this reason, selection of references in this bibliography was restricted to those that in some way indicate that the formation discussed is of high calcium content in the locality studied.

The index provides a geographic cross reference system wherein separate lists of authors are given for each State and Alaska. A list at the beginning of the index under the heading, "General," refers to publications on limestone deposits throughout the States in general.

BIBLIOGRAPHY

Abbott, C. E., 1935, A limestone mine in the Birmingham district: Am. Inst. Min. Metall. Eng. Tech. Pub. 666, 15 p.

Describes mining of the Warsaw formation (Lower Mississippian) in the Muscoda mine of the Tennessee Coal, Iron and Railroad Company, near Bessemer, Jefferson County, Ala. Limestone is 40 to 50 feet thick and averages more than 98 percent calcium carbonate. Mining, crushing and washing, and safety procedures are noted. Summarizes geology and includes a mine map.

Adair, R. B., Doody, T. C., and Schoenborn, E. M., 1947, Evaluation of North Carolina raw materials for the production of portland cement, part 1, Preliminary laboratory investigation: N. C. State Coll., Dept. Eng. Research, Bull. 35, 31 p.

Describes physical and chemical tests of limestones and marls sampled chiefly along Trent and Deep Rivers. Rocks tested offer good possibilities as raw material for manufacture of portland cement. Tables and analyses are included.

Adams, G. I., Haworth, Erasmus, and Crane, W. R., 1904, Economic geology of the Iola quadrangle, Kansas: U. S. Geol. Survey Bull. 238, p. 11-20, 63-69.

The Fort Scott and Iola limestones (Pennsylvanian) are utilized for cement. Discusses cement manufacturing processes. Two geologic maps, Iola quadrangle, scale 1:125,000, and a strip to the east of Iola quadrangle, scale 1:125,000, are included.

Allen, H. W., 1953, Progress report of limestone survey, Knox County [Maine], in Report of the State Geologist for 1951-1952: Maine Devel. Comm., p. 11-30.

Describes geography of the Rockland, Rockport, and Union limestone belts. Discusses these areas, giving reserves and possible uses of deposits in each. Most important uses of Knox County limestones are in agriculture, in the chemical and cement industries, in manufacturing rock wool, and as a flux stone. The Union limestone belt, although small, is chiefly high-calcium limestone. Tables give limestone analyses of 40 samples from the Rockland belt, 27 from the Rockport belt, and a representative sample from the Union belt. A geologic map of each belt, at various scales, is included.

Allen, J. E., 1946, Reconnaissance geology of limestone deposits in the Willamette Valley, Oreg.: Oreg. Dept. Geology and Mineral Industries Short Paper 15, 15 p.

Summarizes geology and describes limestone deposits. Of 25 localities studied, 3 in Polk County and 1 in Clackamas County have commercial significance. Listed for these deposits are owner, location, development, topography, geology, grade and reserves. Includes a summary of characteristics and importance of formations arranged by counties, a bibliography, analyses, index map, and three geologic maps, at various scales.

Ames, J. A., 1949, High-calcium limestones in the area served by the Baltimore and Ohio Railroad: Baltimore, Baltimore and Ohio Railroad Co., 105 p.

Lists stratigraphic occurrences, areal distribution, and chemical composition of high-calcium limestones in New York, Ohio, Pennsylvania, Virginia, and West

Virginia. Appendices include a discussion of the origin of limestone, uses of high-calcium limestone, summary of the stratigraphy of the areas covered, and glossary of terms. A comprehensive bibliography, some analyses, and many geologic maps, at various scales, are included.

Anderson, A. L., 1928, Portland cement materials near Pocatello, Idaho: Idaho Bur. Mines and Geology Pamph. 28, 15 p.

Reviews topography, stratigraphy, and structure. Mentions the Black Rock and Langston limestones (Cambrian) as most economically feasible for cement material. Discusses three suitable quarry sites and summarizes factors controlling location of cement plants.

— 1931, Geology and mineral resources of eastern Cassia County, Idaho: Idaho Bur. Mines and Geology Bull. 14, 164 p.

Presents an extensive discussion of stratigraphy and structure. Summarizes topography, geologic history, mineralization, individual mines, and all types of building stones quarried in Cassia County. The section on limestone and marble includes 3 analyses of the Carboniferous limestones (Brazer and Wells formations) and 4 analyses of Precambrian marbles. All average more than 93 percent calcium carbonate. The Carboniferous limestones have not been utilized, but the Precambrian marble has been quarried for building stone and burned for lime. There is sufficient quality of these rocks to form a valuable potential resource. Analyses, structure sections, and a geologic map, scale 1:250,000, are included.

Argall, G. O., Jr., 1949, Industrial minerals of Colorado: Colo. School Mines Quart., v. 44. no. 2, p. 254-274.

Catalogues industrial nonmetallic minerals. Summarizes uses, occurrences, and production of each. Describes limestone operations in 23 counties. Discusses treatment and marketing of the limestone. Map, scale 1:500,000, shows construction materials and nonmetallic mineral resources of Colorado.

Bain, H. F. See Eckel, 1905.

Baldwin, E. M., 1947, Geology of the Dallas and Valsetz quadrangles: Oreg. Dept. Geology and Mineral Industries Bull. 35, 61 p.

Dallas and Valsetz quadrangles are chiefly within Polk County with western edges in Lincoln County. Discusses geography, topography, stratigraphy, structure, physical geology, geologic history, and economics. Describes the Dallas limestone (basal member of the Umpqua formation, Middle Eocene), its characteristics and uses. Also lists other limestones, their locations and calcium carbonate content. A bibliography, index map, and geologic maps of Dallas and Valsetz quadrangles, scale 1:62,500, are included.

Ball, E. M., and Beck, A. W., 1937, Limestone mining in Muscoda No. 5—A unique underground operation in the Birmingham district: Eng. Min. Jour., v. 138, no. 12, p. 32-36.

Describes history and development of mine in the Warsaw formation (Mississippian), including mining methods and hauling. The limestone is 130 feet thick and is 330 feet above the Clinton iron ore. Cross section of mine and diagrams of methods used are included.

Ball, J. R., 1952, Geology and mineral resources of the Carlinville quadrangle: Ill. Geol. Survey Bull. 77, 110 p.

Résumé of physiography, stratigraphy, structure, geologic history, and economic geology. Describes cores and field sections. At most places limestones in the

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Carlville quadrangle are less than 10 feet thick and not suitable for large-scale commercial operation. Analyses and geologic map, scale 1:62,500, are included.

Banks, D. M. See Bowles, 1933, 1941.

Barnes, V. E., 1952, High purity Marble Falls limestone, Burnet County, Tex.: Tex. Univ., Bur. Econ. Geology Rept. Inv. 17, 27 p.

Describes stratigraphy and areal distribution of the Marble Falls limestone (Pennsylvania), which has a calcium carbonate content greater than 99 percent in this area, and the Honeycut formation (Ordovician), which may be of economic value. Includes detailed description of the type section of the Marble Falls limestone, table of analyses, and two geologic maps, scale 4 inches = 1 mile.

Bascom, Florence, and Stose, G. W., 1938, Geology and mineral resources of the Honeybrook and Phoenixville quadrangles, Pennsylvania: U. S. Geol. Survey Bull. 891, p. 106-110.

Summarizes geography, topography, stratigraphy, structural and historical geology, and mineral resources. Gives location of limestone quarries in Chester County. Colored geologic map and structure sections of Honeybrook and Phoenixville quadrangles, scale 1:62,500, are included. [Many other geologic maps, at various scales, and structure sections are included.]

Bassler, R. S., 1905, Cement materials of the Valley of Virginia: U. S. Geol. Survey Bull. 260, p. 531-544.

Presents information on general geology and suitability of various limestone beds in the Valley of Virginia for commercial use. Locations of favorable sites for cement plants are given. Analyses of samples from Augusta, Rockbridge, Rockingham, and Shenandoah Counties and geologic maps, scale 1 inch = about 10 miles, are included.

——— 1908, Cement materials of western Virginia: Econ. Geology, v. 3, p. 503-524.

Almost all cement materials of western Virginia are confined to outcrops in the Valley of Virginia and surrounding foothills. Most important source rocks for cement materials are of Cambrian and Ordovician age. Cross sections, analyses, and small-scale map showing outcrop of Ordovician limestones and shales are included.

——— 1909, The cement resources of Virginia west of the Blue Ridge: Va. Geol. Survey Bull. 2-A, 309 p.

Discusses general geology, stratigraphy, and cement materials by individual county in western Virginia. E. C. Eckel contributed the chapter on materials and processes used in production of hydraulic cements. Fossil illustrations, analyses, and many geologic maps and cross sections, at various scales, are included.

Bastin, E. S., 1906, The lime industry of Knox County, Maine: U. S. Geol. Survey Bull. 285-J, p. 393-400.

Knox County has the only limestone in Maine that is suitable for the production of lime. Describes physical features and occurrence of the limestone. Locates adjacent dolomite deposits. The limestone from a quarry at Rockland has a calcium carbonate content of 98.17 percent. Seven analyses and two small-scale geologic maps are included.

Bates, R. L., 1939, Geology of Powell Valley in northeastern Lee County, Va.: Va. Geol. Survey Bull. 51-B, p. 31-94.

Gives detailed information on stratigraphy and structure. Geography, physiography, and mineral resources are noted. The limestone of the area is used chiefly as agricultural lime or road metal. Some is of sufficiently high quality for use as a

flux material or for calcining, but it is not so accessible as similar deposits elsewhere. The Mosheim and Lenoir limestones have the highest calcium carbonate content, 93.12 percent. Three analyses, structural cross section across Powell Valley, and structural and geologic maps, at various scales, are included.

Beach, J. O. *See* English, 1940.

Beatty, K. O., and Adair, R. B., 1948, Evaluation of North Carolina raw materials for the production of portland cement, part 2, Small-scale production of portland cement: N. C. State Coll. Eng. School Bull. 42, 51 p.

Briefly reviews laboratory investigations reported in part 1 of this paper. Both high- and low-grade limestone of the Trent formation was used to produce cement, thus proving that, with proper treatment, cement can be made from low-grade limestone. Discusses purification methods. Gives location of other cement raw materials. Describes preparation and physical properties of cement. Report concludes that North Carolina has suitable raw materials for cement. The most promising area is southern Jones and Craven Counties in the vicinity of the Trent River. Analyses and small-scale map showing outcrop of Trent limestone and Triassic shale are included.

Beck, A. W. *See* Ball, 1937.

Bengston, R. J., and others, 1950, Survey report on mineral resources of southeastern Ohio to the southeastern Ohio Regional Council: Ohio Dept. Nat. Res., Div. Geol. Survey, p. 44-57.

Limestones of southeast Ohio are used chiefly as road metal and for portland cement. The Vanport (Pennsylvanian) and the Maxville (Mississippian) limestones have been utilized in the Ohillco area for portland cement. The Maxville is a high-calcium limestone, its composition and thickness vary, and its occurrence is spotty. The Vanport limestone is more persistent and of more uniform composition although only about 10 to 12 feet thick. Reserves and future uses of available limestone are discussed. Includes two sketch maps of southeast Ohio, one showing the known occurrences of the Maxville, the other showing the occurrences of the Vanport, Brush Creek, and Cambridge limestones and some dolomites; production figures, costs and prices, uses and markets; and analyses of Vanport and Maxville limestones.

Berry, E. W. *See also* Loughlin, 1921.

——— 1947, Marls and limestones of eastern North Carolina: N. C. Dept. Conserv. Devel., Div. Min. Res. Bull. 54, 16 p.

Discusses physiography, location of outcrops, and commercial development of marls and limestones for each of the 35 counties in eastern North Carolina. Marls of the New Bern and Wilmington area are described separately because of their persistence and higher grade. Includes analyses of limestones of many counties, 20 partial analyses from New Bern area, and geologic map, scale 1 inch = 10 miles.

Beyer, S. W., 1906, Supplementary report on portland cement materials in Iowa: Iowa Geol. Survey Bull. 3, 36 p.

Discusses limestones of Iowa. Includes analyses of major formations and sketch map of Iowa showing chief localities investigated for portland cement materials.

Blatchley, R. S., 1908, The Indiana oolitic limestone industry in 1907: Ind. Dept. Geology and Nat. Res., Ann. Rept. 32, p. 301-459.

Concerns limestone in Owen, Monroe, and Lawrence Counties. Includes topography, stratigraphy, physical characteristics, and properties of the limestone. Quarrying and handling methods are discussed and individual quarries are described. Also included are a list of quarries, active and inactive, and their locations;

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19 chemical analyses; and geologic maps of Bedford and Bloomington districts, scale 1 inch = 2 miles.

Bleining, A. V., 1904, The manufacture of hydraulic cements: Ohio Geol. Survey, 4th ser., Bull. 3, 391 p.

The report is concerned chiefly with the manufacture of hydraulic cements. However, one chapter reviews the available limestones of Ohio and another chapter describes methods of determining the value of a deposit. Four pages of chemical analyses are included.

Bleining, A. V., Lines, E. F., and Layman, F. E., 1912, Portland cement resources of Illinois: Ill. Geol. Survey Bull. 17, 121 p.

Discusses portland cement materials including impurities and their effects. Roughly half of the report deals with mechanics of the manufacture of portland cement. Describes the stratigraphy of Illinois with special reference to portland cement materials. More than 100 analyses and locations of limestones and many clays are given.

Boucher, L. J., 1930, Limestone quarrying at Northampton plant of the Atlas Portland Cement Co.: Am. Inst. Min. Metall. Eng. Tech. Pub. 272, 19 p.

The cement rock of the Lehigh district of Pennsylvania and New Jersey is from the Jackson series of the Trenton limestone. Its composition is variable and its thickness is from 150 to 300 feet. The Atlas cement plant at Northampton, Pa., is the largest in the world (1930). The article is chiefly concerned with describing the mining procedures at the cement plant's quarry.

Bowen, O. E., Jr., 1950, Lime and limestone, in Mineral commodities of California: Calif. Dept. Nat. Res., Div. Mines Bull. 156, p. 171-176.

The portland cement industry is the most important consumer of limestone in California. Bulletin discusses local limestones used in portland cement, their formation, and distribution and lists the important limestones from each district. Summarizes mining and manufacturing methods, utilization, and markets.

Bowles, Oliver, and Banks, D. M., 1933, Limestone, part 1, General information: U. S. Bur. Mines Inf. Circ. 6723, 21 p.

Reports in general on the uses of limestone, considers many of the uses of high-calcium limestone, and gives production and consumption statistics.

——— 1941, Lime: U. S. Bur. Mines Inf. Circ. 6884R, 48 p.

Presents a history of the use of limestone, its origin, composition, and varieties. Gives location of major limestone areas in the United States and describes many uses for high-calcium limestone. Includes statistics, economics of plant location, and grades of lime produced in selected counties of each producing State. Outlines manufacturing processes.

Boynton, R. S., and Jander, F. K., 1952, Lime and limestone, in Encyclopedia of chemical technology: New York, The Interscience Encyclopedia, Inc., v. 8, p. 346-382.

Describes physical characteristics and chemical behavior of limestone. Includes distribution, origin, mining, quarrying, manufacturing methods, and economics of the limestone industry. Analyses from 16 typical areas of high calcium rocks and small-scale map of the United States showing the occurrence of high-calcium limestone and dolomite are included.

Branner, G. C., 1940, Mineral resources of Benton, Carroll, Madison, and Washington Counties [Ark.]: Ark. Geol. Survey, County Mineral Rept. 2, p. 33-36.

Limestones in Benton, Carroll, Madison, and Washington Counties are used as building stones, road metal, limestone for burning, and agricultural lime. Of 30

analyses, including samples from the Boone, Brentwood, and Pitkin formations, 21 samples contain more than 95 percent calcium carbonate. Map showing location of samples is included.

Branner, G. C., 1941, Limestones of northern Arkansas: Ark. Geol. Survey Pub., 24 p.

Limestones are restricted to northern Arkansas in the Interior Highlands physiographic province. They range in age from Ordovician to Pennsylvanian. Discusses reserves and value from 1889 to 1939. Lists limestone companies and quarries. Includes analyses and locations of 114 limestone samples and small-scale maps.

Brantly, J. E., 1916, Limestones and marls of the Coastal Plain of Georgia: Ga. Geol. Survey Bull. 21, 300 p.

Presents a comprehensive report on physiography, structure, and stratigraphy of the Coastal Plain deposits. About half of the text is devoted to discussions of calcareous deposits considered by county. Included are history of workings, analyses, and future possibilities. Also includes information on quarrying, preparation, and use of limestone. Many analyses and geologic map of the Coastal Plain of Georgia with locations of limestone properties, scale 1:1,000,000, are included.

Bryson, R. P., Fox, E. L., Larrabee, D. M., and others, 1947, Construction materials and nonmetallic mineral resources of South Dakota: U. S. Geol. Survey Missouri Basin Studies Map 12, scale 1:500,000.

Includes information on an outcrop of Niobrara formation (Cretaceous) that has been used for cement manufacture at Yankton.

Buddington, A. F., 1926, Mineral investigations in southeastern Alaska: U. S. Geol. Survey Bull. 783-B, p. 58-62.

Contains a short discussion on the readily accessible high-calcium limestone occurring in thick and extensive deposits on the islands off the west coast of Alaska and at the north end of Prince of Wales Island. In these areas, the Silurian limestones have the highest calcium carbonate content, ranging from 95 to 99 percent. Many deposits are discussed and 20 analyses are included.

Buddington, A. F., and Chapin, Theodore, 1929, Geology and mineral deposits of southeastern Alaska: U. S. Geol. Survey Bull. 800, p. 44, 83-88, 390-393.

Describes outcrops of important limestone beds and their physical characteristics. In 1928 the Pacific Coast Cement Co.'s newly installed plant at Seattle initiated the use of a limestone quarried at Dall Island, Alaska. The calcium carbonate content averaged between 95-99 percent.

Buehler, H. A., 1907, The lime and cement resources of Missouri: Mo. Bur. Geology and Mines, 2d ser., v. 6, 255 p.

Presents a general discussion about limestone and clay. Methods given for manufacturing lime and portland, natural, and pozzolean cements, also specifications for various uses of cement and concrete. County-by-county discussions of the lime and cement materials of Missouri including chemical analyses and the amount and type of development in each county. Seven pages of analyses are included.

Burchard, E. F., 1912, Lime, in Mineral Resources of the United States for 1911, part 2, Nonmetals: U. S. Geol. Survey, p. 645-718.

Includes 50 pages of analyses from nearly every State.

——— 1940, The cement industry in Alabama: Ala. Geol. Survey Circ. 14, 32 p.

Mentions use of Chickamauga, Bangor, Conasauga, and St. Stevens limestones and the Selma chalk as cement materials. Discusses cement plants, their raw materials,

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processes, and production. A few analyses and a map showing areas of high-calcium limestone in Alabama, with portland and puzzolan cement plants located, are included.

Burchard, E. F. and Chapin, Theodore, 1920, Marble resources of southeastern Alaska: U. S. Geol. Survey Bull. 682, 118 p.

This bulletin is primarily concerned with marble suitable for cutting and polishing but many analyses are included which show calcium carbonate as high as 99 percent. Quarries and prospects are located and described. Sketch maps show the location of these deposits.

Burchard, E. F., and Emley, W. E., 1914, The source, manufacture, and use of lime, in *Mineral Resources of the United States for 1913*, part 2, Nonmetals: U. S. Geol. Survey, p. 1509-1593.

Includes small-scale map of Eastern United States showing distribution of high-calcium limestone.

Burr, A. C., Fallgatter, W. S., and MacMillan, W. W., 1950, Raw materials for the manufacture of portland cement in North Dakota: *N. Dak. Acad. Sci. Proc.* 1949, v. 3, p. 15-18.

Reports on feasibility of a cement plant in North Dakota. Discusses Niobrara formation and marl deposits. Concludes that the Colgrove Butte deposits are most favorable. Gives cost statistics.

Butts, Charles, 1907, Limestone and dolomite in the Birmingham district, Alabama: U. S. Geol. Survey. Bull. 315-G, p. 247-255.

The Bangor, Chickamauga, and Conasauga limestones and the Knox dolomite are used for flux stone, and in the manufacture of lime and cement. The Chickamauga (Ordovician) is the limestone used locally in the cement industry. Notes occurrences and includes lithologic sections and a few analyses.

——— 1940, Description of the Montevallo-Columbiana quadrangles, Alabama: U. S. Geol. Survey Geol. Atlas, folio 226, 20 p.

Includes 7 analyses of Newala limestone, which is used for cement manufacture at Leeds, Ala. Geologic and topographic quadrangle maps, scale 1:62,500, are included.

Butts, Charles, and Gildersleeve, Benjamin, 1948, Geology and mineral resources of the Paleozoic area in northwest Georgia: *Ga. Geol. Survey Bull.* 54, p. 127-137.

Report briefly describes the Paleozoic limestones and dolomites that occur throughout northwest Georgia. Analyses of 21 limestones with descriptions of sample locations are given.

Butts, Charles, and Moore, E. S., 1936, Geology and mineral resources of the Bellefonte quadrangle, Pennsylvania: U. S. Geol. Survey Bull. 855, 111 p.

Much high-calcium limestone occurs in this quadrangle. No cement plants have been built, probably because of the lack of adjacent shale beds. Includes a few analyses and a geologic map of the quadrangle, scale 1:62,500.

Butts, Charles, Swartz, F. M., and Willard, Bradford, 1939, Geology and mineral resources, Tyrone quadrangle [Pennsylvania]: *Pa. Geol. Survey*, 4th ser., *Topog. and Geol. Atlas* 96, 110 p.

Limestone is the most important mineral resource. The Lowville (Ordovician) is the highest quality limestone in the area. Publication includes analyses for many Ordovician limestones in the quadrangle; geologic and topographic maps, scale 1:62,500; and geologic structure sections.

Cady, G. H., 1907, Cement making materials in the vicinity of La Salle, in Year-Book for 1907: Ill. Geol. Survey Bull. 8, p. 127-184.

Both natural and portland cement are manufactured in the vicinity of La Salle, Ill. Natural cement is made from the Lower Magnesian limestone and portland cement from the La Salle limestone and the carbonaceous shale underlying it. The article describes thickness and outcrops of these formations. Includes analyses of 7 natural cement rock samples, 21 portland cement rock samples, and 3 clays; also small-scale map showing outcrop of cement formations and location of plants.

Calhoun, F. H. H., 1915, Limestone and marl deposits of South Carolina: S. C. Expt. Sta., Clemson Agr. Coll. Bull. 183, 27 p.

Discusses briefly limestone and its use in agriculture. Possible quarry sites are listed. Forty-four analyses of limestones and marls, a few showing high calcium content, and a small-scale map showing location of limestone and marl are included.

Calhoun, W. A. See Hinchley, 1947.

Catlett, Charles, 1904, Cement resources of the Valley of Virginia: U. S. Geol. Survey Bull. 225, p. 457-462.

The Trenton limestone, famous as the cement rock of the Lehigh Valley of Pennsylvania, is well developed throughout the Valley of Virginia. Two other raw materials also necessary in the manufacture of portland cement are readily available; namely, shale (Hudson) and coal which is used as a fuel. Includes discussion of the limestones and economic factors of the most promising undeveloped locations and analyses of samples from many of these places.

Chapin, Theodore. See Buddington, 1929.

Clabaugh, S. E., Larrabee, D. M., Griffiths, W. R., and others, 1946, Construction materials and nonmetallic mineral resources of Wyoming: U. S. Geol. Survey Missouri Basin Studies Map 9, scale 1:500,000.

High-calcium limestones suitable for cement manufacture occur in the Niobrara, Forelle, Greenhorn, and Sundance formations and in some calcareous Tertiary sediments.

Clapp, F. G., 1905, Limestones of southwestern Pennsylvania: U. S. Geol. Survey Bull. 249, 52 p.

Describes each of the important limestones of southwestern Pennsylvania from the Pocono formation (Mississippian) through the Dunkard series (Permian). The Vanport and Upper Freeport limestones are of sufficiently high quality for cement. Includes a geologic map of southwestern Pennsylvania, scale 1 inch = 20 miles; two maps of the outcrop pattern of the Vanport limestone, scale 1 inch = 10 miles; and many analyses.

Clark, W. B., 1954, The Cool-Cave Valley limestone deposits, El Dorado and Placer Counties, Calif.: Calif. Jour. Mines and Geology, v. 50, p. 439-465.

The Cool-Cave Valley limestone, discussed in this report, consists of two lenses in the Calaveras group (Paleozoic). The limestone was used in the manufacture of portland cement from 1910 to 1942 and was the chief source of limestone in northern California from 1910 to 1930. It is uniformly high in calcium, much averaging about 98 percent calcium carbonate. Geology of the limestone and also quarrying and milling methods are discussed. Gives ownerships for other limestone deposits together with literature references, analyses of 45 samples from the Cool-Cave Valley limestone, and many analyses from other nearby limestones. Includes

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geologic maps showing the Cool-Cave Valley limestone: scale approximately 1 inch = 3,000 feet.

Cobb, E. H. See Moxham, 1953.

Cook, C. W., 1912, Michigan cement, in *Mineral resources of Michigan* * * *: Mich. Geol. Biol. Survey, Pub. 8, Geol. Ser. 6, p. 337-354.

Gives classification of cements and location of raw materials. Only the Traverse and the Michigan limestones are used for cement. Includes list of plants, analyses of 4 limestones and 5 marls, one map showing location of cement plants.

Cooke, C. W., 1945, *Geology of Florida*: Fla. Geol. Survey Bull. 29, p. 111-136.

Mention is made of high calcium content of the Ocala limestone (Eocene) and the Mariana and Suwannee limestones (Oligocene). These formations are shown on the accompanying map of Florida, scale 1:1,000,000.

Cooper, B. N., 1944, Industrial limestones and dolomites in Virginia, New River-Roanoke River district: Va. Geol. Survey Bull. 62, 98 p.

Presents a general discussion of physiography and stratigraphy followed by detailed descriptions of areas with respect to structure, operating quarries, and possible sites for new quarries. Also included are lithologic sections and maps showing occurrences of limestone and dolomite, active quarries and possible quarry locations, and analyses of 89 samples.

— 1945, Industrial limestones and dolomites in Virginia, Clinch Valley district: Va. Geol. Survey Bull. 66, 259 p.

Considering the quality of the available rock, quarrying conditions, and cost of fuel, the cost of producing lime in Clinch Valley is less than in any other section of the Appalachian Valley of Virginia. General geology of Clinch Valley district precedes detailed discussion of geology and stratigraphy by county. Includes many analyses, lithologic sections, and maps, including geologic maps of the three counties in the district. The scales of the county maps range from 1 inch = 1½ miles to 1 inch = 2 miles.

Cooper, B. N., and Dietrich, R. V., 1953, Virginia mineral resources [map]: Va. Eng. Expt. Sta., Va. Poly. Inst., scale 1:500,000.

Shows areas in State that are directly underlain by limestone and dolomite; limestones and dolomites of chemical grade are designated.

Crider, A. F., 1905, Cement resources of northeast Mississippi: U. S. Geol. Survey Bull. 260, p. 510-521.

Selma Chalk is a high-quality cement material. Some well logs and analyses are given.

— 1907, Cement and portland cement materials of Mississippi: Miss. Geol. Survey Bull. 1, 73 p.

Gives a general history of cement and lists cement materials and manufacturing methods. Formations ranging from Devonian to Tertiary in age are discussed. The Selma Chalk (Cretaceous), Jackson marl (Eocene), and Vicksburg formation (Oligocene) are discussed in detail. Analyses are given.

Crump, M. H., 1913, The oolitic limestones of Warren County [Ky.]: Ky. Geol. Survey, 4th ser., v. 1, pt. 2, p. 1037-1051.

Oolitic limestones occur in the Mississippian, immediately below the Chester formation. They are used chiefly as a building stone, but would make a good stainless portland cement. Lists quarrying companies, their holdings and production; and describes their products. Two analyses are given.

Cullen, John, 1917, Lime resources and industry in Oklahoma: Okla. Geol. Survey Bull. 26, 70 p.

Discusses the composition and uses of lime and also the types and uses of cements. Methods of quarrying and milling limestone are described. The limestones of Oklahoma range in age from Cambrian to Cretaceous. Each limestone formation is discussed with respect to distribution, thickness, location of quarries, and, where available, chemical analyses. A history of the Oklahoma lime industry and small-scale map showing limestone areas in the State are included.

Cushman, J. A. See Loughlin, 1921.

Dale, T. N., 1914, The commercial marbles of western Vermont: Vt. State Geologist Rept. 9, for 1913-1914, p. 1-160.

Section summarizes physical properties, origin, and areal distribution. Structure is described and accompanied by cross sections. Both mineralogic and commercial types of marbles are noted. Important quarries are discussed. Includes five analyses and geologic maps of the marble belts of western Vermont, south of Salisbury, scale 1:125,000, and of the Rutland marble belt, scale 1:31,250.

——— 1923, The lime belt of Massachusetts and parts of eastern New York and western Connecticut: U. S. Geol. Survey Bull. 744, 71 p.

Describes, by quadrangle, the limestone and dolomite formations and notes their outcrops. Discusses those suitable for a good grade of finishing lime, those that yield a poorer quality, and those rejected by the lime industry. Four geologic maps distinguishing limestone from dolomite, scale 1:62,500, are included.

Darton, N. H., 1909, Structural materials in parts of Oregon and Washington: U. S. Geol. Survey Bull. 387, p. 21-33.

Report discusses, by county, limestones and marbles suitable for cement. The majority of these are very high in calcium. Some of these deposits occur adjacent to natural harbors which make ocean transportation readily available. Includes analyses and map showing distribution of limestone in Washington and Oregon, scale 1 inch = about 75 miles.

——— 1910, Cement materials in Republican Valley, Nebr.: U. S. Geol. Survey Bull. 430-F, p. 381-387.

The only limestones suitable for cement in the Republican Valley are those of the Niobrara formation. They occur at or near the surface in Webster, Franklin, Harlan, and Furnace Counties. Includes four analyses and map showing outcrop of Niobrara formation, scale 1 inch = about 30 miles.

Decker, C. E., and Merritt, C. A., 1928, Physical characteristics of the Arbuckle limestone: Okla. Geol. Survey Circ. 15, 56 p.

Describes geology of the Arbuckle formation and gives detailed lithologic section 12 miles north of Ardmore, Carter County. One bed, more than 43 feet thick, averages 98 percent calcium carbonate, and another, about 143 feet thick, averages 96 percent. The remainder of this 7,442-foot section is low in calcium.

DeWolf, F. W., 1929, New Castle quadrangle, Topographic and geologic atlas of Pennsylvania, no. 5: Pa. Geol. Survey, 4th ser., p. 169-188.

Describes the Vanport limestone as a valuable resource used for road material, flux stone, sinter stone, cement, and lime. Uniform in both thickness and purity, it commonly occurs in several distinct benches: the bottom two, a total of from 5 to 10 feet, are the high-calcium limestones, averaging about 96 percent calcium carbonate. Individual exposures are described. Includes analyses and map of the

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New Castle quadrangle showing outcrop pattern of the Vanport limestone, scale 1 : 62,500.

Dietrich, R. V. *See* Cooper, 1953.

Diller, J. S., 1904, Mining and mineral resources in the Redding quadrangle, California, in 1903: U. S. Geol. Survey Bull. 225, p. 176-177.

States that the McCloud and Hosselkus limestones are high in calcium. Parts of the Hosselkus limestone could be used for portland cement.

——— 1914, Mineral resources of southwestern Oregon: U. S. Geol. Survey Bull. 546, p. 15-17.

Gives the distribution and age of local limestones. Includes 10 analyses from Josephine and Jackson Counties, Oreg., many showing very high calcium content, and map showing limestone outcrops, scale 1 inch = 5 miles.

D'Inwilliers, E. V., 1883, The geology of the South Mountain belt of Berks County [Pa.]: Pa. 2d Geol. Survey Progress Rept., D-3, v. 2, pt. 1, p. 136-197.

Notes the distribution and uses of those limestones of the Great Valley that occur in Berks County. Includes short descriptions of the limestone exposures giving physical characteristics, thickness, and dip; analyses; and maps, at various scales, supplementing this report in Pennsylvania Geological Survey Atlas D-3.

Doody, T. C. *See* Adair, 1947.

Dott, R. H. *See* English, 1940; 1943.

Dubins, I. M. *See* Runnels, 1949.

Eardley, A. J., 1932, A limestone chiefly of algal origin in the Wasatch conglomerate, southern Wasatch Mountains, Utah: Mich. Acad. Sci. Papers, v. 16, p. 399-414.

Describes a very small fresh-water lake deposit. The limestone is almost 100 percent calcium carbonate, and has been used as an interior decoration. Small-scale map of Utah showing the location of this deposit is included.

Eckart, R. A. *See* Moxham, 1953.

Eckel, E. C., 1904, Cement-rock deposits of the Lehigh district of Pennsylvania and New Jersey: U. S. Geol. Survey Bull. 225, p. 448-456.

Lists the Hudson shale and Trenton and Kittatinny limestones of the Lehigh district as cement resources. Notes the distribution of each of these formations. Discusses manufacturing processes and composition of portland cement. Gives analyses.

——— 1905a, Cement materials and industry of the United States: U. S. Geol. Survey Bull. 243, 395 p.

The bulletin is divided into two parts. Part 1, "Materials and manufacture of portland cement," is concerned with composition of portland cement, composition and characteristics of cement raw materials, mining methods, and manufacturing processes. Part 2, "Portland cement resources of the United States" includes sections by E. C. Eckel, E. A. Smith, J. A. Taff, H. F. Bain, W. H. Weed, E. O. Ulrich, and R. S. Bassler. The States are taken up in alphabetical order and cement resources, both developed and undeveloped, are located and described. The cement industry of each State is noted. Analyses and maps are included.

——— 1905b, Portland-cement resources of New York: U. S. Geol. Survey Bull. 260, p. 522-530.

Notes the Chazy, Trenton, Helderberg, Onondaga, and Tully limestones and marls of Quaternary age as being of such quantity and chemical composition to be

important as portland cement materials. Includes chemical analyses of each of the above formations, their distribution, and relative usefulness as regards composition and location.

Eckel, E. C., 1906, Cement resources of the Cumberland Gap district, Tennessee-Virginia: U. S. Geol. Survey Bull. 285-I, p. 374-376.

Mentions the Newman limestone (Mississippian) as being high in calcium and suitable for portland cement. Notes the proximity of rail transportation and the Middlesboro coal district for manufacture of the cement. Includes some analyses.

——— 1913, Portland cement materials and industry in the United States: U. S. Geol. Survey Bull. 522, 401 p.

Bulletin divided into three parts. Parts one and two are written entirely by Eckel. Part one, "The portland cement industry," reviews types of cements, discusses their history, and gives cement industry statistics. Part two, "Raw materials of the portland cement industry," covers cement materials, elaborating on limestone, its composition and impurities. It lists the types of limestone and the types of fuels used. A section is devoted to factors to be considered when building a cement plant. The third part of this bulletin, entitled, "Portland cement resources of the United States," has chapters contributed by E. C. Eckel, E. F. Burchard, A. F. Crider, G. B. Richardson, E. A. Smith, J. A. Taff, E. O. Ulrich, and W. H. Weed. This part of the bulletin discusses, for each State, general geology, known and possible cement raw materials, and their distribution. Many analyses and maps are included.

——— 1933, Limestone deposits of the San Francisco region: Calif. Jour. Mines and Geology, v. 29, p. 348-361.

The Gavilan limestone of the Santa Lucia series (Paleozoic?) and the Calera limestone of the Franciscan series (Jurassic) are two limestones of this area of major interest as industrial stones. There are several others of less importance. Distribution is discussed and some outcrops and quarries described. Analyses of 31 samples are given.

——— 1935, Large high-calcium deposit found in northwestern Alabama: Pit and Quarry, v. 27, no. 9, p. 26.

Deposit in area near Muscle Shoals discovered and bought by Tennessee Valley Authority. Article states that the deposit may be the largest and purest limestone in the country. Includes 11 analyses; all show more than 98 percent calcium carbonate.

Eckel, E. C., and Bain, H. F., 1905, Cement and cement materials of Iowa, in Ann. Rept. for 1904: Iowa Geol. Survey, v. 15, p. 102-124.

High-calcium limestone occurs throughout Iowa in the following formations: Trenton limestone (Ordovician), Kinderhook limestone, Augusta formation, and St. Louis limestone (Mississippian). Analyses are given.

Edmundson, R. S., 1945, Industrial limestones and dolomites in Virginia—northern and central parts of Shenandoah Valley: Va. Geol. Survey Bull. 65, 195, p.

Emphasis is on the occurrence of high-calcium limestone and high-magnesian dolomite in the northern and central sections of the Valley of Virginia. Geology of the Valley of Virginia is discussed, but most of the report deals with industrial limestones; starting with the northernmost county of the Valley and working southward. Includes, for each of the nine counties, geology and stratigraphy of the local limestones with special attention to high calcium and high magnesium content. Uses

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of high-calcium limestones are listed. Also includes many lithologic sections, some structure sections, a geologic map of each county and analyses.

Emley, W. E. *See* Burchard, 1914.

English, S. G., Dott, R. H., and Beach, J. O., 1940, Limestone analyses: Okla. Geol. Survey Mineral Rept. 5, 28 p.

Includes brief description of chief limestone areas in the State, general information on the importance of limestone in the chemical industry, and list of chemical specifications for limestone in various products. Table 1 lists, by county, limestone analyses with calcium carbonate content greater than 95 percent. Table 2 lists analyses of limestones with combined calcium and magnesium content greater than 90 percent, but magnesium content less than 10 percent. Map, scale 1 inch = about 50 miles, shows principal limestone outcrops and indicates those of commercial thickness and quality.

Fisher, R. B. *See* Hinchey, 1947.

Galloway, J. J., 1919, Geology and natural resources of Rutherford County [Tenn.]: Tenn. Div. Geology Bull. 22, p. 75, 81.

Formerly the Hermitage limestone was used for making a natural hydraulic cement, but its distance from fuel and transportation now makes it of little economic importance. Six analyses (p. 81) of the Lebanon, Ridley, and Murfreesboro limestones show high calcium content. Geologic map of Rutherford County, scale 1 inch = 1 mile, is included.

Gay, T. E., Jr. *See* Wright, 1953.

Gildersleeve, Benjamin. *See also* Butts, 1948.

— 1946a, Minerals and structural materials of the Kentucky Reservoir area: TVA, Commerce Dept., Regional Products Research Div., Rept. 1, p. 13-16.

Principal limestones occur east of the Tennessee River. Notes the Warsaw-St. Louis formations (Mississippian) and some Silurian formations as having a high calcium content. Includes 10 analyses, geologic map, and a map indicating the locations of minerals and structural materials in the Kentucky Reservoir area (scale 1 in. = about 16 mi.).

— 1946b, Minerals and structural materials of the Pickwick, Wilson, and Wheeler reservoir areas: TVA, Commerce Dept., Regional Products Research Div., Rept. 2, p. 27-28.

Most of the limestones in the area have a high calcium content. Gives three analyses of limestones, two exceed 98 percent calcium carbonate. Geologic map, scale 1 inch = 7½ miles is included.

— 1946c, Minerals and structural materials of the Guntersville Reservoir area: TVA, Commerce Dept., Regional Products Research Div., Rept. 3, p. 14-16.

High-calcium limestones (Mississippian) underlie the sandstone and shale formations of Sand Mountain and other erosional remnants of the Cumberland Plateau. Includes limestone analyses from Marshall and Jackson Counties, Ala., and Marion County, Tenn., and a map, scale 1 inch = 4 miles.

— 1946d, Minerals and structural materials of the Hales Bar and Chickamauga reservoir areas: TVA, Commerce Dept., Regional Products Research Div., Rept. 4, p. 43.

High-calcium Mississippian limestones occur in outliers of the Cumberland Plateau. Limestones in this area are quarried for the lime, chemical, and cement industries and for other uses. Map, scale 1 inch = about 9½ miles, is included.

Gildersleeve, Benjamin, 1946e, Minerals and structural materials of southwest Virginia: TVA, Commerce Dept., Regional Products Research Div., Rept. A, p. 29-31.

Notes the Mosheim, Lenoir, and Holston limestones as being high grade. The Mosheim, in places, is nearly 100 percent calcium carbonate.

——— 1946f, Minerals and structural materials of east Tennessee: TVA, Commerce Dept., Regional Products Research Div., Rept. B, p. 19-20.

High-calcium limestones are found in the Mississippian rocks of the Cumberland Plateau and in the Ordovician rocks of the Great Valley. Seven analyses are included.

——— 1946g, Minerals and structural materials of the Watts Bar and Fort Loudoun Reservoir areas: TVA, Commerce Dept., Regional Products Research Div., Rept. 5, p. 8, 21.

Mentions that many of the limestones of the area are high calcium. Limestone analyses are included in the chapter on cement.

Glover, S. L., 1936, Nonmetallic mineral resources of Washington, with statistics for 1933: Wash. Div. Geology Bull. 33, p. 53-61.

Gives important limestone deposits of Washington by county. Notes those that are high in calcium content.

Gordon, C. H., 1911, Cement resources and possibilities, in *The resources of Tennessee*: Tenn. Geol. Survey, v. 1, p. 58-69.

Describes outcrops of the three important cement lime rocks in Tennessee which are the Holston marble, Lenoir (Chickamauga) limestone, and the Bangor or New-man limestone. Locates several favorable sites for cement plants. Analyses are included.

Gould, C. N., 1911, Limestone, in *Preliminary report on the structural materials of Oklahoma*: Okla. Geol. Survey Bull. 5, p. 66-84.

Indicates that high-calcium limestone can be found in most areas of Oklahoma. Maps show limestone areas; one in northern Oklahoma and one in the Arbuckle Mountains, scale 1 inch = 20 miles.

Graf, D. L., 1951, Petrology of the basal high-purity bed of the Burlington limestone: Ill. Geol. Survey Circ. 170, p. 160-164.

A petrographic study of the high-purity, chert-free limestone occurring near the base of the Burlington formation in western Illinois. Discusses the major and minor components of the rock and the history of its formation.

Grasty, J. S. See Mathews, 1910.

Gray, Carlyle, 1951, Preliminary report on certain limestones and dolomites of Berks County, Pa.: Pa. Geol. Survey, 4th ser., Progress Rept. 136, 85 p.

Includes a short summary of local structure and stratigraphy; analyses of 366 samples of Ordovician limestones from the Beekmantown, Annville, and Jacksonburg formations; a short description of locations from which these samples were taken; contour diagrams of the chemical composition of some of the limestones analysed; and a map showing principal limestone areas of Berks County, scale 1 inch = 2 miles.

——— 1952, The high calcium limestones of the Annville belt in Lebanon and Berks Counties, Pa.: Pa. Geol. Survey, 4th ser., Progress Rept. 140, 17 p.

The Annville limestone, upper Cambro-Ordovician, occurs on the north limb of a regional anticlinorium and is exposed in a narrow east-west belt in Lebanon and

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Berks Counties, Pa. It ranges in purity from 88 percent to more than 98 percent calcium carbonate; most of the higher purity stone is in the western part of the belt. Used now in cement, steel, and chemical industries. Geologic mapping indicates large reserves. Includes maps: one showing the Annville outcrop, scale 1 inch = 1 mile, and others showing certain important areas, scale 1 inch = about 600 feet; also cross sections.

Griffitts, W. R. See Larrabee, 1947.

Grimsley, G. P., 1906, Clays, limestones, and cements: W. Va. Geol. Survey, v. 3, p. 330-357.

Describes the limestones of West Virginia from the Kanawha series (Pennsylvanian) through the Dunkard series (Permian). Only the Shenandoah limestone (Silurian) is noted as having a high calcium content. However, in places, this formation is a dolomite of nearly theoretical composition. Gives location of outcrops and discusses development. Includes analyses.

——— 1916, Jefferson, Berkeley, and Morgan Counties [W. Va.]: W. Va. Geol. Survey County Rept., p. 361-511.

Briefly describes limestones of the eastern panhandle counties. These limestones are used for furnace flux, fertilizer, glass industry, in asphalt paving and in cement. Includes description and analyses of marl deposits and location of plants and quarries.

A chapter concerns the chemical characteristics of the low-silica fluxing limestones in Berkeley and Jefferson Counties. Many of these flux stones are high in calcium. Includes location of outcrops and analyses.

The chapter on lime and cement resources includes a general discussion of lime, its properties, uses, and manufacture. Notes existing cement plants and their limestone sources. Advises on locations for new plants.

Analyses are given throughout the report. Includes maps, at various scales, under separate cover: one topographic and one geologic of Jefferson, Berkeley, and Morgan Counties, and a map of low-silica limestones in the Martinsburg area.

Grogan, R. M., and Lamar, J. E., 1940, Agricultural limestone resources of Cumberland, Effingham, Clay, Richland, and Jasper Counties [Ill.]: Ill. Geol. Survey Rept. Inv. 65, 44 p.

In Illinois the following limestones are sufficiently thick to quarry: Bogata, Newton, Omega, and Shumway. Describes thickness variations, outcrops, quantity and substance of overburden, general quarrying considerations, and prospecting suggestions for each of these limestones. The calcium carbonate equivalent of various localities and formations is given throughout the text. Many sketch maps show outcrops.

Grout, F. F., Stauffer, C. R., Allison, I. S., and others, 1932, Geologic map of the State of Minnesota: Minn. Geol. Survey, scale 1:500,000.

According to the explanation, Cedar Valley limestone (Devonian) has beds of nearly pure calcium carbonate; the Galena formation (Ordovician) is also high grade.

Hale, D. J., and others, 1903, Marl (bog lime) and its application to the manufacture of portland cement: Mich. Geol. Survey, v. 8, pt. 3, 399 p.

Includes theories of origin of marls and discussion of the manufacturing of portland cement from marl. Lists plants using marls and locates and describes their source areas. Includes a great many analyses and a map, scale 1 inch = 45 miles, showing marl deposits in lower Michigan, location of portland cement plants, and suggested sites for future developments.

Ham, W. E., Dott, R. H., Burwell, A. L., and Oakes, M. C., 1943, Geology and chemical composition of the St. Clair limestone near Marble City, Okla.: Okla. Geol. Survey Mineral Rept. 16, 24 p.

Gives structure, stratigraphy, and lithologic description of the high calcium and dolomitic St. Clair formation (Silurian). A conservative estimate of 50 million tons of high calcium stone is available for quarrying. Includes analyses of 18 samples and a map showing sample locations, quarries, and distribution of the St. Clair formation in Sequoyah County.

Haworth, Erasmus. *See also* Schrader, 1906.

Haworth, Erasmus, and Schrader, F. C., 1905, Portland-cement resources of the Independence quadrangle, Kansas: U. S. Geol. Survey Bull. 260, p. 506-509.

Independence quadrangle embraces all of Montgomery County and parts of adjacent counties. The Drum and Piqua limestones are used here to manufacture cement. Analyses of nine samples of Piqua limestone are included.

Hazenbush, G. C. *See* Wright, 1953.

Heyl, G. R., and Walker, G. W., 1949, Geology of limestone near Gazelle, Siskiyou County, Calif.: Calif. Jour. Mines and Geology, v. 45, p. 514-520.

Structure and stratigraphy of limestone occurring 2 to 5 miles west southwest of Gazelle along the North Branch of Willow Creek. Large reserves of high-grade stone with very little overburden are available. Only small quarries have been opened. Includes five analyses, a location map, and a geologic map with cross sections showing the Gazelle deposits, scale 3 inches = 4,000 feet.

Heyl, G. R., and Wiese, J. H., 1949, Geology of limestone near Sonora, Tuolumne County, Calif.: Calif. Jour. Mines and Geology, v. 45, p. 509-513.

Describes accessibility, general topography, and geology. The high-calcium limestone is found in two zones in the limestone belt; one in the east along Black Leg Creek, the other on the west near Sullivan Creek. Because of the crystallinity of the formation the limestone can be easily distinguished from the dolomite by a difference in the grain size: the limestone having a grain size of from 0.5 to 5 mm and the dolomite from 0.05 to 0.3 mm. The limestone has been quarried for the glass and chemical industries. Only a minor amount of the available resources has been mined. Includes five analyses and a geologic map and cross sections of limestone at Black Leg Creek, scale 3 inches = 4,000 feet.

Hinchey, N. S., Fischer, R. B., and Calhoun, W. A., 1947, Limestones and dolomites in the St. Louis area: Mo. Geol. Survey and Water Res. Div. Rept. Inv. 5, 80 p.

Gives analyses of 270 samples of Ordovician and Mississippian formations from 17 localities. Description of sample locations includes a stratigraphic section and available transportation. High-calcium limestone is available.

Hodge, E. T., 1935, Available raw material for a Pacific Coast iron industry: U. S. Army Corps of Engineers, Office of the Div. Engineer, North Pacific Div., Portland, Oreg., v. 4, App. L, p. 19-84.

Describes and gives analyses for many deposits in Alaska, Washington, Oregon, and California. Some other deposits outside economic transportation range are mentioned.

——— 1938, Northwest limestones, Section 3, in Market for Columbia River hydroelectric power using northwest minerals: Portland, Oreg., War Dept., Corps of Engineers, Office Div. Engineer, North Pacific Div., 621 p.

Discusses general geology, occurrence of limestone, quarrying, tonnage, and costs. Part 1, volume 1, "Limestones of the Northwestern States," is concerned with

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Washington, Oregon, and Idaho. Part 2, volume 2, "Other limestone occurrences available to (or) competitive with the lower Columbia area," includes chapters on deposits in California, Nevada, southeastern Alaska, and British Columbia. Part 3, volume 2, discusses uses, technology, and available markets for limestone and lime.

——— 1944, Limestones of the Pacific Northwest; available limestones suitable for calcium carbide and/or for flint glass industries: [Portland, Oreg.], Bonneville Power Administration, 104 p.

A comprehensive report on the availability and marketability of high-calcium and high-purity limestones. The introduction discusses transportation costs, rail, ship and barge, and mining costs. Gives potential markets and their consumption. The areas included are the southeastern coastal Alaska, coastal British Columbia, all of Washington, Oregon, and Idaho, western and southwestern Montana, northwestern Nevada, and northern and coastal California. The discussion for each of these areas includes mileage to various markets, estimated transportation costs, composition of the limestone, short description of the deposit, and a map showing the location of the deposit.

Hodges, P. C., 1936, Production and preparation of blast furnace flux: Am. Inst. Min. Metall. Eng. Tech. Pub. 668, 11 p.

The Columbus and Delaware limestones (Devonian) are quarried at Marble Cliff quarry, Franklin County, Ohio. The Columbus limestone is noted as a high-calcium flux and chemical stone; the Delaware is used as an aggregate and as railroad ballast.

Hopkins, T. C., 1893, Marbles and other limestones: Ark. Geol. Survey Ann. Rept. for 1890, v. 4, p. 96-115, 212-356.

The marble belt of Arkansas is in the north and northwestern part of the State. The high-calcium limestones of this part of the Ozark Plateau are the St. Joe marble and the Boone limestones, members of the Boone formation (Mississippian), and the Izard and St. Clair formations (Silurian). Analyses and the location and description of outcrops are included.

Huner, John, Jr., 1939, Geology of Caldwell and Winn Parishes [La.]: La. Geol. Survey Bull. 15, p. 210-214, 284-288.

One of the two limestone quarries in the State is in the cap rock limestone of the Winnfield salt dome. The limestone is used chiefly as chemical lime. Three analyses are given.

Iowa Geological Survey, 1907, Analyses of limestones and chalks, in Ann. Rept. for 1906: Iowa Geol. Survey, v. 17, p. 531-537.

Contains more than 100 analyses of Iowa chalks and limestones arranged alphabetically by county.

Jander, F. K. See Boynton, 1952.

Jewett, J. M. See O'Connor, 1951.

Jicha, H. L., Jr., 1956, A deposit of high-calcium lime rock in Valencia County, N. Mex.: N. Mex. Inst. Mining and Technology, State Bur. Mines and Min. Res., 5 p.

An analysis of two samples of limestone from an area in Valencia County, 34 miles west of Belen, shows an aggregate calcium carbonate content of 97.5 percent. The formation is a travertine deposited on the Chinle formation (Triassic). The deposit is 5½ miles long and 1 mile wide. Its maximum thickness of 150 feet is in the northeast with a thinning to the south and west. There are estimated re-

serves of 100 million tons. Two small-scale maps, one location and one geologic, are included.

Jones, W. B., 1926, Index to the mineral resources of Alabama: Ala. Geol. Survey Bull. 28, p. 60-74.

Divides source areas for cement raw materials in Alabama into four groups. The first district, the Coosa and neighboring valleys, has available the Ordovician limestones and the Bangor limestone. Analyses are given of the Trenton limestone. The second district, the Tennessee Valley region, has available the Bangor and Tusculumbia limestones. Analyses of the Bangor are given. The third district is the Selma chalk belt of central Alabama. The analyses show that the formation is not high in calcium. The fourth district is the St. Stevens limestone belt of south Alabama. Analyses of this formation are included

Kay, G. M., 1943, Chemical lime in central Pennsylvania: Econ. Geology, v. 38, p. 188-203.

Of the many limestones of central Pennsylvania, only the Valentine member of the Curtin formation is suitable for large-scale production of chemical-grade stone. The Valentine limestone is exposed in parts of Centre, Clinton, and Lycoming Counties. Includes a map showing distribution and thickness of the Curtin formation and some chemical analyses of the Valentine member.

Kerns, W. H. See Rutledge, 1953.

Knight, Nicholas, 1929, The chemical composition of the Burlington limestone near Oakville, Iowa: Iowa Acad. Sci. Proc., v. 35, p. 217-218.

Four analyses of limestone from near Oakville, Louisa County, Iowa, are given.

Krey, Frank, and Lamar, J. E., 1925, Limestone resources of Illinois: Ill. Geol. Survey Bull. 46, p. 311-334.

The publication is concerned chiefly with limestone as a road material but includes 23 pages of chemical analyses and location of samples. Many of the limestones tested show high calcium content.

Lamar, J. E. See also Krey, 1925; Grogan, 1940.

Lamar, J. E., 1927, Economic geology of the limestones of Illinois: Rock Products, v. 30, no. 8, p. 56-59.

Discusses Illinois limestones in chronological order. Gives uses and chemical and physical analyses. The formations high in calcium include the Kimmswick, Wapsipicon, Burlington, Salem, St. Louis, Ste. Genevieve, and Shoal Creek limestones.

——— 1929, The limestone resources of the Pontiac-Fairbury region: Ill. Geol. Survey Rept. Inv. 17, 27 p.

Results of a survey of possible uses for the Pontiac limestone (Pennsylvanian). Notes that this stone is of uniform quality, has only from 1 to 5 feet overburden, and estimated reserves of 7.5 million tons. Discusses active quarries. Includes analyses, location map, and a map showing areas sampled.

——— 1936, The economic utilization of the Burlington limestone in the Quincy region: Ill. Acad. Sci. Trans., v. 29, no. 2, p. 170-171.

In the Quincy region the normally cherty Burlington limestone has a 20- to 30-foot chert-free stratum averaging 98 percent carbonate. Because of its white color and high calcium content, this limestone has a variety of uses.

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Lamar, J. E., and Willman, H. B., 1931, High-calcium limestone near Morris, Ill.: Ill. Geol. Survey Rept. Inv. 23, 26 p.

Two high-calcium limestone deposits occur only 60 miles from Chicago and are adjacent to both rail and water transportation. They are in the Divine limestone (Ordovician). Includes one analysis and maps showing outcrops and area underlain by the Divine limestone and areas with less than 3½ feet overburden.

——— 1933, Results of test drilling of limestone near Morris, Ill.: Ill. Geol. Survey Inf. Circ. 4, 6 p.

Four test borings were made to supplement the information given in the Illinois Geological Survey Report of Investigation 23 (Lamar and Willman, 1931). These borings show that the high calcium part of the limestone is buff to brown in color and only the upper 4 to 5 feet contain more than 95 percent calcium carbonate. The purity decreases with depth. The fact that so little of the stone is rich in calcium and that this is discolored would probably limit the use of this stone. Logs and analyses of cores are included.

——— 1938, A summary of the uses of limestone and dolomite: Ill. Geol. Survey Rept. Inv. 49, 50 p.

Discusses the chemical and physical properties required by many of the limestone industries. Many uses of high-calcium limestone are included.

Lamborn, R. E., 1945, Recent information on the Maxville limestone: Ohio Geol. Survey Inf. Circ. 3, 18 p.

The Maxville limestone is thick enough in a few places in Muskingum and Perry Counties to be commercial. Burned for lime to make mortar and also used as flux stone. Article includes lithologic sections and chemical analyses from a few important quarries. These analyses show that the calcium carbonate content varies considerably.

——— 1951, Limestones of eastern Ohio: Ohio Geol. Survey, 4th ser., Bull. 49, 377 p.

Detailed description of limestone formations, by counties, includes distribution, economic significance, and lithologic sections. Chemical analyses given for Mississippian, Pennsylvanian, and Permian limestones that are of unusual commercial importance or that represent some stratigraphic horizon. Map shows sample locations. Table at end of report summarizes the more than 150 analyses given in the text.

Landes, Henry, 1906, Cement resources of Washington: U. S. Geol. Survey Bull. 285-I, p. 377-383.

Limestone is found in Washington from Puget Sound to Idaho County. Report describes the limestone deposits of the northern counties and includes analyses.

Landes, K. K., 1949, Metallurgical limestone reserves in the United States: Washington, D. C., National Lime Assoc., 25 p.

Discusses extent of metallurgical limestone reserves. State-by-State discussion gives important metallurgical limestones, their grade, and possibilities for production expansion.

Larrabee, D. M., Clabaugh, S. E., Griffiths, W. R., and others, 1947, Construction materials and nonmetallic mineral resources of Colorado: U. S. Geol. Survey Missouri Basin Studies Map 10, scale 1:500,000.

The map text notes that the Leadville, Madison, Timpas, and Greenhorn limestones are high in calcium but that the Timpas and Greenhorn have a tendency toward being clayey.

Lincoln, F. C., 1929, Quarrying limestone in the Black Hills of South Dakota: *Rock Products*, v. 32, no. 11, p. 42-47.

There are three sources of high-calcium limestone in the Black Hills. The Minnekahta, which is the highest purity limestone in the State, and the Niobrara are laterally uniform in quality. The Pahasapa is normally a dolomite but in places is quarried as a high calcium stone. Reviews the history of the uses of South Dakota limestones which include road stone, concrete, aggregate, lime, cement, etc.

Lindgren, Waldemar, 1905, Description of the Clifton quadrangle, Arizona: U. S. Geol. Survey Atlas, folio 129, p. 13.

The upper 100 feet of the Modoc formation (Mississippian) has a calcium carbonate content as high as 96 percent. Includes a geologic map, scale 1:62,500.

Ljungstedt, O. A. See Stose, 1932.

Logan, C. A., 1947, Limestone in California: *Calif. Jour. Mines and Geology*, v. 43, p. 175-357.

Reviews the origin and uses of limestone. Discusses, by county, the geology of the State and the history of production of limestone; gives location of existing quarries; and gives a few chemical analyses. Map shows limestone deposits.

Logan, W. N., 1911, The structural materials of Mississippi: *Miss. Geol. Survey Bull.* 9, 78 p.

Report not chiefly concerned with high-calcium limestones but analyses from Tishomingo, Warren, and Wayne Counties are given. Some of these are high calcium.

——— 1916, Preliminary report on the marls and limestones of Mississippi: *Miss. Geol. Survey Bull.* 13, p. 29-82.

Report is primarily concerned with agricultural limestone. Includes chemical analyses for nearly every county in the State, some of which are high in calcium content.

Loughlin, G. F., Berry, E. W., and Cushman, J. S., 1921, Limestones and marls of North Carolina: *N. C. Geol. and Econ. Survey Bull.* 28, 211 p.

Discusses in general limestone and its physical characteristics. First, the limestone areas in western North Carolina are discussed, then those in the east. Describes in detail the distribution and availability of the limestones and gives useful quarrying information. Includes a section on North Carolina's position in the limestone and marble industry, three pages of analyses, and many county maps showing the distribution of limestone.

Luttrell, E. M. See Stokley, 1952.

McCue, J. B., Lucke, J. B., and Woodward, H. P., 1939, Limestones of West Virginia: *W. Va. Geol. Survey*, v. 12, 560 p.

Marine limestones crop out mainly in the eastern panhandle and along the eastern boundary from Mercer County to Preston County. Fresh-water limestones crop out in the north-central part of the State and, in general, are less uniform and of lower grade than the marine deposits. The few outcrops in the central and southwestern parts of the State generally are too thin and low grade to be of economic importance. The most valuable deposits are Ordovician, Silurian, and Devonian.

A brief introduction to the history of limestone is followed by a discussion of the limestones of West Virginia arranged according to their geologic age. The Cambrian to Devonian formations are discussed by H. P. Woodward and the Mississippian to Permian by J. B. Lucke. These sections include distribution of the formation,

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structure, stratigraphy, lithologic sections, and some analyses. The final chapters were contributed by J. B. McCue. They discuss mining methods, preparation, and utilization of the limestone. Analyses are found on pages 379-428. Map shows location of samples and important limestone outcrops.

McFarlan, A. C. See Stokley, 1952.

Martens, J. H. C., 1948, Possibility of shaft mining of Greenbrier limestone: W. Va. Geol. Survey Rept. Inv. 6, 18 p.

Notes localities in the State where underground mining of Mississippian Greenbrier limestone is feasible. It is quarried along the outcrop from Monongalia County to Mercer County and underlies much of the western and central part of the State. Six pages of analyses are included.

Martin, G. C., 1909, The Niobrara limestone of northern Colorado as a possible source of portland cement material: U. S. Geol. Survey Bull. 380-J, p. 314-326.

A survey for cement materials in Boulder and Larimer Counties. Niobrara is the only limestone of sufficiently high calcium content for portland cement. Includes stratigraphy, lithologic sections, and analyses. Map of a part of the foothills area shows distribution of Niobrara formation.

Martin, H. M., 1936, The centennial geological map of Michigan: Mich. Dept. Conserv., Geol. Survey Div. Pub. 39, Geol. Ser. 33, 2 pts., scale 1:500,000.

Lists uses or possible uses of the following high-calcium limestones: the Slonington formation (Ordovician), the Burnt Bluff (Silurian), the Mackinac formation and Traverse group (Devonian), and the Bayport limestone (Mississippian).

Mathews, E. B., and Grasty, J. S., 1910, The limestones of Maryland: Md. Geol. Survey, v. 8, pt. 3, p. 227-477.

Describes the origin, types, and uses of limestone. There is a lengthy section on portland cement and its raw materials. Most of the report is concerned with lime and cement materials of Maryland. The limestones are discussed by physiographic province. Includes a discussion of structure, location of quarries, a description of other cement materials, and a map noting location of samples, scale 1 inch = 8 miles. Many analyses are given throughout text.

Maynard, T. P., 1912, A report on the limestones and cement materials of north Georgia: Ga. Geol. Survey Bull. 27, 293 p.

Presents a short review of the origin and uses of limestones, clays, and shales; discussion of the differences between hydraulic limes, natural cements, and portland cements; and a section on the physiography, stratigraphy, and structure of north Georgia. The remainder of the bulletin describes the limestone and cement materials that occur in the Piedmont Plateau and the Appalachian Mountain areas of Georgia. Describes, by county, individual areas, gives lithologic sections, discusses economic development, and includes analyses throughout the text and a geologic map of the Appalachian Valley and the Cumberland Plateau, scale 1 inch = 4 miles.

Mellen, F. F., 1942, Mississippi agricultural limestone: Miss. Geol. Survey Bull. 46, 20 p.

The report is concerned only with agricultural uses of limestone but analyses appear on pages 10-13. Some of these show high calcium content.

Miller, B. L., 1925, Limestones of Pennsylvania: Pa. Geol. Survey, 4th ser., Bull. M-7, 368 p.

The preliminary discussion includes types of limestone, mineralogy, origin, and uses; also a chart showing the many uses of lime.

The commercial limestones of Pennsylvania are confined to the southern part of the State and high-grade limestones are, in general, confined to the central and southeastern parts. Limestones of the southwest counties are generally too thin or impure to be of great importance. Even the valuable Vanport limestone of southwestern Pennsylvania has small reserves when compared with limestones of the southeastern counties.

The main body of the report discusses Pennsylvania's limestones first by age and then by area. A general section on stratigraphy, structure, and topography is included. A formation-by-formation discussion of physical characteristics, description of quarries, and uses follows. Analyses occur throughout the text. Map, scale 1:500,000, shows limestone outcrops in Pennsylvania.

——— 1934, *Limestones of Pennsylvania*: Pa. Geol. Survey, 4th ser., Bull. M-20, 729 p.

The first few chapters include such general information as the minerals occurring in metamorphosed and unmetamorphosed limestones, origin, effects of weathering, table of physical properties, topography of limestone areas, and uses of Pennsylvania limestones. Stratigraphy is discussed and a columnar section is included. Describes the limestones by counties, arranged in alphabetical order. Each county is preceded by a small-scale geologic map showing limestone outcrops and quarries. The discussion of the individual formations in places includes physical characteristics, lithologic sections, descriptions of quarries, available sites for new quarries, and analyses. Map shows limestones of Pennsylvania, scale 1:750,000.

Minister, P. F., 1930, *Quarrying of limestone at Lime Spur, Mont.*: Mining and Metallurgy, v. 11, no. 278, p. 108-110.

Describes history, geology, and quarry methods. Quarry is $4\frac{1}{2}$ miles east of Cardwell, Jefferson County, in limestone of the Madison formation. Most of the production is for the sugar industry and flux stone; it is also used for concrete aggregate and glass manufacture. The average calcium carbonate content is 98 percent.

Moore, B. N., 1937, *Nonmetallic mineral resources of eastern Oregon*: U. S. Geol. Survey Bull. 875, p. 118-149.

Deposits of commercial importance are limited to crystalline Paleozoic and Mesozoic limestones of the Ochoco and Blue Mountain regions and Baker, Crook, Wallowa, Grant, and Wheeler Counties. Each of these areas is discussed individually and geography, accessibility, structure, stratigraphy, geomorphology, and description of limestone occurrences are included. Most of the limestone of eastern Oregon is high calcium. Analyses are given. Geologic maps of areas are discussed.

Moore, E. S. See Butts, 1936.

Moore, F. H., 1935, *Marbles and limestones of Connecticut*: Conn. Geol. and Nat. History Survey Bull. 56, 56 p.

The marbles of Connecticut are confined to the Western Highlands physiographic division. In general, the calcitic marble occurs south of the village of Brookfield and dolomitic marble to the north. A discussion of topography, weathering, stratigraphy, origin, and physical and chemical properties is included. Describes in detail the marbles of the northern, central, and southern sections of the marble belt, and the Ridgefield and smaller areas. Includes distribution, structure, and description of each marble. Economics, location of quarries, and age relationships are considered. Analyses and a small-scale map showing occurrence of marbles in Connecticut are included.

Moore, W. E., 1955, *Geology of Jackson County, Fla.*: Fla. Geol. Survey Geol. Bull. 37, p. 84-85.

The Eocene limestones of Jackson County have a high calcium carbonate content and are soft and easily mined. County geologic map, scale 1:137,500, is included.

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Moresi, C. K., 1936, Limerock, in Twelfth biennial report: La. Dept. Conserv., General Conserv. Bull. for 1934-35, p. 505-511.

Limestone is quarried from the cap rock of two Louisiana salt domes, the Pine Prairie and the Winnfield. The rock is used for lime and road metal. Analyses are given.

Morse, W. C., 1910, The Maxville limestone: Ohio Geol. Survey, 4th ser., Bull. 13, 128 p.

This bulletin is chiefly concerned with stratigraphy, but the included analyses indicate that the Maxville is a high-calcium limestone in Ohio. Location and description of exposures are given.

Mossom, Stuart, 1925, A preliminary report on the limestones and marls of Florida: Fla. Geol. Survey 16th Ann. Rept., 1923-24, p. 33-203.

Reviews types of limestone found in Florida, their origin, uses, physical properties, structure, and weathering. The section on stratigraphy includes the distribution and uses of each limestone and marl discussed. Describes deposits by counties and locates operating quarries. Many analyses are given throughout the text. Map of Florida shows distribution of workable limestone and marl deposits, scale 1 inch = about 53 miles.

Moxham, R. M., Eckhart, R. A., Cobb, E. H., West, W. S., and Nelson, A. E., 1953, Geology and cement raw materials of the Windy Creek area, Alaska: U. S. Geol. Survey open-file rept. 49 p.

Discusses in general topography, climate, accessibility, and stratigraphy. The Windy Creek area is in the northern part of the Alaska Railroad region. Three deposits of commercial size are described. Many analyses and a geologic map of the Windy Creek area, scale 1 inch = about 4,500 feet, are included. Also included are maps of the three limestone areas discussed.

Mulligan, J. J. See Rutledge, 1953.

Nelson, A. E. See Moxham, 1953.

Oakes, M. C. See Ham, 1943.

O'Connor, H. G., Goebel, E. D., and Plummer, Norman, 1953, Mineral resources of Lyon County, in Geology, mineral resources, and ground-water resources of Lyon County, Kans.: Kans. Geol. Survey, v. 12, pt. 2, p. 24-27.

Gives a short discussion of uses and possible uses of the local limestones, and analyses and locations of 22 samples.

O'Connor, H. G., Jewett, J. M., and Smith, R. K., 1951, Mineral resources of Chase County [Kans.]: Kans. Geol. Survey, v. 11, pt. 2, p. 16-19.

Describes uses of limestone and gives locations of quarries in Chase County. Map, scale 1 inch = $1\frac{1}{2}$ miles, shows, among other things, limestone quarries, limestone plants, location of samples, and a columnar section. Analyses of 17 samples are given.

O'Hara, C. C., 1908, The cement resources of the Black Hills: S. Dak. School Mines Bull. 8, p. 9-27.

Structure and area of outcrop of the high-calcium Minnekahta limestone are discussed. A stratigraphic column and two analyses are included. Report contains maps of individual formations, and a small-scale map shows outcrop of Minnekahta limestone and its relation to cultural features.

Orton, Edward, Jr., and Peppel, S. V., 1906, The limestone resources and the lime industry in Ohio: Ohio Geol. Survey, 4th ser., Bull. 4, p. 20-248.

The beginning chapters include the stratigraphy of Ohio. The limestones of Ohio are discussed first by their occurrence in counties and then each formation is

discussed individually as to areal extent and chemical and physical properties. Thickness, lithologic sections, analyses, location of samples, and the value of each limestone to the cement industry are all considered. Tables of analyses are given for each of the formations discussed. A small-scale geologic map of the State shows location of samples.

Patton, J. B., 1949, Crushed stone in Indiana: Ind. Dept. Conserv., Div. Geology, Progress Rept. 3, 47 p.

Describes briefly the limestones being used for crushed stone in Indiana. Quarry locations are listed and formations being quarried are named. Five pages of analyses and a map showing quarry and location of samples, scale 1 inch = 10 miles, are included.

Peck, F. B., 1908, Geology of the cement belt in Lehigh and Northampton Counties, Pa. * * *: Econ. Geology, v. 3, no. 1, p. 37-55.

Describes physiography, stratigraphy, and structure of the cement belt. Locates and describes the formations used in cement manufacture. Analyses are given throughout. Map, 1 inch = 4 miles, shows the location of plants, quarries, and outcrops.

Peppel, S. V. See Orton, 1906.

Pepperberg, L. J., 1909, Cement material near Havre, Mont.: U. S. Geol. Survey Bull. 380-J, p. 327-336.

Approximately 5 miles south of Havre, Hill County, about 80 acres are underlain by a 15-foot-thick limestone giving a reserve estimate of more than 4 million tons of stone. This cement raw material is important because of the scarcity of other building materials in this area.

Perry, E. S., 1949, Gypsum, lime, and limestone in Montana: Mont. Bur. Mines and Geology Mem. 29, p. 27-43.

Limestone outcrops are confined to the western and central parts of the State. The Upper Madison (Mississippian) and the Meagher (Cambrian) are the two limestones of Montana quarried because of their high calcium content. The Meagher has a variable calcium content. The Tertiary marls of northern Montana, although not yet exploited, are nearly pure calcium carbonate. Individual quarries are described. Small-scale maps show distribution of limestones in Montana and quarry locations. A few analyses are given.

Perry, T. G., Smith, N. M., and Wayne, W. J., 1954, Salem limestone and associated formations in south-central Indiana: Ind. Geol. Survey Field Conf. Guidebook 7, 73 p.

Analyses of samples from stops made during the field trip are given on pages 58-71.

Plummer, Norman. See O'Connor, 1953.

Popoff, C. C., 1948, Investigation of the Sauk Mountain limestone deposits, Skagit County, Wash.: U. S. Bur. Mines Rept. Inv. 4355, 14 p.

Deposit is located 110 miles northeast of Seattle near the towns of Sauk and Rockport. The limestone is probably Carboniferous. It extends from 600 to 4,500 feet on the west and south slopes of Sauk Mountain. The beds are highly metamorphosed and faulted. A list of property owners is given, and individual deposits are discussed. Calcium oxide usually ranges between 53 and 55 percent and magnesium seldom exceeds 3 percent, but silica may be as high as 10 per cent. Numerous analyses and maps, at various scales, showing location of deposits, are included.

——— 1949a, Investigation of limestone deposits near Arlington, Snohomish County, Wash.: U. S. Bur. Mines Rept. Inv. 4393, 14 p.

These deposits are 45 miles north of Seattle. A list of property owners is given, geology is reviewed, and individual deposits are discussed. The calcium oxide con-

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tent is uniformly high and the magnesium oxide is generally less than 1 percent. Analyses and a map showing areal extent of the limestones and sample locations are included.

Popoff, C. C., 1949b, Investigation of Whitehorse limestone deposits, Snohomish County, Wash.: U. S. Bur. Mines Rept. Inv. 4510, 9 p.

Deposit is found in north-central part of Snohomish County. Lists property owners, discusses geology and climate. Of the three limestone deposits described, the Galbraith shows the highest average calcium oxide content, 51.1 percent. Includes analyses and maps showing areal extent of deposits and location of samples.

Richardson, C. H., 1923, The building stones of Kentucky: Ky. Geol. Survey, 6th ser., v. 11, p. 259-329.

A few high-calcium limestones are represented in these 70 pages of analyses.

——— 1927, Cement materials of Kentucky: Ky. Geol. Survey, 6th ser., v. 29, p. 65-154.

Contains chapters on the history of the cement industry, types of cement, its composition, necessary raw materials, and its manufacture. Discusses the cement materials of Kentucky by dividing the State into districts. Gives for each district the available cement raw materials and the best locations for new cement plants. Some analyses are given.

Richardson, G. B., 1908, Portland cement materials near El Paso, Tex.: U. S. Geol. Survey Bull. 340-H, p. 413-414.

Notes that the Carboniferous and Cretaceous limestones of the El Paso region are high calcium. Gives a representative analysis for each.

——— 1909, Description of El Paso quadrangle, Texas: U. S. Geol. Survey Geol. Atlas, folio 166, p. 4-5, 10.

Notes the Hueco and Comanche limestones (Pennsylvanian) as being high calcium. Reserves available for expansion of industries using this grade of stone. Includes a geologic map, scale 1:125,000, and a few analyses.

Ries, Heinrich, 1899, Limestones of New York and their economic value: N. Y. State Geologist 17th Ann. Rept., 1897, p. 355-467.

Report is chiefly concerned with chemical uses of limestone. Describes the important limestones of New York by county. Includes a general section on origin, types, and uses of limestone. Gives analyses throughout text.

——— 1901, Lime and cement industries of New York: N. Y. State Mus. Bull. 44, p. 753-849, 893-955.

Describes the limestones of New York and notes the Trenton and Helderberg as being the most important high-calcium limestones. Includes, by counties arranged in alphabetical order, the areal extent, analyses, and location and description of quarries. Gives many tables of analyses of limestones throughout the United States.

Roehm, J. C., 1946, Some high-calcium limestone deposits in southeastern Alaska: Alaska Dept. Mines Pamph. 6, 85 p.

In southeastern Alaska high-calcium limestones are confined to the Silurian, Devonian, and certain formations of indefinite but pre-Silurian age. The Silurian beds are the most uniform and extensive, have the greatest thickness, and the highest calcium content. Much good-quality limestone suitable for large-scale production is readily accessible to ocean-going vessels. Discusses in detail individual areas, including information about the geology, applicable mining methods, available ship-

ping and housing sites, and recommended uses for the stone. Includes analyses and many index maps showing the areas studied and sampled.

Rothrock, E. P., 1931, A preliminary report on the chalk of eastern South Dakota: S. Dak. Geol. and Nat. History Survey Rept. Inv. 2, 42 p.

Gives descriptions of the Niobrara chalk, lithologic sections, and possible quarry sites for many areas. Includes analyses and a sketch map showing the cultural features and chalk outcrops.

——— 1944, Mineral resources, part 3 of A geology of South Dakota: S. Dak. Geol. Survey Bull. 15, 255 p.

Discusses and gives analyses of the Pahasapa, Minnekahta, and Greenhorn limestones and Niobrara chalk; all are high in calcium. Map shows mineral resources of South Dakota.

Runkle, D. M., 1951, Chemical limestone: Ohio Chamber Commerce, Indus. Devel. Dept., Inf. Brochure 9, 7 p.

Discusses uses of chemical limestones. Map (scale 1 in. = 30 mi.) shows the limestones of Ohio that might contain more than 90 percent calcium carbonate and their areal extent.

Runnels, R. T., 1951, Some high-calcium limestones in Kansas: Kans. Geol. Survey Bull. 90, pt. 5, p. 81-104.

Analyses of samples from 14 formations in eastern Kansas. All have greater than 90 percent calcium carbonate and three are over 98 percent. Discusses possible uses of high-calcium limestone and available quarry sites.

Runnels, R. T., and Dubins, I. M., 1949, Chemical and petrographic studies of the Fort Hays chalk in Kansas: Kans. Geol. Survey Bull. 82, pt. 1, p. 8-9, 22-23.

Gives analyses and location of samples of the Fort Hays member of the Niobrara formation.

Russell, I. C., 1901, Geology and water resources of Nez Perce County, Idaho, Pt. 2: U. S. Geol. Survey Water-Supply Paper 54, p. 120-121.

Describes high-calcium limestone deposits along Snake and Columbia Rivers and gives analyses of limestones from Nez Perce County.

Rutledge, F. A., Thorne, R. L., Kerns, W. H., and Mulligan, J. J., 1953, Preliminary report—nonmetallic deposits accessible to the Alaska Railroad as possible sources of raw materials for the construction industry: U. S. Bur. Mines Rept. Inv. 4932, p. 90-124.

West Fork of Windy Creek near Foggy Pass has large tonnages of high-grade limestone. Includes data on accessibility, ownership, general geology, and description of deposits; logs and analyses of drill cores; small-scale maps showing geology and distribution of limestones; also maps of areas discussed.

Sampson, Edward, 1928, Geology and silver ore deposits of the Pend Oreille district, Idaho: Idaho Bur. Mines and Geology, Pamph. 31, p. 9-10.

The Lakeview limestone is of commercial interest because it is the only limestone in this area and is used for portland cement. Gives short description of deposits.

Schoenborn, E. M. See Adair, 1947.

Schrader, F. C. See also Haworth, 1905.

Search, Herman, and Ranklin, Roy, 1939, The lime content of rocks of the Upper Cretaceous system of Osborne County, Kans. [abs.]: Kans. Acad. Sci. Trans., v. 42, p. 233-236.

Analyses of the Smoky Hill and Fort Hays members of the Niobrara formation show that the Fort Hays has a consistently high calcium carbonate content.

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Schrader, F. C., and Haworth, Erasmus, 1906, *Economic geology of the Independence quadrangle, Kansas*: U. S., Geol. Survey Bull. 296, p. 55-58.

In discussing the growing cement industry of the Independence quadrangle the Drum, Allen, Piqua, and Iola limestones are mentioned as sources of raw materials. The Piqua and Iola limestones are noted as being persistent over wide areas and of uniformly high calcium content. Includes analyses and a geologic map, scale 1 = 125,000.

Shedd, Solon, 1903, *The building and ornamental stones of Washington*: Wash. Geol. Survey Ann. Rept., 1902, v. 2, pt. 1, p. 75-133, 141-142.

Many of these stones used for building purposes have a high calcium content. Analyses are scattered throughout the text from pages 75-133; tables of analyses on pages 141-142.

— 1913, *Cement materials and industry in the State of Washington*: Wash. Geol. Survey Bull. 4, p. 112-251.

Limestones are found in only a few localities of eastern Washington, and in the western half of the State they are found only in the north. In general, western limestones are higher grade. Discusses each county having high-calcium limestone, and includes a summary of topography, general geology, and individual deposits. Gives analyses for important localities and a location map showing cultural features, streams, and the known extent of the limestone. Tables of analyses are on pages 244-251.

Sloan, Earle, 1908, *Catalogue of the mineral localities of South Carolina*: S. C. Geol. Survey, ser. 4, Bull. 2, p. 225-240, 256-261.

Gives description and location of limestone and marble outcrops. Limestone analyses are on pages 256-261.

Smith, E. A., 1903, *The cement resources of Alabama*: U. S. Geol. Survey Bull. 225, p. 424-447.

The limestones suitable for portland cement in northern Alabama are the Carboniferous, especially the Chester, and the Ordovician Trenton limestone. In the central and southern parts of the State the Selma chalk (Cretaceous) and the St. Stephens limestone (Tertiary) are of sufficiently high quality to be used. Tables of analyses are given.

Smith, R. A., 1916, *Limestones of Michigan*, in *Mineral resources of Michigan* * * *: Mich. Geol. Biol. Survey Pub. 21, Geol. Ser. 17, p. 101-311.

Introductory chapters discuss origin, types, and uses of limestone. The stratigraphy and distribution of Michigan limestones follows. The final section describes, by counties, the distribution, character, and development of deposits. Analyses are given throughout the text. Many small-scale maps show extent of individual formations.

— 1917, *The portland cement industry*, in *Mineral Resources of Michigan* * * *: Mich. Geol. Biol. Survey Pub. 21, Geol. Ser. 17, p. 132-141.

The limestones of Michigan sufficiently pure for cement are the Bayport limestone (Upper Mississippian), the Traverse formation and Dundee limestone (Devonian), and the lower part of the Niagara (Silurian). Discusses occurrence, physical characteristics, and past and present uses of each of these formations and includes many tables of analyses.

Smith, R. W., 1937, *Limestone mining at Ste. Genevieve, Mo.*: Am. Inst. Min. Metall. Eng. Tech. Pub. 902, 23 p.; Am. Inst. Min. Metall. Eng. Trans., v. 129, p. 76-98; 1938, *Min. Technology*, v. 2, no. 3.

The high-calcium limestone quarried at Ste. Genevieve, Mo., is the upper part of the Spergen formation. The analyses given show the calcium carbonate content

to be nearly 99 percent. A sketch map shows the area where this limestone is at the surface. The report continues with a lengthy discussion of mining procedures.

Smock, J. C., 1890, Building stone in New York: N. Y. State Mus. Bull. 10, p. 354.

The report is concerned with the building stone industry. A table, opposite page 358, giving the results of physical and chemical tests show that many of the samples have a high calcium content.

Stauffer, C. R., 1944, The geological section of the limestone mine, Barberton, Ohio: Am. Jour. Sci., v. 242, p. 251-271.

The Columbus (Onondaga) limestone of Devonian age is mined at a depth of more than 2,300 feet at Barberton, about 40 miles south of Cleveland, Ohio. It yields high-calcium limestone for the Columbia Chemical Division of the Pittsburgh Plate Glass Co. This operation produces 1.3 million tons per year. The report gives a complete stratigraphic section of the shaft and discusses the key horizons. Includes a small-scale sketch map of Ohio showing the relation of Barberton, Ohio, to the cultural features and geology of the State and nine analyses of the Columbus limestone.

Stauffer, C. R., and Thiel, G. A., 1933, The limestones and marls of Minnesota: Minn. Geol. Survey Bull. 23, 193 p.

An introductory chapter discusses uses of limestone, dolomite, and marl. The main part of the bulletin is divided into two parts: the limestones and dolomites of Minnesota, and the marls of Minnesota.

Part 1 reviews the origin of limestone and dolomite. The limestones and dolomites range from Cambrian to Devonian and occur in the eastern and southeastern parts of the State. Discussion by individual county includes lithologic sections. The Prosser limestone (Ordovician) in Fillmore and Olmsted Counties, the limestone members of the Decorah shale (Ordovician), and the Cedar Valley limestone (Devonian) are noted as high-calcium stones. Analyses are given on pages 72-73.

Part 2 discusses origin of marl and the relation of marl deposits to types of glacial drift. Includes prospecting procedures, discussion by counties, sketch maps showing location of marl beds, and analyses for larger deposits.

Steidtmann, Edward, 1924, Limestones and marls of Wisconsin: Wis. Geol. and Nat. History Survey, Econ. ser. 22, Bull. 66, 208 p.

Discusses origin of marl, limestone, and dolomite. Stratigraphy and distribution included in the chapter on general geology. High-calcium limestone occurs in the upper Black River formation and in the lower part of the Galena formation in Grant, Iowa, and Lafayette Counties. Some found also in Pierce and Dane Counties. Index to high-calcium limestone analyses occurring in the text is given in the last paragraph on page 97. Some marls also have a high calcium content. Analyses of these are given on page 191. Discusses uses and possible uses of Wisconsin marls, limestones, and dolomites with emphasis on portland cement.

Stewart, R. M. See Wright, 1953.

Stokley, J. A., 1949, Industrial limestones of Kentucky: Ky. Geol. Survey, ser. 9, Rept. Inv. 2, 51 p.

Describes uses of limestone and dolomite with emphasis on chemical uses. Gives table of specifications for important chemical uses and detailed discussion of stratigraphy and distribution of formations. About half the report consists of tables of analyses. Map shows approximate location of high-calcium limestone in Kentucky.

Stokley, J. A., and Luttrell, E. M., 1952, High-calcium limestone in the Kentucky Lake area: Ky. Geol. Survey Inf. Circ. 2, 5 p.

High-calcium limestone occurs in the Warsaw formation (Mississippian) where it crops out on the Tennessee River, a few miles upstream from Kentucky Dam, Lyon

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County. Locates, very generally, the extent of that part of the formation that is high calcium. Includes a sketch map showing cultural features and analyses of 47 samples.

Stokley, J. A., and McFarlan, A. C., 1952, Industrial limestones of Kentucky—No. 2: Ky. Geol. Survey, ser. 9, Rept. Inv. 4, 94 p.

The important industrial limestone in eastern Kentucky is the Lower Chester and in southern and western Kentucky, the Lower Chester and the Ste. Genevieve. Discusses Middle and Upper Mississippian stratigraphy. Describes favorable area for quarry sites. Most of report consists of analyses of limestones from quarries. Many of these are accompanied by pictures of the quarry faces with formations and members traced on the photos. Maps include one showing location and available information about quarries in Kentucky, and another showing approximate location of high-calcium limestone belts in Kentucky.

Stokely, J. A., and Walker, F. H., 1952, High-calcium limestone in the Somerset, Pulaski County area [Kentucky]: Ky. Geol. Survey Inf. Circ. 3, 8 p.

High-calcium limestone deposit in Paint Creek formation (Mississippian) where it crops out near Somerset, Pulaski County. Includes maps showing cultural features and probable occurrence of high-calcium limestone, and analyses of 91 samples.

— 1953, Industrial limestones of Kentucky—No. 3: Ky. Geol. Survey Rept. Inv. 8, 62 p.

Includes recently discovered industrial limestone localities. This report adds to the material contained in Stokley and McFarlan, 1952. High-calcium limestone found in the Paint Creek, Warsaw, and Perryville formations. Extent of outcrop discussed and shown on maps. Most of the report consists of analyses from limestone quarries. Many pictures of the quarries are given with formations and members designated. Map shows location and data available for quarries.

Stose, G. W. See also Bascom, 1938.

— 1904, Barite in southern Pennsylvania and pure limestone in Berkeley County, W. Va.: U. S. Geol. Survey Bull. 225, p. 516-517.

Near Martinsburg, W. Va., the limestones at the top of the Cambro-Ordovician are very thick and pure. Quarried for use as a flux stone for Pittsburgh's steel industry. Two analyses show the stone to average about 97 percent calcium carbonate.

Stose, G. W., and Ljungstedt, O. A., 1932, Geologic map of West Virginia: W. Va. Geol. Survey, scale 1:500,000.

The explanation states that the Moccasin, Stones River, and Chambersburg limestones contain beds high in calcium.

Stose, G. W., and Swartz, C. K., 1912, Description of the Pawpaw and Hancock quadrangles [Maryland-West Virginia-Pennsylvania]: U. S. Geol. Survey, Geol. Atlas, folio 179, p. 22.

The Helderberg limestone is sufficiently high in calcium to be used for cement. The Wills Creek formation has some shaly limestone members suitable for natural cement. Includes three analyses and geologic maps of the Hancock and Pawpaw quadrangles, scale 1:62,500.

Stout, W. E., 1941, Dolomites and limestones of western Ohio: Ohio Geol. Survey, 4th ser., Bull. 42, 468 p.

Introductory chapters include a discussion of the origin and early uses of limestone and dolomite in Ohio. Summarizes stratigraphy. Description by individual coun-

ties which gives distribution of each limerock formation in that county. Analyses are given for many. Final chapters review the present uses of limestone and dolomite. Analyses and location of 286 samples are given in tabular form. Map shows location of samples.

Stout, W. E., 1946, Mineral resources of Ohio: Ohio Geol. Survey, 4th ser., Inf. Circ 1, p. 17-18.

Notes the Brassfield, Maxville, Vanport, and locally the Columbus limestones as being high in calcium. Gives some information about thickness, extent, and uses.

Swain, F. M., 1946, Geology and economic aspects of the more important high-calcium limestone deposits in Pennsylvania: Pa. State Coll., Mineral Industries Expt. Sta. Bull. 43, 31 p.

The Bellefonte area in the central part of the State is the most important because of the great extent and the uniform quality of the Middle Ordovician, Valentine limestone. The other areas discussed are the Vanport limestone in western Pennsylvania and the Annville and York-Thomasville in eastern Pennsylvania. Map shows the districts consuming limestone produced in each of these areas. Gives stratigraphic sections. Describes each area separately including lithologic sections, sketch map showing limestone outcrop and cultural features, and discussion of composition, reserves, and present operations.

Swartz, C. K. See Stose, 1912.

Talmage, S. B., and Wootton, T. P., 1936, The non-metallic mineral resources of New Mexico and their economic features (exclusive of fuels): N. Mex. Bur. Mines and Min. Res. Survey Bull. 12, p. 60-61.

Notes the limestone of the Magdalena formation (Pennsylvanian) in Bernalillo County and some of the Permian limestones in Chaves and Eddy Counties as being suitable for portland cement.

Thiel, G. A. See also Stauffer, 1933.

Thiel, G. A., and Stauffer, C. R., 1947, The high calcium limestones of Minnesota: Minn. Geol. Survey Summary Rept. 1, 13 p.

Minnesota has limited reserves of high-calcium limestone. The calcium content of the Prosser formation (Ordovician) varies considerably but in places is high. The Cedar Valley formation (Devonian) has the highest grade limestone in Minnesota, but it is interbedded with dolomite which increases the cost of quarrying a high-grade stone. Report includes lithologic sections and analyses.

Thorn, R. L. See Rutledge, 1953.

Toulmin, L. D., 1940, The Salt Mountain limestone of Alabama: Ala. Geol. Survey Bull. 46, 126 p.

The 90-foot-thick Salt Mountain limestone (Lower Eocene) crops out for a distance of about 3 miles in Clark County. Includes nine analyses and a geologic map, scale 1 inch = nearly 1,000 feet.

Trainer, D. W., Jr., 1932, The Tully limestone of central New York: N. Y. State Mus. Bull. 291, 43 p.

Discusses structure, distribution, and mineral composition of the high-calcium Tully limestone. Includes structure contour and isopach maps of the Tully limestone in the Finger Lakes region, New York, scale 1 inch = 6 miles.

Tucker, W. B., 1923, Limestone deposits of McCloud, Shasta County, and their possible value for cement material, in Report 19 of the State Mineralogist: Calif. State Min. Bur., p. 69-71.

The McCloud limestone is from 200 feet to 2,000 feet thick. The most accessible and largest exposures of this high-calcium limestone are at Gray Rock's, near Bayha,

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and farther north on the McCloud River opposite the United States Fishery. Available raw materials and transportation make this an excellent area for development of a cement industry.

Tucker, W. B., 1929 [Lime and limestone, Kern County, Calif.]: Calif. Dept. Nat. Res., Div. Mines and Mining, Mining in California, v. 25, p. 70-73.

Mentions specifically three important areas in Kern County, stating that the most extensive limestone deposits are in the Tehachapi Range near the town of Tehachapi. Briefly describes some individual limestone deposits.

United States Geological Survey, 1933, Mineral resources of the Tennessee River Basin and adjoining areas [map]: U. S. Geol. Survey, scale 1 = 500,000.

Map shows areas in which high-calcium limestone predominates in parts of Kentucky, Tennessee, Georgia, Alabama, Virginia, and minor parts of Mississippi, North Carolina, and West Virginia.

Valentine, G. M., 1949, Inventory of Washington Minerals, part 1, Nonmetallic minerals: Wash. Dept. Conserv. Devel., Div. Mines and Geology Bull. 37, p. 48-51.

Gives brief description of known limestone, marl, and travertine occurrences with indication that some are high-grade stone. These areas are shown on a map, scale 1 inch = about 25 miles.

Ver Steeg, Karl, and Yunk, George, 1935, Geography and geology of Kelley's Island: Ohio Jour. Sci., v. 35, no. 6, p. 429-431.

Kelley's Island, in Lake Erie, is composed of Columbus limestone (Middle Devonian) underlain by the Monroe limestone (Upper Silurian). This island is the northernmost locality of this high-calcium limestone. The formation in this area decreases in calcium content from the top down. Used for lime and as a flux stone.

Virginia Geological Survey, 1928, Geologic map of Virginia, scale 1:500,000.

The Stones River, Lenoir, and Mosheim limestones are suitable for lime, lime products, and cement manufacture.

Walker, F. H. See Stokley, 1952, 1953.

Walker, G. W. See also Heyl, 1949.

——— 1950a, Sierra Blanca limestone in Santa Barbara County, Calif.: Calif. Div. Mines Special Rept. 1-A, 5 p.

Describes, in detail, the occurrence of the Sierra Blanca limestone in the upper Santa Ynez River basin. The limestone occurs in two lenses, one 7 and the other 18 miles north of the city of Santa Barbara. The northernmost lens reaches the maximum thickness, 250 feet, and the maximum purity, 98 percent. This area is accessible only by poor Forest Service roads, so, as yet, remains underdeveloped but possible quarry sites are discussed. Includes analyses of six samples and a reconnaissance geologic map, scale 1 inch = 1 mile.

——— 1950b, The Calera limestone in San Mateo and Santa Clara Counties, Calif.: Calif. Div. Mines Special Rept. 1-B, 8 p.

Describes geology of the Calera limestone and its physical and chemical properties. Calcium carbonate content of one stratigraphic unit approaches 97 percent. Included in report are analyses of eight samples and a sketch map, scale 1 inch = 2 miles, showing approximate distribution of the limestone.

Wallis, B. F., 1915, The geology and economic value of the Wapanucka limestone of Oklahoma: Okla. Geol. Survey Bull. 23, p. 84-88.

Three limestones of this area—the Wapanucka, Viola, and Chimneyhill—are high in calcium and low in magnesium, and free from silica and iron.

Wayne, W. J. *See* Perry, 1954.

West, W. S. *See* Moxham, 1953.

Whitlatch, G. I., 1941, Limestone and lime: Tenn. Dept. Conserv., Div. Geology, Markets Circ. 10, 38 p.

Discusses limestone specifications of various chemical industries and includes 20 analyses of Tennessee limestones.

Wiese, J. H. *See* Heyl, 1949.

Willard, Bradford, 1931, Commercial limestones of Rhode Island: Pan-Am. Geologist, v. 56, no. 2, p. 116-122.

Two large limestone bodies occur in Rhode Island; they are known as the Lime Rock and Dexter beds. The Dexter quarry is in the town of Lincoln, 1 mile southwest of the village of Berkeley. The gray, upper part of this metamorphosed limestone is high in calcium. The structure and age of the limestone are discussed.

Williams, I. A., 1914, Limestone deposits in Oregon, in Mineral Resources of Oregon: Oreg. Bur. Mines and Geology, v. 1, no. 7, p. 52-70.

Describes distribution of limestones in Jackson and Josephine Counties. Individual outcrops are described and some analyses are given.

Willman, H. B. *See* Lamar, 1931, 1933, 1938.

Wilson, Hewitt, and Skinner, K. G., 1937, Occurrence, properties, and preparation of limestone and chalk for whiting: U. S. Bur. Mines Bull. 395, p. 98-154.

Limestones, chalks, and marbles of high carbonate content and purity are discussed by States in alphabetical order. Includes some analyses and a sketch map showing location of chalk and limestone in the United States.

Wolfe, P. E., 1948, Agricultural mineral resources of New Jersey: Rutgers Univ., Bur. Min. Research Bull. 2, p. 18-50.

High-calcium limestones are restricted to the northern part of the State. The Franklin limestone (Precambrian), Jacksonburg formation (Ordovician), some Silurian and Devonian formations, and Recent calcareous marl deposits have high-grade stone. Discusses each of these limestones and includes a general description of the formation, its areal distribution, the available transportation, a sketch map showing the distribution of the formation, and a table of analyses.

Woodward, H. P., 1932, Geology and mineral resources of the Roanoke area, Virginia: Va. Geol. Survey Bull. 34, p. 121-125.

The Mosheim limestone (Ordovician) is the only high-calcium limestone in the Roanoke area. It averages about 23 feet thick and is uniform in both color and composition. It crops out in a narrow belt in the Catawba Valley just south of the Catawba Sanitorium. Analyses of two samples are given.

Wright, L. A., Stewart, R. M., Gay, T. E., Jr., and Hazenbush, G. C., 1953, Mines and mineral deposits of San Bernardino County, Calif.: Calif. Jour. Mines and Geology, v. 49, p. 166-181.

The limestone produced in San Bernardino County is consumed largely by the local cement industry. The Victorville-Oro Grande district is the chief producing area. This district and others are described in detail. Includes a few analyses and a map of the county showing location of mines and mineral deposits, scale 1 inch = 6 miles.

Yunck, George. *See* Ver Steeg, 1935.

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Anonymous, 1926, Limestone for portland cement in Greene County, N. Y.: Eng. Min. Jour.-Press, v. 121, no. 20, p. 805-806.

The Coeymans and Becraft limestones of the Helderberg group are both high calcium, but because of its higher position in the section, only the Becraft is quarried at present. The problems of mining in this area are discussed and demonstrated by a cross section and a small-scale map showing distribution and fault traces of the limestones. The possibility of underground mining west of the main fault where the rocks are less highly contorted and faulted is discussed.

——— 1931, To sell large limestone deposits in California soon: Rock Products, v. 34, no. 24, p. 83.

Reports on a newly discovered high-calcium limestone deposit in eastern Riverside County, Calif. There are reserves of more than 100 million tons averaging 99.45 percent calcium carbonate.

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Annotated Bibliography and Index Map of Salt Deposits in the United States

GEOLOGICAL SURVEY BULLETIN 1019-J



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Annotated Bibliography and Index Map of Salt Deposits in the United States

by WALTER B. LANG

CONTRIBUTIONS TO BIBLIOGRAPHY OF MINERAL RESOURCES

GEOLOGICAL SURVEY BULLETIN 1019-J

Contains references, to June 1956, on distribution of salt deposits, geologic occurrences, geophysical exploration, technology, experimental research, and historical accounts



UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1957

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

**For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 60 cents (paper cover)**

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III

CONTRIBUTIONS TO BIBLIOGRAPHY OF MINERAL RESOURCES

ANNOTATED BIBLIOGRAPHY AND INDEX MAP OF SALT DEPOSITS IN THE UNITED STATES

By WALTER B. LANG

ABSTRACT

Salt is abundant in the United States. Though of vital importance for domestic purposes in historic times, it has now become one of the most important commodities in industry and the demand for large tonnages of raw salt for industry is steadily increasing. The purpose of the bibliography is to serve as a ready reference to a wide range of subjects on salt which include the geographic distribution of salt deposits, geologic description of occurrences, geophysical exploration, technology, experimental research, and historical accounts.

INTRODUCTION

Common salt, the mineral halite, is of vital importance in the life of man. It was one of the first commodities to enter the arts and crafts of early man and in modern times has become one of the most essential commodities in industry. Where in the past, production of salt was for domestic use, an increasing demand now comes from the chemical industries, for food packing, refrigeration, weed and ice control, water conditioning, and many other technical applications.

The salt resources of the United States are enormous. In late years as prospecting to greater depth has been conducted for various commodities, large bodies of salt previously unknown have been discovered. These discoveries have not only added to the already large volume of known salt but also has widened our knowledge of its geographic distribution in sedimentary formations. Thus the question of adequate salt resources is not a present-day problem; but the coordination and adjustment of these natural occurrences of salt to the ever-changing requirements of economic industrial and chemical production, will be the chief concern for the future.

The great reservoir for salt is the sea. From this source, under certain conditions, concentrations of salt are made in shallow enclosed

basins upon the land where they may later become buried and so preserved along with other sediments. Where ground water encounters buried salt, the latter is dissolved and returns to the surface through springs. The salt either accumulates again in internal drainage basins or is returned to the sea by streams. Where tectonic forces have pressed upon deep-seated salt beds, the salt is squeezed upward and in some places comes out at the surface. Here erosion or ground water depending upon the climatic environment, soon removes it, and the salt ultimately returns to the sea. Some of the sources of commercial salt and the methods of production are listed in the following table.

<i>Source of salt</i>	<i>Method of production</i>	<i>Example</i>
Sea water.....	Solar evaporation.....	San Francisco Bay, Calif.
Salt springs.....	Evaporation vats.....	Star Valley, Wyo.
Salt lakes or flats.....	Harvesting in dry season..	Bristol Lake, Calif.
Rock brines.....	Drilling and pumping.....	Midland, Mich.
Rock-salt beds.....	Drilling, solution, and pumping.	Syracuse, N. Y.
Do.....	Underground mining.....	Detroit, Mich.
Rock-salt domes.....	.....do.....	Avery Island, La.
Rock-salt outcrop.....	Surface mining.....	Sevier Valley, Utah.

EXPLANATION OF THE ANNOTATED BIBLIOGRAPHY

This is an annotated bibliography about salt and, as such, contains information imparted or implied by the authors of the articles. It is intended to provide the reader with a general review of the variety of salt occurrences in the United States. Some references to the Canadian literature are also included because of the rapid recent developments in North Dakota and Montana and the contiguous areas of Canada. The selection covers a wide range of subjects: salt occurrences, geologic description, geophysical exploration, technology, experimental research, and historical accounts. The reader may pursue the subject of his special interest by use of the citations included in most of these references. Geologic names used in the references are those of the various authors and do not necessarily follow the usage of the U. S. Geological Survey.

To facilitate use of the bibliography, the entries are arranged in alphabetical order by the name of the author. The index provides subclassifications of the geologic and technologic subject matter. There is also a geographic classification of the references by their distribution in the States, and a map (pl. 4) which shows the distribution of the various occurrences of salt.

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Adams, J. E., 1944, Upper Permian Ochoa series of the Delaware Basin, West Texas and southeastern New Mexico: *Am. Assoc. Petroleum Geologists Bull.*, v. 28, p. 1596-1625.

Outlines the origin and the formations of the upper Permian evaporites that contain the major salt bodies in the Permian basin.

Adams, T. C., 1938, Recent deposition of salt from Great Salt Lake: *Jour. Geology*, v. 46, p. 637-646.

Great Salt Lake precipitates sodium sulphate each winter and redissolves this salt during the early spring. However, within the last 4 years (1934-38) summer precipitation of sodium chloride has also taken place as an accompaniment of the unprecedented low level of the lake. The sodium chloride returns to solution during the early winter, completing a spectacular annual cycle of salt precipitation and resolution. Winter precipitation of sodium sulphate is caused by the cooling of the water; summer precipitation of the chloride is caused by the annual reduction in volume of the lake, a result of heavy summer evaporation and reduced inflow during the season. A large tabular deposit of almost pure sodium sulphate is buried in the beach sands along the southeast shore of the lake and may be related in its formation to past winter precipitation of this salt similar to that now being observed.

Ageton, R. V., 1938, Salt occurrences in the potash mines of New Mexico: *Am. Inst. Min. Metall. Eng. Trans.*, v. 129, p. 353-363.

Describes certain structural features found in the potash beds of the Salado formation in the mines of the United States Potash Co. and the Potash Co. of America, east of Carlsbad, N. Mex. Gives an interpretation of the manner of formation of the three identified variant types that depart from the normal seam; the depositional, erosional, and structural salt horses.

Alexander, C. W., 1946, Developments in Southeastern States in 1945: *Am. Assoc. Petroleum Geologists*, v. 30, p. 1023.

With respect to exploratory drilling for petroleum in Wilcox County, Ala.: "This test, abandoned at a total depth of 8,250 feet, penetrated 100 feet of Eagle Mills salt, from 8,150 feet to bottom of the hole, extending the salt basin well beyond the previous considered limits. The known presence of salt at this point will be of value as related to geophysical interpretation."

Alling, H. L., 1928, The geology and origin of the Silurian salt of New York State: *N. Y. State Mus. Bull.* 275, p. 5-132.

Discusses at length the stratigraphy of the Silurian in western New York and gives possible explanations for the origin of the salt.

Ames, J. A., 1950, Northern Appalachian salt: *Min. Eng.*, v. 2 (i. e., v. 187), p. 557-559.

Reviews briefly the occurrence, distribution, and future trends in salt production in Ohio, West Virginia, Pennsylvania, and New York.

Andrickuk, J. M., 1954, stratigraphic analysis of Devonian system, in *Western Canada Sedimentary Basin*, Am. Assoc. Petroleum Geologists, p. 68-108.

Gives a review of the stratigraphy of the extensive Devonian system of rocks in western Canada and the contiguous part of the United States east of the Rocky Mountains. Exploration for petroleum in recent years has made possible correlation of the salines of the Middle Devonian.

Applin, P. L., and Applin, E. R., 1953, Cored section in George Vasen's Fee Well 1, Stone County, Miss.: U. S. Geol. Survey Circ. 298, 29 p.

In the deepest well (20,450 feet) east of the Mississippi River anhydrite and rock salt were penetrated below the base of the Smackover formation of Late Jurassic age.

Arthur, E. P., 1941, Annual Report: Denver, Colo. Bur. Mines, p. 43.

Lists U. S. Uranium Corp. as a producer of salt in Montrose County for 1941. Subsequent annual reports do not mention salt.

Bailey, G. E., 1902, Saline deposits of California: Calif. Min. Bur. Bull. 24, 216 p.

Gives a comprehensive and well-illustrated description of the geology of the great basin area of southern California, including chapters on the occurrence of borates, carbonates, chlorides, and nitrates contained within the area. It is particularly valuable for one desiring a perspective of California 50 years ago. Maps are included.

Baillie, A. D., 1953, Devonian system of the Williston basin area: Manitoba Dept. Mines and Nat. Res., Mines Br. Pub. 52-5, 105 p.

Describes by use of subsurface maps and cross sections, the stratigraphy and structural setting of the Devonian in Manitoba, Saskatchewan, Montana, North Dakota, and contiguous areas. Defines the salt-bearing Prairie and Davidson evaporites.

———1955, Devonian system of Williston basin: Am. Assoc. Petroleum Geologists Bull., v. 39, p. 575-629.

An amplification of the author's paper on the same subject contained in the Manitoba Department of Mines and Natural Resources, Mines Branch Publication 52-5.

Baker, A. A., 1933, Geology and oil possibilities of the Moab district, Grand and San Juan Counties, Utah: U. S. Geol. Survey Bull. 841, p. 13-23.

Gives the original description and definition of the Paradox formation which contains the largest body of salt of Pennsylvanian age in North America.

Baker, A. A., Dane, C. H., Reeside, J. B., Jr., 1933, Paradox formation of eastern Utah and western Colorado: Am. Assoc. Petroleum Geologists Bull., v. 17, p. 963-980.

Compares accounts of the geology of the Paradox formation and gives a section of the Hermosa and Paradox formations. Indicates the trend and marginal boundary of the saline basin and suggests a southeastward connection to the open sea.

Balk, Robert, 1949, Structure of Grand Saline salt dome, Van Zandt County, Tex.: Am. Assoc. Petroleum Geologists Bull., v. 33, p. 1791-1829.

This detailed study describes the structure of the salt in a part of the Grand Saline salt dome exposed by mining operations. The layered salt is steeply folded but shows no fractures, faults, cross cutting salt layers, foreign inclusions,

or brine. Anhydrite inclusions display a linear alinement with the salt grain, and in places halite crystals are elongated. Deformation has been by mass molding of the salt. A structure map of the mined area and diagrams of salt doming are included.

———1953, Salt structure on Jefferson Island salt dome, Iberia and Vermillion Parishes, La.: *Am. Assoc. Petroleum Geologists Bull.*, v. 37, p. 2455-2474.

Describes the structure and characteristics of the salt. The origin and dimensions of the salt dome are presented along with a structure map of the mined area.

Baltimore and Ohio Railroad Company, Baltimore, Md., 1949, Salt report for the Baltimore and Ohio Railroad area: *Manager Indus. Devel., Traffic Dept.*, 56 p.

Contains a compilation of rock salt and brine resources of parts of the States of New York, Pennsylvania, West Virginia, and Ohio within the area served by the Baltimore and Ohio Railroad. The book, in looseleaf binding, is well illustrated with simple maps and diagrams, showing the areas underlain by salt and the location, depth, and thickness of brine sands in producing wells. Brines are found from the Ordovician to the Pennsylvanian and at increasing depth from west to east. Analyses of the more representative brines are given. The information provided is sufficiently comprehensive to give the reader an excellent and concise preview of the saline resources of the region.

Bangston, R. J., Moore, D. D., Ramsey, R. H., and Lund, R. J., 1950, *Mineral Resources of southeastern Ohio*: Ohio Dept. Nat. Res., Div. Geol. Survey, p. 79-88.

Presents a compilation of data on salt brines in southeastern Ohio, including maps showing areas of strong bromine and calcium concentrations and a geologic column indicating the brine-producing horizons. Seven companies produce salt in Ohio; 5 from rock salt and 2 from brines. Gives a list of salt producers and chlorine plants, with costs and the uses of the products.

Barksdale, Jelks, 1929, Possible salt deposits in the vicinity of the Jackson fault Alabama: *Ala. Geol. Survey Circ.* 10, 23 p.

Salt seeps in Clarke County apparently are related to the Jackson fault and the Hatchetigbee anticline. The regional dip is to the southwest, and it is believed that ground water descends to a source of salt and from there rises to the surface along fractures. The salinity and flow of the springs have remained constant for more than 70 years. These brines were a source of salt during the Civil War. Many shallow wells have been drilled for salt but none has so far encountered rock salt.

Barnes, R. B., 1933, Plasticity of rock salt and its dependence on water: *Phys. Rev.*, v. 44, p. 898-902.

Measurements indicate that water actually penetrates the interior of a salt crystal when wetted. Wetting causes a high degree of plasticity and tensile strength (Joffe effect) as measured by infrared radiation. *See also Phys. Rev.*, v. 43, p. 82-83.

Bartlett, Z. W., 1946, Salt and sulphur resources of Texas: *Tex. Acad. Sci. Trans.*, v. 29, p. 186-191.

Gives a general statement on the salt resources of Texas.

Barton, D. C., 1926a, The American salt dome problems in the light of the Roumanian and German salt domes, *in* *Geology of salt dome oil fields*: Am. Assoc. Petroleum Geologists, p. 167-208.

Contains a long description and graphic illustration of the representative forms of salt structures found in Roumania and north Germany. In Roumania, salt domes are commonly related to overthrusting in border-mountain areas. In Germany, compressive forces caused linear ruptures along which, and at the intersections of which, salt domes formed, but some apparently were caused by local influences. The roots of American salt domes have not been studied, but it is assumed they have a similar origin in depth. The anhydrite-gypsum-calcite cap rock is a typical feature of American salt domes. This type of cap rock is seldom present in Roumanian salt domes. In Germany the cap is commonly composed of gypsum; sulphur and oil are common associates in American domes.

——— 1926b, Pine Prairie salt dome, *in* *Geology of salt dome oil fields*: Am. Assoc. Petroleum Geologists, p. 419-436.

The article is chiefly concerned with prospecting for petroleum but mentions the occurrence in Louisiana of massive salt at a depth of only 500 feet under a thick cap rock of limestone and gypsum.

——— 1926c, The salt domes of south Texas, *in* *Geology of salt dome oil fields*: Am. Assoc. Petroleum Geologists, p. 718-771.

Describes 3 major (Palangana, Piedras Pentos, and Falfurias), 3 minor (Sal del Rey, Sal Vieja, and Chapeño), and 2 probable (Smith Corkill and La Lomita) salt domes in the tip of Texas. It also gives a comparison of their indicated forms with better explored salt structures in Germany.

——— 1933, Mechanics of the formation of salt domes with special reference to Gulf Coast salt domes of Texas and Louisiana: Am. Assoc. Petroleum Geologists, v. 17, 9, p. 1025-1083.

The salt in salt domes is believed to be of sedimentary origin and to have come from salt beds at depth. Gulf Coast salt domes were formed by static thrust and by downbuilding, a term used for differential compaction of the surrounding sediments. Salt domes may be formed along the crests of folds, zones of faulting, convexities in the top of the salt bed, or over deep canyons. Rim synclines, the limit of upthrust, and isotatic compensation are discussed. A map of the distribution of salt domes and other structural features of the Gulf Coast is included.

The volume of salt contained in Gulf Coast salt domes of Texas and Louisiana is calculated as 520 cubic miles and the age of the source bed is considered as Early Cretaceous or older. A table of compaction figures is also given. In the absence of evidence of dynamic thrust which might explain salt-dome formation, emphasis is placed on the relative merits of static thrust and downbuilding.

Barton, D. C., and Paxton, R. B., 1926, The Spindletop salt dome and oil field, Jefferson County, Tex., *in* *Geology of salt dome oil fields*: Am. Assoc. Petroleum Geologists, p. 478-496.

The report gives little useful information on salt, but contains descriptive data on a salt dome now famous for its early exploitation and prolific production of oil.

Bell, H. W., 1933, Discovery of rock salt deposits in a deep well in Union County, Ark.: Ark. Geol. Survey Inf. Circ. 5, p. 1-21.

The Lion Oil Refining Co. drilled a well 7,255 feet deep in Union County, Ark. Rock salt was drilled into at a depth of 5,960 feet which continued to the

Bottom of the hole. The salt is placed in the Trinity group of the Lower Cretaceous.

Berliner, J. F. T., 1930, Potash bibliography to 1928 (annotated): U. S. Bur. Mines Bull. 327, 530 p.

Many of the 3,967 entries of world literature on potash contain information about salt.

Blake, W. P., 1857, Geological Report, *in* Reports of Explorations and Surveys * * * from the Mississippi River to the Pacific Ocean: 33d Cong., 2d sess. S. Doc. 78, v. 5, p. 47, 309-310.

Mentions Casteca (Castaic) Lake in Tejon Pass as containing a thick crust of salt formerly used by the Indians, also a similar occurrence on the eastern side of the elevated plain of Taheechaypah. Briefly describes the saline bed of dry lake of the Colorado Desert (Salton Sea) and the occurrence of salts in Cajon Pass and the Mojave Desert.

——— 1915, Sketch of the region at the head of the Gulf of California, a review and history, *in* Corey, H. T., The Imperial Valley and Salton Sink: San Francisco, Calif., John J. Newbegin, pt. 1, p. 30-31.

Gives a sketch of the early records of Salton Sink; Emory, 1848; Williamson, 1853, and the changes made by New River. The New Liverpool Salt Co. bored a well 3 miles west of the tracks of the Southern Pacific where a 7-inch crust of salt (sodium chloride and magnesium chloride) was penetrated. The flood of 1891 is mentioned.

Browncker, J. A., 1906, Salt deposits and the salt industry in Ohio: Ohio Geol. Survey, 4th ser., Bull. 8, 42 p.

Presents the occurrences of salt by county and the methods of production and preparation as practiced before 1906.

Bradley, W. W., 1945, Economic mineral resources and production of California: Calif. Div. Mines Bull. 130, p. 196-199.

Lists the areas of salt production from dry lakes and locations of plants where salt is extracted by solar evaporation from sea water in California. Gives tonnage and value of salt production in California since 1887, markets, prices, and estimated reserves.

Breger, C. L., 1909, The salt resources of the Idaho-Wyoming border: U. S. Geol. Survey Bull. 430, p. 555-569.

Brine springs and rock salt occur in the area of Star Valley near Afton, Wyo. The brines are saturated and served in the early years as a source of salt for many mining camps of the region and for domestic use. The article contains a review of regional geology; considers the salt originally disseminated in the Beckwith formation, later accumulated in anticlines when folding took place, and subsequently transferred to Tertiary or Quaternary lake deposits when the latter were formed. Estimates of the quantity are given.

Browdesch, F. W., 1951, Beneficiation of Kansas number four salt: Kans. Geol. Survey Bull. 90, pt. 8, p. 192-218.

Discusses the methods of improving the quality of crude salt for market.

Brown, L. S., 1934, Age of Gulf Border salt deposits. Am. Assoc. Petroleum Geologists Bull., v. 18, p. 1227-1296.

The author contends that a basin must be isolated from the sea before halite beds form and that no large basin can be isolated from land drainage. From

Usiglio's succession the postulated sequence of deposition, in ascending order, is limestone, anhydrite, and halite. Salt deposits are not found throughout the Coastal Plain, but at Smackover, Ark., in Texas and Louisiana interior areas, and in the Gulf Coast proper. They are shown to be of different ages. The Comanche rocks occur upon the Pennsylvanian without intervening Permian, Triassic, or Jurassic. The salt at Smackover is said to be in the lowest lower Comanche, and the Louisiana-Texas salt to be of Glen Rose age.

Brown, W. F., 1952, Metals and nonmetallic minerals in the Arkansas River Basin, Kans.—preliminary report: U. S. Interagency Comm. Arkansas—White-Red Basins, Minerals and Geology Work Group, p. 9-11.

Gives annual production figures, estimate of reserves, and a map showing the subsurface distribution of salt in Kansas.

Buchen, J. C., 1937, Evaporating salt from the world's largest mineral deposit. *Am. Inst. Min. Metall. Eng.*, v. 18, no. 367, p. 335-338.

An outline of the production of salt by the Leslie Salt Co. from sea water in San Francisco Bay. Explains preparation of vats, evaporation process, and harvesting of salt. The production months are April to October when rainfall is slight. Rainfall is 10 to 18 inches per year; the evaporational differential is 31 to 43 inches per year for salt production. The bittern removed after salt crystallization contains 16.0 percent NaCl; 6.0 percent MgCl₂; 4.2 percent MgSO₄; 1.4 percent KCl; and 0.121 percent Br at 28° B_é. The ratio of K to Br is 11.5 to 1.

Buckley, S. B., 1874, Salt: *Tex. Geol. Agr. Survey 1st Ann. Rept.*, p. 52-54.

Gives an account of salt formed at low water, caused by tide and wind, along the Gulf Coast west of Corpus Christi. At Grand Saline, brine seeps and a well made available during the Civil War, 1,000 sacks of salt of 200 pounds each per day. Near Graham, Young County, salt was obtained from seeps along the banks of the Salt Fork. Also in Wise and Lampasas Counties, along the Red River, and at the crossing of the Pecos there were sources of salt.

——— 1876, Salt: *Tex. Geol. Agr. Survey 2d Ann. Rept.*, p. 22.

Salt "Abounds in the country along the upper Pecos above the road from Fort Concho to Fort Stockton. Near the Horse Head crossing of the Pecos are large deposits of salt in the bed of what is called Salt Lake. To this place wagons resort for supplies of salt for El Paso, Presidio and other counties."

California Division of Mines Mineral Information Service, 1954, Salt: v. 7, no. 2, p. 1-6.

Reviews the sources and methods of salt production in California and gives a supporting list of references.

Campbell, M. R., 1897, Description of the Charleston quadrangle, West Virginia: *U. S. Geol. Survey Geol. Atlas*, folio 72, p. 6.

The first salt furnace in Kanawha Valley was erected in 1797 at the Great Buffalo Lick. In 1808 the first salt well west of the Alleghany Mountains was drilled here. By 1844-54 salt production varied from 400,000 to 600,000 barrels annually and rivaled the output from New York State. It was found later that the salt water was coming from the Pottsville series at depths of 600 to 1,000 feet.

Campbell, M. R., 1904, Description of the Latrobe quadrangle, Pennsylvania: U. S. Geol. Survey Geol. Atlas, folio 110, p. 15.

Brine issuing from the Pocono sandstone was used in the early days to make salt, and gave name to Saltsburg, on the Conemaugh River. The salt works which stand by the old canal, and were fired with Freeport coal, ceased operations long ago.

Carsey, J. B., 1950, Geology of Gulf coastal area and continental shelf: Am. Assoc. Petroleum Geologists Bull., v. 34, p. 361-385.

Discusses in particular the characteristics and form of the continental shelf off the coast of Texas and Louisiana. Gives a stratigraphic cross section of the coast and shelf area in central Louisiana. The Eagle Mills formation is shown as the source of salt that has been squeezed into salt stocks to heights of 35,000 feet.

Clapp, F. G., 1931, Salt domes of Texas and Louisiana Gulf coast: Jour. Inst. Petroleum Technologists, v. 17, no. 91, p. 281-299.

Contains a review of the Gulf Coast salt domes and maps and tables indicating their distribution, geologic characteristics, stratigraphy, structure, and the methods and time of discovery.

Clarke, F. W., 1924, Data of Geochemistry: U. S. Geol. Survey Bull. 770 (fifth edition), p. 124-260.

Contains geochemical data on the ocean, waters of enclosed basins, mineral wells and springs, and saline residues.

Condra G. E., 1941, Industrial Nebraska in outline: Nebr. Conserv. Survey Div., Bull. 28, p. 16.

Gives a brief statement of early salt production and the possible development of a future salt industry under more favorable economic conditions.

Connolly, J. P., and O'Harra, C. C., 1929, The mineral wealth of the Black Hills: S. Dak. School Mines Bull. 16, p. 336-338.

In Wyoming, salt water issues from the Spearfish formation (Triassic) 9 miles north of Newcastle, near Cambria and the head of Salt Creek. During 1878 and later, salt was produced in wood-fired evaporating pans also used for chloridizing gold and silver ores from the Black Hills. The estimated spring flow is 60 gallons per minute. The water contains 3 percent of NaCl and minor amounts of CaSO₄, MgSO₄, MgCO₃, FeCO₃, SiO₂, but no Br or I.

Cook, C. E., 1938, Darron salt dome, Ascension Parish, La.: Am. Assoc. Petroleum Geologists Bull., v. 22, p. 1412-1422.

The Darron salt dome, believed to have been formed by faulting, is the first one found east of the Mississippi River from which there has been sustained oil production. Oil is from Miocene sands above salt or from the same sands faulted up from depth. The top of the salt is 4,627 feet below the surface. A minor deflection of the river suggests recent movement of the dome. There is no gypsum or anhydrite cap on the salt.

Cook, C. W., 1914, The brine and salt deposits of Michigan, their origin, distribution, and exploration: Mich. Geol. Survey Pub. 15, Geol. Ser. 12, 188 p.

Presents at length the history of development, processes of manufacturing, and marketing of salt, with a table of the geologic occurrence of salt in the United States as known at the time.

Discusses the theories of salt formation and the geology of the southern peninsula, with maps and sections. Each formation is treated separately and analyses are given.

Cooke, C. W., 1939, The scenery of Florida interpreted by a geologist: Fla. Geol. Survey Bull. 17, p. 90.

A spring of salty water on the north side of Lake Kerr, Marion County, has the composition of dilute sea water. Fissures in the limestone from which the spring issues are 30 feet deep and extend below the fresh-water horizon and sea level. The salt water may be siphoning out of the limestone.

Cummins, W. F., 1890, The southern border of the central coal field: Tex. Geol. Survey 1st Ann. Rept. for 1889, p. 172-174, 195-196.

Mentions the occurrence of flowing salt wells at Waldrip and San Angelo and of salt at Colorado City, Salt Flat, and Salt Croton Creek. Describes Hanna and Hancock Springs at Lampasas.

——— 1891, Report on geology of northwestern Texas: Tex. Geol. Survey 2d Ann. Rept. for 1890, p. 444-448, 505.

Describes the early known occurrences of salt springs, flats, and wells along the eastern exposures of the Permian and drained by the Red, Wichita, and Brazos Rivers. Also mentions salt production at Colorado, Tex.

Cunningham, W. A., 1934, The potassium sulphate mineral polyhalite in Texas: Tex. Univ. Bull. 3401, p. 833-867 [1935].

Discusses the occurrence of polyhalite in the Permian salt deposits of West Texas, including its mineralogic characteristics, geologic associations, and economic possibilities.

Dane, C. H., 1935, Geology of the Salt Valley anticline and adjacent areas, Grand County, Utah: U. S. Geol. Survey Bull. 863, p. 25-33.

Gives a description of the Paradox formation (salt bearing) and related geology. Salt is not exposed at the surface but occurs at depth.

Darton, N. H., 1904a, Description of the Newcastle quadrangle, Wyoming-South Dakota: U. S. Geol. Survey Geol. Atlas, folio 107, p. 9.

Map shows location of a salt spring at the head of Salt Creek in Wyoming. Considers source of salt to be in the Spearfish formation and gives an analysis and estimate of flow of the spring.

——— 1904b, Zuni salt deposits, New Mexico: U. S. Geol. Survey Bull. 260, p. 565-566.

Twenty miles northwest of Quemado in central-western New Mexico is an elliptical depression about 1 mile wide that holds a shallow salt lake. This lake is spring fed near its southern border and the shallow margins are salt encrusted. Indians and Mexicans have gathered salt here for centuries.

——— 1920, Permian salt deposits of south-central United States: U. S. Geol. Survey Bull. 715-M, p. 205-230.

Includes a list and a discussion of logs of wells drilled in the Permian basin of Kansas, Oklahoma, Texas, and New Mexico which have penetrated notable thicknesses of salt in association with potash.

Darton, N. H., 1928, "Red Beds" and associated formations in New Mexico, with an outline of the geology of the State: U. S. Geol. Survey Bull. 794, p. 235-254 [1929].

Contains logs and records of wells drilled into Permian salt in the Pecos Valley of southeastern New Mexico.

De Golyer, E. L., 1926, Origin of North American salt domes, *in* Geology of salt dome oil fields: Am. Assoc. Petroleum Geologists, p. 1-44.

Presents an excellent historical review of the evolution of opinions and concepts on the origin of salt domes in the United States. The review of the literature is grouped into periods. The theoretical concepts are classified under four headings. Domes are regarded as formed (1) from old erosional outliers, (2) as salts deposited from rising solutions, (3) from volcanic sources, and (4) as a consequence of tectonic forces applied to sedimentary beds of salt at depth. De Golyer concludes that he favors the tectonic origin for salt domes, although he admits he cannot fully document his beliefs.

——— 1931, Origin of salt domes of the Gulf Coastal Plain of the United States: Jour. Inst. Petroleum Technologists, v. 17, no. 92, p. 331-333.

Gives a brief review of the concept of the origin of salt domes as of 1930. Also states that evidence of potash was found in the Bayou Bouillon dome of Louisiana as well as the Markham dome of Texas.

Dellwig, L. F., 1954, The process of deposition of Salina salt of Michigan: Jour. Sed. Petrology, v. 24, p. 129-130.

Compares the salt of the Salina formation with marine solar salt and concludes that as they have similar characteristics, they were formed under similar conditions. Believes seasonal or temperature changes are indicated by banding. Temperatures of deposition as indicated by liquid inclusions suggest lower temperatures of formation than previously considered.

Deussen, Alexander, and Lane, L. L., 1925, Hockley salt dome, Harris County, Tex.: Am. Assoc. Petroleum Geologists Bull., v. 9, p. 1031-1060.

Hockley salt dome, one of the largest known, has been prospected by many oil companies since 1905 with no discoveries of commercial oil or sulphur. Fifty wells have been drilled, ranging in depth from 200 to 4,600 feet.

Dobrin, M. B., 1941, Some quantitative experiments on a fluid salt-dome model and their geological implications: Am. Geophys. Union Trans., v. 22, pt. 2, p. 528-542.

An analysis of salt-dome formation made by the use of working models simulating geologic conditions. Viscous liquids assume movement comparable to salt under pressure. It is believed that plasticity is an essential for the intruded as well as the intruding rock. Movement is accelerated until a domal shape is well established, after which growth continues at a constant rate. Continued growth indicates a plentiful supply of salt, and, where the height of the dome is more than 10 times the thickness of the salt bed, additional salt is pressed from the marginal area.

Dole, R. B., 1913, Exploration of salines in Silver Peak Marsh, Nev.: U. S. Geol. Survey Bull. 530-R, p. 330-345.

The playa is estimated to contain 15 million tons of high-grade salt at depths of less than 40 feet. There were no promising indications of associated potash. The sediments to a depth of 50 feet were tested by drill and the results are presented graphically.

Donoghue, David, 1926, The Bayou Bouillon salt dome, St. Martin Parish, La., in *Geology of salt dome oil fields*: Am. Assoc. Petroleum Geologists, p. 345-351.

Gives a chronological record of prospecting the Bayou Bouillon salt dome before 1925. It is an asymmetrical salt dome with steep south and west flanks.

Dyer, B. W., 1945, Discoveries of potash in eastern Utah: Am. Inst. Min. Metall. Eng. Tech. Pub. 1755, p. 1-6.

Although this paper deals primarily with the occurrence of potash, the article also presents data on wells drilled into the salt of the Paradox formation in the Moab-Thompson area of Utah.

Eckel, E. C., 1903, Salt and gypsum deposits of southwestern Virginia: U. S. Geol. Survey Bull. 213, p. 406-416.

Thomas Jefferson, in his *Notes on Virginia in 1781*, mentions the occurrence of salt springs in southwestern Virginia, but rock salt was not discovered until 1840. Eckel considered the salt and gypsum to be an integral part of the Greenbrier formation. Logs of wells drilled for gypsum and possible rock salt on the Robertson property between 1815 and 1857 are given. Concludes that the salt aggregates 175 feet in thickness.

——— 1904, The salt industry in Utah and California: U. S. Geol. Survey Bull. 225, p. 488-495.

Describes salt production from Great Salt Lake, Utah, where salt is produced by solar evaporation. In the summer season 2 inches of water is evaporated per day from the salt ponds and about 3 inches of salt is formed in an average season, although 6-inch crops have been reported. Analyses of the water and a brief history of the salt industry are given. Comments on salt production in California at San Diego and San Francisco Bay are added.

Eskew, G. L., 1948, *Salt, the fifth element*: Chicago, Ill., J. A. Ferguson and Associates, p. 228.

This book although of mainly commercial interest, offers the reader a comprehensive review of the nontechnical and historic phase of salt production.

Fettke, C. R., 1941, *Subsurface sections across western Pennsylvania*: Pa. Topog. Geol. Survey Progress Rept. 127, p. 1-51.

Consists of descriptions of sample cuttings from wells drilled in western Pennsylvania, with a discussion of the correlation of formations from the St. Peter sandstone (Ordovician) to the Pennsylvanian. A map of the location of the wells and a table of formation thicknesses accompany the article. Salt is indicated in some of the Salina sections.

——— 1955, Preliminary report, occurrence of rock salt in Pennsylvania: Pa. Geol. Survey, 4th ser., Progress Rept. 145, maps, scale 1 : 960,000, with text.

Gives a graphic presentation, by columnar sections and depth and thickness contours, of the distribution of Salina salt in northwestern Pennsylvania. Also shown are the limits of salt occurrence and the position of the outcrops of rocks of the Salina group.

Filson, John, 1784, *Map of Kentucke [sic] for the Congress of the U. S. and George Washington*: Washington, D. C., Libr. Cong. (Sesquicentennial reprints).

On this map are indicated the following salt licks and rivers of importance as sources of supply to the early travellers migrating westward.

Bigbone Lick	Flat Licks
Blue Lick	Knob Lick
Blue Licks	Muddy Creek Lick
Blue Spring	Upper Blue Licks
Boonsboro Lick	
Bryans Lick	Licking River
Bulletts Lick	Salt River
Flat Lick	

Foshag, W. F., 1926, Saline lakes of the Mojave desert region: *Econ. Geology*, v. 21, p. 56-64.

Reviews the geologic and mineralogic conditions in the areas of Mojave saline lakes. Concludes with four premises: (1) The chief sources of playa salts are Tertiary saline sediments, rock decay, volcanic emanations, and hot springs. (2) Concentration of saline is largely confined to the surface layers. (3) The occurrence of crystals in playa muds is due to the downward diffusion of saturated solutions. (4) The concentration of large bodies of salts are the result of special conditions seldom duplicated.

Four Corners Geological Society, 1952, Geological symposium of the Four Corners region: Durango, Colo., 145 p.

Contains a group of papers on stratigraphy of the four contiguous corners of Utah, Colorado, New Mexico, and Arizona, and a description of the saline deposits of the Paradox formation.

Gale, H. S., 1915, Salines of the Owens, Searles, and Panamint basins, southeastern California: *U. S. Geol. Survey Bull.* 580-L, p. 251-323.

Gives geologic descriptions of the basins, their history, composition of dissolved salts, sediments, and character of the minerals contained.

——— 1951, Geology of the saline deposits, Bristol Dry Lake, San Bernardino County, Calif.: *Calif. Dept. Nat. Res., Div. Mines Special Rept.* 13, 21 p.

Gives a description of the geologic setting for Bristol Dry Lake near Amboy, San Bernardino County; the deposits, and a review of exploration and production operations. On the north side of the present playa, salt is mined at shallow depth below the surface. Calcium chloride and sodium chloride brines are drained off from the top clay bed by ditches. Where the brine is concentrated, sodium chloride crystallizes out leaving a concentrate of calcium chloride which is shipped in tank cars to Los Angeles. Gypsum was mined 2 miles southeast of Amboy. Concentrations of celestite occur in the top muds of the playa.

Gamb, G. C., and White, G. W., 1946, Salt reserves in Ohio's mineral resources, part 3: *Ohio State Univ., Eng. Expt. Sta. Circ.* 49, v. 15, no. 3, 22 p.

Lists seven salt producers. Diamond Alkali Co., at Painesville, and Pittsburgh Plate Glass Co., at Barberton, are the two largest, employing 90 percent of the salt workers. Includes brief data arranged by county on rock salt and brine production with tables. Two maps show areas underlain by rock salt or containing brines.

Goldman, M. I., 1926, Petrography of salt dome cap rock, in *Geology of salt dome oil fields*: Am. Assoc. Petroleum Geologists, p. 50-86.

Gives a detailed petrographic description of cap-rock core specimens from the Gulf Coast salt dome region. The specimens are composed mainly of anhydrite, gypsum, calcite, and sulfur. From the evidence, an attempt is made to ascertain the origin of cap rock.

——— 1952, Deformation, metamorphism, and mineralization in the gypsum-anhydrite cap rock, Sulphur Salt Dome, La.: *Geol. Soc. America Mem.* 50, p. 1-169.

Contains a detailed study of cores obtained by the Union Sulphur Co. from its test 194, drilled through 628 feet in the cap rock of Sulphur Salt Dome. Presents an identification of the minerals and an interpretation of their relation in the cap-rock formation.

Goldschmidt, V. M., 1954, *Geochemistry*: London, Oxford Univ. Press, 702 p.

A modern compilation of geochemical data. Ten pages of data on sodium appear in group IA of the alkali metals along with a statement of its place in the cycle of sedimentation. Chlorine appears in Group VIIB, requiring 14 pages to cover the subject.

Goldston, W. L., and Stevens, G. D., 1934, Esperson dome, Liberty County, Tex.: *Am. Assoc. Petroleum Geologists Bull.*, v. 18, p. 1632-1654.

This salt dome was one of the first discovered by geophysical methods (torsion balance). Oil was found in 1928. The salt mass was thrust up at a slight angle to the north. The Beaumont clay, which occurs at the surface, does not indicate the presence of a dome.

Gould, C. N., 1901, The Oklahoma salt plains: *Kans. Acad. Sci. Trans.*, 33d Ann. Mtg., 1900, v. 17, p. 181-184.

Presents an early description of the Big and Little Salt Plains of the Cimarron in Oklahoma just south of the Kansas boundary.

Grabau, A. W., 1920, *Principles of salt deposition*: New York, McGraw-Hill Book Co., 402 p.

This textbook covers rather completely the essentials of saline deposition and the geologic processes related to it. Abundant references are given.

Greter, R. E., 1949, Brine production and utilization from the salt sands of the Pottsville series: *Appalachian Geol. Soc. Bull.*, v. 1, p. 320-324.

Briefly mentions the geology of the Pottsville series in relation to brines. Of a hundred or more companies that began production of salt products in West Virginia, only two remain, the Hartford Salt Co. and the Westvaco Chemical Division of Food Machinery and Chemical Corp. Diamond Alkali Co. is in process of building a plant on the Kanawha River. Reviews the many products that are derived in part from brines.

Grossman, I. G., 1949, Geomorphology of the interior saline basins of western North Dakota: *N. Dak. Acad. Sci.*, v. 3, p. 14-15.

Postulates that in western North Dakota (1) where ground water drains along preglacial channels into kettle depressions with impervious bottoms, concentration of mineral matter occurs, (2) but where lakes drain through their bottoms or overflow into other lakes at lower levels during flood periods, they remain fresh.

Halbouty, M. T., and Hardin, G. C., Jr., 1954, New exploration possibilities on piercement-type salt domes, established by thrust fault at Boling Salt Dome, Wharton County, Tex.: Am. Assoc. Petroleum Geologists Bull., v. 38, p. 1725-1740.

Includes diagrams and a discussion of an interpretation of thrust faulting along the expanded head of a salt dome. Such an explanation gives a new concept for consideration in future exploration for oil in domes of this type.

——— 1956, Genesis of salt domes of Gulf Coastal Plain: Am. Assoc. Petroleum Geologists Bull., v. 40, p. 737-746.

The authors consider the Louann salt of the Gulf Coast to be the same age as the Castile formation (Permian) of the Delaware Basin, postulating that the Louann salt is the equivalent of the anhydrite of this basin. A connection between the two basins is proposed north of the central mineral region. Salt plugs are formed from the Louann salt by differential pressure of the overlying sediments on the lighter salt.

Hanna, M. A., and Wolf, A. G., 1934, Texas and Louisiana salt dome cap rock minerals: Am. Assoc. Petroleum Geologists Bull., v. 18, p. 212-225.

Lists 28 minerals found in a study of cap rocks. Contains illustrations of 47 specimens and a bibliography of related subjects.

Harris, F. E., 1939, Marketing of salt: U. S. Bur. Mines, Inf. Circ. 7062, 56 p.

Contains much data on the production, refining, and marketing of salt in domestic and world markets.

——— 1952, Salt in Mineral resources of the world: New York, Prentice-Hall, Inc., v. 2, p. 157-161.

Reviews the world production and trade in salt: world occurrences, production methods, preparatory processes, annual production by countries, and its various uses in the United States. Maps show distribution of major world deposits, world production, also salt deposits and producing plants in the United States.

Harris, G. D., 1907, Rock salt: La. Geol. Survey, Bull. 7, p. 48-259 [1908].

Gives the origin, geologic occurrences, and economic importance of rock salt in the State of Louisiana together with brief notes and references to all known salt deposits and industries of the world.

Harris, W. R., and Corell, E. J., 1945, Ohio's mineral resources, salt: Ohio Eng. Expt. Sta., Circ. 47, v. 14, no. 2, p. 13-19.

The earliest salt production by settlers was in 1797 in Jackson County where Indians had evaporated brines. In Gallia County, 1809, the first brine well was drilled 100 feet deep. Rock salt was first found in the Salina formation by the Cleveland Rolling Mill Co. at Newberg, and thus began a new era in salt production. Data on later developments are given. Salt production as an industry began in Muskingum Valley in 1817 with production rising to 400,000 bushels by 1833. (A bushel equals 80 pounds.)

Harrison, T. S., 1927, Colorado-Utah salt domes: Am. Assoc. Petroleum Geologists Bull., v. 11, p. 111-135.

The discovery and investigation of saline-bearing anticlines in southwestern Colorado and southeastern Utah has led to their classification into 4 groups, namely; saline anticlines bearing plugs, saline anticlines that bear no plugs, domes

not associated with anticlines, and structural anticlines. The regional geology and stratigraphy are presented along with maps, diagrams, and many illustrations.

Hayes, J. J., 1942, Great Salt Lake and its economic importance: Utah Mineralog. Soc. News Bull., v. 3, no. 2, p. 11-23.

Includes a geographic description of the lake, the early historical events, and analyses of the waters taken at various times. Gives the probable combination of the ions in solution, NaCl, Na₂SO₄, MgCl₂, CaSO₄, K₂SO₄. Estimates, as of 1942, the total worth of the salts in Great Salt Lake as \$44.5 billion as compared with \$3 billion for total value of mineral production in Utah since 1869. Briefly outlines the uses of the salines. Contains a bibliography.

Hazzard, R. T., Spooner, W. C., Blampied, B. W., 1945, Notes on the stratigraphy of the formations which underlie the Smackover limestone in south Arkansas, northeast Texas, and north Louisiana: Shreveport Geol. Soc., v. 1-2, p. 483-503.

Presents data for the depth to, and thickness of, the Louann salt and the underlying Werner anhydrite. Attempts to correlate these formations with the Permian of West Texas and to reconcile their thickness with the proportional volumes of salts contained in sea water. Invokes the Branson theory as a means of explaining deficiencies. Contains correlation charts and well records for the area.

Hewett, D. F., Callaghan, Eugene, Moore, B. N., and others, 1936, Mineral resources of the region around Boulder Dam: U. S. Geol. Survey Bull. 871, p. 92-98.

Lake-bed deposits of the Verde formation crop out along the Verde River valley near Camp Verde, Ariz. Some salt occurs along with thenardite in these beds. Salt crops out in the Virgin Valley.

Hildreth, S. P., 1945, Ohio's mineral resources, part 3, Salt; part 1, Salt springs, early history of the salt manufacture in Ohio; (repr.) with Foreword by W. E. Stout: Ohio State Univ. Studies, Eng. Ser. Eng. Expt. Sta. Circ. 47, p. 1-12.

This is a reprint of a paper published in 1838 and presents the conditions and sources of salt supply (salt springs or salines) from about 1800 to 1835.

Holyman, H. W., 1946, Seismograph evidence on depth of salt column, Moss Bluff dome, Texas: Geophysics, v. 11, no. 1, p. 128-134.

Presents an interpretation of seismograph data obtained from a traverse of Moss Bluff dome. Reflections yield figures of 36,000, 26,000, and 16,000 feet as the base of the salt column. Reasons are given for preferring the multiple reflection interpretation of 16,000 feet.

Hoskins, H. A., 1947, Analyses of West Virginia brines: W. Va. Geol. Econ. Survey Rept. Inv. 1, 22 p.

Gives tables of analyses of brines found in wells drilled into brine-producing formations of western West Virginia with information on the owner, location, depth to production, and the flow of the wells sampled.

Howard, K. C., 1951, Development and operation of LPG storage cavities in salt strata: *Jour. Petroleum Technology*, v. 3, no. 3, sec. 1, p. 10-11, sec. 2, p. 3.

Reviews the developments and experiences resultant from the operation of two reservoirs formed in salt for storage of propane: one in Winkler County and the other in Upton County, Tex. [LPG, low-pressure gas.]

Imlay, R. W., 1943, Jurassic formations of the Gulf region: *Am. Assoc. Petroleum Geologists Bull.*, v. 27, p. 1431.

"In southwest Alabama, 108 feet of the salt facies of the Eagle Mills formation was penetrated in the Union Producing Companies M. M. Waite No. 1, sec. 27, T. 8 N., R. 1 W., Clarke County, Alabama."

Inman, A. E., 1951, Salt—an industrial potential for Kansas: Lawrence, Univ. Kans. Pubs., 83 p.

Summarizes information on the occurrence and production of salt in the United States and Kansas. Outlines methods of mining and refining, uses, markets, and chemical products requiring salt for their manufacture; costs of plant construction and operation.

Joesting, H. R., and Fautschy, J. D., 1948, Reconnaissance gravity map of part of Gulf of Mexico: U. S. Geol. Survey. Prepared in cooperation with the Office of Naval Research.

A map covering an area of the Gulf Coast between Sabine Pass and Grand Cheniere, La., and extending out 75 miles from shore, records the gravity variations made within depths of 20 fathoms (120 feet). Within the area mapped, numerous salt domes have been discovered and the presence of others are suggested by anomalous gravity variations.

Johnson, O. B., Jr., 1951, Underground storage of propane in a salt water sand: *Jour. Petroleum Technology*, v. 3, no. 1, sec. 1, p. 14-15.

Outlines the technical factors and cost advantages for underground storage of propane in a salt-water sand as an alternative to reservoirs formed in rock salt or in steel tanks.

Jones, C. L., 1954, Occurrence and distribution of the potassium minerals in southeastern New Mexico: *N. Mex. Geol. Soc., Guidebook, Southeastern N. Mex.*, 5th Field Conf., p. 107-112.

Presents a cross section of the Ochoa series in a part of the New Mexico Permian salt basin, the stratigraphic succession of beds, and their relation to potash accumulation.

Jones, F. A., 1904, Salt, in *N. Mex. Mines and Minerals*: Sante Fe, N. Mex. Printing Co., p. 223-230.

Describes sources of salt supply in the early days, with analyses and production figures. Contains a picture of Crater Salt Lake.

Jones, G. E., Starkey, R. L., Feely, H. W., Kulp, J. L., 1956, Biological origin of native sulfur in salt domes of Texas and Louisiana. *Science*, v. 123, no. 3208, p. 1124.

The composition and environmental conditions of the salt-dome formations and the results of laboratory investigations of the S^{32} and S^{34} ratios of sulfate reduction to sulfide indicate that sulfate-reducing bacteria played an important part in the formation of sulfur. The bacteria probably reduced dissolved sulfate to hydrogen sulfide. The subsequent formation of sulfur was most likely due to a nonbiological process, such as a reaction between sulfide and sulfate.

Jones, T. S., 1953, Stratigraphy of the Permian basin of West Texas: *West Tex. Geol. Soc.*, 57 p.

Lists and describes the rocks of the Permian basin occurring in West Texas by systems and formations from the Precambrian to the Quaternary, including the salt-bearing formations of the Permian. An ample bibliography is given.

Keller, R. M., and Quirke, T. T., 1939, Mineral resources of the chemical industries: *Econ. Geology*, v. 34, p. 287-296.

Lists 150 chemicals essential to industry. For the manufacture of these chemicals, 34 raw materials are required. Salt is fifth in importance, being preceded by water, air, coal, and sulfur. Salt is essential to the production of 75 percent of the chemical products listed.

Kelly, P. K., 1926, The sulphur salt dome, Louisiana, in *Geology of the salt dome oil fields*: *Am. Assoc. Petroleum Geologists*, p. 452-469.

This article is of interest for its description of a salt dome of the typical small sulphur-bearing type, with a thick cap rock of the anhydrite-sulfur-limestone succession. It is also the place where the Frasch process was developed for the extraction of sulfur. A brief historical note, cross sections of the cap rock, and an outline of the Frasch process are included.

Kindle, E. M., 1904, Salt and other resources of the Watkins Glen district, New York: *U. S. Geol. Survey Bull.* 260, p. 567-572.

Rock salt was first found at Ithaca in 1885. The salt occurs in beds in the Salina from 5 to 50 feet thick and at depths of from 1,800 to 2,100 feet. The Cayuga Lake depression offers a 400-foot topographic advantage, with from 100 to 400 feet of easy drilling in the overlying glacial fill from Watkins Glen to Ithaca. Logs of wells drilled through the Salina at Watkins Glen and Ithaca are recorded; a brief sketch of the early salt development is given.

Knight, S. H., 1939, The Rock Creek lakes, Albany County, Wyo., part 2, in *The saline lake deposits of Wyoming*: *Wyo. Geol. Survey Rept. Inv.* 2, 8 p.

Gives an outline map of the saline lakes and descriptions and analyses of the salts in Brooklyn and Philadelphia lakes. The dominant salts are mirabilite and epsomite. Sodium chloride is present in negligible amount.

Kroenlein, G. A., 1939, Salt, potash and anhydrite in the Castile formation of southeast New Mexico: *Am. Assoc. Petroleum Geologists Bull.*, v. 23, p. 1682-1693.

Attributes the close of Capitan reef building to excess of evaporation over inflow to the basin. Confines the lower Castile to the Delaware Basin, with a total thickness of 2,000 feet of banded and white anhydrite, white halite, without potash. The top of the lower Castile has a depositional relief of hundreds of feet which makes correlation from this base inaccurate. Potash is the important mineral of the upper part of the Castile (Salado) and is present in amounts sufficient to satisfy the future requirements of the country.

Krumbein, W. C., 1951, Occurrence and lithologic associations of evaporities in the United States: *Jour. Sed. Petrology*, v. 21, p. 63-81.

Presents by maps the geographic distribution of evaporite deposits in the systems of rocks from the Ordovician to the Tertiary and gives a discussion of the lithologic relations of the evaporites to other sediments and to the structural basins in which they are formed.

Laizure, C. M., 1925 [Salines in Monterey County, Calif.]: Calif. State Min. Bur., Mining in California, v. 21, no. 1, p. 53-54.

Salt is extracted from sea water by solar evaporation at Moss Landing for local use in fish curing, ice cream, dairy and cattle markets. It requires 2 months of evaporation for initial salt crystallization, ultimately producing a layer of salt 4 to 6 inches thick. The salt is said to be more uniform in composition than that from San Francisco Bay.

——— 1927 [Salines in Solano County, Calif.]: Calif. State Min. Bur., Mining in California, v. 23, p. 211-212.

A well drilled by the Rochester Oil Co. in sec. 24, T. 5. N., R. 1. W., encountered a flow of natural gas and salt water. Salt was obtained by solar evaporation and marketed for many years as stock salt. There has been no production for about 10 years.

——— 1929 [Salines in Alameda County, Calif.]: Calif. Dept. Nat. Res., Div. Mines and Mining, Mining in California, v. 25, p. 441-447.

Salt, the chief mineral product of Alameda County, is obtained by solar evaporation of San Francisco Bay water. The Indians made periodic trips to the marsh lands for salt which had accumulated to a thickness of 8 inches. These natural deposits were worked by the early settlers from 1848 to 1860, when earthen evaporation vats were constructed, and by 1868, 17,000 tons of salt were produced annually. The new salt industry then extended from San Leandro Creek to Centerville, with 17 companies operating. When the Comstock lode was discovered a scarcity of salt developed and its cost rose to \$35 a ton. The operations of the Arden Salt Co., California Chemical Corp., Leslie-California Salt Co., and Morton Salt Co. are described.

Lamar, J. E., 1938, Brines, in Unexploited or little known industrial minerals of Illinois: Ill. State Geol. Survey Circ. 23, 5th Ann. Mineral industries Conf., p. 222-224.

Illinois was at one time an important salt-producing State. Formerly, salt works were in operation at Equality, Central City, Murphysboro, St. John, Danville, and probably elsewhere. All were in central or southern Illinois. Ultimately these works were closed because of salt production from other sources. The St. Peter sandstone seems to yield the strongest brines. A table of 13 analyses accompanies the article.

Landes, K. K., 1951, Detroit River group in the Michigan basin: U. S. Geol. Survey Circ. 133, 23 p.

Reviews the stratigraphy of Devonian rocks of the Detroit River group in the southern peninsula of Michigan. Contains a series of structure contour maps that are helpful in saline investigations.

Landes, K. K., Ehlers, G. M., and Stanley, G. M., 1945, Geology of the Mackinac Straits region and subsurface geology of the northern part of the southern peninsula: Mich. Dept. Conserv., Geol. Survey Div., Pub. 44, Geol. Ser. 37, p. 155-176.

Gives a description of the Salina formation and its stratigraphic position in the northern part of the southern peninsula. Near Saginaw Bay the Salina is 3,000 feet thick and the top of the section is at a depth of 5,000 feet. It is composed of dolomite, salt, and shale; 36 percent of the section is salt. The salt does not crop out; instead, breccia resulting from solution and collapse is found near the outcrop.

Lang, W. B., 1937, The Permian formations of the Pecos Valley of New Mexico and Texas: *Am. Assoc. Petroleum Geologists Bull.*, v. 21, p. 833-898.

Contains an outline of the stratigraphic position and distribution of the salines of the Permian basin and a discussion of the factors controlling Permian sedimentation.

La Vigne, E. F., 1938, Mining and preparation of rock salt at the Retsof mine: *Am. Inst. Min. Metall. Eng. Trans.*, v. 129, p. 381-403.

The economic depression in salt mining in 1895 brought most of the New York salt mining companies together under the Retsof Mining Co. banner. Retsof later became a subsidiary of the International Salt Co. Salt is mined by shaft at a depth of 1,063 feet. In 1926 a core test was drilled 784 feet below the mined salt bed. Logs of both mine shaft and core test are given, also a full description of the methods of mining and preparation of salt.

Le Grand, H. E., 1955, Brackish water in great Carolina ridge: *Am. Assoc. Petroleum Geologists Bull.*, v. 39, p. 2020-2037.

Brackish water of moderate salinity occurs in Bladen County, N. C. This salinity is apparently related to faulting associated with the great Carolina ridge. It is believed that the water entering Salt Marsh Creek is artesian and not invading sea water, which is likely true in Florida (Salt Spring and Warm Salt Spring, 86°F).

Lloyd, S. J., 1947, The world's greatest mine: *Jour. Chem. Education*, v. 24, p. 273-277.

Refers briefly to the various mineral products recoverable from sea water, the world's greatest mine. Gives a table in pounds of the minerals in sea water and paragraphs on salt and on gold, bromine, magnesium, and other elements.

Longwell, C. R., 1928, Geology of the Muddy Mountains, Nev., with a section through the Virginia Range to the Grand Wash Cliffs, Ariz.: *U. S. Geol. Survey Bull.* 798, p. 18-19, 93-94.

Lenses or beds of salt from 85 to 100 feet thick crop out in washes of Virgin Valley near St. Thomas.

Looker, C. D., 1938, Some recent developments in the use of sodium chloride (common salt): *Am. Inst. Min. Metall. Eng. Trans.* v. 129, p. 423-431.

Describes in general the uses of salt, with special reference to the Lixate solution process, the making and use of eutectic salt ice, and the stabilization of clay roads by the application of salt.

———1941, Salt as a chemical raw material: *Chem. Industry*, v. 49, pt. 1, p. 594-601; pt. 2, p. 790-799.

Reviews the salt industry in the United States, covering briefly the early uses and history of salt, production and refining methods, and the products and present uses of salt. Contains density tables for sodium chloride brines at 60°F, and diagrams of the relations of the alkalis to one another, byproducts and their uses, and the electrolytic products derived from fused salt.

Lotze, Franz, 1938, Steinsaltz und kalisalz geologie: Berlin, Verlag von Gebrüder Borntraeger, Band 3, Teil 1, 936 p. (Otto Stutzer, Die wichtigsten lagerstätten der nicht-erze ser.)

Summarizes the geologic occurrences of salt and potash in the world, including many maps and diagrams.

McGrain, Preston, 1953, Miscellaneous analyses of Kentucky brines: Ky. Geol. Survey, ser. 9, Rept. Inv. 7, 16 p.

Lists analyses of brines from oil wells in eastern and western Kentucky.

McGrain, Preston, and Thomas, G. R., 1951, Preliminary report on the natural brines of eastern Kentucky: Ky. Geol. Survey Rept. Inv. 3, p. 1-22.

Lists analyses of brines from oil wells in eastern Kentucky.

McLellan, H. J., Wendlandt, E. A., Murchison, E. A., 1932, Boggy Creek salt dome, Anderson and Cherokee Counties, Tex.: Am. Assoc. Petroleum Geologists Bull., v. 16, p. 584-600.

Boggy Creek salt dome is near the axis of the East Texas geosyncline. Its large size and shape are uncommon for salt domes, for it has a low central area on top. Faulting has occurred in the south end of the uplift. Oil is produced from the southeast flank of the dome.

Manning, P. D. V., 1941, Chemicals from California's desert: Chem. Metall. Eng. v. 48, p. 96-99.

Describes briefly the economic extraction of salts from the brines of three California desert lakes: the American Potash and Chemical Co. and West End Chemical Co. at Searles Lake: the Natural Soda Products Co. of Keeler, and Pacific Alkali, both at Owens Lake: and the Desert Chemical Co. producing sodium sulphate and sodium chloride at Dale Lake, discovered by Irwin Bush in 1920 to be a source of salts. The Pacific Coast Borax Co. operations at Mojave and Death Valley Junction are mentioned.

Mansfield, G. R., 1927, Geography, geology, and mineral resources of part of southeastern Idaho: U. S. Geol. Survey Prof. Paper 152, p. 98-99, 338-340.

In 1922 the Wallace-Wyoming Oil Co. drilled a well in Tygee Valley. Six beds of salt from 6 to 29 feet thick were penetrated in a section of 456 feet, from a depth of from 123 to 579 feet. The salt is in the Preuss sandstone of the Jurassic.

Mansfield, G. R., and Lang, W. B., 1934, The Texas-New Mexico potash deposits: Tex. Univ. Bull. 3401, p. 641-832 [1935].

Briefly reviews occurrences of potash contained in salt deposits of the world. Gives an account of the search for potash in the United States with special reference to the Permian salt basin of the Southwest. Analyses of salt samples from Government and oil-well tests in percentages of potash present are given.

Martens, J. H. C., 1943, Rock salt deposits of West Virginia: W. Va. Geol. Survey Bull. 7, p. 1-58.

Reviews stratigraphy of the Ohio basin in West Virginia, Pennsylvania, Ohio, New York, and includes logs of salt sections of many important wells. Gives analyses of the salt, estimates of reserves, and considers the possibility of salt in eastern West Virginia. Outlines salt production and uses.

Matheny, Frank, 1951, Underground storage for liquified petroleum gases: Petroleum Eng. Ref. Annual. v. 23, no. 8, p. C-49-52.

Outlines the problem of petroleum byproducts in seasonal demand the search for suitable storage in off-season periods. After a review of the situation, the conclusion is reached that a dissolved-out reservoir in salt is the most satisfactory and economical solution to the problem. Salt domes and salt beds are advantageously situated in or near many large oil-producing areas.

Matheny, W. F., and Billue, G. H., 1950, Underground storage tanks: *Chem. Eng.* v. 57, no. 12, p. 115.

Describes a test of underground storage of petroleum where, by dissolving the salt, a reservoir of 50,000 barrel capacity was formed between the depths of 1,167 to 1,750 feet. Five tests were made by filling and removing the petroleum from the reservoir. The first test recovered 95 percent of oil: the last 4 tests returned 99 percent of it to the tanks. The only noticeable effect on the oil was a slight inclusion of moisture. The maximum cost of storage per barrel is \$2.50 or about one-seventh that of steel-tank storage on the surface. The test was made in Winkler County, Tex.

Meinzer, O. E., 1911, Geology and water resources of Estancia Valley, N. Mex., with notes on ground-water conditions in adjacent parts of central New Mexico: U. S. Geol. Survey Water-Supply Paper 275, p. 7-86.

Describes the geologic setting for the saline lakes of central New Mexico, from which salt has been produced over the centuries.

Meinzer, O. E., and Hare, R. F., 1915, Geology and water resources of Tularosa Basin, N. Mex.: U. S. Geol. Survey Water-Supply Paper 343, p. 72.

Deposits of sodium chloride and sodium sulphate occur in certain low places. Thin crusts of sodium chloride occur on small northern alkali flats along Salt Creek and in arroyos and small flats east of the White Sands. Sodium sulphate in considerable quantities underlies Lake Lucero in the southern part.

Mendenhall, W. C., 1909, Ground waters of the Indio region, California, with a sketch of the Colorado Desert: U. S. Geol. Survey Water-Supply Paper 225, p. 27-28.

States that the Salton depression was covered by a salt marsh with salt crusts 6 inches to 1 foot thick before flooding by the Colorado River in 1904. The New Liverpool Salt Co. had developed a profitable salt industry before 1904. As much as nine-sixteenths of an inch of water was reported to have evaporated from salt pans in 24 hours when temperatures reached a maximum of 140°F.

Moise, T. S., and Haddock, G. B., 1936, The salt producing industry: Manufacturer's control of distribution; a study of Trade Practice Provisions in selected N. R. A. Codes, work materials No. 62. Trade Practice Studies Section, p. 2, 20-24, 67-159.

Reviews the salt industry with respect to its trade practices, sales, marketing, price maintenance, discounts, price discriminations, and freight equalization as it affects customer classification. Lists members of the Salt Producers Assoc. and their division of sales territory.

Murray, G. E., 1953, Résumé of salt and sulphur in Louisiana, in Proceedings of the southeastern mineral symposium, 1950: Ky. Geol. Survey, ser. 9, Special Pub. 1, p. 48-68.

A brief review of the geology of the Gulf Coast salt domes, with maps and diagrams.

National Petroleum Council, Committee on underground storage for petroleum, 1952, Report of the technical sub-committee: Washington, app. 1, 10 p.; app. 2, 8 p.; app. 3, 6 p.

Appendix 1 presents data on salt deposits suitable for the storage of petroleum products in various areas in the United States as a means of saving steel for

storage tanks. Appendix 2 deals with some chemical aspects of underground storage and appendix 3 with the engineering aspects of underground storage. Comparative costs are presented.

Nettleton, L. L., 1934, Fluid mechanics of salt domes: *Am. Assoc. Petroleum Geologists Bull.*, v. 18, p. 1175-1204.

The prime cause for salt dome formation is ascribed to density difference and plasticity of the sediments. The peripheral sink formed about the base of a salt stock may cut off the supply of salt. Expressions for volume relations and relative dimensions are given in terms of thickness of salt and radius of peripheral sink. The differential behavior of two liquids of different viscosities and densities is given by experiments. Diagrams are presented to show the effects of contemporaneous sedimentation and salt doming as an explanation for many of the geologic features of salt domes. A list of related references is included.

——— 1943, Recent experimental and geophysical evidence of mechanics of salt dome formation: *Am. Assoc. Petroleum Geologists Bull.*, v. 27, p. 51-63.

Gives a comparison of the factual data to experimental evidence in formulating a concept of salt dome evolution. It is concluded that salt domes are the consequence of fluid-mechanics where pressure and plasticity are the motivating factors. Recent evidence for the existence of rim synclines favor this postulation.

——— 1947, Geophysical history of typical Mississippi piercement salt domes: *Geophysics*, v. 12, no. 1, p. 30-42.

Describes the discovery and exploration of the New Home and D'Lo salt domes by geophysical methods. They were indicated by gravity surveys, checked by the refraction seismograph, and their depth and position confirmed by drilling. Gives examples of how strong, but local gravity expressions, may be missed by reconnaissance surveys.

——— 1955, History of concepts of Gulf Coast salt-dome formation: *Am. Assoc. Petroleum Geologists Bull.*, v. 39, p. 2373-2383.

A comparison is made of the earlier concepts of salt-dome formation with those of today. It seems evident that salt domes are due to a fluid adjustment of salt to density differences. A study of the quantitative relations involved in salt doming and of increasing evidence of the occurrence of rim synclines are impressive assurances of a displacement origin for the domes.

Nettleton, L. L., and Elkins, T. A., 1947, Geologic models made from granular materials: *Am. Geophys. Union Trans.*, v. 28, p. 451-466.

In part presents some results of experiments with dry powders as model materials to simulate salt-dome formation.

New Mexico Geological Society, 1954, Guidebook of southeastern New Mexico, 5th field conference: Socorro, N. Mex., 209 p.

A symposium of 19 papers which describes the geologic setting of the Permian salt basin in southeastern New Mexico.

New York State Department of Commerce, 1950, Mineral industries of New York: p. 54-60.

Gives a brief review of the salt industry in the State, a block diagram, a map of the salt area and a list of companies producing salt in the State.

Newland, D. H., 1919, Salt, in Mineral resources of the State of New York: N. Y. State Mus. Bulls. 223-224, p. 221-235.

Presents a comprehensive review of early history and development of the salt industry of New York State; also the mining, manufacture, and production of salt. Lists the plants, producers, and grades of salt marketed.

— 1928, Recent progress in the study of the Salina formation: Natl. Research Council Repr. and Circ. Ser. 85, p. 36-43.

Reviews the information accumulated on the Salina formation. Compares the sedimentary characteristics of the Vernon, Camillus, and Bertie beds. States the Camillus problem and concludes that the Salina sea was of marine origin, that the volume of salt present could not have been derived from erosional leachings, and that the cause of saline accumulation varied from place to place. Because there is no trustworthy evidence, concedes the point that the Silurian sea may not have had the same composition as the sea today has.

O'Donnell, Lawrence, 1935, Jefferson Island salt dome, Iberia Parish, La.: Am. Assoc. Petroleum Geologists Bull., v. 19, p. 1602-1644.

Jefferson Island is the only one of the Five Islands in southern Louisiana from which sulfur is produced. It is a flat-topped dome, capped by sulfur-bearing limestone and anhydrite. A salt spine rises 850 feet above the cap on the east side. Salt was discovered in 1894. Sulfur was accidentally drilled into in the late twenties. By 1935 more than 2,225,000 long tons of salt had been produced and 500,000 long tons of sulfur. The author believes that the spine and cap were initially formed and were later thrust up from the source of the salt. Salt is produced by conventional mining and sulfur by the Frasch process. The sulfur wells are in Lake Peigneur and are connected by pipeline to the plant on shore.

Osterwald, F. W., and Osterwald, D. B., 1952, Wyoming mineral resources: Wyo. Geol. Survey Bull. 45, p. 131-141.

Most of the saline deposits of Wyoming are of the sodium sulphate-sodium carbonate types. Sodium chloride occurrences in brines or in deposits associated with other salines are given by counties.

Parker, T. J., and McDowell, A. N., 1955, Model studies of salt-dome tectonics: Am. Assoc. Petroleum Geologists Bull. v. 39, p. 2384-2470.

Describes various experiments using asphalt and semifluid muds of greater density to simulate salt-dome formation.

Pepper, J. F., 1947, Areal extent and thickness of the salt deposits of Ohio: Ohio Jour. Sci., v. 47, p. 225-239.

From a study of the records of 3,555 wells, contour maps of the total thickness of salt, position of the top of the salt, and the variation in thickness of rocks between the top of the Big Lime and the top of the uppermost salt bed were constructed. The first salts were deposited in local basins; subsequent deposition occupied enlarged basins which later coalesced to form continuous beds of salt. Salt beds, 100 feet thick, approach to within 1,300 feet of the surface southwest of Cleveland (Lorain and Cuyahoga Counties) and descend southeastward to 6,734 feet (Monroe County) below surface. The western limit of the salt is defined.

Phalen, W. C., 1912, Description of the Kenova quadrangle [Kentucky-West Virginia-Ohio]: U. S. Geol. Survey Geol. Atlas, folio 184, p. 16.

"Many years ago salt was obtained from wells sunk on Big Sandy River near Zelda. The old salt works have long since disappeared. South of Zelda, near Catalpa, some of the wells drilled for oil and gas have struck salt water, which is still running."

——— 1919, Salt resources of the United States: U. S. Geol. Survey Bull. 669, 284 p.

This comprehensive study includes descriptions of salt deposits by States. History of production, extent of deposits, geology of the deposits, and a bibliography of literature available for each State are included. Maps indicate locations of deposits. The origin and formation of saline deposits, chemical composition of saline materials, and tables on production are also given.

——— 1949, Salt, in *Industrial minerals and rocks*: New York, Am. Inst. Min. Metall. Eng., 2d ed., p. 807-843.

Summarizes most of the essential factors of salt: its properties, composition, mode of occurrence, origin, and world distribution. Operations relating to production, consumption, processing, marketing, with tests and specifications of salt for human consumption, uses and prices are described. A bibliography is given.

Poindexter, O. F., Martin, H. M., and Bergquist, S. G., 1951, *Rocks and minerals of Michigan*: Mich. Dept. Conserv., Geol. Survey Div. Pub. 42, 3d ed. revised, p. 101.

Gives data on the salt beds of Michigan. In Ogemaw County a well was drilled through 1,066 feet of the Detroit River formation containing 300 feet of rock salt in 12 beds from 6 to 78 feet thick. Also in this well, 3,144 feet of Salina was penetrated, which contained 38 rock salt beds from 2 to 463 feet thick, totaling 1,260 feet of rock salt. A deep well in Bay County penetrated 2,790 feet of Salina with 1,700 feet of rock salt in beds of from 30 to more than 400 feet thick. The top of the Salina formation varies from 5,393 to 8,547 feet below the surface in Ogemaw County; from 5,480 to 8,270 feet in Bay County; and from 1,000 to 2,000 feet below the surface in Wayne County where 550 feet of salt occurs in 17 beds 20 to 90 feet thick.

Rock salt is mined from a depth of 1,100 feet below Detroit. Elsewhere at Midland, Taganau, Bay City, St. Clair, Port Huron, and also in Detroit, salt is manufactured from natural and artificial brines.

Powers, Sidney, 1926, Interior salt domes of Texas, in *Geology of salt dome oil fields*: Am. Assoc. Petroleum Geologists, p. 209-268.

Discusses the characteristic features of six salt domes located in the interior of eastern Texas—Grand Saline, Steen, Brooks, Keechi, Palestine, and Butler—and compares them with the interior domes of Louisiana. Contains an introductory outline of the history, exploitation, and stratigraphy of the salt-dome area.

Powers, Sidney, and Hopkins, O. B., 1922, The Brooks, Steen, and Grand Saline salt domes, Smith and Van Zandt Counties, Tex.: U. S. Geol. Survey Bull. 736-G, p. 179-239.

Gives geologic descriptions of the salt domes with logs of wells, maps, and gas analyses. Also gives a general description of the origin of salt domes.

Pray, L. C., 1954, Outline of the stratigraphy and structure of the Sacramento Mountain escarpment: N. Mex. Geol. Soc., Guidebook southeastern N. Mex., 5th Field Conf., p. 92-107.

Outlines the stratigraphy of the Sacramento Mountains, covering the complete section of rocks of Paleozoic age which include or are related to the salt beds of the Permian salt basin to the east of the mountains. Maps, illustrations, and a bibliography are included.

Price, P. H., 1952, Geologic field conference in Wayne, Cabell, and Lincoln Counties [W. Va.]: W. Va. Geol. Econ. Survey, p. 5.

At present there are no salt brine industries in Wayne, Cabell, or Lincoln Counties. Brines from the Salt Sand of Pottsville age and the Big Injun of Mississippian age have a specific gravity of 1.08 or more. The Big Injun sand always yields large flows of salt water when penetrated by drill holes.

Price, P. H., Hare, C. E., McClue, J. B., Hoskins, H. A., 1937, Salt brines of West Virginia: W. Va. Geol. Surv., v. 8, 203 p.

Gives a descriptive and historic sketch of the brine industry, the geology and chemistry of production, and many tables of analyses of brine samples from wells.

Price, P. H., and Nolting, J. P., 1949, Salt resources of West Virginia: Am. Inst. Min. Metall. Eng. Trans. 184, p. 259-263.

Reviews history of salt production from brines that are believed to be connate waters in marine sediments. The Middle and Lower Pennsylvanian and the Mississippian rocks are the most important containers of brine. The Salt Sand yielded a heavy brine of 1.1243 specific gravity; Big Lime, 1.1299; Big Injun, 1.1449; Brown Shale, 1.1617, and the Oriskany a brine of 1.2246 specific gravity. Calcium saturates the lower horizons. The brine section is calculated to contain 800 million tons of salt. Rock salt is available only from the Salina (Silurian). The northern part of the State is underlain by a bed of salt about 100 feet thick. Production is by solution only. A table of depths to the Salina salt is given.

Prommel, H. W. C., and Crum, H. E., 1927, Salt domes of Permian and Pennsylvanian age in southeastern Utah and their influence on oil accumulation: Am. Assoc. Petroleum Geologists Bull., v. 11, p. 373-393.

Presents explanations of the relation of subsurface saline formations to anticlinal structures and the stratigraphy of the region. Maps, cross sections, and other illustrations accompany the article.

Rall, C. G., and Wright, Jack, 1953, Analyses of formation brines in Kansas: U. S. Bur. Mines Rept. Inv. 4974.

Contains a list of 600 analyses of oilfield waters in which, with other elements, the amounts of sodium and chlorine are given.

Rankama, Kalervo, and Sahama, T. G., 1950, Geochemistry: Chicago, Ill., Chicago Univ. Press, 912 p.

This is a voluminous compilation of data on geochemistry containing many items having particular reference to both sodium and chlorine and to their combined form, salt. Subjects such as sea water, evaporation, chemical differentiation during sedimentation, the alkali metals and the halogens which are of importance in problems concerning salt are discussed.

Reidel, J. C., 1951, Ninety percent propane recovery from 50,000-bbl salt reservoir: *Oil and Gas Jour.* v. 49, p. 167-168, 236-237.

Describes a reservoir dissolved out of salt for the storage of propane at the Texas Gasoline Corp. plant in the Benedum field, Upton County, Tex. The top of the 1,000-foot section of salt is at a depth of 1,290 feet. The first test showed a recovery of 93.79 percent of the propane stored in the reservoir.

Richardson, G. B., 1904, Salt, gypsum, and petroleum in trans-Pecos, Tex.: *U. S. Geol. Survey Bull.* 260, p. 573-585 [1905].

Presents data on the salt lakes in Salt Basin west of the Guadalupe Mountains, with analyses of some of the salts. Traces of strontium, lithium, and potassium have been identified, also borax. Mexicans for centuries have come from as far as Chihuahua to gather salt from these lake flats. Denial of their use without payment caused the Salt War of 1877.

——— 1907, Underground waters in Sanpete and central Sevier Valleys, Utah: *U. S. Geol. Survey Water-Supply Paper* 199, p. 8-9.

The Jurassic rocks exposed in Sevier Valley contain lenses of salt and gypsum.

Ries, Heinrich, 1938, Use of sodium chloride in road stabilization: *Am. Inst. Min. Metall. Eng. Trans.*, v. 129, p. 432-438.

Presents data and explanations for the behavior of salt as a road binder for clay and soil surfaces.

Rogers, G. S., 1918, Intrusive origin of Gulf Coast salt domes: *Econ. Geology*, v. 13, p. 447-485.

Gives a critical review of the mechanics of salt-dome formation as evident from data known at the time. It assumes that salt from unknown depth is pressed through the overloading sediments toward the surface as opposed to a contemporary view held by most geologists that the salt was deposited by ascending waters.

Root, Bradley, 1953, The largest salt mine in the Western Hemisphere: *Explosives Engineer*, v. 31, no. 1, p. 49-52, 59.

Describes briefly the mining method and equipment used in the Retsof salt mine of the International Salt Co., Retsof, N. Y. The article is well illustrated.

Ross, C. P., 1941, The metal and coal mining districts of Idaho, with notes on the nonmetallic minerals resources of the State; annotated bibliography by C. P. Ross and M. S. Carr: *Idaho Bur. Mines Geology Pamph.* 57, 2 v., p. 109-110.

Describes briefly the occurrence of salt in the Preuss sandstone in southern Caribou County. Gives citations to salt, items 110, 406, 457, 565, 625, 726 in part 2, the Bibliography, volume 2 of this report. Also lists U. S. Geological Survey Mineral Resources 1882 to 1915 as references to information on salt.

Runnels, R. T., Reed, A. C., Schleicher, J. A., 1952, Minor elements in Kansas salts: *Kans. Geol. Survey Bull.* 96, p. 185-200.

Spectrochemical examination of mined salts, brines, and processed salts from Kansas revealed the presence of celestite, iron, and possibly polyhalite. Elements identified as present in minute quantity are Si, Al, V, Ti, Mn, Cr, Ca, Sn, Pb, Zn, and Ag.

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Schaller, W. T., and Henderson, E. P., 1932, Mineralogy of drill cores from the potash field of New Mexico and Texas: U. S. Geol. Survey Bull. 833, 124 p.

Contains a descriptive list of the minerals found in an examination of the salt cores obtained in wells drilled into the Permian salt beds of western Texas and southeastern New Mexico.

Schrader, F. S., Stone, R. W., and Sanford, Samuel, 1917, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, 412 p.

A revised edition of U. S. Geological Survey Bulletin 585 on the same subject. Lists and describes mineral occurrences including salt by States.

Senior, S. P., Jr., 1929, San Mateo County [Calif.]: Calif. Dept. Nat. Res., Div. Mines and Mining., Mining in California, v. 25, p. 253-254.

Describes the San Mateo plant of the Leslie-California Salt Refining Co. on the west side of San Francisco Bay where salt is produced from sea water by solar evaporation. The San Francisco Salt Refining Co. also produces salt on the marsh flats east of Redwood City.

Shoewe, W. H., 1943, Kansas oil field brines and their magnesium content, with chemical analyses by R. Q. Brewster and Calvin Vander Werf: Kans. Geol. Survey Bull. 47, p. 37-76.

Gives geographic distribution of oilfield brines and their analyses by stratigraphic position. Although the emphasis is on magnesium, data on sodium chloride are adequately presented.

Shrewsbury, R. D., 1946, A theory of the occurrence of salt domes: Oil Weekly, v. 122, no. 1, p. 36-39.

Presents largely a speculative view of an origin of salt domes with particular reference to their possible mode of occurrence in offshore locations.

Silsbee, J. L., 1925, Saline deposits of western Utah: Mining and Metallurgy, v. 6, p. 425-429.

Describes the operations and developments at Salduro for the extraction of potash from brines drained from the marsh. Gives representative analyses of the brine and a review of the economic factors involved. The very superabundance of salt in the intermountain region where industrial requirements are small makes production of sodium chloride for other than immediate local use uneconomic.

Sloss, L. L., 1950, Paleozoic sedimentation in Montana area: Am. Assoc. Petroleum Geologists Bull. v. 34, p. 423-451.

The Middle Devonian in western Montana is reported to contain large deposits of anhydrite and salt.

Smith, J. A., 1881, Biennial report of the Colorado State Geologist: Salt, p. 34.

"Several large salt springs exist in South Park, some 15 miles southeast of Fairplay, and some years since works were erected there capable of turning out 10,000 pounds of salt per day. Saline springs of various degrees of strength also exist at several other points in the State, some of which could be made profitable, but none of them have been improved, and many are not even claimed. Among the best of these are springs near the head of Salt Creek, a tributary of the Rio Dolores, which are so strongly saline as to render the waters of the creek quite briny."

Smith, R. A., 1914, Nonmetallic minerals; Mineral resources of Michigan: Mich. Geol. Survey Pub. 19, Geol. Ser. 16, pt. 2, p. 284-289.

Outlines the salt industry of the time. The record shows that most of the salt-producing areas of the present were then known. Along the shores of Lake Huron and Saginaw Bay, lumber mills in the early days engaged in salt production by burning waste sawdust to evaporate the brine obtained from wells. The decline in lumbering curtailed much of this production.

Snider, L. C., 1913, Gypsum and salt of Oklahoma: Okla. Geol. Survey Bull. 11, p. 202-214.

Describes the Alfalfa County salt plain, the salt plains of the Cimarron, known as Big and Little salt plains in Harper, Woods, and Woodward Counties; also those in Blaine, Beckham, Harmon, and Jackson Counties. The salt plains of the Cimarron are of historic interest because their salt was widely drawn upon by explorers and early settlers.

Spooner, W. C., 1926, Interior salt domes of Louisiana, in *Geology of salt dome oil fields*: Am. Assoc. Petroleum Geologists, p. 269-344.

Gives a general survey of the geology of northwestern Louisiana, including a note on exploitation of salt, and a comprehensive description of the Vacherie, Prothro, Bistineau, King's, Rayburn's, Price's, Drake's, Winnfield, Cedar Creek, and Coochee Beake salt domes.

— 1932, Salt in Smackover field, Union County, Ark.: Am. Assoc. Petroleum Geologists Bull., v. 16, p. 601-610.

Salt was discovered at a depth of 5,974 feet in the Hayes well A-9, sec. 4, T. 16 S., R. 15 W., Union County, Ark., and the drill continued in salt and thin lenses of anhydrite to 7,255 feet. On the basis of this and other data it is believed that the Smackover oilfield is on a salt-dome structure.

Stafford, O. F., 1939, Preliminary report upon Oregon saline lakes: Oreg. Dept. Geology and Mineral Industries Short Paper 1, 4 p.

The Abert, Summer, and Alkali dry lakes of south-central Oregon contain sodium chloride, sodium sulphate, sodium carbonate, potassium chloride, and borax. Production and delivery of salt from these lakes to markets along the Columbia River in competition with imports of solar salt from San Francisco is not considered likely. The economic production of sodium carbonate and the other salts from these lakes depends on successful research and better facilities to meet the competitive market.

Stone, R. W., 1937, Rock salt in Pennsylvania [abs.]: Econ. Geology, v. 32, p. 1072.

Although salt is not produced from deposits in Pennsylvania, large quantities are available. Fifteen deep wells drilled in 9 counties of western and northwestern Pennsylvania penetrated beds of salt in the Salina formation at depths of from 2,300 to 7,000 feet. Single salt beds are from 5 to 70 feet thick; one bed in Erie County is 15 feet thick; 4 beds in Washington County total 100 feet. Another test penetrated 22 beds from 6 to 55 feet thick which, with intercalated shale, represents a 407-foot section.

Stoep, G. W., 1911, Geology of the salt and gypsum deposits of southwestern Virginia: U. S. Geol. Survey Bull. 530, p. 232-255.

Describes the Holston River valley, giving an outline of the stratigraphy and structure of the rocks. The Maccrady formation, of the Mississippian, contains salt and gypsum. The gypsum occurs irregularly along an overthrust fault; the

salt is produced by solution from a depth of 2,000 feet on the east side of valley; it is shallower on the west. Natural brine seeps indicated the presence of salt below, which formed the only source of salt for the South during the Civil War. The author considers the salt and gypsum to be replacement deposits in relation to the fault.

Stout, Wilber, Lamborn, R. E., and Schaaf, Downs, 1932, Brines of Ohio: Ohio Geol. Survey, 4th ser., Bull. 37, 123 p.

Covers the history, origin, and stratigraphic succession of the occurrences of brines and their utilization and distribution by county and formation.

Stow, M. H. 1951, The mineral resources and mineral industry of Virginia: Advisory Council on Va. Economy, Comm. on Mining Rept., p. 43-44.

Rock salt occurs in association with gypsum in the valley of the North Fork of the Holston River. The valley extends 30 miles northeastward. No rock salt is mined in Virginia, but brine is produced by the Olin Mathieson Chemical Corp. at Saltville. It is believed that exploratory drilling might uncover additional deposits of salt.

Taft, Robert, 1946, Kansas and the nation's salt: Kans. Acad. Sci. Trans., v. 49, no. 3, p. 223-272.

Presents a general review of the occurrence of salt, its production and marketing, with special reference to Kansas.

Taylor, R. E., 1938, Origin of the cap rock of Louisiana salt domes: La. Dept. Conserv. Geol. Bull. 11, p. 1-183.

Gives a review of the geology, mineralogy, and literature of Louisiana salt domes. Describes the form and structure of cap rocks. Rejuvenated movement of the salt core in places may bypass the old cap, giving the impression, on insufficient exploration, that no cap rock is present. Concludes that the anhydrite of a cap is the same anhydrite as that found in the salt. Considers that ground water plays an important part in determining the size and composition of the cap rock.

——— 1955, Field trip to south Louisiana salt domes, in Russell, R. J., ed. Guides to southeastern geology: New York, Geol. Soc. America. p. 538-548.

Notes that 83 salt domes have been found in southern Louisiana: 27 in the northern part of the State, 50 in Mississippi, 1 in Alabama, 21 in east Texas, 51 along the Gulf Coast, and 5 in southwest Texas, making a total of 238 for the Gulf Coast region. Describes the general characteristics of salt domes, their size, depth, and mineral content, with more detailed data on Avery Island, Jefferson Island, and Weeks Island salt domes. Contains references and a map that shows the distribution of salt domes, both inland and offshore.

Teeple, J. E., 1929, The industrial development of Searles Lake brines, with equilibrium data: New York, The Chemical Catalog Co., Inc., 182 p.

Gives a brief historical outline and the operational development of the chemical plant for the successful production of the various salts from the Searles Lake brine. The presentation of equilibria diagrams constitutes two-thirds of the book.

Todd, J. E., 1909, Description of Aberdeen-Redfield district, South Dakota: U.S. Geol. Survey Geol. Atlas, folio 165, p. 9.

Saline waters and crusts are found in Salt Lake, Lord Lakes, and their vicinities. Some shallow wells also yield water too saline for domestic use. The salt is believed to be leachings from the Pierre shale.

Trump, E. M., 1947, Mining soluble salines by wells: *Am. Inst. Min. Metall. Eng. Trans.*, v. 173, p. 223-229.

Outlines the Tully and Detroit methods previously developed to dissolve bedded salt from depth by solution and shows by description and diagram the advantages gained in using the Trump plan. In the Trump plan air is forced down with the water which forms a protective blanket between the salt above and the water, thus forcing solution of the salt to advance radially from the base of the well along the floor of the salt bed. By periodically raising the water level more salt is dissolved, and any impurities contained in the salt falls to the floor where it is eliminated from subsequent mining and refining operations.

Tucker, W. B., and Sampson, R. J., 1929 [Salines in Riverside County, Calif.]: *Dept. Nat. Res., Div. Mines, Mining in California*, v. 25, p. 524-526.

Before the flooding of Salton Sink in 1903 by the Colorado River, salt was produced from the dry bed by the New Liverpool Salt Co. The salt layer was reported to range from 10 to 20 inches thick. Salt is now produced by solar evaporation at the north end of Salton Sea, 6 miles southeast of Mecca. The present concentration of salt in the water is from 12 to 22 per cent: annual rainfall 1.48 inches, and an evaporation of 87 to 129 inches per year.

Tucker, W. B., Sampson, R. J., and Oakeshott, G. B., 1949, Mineral resources of Kern County [Calif.]: *Calif. Jour. Mines and Geology*, v. 45, p. 250.

A brief note indicates that the Long Beach Salt Co. is producing salt from Dry Salt Lake, 6 miles northeast of Cantil. Industrial salt is recovered from lake brine by solar evaporation.

Tustin, E. B., Jr., 1946, Salt, the most useful of mineral substances: *Calif. Jour. Mines and Geology*, v. 42, no. 1, p. 379-383.

Relates some of the early beliefs, superstitions, and biblical customs of ancient times regarding salt and its place in war and peace. Describes briefly the present vacuum process of salt production and mentions some of the uses of salt.

United States Bureau of Mines, 1924-31: *Mineral Resources of the United States*.

These annual reports are a continuation of those formerly issued by the Geological Survey and contain a chapter on salt, giving statistics on production, consumption, prices, uses, imports, exports, and any notable changes in the industry during the year.

——— 1932-52: *Minerals yearbook*.

These annual reports are a continuation of those previously appearing under the title of *Mineral Resources of the United States*. Each annual report contains statistics on the production, consumption, uses, prices, imports, and exports of salt. New developments in the industry are also noted.

United States Geological Survey, 1882-1923: *Mineral Resources of the United States*.

These annual publications contain reports on the geology of salt production with special reference to statistics of consumption, uses, prices, imports, exports, and current developments in the industry.

Vaughn, F. E., 1926, The Five Islands, La., in *Geology of salt dome oil fields*: *Am. Assoc. Petroleum Geologists*, p. 356-397.

Includes lucid descriptions and contour maps of each of the Five Islands, giving a general review of its history, geology, physiography, and paleontology.

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A final summation gives opinions on the age, formation, and lineal orientation of the five salt domes—Jefferson Island, Avery Island, Weeks Island, Cote Blanche, and Belle Isle. The domes have long been a major source of salt in Louisiana.

Veatch, A. C., 1899, *The Five Islands: La. Geol. Survey, Geol. and Agr., pt. 5, Special Rept. 3*, p. 209–262.

The article is of value as an historical review of the geology of the Five Islands and the various interpretations of their origin before the salt-dome concept. Rock salt was first discovered here in the United States in 1862 (Avery Island). The salt masses were postulated to be upturned salt blocks.

Names by which the Five Islands have been known are as follows:

<i>Early name</i>	<i>Later Names</i>
Belle	Iberia dome
Cote Blanche	Cote Blanche Island dome
Cote Carline	Jefferson Island (Depuys, Millers, Orange)
Grande Cote	Weeks Island
Petite Anse	Avery Island (Thomas, Salt, Marsh)

Veitch, W. M., 1943, Mining salt beneath the Kansas prairies: *Explosives Engineer*, v. 21, p. 180–182, 198.

Four companies mine salt in Kansas: Morton Salt Co., American Salt Co., Carey Salt Co., Independent Salt Co. Salt is produced by both solution and mining from a bed $8\frac{1}{2}$ feet thick and at a depth of 600 feet. Mining is done by the room-and-pillar method. A brief description is given of the solution process and vacuum refining.

Ver Plank, W. E., 1951, Salines in the Bay area, in *Geologic guide book of the San Francisco Bay Counties: Calif. Div. Mines Bull. 154*, p. 219–222.

The major production of salt in California is by solar evaporation. Favored by climate and natural facilities this method remains economically competitive. By modernization of refining methods salt of high purity is produced along with bromine, potassium, and magnesium chlorides from the bittern, when the market will permit. The raw water is drawn from San Francisco Bay which is only slightly less salty than the open-sea water (3.40 in comparison with 3.72 percent).

Voskuil, W. H., 1955, Salt, in *Minerals in world industry: New York, McGraw-Hill, Inc.* p. 286.

Briefly mentions salt as one of the primary necessities of life as well as of industry, and broadly states the areas of salt production in the United States and the uses for salt.

Wagner, N. S., 1947, Sodium chloride occurrence near Vale, Oreg.: *Oreg. Dept. Geology and Mineral Industries, Ore.-Bin*, v. 9, no. 9, p. 67–73.

Brines were early reported near Vale, Malheur County. To determine the facts, 9 hand-auger tests were drilled in the clay sediments of the area to a depth of 31 feet or less. Water samples taken in the wells gave salinities as much as 51,500 parts per million. Wells in the northwest sector of the group were strong in sulphates, those to the southeast high in sodium chloride. The origin of the brines remains uncertain. No bromine or iodine was found.

Weigel, W. M., 1938, The salt industry of Louisiana and Texas: *Am. Inst. Min. Metall. Eng. Trans.*, v. 129, p. 405–422.

Gives a general review of the salt industry in Louisiana and southeastern Texas.

Wharton, J. B., Jr., 1953, Jefferson Island salt dome, Iberia and Vermilion Parishes, La.: Am. Assoc. Petroleum Geologists Bull., v. 37, p. 433-443.

Reports on results of exploration in the last 20 years. Drilling on the south and southeast sides of the dome has revealed small individual accumulations of oil in sand with possibilities of finding many more on opposite sides of the dome. This drilling has made it possible to define the shape of the salt stock to a depth of 12,000 feet and has disclosed sharply upturned marginal sediments and radial faulting. The positions of the calcite-anhydrite cap and the sulfur pocket have been outlined.

Whitlatch, G. I., 1945, Minerals, in *Industrial resources of Tennessee; forests, agriculture, and minerals*: Tenn. State Plan. Comm., v. 2, revised ed., p. 90-91.

Although some occurrences of rock salt have been reported, no economically important bed has been found. Drilled wells have encountered brines from the Ordovician to Mississippian. Counties from which brines have been produced are mentioned. Hawkins County, contiguous to Virginia, is suggested as the most likely place to prospect for salt in Tennessee.

Willard, D. E., 1907, Salt and alkaline waters in lakes, in *Story of the Prairies*: Chicago, Ill., Rand McNally & Co., p. 154-156, 165.

Explains in simple terms that the mineralized lake waters of North Dakota are derived from leachings of Cretaceous rocks. The shallow wells generally yield hard, or alkali-bearing waters; the deep or artesian wells yield soft, or sodium waters.

Willis, Bailey, 1948, Artesian salt formations: Am. Assoc. Petroleum Geologists, v. 32, p. 1227-64.

Presents a lengthy discussion of what the author calls an artesian process of salt-dome formation in which it is postulated that saturated warm water rising from salt beds through fissures deposit salt and other minerals on cooling, and by the force of crystal growth enlarge the mass of the salt body.

Wilson, E. D., 1944, Salt—nonmetallics of Arizona: Ariz. Univ. Bull., v. 15, no. 4, p. 43; Ariz. Bur. Mines Bull. 152, Min. Tech. Ser. 41, p. 42.

A small tonnage of salt has been mined from the Camp Verde sulphate deposits in Yavapai County. Salt also is found in dry marshes along the Salt River, particularly in the brine seeps at Salt Banks. It is dispersed in the muds of dry lakes and playas.

Winchell, N. H., 1885, The Humboldt salt well in Kittson County [Minn.]: Minn. Geol. and Natural History Survey 13th Ann. Rept., p. 41-47.

There are salt springs in the Red River valley in the northwest corner of Minnesota and adjacent North Dakota and Manitoba. This fact was known as early as 1823. Wells drilled in the area for stock water gave an overflow of brine. It is suggested that the source of the salt is in the Devonian, although it may be in older rocks, or even the younger Carboniferous. The salt springs issue through openings in the covering sheet of clay.

Wright, A. J., 1953, Economic geography of Ohio: Ohio Geol. Survey, 4th ser., Bull. 50, p. 43-44.

Briefly mentions the salt and brine industry in Ohio, stating that salt production is both the oldest and newest mineral activity because of the rise in chemical

industries. Anticipates increased production of salt as a companion to abundant local sources of limestone and fuel which are required for the production of numerous chemicals.

Zimmerman, E. W., 1951, *World resources and industries*: New York, Harper & Bros., revised ed., p. 784-785.

Comments in general on the production and economic use of salt in the chemical industry.

Anonymous, 1929, Open pit salt mining in Utah: *Eng. Min. Jour.* v. 128, p. 814.

Salt crops out over an area 1.5 miles by 0.5 mile, east of Salina, Utah. The method of mining by the Great Western Salt Co. is described, also the procedure followed in recovering salt from a strong brine (27 percent) formed by solution of exposed salt by rain water.

——— 1951, Cities Service's Lowell project storing propane, Michigan: *Oil and Gas Jour.*, v. 50, p. 101.

A cavern was formed in a 250-foot bed of salt at a depth of 3,798 feet by dissolving out the salt, requiring 6 barrels of water for each barrel of underground space formed. Propane from the Pampa, Tex., plant was injected at 1,200 pounds per square inch gage. Withdrawal of the propane will be made by water displacement at 200 gallons per minute.

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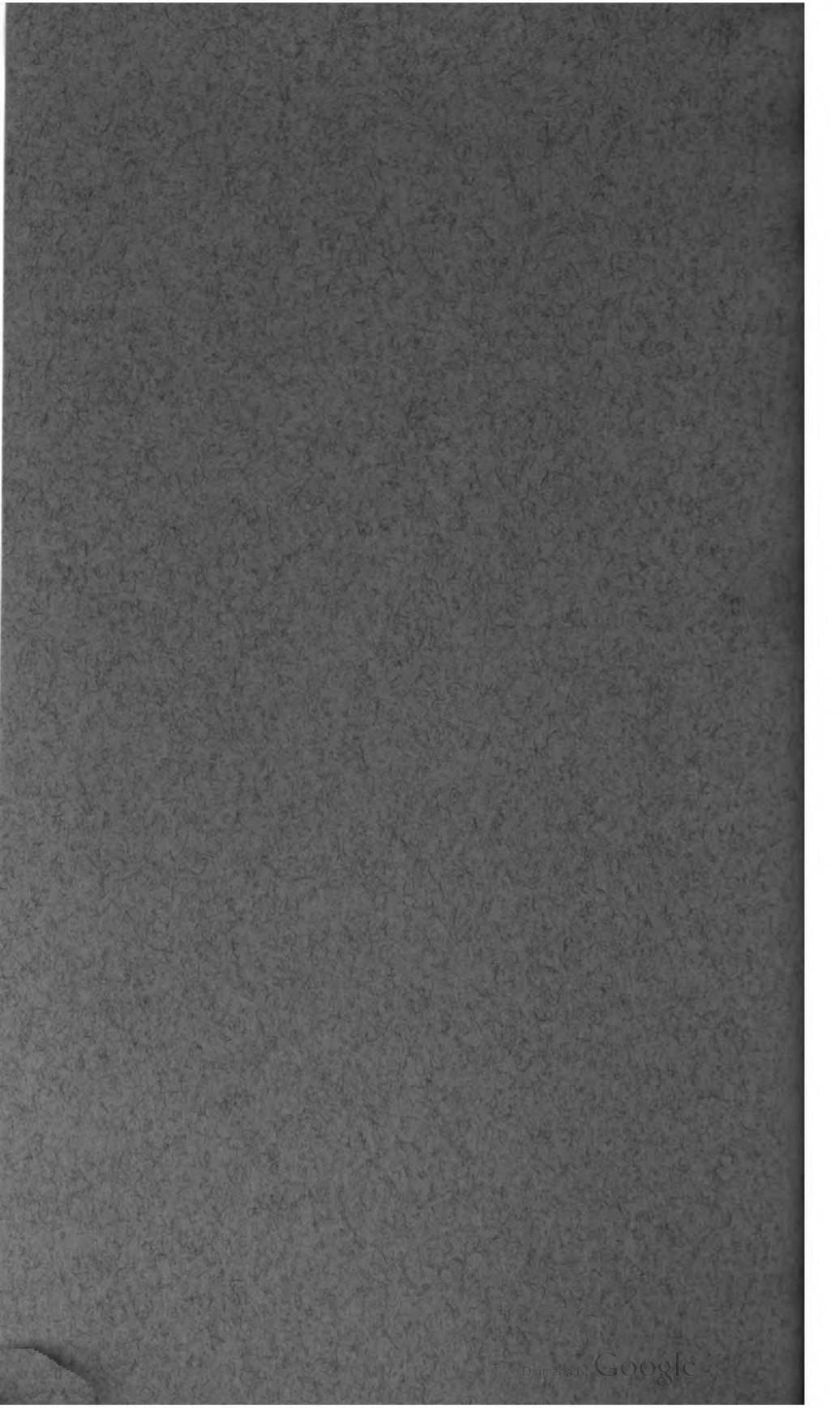
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Bibliography of Nickel

GEOLOGICAL SURVEY BULLETIN 1019-K





Bibliography of Nickel

By ETHEL M. PRATT and HENRY R. CORNWALL

CONTRIBUTIONS TO BIBLIOGRAPHY OF MINERAL RESOURCES

G E O L O G I C A L S U R V E Y B U L L E T I N 1 0 1 9 - K

Contains references, to June 1956, on the geology, ore deposits, history, economics, and metallurgy of nickel



UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1958

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

**For sale by the Superintendent of Documents, U. S. Government Printing Office
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BIBLIOGRAPHY OF NICKEL

By ETHEL M. PRATT and HENRY R. CORNWALL

ABSTRACT

This bibliography of nickel includes articles and books on nickel and represents references available to the authors in Washington, D. C. References are listed by author, location, and subject. Coverage is probably most nearly complete for publications on the geology and ore deposits of nickel, but an attempt was also made to include all available references on the history, economics, metallurgy, and other aspects of the nickel industry.

INTRODUCTION

Nickel is found in nature mainly in hydrothermal or magmatic sulfide deposits and in the lateritic mantle developed by the weathering of peridotite. In the sulfide deposits nickel occurs as pentlandite, $(\text{Fe, Ni})_9\text{S}_8$, associated with pyrrhotite, $\text{Fe}_9\text{S}_{8-11}$, and chalcopyrite, CuFeS_2 . Nickel also occurs in minor amounts in the following sulfides: Polydymite, millerite, siegenite, bravoite, and violarite. Nickel is also found combined with arsenic in niccolite, skutterudite, chloanthite, gersdorffite, and annabergite; it is combined with antimony in breithauptite and ullmannite. The largest and richest sulfide deposits of nickel are those being mined in the Sudbury district, Ontario, Canada.

Vast nickeliferous laterites are located in Cuba, New Caledonia, Indonesia, and the Philippines. Most of the laterite in Cuba, the Philippines, and Indonesia is of the nickeliferous iron type; the mode of occurrence of nickel in these deposits has not been determined. The laterite of New Caledonia and part of that in Indonesia, as well as smaller deposits in Venezuela and Oregon, are of the nickel silicate type in which nickel occurs as the hydrous silicate garnierite, the composition of which is variable.

Nickel was used as a coinage metal in very old times. As an alloy it has wide use for utensils, hospital apparatus, surgical instruments,

and monel metal. Pure nickel is now also used for domestic appliances and for laboratory equipment. Having great tensile strength and toughness, it is widely employed in the manufacture of steel—it is popular because of its corrosion resistance. Certain nickel alloys are used as electrical resistance wires, because of low conductivity. The salts of nickel are used in nickel-plating baths and to some extent in ceramics as a coloring agent.

References marked by an asterisk (*) are out of print, but they can be seen at many public and university libraries. Open-file reports and maps can be seen at the Geological Survey Library, Room 1033, General Services Building, Washington, D. C., and at various field offices whose addresses can be obtained by writing to the Geological Survey.

U. S. Bureau of Mines book publications can be purchased from the Superintendent of Documents, Government Printing Office, Washington 25, D. C. Reports of Investigations and Information Circulars can be obtained free from the Bureau of Mines Publications Distribution Section, 4800 Forbes Street, Pittsburgh 13, Pa.

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Selected Annotated Bibliography of Asbestos Resources in the United States and Canada

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Selected Annotated Bibliography of Asbestos Resources in the United States and Canada

By RUTH BUTLER AVERY, MARY LOU CONANT, and HELEN F. WEISSENBORN

CONTRIBUTIONS TO BIBLIOGRAPHY OF MINERAL RESOURCES

G E O L O G I C A L S U R V E Y B U L L E T I N 1019-L

*Contains references on the geology,
mineralogy, and origin of asbestos
resources*



UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1958

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

**For sale by the Superintendent of Documents, U. S. Government Printing Office
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CONTRIBUTIONS TO BIBLIOGRAPHY OF MINERAL RESOURCES

SELECTED ANNOTATED BIBLIOGRAPHY OF ASBESTOS RESOURCES IN THE UNITED STATES AND CANADA

By RUTH BUTLER AVERY, MARY LOU CONANT, and HELEN F.
WEISSENBORN

ABSTRACT

This bibliography of 198 annotated references to asbestos resources in the United States and Canada lists publications that appeared before January 1956. The alphabetically arranged annotations emphasize the geology, mineralogy, and origin of asbestos resources. The entries in the bibliography are cross indexed by geographic areas, geologic and mineralogic terms, and other topics of interest for research, mining, and prospecting.

INTRODUCTION

Asbestos has been recorded in literature from the days of the Romans, but it was not mined and used in large quantities until the deposits in Canada, near Thetford, Quebec, were opened in 1878. The first asbestos mined in quantity in the United States was from Georgia, as early as 1894. These discoveries encouraged prospecting and by the early 1900's many States reported deposits of asbestos.

The first major uses were as fireproofing fabrics; as woven, then molded brake linings; and as industrial packing. During World War II, spinning fibers with low-iron content became of strategic importance. Domestic asbestos production is greatly exceeded by domestic use, and foreign sources supply most of the ore. This bibliography contains information on mines, occurrences, and areas geologically favorable for asbestos in the United States (including Alaska) and Canada. Its preparation was prompted by an increasing need for asbestos and the consumption of reserve in asbestos-producing regions.

Asbestos comprises the naturally fibrous forms of the serpentine and amphibole groups of minerals. The important commercial varieties are chrysotile of the serpentine group, and crocidolite, amosite, anthophyllite, and tremolite of the amphibole group. Picrolite, a columnar brittle form of serpentine, has no known commercial value.

Actinolite, a common amphibole, rarely occurs in useful fibrous form. Paligorskite, also known as mountain leather, mountain cork, mountain flax, and pilolite, occurs in flexible sheets of interwoven fibers or as masses of matted fibers; it has little commercial use.

The asbestiform minerals occur in cross-, slip-, and mass-fiber habits. Cross fibers are nearly perpendicular to the walls of the veins, whereas slip fibers range from oblique to approximately parallel to the vein walls. Mass fibers are diversely oriented, sometimes as radiating aggregates but commonly as felted masses.

Chrysotile commonly occurs as cross and slip fiber, whereas crocidolite and amosite are principally cross fiber, Anthophyllite is commonly slip fiber and, like paligorskite, occurs also as mass fiber. Tremolite is ordinarily slip fiber.

Chrysotile, anthophyllite, and tremolite are the only commercial asbestiform minerals that occur in the United States. Chrysotile is associated with ultramafic rocks that occur in a narrow belt extending from Alabama to Maine along the east coast and in another belt from California to Washington on the west coast. Scattered occurrences of ultramafic rocks in Texas, Wyoming, Montana, Washington, and Idaho contain chrysotile. The large commercial chrysotile deposits associated with ultramafic rocks are in Vermont, but numerous small deposits have been mined in California. Minor deposits are known in Maine, Michigan, Montana, Oregon, Wisconsin, and Wyoming. In Arizona commercial deposits of chrysotile in metamorphosed limestone near diabase intrusives are mined; similar occurrences are known in New York, California, and Montana. Anthophyllite associated principally with ultramafic rock is reported in Georgia, Idaho, and Montana. Tremolite associated with serpentized peridotite occurs in California, Maryland, North Carolina, Oregon, Texas, Virginia, and Washington. In Alaska, tremolite, chrysotile, and paligorskite occur in ultramafic rocks, but only small quantities have been produced.

Most of the Canadian deposits are chrysotile asbestos associated with serpentized peridotite. They occur chiefly in Quebec, Ontario, and in British Columbia, but deposits are known in the Yukon Territory, Saskatchewan, and Newfoundland. The important ore bodies are associated with the ultramafic belts that extend northward from those in the United States. The eastern belt trends northeast from Magog, Quebec, through the Gaspé Peninsula, and into Newfoundland. The western belt trends northward from Princeton, British Columbia, into the Yukon Territory where it bends sharply and trends southwest through Alaska. Some chrysotile asbestos is found in limestones of the Grenville series in southern Quebec.

Canada produces about 60 percent of the world's asbestos, principally from chrysotile deposits in the Eastern Townships of Quebec,

the Cochrane district of Ontario, and the Cassiar district of north-western British Columbia. The Cochrane and Cassiar districts have been developed since 1950. Mines in southern Africa, especially those in Rhodesia, Swaziland, and Union of South Africa, produce about 15 percent of the world's asbestos. These three countries contain the major sources of crocidolite and amosite; they also produce chrysotile and anthophyllite. Although the United States consumes about 50 percent of world asbestos production (exclusive of Russia), it produces only about 4 percent of the world's asbestos. Most of the asbestos in the United States is produced from Vermont and Arizona; California, Georgia, and North Carolina are sporadic producers; and, until 1941, Maryland was an important producer. Small quantities of asbestos have been mined in Idaho, Montana, Oregon, Virginia, Washington, and Wyoming.

Asbestos is important because of its fibrous character and electric and thermal nonconductivity. Its various uses depend on the length, strength, flexibility, chemical and thermal stability, and iron content of the fibers. The most strategic fibers are those of spinning quality which have a low iron content. The major source in the United States is Arizona; the major source in the world is Southern Rhodesia.

Asbestos may be divided according to use into two major groups: (a) spinning fiber suitable for textiles, yarn, tape, rope, cord, thread, and wick, and (b) nonspinning fiber suitable for paper and cement products, for which uses the fibers are felted. Spinning fibers are of two types: crudes, which are hand cobbled, and milled fiber. All nonspinning grades are milled fiber. A few uses for fibers of spinning quality are yarn for cable wrapping, cloth for fireproof insulation and friction materials, tape for wrapping and oil wicks, and industrial filters. Shorter fibers, not of spinning quality, are used in felt, paper, and millboard for heat insulation and in molded form for brake linings. Increasingly large amounts of short fiber and impure grades of asbestos are used in composition materials, such as furnace linings, pipe coverings, siding shingles, and roof and floor tiles.

EXPLANATION OF THE ANNOTATED BIBLIOGRAPHY

The compilation of references, organization of material, and annotations for many of the references were done in 1953-54 by Ruth Butler Avery. Most of the references concerning New England and Canada were annotated by Alfred H. Chidester, aided by Wallace M. Cady and Arden L. Albee. Some of the references pertaining to the Arizona deposits were annotated by Andrew F. Shride, Fred N. Houser, and William P. Shulhof. The annotations were compiled and prepared for publication by Mary Lou Conant and Helen F. Weis-

senborn. They are selected from serials published through December 31, 1955.

The principal sources of references are—

Bibliography of North American Geology, 1919-54: U. S. Geol. Survey Bulls. 746, 747, 823, 937, 938, 949, 958, 968, 977, 985, 1025, 1035, 1049, and 1054;

Annotated Bibliography of Economic Geology, published semi-annually 1928-55; and

U. S. Geological Survey Library, Washington, D. C.

Geologic names listed are those of various authors and do not necessarily follow the usage of the U. S. Geological Survey.

The annotated references are listed in alphabetical order by author (or authors) with full title and publication data.

The references have been selected and annotated with emphasis on the geology and location of asbestos deposits and prospects. As an aid to understanding the geology, several papers on the origin of asbestos have been included. Articles on the origin of ultramafic rocks are also included inasmuch as asbestos is closely associated with them in many places. Work is being done on the synthesis of asbestos fibers to help supply the demand for some varieties; as a background for synthesis, studies have been made of the mineralogy. Articles on both these subjects have been annotated. References which cover mining and milling technology were excluded unless a description of the geology or exploration was included. Some older articles that have been superseded by more recent publications have been omitted. Newspaper and popularized descriptions are generally omitted. If several articles on one district, occurrence, or subject exist, only the more comprehensive ones are annotated.

The index serves as a cross reference between subjects and geography, and is based on the publications more than on the annotations. The deposits are indexed under the State or Province in which they occur. Subject emphasis is on geographic area, source rocks, and mineralogy; other topics include world resources, bibliography, prospecting, mining and milling methods, classification, production, uses, recovery, properties, and synthesis.

ANNOTATED BIBLIOGRAPHY

Alcock, F. J., 1947, The Appalachian region, in *Geology and economic minerals of Canada*, 3d ed.: Canada Geol. Survey Econ. Geology Ser. 1, p. 137-141.

The Eastern Townships of Quebec have yielded large quantities of cross-fiber chrysotile asbestos from serpentinized peridotite in the vicinity of Thetford, Black Lake, East Broughton, and Asbestos. Northeast of the main mining area similar serpentinized peridotites occur near Lake Matapedia, Mount Albert, Serpentine Mountain, and Port Daniel on the Gaspé Peninsula, but these areas have yielded no commercial fiber. The serpentinized peridotites and associated pyroxenites occur as sheets and stocks which are intruded by granites. Cross- and slip-fiber asbestos occurs in fissure veins as wide as 5 inches in the serpentinized peridotites. In some cross-fiber veins a single set of fibers extends unbroken from wall to wall; in other veins fiber extends from both walls, meeting at a central fissure that may contain serpentine similar to the wall rock or magnetite. The walls of the veins are serpentinite that grades quickly into the partly serpentinized peridotite. The veins may also be grouped as simple fissure veins or as ribbon veins in which a series of closely spaced parallel fissures are filled by asbestos. The asbestos is believed to have formed after the intrusion of the granite, when "vapors" traveling along fissures reacted with the peridotites, converting them to serpentine and depositing some of the excess material in fissures as asbestos.

Ambrose, J. W., 1942, Preliminary map, Mansonville, Brome, and Stanstead Counties, Quebec: Canada Geol. Survey Paper 42-1, scale 1 inch=1 mile.

Geologic map, with marginal descriptive notes, shows several long, narrow bodies of serpentine [serpentinite] in Precambrian(?) and Cambrian(?)-Ordovician rocks along Missisquoi Valley. Asbestos occurs in small amounts throughout the [serpentinite] bodies. "Some ore was quarried from the west side of the dike one mile south of Mansonville. Cross-fibre $\frac{1}{4}$ inch long and slip-fibre 3 inches long was seen in fragments on the dump, but the grade appears to be low."

Anderson, A. L., 1930, The geology and mineral resources of the region about Orofino, Idaho: Idaho Bur. Mines and Geology Pamph. 34, p. 43-51.

Mass, cross- and slip-fiber anthophyllite and tremolite occur in three deposits in the Orofino area, but only mass-fiber anthophyllite has been produced. Most of the asbestos is brittle, lacks tensile strength, and is usable for fillers in millboard, plasters, cements, and paints.

Near Kamiah, dikes and lenses of dunite largely altered to mass-fiber anthophyllite occur in Precambrian schists and gneiss which have been highly metamorphosed by the Idaho batholith. The deposits are as much as 80 feet wide and 600 feet long. Some ore has been produced. Near Teakean, narrow irregular fissure veins of slip-fiber anthophyllite as much as 18 inches long occur in lenses and dikes of serpentinized harzburgite in Precambrian schist and

gneiss. Minor quantities of mass-fiber tremolite and talc are present in the altered harzburgites but none of the tremolite has been produced. The Black-tail deposit consists of slip-fiber anthophyllite veins, 1 to 4 inches wide, in "talcose and serpentine rocks" in the upper part of the Triassic series.

It is believed that the asbestos deposits formed as replacement of ultramafic bodies, probably dunite or harzburgite, and are products of hydrothermal metamorphism related to igneous emanations. Geologic map, scale 1 inch=1 mile, is included.

Anderson, A. L., 1931, Genesis of the anthophyllite deposits near Kamiah, Idaho: Jour. Geology, v. 39, p. 68-81.

Anthophyllite occurs as lenticular bodies of mass-fiber formed by replacement of olivine in ultramafic intrusives. The anthophyllite is associated with antigorite, talc, carbonates, and pyrite, and commonly occurs in radiated aggregates. Deposits are believed to have been formed by hydrothermal metamorphism related to igneous emanations from the Idaho batholith. There has been a small production since 1909.

Anderson, Eskil, 1945, Asbestos and jade occurrences in the Kobuk River region, Alaska: Alaska Dept. Mines Pamph. 3-R, 26 p., revised ed.

Asbestos deposits are known on Dahl Creek, Shungnak River, Cosmos Creek, and Jade Mountain. Asbestos is reported along Wesley Creek and Kogoluktuk Creek.

Massive serpentinite containing chrysotile and tremolite crops out on Asbestos Mountain near the head of Dahl Creek. Cross- and slip-fiber chrysotile in veins as much as 2 inches thick occur in faults. Small quantities of slip fiber were produced. "High-grade tremolite" has been mined from narrow veins and lenses in a 100- to 200-foot-wide shear zone.

A peridotite mass on Bismark Mountain, just west of Shungnak River, contains a serpentinite zone as much as 2 miles long. Slip- and cross-fiber chrysotile occur in the sheared serpentinite. Most of the chrysotile observed was in float (talus).

The Cosmos Creek deposit consists of a network of cross-fiber veins, most of which are $\frac{1}{4}$ to $\frac{1}{2}$ inch wide, in a band of serpentinite. A zone as much as $\frac{1}{4}$ mile long in the serpentinite contains abundant chrysotile float.

At Jade Mountain, near the head of Jade Creek, a peridotite mass has been extensively sheared and serpentinized. Minor quantities of cross-fiber tremolite and chrysotile are common throughout the serpentinite. Throughout a small area along the eastern side of Jade Mountain, a network of cross-fiber veins averaging $\frac{1}{4}$ inch wide fill fractures in the serpentinite. Two geologic maps, scales about 1 inch=3,000 feet and 1 inch=45 miles, are included.

— 1947, Mineral occurrences other than gold deposits in northwestern Alaska: Alaska Dept. Mines Pamph. 5-R, p. 13-15, revised ed.

Pamphlet contains a list of known mineral occurrences of possible economic importance in northwestern Alaska. Only a brief description, or, if no description is available, a brief record of each occurrence is given. Each commodity is discussed with reference to the 6 mining precincts of northwestern Alaska. Asbestos occurrences are known from the Cape Nome, Fairhaven, Koyuk, and Noatak-Kobuk precincts. Little is known of occurrences in the first 3 precincts, but in the Noatak-Kobuk precinct asbestos occurs at California Creek, Dahl Creek, Cosmos Creek, Shungnak River, Jade Creek, and Hunt River. At Dahl Creek chrysotile and tremolite slip-fiber as much as 12 inches long occurs in ultramafic rocks. Chrysotile veins are less than 2 inches wide, whereas tremolite

Veins are as wide as 6 inches. Along Shungnak River asbestos occurs as fibers in a "mass of scaly serpentinite" float. Most of the asbestos probably occurs as short slip-fiber chrysotile on the flakes of serpentinite.

Arbeitstagung "Asbest" [1942], 1944, in Reichsberichte Chemie: Band 1, Heft 2, p. 103-147, 161-181.

Report contains papers on the occurrence, use, and synthesis of asbestos presented at a convention on asbestos in Dresden in December 1942. Each paper dealing with asbestos is cited as follows: the author's last name, complete title in German, followed by an English translation.

Sauerbrey, D. E.: Vorkommen und Verwendung von Asbest. [Occurrence and use of asbestos.]

Heyl: Bereitstellung, Verteilung und Einsatz von Asbest und -Austauschstoffen; Erzeugnisse für die verschiedenen Industrien und Verwendungszwecke. [Stockpiling, distribution, and use of asbestos and its substitutes; products for the various industries and uses.]

Lüdke, Werner: Die wissenschaftlichen Grundlagen der Asbest-synthese nach dem Verfahren Dr. Lüdke und Eigenschaften des synthetischen Asbestos. [The scientific basis of the Lüdke asbestos synthesis and properties of synthetic asbestos.]

Sitz, G.: Die technische Entwicklung der Asbestsynthese nach dem Verfahren Dr. Lüdke. [The technical development of the Lüdke asbestos synthesis.]

Preisser, F.: Asbest in der Asbestzementindustrie und sein Austausch in Kriegszeit. [Asbestos in the cement industry and its wartime substitutes.]

Schwab, K.: Asbest als Isolier- und Dichtungsmaterial. [Asbestos as insulation and packing.]

Krannich, W.: Austausch von Asbest Bei Flachdichtungen für Dampf und Wasser. [Substitutes for asbestos in flanges for steam and water pipes.]

Abstracts of these articles, in English, may be found in *Bibliography of scientific and industrial reports: U. S. Dept. Commerce, Office Tech. Services, v. 7, no. 8, PBL 52025, p. 677-679, 1947, and Chemical Abs., v. 41, no. 16, col. 5235-5236, 1947.*

Armstrong, J. E., 1940, The ultrabasic rocks of the Fort Fraser map-area (west half), northern British Columbia: Royal Soc. Canada Trans., 3d ser., v. 34, sec. 4, p. 21-32.

Discusses distribution and geology of ultramafic rocks in the area, and the existing theories of origin, mode of emplacement, serpentization, and steatitization of the ultramafic rocks. Veins and veinlets of chrysotile and picrolite were observed at some localities. White tremolite schist crops out on Mount Williams. Geologic map, scale 1 inch = 8 miles, is included.

— 1949, Fort St. James map-area, Cassiar and Coast Districts, British Columbia: Canada Geol. Survey Mem. 252, 210 p.

On pages 79-92, Armstrong describes distribution, composition, and geologic relations of ultramafic rocks and discusses the problems concerning mode of emplacement and serpentization of these rocks. Many bodies of ultramafic rock, the largest about 80 square miles in area, are shown on the geologic map.

Two occurrences of asbestos are briefly described (p. 136 and 197). At the head of Van Decar Creek on Mount Sydney Williams numerous chrysotile veins, as much as 1½ inches wide, occur in serpentized peridotite. The chrysotile is brittle and of poor quality. Two miles northwest of this deposit, 3 veins of cross-fiber tremolite, each 4 to 10 inches wide, are separated by 200 feet of

serpentinized peridotite. Fibers are brittle and are associated with picrolite. Geologic map, scale 1 inch = 1 mile, is included.

"Asbestos," 1919-55, Philadelphia, Pa., Secretarial Service.

Contains technical and nontechnical articles and reports pertaining to the asbestos industry. Current market conditions and changes in sale prices are reported. World asbestos export and import figures of the U. S. Bureau of Census are given.

Asbestos Textile Institute, 1953, Handbook of asbestos textiles: New Brunswick, N. J., 78 p.

Geology, mining, milling, grading, and processing of asbestos and asbestos fibers and textiles are discussed briefly. Emphasis is placed on Canadian deposits although most of the material is general. Descriptions of several asbestos textile products and the American Society for Testing Materials specifications and methods of testing these products are included.

Aubert de la Rue, Edgar, 1941, Matapédia Lake area; parts of the counties of Matane, Matapédia, and Rimouski: Quebec Bur. Mines Geol. Rept. 9, 40 p.

Ultramafic rocks are exposed at several localities in Awantjish Township, mainly along a hill known as Petit Mont Saint-Pierre, on the northern slope of the Notre-Dame mountains. These rocks represent a northeasterly prolongation of the serpentinite belt of the Eastern Townships and are intrusive into Silurian sediments. Prospecting for asbestos in ultramafic rocks has been carried on in Awantjish Township in the district just east of La Redemption. Most of the fiber is brittle picrolite but locally cross-fiber chrysotile as long as $\frac{1}{2}$ inch occurs. Geologic maps, scales, 1 inch = $\frac{3}{4}$ mile and 1 inch = 4 miles, are included.

Badollet, M. S. *See also* Faessler, 1947.

— 1948, Research on asbestos fibers: Canadian Mining and Metall. Bull., v. 41, no. 432, p. 213-216; Canadian Inst. Mining and Metallurgy Trans., v. 51, p. 131-134.

Research on the strength, composition, length, harshness or softness, filtration characteristics, and mineral associates of asbestos fibers are discussed with particular regard to the importance of these properties to utilization of asbestos in commercial products. The value of X-ray and petrographic studies and knowledge of geology and fiber characteristics of deposits are stressed.

— 1949, Filterability of asbestos fibers used in wet processes: Canadian Mining and Metall. Bull., v. 42, no. 451, p. 594-598; Canadian Inst. Mining and Metallurgy Trans., v. 52, p. 260-264.

Results of filtration studies made on asbestos fibers are described in detail. Filtration characteristics of different fibers are important in determining fiber or blend of fiber suitable for certain wet or semiwet manufacturing processes. Soft, silky fibers are difficult to filter, whereas semiharsh to harsh fibers filter easily. Article contains tables and graphs showing effects of asbestic fines, water temperature, serpentinite fragments, and "crudy fibre bundles" on filterability of asbestos.

— 1950, Processing asbestos fibers—Effects upon physical properties: Canadian Mining and Metall. Bull., v. 43, no. 461, p. 335-339, 487-491; Canadian Inst. Mining and Metallurgy Trans., v. 53, p. 321-325.

Physical properties of African blue crocidolite, Rhodesian chrysotile, Canadian semiharsh chrysotile, Canadian soft chrysotile, and Canadian harsh chrysotile during willowing are described. The changes caused by willowing are

shown graphically and include "lowering of fibre strength, loss in length, formation of fines, different degrees of buoyancy, changes in density, increase in surface area, and a tendency to become more difficult to filter."

Badollet, M. S., 1951, Asbestos, a mineral of unparalleled properties: Canadian Mining and Metall. Bull., v. 44, no. 468, p. 237-246; Canadian Inst. Mining and Metallurgy Trans., v. 54, p. 151-160.

Detailed article deals with principal properties of six varieties of asbestos: actinolite, amosite, anthophyllite, chrysotile, crocidolite, and tremolite. Tables showing physical properties, solubility, effect of temperature on loss of weight, combustion analysis of chrysotile, comparison of tensile strength of various materials, and comparison of approximate fiber diameters are included. Tests to determine properties are described. Electron micrographs of the various types of asbestos are also included.

Badollet, M. S., and Streib, W. C., 1955, Heat treatment of chrysotile asbestos fibers: Canadian Mining and Metall. Bull., v. 48, no. 514, p. 65-69; Canadian Inst. Mining and Metallurgy Trans., v. 58, p. 33-37.

A commercial method was developed whereby the "soft, silky and slimy" chrysotile fibers can be converted to fibers which have characteristics of natural semiharsh to harsh fibers. By "flash-heating" the fibers, a part of the molecular water was removed and some of the magnetite was converted to nonmagnetic Fe_2O_3 . Controlled temperature and heating time increases the bulk and surface area, and improves the filterability and electrical properties of the fibers; tensile strength will, however, decrease slightly.

Bain, G. W. See also Keith, 1932; Hess, 1933.

——— 1932, Chrysotile asbestos—II. Chrysotile solutions: *Econ. Geology*, v. 27, p. 281-296.

Serpentine in peridotite and dunite masses in Vermont is related to fractures and constitutes 30 to 100 percent of the masses. Chrysotile asbestos fills fractures in serpentinite, peridotite, and dunite. The three processes of vein filling are serpentinization, conversion of serpentine to talc, and granitization. "Each is a constant volume change and * * * volume balance is maintained by removal of material." Each process is discussed with emphasis on volume and mass relations. Of the 88 serpentinite masses studied, about 50 percent have talc at one end of the mass and asbestos at the other. Cross-fiber chrysotile is concentrated in the least altered rocks, whereas slip fiber is more generally distributed. Movements of serpentine dissolving solutions and chrysotile depositing solutions and the chrysotile-talc-serpentine-dunite relations are described. Solutions seem to have moved from areas of highly altered rocks to those less altered rocks which have a fracture cleavage vital for chrysotile deposition. The alteration was produced by "silicon acid" solutions derived from granite intrusions.

——— 1936, Serpentinization of Vermont ultrabasics: *Geol. Soc. America Bull.*, v. 47, p. 1961-1980.

Report has no specific mention of asbestos occurrences; however, it contains sketch maps and describes several ultramafic bodies in which asbestos is known to occur. Reviews existing theories of origin and serpentinization of ultramafic rocks. Bain concludes that in Vermont there are three types of serpentinite: a red-weathering type of autometamorphic origin, a whitish-weathering type (verde antique) of tectonic origin, and a much later type formed by weathering.

Bain, G. W., 1942, Vermont talc and asbestos deposits, in Newhouse, W. H., ed., Ore deposits as related to structural features: Princeton, N. J., Princeton Univ. Press, p. 255-258.

Talc and asbestos deposits occur in partly or wholly altered steeply-dipping "lens-shaped" masses of saxonite or dunite. The three stages of alteration which have been recognized are autometamorphic serpentinization, followed by antigoritization, and then formation of talc and chrysotile deposits. Talc deposits are commonly found on the "keel," or at one end of the mass, whereas asbestos deposits generally occur in the serpentinized rocks at the opposite end of the mass. The asbestos and talc deposits were formed through the reaction of "alkalic solutions" with ferromagnesian minerals in the saxonite and dunite. Distribution of the alteration products suggests that the mineralizing solutions ascended the tectonic axes along which the igneous rocks were intruded. Several talc and asbestos deposits are briefly described.

Bain, H. F., 1946, Alaska's minerals as a basis for industry: U. S. Bur. Mines Inf. Circ. 7379, p. 74-76.

A general description of the properties, market, uses, and sources of asbestos is followed by a description of asbestos occurrences in the Kobuk River region about 300 miles northeast of Nome and 150 miles east of Kotzebue. Both chrysotile and tremolite asbestos are known in the form of veinlets of cross fiber and as slip fiber along planes of movement in ultramafic rocks of the area. The most important occurrences are on Dahl Creek where tremolite suitable for use in acid filters was mined during 1944 and 1945.

Baird, D. M., Gillespie, C. R., and McKillop, J. H., 1954, Bibliography of the geology of Newfoundland, 1936-1954; Bibliography of the geology of Labrador, 1814-1954: Newfoundland Dept. Mines and Resources Bull. 36, p. 3-7, 10-12, 14.

The bibliography contains references to 20 reports on asbestos, including one preliminary report on asbestos-bearing rocks of Newfoundland. Some of the references are unpublished reports by the Newfoundland Department of Mines. Material published by outside sources is included. The index contains no references to asbestos from Labrador.

Baker, C. L. *See* Sellards, 1934.

Baker, W. G. *See* Morton, 1941.

Bancroft, M. F., 1922, Lardeau map-area, British Columbia: Canada Geol. Survey Summ. Rept., 1921, pt. A, p. 107-116.

The geology of the Lardeau map-area, in the Kootenay district of southeastern British Columbia, is described. At the Asbestos group of claims, on the east side of the Columbia River northwest of Arrowhead, chrysotile asbestos occurs in a serpentinite body that intrudes a series of quartzite, crystalline limestones, and argillaceous schists. Cross fibers, as much as $\frac{3}{4}$ inch long, are suitable for use as a filler. The best quality of slip fiber consisted of fine silky fibers 4 to 5 inches long. Picrolite is associated with the cross-fiber chrysotile.

Bangs, Herbert, 1946, Asbestos in Maryland: Maryland—Jour. Nat. History, v. 16, no. 4, p. 67-73.

Slip-fiber amphibole asbestos is associated with pyroxenite and peridotite and their alteration products. The largest deposit was near Pylesville; however, some amphibole was produced from deposits near Coopstown, Dublin, and Woodlawn. Small deposits of lower quality fiber occur near Hollofield, Alberton, and

Parkton. The best domestic fibers for use as chemical filters were obtained from Maryland. The mill at Pylesville was in operation as late as 1946.

Bannerman, H. M., 1940, Lépine Lake area, Destor Township, Abitibi County [Quebec]: Quebec Bur. Mines Geol. Rept. 4, 28 p.

Narrow veins of cross-fiber and slip-fiber chrysotile occur in bluish-gray serpentinite, which weathers rusty buff. The best development of both types of fiber is in and adjacent to a shear zone. The richest part of the deposit is about 400 feet wide and 1,000 feet long, in which the asbestos content might be as much as 5 percent. The cross fiber, generally less than $\frac{1}{8}$ inch long, has a maximum length of $\frac{5}{8}$ of an inch. The slip fiber is as much as 2 $\frac{1}{4}$ inches long. The asbestos, bluish-gray to olive as seen in place, mills white and fluffy. The deposit was explored for commercial fiber in 1938.

Barlow, A. E. See also Faribault, 1911.

——— 1910, Some notes on the origin of asbestos: Canadian Mining Inst. Jour., v. 13, p. 438-443 [1911]; Canadian Mining Inst. Quart. Bull., v. 12, p. 113-118.

Chrysotile, a fibrous form of serpentine, forms as an alteration product along the boundaries and in the fractures of the olivine grains. The volume of the asbestos-bearing serpentinite is 20 to 35 percent greater than that of the original dunite, which is the reverse of previous conclusions. Study of the veins has shown that they grew in direct proportion to the amount of magmatic water supplied. Barlow suggests that if formed quietly, long cross-fiber asbestos is produced, but, if violent dislocation occurs, slip-fiber asbestos forms. Picrolite is a common constituent in the slip-fiber asbestos veins.

Bateman, A. M., 1923, An Arizona asbestos deposit: Econ. Geology, v. 18, p. 663-683; discussion by Edward Sampson, 1924, Arizona asbestos deposit: Econ. Geology, v. 19, p. 336-338.

The author describes in detail a Sierra Ancha asbestos deposit. He ascribes the origin of asbestos and serpentine in limestone to diabase intrusives and suggests that chrysotile replaced serpentine. Discussion is based on fieldwork in the Sierra Ancha district.

Sampson suggests that displacement is more important in chrysotile vein formation than replacement. Relation of deposits to discordant diabase intrusions and to stratigraphy is emphasized.

Bates, T. F. See also Nagy, 1952.

Bates, T. F., and Mink, J. F., 1950, Morphology and structure of the serpentine minerals: Pennsylvania State College, School Mineral Industries Tech. Rept. 3, Proj. NR 081-098, 30 p.

"Studies made of the serpentine minerals with the electron microscope aided by X-ray and differential thermal analyses suggest that chrysotile crystallizes as tubular fibers whereas antigorite characteristically has a lath-like or platy habit. All serpentine specimens examined were found to consist of one or a combination of the above particle types. By considering serpentine as 1:1 layer lattice silicate, the difference in morphology between the two fundamental varieties, antigorite and chrysotile, is explained through the discrepancy in dimensions of the opposite sides of the unit cell and the effect of interlayer bonds. In the case of chrysotile curvature occurs because the opposite faces of the layer lattice are unequal. It is suggested that replacement of magnesium by trivalent iron and aluminum in antigorite has the effect of equalizing the

dimensions of the opposite sides of the same layer and increasing the strength of the interlayer bonds, thus inhibiting the expected curvature." Chemical analyses of 29 chrysotile and 15 antigorite specimens are included.

Bates, T. F., Sand, L. B., and Mink, J. F., 1950, Tubular crystals of chrysotile asbestos: *Science*, v. 111, no. 2889, p. 512-513.

Electron photomicrographs show that synthetic chrysotile crystals are hollow cylindrical tubes similar to tubular crystals of the clay mineral halloysite. Tubular crystals may be formed in minerals that have a sheet structure of the 1:1 type. In these types adjacent sheets are of different size, and bonding between structural units is not strong enough to overcome the size discrepancy, thus allowing adjustments so that adjacent units are compatible. A general structural analogy exists between the serpentine and kaolin mineral groups.

Bayley, W. S., Salisbury, R. D., and Kummel, H. B., 1914, Description of the Raritan quadrangle, New Jersey: U. S. Geol. Survey Geol. Atlas, Folio 191, 32 p.

"The talc and asbestos have been quarried from the Franklin limestone at the northeast end of Jenny Jump Mountain, where they were developed along slickensides and shear zones in the limestone, not, however, in sufficient quantity to make the deposit of economic value."

Beckwith, R. H., 1939, Asbestos and chromite deposits of Wyoming: *Econ. Geology*, v. 34, p. 812-843; *Wyoming Geol. Survey Bull.* 29, p. 812-843.

Summarizes the geology of asbestos and chromite deposits in Wyoming. All deposits are of Precambrian age occurring in lenses of serpentinite, which are from 50 feet to several miles across. Chrysotile occurs both as cross fiber and slip fiber. Ten deposits are described. Geologic maps of 5 deposits at scales ranging from 1 inch=900 feet to 1 inch=3,500 feet are included. Briefly discusses the brittleness and harshness in chrysotile.

Beeler, H. C., 1911, Asbestos deposits of Casper Mountain, Wyo.: *Colo. School Mines Mag.*, v. 1, no. 10, p. 5-9; no. 11, p. 5-9.

Author predicts that Wyoming will be a large asbestos producer in the future. Cross-fiber chrysotile, with some slip fiber, is found in serpentinized dunite, which occurs with granites and schists. Many fibers are from $\frac{1}{2}$ to 1 inch long.

Bell, Fred, 1955, Asbestos mining in northern British Columbia: *Mining Cong. Jour.*, v. 41, no. 5, p. 45-47.

Discovered in 1949, active work at the Cassiar mine was started in 1952; production started in 1954, during which 140,000 tons of ore were produced. Mining can usually be carried out from June to September. In this area argillites, shales, limestones, and quartzites are intruded by granite and basic igneous rocks. Cross-fiber chrysotile occurs in the basic rocks that have been altered to serpentinite. Most of the reserves are in talus. Much of the fiber is of spinning grade.

Benson, W. N., 1918, The origin of serpentine, a historical and comparative study: *Am. Jour. Sci.*, 4th ser., v. 46, p. 693-731.

Discusses the general problem of serpentinization of ultramafic igneous rocks, including several references to origin of chrysotile asbestos. Historical development of theories of serpentinization are summarized; characteristics, textures, structures, and composition of serpentinite bodies throughout the world are

reviewed. Benson concludes that large chrysotile- and antigorite-bearing serpentinite masses were derived from intrusive peridotite, and that "in some cases" hydration and carbonation were produced by magmatic waters derived from the "same magma that produced the peridotite." Serpentinization generally occurred after considerable differentiation of original magma, but before the end of orogenic cycle. Formation of serpentine through action of ground water seems improbable. Unaltered peridotite core of the mass commonly is surrounded by an inner zone of serpentinite and an outer zone of talc and carbonates.

Billings, M. P. *See* Chidester, 1951.

Birch, R. W. [1955?], Wyoming's mineral resources: [Laramie?] Wyoming Nat. Resource Board, p. 85-87.

Report summarizes the mineral resources of Wyoming. Deposits and reported occurrences are listed by county under each commodity, and the location and geology of each occurrence are given where known. Chrysotile and amphibole asbestos deposits are found in Converse, Fremont, Natrona, and Felton Counties, some of which may have economic possibilities. Asbestos is reported in Albany, Carbon, Crook, Laramie, Platte, Sheridan, and Washakie Counties.

Bostock, H. S., 1948, Preliminary map, McQuesten, Yukon Territory: Canada Geol. Survey Paper 48-25, p. 9, 12, scale 1 inch=2 miles.

Geologic map with descriptive text. Chrysotile fibers, as much as 1 inch long, have been found in a serpentine body in White Mountains.

Bowen, N. L., 1927, The origin of ultra-basic and related rocks: *Am. Jour. Sci.*, 5th ser., v. 14, p. 89-108.

Report deals indirectly with the origin of asbestiform minerals of the serpentine group but is concerned primarily with the origin of ultramafic rocks. Through examination of the composition of aphanitic rocks, Bowen concludes that magmas of ultramafic composition do not exist, and that ultramafic rocks form by crystal accumulation from a less mafic magma.

Bowen, N. L., and Tuttle, O. F., 1949, The system $MgO-SiO_2-H_2O$: *Geol. Soc. America Bull.*, v. 60, p. 439-460.

Reports the results of a laboratory study of the stability relations of minerals in the system $MgO-SiO_2-H_2O$ at pressures as much as 40,000 lbs./in.² and temperatures as high as 1,000°C, with a discussion of the significance of the results as applied to the problem of the origin of ultramafic rocks and the processes of serpentinization and steatitization. The upper temperature limit at which serpentine is stable is about 500°C; forsterite is stable in the presence of water vapor at all pressures and at temperatures a little more than 400°C. Under the conditions of the experiment (no aluminum in the system), chrysotile was the only serpentine mineral formed. It is shown that a dunitic magma containing large amounts of water cannot exist below 1,000°C and probably cannot exist at all. A hypothesis of solid intrusion is proposed for ultramafic rocks.

Bowles, Oliver. *See also* U. S. Bureau of Mines, 1952.

——— 1934, Asbestos—domestic and foreign deposits: *U. S. Bur. Mines Inf. Circ.* 6790, 29 p.

The first of three general reports on the asbestos industry gives summary information on domestic and foreign distribution of asbestos deposits.

Bowles, Oliver, 1935a, *Asbestos—general information*; U. S. Bur. Mines Inf. Circ. 6817, 21 p.

The second of three general reports on the asbestos industry contains data on the varieties of asbestos, mode of occurrence, physical and chemical properties, uses, mining methods, world production, and political and commercial control. Tables showing world production, consumption, exports, and imports are included.

——— 1935b, *Asbestos—milling, marketing, and fabrication*: U. S. Bur. Mines Inf. Circ. 6869, 26 p.

The third of three general reports on the asbestos industry includes data on the classification of fiber, domestic and foreign milling methods, marketing, and fabrication of asbestos products. Tables show current classification of fiber, quantity and value of asbestos products manufactured in the United States, and the current prices of several asbestos varieties.

——— 1955a, *The asbestos industry*: U. S. Bur. Mines Bull. 552, 122 p.

Comprehensively covers nearly all aspects of asbestos. Deposits of the world are described with emphasis on the United States. Selected topics discussed are varieties and composition, origin, occurrence, physical and chemical properties, history, uses, production, world reserves, controls, prospecting, mining and milling methods of the principal producers, classifications, markets, prices, substitutes, beneficiation, synthesis, and manufacture of products. Geologic map (1 in.=2 mi.) of Quebec Asbestos region and location maps of major world asbestos deposits and of Gila County, Ariz., deposits are included.

——— 1955b, *A new asbestos development in Quebec*: *Asbestos*, v. 37, no. 5, p. 4, 8.

Eastern Asbestos Co., Ltd., is exploring and developing a deposit north of Buckingham in Papineau County, Quebec. Cross-fiber chrysotile veins as much as $\frac{3}{4}$ inch wide occur in 4 serpentinized zones in Grenville limestone. Asbestos-bearing zones parallel the limestone bedding and are more persistent than similar deposits in Arizona. Origin of serpentine and asbestos has not been determined. This asbestos can be used for electric insulation because of its low iron content and for filtration because of its purity and white color. There seems to be no brittle or harsh fiber.

Bowles, Oliver, Currier, L. W., and Waggaman, W. H., 1948, *Asbestos in U. S. Bureau of Mines and U. S. Geological Survey, Mineral resources of the United States*: Washington, D. C., Public Affairs Press, p. 61–62.

The characteristics and uses of different varieties and grades of asbestos are summarized. The principal world sources are enumerated. Occurrences of chrysotile are known in many States of the United States, but Vermont and Arizona are the only consistent producers. Vermont is by far the largest producer and contains substantial reserves of nonstrategic asbestos.

Brandenberger, El., Epprecht, W., and Niggli, F., 1947, *Serpentine minerals and their synthesis*: *Helvetica Chimica Acta*, v. 30, p. 9–14; *abs.*, *Chem. Abs.*, v. 41, no. 9, col. 2661, by Cyrus Feldman.

“The most workable chrysotiles are those having the greatest degree of parallelism among the fibers and the lowest degree of unification of structural units into crystals. The structure, hydration-dehydration behavior, and previous attempts at hydrothermal synthesis of the serpentines are reviewed briefly. Preliminary experiments indicate the possibility of synthesizing chrysotile at temperatures under 500 degrees and pressures under 300 atm.”

British Columbia Department of Mines, 1961, Structural materials and industrial minerals: British Columbia Dept. Mines Ann. Rept. 1960, p. 207-217.

According to B. T. O'Grady, serpentinized peridotite and augite porphyrite intrusives occur in a belt as much as 8 miles long in the McDame Creek area, northwest British Columbia. Chrysotile veinlets occur throughout the serpentinized rocks, and amphibole asbestos is more abundant along the margins of the serpentinite. In the Rugged Group of claims, a zone some 900 feet long and 450 feet wide, contains as much as 5 percent chrysotile. The fibers are of spinning grade. Asbestos "fluff" is abundant in the talus.

The geology of the Asbestos, I. X. L., and Acme claims in southeastern British Columbia is described by J. W. McCammon. In this area, a north-trending, 300- to 700-foot-wide, basic dike altered to serpentine and talc intrudes sedimentary rocks. Cross-fiber chrysotile veinlets as much as $\frac{3}{4}$ inch wide are erratically scattered through the serpentine. Slip-fiber chrysotile as much as 8 inches long occurs in small shear zones in the serpentine. The asbestos content of the rocks ranges from "1 to 3 percent with selected areas running higher." Tests of the fibers indicate they would be suitable for use in manufacture of asbestos board. Two analyses are given. Geologic maps, scale 1 inch = 150 feet and 1 inch = 800 feet, are included.

——— 1962, Structural materials and industrial minerals: British Columbia Dept. Mines Ann. Rept. 1961, p. 208-214.

According to J. W. McCammon, the Heli and Copter claims, in northwestern British Columbia, have harsh short cross-fiber chrysotile in serpentine. Chrysotile and Olivine property, on Mount McDame, has veinlets of cross-fiber chrysotile in serpentine. Fibers are commonly less than $\frac{1}{2}$ inch long; wider veinlets have central parting which reduces the fiber length.

Cassiar Asbestos Corp., Ltd., north of Mount McDame, has asbestos in serpentine, exposed in west limb of a syncline. Best fibers are found in talus piles more than 6 feet deep. Scattered masses of serpentine to the east may contain small amounts of asbestos.

Geologic maps, scales 1 inch = 4,500 feet and 1 inch = 600 feet, are included.

——— 1964, Structural materials and industrial minerals: British Columbia Dept. Mines Ann. Rept. 1963, p. 181-184.

Mining developments of Cassiar Asbestos Corp., Ltd., are summarized by J. W. Patterson.

According to J. W. McCammon, veinlets of cross-fiber chrysotile occur in narrow zones within an elongate mass of serpentinite on the P. H. claims in southern British Columbia. The fibers, $\frac{1}{32}$ to $\frac{1}{2}$ inch long, are "fairly harsh" and have good strength. The fiber content appears to be low.

In southeastern British Columbia the occurrence of irregular lenses (1 to 10 ft long) and cross-fiber veins ($\frac{1}{4}$ in. to 27 in. wide) of anthophyllite in an irregular mass of dunite on the Pedro, Sunshine, etc. claims is described by J. W. McCammon. The anthophyllite occurs as fibers as much as 10 inches long in "hard, woody-looking chunks," as sheaflike clumps, and as powdery aggregates. Geologic map, scale 1 inch = 1,400 feet, is included.

Development work on Sprout Mountain at the Asbestos, I. X. L., and Sidmouth claims is described by J. W. Peck.

Butler, G. M. See Wilson, 1928.

Byers, A. R., and Dahlstrom, C. D. A., 1954, *Geology and mineral deposits of the Amlak-Wildnest Lakes area, Saskatchewan*: Saskatchewan Dept. Mineral Resources, Geol. Br. Rept. 14, p. 135-137.

Cross-fiber chrysotile occurs in narrow veinlets cutting serpentinized peridotite; slip fiber occurs along walls of faults in serpentinite and altered gabbro. There has been some prospecting at Ruth Lake, Cable Lake, and Mosher Lake, where fiber lengths range from $\frac{1}{8}$ to $\frac{3}{8}$ inch, and make up as much as 12 percent of the rock. Geologic map in 8 parts, scale 1 inch= $\frac{1}{4}$ mile, is included.

Oady, W. M. *See* Chidester, 1951.

California Bureau of War Minerals Production, 1942, *Asbestos in California*: California Dept. Nat. Resources, Bur. War Minerals Production Bull. 12, 27 p.

A brief summary is given of asbestiform minerals, their mode of occurrence, guides for evaluating asbestos deposits, methods of testing, and uses of asbestos. Location and description of 12 asbestos occurrences in California are given. Cross- and slip-fiber chrysotile, anthophyllite, and tremolite occur as veins in serpentinite, and at contact of serpentinite bodies. Some tremolite occurs as veins in sheared and fractured limestone and in "basic dikes." Commercial possibilities of each occurrence are discussed.

California Division of Mines, 1950, *Asbestos: Mineral Inf. Service*, v. 3, no. 9, p. 5-8.

Gives general information on California asbestos and briefly mentions developments in scattered asbestos deposits in Calaveras, Nevada, San Benito, Monterey, Riverside, Napa, Shasta, and Placer Counties. Production and prices for 1948 are included for Canada and California.

——— 1951, *California mineral fillers: Mineral Inf. Service*, v. 4, no. 12, p. 1.

Brief article contains general information about California asbestos with emphasis on 1951 activity. Occurrence of chrysotile discovered in the Panamint Mountains, Inyo County. Phillip Carey Manufacturing Co. began to drill deposit near Washington, Nev. A small deposit in southern Trinity County is noted. Only California production in 1951 was from Stock Mine in Shasta County, from which Powhatan Mining Co. shipped 44 tons of tremolite.

California Journal of Mines and Geology, 1932-55: San Francisco, Calif.

Quarterly publication, generally in two parts, one topic a mineral commodity, the other a survey of mineral resources of a county. The following volumes have notations of asbestos: v. 31, p. 264; v. 32, p. 226; v. 34, p. 207; v. 35, p. 112; v. 37, p. 16, p. 378; v. 38, p. 14; v. 39, p. 85, p. 508; v. 41, p. 158; v. 43, p. 47, p. 117, p. 418; v. 44, p. 168, p. 354; v. 45, p. 49; v. 46, p. 285; v. 48, p. 108; v. 49, p. 182, p. 155; v. 50, p. 203, p. 650. The serial first was published as the Report of the State Mineralogist, 1880-1931, the following reports noting asbestos: v. 14, 15, 16, 17, 18, 20, 21, 22; v. 23, p. 6; v. 25 p. 63, p. 154, p. 216, p. 306, p. 340, p. 499; v. 26, p. 91, p. 296; v. 27, p. 26. In California, asbestos occurs as anthophyllite, chrysotile, and tremolite associated with large serpentinite masses in the Pacific Coast Range, Klamath Mountains, and Sierra Nevada, and with dolomite and syenite in the Panamint Mountains of Death Valley.

Canada Geological Survey, 1948, *Geological map of British Columbia*, Map 932-A, 2 sheets, scale 1 inch=20 miles.

Map, with descriptive notes, shows the distribution of ultramafic rocks in British Columbia. Recent discovery of commercial deposits of chrysotile as-

bestos in northern British Columbia indicates the possibility of other commercial deposits in some of these bodies of ultramafic rock.

Carlson, D. W., and Clark, W. B., 1954, Mines and mineral resources of Amador County, California: *California Jour. Mines and Geology*, v. 50, p. 203.

Amphibole and chrysotile asbestos occur in or near massive serpentinite bodies. No recorded production since 1909. Amphibole asbestos prospects are near Jackson.

Carr, M. S. *See* Ross, 1941.

Chawner, W. D. *See* Hess, 1933.

Chidester, A. H., Billings, M. P., and Cady, W. M., 1951, Talc investigations in Vermont, preliminary report: *U. S. Geol. Survey Circ.* 95, 33 p.

Classification, characteristics, and origin of ultramafic rock bodies and their alteration products are briefly discussed. Detailed locations are given for 145 places at which ultramafic rocks are known or reported. Brief descriptions of the geology are given for 29 localities; talc is being mined at four localities and asbestos at one. Talc has been mined at many other localities. Asbestos prospects at several northern localities, particularly 9, 18a, 18b, 18c, 19, and 20, are shown on the map (scale 1 in.=10 mi.) of ultramafic rocks.

Chidester, A. H., Stewart, G. W., and Morris, D., 1952, Geologic map of the Barnes Hill talc prospect, Waterbury, Vt.: *U. S. Geol. Survey Mineral Inv. Field Studies Map MF-7*.

Chrysotile asbestos, both cross-fiber and slip-fiber, occurs locally in small quantities in the ultramafic body at Barnes Hill. The ultramafic body is 1,600 feet long by a maximum of 360 feet wide.

Cirkel, Fritz, 1910, Chrysotile asbestos, its occurrence, exploitation, and uses: *Ottawa, Canada Mines Branch*, 2d ed., 316 p.

Chapter topics are—historical, physical and chemical properties of asbestos, and summary of asbestos minerals; Canadian serpentine areas; productive serpentine range; quarrying asbestos; dressing of asbestos for market, summary of principles in the separation of asbestos, general features of the mills in the district; cost of extraction, market, prices, statistics and status of asbestos industry; asbestos mines and prospects; asbestos in foreign countries; commercial application of asbestos; bibliography. Analyses and maps, at scales of 1 inch=about 20 miles to 1 inch=1 mile, are included.

Clark, W. B. *See* Carlson, 1954.

Coats, R. B., 1944, Asbestos deposits of the Dahl Creek area, Kobuk River district, Alaska: *U. S. Geol. Survey open-file report*, April 6, 1944, 5 p.

Asbestos deposits near the head of Dahl Creek, a tributary to the Kobuk River, near the village of Shungnak, are associated with an altered stock of ultramafic rock which intrudes schist and limestone country rock. The ultramafic rock is altered principally to massive and schistose serpentine. Slip-fiber chrysotile, in layers as much as 3 inches thick and made up of fibers as much as 10 inches long, occurs in irregular faults which cut the serpentine. Cross-fiber chrysotile, as much as $\frac{3}{4}$ inch long, fills joints in the serpentine. Locally a large proportion of the ultramafic rock contains veinlets of pale-green chlorite which enclose lenses of serpentine. No asbestos was seen in rock of this type. A third phase of the ultramafic rock, consisting of interlaced fibers of tremolite, is referred to as nephrite because of its close resemblance to the nephrite variety of jade. Tremolite asbestos, confined to bodies of nephrite, occurs on Asbestos Mountain

as float apparently derived from a vein or veins of asbestos. In one place a vein, ranging from 2 to 6 inches in thickness and containing fibers as much as 1.8 feet long, was found in place. Geologic map, scale 1:24,000, is included.

Comeforo, J. E. *See also* Kohn, 1955.

Comeforo, J. E., and Kohn, J. A., 1954, Synthetic asbestos investigations, I. Study of synthetic fluor-tremolite: *Am. Mineralogist*, v. 39, p. 537-548.

"A study of synthetic fluor-tremolite by X-ray and optical methods was considered basic to research on fluor-amphiboles as potential substitutes for asbestiform minerals.

"A review and critique of previous syntheses is given, together with earlier optical and X-ray data on both natural hydroxy- and synthetic fluor-tremolite." Optical determinations were made on chemically analyzed synthetic fluor-tremolite. "The values were compared with those for natural hydroxy-tremolite. On an X-ray powder pattern of synthetic fluor-tremolite, all resolved maxima were indexed up to $76^{\circ} 2\theta$." The monoclinic cell dimensions of the mineral were obtained. "A comparison was made with the values for natural hydroxy-tremolite. Goniometric measurements on well-formed single crystals of synthetic fluor-tremolite gave values in agreement with the calculated figures. Single-crystal X-ray patterns (rotation and Weissenberg) were made."

Connolly, J. P., and O'Harra, C. C., 1929, The mineral wealth of the Black Hills: *South Dakota School Mines Bull.* 16, p. 340.

Weathered cottonlike asbestos has been found in Custer and Lawrence Counties. The occurrence in Lawrence County has been prospected but not worked. Fibers as much as 4 inches long have been found.

Cooke, H. C., 1931, Thetford map-area, Quebec: *Canada Geol. Survey Summ. Rept.*, 1930, pt. D, p. 1-14.

Most of report is description of general geology and discussion of the stratigraphic succession. Peridotite masses crop out at or near the summits of the major anticlines, into which they were intruded. Asbestos deposits of Thetford occur at the intersection of an anticlinal cross fold with a major anticline, suggesting a possible structural control.

——— 1935, The composition of asbestos and other fibers of Thetford district, Quebec: *Royal Soc. Canada Trans.*, 3d ser., v. 29, sec. 4, p. 7-19.

Analyses of cross-fiber chrysotile asbestos and of other fibrous forms of serpentine are presented. Six samples of cross fiber, obtained from six localities, are representative of different commercial grades of fiber. Care was taken, in preparing the samples for analysis, to remove impurities and avoid contamination. Analyses are recalculated into terms of "mineral molecules," and the chemical composition and "mineral molecule" composition of the fibers are correlated with physical properties. High-silica and low-water content are concluded to induce harshness of fiber.

——— 1937, Thetford, Disraeli, and eastern half of Warwick map-areas, Quebec: *Canada Geol. Survey Mem.* 211, 160 p.

Distribution of ultramafic rocks is shown on five geologic maps. On pages 59-75, Cooks discusses distribution, geologic features, and mode of origin of ultramafic rocks.

On pages 86-140, Cooke discusses distribution of asbestos deposits and geologic features of asbestos, with many detailed sketches, tables of measurements, and chemical analyses.

Cooke concludes (p. 139-140) that "injection of heated waters or vapours" into fissures brought about serpentinization of the peridotite, and that excess material carried from the peridotite into the fissures during serpentinization was "deposited as asbestos." Geologic maps (scale 1 in.=1 mi.), many diagrams and sketches, and an extensive bibliography are included.

Cooke, H. C., 1947, *The Canadian Shield, in Geology and economic minerals of Canada*, 3d ed. : Canada Geol. Survey Econ. Geology Ser. 1, p. 11-97.

North and east of Ottawa several small bodies of serpentinite in rocks of Grenville series contain asbestos veins. Attempts to mine the asbestos which "is of high quality, low in iron" have been unsuccessful. In western Bannockburn Township, Ontario, asbestos veinlets in a fault zone at contact of rhyolite and serpentinized peridotite has been prospected. No production was reported.

East of Actinolite Village, Hastings County, Ontario, large bodies of actinolite in altered basalt or greenstone have been mined.

——— 1950, *Geology of a southwestern part of the Eastern Townships of Quebec* : Canada Geol. Survey Mem. 257, 142 p.

Distribution and geologic relations of the ultramafic rocks are discussed on pages 99-100 and are shown on the geologic map (scale 1 in.=2 mi.). Ultramafic rocks occur throughout a belt, rarely more than 2 miles wide, that trends northeast from the United States border to near Shipton Pinnacle.

On pages 135-136 the 7 localities within the mapped area at which prospecting for asbestos has been carried out are listed. None has been exploited commercially (1950).

Cooper, J. R., 1936, *Geology of the southern half of the Bay of Islands igneous complex* : Newfoundland Dept. Nat. Resources, Geol. Sec. Bull. 4, 62 p.

Chrysotile asbestos, as tiny cross-fiber veins, is widespread among the serpentinized rocks of western Newfoundland. Deposits west of St. George's Lake and in the Bluff Head-Lewis Brook region are briefly described. In the latter region chrysotile occurs in two belts of serpentinized ultramafic rocks. The deposits in the Bluff Head belt, containing fiber as long as $\frac{3}{4}$ inch, appear more promising than those near Lewis Brook. The fiber is of good quality, but somewhat harsher than the best grades from Thetford, Quebec.

Currier, L. W. *See* Bowles and others, 1948.

Dahlstrom, C. D. A. *See* Byers, 1954.

Davis, F. F., 1950, *Mineral commodities of California* : California Div. Mines Bull. 156, pt. 3, p. 121-124.

Gives a résumé of California's asbestos industry. Mineralogy and geologic occurrence, localities and history of production, utilization, mining methods and treatment and markets are briefly summarized. Developments in Calaveras, Nevada, San Benito, Monterey, Riverside, Napa, Shasta, and Placer Counties are mentioned.

Dawson, A. S. *See* Wing, 1949.

Denis, B. T., 1931, *Asbestos occurrences in southern Quebec* : Quebec Bur. Mines Ann. Rept. 1930, pt. D, p. 147-193.

Summarizes results of investigation of asbestos occurrences in the serpentine belt of the Eastern Townships of Quebec, exclusive of those occurring within the main asbestos producing centers, such as the Danville, Black Lake-Thetford, and East Broughton fields. The subject area includes parts of Richmond, Artha-

baska, Wolfe, Frontenac, Megantic, Beauce, Dorchester, and Montmagny Counties. Locations, descriptions of mine workings and mills, and brief discussions of the geologic features of 23 asbestos deposits are given. Each occurrence is shown on a map by a number keyed to a table in the text (p. 151). Includes detailed sketch maps of 16 occurrences and a map, scale 1 inch=about 4 miles, showing ultramafic and asbestos-bearing rocks.

Denis, T. C. *See* Dresser, 1939-51.

Dietrich, R. V., 1953, Virginia mineral localities: Virginia Polytech. Inst., Eng. Expt. Sta. Bull. 88, p. 37, 41.

Occurrence of asbestiform minerals of the serpentine and amphibole groups are listed by counties under these two general mineral groups. References to the mineral occurrences are included where known. Asbestiform minerals are reported from 18 counties.

— 1955, Additions to Virginia mineral localities: Virginia Polytech. Inst., Eng. Expt. Sta. Bull. 105, p. 21.

Asbestos occurrences are reported from Bedford, Carroll, Fairfax, Floyd, Grayson, and Henry Counties. Some references are given, but many sources are oral communications.

Diller, J. S., 1911, The types, modes of occurrence, and important deposits of asbestos in the United States: U. S. Geol. Survey Bull. 470-K, p. 505-524.

Descriptions of deposits of the United States include Lowell region, Vermont, and Casper region, Wyoming, which have cross-fiber veins in serpentinite derived from peridotite; Grand Canyon, Ariz., which has cross-fiber veins in serpentinite in limestone; Sall Mountain, Ga., and Kamiah, Idaho, which have mass-fiber amphibole asbestos in stocks and dikes of amphibolite; Bedford and Rockymount, Va., which have slip-fiber veins in cortlandite and pyroxenite.

Dresser, J. A. *See also* Hess, 1933.

— 1912, Reconnaissance along the National Transcontinental Railway in southern Quebec: Canada Geol. Survey Mem. 35, 42 p.

A deposit of short-fiber asbestos was found in a body of serpentinite in Talcon Township, Montmagny County. Serpentinite also is known in the southeastern part of the counties of Bellechasse, Montmagny, and L'Islet.

— 1913, Preliminary report on the serpentine and associated rocks of southern Quebec: Canada Geol. Survey Mem. 22, 103p.

Discusses in detail the distribution and geology of ultramafic rocks in southern Quebec. Twenty pages are devoted to description of asbestos, which occurs in two varieties of serpentinite. Asbestos of the "Thetford type" occurs in veins, and is generally longer and stronger than the "Broughton type," which occurs principally as slip fiber, often associated with talc or soapstone. Relations of asbestos veins are described and illustrated. Modes of origin advocated by others are discussed. Dresser concludes that the veins are crystallized portions of serpentinite walls, and the fibers have grown outward from the original crevices which are now represented by partings near the center of the veins. Maps of the Danville and Thetford-Black Lake mining districts at a scale of 1 inch=1 mile and of the northeast part of the Serpentine belt at a scale of 1 inch=4 miles, are included.

Dresser, J. A., 1920, Granitic segregations in the serpentine series of Quebec: Royal Soc. Canada Trans., 3d ser., v. 14, sec. 4, p. 7-13.

Describes briefly the geologic relations of ultramafic rocks and in detail the geology and petrography of granitic rocks associated with ultramafic masses. Dresser discusses mode of origin of serpentine and chrysotile asbestos, particularly the role of granitic rocks and related magmatic solutions in serpentinization and formation of asbestos.

Dresser, J. A., and Denis, T. C., 1939-51, Geology of Quebec: Quebec Dept. Mines Geol. Rept. 20, v. 1, 1939; Supp. A, 1951; v. 2, 1944; v. 3, 1949.

Volume 1, 1939, Bibliography and Index.—A compilation of all geologic work done in the province of Quebec through 1936. Supplement A, 1951, covers the years 1937-49.

Volume 2, 1944, Descriptive Geology (p. 174, 302-304, 413-442).—Distribution and geologic relations of ultramafic bodies in Ottawa North Shore region, Gaspé Peninsula, and Eastern Townships of Quebec are described. Two occurrences are known in the Ottawa North Shore region (p. 174); four occurrences are reported in the Gaspé Peninsula (p. 302-304). The geology of the "serpentine belt" of the Eastern Townships is described in considerable detail, and the concepts of earlier Canadian geologists on problems of serpentinization and the origin of chrysotile asbestos are discussed and evaluated. This report summarizes the significant features of all of Dresser's earlier work on asbestos in the ultramafic rocks of the Eastern Townships and contains his latest ideas on the origin of serpentine and asbestos (p. 413-442).

Volume 3, 1949, Economic Geology (p. 453-459).—Describes the principal occurrences in the several districts and discusses the status and future of the asbestos industry. Locations of the principal asbestos mining operations in the Eastern Townships are given. Occurrence of asbestos in limestone of the Grenville series and production of a few tons of asbestos in 1942-43 from an occurrence in Grenville township are mentioned. In northern and western Quebec, occurrences are briefly described at Asbestos Island, Chibougamau Lake; Destor Township, Abitibi-West County; and Gaboury and Duhamel Townships, Temiscamingue County.

Dufresne, A. O., and Laroche, Eugene, 1932, The classification of Canadian chrysotile asbestos: Canadian Mining and Metall. Bull., v. 25, no. 240, p. 224-232; Canadian Inst. Mining and Metallurgy Trans., v. 35, p. 224-232.

Methods used in the classification of asbestos before 1931 are discussed. A classification containing 9 groups, each of which is subdivided into grades, is described. Groups 1 and 2 are classed as "crude asbestos" or hand selected cross vein material. Groups 3 through 9 are classed as "milled asbestos" and, except for groups 8 and 9, all "milled asbestos" is classified on the basis of results of tests on the "Quebec testing machine". Groups 8 and 9 are determined on the basis of weight per cubic foot.

Emerson, B. K., 1917, Geology of Massachusetts and Rhode Island: U. S. Geol. Survey Bull. 597, p. 215-217.

A block of saxonite in the Pelham granite has been mined for asbestos and corundum near Pelham, Mass. Fibrous anthophyllite occurs in narrow replacement veins in a 3- to 12-foot thick breccia zone. The fibers, as much as 2 feet long, are normal to the vein walls and meet in a suture which represents the original fissure. Similar masses are known near Shutesburg, Leverett, New Salem, and Wilbraham.

Epprecht, W. See Brandenberger, 1947.

Faessler, Carl, and Badollet, M. S., 1947, The epigenesis of the minerals and rocks of the serpentine belt, Eastern Townships, Quebec: *Canadian Mining Jour.*, v. 68, no. 3, p. 157-167.

Report is concerned primarily with discussion of the mineralogy of the ultramafic and acidic intrusives and associated alteration products. The alteration processes are discussed and depicted diagrammatically. Two stages of serpentinization of the ultramafic rocks are recognized. The first stage is essentially deuteric and resulted in formation of "mesh antigorite," whereas the second stage occurred after injection of felsic dikes and masses and resulted from the action of "aqueous hot (siliceous?) solutions" along faults, shears, and fractures in the ultramafic masses. "Asbestization" succeeded by formation of talc deposits followed immediately the second stage of serpentinization. The chrysotile veins were formed by removal of antigorite from along fissure walls by the hydrothermal solutions and deposition of chrysotile in the same or other fractures that formed concurrently with deposition of chrysotile. The width of the original fissure is an important factor in formation of one or two fiber veins. Both slip- and cross-fiber chrysotile are found. The hydrothermal solutions may be related to felsic intrusive rocks.

Faribault, E. R., Gwillim, J. C., and Barlow, A. E., chm., 1911, Report on the geology and mineral resources of the Chibougamau region, Quebec: Quebec Dept. Colonization, Mines and Fisheries, Mines Branch, 215 p.

The Chibougamau region is underlain by Precambrian rocks that are intruded by "gabbro-anorthosite." Geological relations and mode of origin of rock types are discussed. Mode of occurrence of mineral deposits, including asbestos-bearing serpentinite, are discussed in detail. Asbestos is found as narrow veins of cross-fiber chrysotile in narrow lenticular masses of serpentinized periodotite. Asbestos Island and vicinity have the most favorable deposits of asbestos.

Fisher, R. B., Thorne, R. L., and Van Cott, Corbin, 1945, Paligorskite, a possible asbestos substitute: U. S. Bur. Mines Inf. Circ. 7313, 5 p.

Gives a preliminary description of a paligorskite occurrence on Lemesurier Island, Alaska, together with chemical analysis, optical properties, and some physical properties. The property has commercial possibilities. Paligorskite could be used as a substitute for asbestos for sound deadening, vibration dampening, and filtration.

Frank, Karl, 1952, *Asbest*: Hamburg, Germany, Becker and Haag, 2d ed., 234 p.

Comprehensive report on asbestos includes general geology, varieties, X-ray identification and crystal structure analysis, macroscopic and electron-microscopic morphology; physical properties, including description and results of tests at variable temperature and humidity of tensile strength, ultimate strength, elasticity and spinability; chemical properties, with data on reaction to acid, leaching by alkalis, effects of alcohol, phosphate, chloride, and other solutions; industrial properties including spinability, filterability, fire proofing, insulating, dyeing, and bonding. Large occurrences of the world are discussed in detail; smaller and unworked occurrences are described. Discussions include mining and milling methods, transportation, manufacturing, production. Text augmented by many graphs, tables, diagrams, drawings, and photographs.

Gamble, W. B., 1929, *Asbestos—a list of references to material in the New York Public Library*: New York, New York Public Library, 72 p.

Annotated bibliography on asbestos includes world-wide coverage of all

phases of asbestos industry and fictional material. There are 1,075 references to publications and 519 to patents granted between 1871 and 1928.

Gates, G. O. *See* Twenhofel, 1949.

Gillespie, C. R. *See* Baird, 1954.

Gordon, S. G., 1922, The mineralogy of Pennsylvania: Acad. Nat. Sci. Philadelphia Spec. Pub. 1, p. 81-84, 122.

Article, in two sections, describes the minerals and mineral localities of Pennsylvania. In the first section are described the mineralogy and chemical composition of anthophyllite, p. 81, tremolite, p. 82, actinolite, p. 82, crocidolite, p. 84, and serpentine (noncommercial), p. 122. The second section lists mines, prospects, and mineral localities by county.

Graham, R. P. D., 1917, Origin of massive serpentine and chrysotile-asbestos, Black Lake-Thetford area, Quebec: Econ. Geology v. 12, p. 154-202.

Topics covered are general geology, mode of occurrence of massive serpentine and chrysotile, mode of origin of massive serpentine, composition of the olivine and serpentine, alteration of olivine and pyroxene to serpentine, nature of reagents producing metamorphism, evidence that magmatic siliceous waters were available, origin of chrysotile asbestos, relation between massive serpentine and chrysotile, change from massive serpentine to chrysotile, curved or bent fiber, slip fiber, junction and intersection of chrysotile veins, and inclusions of massive serpentine within veins.

Gruner, J. W., 1937, Notes on the structure of serpentines: Am. Mineralogist, v. 22, p. 97-103.

Further X-ray investigations of the serpentine minerals support Selfridge's (1936) conclusions that the serpentines may be classified into two main divisions: those which possess a fibrous structure like chrysotile and those which are platy like antigorite. It is believed that dimorphism exists, as chemical analyses show no appreciable differences in the chemical composition of the two varieties.

Gwillim, J. C. *See* Faribault, 1911.

Haury, P. S. *See* Stewart, 1955.

Heide, H. E., Wright, W. S., and Rutledge, F. A., 1946, Investigation of the Kobuk River asbestos deposits, Kobuk district, northwestern Alaska: U. S. Bur. Mines Rept. Inv. 4414, 25 p.

Asbestos occurs in serpentized ultramafic rocks that intrude sedimentary rocks. Describes deposits from Shungnak River, Cosmos Creek, Dahl Creek, and Jade Mountain; also procedures for taking samples and tests for treatment. Eight maps, ranging in scale from 1 inch=120 feet to 1 inch=250 miles, are included.

Hendry, N. W., 1951, Chrysotile asbestos in Munro and Beatty Townships, Ontario: Canadian Mining and Metall. Bull., v. 44, no. 465, p. 29-36; Canadian Inst. Mining and Metallurgy Trans., v. 54, p. 28-35.

The principal deposit is at the Munro Mine about 10 miles east of Matheson. The asbestos occurs in a steeply dipping differentiated ultramafic "sill-like body" as much as 1,000 feet wide, which has been traced for as much as 3½ miles by geophysical methods. Potential commercial chrysotile deposits have been found in part or wholly by diamond drilling throughout a 2-mile section of the ultramafic mass. Cross-fiber chrysotile veins, ½ to 1¼ inches wide, fill fractures in

the serpentized dunite that forms the core of the sill. Small quantities of slip fiber and picrolite are associated with faults. The chrysotile is a "harsh grade of fibre" that possesses "considerable strength." Mining and milling methods are discussed. Geologic maps, scales 1 inch=about $\frac{1}{2}$ mile and 1 inch=500 feet, are included.

Hess, H. H. *See also* Phillips, 1936.

— 1933, The problem of serpentization and the origin of certain chrysotile asbestos, talc, and soapstone deposits: *Econ. Geology*, v. 28, p. 634-657; discussion by J. A. Dresser, 1934, The problem of serpentization: *Econ. Geology*, v. 29, p. 306-307; G. W. Bain, 1934, Serpentization, origin of certain asbestos, talc, and soapstone deposits: *Econ. Geology*, v. 29, p. 397-400; and W. D. Chawner, 1934, The problem of serpentization: *Econ. Geology*, v. 29, p. 777-778; answer to discussion by H. H. Hess, 1935, The problem of serpentization: *Econ. Geology*, v. 30, p. 320-325.

The author believes that serpentization is an autometamorphic and largely a deuterio reaction that precedes steatitization. During serpentization of ultramafic intrusive small fissures developed as a result of a slight volume decrease. Chrysotile veins fill these fissures. Tables and illustrative diagrams are included.

Dresser points out that Hess's conclusions are based on study of slip-fiber asbestos deposits. Some cross-fiber veins have wide borders of serpentine that grade sharply into peridotite containing 5 to 25 percent serpentine. Dresser suggests that serpentization occurred while asbestos was being deposited.

Bain refutes conclusions that amphibole is an early mineral in talc deposits, that serpentine and chrysotile veins are restricted to ultramafic bodies, and that serpentine is formed by autometamorphic and deuterio processes. Examples of Vermont talc deposits and serpentinite masses are cited.

Chawner disagrees with Hess's theory that serpentization of an ultramafic mass involves a decrease in volume or no volume change. Author contends that serpentization of ultramafic rocks was accompanied by an increase in volume and cites the presence of serpentine in crests of anticlines and the minutely fractured, faulted, and slicksided character of the serpentine as evidence to support this theory. Evidence based on field observations in Cuba.

Hess reaffirms his conviction that chrysotile veins are fissure fillings, that serpentization is autometamorphic, and that serpentization is earlier than steatitization.

— 1955, Serpentine, orogeny, and epeirogeny, *in* Poldervaart, Arie, ed., *Crust of the Earth*: Geol. Soc. America Spec. Paper 62, p. 391-408.

The author believes that the association of serpentinite and alpine mountains indicates that island arcs are early stage of mountain building. Peridotites were intruded only during the first phase of deformation and are found in two belts bordering a central axis of intense deformation. Thus, orogenies may be dated by dating the accompanying serpentinites. Hess implies that field geologists support the theory that serpentinites were intruded as magma, whereas laboratory investigators think such magmas are not possible; he also suggests that field evidence should have precedence. A theory that serpentines were intruded in a solid state is gaining favor. Some geologists believe that the serpentinites in Turkey are submarine lava flows. Peridotite occurs 10-12 km (6-7 miles) below oceans and on the Mid-Atlantic Ridge. Serpentinite is found throughout oldest peridotites, as in Canada and Rhodesia. Many submarine

topographic features may be caused by serpentinization below and deserpentinization above the Mohorovičić discontinuity.

Hewitt, D. F., and Satterly, Jack, 1953, *Asbestos in Ontario*: Ontario Dept. Mines Indus. Mineral Circ. 1, revised ed., 23 p.

Summarizes information on asbestos deposits in Ontario: mode of occurrence, description of properties, grade and evaluation of asbestos deposits, uses, mining and milling methods, production. Includes table of asbestos mines and prospects in Ontario and map (scale 1 in.=2 mi.) of Abitibi peridotite belt. Contains bibliography including general references and those pertaining to specific Ontario deposits.

Heyl. See Arbeitstagung "Asbest" [1942], 1944.

Hopkins, O. B., 1914, *Asbestos, talc, and soapstone deposits of Georgia*: Georgia Geol. Survey Bull. 29, p. 75-189.

General topics discussed include properties of asbestiform minerals, modes of occurrence, origin, mining and milling in Georgia and Canada, future of the industry in Georgia, and deposits of North America with emphasis on Georgia. Mines and deposits are described and located. Asbestos is of anthophyllite type and is found in serpentine in the metamorphosed mafic rocks of northwestern Georgia. Map, scale 1:1,000,000, shows asbestos, talc, and soapstone occurrences.

Howling, G. E., 1937, *Reports on the mineral industry of the British Empire and foreign countries, Asbestos*: London, Great Britain Imp. Inst., Mineral Resources Dept., 2d ed., 88 p.

Contents include varieties of asbestos, mining methods, dressing and grading, uses, manufactured products, marketing, world's production, asbestos in the British Empire and foreign countries (including United States and Canada), and references to technical literature.

Hurley, P. M., and Thompson, J. B., 1950, *Airborne magnetometer and geological reconnaissance survey in northwestern Maine*: Geol. Soc. America Bull., v. 61, p. 835-842.

An airborne magnetometer survey, followed by reconnaissance field studies, was made in several townships in northwestern Maine from Moosehead Lake to Chain of Ponds. The belt of ultramafic rocks in the Spencer Lake region, where there has been active prospecting for asbestos, was of particular interest. Magnetic anomalies were found to coincide with occurrences of ultramafic rocks; the most clearly defined anomaly was found over the asbestos-bearing serpentinite body on Spencer Stream. Dip-needle traverses across the ultramafic mass sharply outlined the width of the body. Magnetization of the mass appears, in general, to be uniform over the entire width, although magnetite is concentrated somewhat toward the northern edge. "A theoretical total intensity curve was found to match the observed central profile quite closely on the basis of a semi-infinite dike striking N 55° E, dip 75° NW, and width of 450 feet." A geologic map (scale 1 in.=2 mi.) of the area with superimposed total magnetic intensity variations is included.

Jenkins, G. F., 1949, *Asbestos, in Industrial minerals and rocks*: New York, Am. Inst. Mining Metall. Engineers, 2d ed., p. 55-76.

Contains the following headings: Properties, distribution of deposits, political and commercial control, production and consumption, prospecting and evaluation, mining methods, preparation for market, tests and specifications, market-

ing, uses of asbestos, and prices. A selected bibliography of 32 items, covering all aspects of asbestos industry, is appended.

Jones, A. G., 1948, Salmon Arm map-area, British Columbia: Canada Geol. Survey Paper 48-7, 7 p.; Geol. Map 48-4A, by H. M. A. Rice and A. J. Jones, scale 1 inch=2 miles.

Preliminary geologic map with descriptive text. Asbestos and chromite have been found in peridotite dikes in this area. One asbestos prospect is shown on the map.

Jones, I. W., 1935, Dartmouth River map-area, Gaspé Péninsula: Quebec Bur. Mines Ann. Rept. 1934, pt. D, p. 3-44.

Narrow asbestos veins occur locally in the serpentinites which cut Lower Devonian limestones on and near Mount Serpentine in southern Blanchet township. Prospecting for asbestos has been carried on at Mount Serpentine where fibers as much as $\frac{3}{8}$ inch long have been found. Geologic map, scale 1 inch=1 mile, is included.

Keith, S. B., and Bain, G. W., 1932, Chrysotile asbestos—I. Chrysotile veins: Econ. Geology, v. 27, p. 169-188. See also Bain, 1932.

Geologic features of asbestos-bearing ultramafic bodies in the Missisquoi Valley, Quebec, and on Belvidere Mountain, Vt., are described. Attitudes of "fracture cleavage" and "shear cleavage" in ultramafic rocks are correlated with size and shape of ultramafic body. Chrysotile veins occur in complex torsion and crush fractures, formed after development of fracture cleavage. Geometric relations to their serpentinized borders, and textural features of their minerals, lead to the conclusions that veins were formed by fracture filling with minor replacement of wall rock by asbestos.

Kindle, E. D., 1953, Dezadeash map-area, Yukon Territory: Canada Geol. Survey Mem. 268, p. 38.

Several bodies of peridotite have been found in the mapped area. One, an island in Bates Lake, "is traversed by many small picrolite asbestos veins that have developed along irregular intersecting fractures * * *. Two of the veins are more than 1 inch wide, though widths of 6 inches were noted for a few feet near the intersections of fractures. The picrolite asbestos is pale gray to white and the fibers are stiff and brittle. This occurrence, though of doubtful economic importance, suggests the possibility of finding more valuable chrysotile asbestos * * * in the large peridotite bodies in the Kluane Ranges." Geologic map, scale 1 inch=4 miles, accompanies report.

Kohn, J. A. See also Comeforo, 1954.

Kohn, J. A., and Comeforo, J. E., 1955, Synthetic asbestos investigations—II. X-ray and other data on synthetic fluor-richterite, -edenite, and -boron edenite: Am. Mineralogist, v. 40, p. 410-421.

"As a portion of a general research program on the synthesis of asbestiform minerals, X-ray and other data have been obtained on the following chemically analyzed synthetic fluor-amphiboles: richterite * * *, edenite * * *, and boron edenite * * *. Comparisons are made with the values previously reported for fluor-tremolite * * *.

"A detailed indexing of X-ray powder diffraction patterns has been made in the range up to $76^\circ 2\theta$, and accurate unit cell dimensions have been determined. The observed cell-dimension variations are discussed with reference to ionic location and polarization. The synthesis and analysis of additional specified

compositions are needed to elucidate the factors controlling fibrosity and flexibility in layered and allied silicate structures."

Krannich, W. *See* Arbeitstagung "Asbest" [1942], 1944.

Kümmel, H. B. *See* Bayley, 1914.

Larsen, E. S. *See* Pardee, 1929.

Larochelle, Eugene. *See* Dufresne, 1932.

Lewis, J. V. *See* Pratt, 1905.

Low, J. H., 1951, Magnetic prospecting methods in asbestos exploration: Canadian Mining and Metall. Bull. v. 44, no. 473, p. 610-617; Canadian Inst. Mining and Metallurgy Trans., v. 54, p. 388-395.

Magnetic method is useful in prospecting for near-surface asbestos deposits if data are integrated with geologic information and limitations of the method are realized. To develop the technique, tests were made on known deposits which were checked by drilling; results were satisfactory. Several small ore bodies were discovered in the Black Lake district, Quebec, by using this technique.

Lüdke, Werner. *See* Arbeitstagung "Asbest" [1942], 1944.

McCallie, S. W., 1910, A preliminary report on the mineral resources of Georgia: Georgia Geol. Survey Bull. 23, p. 33-36.

Asbestos deposits in White, Habersham, and Rabun Counties are described. Sall Mountain Asbestos Co., in White County, is the only producer. Anthophyllite, as long, short, and mass fiber, often brittle or "rotted," occurs in peridotites in crystalline rocks. Chemical and physical properties, analysis of Sall Mountain asbestos, uses, and statistics (1890-99) are given.

McKillop, J. H. *See* Baird, 1954.

Mallory, J. M. *See* Maynard, 1923.

Marsters, V. F., 1904, A preliminary report on a portion of the serpentine belt of Lamolle and Orleans Counties: Vermont State Geologist 4th Bienn. Rept., 1903-04, p. 86-102.

This and succeeding report by Marsters (1905) are the only detailed accounts of the geology of Belvidere Mountain asbestos deposits, the largest in the United States. Report describes general geology of the area embracing the Belvidere Mountain and Lowell ultramafic bodies and considers the problem of mode of origin of serpentine and asbestos. Asbestos occurrences on which "much prospecting" has been done are reported in the vicinity of Lowell village and to the south, and on Belvidere Mountain. Annual production figures for the United States and Canada, and imports for the United States, are quoted for 1890-1902.

———1905, Petrography of the amphibolite, serpentine and associated asbestos deposits of Belvidere Mountain, Vermont: Geol. Soc. America Bull., v. 16, p. 419-446; reprinted in part in Vermont State Geologist 5th Bienn. Rept., 1905-06, p. 36-62.

Report is concerned primarily with petrographic description of the principal rocks in the Belvidere Mountain area. Asbestos deposits and the early history of asbestos mining in this area are described. Slip- and cross-fiber asbestos veins are limited to "zones of fracture and shearing" in the serpentinite mass. In general, pyrite, chromite, and magnetite occur in the core whereas the asbestos forms the selvage of the veins. Marsters concludes from a study of

the textural fractures of the cross-fiber veins that the fibers grew inward from the vein walls.

Maynard, T. P., Mallory, J. M., and Still, R. T., 1923, *Directory of commercial minerals in Georgia and Alabama along the Central of Georgia Railway: Savannah, Ga., Indus. Dept., Central of Georgia Railway, 134 p.*

Mentions asbestos occurrences in Carroll, Clayton, Coweta, Felton, Harris, Meriwether, and Morgan Counties, Ga., giving brief discussion of some. Short-fiber amphibole asbestos associated with talc and corundum was found in crystalline rocks in Tallapoosa County, Ala.

Mertie, J. B., Jr. *See also* Smith, 1930.

——— 1937, *The Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 872, p. 203-205.*

Many large bodies of ultramafic rock, which are referred to the Upper Devonian, occur in the region. Their distribution is shown on plate 1 as "ultramafic and basic intrusives of greenstone habit." No occurrences of asbestos are noted. Map, scale 1 : 500,000, is included.

——— 1940, *The Goodnews platinum deposits, Alaska: U. S. Geol. Survey Bull. 918, p. 45-55.*

Two principal masses of ultramafic rock occur in this area. The larger, about 8 square miles in area, crops out at Red Mountain and along north side of Smalls River. The smaller, about 1 square mile in area, crops out between Medicine Creek and headwaters of Salmon River. A small amount of asbestos occurs in talus of Red Mountain. Geologic map, scale 1 inch=about 1 mile (1 : 62,500), is included.

Messel, M. J., 1947, *Examination and valuation of chrysotile asbestos occurring in massive serpentine: Am. Inst. Mining Metall. Engineers Tech. Pub. 2285, 6 p.*

Comprehensively outlines factors for evaluating an asbestos deposit. Fiber content and fiber length, which ultimately control value of a deposit, are determined by prospecting, sampling, diamond drilling, testing, and grading. Secondary, but important factors, are market proximity, import tariffs, mill efficiency, and presence of marginal ores.

Mink, J. F. *See* Bates, 1950; Bates and others, 1950.

Moore, B. N., 1937, *Nonmetallic mineral resources of eastern Oregon: U. S. Geol. Survey Bull. 875, p. 8-17.*

Report contains a brief summary on production and mineralogy of asbestiform minerals and a description of Pine Creek asbestos deposits. Cross- and slip-fiber chrysotile and anthophyllite veins closely associated with talc occur in "irregular crush zones" in schists, near schist-greenstone contacts, and in serpentinized greenstones. The more abundant anthophyllite occurs in bundles composed of harsh, weak, and brittle fibers as much as 16 inches long. No resources were determined. Geologic map, 1 inch scale=750 feet, is included.

Morris, D. *See* Chidester, 1952.

Morton, Maurice, and Baker, W. G., 1941, *Identification stain for chrysotile asbestos: Canadian Mining and Metall. Bull., v. 34, no. 354, p. 515-523; Canadian Inst. Mining and Metallurgy Trans., v. 44, p. 515-523.*

Chrysotile is the only asbestiform mineral that can be identified using the described iodine stain. Preparation of sample and chemical reactions during

staining are described. Tables showing staining characteristics of asbestiform minerals, pulverized minerals (indicating serpentine rock, soapstone, brucite, and serpentinized olivine), and chemical compounds are included.

Murdock, T. G., 1950, The mining industry in North Carolina from 1937 to 1945: North Carolina, Div. Mineral Resources Econ. Paper 65, p. 21-22.

General mineralogy and uses of asbestos are given. Activities from 1936 to 1944 are summarized. Amphibole asbestos, primarily anthophyllite, was produced in Avery, Yancey, and Clay Counties.

Nagy, Bartholomew, 1953, The textural pattern of the serpentines: *Econ. Geology*, v. 48, p. 591-597.

Many serpentine specimens have been studied and found to be chrysotile, antigorite, or mechanical mixtures of the two. Electron microscope examination, solubility tests, X-ray diffraction, and differential thermal analyses reveal existence of such mixtures. Evidence indicates that one mode of formation of antigorite may involve recrystallization of chrysotile.

Nagy, Bartholomew, and Bates, T. F., 1952, Stability of chrysotile asbestos: *Am. Mineralogist*, v. 37, p. 1055-1058.

Chrysotile fibers are hollow tubes whereas antigorite is flaky in structure. Chrysotile and antigorite after treatment with 1 to 10 normal hydrochloric acid were studied by X-ray, differential thermal analysis, and electron microscopy. The results of this study are discussed. Chrysotile is more soluble in hydrochloric acid and has a lower thermal stability than antigorite and other hydrous silicate minerals. The lower stability of chrysotile may be due to a strain in the crystal structure.

Newland, D. H., 1921, The mineral resources of the State of New York: *New York State Mus. Bull.* 223-224, p. 30-32.

Describes geology of asbestos deposits of Canada, Vermont, and New York and explains why the latter seems to have no economic deposits. Asbestos is found in scattered occurrences of serpentinite in crystallized limestones in St. Lawrence, Essex, and Warren Counties, but it is not economically available under present conditions. In Warren County a small amount of chrysotile fiber, averaging $\frac{1}{4}$ inch in length, was produced from a prospect. Other occurrences are mentioned.

Niggli, F. *See* Brandenberger, 1947.

Noble, L. F., 1910, Contributions to the geology of the Grand Canyon, Ariz.; the geology of the Shinumo area: *Am. Jour. Sci.*, 4th ser., v. 29, p. 520-522.

Serpentine and asbestos occur in limestone as a contact-metamorphic phenomenon where the limestone has been intruded by diabase. Serpentine is formed in limestone, not in diabase. Limestones are magnesian and locally siliceous; shales are altered to jasper near diabase. Emanations from diabase converted siliceous parts of limestone to serpentine. Chrysotile asbestos is a later phenomenon. Generalized geologic map, scale, 1 inch= $5\frac{1}{2}$ miles, is included.

O'Harra, C. C. *See* Connolly, 1929.

Ontario Department of Mines, 1953, Mineral map of the Province of Ontario: Ontario Dept. Mines Map 1953-A, scale 1:1,267,200.

Mines and mineral occurrences, distinguished according to commodity by appropriate symbols, are shown on a generalized geologic map and indexed by

mining division in the margin. Mines and mineral localities for asbestos are shown in Sudbury, Porcupine, Larder Lake, and Montreal River mining districts.

Osterwald, D. B. *See* Osterwald, 1952.

Osterwald, F. W., and Osterwald, D. B., 1952, Wyoming's mineral resources: Wyoming Geol. Survey Bull. 45, p. 7-9.

Locates Wyoming asbestos deposits by counties. Each item has a brief description of the geology, where known. Some of the data are from the Wyoming Geological Survey files and unpublished sources.

Pardee, J. T., and Larsen, E. S., 1929, Deposits of vermiculite and other minerals in the Rainy Creek District, near Libby, Montana: U. S. Geol. Survey Bull. 805-B, p. 17-29.

A stock composed of pyroxenite and syenite in part hydrothermally altered intrudes rocks of the Belt series. On the Vermiculite and Asbestos Co. properties, "dike like tabular" masses of amphibole asbestos occur in the altered pyroxenite. The fibers are weak, inelastic, and break into short pieces and are less resistant to heat than tremolite, which they resemble. Analyses of pyroxenite are included. Geologic map, scale 1 inch=1 mile, is included.

Perkins, G. H., 1903, Mineral industries and geology of certain areas of Vermont: Vermont State Geologist 3d Bienn. Rept., 1901-02, p. 36-40.

Deposits at Eden, Belvidere Mountain, Lowell, and South Duxbury are described. Chrysotile asbestos occurs as cross and slip fibers in serpentinite. Belvidere Mountain mines are the most active, with five companies operating there, although the deposit at South Duxbury seems to have longer fibers.

Perry, E. L., 1929, The geology of Bridgewater and Plymouth Townships, Vermont: Vermont State Geologist 16th Bienn., Rept., 1927-28, p. 1-64.

Several ultramafic bodies are mentioned in this report which is concerned chiefly with areal geology. Slip-fiber amphibole asbestos has been found near Five Corners (Plymouth) where it occurs in serpentinite. Asbestos was found in float, probably from ultramafic intrusives, on Bridgewater Hill.

Perry, E. S., 1948, Talc, graphite, vermiculite, and asbestos in Montana: Montana Bur. Mines and Geology Mem. 27, p. 35-41.

The Karst, Cliff Lake, and Libby asbestos deposits are described. At the Karst deposit anthophyllite veinlets, 1 to 12 inches thick, occur in small altered peridotite dikes in highly metamorphosed Precambrian rocks. Anthophyllite fibers, as much as 1 foot long, are estimated to make up as much as 50 percent of the mined rock. At the Cliff Lake deposit, narrow veinlets of cross-fiber chrysotile cut serpentinite and marble of Precambrian age. Near Libby, amphibole asbestos occurs with vermiculite in altered dike-like masses of pyroxenite. The amphibole fibers are weak and inelastic. Locally the altered rocks contain 75 percent amphibole. A chemical analysis of the Karst asbestos and a geologic map of the Cliff Lake deposit, scale 1 inch=2 miles, are included.

Phillips, A. H., and Hess, H. H., 1936, Metamorphic differentiation at contacts between serpentinite and siliceous country rocks: *Am. Mineralogist*, v. 21, p. 333-362.

The paper is concerned chiefly with alteration and metasomatism at the contacts of ultramafic bodies during steatitization and bears incidentally on the general problem of serpentinitization and formation of asbestos. It is suggested that the bulk of serpentinitization is autometamorphic and unrelated to steatitization. Asbestos veins in Thetford district, Quebec, have been traced from un-

altered serpentinite into soapstone near the contact, where the veins were replaced by talc, though the fibrous structure of the asbestos remains. It is concluded that talc and associated minerals were formed after serpentinite and asbestos veins.

Pratt, J. H., and Lewis, J. V., 1906, Corundum and peridotites of western North Carolina: North Carolina Geol. Survey [Rept.], v. 1, 464 p.

Report covers geology, petrology and mineralogy of corundum-bearing rocks of western North Carolina. Classification, distribution, petrography, alteration, and origin of peridotites and associated basic magnesian rocks are described. Asbestos is reported from Jackson, Buncombe, Macon, Clay, and Mitchell Counties. There are 7 chemical analyses of asbestos, a long bibliography, and several illustrations. Geologic map, scale 1:493,000, shows distribution of corundum and basic magnesian rocks in North Carolina.

Preisser, F. *See* Arbeitstagung "Asbest" [1942], 1944.

Quebec Department of Mines, 1930-37, Annual report of the Bureau of Mines, 1929-36; previously published as Rept. of Commissioner of Colonization and Mines; Rept. of Minister of Crown Lands, Mines and Fisheries; Rept. of Minister of Lands, Mines, and Fisheries; Rept. of Minister of Colonization, Mines and Fisheries, from 1883 to 1928.

Part A—Mining operations and statistics—contains statistics on asbestos and other minerals. Parts B, C, and D contain articles of geologic interest, many of which are annotated separately in this bibliography. Since 1937, Part A has been published as a separate volume, "Mining Industry and Statistics." Results of geologic work are published in a new series, "Geologic Reports."

Rabbitt, J. C., 1948, A new study of the anthophyllite series: *Am. Mineralogist*, v. 33, p. 263-323.

Study of composition and physical properties of 96 specimens shows that identification of asbestos in the form of anthophyllite is usually impossible by means other than X-ray study. Some asbestiform amphibole, identified as anthophyllite on the basis of parallel extinction, was determined by X-ray to be tremolite in which the *c* axis is parallel to fibers but the *a* and *b* axes are distributed at random around the long direction, giving an apparent extinction angle of zero. Many analyses are given.

Reed, G. C., 1951, Mines and mineral deposits (except fuels), Gallatin County, Mont.: U. S. Bur. Mines Inf. Circ. 7607, p. 10-11.

The Karst asbestos deposit, near Bozeman, Mont., occurs in small bodies of peridotite which intrude gneiss and schist correlated with the pre-Beltian Pony series. Unaltered pegmatite dikes are closely associated with the asbestos-bearing peridotites. Altered zones in the peridotite consist of a network of cross- and slip-fiber anthophyllite veins. It is estimated that 25 percent of the anthophyllite can be recovered from the veins. A chemical analysis is given.

Reed, J. C. *See* Twenhofel, 1949.

Reifsnider, L. B., 1925, Amphibole asbestos deposits at Hollywood, Georgia; their development and treatment: *Eng. Mining Jour.*, v. 119, no. 15, p. 606-608.

Includes history and development of Hollywood deposit. Extensive exploration carried on to determine reserves. Four ore-bodies and a highly micaceous pegmatite dike were found. James method of wet treatment perfected to give higher fiber yield. Ore is reduced in size by multiple stages of squeezing action. Released fiber floats on water to tables.

Betty, J. A., 1931, Gaboury-Blondeau Townships map-area, Témiscamingue County: Quebec Bur. Mines Ann. Rept., 1930, pt. B, p. 53-88.

Narrow, lenticular veins of cross- and slip-fiber chrysotile occur in small irregular serpentinite stocks which intrude Keewatin volcanics near McKenzie Lake. The green cross fiber, as much as $\frac{3}{8}$ inch long, has a fine clear lustrous appearance, and is somewhat harsh, though easily separable. The slip fiber is dull, white to green, and breaks easily. The Bellehumeur-Ferron and Crevier claims are described. Geologic map, scale 1 inch=2 miles, is included.

Rice, H. M. A. *See* Jones, 1948.

Riordon, P. H., ed., 1952, Geological excursion to Eastern Townships, Quebec: Montreal, Canada, Geol. Div., Canadian Inst. Mining and Metallurgy, p. 1-21.

Sections on asbestos were prepared by geology staffs of the mining companies in Thetford-Black Lake and Asbestos districts. Many references to and descriptions of geologic features of the asbestos deposits are included. On pages 15-21 there is a description of the history, mining, milling, and geology of the Jeffrey mine of Canadian Johns-Manville Co., Lt., which produces 57 percent of current (1951) Canadian production and 35 percent of world production of chrysotile asbestos. Illustrations include aerial photographs, sections, and geologic maps at various scales.

——— 1954, Preliminary report on Thetford mines-Black Lake area, Frontenac, Megantic and Wolfe counties: Quebec Dept. Mines, Mineral Deposits Br. Prelim. Rept. 295, 23 p.

Geology of area is described. Intrusions and folding and faulting during Late Ordovician age metamorphosed some of the earlier rocks to serpentine and steatite. Asbestos deposits are divided into five groups: Pennington; Thetford mines; Reed, Murphy, and Quarry Hills; Black Lake; and "C." Principal deposits are discussed within the groups. Other occurrences are mentioned. Economic occurrences are commonly in fracture zones near contact of peridotite and country rock. Geologic map, scale 1 inch= $\frac{1}{2}$ mile, is included.

——— 1955, The genesis of asbestos in ultrabasic rocks: *Econ. Geology*, v. 50, p. 67-81.

"Field and laboratory evidence suggests that the original vein serpentine was in an amorphous or nearly amorphous state, and that the veins are, in many cases, of a composite nature, resulting partly from fissure-filling and partly from wall rock replacement. It is proposed that the picrolite and asbestos were derived through crystallization of this vein material and that two stages of crystallization were involved such that a first stage gave rise to picrolite and a second resulted in the conversion of picrolite to asbestos."

Ross, C. P., and Carr, M. S., 1941, Part 1, The metal and coal mining districts of Idaho, with notes on the nonmetallic mineral resources of the State; Part 2, Bibliography and Table of contents: Idaho Bur. Mines and Geology Pamph. 57, p. 101.

Gives location and brief description of the geology of amphibole asbestos in Clearwater and Idaho Counties and chrysotile asbestos in Idaho County. References to asbestos in bibliography have brief annotations.

Ross, J. G., 1931, Chrysotile asbestos in Canada, Ottawa, Canada Dept. Mines, Mines Br., 146 p.

Chapter headings are—History, physical and chemical properties, and origin of asbestos; Quarrying of asbestos; Dressing of asbestos for the market; Cost of extraction, market prices, statistics, and status of the industry; Asbestos

mines and prospects in Canada; Manufacturing of asbestos products; and Commercial applications of asbestos. Operations of major companies are described. Other locations and prospects in Dorchester, Beauce, Magantic, Frontenac, Wolfe, Richmond, Brome, and Papineau Counties and Abitibi district, Quebec, and Cochrane and Timiskaming districts, Ontario, are mentioned. Analyses are given.

Roy, D. M., and Roy, Rustum, 1954, An experimental study of the formation and properties of synthetic serpentines and related layer silicate minerals: *Am. Mineralogist*, v. 39, p. 957-975.

Chemical substitution is used to test the hypothesis that tubular crystals of chrysotile result from a misfit of alternate brucite and silica layers. Some of the results are as follows: Hexagonal plates were formed when Ge^{4+} substituted for Si^{4+} ; platy crystals were formed when Al^{3+} substituted for both Si^{4+} and Mg^{2+} ; either platy or tubular crystals were formed when Ni^{2+} substituted for Mg^{2+} ; however, this is dependent also upon other factors. Serpentine structures were not formed when Mn^{2+} , Zn^{2+} , Co^{2+} , Fe^{2+} , Cr^{3+} , and Ga^{3+} were substituted in the structure. Of secondary importance in the formation of tubular crystals are the following factors: Temperature of growth, length of time of growth, and presence of foreign ions. Other hydrosilicate type structures were synthesized and comparisons were made of the phase equilibria in the systems, $\text{MgO-SiO}_2\text{-H}_2\text{O}$, $\text{NiO-SiO}_2\text{-H}_2\text{O}$, and $\text{MgO-GeO}_2\text{-H}_2\text{O}$.

Roy, Rustum. *See* Roy, 1954.

Rukeyser, W. A., 1950, New uses for low-priced fibers vital to Canadian asbestos: *Eng. Mining Jour.*, v. 151, no. 3, p. 76-80.

The shorter grades of asbestos have been utilized in increasingly large amounts in the last 10 years. Graphs show annual production since 1878. Effects on the industry and technical problems are discussed. Standard classification and discussion of Quebec testing machine are included.

Rutledge, F. A. *See* Helde, 1946.

Salisbury, R. D. *See* Bayley, 1914.

Sampson, Edward. *See* Bateman, 1923.

Sand, L. B. *See* Bates, 1950.

Satterly, Jack. *See also* Hewitt, 1953.

— 1952, Geology of Munro township: Ontario Dept. Mines Ann. Rept. 1951, v. 60, pt. 8, 1951, p. 35-42.

Chrysotile asbestos occurs as cross-fiber veins in serpentinized peridotite and dunite that occur as sills in the volcanic rocks. Fibers range from less than $\frac{1}{4}$ inch to more than 1 inch in length. Chrysotile throughout the district seems to be structurally related to diabase dikes. Geology of Munro mines (see Hendry, 1951) is reprinted. Deposits at seven other properties are described; several have short chrysotile fibers in serpentinite, but none have been extensively developed. Geologic map, scale 1 inch=400 feet, is included.

Sauerbrey, D. E. *See* Arbeitstagung "Asbest" [1942], 1944.

Schwab, K. *See* Arbeitstagung "Asbest" [1942], 1944.

Selfridge, G. C., Jr., 1936, An X-ray and optical investigation of the serpentine minerals: *Am. Mineralogist*, v. 21, p. 463-503.

On the basis of X-ray and optical studies, Selfridge concludes that most of the species now classed within the serpentine group can be referred to two

main divisions. The first division, which is referred to as the mineral serpentine, consists of varieties of X-ray diffraction patterns similar to those of serpentine, and best represented by patterns of chrysotile. The second division, referred to as the mineral antigorite, consists of varieties with patterns similar to those of antigorite. The fundamental structures of both divisions appear to be fibrous. The author proposes that all other varietal names should be dropped; however, he retains the term "chrysotile" for "serpentine occurring in veins and consisting of flexible fibers." The term "serpentinite" is suggested for rocks composed of serpentine or antigorite or a mixture of both.

Sellards, E. H., and Baker, C. L., 1934, *The geology of Texas*, v. 2, pt. 3, *Economic geology of Texas*: Texas Univ. Bull. 3401, p. 250-253.

Brief article discusses the uses of asbestos. Cross-fiber amphibole asbestos veins in serpentinite are known from four localities in Llano and Gillespie Counties. It is thought that the material from these localities is in part chrysotile. Little is known of the geology of the deposits.

Shannon, E. V., 1922, Description of ferroanthophyllite, an orthorhombic iron amphibole from Idaho, with a note on the nomenclature of the anthophyllite group: U. S. Natl. Mus. Proc., v. 59, p. 397-401.

Splintery fibrous masses of an asbestiform mineral containing fibers as much as 6 cm long occur in the Tamarack-Custer and Hercules mines of the Coeur d'Alene district. Chemical and optical data indicate that this is ferroanthophyllite, the iron end member of the anthophyllite group. It resembles chrysotile and separates easily into fine, silky, strong, and flexible fibers.

Shride, A. F., 1952, Localization of Arizona chrysotile asbestos deposits [abs.]: Geol. Soc. America Bull., v. 63, p. 1344.

Chrysotile asbestos is genetically related to dikes and sills of diabase intruded into Precambrian Mescal limestone. Cross-fiber veins occur in serpentine that has replaced certain limestone beds. Largest deposits are in zones of fractures associated with small open folds formed at the time of diabase intrusion.

Sinclair, W. E., 1955a, Evaluation of asbestos deposits: *Asbestos*, v. 36, no. 10, p. 2-14.

Deposits with regular structural control can be evaluated on basis of fiber measurements and (or) core drilling. This is possible with stratified deposits, such as those of Arizona and South Africa. Regular bulk sampling and large-scale tests from representative samples are the best procedure where the controlling factors are irregular, as in mass- or slip-fiber deposits. Hardness of parent rock and fiber characteristics must be determined by test milling. General picture of the geological character, structure, and zoning are important, as are the proportion and grade of fiber, the fiber quality, and the market price. Development and working methods will ultimately control ore value. This article discusses primarily the deposits that have structural controls, and also methods to determine ore value.

——— 1955b, *Asbestos, its origin, production, and utilization*: London, Mining Pubs., Ltd, 365 p.

Chapter topics are—History; Serpentine Group; Amphibole Group; Form and Nature of Deposits, World Distribution of Deposits; Mining; Evaluation of Ore Bodies; Milling; Classification, Grading, Marketing and Prices; Commercial Application; Synthetic Asbestos and Substitutes; Economic Considerations.

Emphasis is on deposits of southern Africa and production methods. Chemical analyses, illustrations, and index and sketch maps are included.

Sitz, G. See Arbeitstagung "Asbest" [1942], 1944.

Sloan, Earle, 1908, Catalogue of the mineral localities of South Carolina: South Carolina Geol. Survey Bull. 2, ser. 4, p. 122-125.

Cross-fiber chrysotile occurs in several zones of metamorphic rocks that include serpentinite. Some outcrops contain long fibers. Reported occurrences in Anderson, Oconee, Pickens, Newberry, and Spartanburg Counties are located and described.

Smith, P. S., 1932, Mineral industry of Alaska in 1929: U. S. Geol. Survey Bull. 824-A, p. 80.

Occurrences of asbestos in the Kobuk River district near Shungnak and the Ambler River are mentioned. Chrysotile asbestos was found by prospectors on Bear Creek, near the north end of Admiralty Island in southeast Alaska. The fibers from the deposit are rather weak and brittle, but they are from the surface and are weathered. The strength of the material may improve with depth.

Smith, P. S., and Mertie, J. B., Jr., 1930, Geology and mineral resources of north-western Alaska: U. S. Geol. Survey Bull. 815, p. 344-345.

"Asbestos has been found in the vicinity of Shungnak and in the Jade Hills, and several attempts have been made in a small way to develop it. The asbestos near Shungnak occurs as small veins in close association with greenstone and serpentine." The most important occurrences are on the east side of Dahl Creek. Specimens having fibers several inches long have been found. "* * * although the color is good the tensile strength of the fibers is small * * *." In 1925 and 1926 prospecting interest was revived in the Jade Hills, where the asbestos is thought to be similar to that near Shungnak.

Snelgrove, A. K., 1953, Mines and mineral resources of Newfoundland: Newfoundland Geol. Survey Inf. Circ. 4, p. 97-100.

Summarizes information pertaining to five Newfoundland asbestos areas. Chrysotile and tremolite are in serpentinite that occurs in several belts. Localities described are Bluff Head-Lewis Brook prospects, Bond's Asbestos property, Hare Bay, Sops Arm prospect, and Larke Harbour. Brief bibliography is appended.

Soboleff, N. D., and Tatarinoff, M. V., 1933, The cause of brittleness in chrysotile asbestos: Econ. Geology, v. 28, p. 171-177.

Authors classify chrysotile fibers as "normal, harsh, and brittle." "Brittle" fibers are hard to the touch and break easily when bent; they are believed to represent a transition stage between asbestos and talc. Chemical studies of the fibers have shown that "normal" asbestos contains excess water, whereas "brittle" chrysotile is characterized by excess SiO₂ and some by MgO. The authors conclude that "brittle" chrysotile "may be regarded as a product of metamorphism of normal chrysotile-asbestos;" and that "the explanation of the brittleness by the presence of CaO in the chemical composition of asbestos, *i. e.*, by the isomorphous replacement of MgO, is inconclusive." Previous theories of the origin of brittleness in chrysotile are briefly reviewed.

Spencer, A. C., 1916, The Atlantic gold district and the North Laramie Mountains, Fremont, Converse, and Albany Counties, Wyoming: U. S. Geol. Survey Bull. 626, p. 3-85.

Describes asbestos prospects in serpentinite belts of Fremont, Natrona, and Converse Counties. In Atlantic gold district, three of the four known serpen-

finite bodies have been prospected; weathered asbestos fibers commonly less than $\frac{1}{2}$ inch long, were found at one locality (p. 18-19). Little commercial asbestos has been reported from the North Laramie Mountains (p. 57, 79). Geologic maps, scales 1 inch=1 mile and 1 inch=5 miles, are included.

Stephens, F. H., 1952, B. C.'s first asbestos mine: *Western Miner and Oil Review*, v. 25, no. 12, p. 35-37.

Cassiar Asbestos Corp., incorporated in 1951, anticipates first production by end of 1952. Geology, development, townsite, and equipment are discussed. Asbestos veins are in serpentinite intruded into folded sediments. Fiber ranges from $\frac{1}{8}$ to $1\frac{1}{2}$ inches, common lengths being $\frac{1}{2}$ to $\frac{3}{4}$ inch. Outcrops average 5 to 10 percent fiber. Serpentinite talus covers much of the area and averages 10 to 20 percent asbestos. Numbers 1 and 2 crude fiber and some group 3 have been stockpiled.

——— 1953, Asbestos in southern B. C.: *Western Miner and Oil Review*, v. 26, no. 7, p. 44-46.

Two promising asbestos deposits are being developed. The Okanagan Falls deposit contains "veinlets and horses" of long-fiber amphibole asbestos in serpentinitized fault breccias. Small quantities of cross-fiber chrysotile in narrow veins are believed to be related to contact metamorphism produced by a later aplite dike intrusion. The asbestos fibers are divisible to fine threads of fair strength. Economic possibilities of the deposit are discussed. The Revelstoke deposit has cross-fiber chrysotile from $\frac{1}{16}$ to $\frac{5}{8}$ inch long and slip fiber as much as 5 inches in length. Further exploration is needed. Asbestos fibers are similar in quality to those of Thetford, Quebec.

Stewart, G. W. See Chidester, 1952.

Stewart, L. A., 1955, Chrysotile asbestos deposits of Arizona: U. S. Bur. Mines Inf. Circ. 7706, 124 p.; supplemented by U. S. Bur. Mines Inf. Circ. 7745, 41 p., 1956.

About 50 prospects and mines in the Salt River, Sierra Ancha, and Globe districts of central Arizona, 2 deposits in the Grand Canyon district of northern Arizona, 2 deposits in Pinal County, and 1 occurrence in Cochise County of southeastern Arizona are discussed. Many areal and local maps and production figures are included.

An additional 18 properties are described in the supplement, virtually completing the list of known asbestos properties in Arizona.

Stewart, L. A., and Haury, P. S., 1947, Arizona asbestos deposits, Gila County, Arizona: U. S. Bur. Mines Rept. Inv. 4100, 28 p.

Résumé of work of U. S. Bureau of Mines and U. S. Geological Survey, 1941-44, on Arizona asbestos deposits. Describes in general the asbestos industry in Arizona including geology, production, grading and marketing, mining methods, and present activity. Results of U. S. Bureau of Mines exploration program at the Grandview No. 4 and Euders' White Tail No. 2 mines, at the Cowboy and Last Chance claims of the Kyle's Sloan Creek group, and at the Reynolds Falls group of claims are summarized. Plans and sections of mines, mill-flow sheets, and table showing Arizona asbestos production are included. Geologic maps of the 4 areas described are included at scales ranging from 1 inch=150 feet to 1 inch=about 375 feet. A geologic map of the Salt River area, scale 1 inch=10 miles, is also included.

Still, R. T. See Maynard, 1923.

Straw, D. J., 1955, A world survey of the main chrysotile asbestos deposits: Canadian Mining and Metall. Bull., v. 48, no. 522, p. 610-630; Canadian Inst. Mining and Metallurgy Trans., v. 58, p. 340-360.

Discusses chrysotile associated with "serpentinized ultrabasic" rocks throughout the world. The geology of the following areas is more detailed: Canada—Jeffrey, Vimy Ridge, Munro, and Cassiar mines; Transvaal—New Amianthus mine; Southern Rhodesia—Shabani district, Mashaba district; Russia—Bejenova district; Japan—Hokkaido district; Cyprus—Amiando mine; and Colombia. Other countries mentioned are Union of South Africa, Swaziland, French Morocco, Madagascar, Spain, Yugoslavia, Italy, China, Venezuela, and Australia. There is no discussion of asbestos deposits in the United States.

Streib, W. C. See Badollet, 1955.

Taber, Stephen, 1924, The origin of veins of fibrous minerals: Econ. Geology, v. 19, p. 475-486.

Based on results of laboratory experiments and detailed study of structure and texture of asbestos veins, the author concluded that cross-fiber veins formed by "material for growth being supplied through small, closely spaced openings in the walls, which have been pushed apart by the growing vein." The "peculiar structure" of these veins is due to "mechanical limitation of crystal growth through addition of new material in only one direction." The hypotheses that fibrous veins were deposited in open fissures or were formed by replacement or recrystallization of wall rock in place are discounted by the author.

Tatarinoff, M. V. See Soboleff, 1933.

Thompson, J. B. See Hurley, 1950.

Thorne, R. L. See Fisher, 1945.

Trischka, Carl, 1927, Asbestos and the Arizona industry: Eng. Mining Jour., v. 124, p. 337-340.

Report contains general information on the mineralogy and uses of asbestiform minerals and specific descriptions of the chrysotile deposits in Gila County, Ariz. Chrysotile was deposited in fractures and folds near diabase sills in the serpentinized Mescal limestone of Precambrian age. The ore bodies are as much as 60 feet wide and 200 feet long, and may contain several chrysotile-bearing zones. Factors that have increased mining costs are the extensive exploration and the development that are needed to discover and mine the small erratically distributed ore bodies. Generalized vertical sections and plans of typical commercial asbestos deposits in Arizona are given.

Tuttle, O. F. See Bowen, 1949.

Twenhofel, W. S., Reed, J. C., and Gates, G. O., 1949, Some mineral investigations in southeastern Alaska: U. S. Geol. Survey Bull. 963-A, p. 34-37.

Tremolite asbestos on Admiralty Island occurs as "leaves and sheaves of parallel fibers, as much as 18 inches long" in a band that parallels the foliation in amphibole schist. Fibers examined were probably weathered, and therefore had no commercial value. Geologic map, scales 1 inch = 1¼ miles; 1 inch = about 20 feet, are included.

U. S. Bureau of Mines, 1924-31: Mineral resources of the United States.

These annual publications list statistics on asbestos production, consumption, use, price, imports, and exports. Current developments are noted.

U. S. Bureau of Mines, 1932-55: Minerals Yearbook 1932-54. Preprints for 1955.

These annual publications list statistics on asbestos production, consumption, use, price, imports, and exports. Current developments are noted.

— 1952, Materials survey, Asbestos, 1950. U. S. Bur. of Mines. Data Assembled by Oliver Bowles.

Compilation covers briefly nearly all aspects of the asbestos industry from geologic occurrence to uses. The chapter headings indicate the scope of the report: 1, Varieties and Composition of Asbestos; 2, Description of Deposits; 3, Mining Methods; 4, Milling Methods; 5, Grading and Classification; 6, World Production; 7, World Reserves; 8, Political and Commercial Control; 9, International Trade; 10, Marketing; 11, Prices; 12, Uses and Requirements of Use; 13, Substitutes for Asbestos; 14, Beneficiation of Asbestos; 15, Synthetic Asbestos; 16, Problem of Low-Iron Asbestos; 17, Search for New Sources of Supply; 18, World War II Controls and Experiences. Geologic map (scale 1 in.=2 mi.) of the Quebec Asbestos region, and location map of major world asbestos deposits are included.

U. S. Geological Survey, 1882-1923: Mineral resources of the United States.

These annual publications list statistics on asbestos production, consumption, use, price, imports, and exports. Current developments are noted. Geology of several deposits is described in the following volumes: 1895-96, 1900, 1901, 1903, 1904, 1907, 1909, 1913, 1914, 1917, 1918, 1919, and 1920.

Valentine, G. M., 1949, Inventory of Washington minerals, part 1, Nonmetallic minerals: Washington Div. Mines and Geology Bull. 37, p. 8, 9.

State map shows asbestiform mineral localities, differentiating between reported occurrences, known occurrences, and those with a record of production. This is accompanied by a list of deposits, giving name, location, description, value, and reference, where known. There are no known commercial deposits of asbestos in Washington, but favorable rock types occur at several localities.

Van Cott, Corbin. See Fisher, 1945.

Vermont State Geologist Reports, 1898-1947: Burlington, Vt., v. 1-25.

Most of the biennial reports of the State Geologist contain sections variously entitled, in succeeding reports, "Report on the Mineral Industries," "Mineral Resources," "Mineral Resources and Industries," and "Mineral Industries." Many contain brief accounts of asbestos, devoted chiefly to reviewing mining and prospecting activities and listing personnel and equipment of the companies. Three of these references (Perkins, 1902, and Marsters, 1904, 1905) are annotated separately. Others constitute an account of development of the asbestos mine at Belvidere Mountain and are contained in the following reports: v. 3, 4, 6, 7, 8, 12, 13, 17, 19, 20, 22, 23, 24, and 25.

Waggaman, W. H. See Bowles and others, 1948.

Wahlstrom, E. E., 1934, An unusual occurrence of asbestos: Am. Mineralogist, v. 19, p. 178-180.

Amphibole asbestos associated with copper-bearing pyrite, galena, sphalerite, calcite, feldspar, quartz, and pyroxene was found in a banded fissure-vein deposit in the Snowy Range mine at Camp Albion, Boulder County, Colo. Analysis of asbestos is included and properties are described. Occurrence is of mineralogic interest only.

Watson, T. L., 1907, Mineral resources of Virginia; Lynchburg, Va., J. P. Bell Co., p. 285-287. (Virginia Jamestown Exposition Comm.)

All the known asbestos occurrences are in the Piedmont province. The asbestiform minerals are members of the amphibole group and have been mined in Amelia, Bedford, and Franklin Counties. Asbestos has been reported from Albemarle, Buckingham, Floyd, Goochland, Grayson, Fauquier, and Powhatan Counties. Two chemical analyses of amphibole asbestos are given.

White, W. H. See Wolochow, 1941.

Willis, C. E., 1894, The asbestos fields of Port au Port, Newfoundland (with discussion): Mining Soc. Nova Scotia Jour. 2, p. 166-173.

Serpentinite belt of Thetford-Black Lake continues through the Gaspé Peninsula, and across Newfoundland. At Cape Gregory talus contains chrysotile fibers as long as 2½ inches in serpentine. Much prospecting done in rocks similar to those of Eastern Townships of Quebec.

Wilson, E. D., 1928, Asbestos deposits of Arizona; with an introduction on asbestos minerals, by G. M. Butler: Arizona Bur. Mines Bull. 126, 100 p.

Discusses asbestos minerals and their geologic occurrences, grades and specifications, uses, demand, market value, world production, mining and milling processes and acquisition of claims. Describes geologic settings of deposits in Chrysotile-Salt River region, Sierra Ancha region, and other deposits in Gila County; also those of Coconino, Pinal, and Yuma Counties. Asbestos occurs in Precambrian Mescal limestone, near diabase contact. Character of limestone and diabase, general features of asbestos deposits, and origin of asbestos are discussed.

Wing, L. A., 1951, Asbestos and serpentine rocks of Maine: Maine Geol. Survey, Rept. State Geologist, 1949-50, p. 35-46.

Large masses of serpentinite have been mapped at two places in Maine; Spencer area and Deer Isle area. Other serpentinite occurrences in the State are too small to be of economic importance. All known serpentinite bodies in the Spencer area contain asbestos; possibly one has commercial quantities. Geologic relations of serpentinite bodies are described briefly. In the Deer Isle area only one ultramafic body was observed to contain asbestos, and that in very small amounts. Geology is briefly described. Geologic maps, scales, 1 inch=about 100 feet and 1 inch=400 feet, are included.

Wing, L. A., and Dawson, A. S., 1949, Preliminary report on asbestos and associated rocks of northwestern Maine: Maine Geol. Survey, Rept. State Geologist 1947-48, p. 30-62.

The Parmachenee area in northern Oxford County, the Jim Pond area in northern Franklin County, and the Spencer area in central Somerset County in northwestern Maine were studied to evaluate their asbestos resources.

The authors believe that the deposits of the Parmachenee and Jim Pond areas are not of commercial importance at present. In the Spencer area, 4 of the 5 known serpentinite masses contain asbestos, but other asbestos-bearing serpentinite masses may be discovered. The "Spencer serpentine" along Little Spencer Stream, considered by the authors as a potential source of asbestos, contains two fiber-bearing zones with as much as 8 percent asbestos, all of short length but good quality, in fracture zones in the serpentinite. Although the results of diamond drilling in the eastern part of this body have been inconclusive, the authors feel that further exploration in this area is warranted. Geologic maps of the "Spencer serpentine" (scale 1 in.=about 300 ft.), the "Stony Brook

Mountain serpentine" (scale 1 in.=200 ft.), and the Jim Pond area (scale 1:62,500) are included.

Wolochow, David, 1941, Thermal studies on asbestos, II, Effect of heat on the breaking strength of asbestos tape and glass fiber tape: Canadian Jour. Research, v. 19, pt. B, p. 56-60.

Effects of heat on chrysotile asbestos tape, crocidolite (blue) asbestos tape, and glass fiber tape are presented. Absorbed moisture is driven off, which increases breaking strength. Chrysotile keeps strength to 370°C. Prolonged heating at higher temperatures produces partial loss in strength. Above 540°C it loses strength rapidly. Crocidolite loses strength more rapidly. Glass fiber is less heat resistant, losing strength rapidly at 250°C. Several graphs show results.

Wolochow, David, and White, W. H., 1941, Thermal studies on asbestos, I, Effect of temperature and time of heating on loss in weight and resorption of moisture: Canadian Jour. Research, v. 19, pt. B, p. 49-55.

Loss in weight of chrysotile asbestos heated to between 500° and 700°C varied with time and temperature. Prolonged heating near 500°C expelled as much as 50 percent of the combined water. Near 600°C prolonged heating expelled all the water. Above 700°C, loss in weight was rapid. Data suggest that heating near 215°C would be an accurate and rapid method to determine free moisture. The results are shown on several graphs and tables.

Woodward, H. P., 1932, Geology and mineral resources of the Roanoke area, Virginia: Virginia Geol. Survey Bull. 34, p. 133-134.

Asbestos fibers as much as 18 inches long have been mined from "vertical dike-like masses" parallel to the schistosity of the metamorphic rocks near Bedford and Roanoke. Small masses of asbestiform minerals are known to occur along shear zones in the crystalline rocks of the Blue Ridge province and locally along bedding- and fault-planes in limestones of the Roanoke area. Most of this material is not of commercial value.

Wright, W. S. See Heide, 1946.

Yoder, H. S., Jr. 1952, The $MgO-Al_2O_3-SiO_2-H_2O$ system and the related metamorphic facies: Am. Jour. Sci., Bowen Volume, pt. 2, p. 569-627.

Equilibrium relations in part of this 4-component system were studied at temperatures from 430° to 990°C at pressures of water vapor as high as 30,000 psi (pounds per square inch). Powders of the composition, $3MgO.2SiO_2$, when hydrothermally treated, formed serpentine below temperatures of about 520°C and at pressures from 2,000 to 20,000 psi. On the basis of X-ray patterns, non-aluminous serpentine appears to be chrysotile; aluminous serpentine appears to be similar to antigorite in X-ray pattern and platy habit. Assemblages stable in presence of excess water vapor at significant temperature intervals and at pressures as high as 30,000 psi are discussed with the aid of pressure-temperature curves and triangular-composition diagrams.

Zimmerman, E. W., 1953, Reclamation of asbestos: [U. S.] Natl. Bur. Standards Tech. News Bull., v. 37, no. 9, p. 139; Asbestos, v. 35, no. 3, p. 16-18.

Describes simple effective procedure developed for reclaiming asbestos from discarded pipe insulation. Samples used in study are of three general types: asbestos cloth, asbestos-cotton cloth, and a molded pipe lagging that has asbestos fiber as filler and magnesia cement as binder. Extraneous material is removed from the asbestos insulation by chemical treatment and the cleaned ma-

material is reduced to fiber form in a paper pulp beater. Recovery from the molded pipe insulation averaged only 15 percent of the fiber and this was contaminated with foreign material. The uses of reclaimed asbestos, particularly that from asbestos cloth and asbestos-cotton cloth, are discussed.

Zodac, Peter, 1939, Mountain leather at Paterson, N. J.: *Rocks and Minerals*, v. 14, no. 1, p. 3-9.

Mountain leather is found in Wappinger limestone quarry as vertical sheets in limestone. Interwoven fibers make up a porous material with low specific gravity and low absorption of water.

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- Maynard and others 1923
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Grading. *See* Classification.

Idaho.

General:

- Ross and Carr 1941
- Shannon 1922
- Orofino region: Anderson, A. L. 1930, 1931

Limestones with asbestos. *See* Source rocks.

Magnetometer tests. *See* Prospecting.

Maine:

- Hurley and Thompson 1950
- Wing 1951
- Wing and Dawson 1949

Maryland: Bangs 1946

Massachusetts: Emerson 1917

Metamorphic rocks. *See* Source rocks.

Milling methods. *See* Mining and milling methods.

Mineralogy.

General:

- Badollet 1951
- Bowles 1935a, 1955a
- Bowles and others 1948
- Frank 1952
- Sinclair 1955b
- Taber 1924
- U. S. Bureau of Mines 1952
- Wilson 1928
- Yoder 1952

Mineralogy—Continued

Amphibole asbestos: Wahlstrom 1934

Anthophyllite:

- Rabbitt 1948
- Shannon 1922

Chrysotile:

- Bates and Mink 1950
- Bates and others 1950
- Gruner 1937
- Morton and Baker 1941
- Nagy 1953
- Selfridge 1936
- Wolochow 1941
- Wolochow and White 1941

Serpentine:

- Bates and Mink 1950
- Gruner 1937
- Nagy 1953
- Selfridge 1936

Tremolite:

- Anderson, Eskil 1945, 1947
- Comeforo and Kohn 1954
- Kohn and Comeforo 1955

Mining and milling methods:

- "Asbestos" 1919-55
- Asbestos Textile Institute 1953
- Badollet 1949, 1950, 1955
- Bowles 1935b, 1955a
- Cirkel 1910
- Dresser 1939
- Morton and Baker 1941
- Sinclair 1955b
- Stewart 1932
- U. S. Bureau of Mines 1924-31, 1932-55, 1952

Mode of occurrence of asbestos:

- Alcock 1947
- Anderson, A. L. 1930, 1931
- Anderson, Eskil 1945, 1947
- Armstrong 1940, 1949
- Bain, G. W. 1932, 1942
- Bangs 1946
- Bannerman 1940
- Barlow 1910
- Bateman 1923
- Beckwith 1939
- Beeler 1911
- Bowles 1935a, 1955a
- Bell 1955
- British Columbia Department of Mines 1951, 1952, 1954
- Byers and Dahlstrom 1954
- California Bureau War Minerals Production 1942
- California Journal of Mines and Geology 1932-55
- Chidester, Billings, and Cady 1951
- Coats 1944
- Cooke 1931, 1937, 1947, 1950
- Cooper 1936
- Denis 1931
- Diller 1911
- Dresser 1918, 1939
- Emerson 1917

Mode of occurrence of asbestos—Con.

- Helde and others 1946
 Hendry 1951
 Hewitt and Satterly 1953
 Hopkins 1914
 Jones, I. W. 1935
 Keith and Bain 1932
 Marsters 1904, 1905
 Moore 1937
 Newland 1921
 Noble 1910
 Pardee and Larsen 1929
 Perkins 1903
 Perry, E. L. 1929
 Perry, E. S. 1948
 Pratt and Lewis 1905
 Reed 1951
 Reifsnieder 1925
 Retty 1931
 Riordon 1952, 1954
 Satterly 1952
 Sellards and Baker 1934
 Shride 1952
 Sinclair 1955a, b
 Sloan 1908
 Smith and Mertie 1930
 Snelgrove 1953
 Spencer 1916
 Stephens 1952, 1953
 Stewart 1955
 Stewart and Haury 1947
 Straw 1955
 Trischka 1927
 Twenhofel and others 1949
 U. S. Bureau of Mines 1952
 Valentine 1949
 Wahlstrom 1934
 Willis 1894
 Wilson 1928
 Wing 1951
 Wing and Dawson 1949
- Montana :
 Pardee and Larsen 1929
 Perry, E. S. 1948
 Reed 1951
- Mountain leather. See Pailgorskite ; Substitutes for asbestiform minerals.
- Newfoundland :
 Baird and others 1954
 Cooper 1936
 Snelgrove 1953
 Willis 1894
- New Jersey : Bayley and others 1914
- New York :
 Newland 1921
 Zodac 1939
- North Carolina :
 Murdock 1950
 Pratt and Lewis 1905

Olivine. See Source rocks, Ultramafic.

Ontario.

General :

- Cooke 1947
 Hewitt and Satterly 1953
 Ontario Department of Mines 1953

Cochrane District (Munro) :

- Hendry 1951
 Satterly 1952

Oregon : Moore 1937

Origin.

Asbestos.

General :

- Bain, G. W. 1932, 1942
 Bowles 1955a
 Frank 1952
 Hess 1933
 Keith and Bain 1932
 Riordon 1955
 Ross 1931
 Sinclair 1955b
 Taber 1924
 U. S. Bureau of Mines 1952

Deposits :

- Anderson, A. L. 1930, 1931
 Bateman 1923
 Cooke 1937
 Dresser 1913, 1920
 Faessler and Badollet 1947
 Graham 1917
 Noble 1910
 Stewart 1955
 Stewart and Haury 1947
 Wilson 1928

Ultramafic Rocks :

- Armstrong 1940, 1949
 Bain, G. W. 1932, 1936
 Benson 1918
 Bowen 1927
 Bowen and Tuttle 1949
 Chidester, Billings, and Cady, 1951
 Cooke 1937
 Dresser 1920
 Faessler and Badollet 1947
 Frank 1952
 Graham 1917
 Hess 1933, 1955
 Sinclair 1955b

Pailgorskite :

- Fisher and others 1945
 Valentine 1949
 Zodac 1939

Pennsylvania : Gordon, 1922

Peridotite. See Source rocks, Ultramafic.

Picrollite :

- Armstrong 1940, 1949
 Aubert de la Rue 1941
 Barlow 1910
 Bowles 1955a

Picrolite—Continued

- British Columbia Department of Mines, 1951
- Kindle 1958
- Riordon 1965
- U. S. Bureau of Mines 1952

Properties of asbestiform minerals, physical and chemical.

General:

- Badollet 1951
- Bowles 1935a, 1955a
- Cirkel 1910
- Frank 1952
- Jenkins 1949
- Ross 1931
- Sinclair 1955b
- U. S. Bureau of Mines 1952

Chemical:

- Morton and Baker 1941
- Nagy 1953
- Nagy and Bates 1952

Physical:

- Badollet 1948, 1949, 1950, 1955
- Soboleff and Tatarinoff 1933
- Wolochow 1941
- Wolochow and White 1941

Prospecting.

General:

- Bowles 1955a
- Sinclair 1955b

Evaluation:

- Messel 1947
- Sinclair 1955a

Exploration:

- Cirkel 1910
- Stewart 1955

Geophysical methods:

- Hendry 1951
- Hurley and Thompson 1950
- Low 1951

Stain test: Morton and Baker 1941

Pyroxenite. *See* Source rocks, Ultramafic.

Quebec.

General:

- Dresser 1920
- Dresser and Denis 1939-51
- Graham 1917
- Quebec Department of Mines, 1930-37

Abitibi County: Bannerman 1940

Chibougamau region: Faribault and others 1911

Eastern Townships:

General:

- Alcock 1947
- Ambrose 1942
- Aubert de la Rue 1941
- Cooke 1950
- Denis 1931
- Dresser 1912, 1913
- Faessler and Badollet 1947

Quebec—Continued

Eastern Townships—Continued

- Jones, I. W. 1935
- Thetford-Black Lake area
- Cooke 1931, 1935, 1937
- Riordon 1952, 1954
- Papineau County: Bowles 1955b
- Temiscamingue County: Retty 1931

Reclamation of asbestos: Zimmerman 1958

Rhode Island: Emerson 1917

Saskatchewan: Byers and Dahlstrom 1954

Sedimentary rocks containing asbestos. *See* Source rocks, Limestones and Metamorphic rocks.Serpentine. *See* Source rocks, Ultramafic.

Source rocks containing asbestos.

Limestones:

- Bateman 1923
- Bayley and others 1914
- Bowles 1955a, b
- Diller 1911
- Dresser 1939
- Hewitt and Satterly 1953
- Newland 1921
- Noble 1910
- Stewart 1955
- Stewart and Haurly 1947
- Shride 1952
- Sinclair 1955a, b
- Trischka 1927
- U. S. Bureau of Mines 1952
- Wilson 1928

Metamorphic rocks:

- Anderson, A. L. 1930
- Dietrich 1953, 1955
- Diller 1911
- Maynard and others 1923
- Moore 1937
- Newland 1921
- Osterwald and Osterwald 1952
- Pratt and Lewis 1905
- Reifmeider 1925
- Sloan 1908
- Twenhofel and others 1949
- Valentine 1949
- Wahlstrom 1934
- Watson 1907
- Woodward 1932

Ultramafic rocks:

- Alcock 1947
- Ambrose 1942
- Anderson, A. L. 1931
- Armstrong 1940, 1949
- Aubert de la Rue 1941
- Bain, G. W. 1932, 1936, 1942
- Bain, H. F. 1946
- Bancroft 1922
- Bannerman 1940
- Barlow 1910
- Beckwith 1939
- Beeler 1911

Source rocks containing asbestos—Continued

Ultramafic rocks—Continued

Bell 1955
 Benson 1918
 Bostock 1948
 Bowen 1927
 Bowen and Tuttle 1949
 Bowles 1955a
 British Columbia Department of
 Mines 1951, 1952, 1954
 California Bureau War Minerals
 Production 1942
 California Division of Mines
 1950, 1951
 California Journal of Mines and
 Geology 1932-55
 Canada Geological Survey 1948
 Carlson and Clark 1954
 Chidester, Billings, and Cady
 1951
 Chidester, Stewart, and Morris
 1952
 Cirkel 1910
 Coats 1944
 Cooke 1931, 1937, 1947, 1950
 Cooper 1936
 Davis 1950
 Denis 1931
 Diller 1911
 Dresser 1912, 1913, 1920, 1939
 Emerson 1917
 Faessler and Badollet 1917
 Faribault and others 1911
 Graham 1917
 Heide and others 1946
 Hendry 1951
 Hess 1933, 1955
 Hewitt and Satterly 1953
 Hopkins 1914
 Hurley and Thompson 1950
 Jones, A. G. 1948
 Kindle 1953
 McCallie 1910
 Marsters 1904, 1905
 Mertle 1937, 1940
 Messel 1947
 Nagy 1953
 Nagy and Bates 1952
 Noble 1910
 Osterwald and Osterwald 1952
 Perkins 1903
 Perry, E. L. 1929
 Perry, E. S. 1948
 Phillips and Hess 1936
 Pratt and Lewis 1905
 Reed 1951
 Riordon 1952, 1954, 1955
 Ross 1931
 Satterly 1952
 Sellards and Baker 1934
 Sloan 1908
 Smith and Mertle 1930
 Snelgrove 1953
 Spencer 1916
 Stephens 1952, 1953

Source rocks containing asbestos—Continued

Ultramafic rocks—Continued

Straw 1955
 U. S. Bureau of Mines 1952
 Valentine 1949
 Willis 1894
 Wing 1951
 Wing and Dawson 1949
 Yoder 1952

South Carolina : Sloan 1908

South Dakota : Connolly and O'Harra 1929

Specifications. *See* Classification.

Substitutes for asbestiform minerals :

Bowles 1955a
 Fisher and others 1945
 Sinclair 1955b
 U. S. Bureau of Mines 1952
 Zodac 1939

Synthesis of asbestiform minerals

Arbeitstagung "Asbest" [1942]
 Bowles 1955a
 Brandenberger and others 1947
 Comeforo and Kohn 1954
 Frank 1952
 Kohn and Comeforo 1955
 Roy and Roy 1954
 Sinclair 1955b
 U. S. Bureau of Mines 1952

Texas : Sellards and Baker 1934

Tremolite :

Anderson, A. L. 1930
 Anderson, Eskil 1945
 Badollet 1951
 Bain, H. F. 1946
 Bowles 1955a
 California Bureau War Minerals
 Production 1942
 California Journal of Mines and
 Geology 1932-55
 Coats 1944
 Davis 1950
 Dietrich 1953, 1955
 Gordon 1922
 Heide and others 1946
 Pardee and Larsen 1929
 Perkins 1903
 Pratt and Lewis 1905
 Snelgrove 1953
 Twenhofel and others 1949
 U. S. Bureau of Mines 1952
 Valentine 1949

Ultramafic rocks. *See* Source rocks.

Uses :

Asbestos Textile Institute 1953
 Bowles 1955a, 1955a

Uses—Continued

Bowles and others, 1948
 Cirkel 1910
 Frank 1952
 Rukeyser 1950
 Stewart 1955
 Stewart and Haury 1947
 U. S. Bureau of Mines 1952

Vermont.

General:

Bain, G. W. 1936, 1942
 Chidester, Billings and Cady
 1951
 Chidester, Stewart, and Morris
 1952
 Hess 1933
 Keith and Bain 1932
 Perkins 1908
 Vermont Geological Survey 1947
 Lamolle and Orleans Counties: Mar-
 sters 1904, 1905
 Washington County: Chidester, Stewart,
 and Morris 1952
 Windsor County: Perry, E. L. 1929

Virginia.

Dietrich 1953, 1955
 Watson 1907
 Woodward 1932

Washington: Valentine 1949

World resources:

Bowles 1934, 1935a, 1955a
 Bowles and others 1948
 Frank 1952
 Howling 1937
 Sinclair 1955b
 Straw 1955
 U. S. Bureau of Mines 1952

Wyoming.

General:

Beckwith 1939
 Birch 1955
 Osterwald and Osterwald 1952
 Atlantic gold district: Spencer 1916
 Casper Mountain: Beeler 1911
 North Laramie Mountains: Spencer
 1916

X-ray analysis.

General:

Bates and Mink 1950
 Gruner 1937
 Selfridge 1936
 Anthophyllite: Rabbitt 1948
 Tremolite:
 Comeforo and Kohn 1954
 Kohn and Comeforo 1955
 Ultramafic rocks: Yoder 1952

Yukon:

Bostock 1948
 Kindle 1953



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Annotated Bibliography on the Geology of Selenium

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Annotated Bibliography On the Geology of Selenium

BY GWENDOLYN W. LUTTRELL

CONTRIBUTIONS TO BIBLIOGRAPHY OF MINERAL RESOURCES

GEOLOGICAL SURVEY BULLETIN 1019-M

Contains references on geologic occurrence, mineralogy, geochemistry, metallurgy, analytical procedures, biologic effects, production, and uses of selenium



UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

The U. S. Geological Survey Library has cataloged this publication as follows:

Luttrell, Gwendolyn Lewise (Werth) 1927-

Annotated bibliography on the geology of selenium.
Washington, U. S. Govt. Print. Off., 1959.

iii, 867-972 p. maps (1 fold. in pocket) 25 cm. (U. S. Geological Survey. Bulletin 1019-M. Contributions to bibliography of mineral resources)

1. Selenium—Bibl. I. Title: The geology of selenium. (Series: U. S. Geological Survey. Bulletin 1019-M. Series: U. S. Geological Survey. Contributions to bibliography of mineral resources)

016.55349

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CONTRIBUTIONS TO BIBLIOGRAPHY OF MINERAL RESOURCES

ANNOTATED BIBLIOGRAPHY ON THE GEOLOGY OF SELENIUM

By GWENDOLYN W. LUTTRELL

ABSTRACT

This bibliography includes annotations of nearly 400 papers on the geologic occurrence, mineralogy, and geochemistry of selenium, as well as papers on metallurgy, analytical procedures, biologic effects, production, and uses of selenium which are of geologic interest. A summary of the uses, mineralogy, geochemistry, and geologic occurrence of selenium is contained in the introduction.

INTRODUCTION

Selenium, a comparatively rare element, is playing an increasingly large part in manufacturing processes and in articles of everyday use because of its unique properties. Selenium was discovered by J. J. Berzelius in 1817, but it remained only a laboratory curiosity until one of its valuable properties, its variation in electrical resistance when exposed to light, was discovered by Willoughby Smith in 1873. Since then, this and other unusual properties of selenium, especially its rectifying property, or the ability to change alternating to direct current, have led to its wide use in industry.

The two principal uses for selenium, accounting for 50 percent and 25 percent respectively of U. S. consumption, are in rectifiers and pigments. Rectifiers are used in voltage multiplier circuits, in other electronic devices, and in television and radio equipment. Selenium pigments impart a red color to paint, ceramics, rubber, paper, silks, leather, and other products. Other uses for selenium are as a decolorizer in flint glass; as a coloring agent in ruby and amber industrial glass; as a degasser in the manufacture of stainless steel, where it also improves machinability; as an alloying element to increase the machinability of copper; as a vulcanizing agent in rubber, where it improves resistance to heat, oxidation, and abrasion; as a catalyst in the preparation of drugs and pharmaceuticals; as an antioxidant in lubricating

oils; in photoelectric cells; as a toner in photography; in blasting caps; in insecticides; as a resin solvent; and in the separation and purification of hydrocarbons. Many of these uses are increasing, and the resulting demand has stimulated research on the geology and geochemistry of selenium, for it is through such studies that new sources of the element will be found.

The ores of many of the world's large copper mines contain minute amounts of selenium, and at present the most important commercial source of selenium is copper anode slimes from which it is recovered as a byproduct. Increased demand for selenium has led to improved practices in byproduct recovery, so that the supply has increased notably in recent years. Selenium also is produced as a byproduct of the flash roasting of pyrites in the manufacture of sulfuric acid.

United States production of selenium in 1954 was 713,200 pounds and imports in that year were 209,600 pounds, as reported in the Bureau of Mines Minerals Yearbook for 1954. The price of selenium, which was \$1.50 per pound in the early 1930's, increased to a high of \$18.50 for 99.99 percent selenium in late 1956, but dropped to \$13.50 in mid-1957.

GEOCHEMISTRY

The distribution of selenium in nature and its concentration in ore deposits are subjects which have not been given detailed study until recently. The abundance of selenium in magmatic rocks given by V. M. Goldschmidt (1954) is 0.09 ppm. The atomic number of selenium is 34 and its atomic weight is 78.96; selenium is between sulfur and tellurium in the periodic table, and it is closely related to these elements in certain aspects of its geochemical behavior. Selenium is a chalcophile element and has a high affinity for sulfur. The atomic radii of selenium and sulfur are so similar that selenium readily replaces sulfur diadochically in sulfide minerals. The substitution appears to occur more readily at high than at low temperatures, for the sulfur-selenium ratio ranges from 400:1 to 20,000:1 in high temperature sulfides, but ranges from 70,000:1 to 250,000:1 in low temperature magmatic sulfides. Selenium also accompanies sulfur in some volcanic sulfur deposits.

The close relationship between sulfur and selenium in primary ores does not continue during the cycle of weathering and leaching because a much higher oxidation potential is required to oxidize selenides to selenates than to oxidize sulfides to sulfates, and the low oxidation potential under which weathering commonly takes place is not sufficient to form selenates. Ordinarily only selenites form, and these are readily removed from solution by reduction or absorption. Thus selenium is separated from sulfur in evaporites and in sulfur deposits

formed by the reduction of sulfates. Very little of the selenium carried into sea water remains in solution, the bulk of it being removed with organic matter, iron and manganese hydroxides, and iron sulfide.

MINERALOGY

Selenium occurs in nature in crystalline and amorphous elemental form; in solid solution with tellurium and sulfur; combined with other metals as selenides, sulfoselenides, selenites, and selenates; in many sulfide and sulfosalt minerals in which it substitutes for a small part of the sulfur in the crystal lattice; and as an oxide of selenium.

A list of minerals of selenium follows. Selenium is listed in the formulas of minerals in which it may be a major constituent.

<i>Selenides, sulfoselenides</i>	<i>Minerals of selenium</i>	<i>Composition</i>
Achavalite.....	FeSe(?)
Agularite.....	Ag ₂ SeS
Berzelianite.....	Cu ₂ Se
Bornhardtite.....	(Co, Cu, Ni) ₂ Se ₄ (?)
Cadmoseelite.....	Cd (Se, S)
Clausthalite.....	PbSe
Crookesite.....	(Cu, Tl, Ag) ₂ Se
Eskebornite.....	CuFe ₃ Se ₄ (?)
Eucairite.....	CuAgSe
Ferroselite.....	FeSe ₂
Guanajuatite (frenzelite, castillite).....	Bi ₂ Se ₂
Hastite.....	(Co, Fe)Se ₂
Klockmannite.....	CuSe
Metacinnabar, selenian (onofrite, guadalcazarite).....	Hg(S, Se)
Naumannite (cacheutaite).....	Ag ₂ Se
Paraguanajuatite.....	Bi ₂ Se ₂
Penroseite (blockite).....	(Ni, Cu, Pb)Se ₂
Stilleite.....	ZnSe
Tiemannite.....	HgSe
Trogtalite.....	CoSe ₂
Umangite.....	Cu ₄ Se ₂
Unnamed cobalt selenide.....	CoSe(?)
<i>Sulfides and tellurides</i>		
Argentite.....	Ag ₂ S
Arsenopyrite.....	FeAsS
Bismuthinite.....	Bi ₂ (S, Se) ₂
Bornite.....	Cu ₅ FeS ₄
Chalcopyrite.....	CuFeS ₂
Cinnabar.....	HgS
Csiklovaite.....	Bi ₂ TeS ₂
Galena.....	PbS
Gruenlingite.....	Bi ₄ TeS ₃
Joseite.....	Bi ₄ TeS(?)
Marcasite.....	FeS ₂
Molybdenite.....	MoS ₂

Minerals of selenium—Continued

<i>Sulfides and tellurides—Continued</i>	<i>Composition</i>
Pyrite.....	FeS ₂
Pyrrhotite.....	Fe _{1-x} S
Siegenite (selenosiegenite).....	(Co,Ni) ₃ (S,Se) ₄
Sphalerite (wurtzite).....	ZnS
Stannite.....	Cu ₂ FeSnS ₄
Stibnite.....	Sb ₂ S ₃
Tetradymite.....	Bi ₂ Te ₂ S
Troilite.....	FeS
Vaesite (selenovaesite).....	Ni(S,Se) ₂
Villamaninite (bravoite).....	(Ni,Fe,Cu)S ₂
<i>Sulfosalts</i>	
Chiviatite.....	Pb ₂ Bi ₄ (S,Se) ₁₅ (?)
Cosalite (selenocosalite).....	Pb ₂ Bi ₂ (S,Se) ₃
Kobellite (selenokobellite).....	Pb ₂ (Bi,Sb) ₂ (S,Se) ₃ (?)
Platynite.....	PbBi ₂ (Se,S) ₃ (?)
Tetrahedrite.....	(Cu,Fe) ₁₂ Sb ₄ S ₁₃
Weibullite (seleniferous galenobismutite).....	PbBi ₂ (S,Se) ₄ (?)
Wittite.....	Pb ₂ Bi ₄ (S,Se) ₁₄ (?)
<i>Selenites</i>	
Ahlfeldite.....	NiSeO ₃ ·6H ₂ O(?)
Chalcomenite.....	CuSeO ₃ ·2H ₂ O
Cobaltomenite.....	hydrous cobalt selenite
<i>Selenite or selenate</i>	
Kerstenite (molybdomenite).....	hydrous lead selenite or selenate PbSeO ₄ (?)
<i>Tellurite</i>	
Emmonsite (durdenite).....	Fe ₂ (TeO ₃) ₂ ·2H ₂ O?SeO ₂
<i>Oxide</i>	
Selenolite.....	SeO ₂
<i>Mixtures of selenides</i>	
Lehrbachite.....	Tiemannite, clausthalite
Zorgite, "seebachite".....	Clausthalite, umangite, tiemannite
Tilkerodite, selenkobaltblei.....	Clausthalite, cobaltite, hematite

GEOLOGIC OCCURENCE

Selenium occurs in metallic ore deposits, most commonly in hydrothermal base metal sulfide deposits of all temperature and depth ranges. It is present in disseminated copper deposits of the porphyry type, in vein and replacement copper deposits, in massive sulfide ores, in copper-lead sulfide vein deposits, in epithermal silver-gold veins, in quicksilver and antimony deposits, and in the sandstone-type uranium-vanadium deposits of the Western United States. It is also present in volcanic emanations and deposits. Selenium also occurs as a trace element in many sedimentary deposits, particularly coals, volcanic tuffs, phosphate deposits, and sedimentary iron ores. It is

present in shales and other sedimentary rocks, and in soils and vegetation associated with or derived from seleniferous formations.

In hydrothermal base metal sulfide deposits most of the selenium replaces sulfur in the lattices of sulfide minerals, such as pyrite, halcopyrite, sphalerite, galena, marcasite, and arsenopyrite. Selenium minerals have been identified only in a few massive sulfide deposits, and sulfide vein deposits.

Selenium has been detected in amounts of not more than a few hundredths of a percent in the ores of most of the world's large copper deposits, including the disseminated deposits at Ray and Morenci, Ariz.; Ely, Nev.; Bingham, Utah; Chino, N. Mex.; and Cananea, Mexico; and the replacement and vein deposits of Butte, Montana; Cerro de Pasco, Peru; Northern Rhodesia; and Belgian Congo. Some of the better known seleniferous massive sulfide deposits are at Rio Tinto, Spain; Mt. Lyell, Tasmania; Mt. Isa, Queensland; Bor, Yugoslavia; Boliden, Sweden; Flin Flon, Manitoba; Sudbury, Ontario; and Ducktown, Tenn.

In certain sulfide vein deposits a variety of selenium minerals is found. The copper-silver-lead veins of Skrikerum, Sweden; Harz Mountains, Germany; Copiapo, Chile; and Colquechaca, Bolivia; and the pitchblende-bearing sulfide veins of Goldfields, Saskatchewan, and Shinkolobwe, Belgian Congo are characterized by a wide variety and abundance of selenium minerals.

Selenium minerals are found in many epithermal silver-gold fissure vein deposits. Examples are deposits in the Silver City district, Idaho; Comstock Lode and Jarbidge district, Nev.; and Guanajuato, Mexico, where naumannite, sometimes in large quantities, has been identified. Unidentified selenium minerals in combination with gold and silver are found in the Republic district, Wash., and in Radjang Lebong, Sumatra. The seleniferous silver-gold ores of Tonopah and Aurora, Nev.; San Francisco district, Utah; and the Liberty Bell mine, Telluride district, Colo., all contain small amounts of an unidentified black mineral, which is possibly a gold or silver selenide.

Some epithermal quicksilver deposits contain tiemannite. Tiemannite has been noted at Buckskin Peak, Nev.; the Abbott mine, Calif.; the Lucky Boy mine, Piute County, Utah; and at Guadalcázar, San Onofre, and Huitzuco, Guerrero, Mexico. At Huitzuco the selenium is associated with antimony ores.

In most epithermal veins selenium minerals are rare, but in a few deposits they constitute a major part of the ore. At the Lucky Boy quicksilver mine the ore consisted almost entirely of tiemannite, and at the De Lamar mine, Silver City district, Idaho, the principal silver mineral was naumannite, although it was mistaken for argen-

tite. The unusual deposit at Radjang Lebong, Sumatra, consists of a combination of gold and silver with selenium.

A few rare veins of selenide minerals are known in which sulfide minerals are absent. The Hiaco (Pacajake) silver mine near Colquechaca, Bolivia, and the silver-lead selenide vein at Cerro de Cacheuta, Argentina, are veins that contain only selenide minerals and a few secondary selenite minerals.

Uranium deposits in sandstone in the Western United States generally contain selenium in association with sulfide minerals or with carbonaceous material. Recent studies have shown that the selenium in some of these deposits occurs in elemental crystalline form, but in most the element seems to be substituting for sulfur in sulfide minerals.

Selenium is found associated with products of volcanic origin. A volcanic tuff deposit in Fremont County, Wyo., was found to be seleniferous, and soils derived from volcanic materials in the Hawaiian Islands are seleniferous. The source of the selenium in the Hawaiian soils is believed to be volcanic gases and sublimates. Seleniferous sulfur of volcanic origin has been reported from the Valley of Ten Thousand Smokes, Alaska; from Krisuvik, Iceland; from Vesuvius, Lipari Island, and Sicily, Italy; from Kilauea, T. H.; from Tateyama and Iwojima Islands, Japan; and from New Zealand. Seleniferous sulfur locally containing as much as 5.18 percent selenium is reported from Kilauea, T. H.

Selenium is a minor constituent of rocks and soils in many areas. The average concentration of selenium in shale calculated by Krauskopf (1955) is 0.5-1 ppm; in sandstone 1 ppm; in limestone 0.1-1 ppm. These figures are tentative, based on only a few published analyses. An unusually large concentration of selenium in the rocks and soils of certain of the Western United States has attracted much attention because of livestock losses resulting from selenium poisoning and the possibility that humans may suffer ill effects from consumption of seleniferous grains and crops.

The selenium in sedimentary shales and sandstones may have been derived from volcanic dust or gases, or from decomposed igneous rocks in which it was a primary constituent, and deposited by normal processes in the seas. Sedimentary iron oxide formations and pyrite concretions in sedimentary rocks are enriched in selenium. The selenium in these rocks is believed to represent the removal by ferric ions of selenium carried into sea water.

Selenium in soils commonly is derived from the parent rocks, although surface ground water containing selenium may increase the content.

In the Western United States the most seleniferous formations are shales and sandstones for the most part of Cretaceous age, but certain Permian, Triassic, Jurassic, and Tertiary formations are also highly seleniferous. These are found in Arizona, Colorado, Kansas, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Utah, Idaho, and Wyoming. Certain plants, including species of *Astragalus*, *Stanleya*, and *Xylorrhiza*, which require selenium for growth, are found in these areas. These plants, called indicator plants, absorb large amounts of selenium from the soil and convert it into a form available to other vegetation. Indicator plants frequently contain enough selenium to be toxic to grazing animals.

Soils with an unusually high content of selenium are also found in Ireland, Japan, Mexico, Cuba, Colombia, Puerto Rico, and Hawaii. The seleniferous soils of Hawaii and Puerto Rico are unusual in that although they contain a high concentration of selenium they do not support seleniferous vegetation. It is thought that in regions such as these selenium is combined with iron in an insoluble form.

Phosphate rock deposits, particularly those that contain pyrite and large amounts of organic material, are among the most seleniferous sedimentary rocks known. Recent studies have shown that phosphate rock from the Phosphoria formation in Wyoming contains up to 300 ppm selenium, and a vanadiferous shale in the Phosphoria formation locally contains as much as 1500 ppm selenium. Dark colored phosphate rock from the Western United States and Canada, most Tennessee "blue rock," South Carolina phosphates, and phosphates from Africa and Palestine contain unusually large amounts of selenium.

Selenium has been found in coal in England and Belgium, where it is believed to be associated with pyrite seams.

EXPLANATION OF ANNOTATED BIBLIOGRAPHY

This bibliography includes annotated references to papers on the geologic occurrence, mineralogy, and geochemistry of selenium; and papers on other subjects such as metallurgy, analytical procedures, biologic effects, production, and uses of selenium, which also contain geologic information. Annotations taken from "Chemical Abstracts" give the page or column number and volume. The maps (pl. 5 and fig. 2) show the location of ore deposits in which selenium minerals have been found or in which selenium occurs as an ore constituent. Areas of seleniferous soils and rocks and seleniferous sulfur, coal, and phosphate deposits are not shown on the maps.

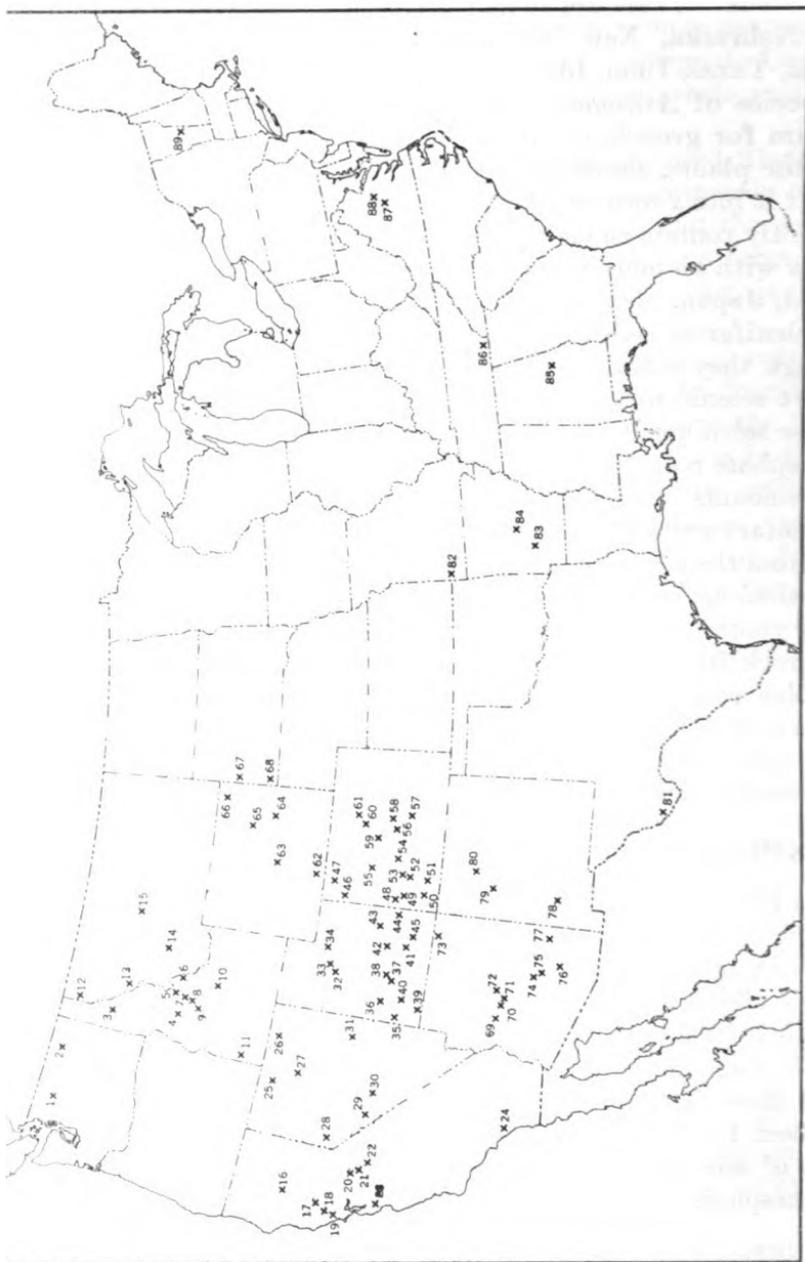


FIGURE 2.—Map showing selenium bearing ore deposits of the United States.

EXPLANATION OF FIGURE 2

Locality	Mine or district	County	State	Locality	Mine or district	County	State
1	Chelan Lake district	Chelan	Washington*	49	Slick Rock and Gypsum Valley districts	San Miguel	Colorado
2	Republic district	Ferry	Do.	50	Cortez and Rico districts	Montezuma	Do.
3	Coeur d'Alene district	Shoshone	Idaho	51	La Plata Mountains	La Plata	Do.
4	Yellow Pine district	Valley	Do.	52	Liberty Bell mine, Telluride district	San Miguel	Do.
5	Blackbird district	Lemhi	Do.	53	Camp Bird mine	Ourray	Do.
6	Kirtley Creek district	do.	Do.	54	Vulcan mine	Garrison	Do.
7	Gravel Range district	do.	Do.	55	Rifle district	Garfield	Do.
8	Parker Mountain district	do.	Do.	56	Whitehorn district	Fremont	Do.
9	Yankee Fork district	Custer	Do.	57	Wet Mountains	Fremont and Custer	Do.
10	Mackay district	do.	Do.	58	Cripple Creek district	Twiler	Do.*
11	Silver City district	Owyhee	Do.	59	Leadville district	Lake	Do.
12	Troy district	Lincoln	Montana*	60	Gilpin County mines	Gilpin	Do.
13	Cedar Creek district	Mineral	Do.	61	Gold Hill	Boulder	Do.
14	Butte district	Silver Bow	Do.	62	Baggs area	Carbon	Wyoming
15	Montana district	Cascade	Do.	63	Gas Hills and Crookes Gap districts	Fremont	Do.
16	Iron Mountain district	Shasta	California	64	Converse County district	Converse	Do.
17	Abbott and Clear Lake	Lake	Do.	65	Pumpkin Buttes district	Campbell	Do.
18	Socrates mine	Sonoma	Do.	66	Crook County district	Crook	Do.
19	Mt. Jackson mine	do.	Do.	67	Homestake mine	Lawrence	South Dakota*
20	Mother Lode	Amador	Do.	68	Edgemont district	Fall River	Do.
21	Murphys district	Calaveras	Do.	69	Eureka district	Yavapai	Arizona*
22	Mother Lode	Tuolumne	Do.	70	Walker district	do.	Do.*
23	Guadalupe mine	Orange	Do.	71	Big Bug and Black Canyon districts	do.	Do.*
24	San Joaquin Ranch mine	Santa Clara	Do.	72	United Verde mine	Apache	Do.
25	Buckskin Peak, National district	Humboldt	Nevada	73	Monument Valley district	Final	Do.
26	Jarbridge district	Elko	Do.	74	Magma mine	do.	Do.
27	Potosi (Preble) district	Humboldt	Do.	75	Ray district	do.	Do.
28	Comstock Lode	Storey	Do.	76	Old Hat district	do.	Do.
29	Aurora district	Mineral	Do.	77	Morenci district	Greenlee	Do.
30	Tonopah district	Nye	Do.	78	Chino mine	Grant	New Mexico.†
31	Ely district	White Pine	Utah*	79	Grants district	Valencia	Do.
32	Camp Floyd district	Tooele	Do.	80	La Ventana mesa	Sandoval	Do.
33	Bingham district	Salt Lake	Do.	81	Shafter district	Presidio	Texas*
34	Park City district	Summit	Do.	82	Tri-State district	do.	Missouri,
35	Gold Springs-State Line district	Iron	Do.			Oklahoma,	
36	San Francisco district	Beaver	Do.			Kansas*	
37	Ohio district, Tuslar Range	Plute	Do.			Arkansas*	
38	Marysvale district	do.	Do.			Alabama*	
39	Silver Reef district	Washington	Do.	83	Antoine Creek district	Clark	Do.
40	Iron Mountain district	Iron	Do.	84	Bauxite district	Pulaski	Do.
41	Hemp Mountains district	Garfield	Do.	85	Hog Mountain mine	Tullahoma	Tennessee.
42	Temple Mountains and San Rafael Swell	Emery	Do.	86	Ducktown district	Polk	Virginia.
43	Thompsons district	Grand	Do.	87	Tellurium mine	Furvanna and Goochland	Do.
44	Paradox Valley	San Juan	Do.			Spotsylvania	
45	Monticello and White Canyon districts	do.	Do.	88	White Hall mine	Orange	Vermont.*
46	Blue Mountain	do.	Colorado	89	Elizabeth mine	do.	
47	Maybell district	Moffat	Do.			do.	
48	Uravan, Bull Canyon, Paradox Valley, Piceaville districts	Montrose	Do.			do.	

*Information obtained from unpublished sources.

†Information obtained from company annual reports.

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Analyses of lead bismuth selenide mineral from Falun are given.

Bancroft, Howland, 1914, The ore deposits of northeastern Washington, including a section on the Republic mining district, by Waldemar Lindgren and Howland Bancroft : U. S. Geol. Survey Bull. 550, p. 24, 148-150.

In the Republic district, veins of quartz, adularia, and calcite in andesites and lake beds of Tertiary age and in porphyritic rocks intrusive into these formations contain narrow concentric dark bands consisting of finely distributed tetrahedrite, chalcopyrite, native gold, and selenium in an unknown form. An analysis of a gold-selenium ore from the Republic mine gave 4.36 percent gold and 2.62 percent selenium. After free gold was eliminated by treating the ore with an alkaline sulfide solution, the gold-selenium ratio was 2:3, suggesting the presence of a gold selenide mineral with the formula Au_2Se_3 . Gold and selenium appear to be intimately associated in the ore, but it is not known whether they constitute an integral substance or are otherwise associated. No definite selenium minerals could be identified in the ore, although small crystals of pyramidal habit giving a reaction for selenium were found. The authors suggested that they may be a selen-antimonide of silver, analogous to rittingerite.

Bannister, F. A., and **Hey, M. H.**, 1937, The identity of penroseite and blockite : *Am. Mineralogist*, v. 22, p. 319-324.

Specimens of penroseite from Colquechaca, Bolivia, and blockite from the Hiaco mine, Bolivia, were studied. They were thought to be different minerals because blockite contained less lead and more selenium than penroseite. X-ray studies show that both minerals are intergrown with naumannite and variations in lead and silver content are due to admixture with naumannite. Penroseite and blockite may be regarded as identical minerals, the true composition of which is still uncertain.

Bartlett, F. L., 1889, Some notes on the rarer elements found in the Leadville sulphurets : *Eng. Mining Jour.*, v. 48, p. 342-343.

Low-grade sulphurets from the Iron Silver mine contained selenium, cadmium, thorium, gallium, indium, mercury, antimony, and arsenic. The ores were heavy zinc sulphurets containing 35 percent zinc and 6 percent lead.

Bastin, E. S., 1923, Silver enrichment in the San Juan Mountains, Colorado : U. S. Geol. Survey Bull. 735-D, p. 65-129.

Some selenium and tellurium are present in the matte obtained from smelting the concentrates from the Liberty Bell mine near Telluride, but no selenium or tellurium minerals have been recognized in the ores. The ore veins are late Tertiary fissure veins in Tertiary volcanic rocks. The ore consists of sphalerite, galena, pyrite, chalcopyrite, tetrahedrite, pearcite, argentite, native silver, and an unidentified black mineral in quartz and calcite gangue. Gold is present in the ore but was not observed.

Bastin, E. S., and **Laney, F. B.**, 1918, The genesis of the ores at Tonopah, Nevada : U. S. Geol. Survey Prof. Paper 104, p. 17-18, 46.

The mineral combination in which selenium occurs is not known, but it is believed to be associated with gold and silver in electrum. Selenium was found in pannings consisting mostly of electrum from ore in the West End mine.

Pannings from heavy sulfide ore contained 2.56 percent selenium. Five analyses of ores, concentrates, and bullion containing selenium are given.

Bateman, A. M., 1927, Ore deposits of Rio Tinto (Huelva) district, Spain: *Econ. Geology*, v. 22, p. 569-614.

Umgangite occurs as a primary ore mineral at Rio Tinto. Three unidentified minerals account for the presence of silver, bismuth, nickel, cobalt, antimony, and selenium in the ore. Ore deposits of the Rio Tinto type, which are of replacement origin, are characterized by—large bodies of massive pyrite ores in schistose or sheared rock, associated with igneous intrusions; the minerals pyrite, chalcopyrite, sphalerite, galena, quartz; usually barite and arsenopyrite; absence of high temperature minerals; scarcity of gangue minerals; presence of gold and silver; small amounts of less common metals such as bismuth, selenium, and antimony; lenslike form; association of sericitized rocks; original deep burial; and relatively old age.

Bauerle, L. C. *See* Everett and Bauerle, 1957.

Bear, F. E., 1955, *Chemistry of the soil*: New York, Reinhold Pub. Corp., p. 72, 280.

Seleniferous areas of the United States, and the form and behavior of selenium in soils and vegetation are briefly described.

Bearse, A. E. *See* Waitkins and others, 1942.

Beath, O. A. *See also* Trelease and Beath, 1949.

——— 1936, Selenium in native range plants occurring on soils derived from Permian and Triassic (?) sediments: *Science*, v. 83, p. 104.

Selenium indicator plants were found growing on soils derived from two sandstone members of the Chugwater formation in central Albany County, Wyoming, one a sandstone member near the middle of the formation, and the other a limy sandstone in the basal portion, equivalent to the "Embar" of central Wyoming. The average selenium content of a composite sample was 2.4 ppm; one sample from the middle sandstone member gave 10 ppm. selenium.

——— 1937, The occurrence of selenium and seleniferous vegetation in Wyoming; Pt. 2, Seleniferous vegetation of Wyoming: *Wyoming Agr. Expt. Sta. Bull.* 221, p. 29-64.

Sources of selenium available to plants are limonite concretions, iron pyrites, marcasite, carbonaceous shales, buried alkali beds, bentonite, jarosite, lignite, phosphate rock, ferruginous sandstone, and limy sandstone. Experiments on the distribution and form of selenium in plants and soils are described. The form of selenium in soils derived from most formations in Wyoming is insoluble and not available to most vegetation. Soils derived from the Morrison formation are toxic.

——— 1943, Toxic vegetation growing on the Salt Wash sandstone member of the Morrison formation: *Am. Jour. Botany*, v. 30, no. 9, p. 698-707.

Native vegetation growing on the Morrison formation in southeast Utah and southwest Colorado is generally seleniferous. The shales, sandstones, and over-

lying alluvial wash contain selenium, some of which is in a form available to all types of vegetation. No correlation exists between the amount of selenium in the rocks and the amount in the plants growing on them. Selenium concentrations are highest in the Salt Wash member of the Morrison formation, particularly in the uranium-vanadium ore zones. The origin of selenium is believed to parallel that of vanadium and other trace elements in the Salt Wash member. A study was made of the selenium content of the uranium-vanadium ores, shales, alluvial wash, and vegetation in the Thompsons district, Utah.

Beath, O. A., and Eppson, H. F., 1947, The form of selenium in some vegetation: Wyoming Agr. Expt. Sta. Bull. 278, 15 p.

Unrelated plant species rooted in the same soil absorb and concentrate selenium in several different chemical forms and follow a consistent pattern in the forms of selenium they contain. *Astragalus*, *Stanleya*, and certain cereal grains yield only organic selenium; *Aster*, *Atriplex*, and *Xylorhiza* yield only inorganic selenate; certain native grasses yield both inorganic and organic selenium. It is not known what influence the form of selenium in the soil may exert on the form of selenium in plants. Usually 50 percent or more of the selenium in accumulator plants is water soluble, so that the decay of such plants can return a significant amount of available selenium, both organic and inorganic, to the soil.

Beath, O. A., and Gilbert, C. S., 1936, Selenium-bearing vegetation during late Cretaceous time: *Science*, v. 84, no. 2187, p. 484-485.

Leafy carbonaceous seams in shales of the continental portion of the Medicine Bow formation of Cretaceous age in southern Albany County, Wyo., contain over 150 ppm selenium. The concentration of selenium in carbonaceous material is confined to the top part of the seams where skeletal leaves and other vegetable matter are still recognizable. These data confirm the authors' theory of vegetative enrichment of selenium through cycles of growth and decay of highly seleniferous native plants.

Beath, O. A., Draize, J. H., and Gilbert, C. S., 1934a, Plants poisonous to livestock: Wyoming Agr. Expt. Sta. Bull. 200, p. 5-84.

The toxic nature of seleniferous plants grown on shales of the Benton, Niobrara, Steele, and Pierre formations of Cretaceous age in Wyoming is discussed. Seleniferous plants are pictured and described.

Beath, O. A., Eppson, H. F., and Gilbert, C. S., 1935, Selenium and other toxic minerals in soils and vegetation: Wyoming Agr. Expt. Sta. Bull. 206, 55 p.

Seleniferous formations of Cretaceous and Eocene ages in Wyoming are described. The source of the selenium in these formations is believed to be volcanic material from which the sediments were derived, for there was extensive volcanic activity and selenium was a primary constituent of the magma from these volcanoes. Methods of analysis for selenium in plants and soils are given, and absorption of selenium by vegetation, highly seleniferous drainage basins known as poison basins, and poisonous plant groups are discussed. Pyrite concretions from the Niobrara formation contained up to 548 ppm selenium and averaged from 250 to 350 ppm selenium. Concretions from the Benton, Steele, Lewis, Mesaverde, and Morrison formations contained 0.5 to 4.1 ppm selenium. Selenium in such concretions is almost totally insoluble.

Beath, O. A., Eppson, H. F., and Gilbert, C. S., 1937a, Selenium distribution in and seasonal variation of type vegetation occurring on seleniferous soils: *Am. Pharmaceutical Assoc. Jour.*, v. 26, no. 5, p. 394-405.

Report on studies of the form of selenium in soils and plants, and the growth behavior of and distribution of selenium in plants grown on seleniferous soils.

Beath, O. A., Gilbert, C. S., and Eppson, H. F., 1937b, Selenium in soils and vegetation associated with rocks of Permian and Triassic age: *Am. Jour. Botany*, v. 24, no. 2, p. 96-101.

Selenium is found to be a primary constituent of stratigraphically equivalent rocks of Permian and Triassic age in Wyoming, including the Phosphoria, Dinwoody, "Embar", and basal Chugwater formations. One of the source materials from which these formations were derived was selenium-bearing magma from volcanoes active during Permian and Triassic time. Analyses are given of phosphate and selenium content of the Phosphoria formation from several places in Wyoming. There is no correlation between phosphate and selenium; selenium is distributed unevenly and its content is highly variable, ranging from 5.2 to 200 ppm at Rocky Point. Lighter colored phosphate rock is lower in selenium content than dark colored material. No selenium was found in crude oils from Fremont County.

——— 1939a, The use of indicator plants in locating seleniferous areas in western United States; Pt. 1, General: *Am. Jour. Botany*, v. 26, no. 4, p. 257-269.

The presence of selenium in the soil may have been caused by the erosion of igneous rocks containing seleniferous material or the absorption of selenium from brackish water or shallow basins by marine organisms or plants. In some places selenium occurs in carbonaceous beds, but not in carbonate beds of the same formations. Geographical and geological occurrences of 32 species of native selenium indicator plants are reported. The origin and form of selenium in soil were studied. Selenium in the soil is believed to be in a highly insoluble form, and the number of plants capable of absorbing it is small compared with the total forage cover.

——— 1939b, The use of indicator plants in locating seleniferous areas in western United States; Pt. 2, Correlation studies by States: *Am. Jour. Botany*, v. 26, no. 5, p. 296-315.

Studies of 563 specimens of native plants from Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Texas, and Utah. Species of known indicator plants were given special attention. The studies demonstrated that many formations of late Paleozoic to Quaternary age, including igneous and sedimentary rocks, support seleniferous vegetation.

——— 1940, The use of indicator plants in locating seleniferous areas in western United States; Pt. 3, Further studies: *Am. Jour. Botany*, v. 27, no. 7, p. 564-573.

In a study of the distribution of types of selenium-bearing plants, seleniferous vegetation from Arizona, California, Colorado, Montana, New Mexico, North Dakota, Texas, Utah, and Wyoming was analyzed. Data were obtained on seleniferous areas in Stoddard County, Mo., and Dryden, Tex., where no selenium indicator plants had been reported. The Dakota and Morrison formations were found to be seleniferous over large areas.

Beath, O. A., Gilbert, C. S., and Eppson, H. F., 1941, The use of indicator plants in locating seleniferous areas in western United States; Pt. 4, Progress report: Am. Jour. Botany, v. 28, no. 10, p. 887-900.

Further studies on the occurrence and classification of selenium indicator plants are reported. From formations not previously tested in Arizona, California, Colorado, Montana, Nebraska, New Mexico, North Dakota, South Dakota, Texas, Utah, and Wyoming, 407 analyses were made of indicator plants.

Beath, O. A., Hagner, A. F., and Gilbert, C. S., 1946, Some rocks and soils of high selenium content: Wyoming Geol. Survey Bull. 36, 23 p.

Five tufts from Lysite poison draw, Fremont County, Wyo., contained 12.5, 29, 112, 175, and 187 ppm selenium. In the last three, 84 to 96 percent of the total was water-soluble selenium, mostly in the form of selenate. Tertiary sandstone in the Poison Butte area, Carbon County, contained 112 ppm selenium, of which 91.4 ppm was water-soluble selenate. Vanadiferous siltstone in the phosphatic shale member of the Phosphoria formation in western Wyoming contained from 188 to 680 ppm selenium and from 0.12 to 2.12 percent vanadium. Selenium showed a positive correlation with the vanadium content of the rock. Phosphatic rocks from the Phosphoria formation contained from a few to 212 ppm selenium. Uranium-vanadium ores and carbonaceous shales also had high selenium content. Vanadiferous rocks contained a high proportion of insoluble selenium in the form of selenite, whereas the tufts and sandstone contained mostly soluble selenates.

Beath, O. A., Draize, J. H., Eppson, H. F., Gilbert, C. S., and McCreary, O. C., 1934b, Certain poisonous plants of Wyoming activated by selenium and their association with respect to soil types: Am. Pharmaceutical Assoc. Jour., v. 23, no. 2, p. 94-97.

A correlation of seleniferous range plants with the geological formations on which they grow shows that shales of the Niobrara, Steele, Pierre, Morrison, Wasatch, Benton, Hilliard-Cody, Lewis, and Bridger formations, and a dark band of the Dakota formation support seleniferous vegetation.

Becker, G. F., 1888, Geology of the quicksilver deposits of the Pacific slope, with an atlas: U. S. Geol. Survey Mon. 13, p. 385-386.

The Lucky Boy claim, Mt. Baldy district, Piute County, Utah, contains bunches of tiemannite in limestone. One ore body was 4 feet thick. Seventy-six flasks of mercury were produced from this ore, which averaged 10 percent mercury.

Bellini, Raffaello, 1907, Spuren von Selen auf der Vesuvlava von 1906: Zentralbl. Mineralogie, Jahrg. 1907, no. 20, p. 611-612.

Free selenium occurs in association with crusts of sodium chloride on the lava as small connected spots or aureoles surrounding the sodium chloride. Chlorides of potassium and iron were also found with the selenium. (Chem. Abs., v. 2, p. 249.)

Benard, Frederick, 1933, Electrolytic copper refinery of Ontario Refining Company, Limited, at Copper Cliff, Ontario: Am. Inst. Mining Metall. Engineers Trans., v. 106, p. 369-397.

Typical tank house slimes from ores of the Froid and other mines in the Sudbury district have an average content of 15.03 percent selenium. Refining process and equipment are described.

Benard, Frederick, 1944, Recovery of selenium and tellurium at Copper Cliff, Ontario: Am. Inst. Mining Metall. Engineers Trans., v. 159, p. 521-529; Tech. Paper 908, 9 p., 1938.

Description of selenium plant and recovery process used by the Ontario Refining Company.

Bergenfelt, Sven, 1953, Om förekomst av selen i Skelleftefältets sulfidmalmer: Geol. fören. Stockholm Förh., v. 75, no. 37, p. 327-359. [Swedish, English summary.]

Analyses of ores, minerals, and concentrates to determine the distribution of selenium in sulfide ores of the Skellefte district show that pyrite, pyrrhotite, and sphalerite are generally low in selenium; chalcopyrite is richer than pyrite; arsenopyrite and galena are generally high in selenium. No correlation was found between copper, arsenic, or zinc and selenium; correlations were found between bismuth and antimony and selenium. Study included the Bollden, Åkulla, Renström, Långdal, Kristineberg, Rävliiden, eastern Bjurfors, Laver, Adak, and Lainijaur deposits. Ores from the Bollden mine are generally richer in selenium than those of the other mines. The largest concentration of selenium was found in the quartz-tourmaline veins, where sulfo minerals and tellurides with considerable amounts of selenium occur. Arsenopyrite ore is also rich in selenium; pyrite ore is low in selenium. At Bollden the average selenium content of pyrite was from 0.004 to 0.03 percent; of galena, 1 to 1.5 percent; of chalcopyrite, 0.07 to 0.14 percent; of sphalerite, 0.03 to 0.09 percent; of arsenopyrite, 0.04 to 0.16 percent; of pyrrhotite, 0.002 to 0.007 percent. Variations in selenium content of a given mineral from various deposits are attributed to the great differences in selenium content of the ores, as regulated by the selenium content of the mineralizing solutions.

Berman, Harry. See Palache and others, 1944.

Berry, L. G. See Peacock and Berry, 1940.

Bertrand, Émile, 1882, Sur la molybdoménite (sélénite de plomb), la cobaltoménite (sélénite de cobalt), et l'acide sélénieux de Cacheuta (La Plata): Soc. minéralog. France Bull., v. 5, p. 90-92.

Molybdomenite and cobaltomenite, selenites of lead and cobalt, formed as alteration products of selenides, are associated with chalcomenite, copper selenite, at Cerro de Cacheuta, Mendoza, Argentina. Lead carbonate and white needles believed to be selenious acid, selenolite, are found in veins in molybdomenite and are believed to be alteration products of molybdomenite.

Berzelius, J., 1818, Des recherches sur un nouveau corps minéral trouvé dans le soufre fabriqué à Fahlun: Annales chimie et physique, ser. 2, v. 9, p. 225-267. [Also in Jour. Chemie u. Physik, v. 23, p. 300-344, 430-484, 1818 (German).]

Describes the chemistry and chemical compounds of selenium separated from sulfur from the Falun mine, Sweden.

Bethke, P. M., 1956, Sulfo-selenides of mercury [abs.]: Geol. Soc. America Bull., v. 67, no. 12, pt. 2, p. 1671.

Sulfoselenides of mercury form a complete isomorphous series defined by the diadochy of sulfur and selenium which is denoted as the metacinnabar series, including the minerals metacinnabar, onofrite, and tiemannite. The

series is found in its entirety at Marysvale, Utah. Selenium is unable to replace sulfur in the cinnabar structure except for possible trace amounts. It is proposed that the distribution of selenium between cinnabar and metacinnabar is related to differences in bond type. Some crystallographic data are given.

Beyschlag, F., Krusch, P., and Vogt, J. H. L., 1914, *The deposits of the useful minerals and rocks, their origin, form, and content*: London, MacMillan and Co., v. 1, p. 166-167; v. 2, p. 589.

Selenium is closely related to sulfur and it almost always accompanies sulfur. Types of deposits in which selenium occurs are: (a) native sulfur in volcanic districts; (b) sulfide lodes as at Lehrbach, Zorge, and Tilkerode in the Harz; (c) copper shales; (d) pyrite deposits as at Fahlun, Río Tinto, and Rammelsberg. In most deposits the sulfur-selenium ratio is 10,000:1. Although tellurium tends to occur in separate deposits, it is found with selenium in telluride lodes of the young gold-silver group. In such cases about 1.5 percent of the tellurium is replaced by selenium. The gold-selenium deposits of Radjang Lebung, Sumatra, are described.

Bianchi, Umberto, 1919, *Il selenio*: Milan, Ulrico Hoepli, 136 p.

Describes forms, properties, and uses of selenium.

Biltz, Wilhelm. *See* Geilmann and Biltz, 1931.

Block, Hans, 1937, *Das Selenvorkommen von Pacajake in Bolivien*: Metall u. Erz, v. 34, no. 10, p. 237-238.

Clausthalite, blockite (penroseite), and other selenides occur in a vein with a gangue of limonite, barite, and hematite at the Hiaco silver mine, near Colquechaca, Bolivia. Analysis of blockite shows it to contain copper and nickel with minor amounts of cobalt, iron, lead, mercury, silver, and platinum.

Block, Hans, and Ahlfeld, Friedrich, 1937, *Die Selenerzlagerstätte Pacajake, Bolivia*: Zeitschr. prakt. Geologie, v. 45, p. 9-14.

Selenium minerals occur in a vein along a fault area in the Hiaco silver mine in the Pacajake anticline in the central Bolivian cordillera, 30 km from Colquechaca, Bolivia. The chief mineral is blockite (penroseite), a nickel-copper selenide, with some clausenthalite, chalcocite, naumannite, native selenium, and other selenium minerals, in a gangue of barite, siderite, hematite, and calcite.

Bodenbender, G., 1902, *Comunicaciones mineras y mineralógicas. 8. Criaderos de seleniuro de cobre, de sulfuro de cobre y de sulfuro de plata*: Acad. Nac. Cienc. Córdoba Bol., v. 17, p. 368-371.

At Tinogasta, Catamarca Province, Argentina, umangite mixed with sulfides and gypsum, occurs in thin layers in stratified calcitic-silicic gangue.

Borgström, L. H., 1914-15, *The melting and boiling points of metalloids-sulfide, selenide, and telluride minerals*: Finska vetensk.-soc. Öfversikt av Förh. (A), v. 57, no. 24, 13 p.

The behavior of the minerals studied is described in detail, and values of melting points are given as: realgar, 310; orpiment, 320; kermesite, 517; stibnite, 546; tetradymite, 600; guanajuatite, 690; bismuthinite, 718° C. The occurrence of the minerals is discussed, and by tabulating their melting points and modes of occurrence it is shown that in a general way those with the lowest melting points form under conditions of low temperature and pressure, near the surface

of the earth, while the higher the melting point becomes the more the mineral is found in deep-seated rocks. (Chem. Abs., v. 9, p. 2364.)

Botinelly, Theodore, 1956, Ore mineralogy, in Geologic investigations of radioactive deposits—semi annual progress report for December 1, 1955, to May 31, 1956: U. S. Geol. Survey TEI-620, issued by U. S. Atomic Energy Comm., Tech. Inf. Service, Oak Ridge, Tenn., p. 117-119.

Studies of uranium-vanadium deposits in the Salt Wash sandstone member of the Morrison formation indicate that the deposits are similar in mineralogy. Metallic minerals associated with the ore are pyrite, marcasite, and galena. Many of the deposits contain clausthalite, which forms thin zones or layers of limited extent.

Braddock, William. See Thompson, M. E., and others, 1956.

Bradley, W. W., 1916, Selenide of silver: Mining Sci. Press, v. 112, p. 741.

A dull black mineral was found closely associated with argentite in a quartz vein on the ninth level of the De Lamar mine, Owyhee County, Idaho. The author provisionally identified the mineral as agullarite, a silver sulfoselenide.

——— 1918, Quicksilver resources of California: California State Mining Bur. Bull. 78, p. 27-28, 193.

Tiemannite was found in large masses in association with cinnabar in the Abbott mine, Lake County, in the Socrates mine, Sonoma County, and in Orange and Santa Clara Counties.

Bright, M. S. See Hillebrand and others, 1953.

Brooker, E. J. See Robinson, C. S., and Brooker, 1952.

Brown, F. C., 1914, The crystal forms of metallic selenium and some of their physical properties: Phys. Rev., ser. 2, v. 4, p. 85-98.

A large number of crystals of metallic selenium, some of which were of large size, were formed by sublimation. The larger crystals were formed at higher temperatures. All were believed to belong to the hexagonal system. The properties, reaction to light, conductivity, and effects of mechanical pressure of the crystals are described.

——— 1915, Isolated crystals of selenium of the second and fifth systems, and the physical conditions determining their production: Phys. Rev., ser. 2, v. 5, p. 236-237.

Hexagonal and monoclinic artificial crystals of selenium are described.

Brown, G. F., and others, 1952, Geologic reconnaissance of the mineral deposits of Thailand: U. S. Geol. Survey Bull. 984, p. 82-87.

Disseminated sulfide replacement ore from the Nong Phai lead-zinc mine, Kanchanaburi, western Thailand, contains 0.05 percent selenium.

Brown, G. V., 1916, Composition of the selenosulfur from Hawaii: Am. Jour. Sci., ser. 4, v. 42, p. 132-134.

Analysis of a specimen of selenosulfur from Kilauea, Hawaii, gave 5.18 percent selenium and 94.82 percent sulfur. Lava which had been discarded as showing

practically no selenosulfur contained 0.07 percent selenium and 3.32 percent sulfur. Also present were silica, phosphorous, iron, aluminum, titanium, calcium, magnesium, sodium, and potassium. No tellurium or arsenic were found. Such a small amount of selenium was found that the mineral was considered only a variety of sulfur, and "seleniferous sulfur" was suggested as a more appropriate name for the mineral.

Brown, G. V., 1917, The composition of seleniferous sulfur: *Am. Mineralogist*, v. 2, p. 116-117.

Seven specimens of seleniferous sulfur contained selenium in the following uniform but small amounts: from Kilauea, 5.18 percent; from New Zealand, 0.298 and 0.195 percent; from Lipari Island, 0.285 and 0.272 percent; from Sicily, 0.070 and a trace.

Brown, I. C. See Miller and Brown, 1938.

Brown, J. C., and Dey, A. K., 1955, *India's mineral wealth*: 3d ed., Bombay, New York, Oxford University Press, p. 301-302.

There is reason to suspect the presence of selenium in the copper ores of Singhbhum and in the lead-zinc-copper ores of Bawdwin, in the Shan States, but in neither case are analyses available of the waste products in which it may have accumulated during their treatment.

Brush, G. J., 1881, On American sulpho-selenides of mercury; with analyses of onofrite from Utah, by W. J. Comstock: *Am. Jour. Sci.*, ser. 3, v. 21, no. 124, p. 312-316.

Specimens of sulfoselenide of mercury from Marysvale, Utah, were identified as onofrite. Compositions of several sulfur-selenium-mercury minerals are compared. Sulfoselenides of mercury form an isomorphous series from meta-cinnabarite, which contains no selenium, through guadalcazarite, onofrite, and tiemannite, which contains very little sulfur. Sulfoselenides of mercury are found at Culebras, San Onofre, and Guadalcazar, Mexico, and at Marysvale, Utah.

Burkart, J., 1866, Über einige mexicanische Mineralien; Chlorselenquecksilber; Schwefelselenzinkquecksilber: *Neues Jahrb. Mineralogie, Geologie u. Paläontologie*, Jahrg. 1866, p. 411-417.

Descriptions of selenium minerals from Guadalcazar, Mexico, are given.

— 1872, Ueber den Guadalcazarit: *Mineralog. Mitt.*, Jahrg. 1872, no. 4, p. 243-244.

The mineral guadalcazarite, from Guadalcazar, Mexico, is described.

Burris, Robert. See Franke and others, 1936.

Buryanova, E. Z., 1956, Ferroselite: *Vses. mineralog. obshch. Zapiski*, v. 85, no. 3, p. 286-291. [Russian.]

Ferroselite was first observed in Middle Devonian sandstone of the Tuvinsk Autonomous Territory associated with barite, pyrite, sphalerite, chalcopyrite, and a calcite-laumontite cement of the quartz sand grains. Its occurrence in clastic portions of effusive rock fragments and pelites indicates enrichment of selenium from highly dispersed selenium in sediments. Widespread Paleozoic

acidic effusive rocks must have been the source of the selenium. The mineralogy is described. (Chem. Abs., v. 51, col. 2477.)

Buryanova, E. Z., and Komkov, A. I., 1955, A new mineral—ferroselite: *Akad. Nauk SSSR Doklady*, v. 105, p. 812–813. [Russian.]

Ferroselite occurs associated with chalcopyrite and pyrite, in disseminations in calcite, cementing polymict sandstones and in coarse fragmental pelites in Middle Devonian deposits of the Tuvinak Autonomous Territory. The composition of ferroselite is FeSe_2 , and it is found in small prismatic crystals of 0.2 to 0.5 mm in length and 0.1 mm in cross section. (Chem. Abs., v. 50, col. 9239.)

Buryanova, E. Z., Kovalev, G. A., and Komkov, A. I., 1957, The new mineral cadmoselite: *Vses. mineralog. obshch., Zapiski*, v. 86, no. 5, p. 626–628. [Russian.]

A new cadmium selenide mineral was found in association with ferroselite, clausenthalite, native amorphous selenium, cadmium-bearing sphalerite, pyrite, and other minerals. The mineral, named cadmoselite, forms fine disseminations in the cement of sandstone. Mineralogic and crystallographic data are given.

Butler, B. S., 1913, Geology and ore deposits of the San Francisco and adjacent districts, Utah: U. S. Geol. Survey Prof. Paper 80, p. 95, 186.

The presence of selenium was detected in ore from the Golden Reef mine on the east side of the San Francisco Range. The primary ore mineral is galena with small amounts of pyrite. The ore is valuable chiefly for its gold, which is present in an unknown form, but it is probably not free. The form in which selenium is present has not been determined.

Butler, B. S., Loughlin, G. F., Helkes, V. C., and others, 1920, The ore deposits of Utah: U. S. Geol. Survey Prof. Paper 111, p. 106–108, 144–145, 152, 347, 542, 543, 544, 551–552, 555–556, 592, 593.

Selenium occurs in small amounts in many of the ore deposits of Utah. It collects in bullion and some of it is probably recovered in refining. In 1913, blister copper from the Garfield smelter, which derived most of its ore from the Bingham district, contained an average of 56 pounds of selenium per 100 tons of blister copper. Selenium is present in the gold-silver ores of the Gold Springs-State Line region and the Tushar Range, in mercury ore of the Lucky Boy mine near Marysvale, and is widely distributed in the sandstone deposits in southeastern Utah. The only apparently primary silver mineral recognized in banded quartz veins in the Tushar Range has a silver-white metallic luster and contains both selenium and tellurium. The mineral contains free gold in minute fissures, and possibly gold is one of its essential constituents. The rich gold ore of the Bully Boy and Webster mine in the Ohio district is in part native and in part probably combined with silver as telluride and selenide. Tiemannite and onofrite were found in a replacement deposit from 2 to 8 inches thick in limestone at the Lucky Boy mine, Mount Baldy district. The silver ore of the Silver Reef sandstone deposit carries selenium, which would suggest that part of the silver at least may be combined in some form with selenium.

Byers, H. G. *See also* Edgington and Byers, 1942; Lakin and Byers, 1941, 1948; Lakin and others, 1938; Miller and Byers, 1935; Robinson, W. O. and others,

1934, Slater and others, 1937; Williams and Byers, 1934, 1935a, b, 1936; Williams and others, 1940, 1941.

Byers, H. G., 1934, Selenium, vanadium, chromium, and arsenic in one soil: *Indus. Eng. Chemistry, News Ed.*, v. 12, p. 122.

Two samples of Pierre loam contained 2 ppm selenium, 460 and 470 ppm vanadium, and wheat grown on the soil contained 25 ppm selenium and 9 ppm vanadium.

——— 1935, Selenium occurrence in certain soils in the United States, with a discussion of related topics: *U. S. Dept. Agriculture Tech. Bull.* 482, 47 p.

Results of a reconnaissance survey of seleniferous soils in Wyoming, Montana, South Dakota, Colorado, Nebraska, Kansas, Oklahoma, Utah, New Mexico, and Arizona are given. Large areas of South Dakota were sampled and contour maps were prepared to detect the distribution of selenium in the soils. Investigations were made of selenium in Pierre shale in Nebraska and South Dakota, in water, and in pyrites. The author concluded that the source of selenium is sulfide minerals in the soil parent materials, and the selenium content of vegetation is dependent on the quantity and distribution of selenium and the amount of available sulfur in the soil.

——— 1936, Selenium occurrence in certain soils in the United States, with a discussion of related topics, second report: *U. S. Dept. Agriculture Tech. Bull.* 530, 78 p.

Analyses of soils and vegetation in Nebraska, South Dakota, and Wyoming, south and southwest of the Black Hills; in Mesa, Montrose, and Delta Counties, Colo., near the Grand Valley and Uncompahgre irrigation projects; in a large area of western Kansas; and in areas of Montana are given. These show that seleniferous soils are derived from the Pierre and Niobrara formations, and that irrigation or drainage removes the selenium from the soil. The effects of rainfall, relation of selenium in the soil to that in the plant, selenium poisoning of water, and miscellaneous analyses of soils and vegetation of Wyoming, Canada, New Mexico, Texas, North Carolina, Puerto Rico, and Cuba are discussed.

——— 1937a, The origin, distribution, and effects of selenium: *Soil Sci. Soc. America Proc.*, v. 1, p. 327.

Selenium is of general distribution throughout all soils, as it is through all igneous rocks. The source of exceptional quantities of selenium in soils derived from shales was seleniferous volcanic emanations deposited in seas of the Cretaceous or other periods when shales were produced.

——— 1937b, Selenium in Mexico: *Indus. Eng. Chemistry, Indus. Ed.*, v. 29, no. 10, p. 1200-1202.

High selenium content of soils near the town of Irapuato in the Guanajuato River valley, State of Guanajuato, is caused by selenium-bearing waste from the Guanajuato silver mines. Slimes left after silver and gold extraction were dumped in the canyon and during periods of inundation were deposited over the flood plain of the stream. Ore from the Sirena mine, Guanajuato, contained 16 ppm selenium; slimes contained 4.6 ppm selenium.

——— 1938, Selenium in meteorites: *Indus. Eng. Chemistry, News Ed.*, v. 16, p. 459.

Eighteen meteorites of various compositions were examined for selenium content. All stony meteorites—stone, chondrite, pallasite, and mesosiderite—examined contained from 3 to 15 ppm selenium. Iron alloy samples from octahedrite meteorites contained no selenium; concretions of troilite (iron sulfide) found in octahedrite meteorites contained 23 ppm and 200 ppm selenium.

Byers, H. G., and Knight, H. G., 1935, Selenium in soils: *Indus. Eng. Chemistry, Indus. Ed.*, v. 27, p. 902-904.

The quantity of selenium in vegetation grown upon seleniferous soil depends on the concentration of selenium in the soil, plant species, composition of soil, moisture, stage of development of plant, and part of plant examined.

Byers, H. G., and Lakin, H. W., 1939, Selenium in Canada: *Canadian Jour. Research*, v. 17, sec. B, p. 364-369.

Three hundred analyses of shales, soils, and plants collected in Cretaceous areas of Alberta, Saskatchewan, and Manitoba provinces indicate a large area of seleniferous soil. Selenium content of shales varied from 0.3 to 3.0 ppm; soils, from 0.1 to 6 ppm, plants, from 3 to 4190 ppm. Analyses are given.

Byers, H. G., Williams, K. T., and Lakin, H. W., 1936, Selenium in Hawaii and its probable source in the United States: *Indus. Eng. Chemistry, Indus. Ed.*, v. 28, p. 821-823.

Volcanic gas and sublimates of Hawaiian volcanoes are high in selenium; lavas and volcanic ash are low in selenium. Selenium is present in all the soils of Hawaii as insoluble basic ferric selenite. Selenium content of soils varies from 1 to 26 ppm and is higher in soils in areas of higher rainfall. Selenium of Hawaiian soils is derived from volcanic gases or sublimates and is carried down into the soil by rain and held there in a highly insoluble form. The authors conclude that selenium is of volcanic origin and was brought down by rainfall into the Cretaceous seas of the Western United States in which seleniferous shales were formed.

Byers, H. G., Miller, J. T., Williams, K. T., and Lakin, H. W., 1938, Selenium occurrence in certain soils in the United States, with a discussion of related topics; third report: *U. S. Dept. Agriculture Tech. Bull.* 601, 74 p.

This report contains tables showing the selenium content of soils in Prowers, Kiowa, Cheyenne, Bent, Otero, Crowley, Lincoln, Las Animas, Huerfano, Pueblo, El Paso, and Fremont Counties, Colo.; Colfax, Mora, San Miguel, and Harding Counties, N. Mex.; and parts of Arizona and Utah. Results are given of studies on variations in selenium content of plants, effect of irrigation on selenium, selenium in the Colorado River and in the ocean, selenium in soils of Hawaii and Puerto Rico, and the distribution of selenium in the soil profile.

Čadek, Josef, and Doležal, Jan, 1957, Determination and geochemistry of selenium: [Czechoslovakia] *Ustřední ústav geol. Věstník*, v. 32, no. 1, p. 28-40 [Czech, English summary.]

Very small amounts of selenium in pyrite were determined. Analyses of 8 pyrites gave 11-72 ppm selenium; of 1 marcasite, 4 ppm; of 1 pyrrhotite, 1.5 ppm; of 1 sphalerite, 67 ppm selenium. (*Chem. Abs.*, v. 51, col. 9422.)

Cahen, Edward, 1919, Selenium: *Mineral Foote-Notes*, v. 3, no. 5, p. 5-16.

Occurrence, source, chemical and physical properties, and uses of selenium are described.

Cohen, Edward, and Wootton, W. O., 1920, The mineralogy of the rarer metals: 2d ed., London, Charles Griffin and Co., p. 97-106.

Properties, uses, and detection of selenium and selenium minerals are described.

Callaghan, Eugene. See Hewett and others, 1936.

Campbell, T. W. See McCullough and others, 1946.

Canada, Department of Mines and Technical Surveys, 1952, Canadian mineral industry: Ottawa, p. 71-72.

Canadian selenium occurs in copper sulfide and gold ores; it is produced by two companies.

Canney, F. C. See Lovering and others, 1956.

Cannon, H. L., 1952, The effect of uranium-vanadium deposits on the vegetation of the Colorado Plateau: Am. Jour. Sci., v. 250, p. 735-770.

Biogeochemical studies of the relationship of plants to uranium-vanadium deposits were made in the Thompsons district, Grand County, Utah, where uranium ore in the Salt Wash sandstone member of the Jurassic Morrison formation contains unusual concentrations of uranium, vanadium, and selenium. Plants growing near shallow ore deposits accumulate small amounts of these metals. The effects of these metals on plant growth were observed, the ecology of the plants was studied, and the distribution of various species of indicator plants was mapped in detail. A uranium-tolerant flora has been recognized and is characterized by selenium-indicator plants. Where selenium-bearing ore lies at shallow depth and where the geography and rainfall are favorable for plant growth, the distribution of selenium-indicator plants is the same as that of the carnotite ores. Certain species of selenium-indicator plants can be mapped as guides to exploration.

——— 1953, Geobotanical reconnaissance near Grants, N. Mex.: U. S. Geol. Survey Circ. 264, 8 p.

Carbonaceous uranium ore in the Westwater Canyon member of the Jurassic Morrison formation contains a high percentage of selenium and the mapping of selenium-indicating *Astragalus* and *Oryzopsis* plants commonly associated with these deposits is suggested as a method of prospecting for uranium. Selenium-indicator plants apparently do not grow on the Todilto limestone member of the Wanakah formation in the same area, although in places the uranium ore contains sufficient selenium to support such plants.

——— 1954, Botanical methods of prospecting for uranium: Am. Inst. Mining Metall. Engineers Trans., v. 199, p. 217-220.

Botanical methods of prospecting for metalliferous ores are based on the premise that deposits at depth may be reflected chemically in surface vegetation. Uranium is a necessary nutrient for plant growth and therefore is present in all plants. Selenium, which is associated with uranium ores in many areas, is necessary only to certain plants known as selenium-indicator plants. *Astragalus confertiflorus*, *A. preussi* var. *arctus*, *A. thompsonae*, *A. pattersoni*, *Oryzopsis hymenoides*, and *Aster venusta* are selenium-indicator plants common in uranium districts. They bear a recognizable relationship to carnotite de-

posits of the southwest and have distinct distribution patterns which depend on the amount of selenium in the ore and the amount required by the plant. In the Thompsons district, Utah, plants were mapped over an area of 6 square miles and 1000 holes were drilled. Of 194 holes drilled in areas supporting the growth of indicator plants, 90 were in mineralized ground. Indicator plants were present in the vicinity of 12 percent of the unmineralized holes, 54 percent of the mineralized holes (including ore holes), and 81 percent of the ore holes. Of 10 orebodies discovered in the Yellow Cat area, 4 would not have been found had it not been for the additional information furnished by indicator plants.

Cannon, H. L., 1956, Advances in botanical methods of prospecting for uranium: Internat. Geol. Cong., 20th, Mexico 1956, Resumenes Trabajos Presentados, p. 359-360.

Mapping the distribution of indicator plants rooted in ore-bearing formations is an effective prospecting method. Distinctive plants requiring selenium or sulfur may indicate associated uranium ores. *Astragalus* plants have delineated ore bodies to depths of 25 meters.

——— 1957, Description of indicator plants and methods of botanical prospecting for uranium deposits on the Colorado Plateau: U. S. Geol. Survey Bull. 1030-M, p. 399-516.

Botanical prospecting by mapping indicator plants is used in semiarid parts of the Colorado Plateau at low altitude. The distribution of indicator plants is controlled by the availability of chemical constituents of the ore, such as selenium, sulfur, and calcium. Plants of the genus *Astragalus* are most useful in prospecting for uranium deposits of high selenium content. Fifty indicator plants usually associated with carnotite deposits and plants tolerant of mineralized ground are described and illustrated.

Cannon, H. L., and Kleinhampl, F. J., 1956, Botanical methods of prospecting for uranium, in Contributions to the geology of uranium and thorium by the United States Geological Survey and Atomic Energy Commission for the United Nations International Conference on Peaceful Uses of Atomic Energy. Geneva, Switzerland, 1955: U. S. Geol. Survey Prof. Paper 300, p. 681-696.

Selenium-indicator plants are used in prospecting for uranium on the Colorado Plateau because the availability of selenium to plants is increased many fold by the presence of carnotite, and the distribution of selenium-indicator plants is controlled by the distribution of carnotite. The most useful plant is *Astragalus pattersoni*, which commonly absorbs several thousand parts per million selenium from uranium ores, and is capable of extracting selenium directly from ore bodies as deep as 75 feet. Prospecting by indicator plants is advantageous where the uranium content is 0.01 percent or more and the selenium content is 0.01 percent or more, if the upper limits of the ore body are not more than 40 feet below the surface.

Cannon, H. L., and Starrett, W. H., 1956, Botanical prospecting for uranium on La Ventana Mesa, Sandoval County, New Mexico: U. S. Geol. Survey Bull. 1009-M, p. 391-407.

Minor amounts of selenium are concentrated in uranium-bearing coal. The ratio of selenium to uranium is very high in mineralized coal, with 600 ppm selenium reported in one sample. Selenium indicator plants associated with

sulfur indicator plants were noted on the slope below the outcrop of uranium-bearing coal.

Carlos, G. C. *See* Edwards and Carlos, 1954.

Caron, P. E. *See* Stone and Caron, 1954.

Carstens, C. W., 1941a, Om geokjemiske undersøkelser av malmer: Norsk geol. tidsskr., v. 21, no. 2-3, p. 213-227.

The selenium content and sulfur-selenium ratios of sedimentary and hydrothermal pyrites of the Bymark group of the Trondheim area, Norway, including the Leksdals and Løkken-Grong types, are discussed. The article contains many analyses of ores containing selenium.

——— 1941b, Über sedimentäre Schwefelkiesvorkommen: Kgl. Norsk Vidensk. Selsk. Förh., v. 14, p. 120-122.

Sedimentary pyrite of the Leksdals type contains no selenium; hydrothermal pyrite of the Løkken-Grong type contains more than 10 ppm selenium.

——— 1941c, Zur Geochemie einiger norwegischen Kiesvorkommen: Kgl. Norsk Vidensk. Selsk. Förh., v. 14, no. 10, p. 38-39.

The pyrite in the Bymark group of the Trondheim area is of two types: the Leksdals type of sedimentary origin, and the Løkken-Grong type of hydrothermal origin. Pyrite of the Leksdals type contains less than 0.1 percent copper and is relatively selenium free. Pyrite of the Løkken-Grong type customarily contains a minimum of 0.5 percent copper and a significant amount of selenium, averaging from 20 to 30 ppm. A table gives copper, sulfur, and selenium contents of copper-bearing sulfide ores and concentrates, and sulfur-selenium ratios, which range from 42,000:1 for copper-poor ore at Løkken-Grong to 1800:1 for copper-rich ore.

Castillo, Antonio del, 1873, Descubrimiento de una nueva especie mineral de bismuto: Naturaleza [Mexico], v. 2, p. 274-276.

Description of a double selenide of bismuth and zinc from Guanajuato, Mexico, is given.

——— 1874, Über eine neue Mineral-Species des Wismuths: Neues Jahrb. Mineralogie, Geologie u. Palaeontologie, Jahrg. 1874, p. 225-229.

A bismuth-zinc-selenium mineral from Guanajuato, Mexico, is described.

Christman, R. A., Heyman, A. M., Dellwig, L. F., and Gott, G. B., 1953, Thorium investigations 1950-52, Wet Mountains, Colorado: U. S. Geol. Survey Circ. 290, p. 7.

Strong, fetid odor in newly broken reddish-stained granitic rocks in the thorium area from Querida to Rosita, Custer and Fremont Counties, Colo., was thought to be caused by selenium compounds, but a chemical analysis showed only traces of selenium. However, volatile compounds may have escaped during grinding of the sample.

Clark, C. W., and Schloen, J. H., 1944, Recovery of precious metals and production of selenium and tellurium at Montreal East: Am. Inst. Mining Metall. Engineers Trans., v. 159, p. 495-520; Tech. Paper 962, 22 p., 1938.

Blister cakes from Hudson Bay Mining and Smelting Company, Flin Flon, Manitoba, and anodes from Noranda Mines, Ltd., Noranda, Quebec, are refined

at Montreal East. Both ores have unusually high selenium and tellurium content. Average assay of slimes from Noranda is 22 percent selenium. Selenium recovery plant and process are described.

Clarke, F. W., 1924, The data of geochemistry: U. S. Geol. Survey Bull. 770, p. 19, 186, 273.

Occurrence of selenium in mineral waters and with sulfur as selenosulfur in volcanic sublimes of the Lipari Islands is noted.

Clarke, F. W., and Washington, H. S., 1924, The composition of the earth's crust: U. S. Geol. Survey Prof. Paper 127, p. 27, 83, 89, 90, 91-92, 93.

The occurrence of selenium and the association and distribution of selenium minerals are described.

Clennell, J. E., 1906, Assay of bullion containing selenium: Eng. Mining Jour., v. 82, no. 23, p. 1057-1059.

The assay method is described.

——— 1907, Method for analysis of gold-silver bullion: Eng. Mining Jour., v. 83, no. 23, p. 1099-1100.

The method used for determining elements, including selenium, in bullion produced by *Mijnbouw Maatschappij Redjang Lebong*, Sumatra, is described.

Coats, R. R., 1936, Agullarite from the Comstock Lode, Virginia City, Nevada: Am. Mineralogist, v. 21, p. 532-534.

Silver sulfoselenide occurs in dark-gray sectile masses intimately admixed with other minerals. It appears to be an isomorphous mixture of naumannite and argentite molecules, associated with argentite and silver and replaced by stephanite.

Coleman, R. G., 1956, The occurrence of selenium in sulfides from sedimentary rocks of the western United States [abs.]: Econ. Geology, v. 51, no. 1, p. 112.

Sulfides in the Morrison and Entrada formations of Jurassic age and the Wind River formation of Eocene age contain abnormally large amounts of selenium substituting for sulfur. Sulfides from the same stratigraphic zone usually contain the same relative amounts of selenium regardless of their position with respect to uranium ore deposits. As much as 5 percent selenium was found in pyrite and chalcocite. Sulfides from the Chinle and Shinarump formations of Triassic age usually contain less than 3 ppm selenium except in the Temple Mountain mining district, Utah, where they contain as much as 0.5 percent selenium. Clausthalite and eucairite have been identified from several uranium ore deposits in the Morrison formation. Oxidation of these seleniferous minerals underground or in damp cool places produces a characteristic pink bloom of monoclinic native selenium, which may invert to more stable hexagonal native selenium at higher temperatures on the surface.

Coleman, R. G., and Delevaux, Maryse, 1957, Occurrence of selenium in sulfides from some sedimentary rocks of the western United States: Econ. Geology, v. 52, no. 5, p. 499-527.

Investigations of the minor—and trace-element content of sulfides associated with uranium ore deposits from sandstone-type deposits have shown that selenium commonly substitutes for sulfur. The Morrison formation and Entrada sandstone of Jurassic age and the Wind River formation of Eocene age seem to be

seleniferous stratigraphic zones; sulfides deposited within these formations generally contain abnormal amounts of selenium. Tables showing selenium content of sulfides from sedimentary rocks of Triassic, Jurassic, Cretaceous, and Tertiary ages, from many uranium mines in Utah, Colorado, Arizona, New Mexico, and Wyoming, and from some hydrothermal vein deposits are given. The average selenium content of iron sulfides from mineralized rock of Triassic age was 0.0019 percent; of Jurassic age, 0.20 percent; of Cretaceous age, 0.005 percent; of Tertiary age, 0.087 percent. The selenium content of pyrite, marcasite, and chalcocite is much greater than that reported in previously published data. The maximum amount of selenium substituting for sulfur in the pyrite structure was found to be 3 percent by weight. Some copper sulfide samples of Jurassic age which had an extremely high selenium content were shown to contain small inclusions of clausthalite and rarely eucairite. Ferroselite was found in 2 deposits on the Colorado Plateau, and it was established that galena forms an isomorphous series with clausthalite in nature.

During oxidation of the selenium-bearing sulfides and selenides from the Colorado Plateau and Wyoming, the selenium forms pinkish crusts of either monoclinic or hexagonal native selenium intergrown with soluble sulfates, suggesting that under "normal" oxidizing conditions native selenium is more stable than selenites or selenates. The selenium content of sulfides from sedimentary rocks of Mesozoic and Tertiary age is above normal and is related to periods of volcanic and intrusive activity penecontemporaneous with the formation of the containing sediments.

Coleman, W. C., and McCrosky, C. R., 1937, Volumetric determination of selenium—a critical study of the Norris and Fay method: *Indus. Eng. Chemistry, Anal. Ed.*, v. 9, p. 431–432.

Description of simplified procedure for determination of selenious acid by the Norris and Fay method is given.

Collins, W. H., 1937, Timiskaming Sub-province: *Geol. Soc. America Bull.*, v. 48, no. 10, p. 1427–1458.

Sudbury nickel-copper ores contain recoverable amounts of selenium.

Coniglio, L. *See* Zambonini and Coniglio, 1925.

Connor, J. J. *See* Miesch and Connor, 1956.

Cox, T. H. *See* Pugsley and Cox, 1937.

Curl, A. L. *See also* Mathews and others, 1937.

Curl, A. L., and Osborn, R. A., 1938, Report on selenium: *Assoc. Official Agr. Chemists Jour.*, v. 21, no. 2, p. 228–235.

Volumetric determination of selenium using starch indicator is described.

Curran, J. M., 1895, On selenium associated with gold and bismuth, from Mount Hope, N. S. Wales: *Royal Soc. New South Wales Jour. and Proc.*, v. 29, p. 404–406.

Gold occurs at the Mount Allen mine near Mount Hope in an auriferous belt of slate interbedded with Silurian slates. The gold is in plates along laminae of the slate, in grains associated with quartz nodules, and in grains enclosed

in aggregates of bismuth oxide and carbonate. Selenium is distributed irregularly throughout the stone. The author believes that selenium and bismuth once existed as a selenide of bismuth which was probably auriferous.

Dake, H. C. *See* DeMent and Dake, 1946.

Damour, A. *See also* DesCloizeaux and Damour, 1881.

— 1881, *Essais chimiques et analyse de la chalcomérite, espèce minérale*: Soc. minéralog. France Bull., v. 4, p. 164-167.

Analysis of chalcomérite from Cacheuta, Mendoza, Argentina, is described. The mineral was found in silver, lead, and copper selenide veins, associated with azurite, iron oxide, and lead carbonate.

Dana, E. S., and Wells, H. L., 1890, On some selenium and tellurium minerals from Honduras: *Am. Jour. Sci.*, ser. 3, v. 40, no. 235, p. 78-82.

Specimens from El Plomo mine, Ojojoma district, Department of Tegucigalpa, Honduras, included a blackish gray mineral in quartz-barite gangue found to be an isomorphous mixture intermediate between selenium and tellurium in composition, called selen-tellurium. It most closely resembles native tellurium from Faczebaja which contained 6.7 percent selenium. Also analyzed was a greenish yellow ferric tellurite mineral with selenium replacing part of the tellurium, which was named durdenite.

De la Peña P., R. Luis, 1944, *Economic geology, or monograph on the mining region of Huitsuco, State of Guerrero, Mexico*: *Ingeniería [Mexico]*, v. 13, p. 205-224.

Livingstonite, stibnite, cinnabar, metacinnabar, barcenite, terlinguaite, guadalcazarite, tiemannite, and onofrite are associated with pyrite, realgar, sulfur, graphite, fluorite, and gypsum in matrices of calcite, gypsum, and dolomite. The sulfides and selenides ascended in hot alkaline solutions and were deposited near the surface by diminution of pressure, temperature, dilution, and oxidation of solutions, and by precipitating agents. (*Chem. Abs.*, v. 39, col. 44.)

Delevaux, Maryse. *See* Coleman and Delevaux, 1957.

Del Rio, Andrea, 1828, Analysis of two new mineral substances, consisting of biseleniuret of zinc and sulphuret of mercury, found at Culebras in Mexico: *Philos. Mag.*, ser. 2, v. 4, p. 113-115.

Two mineral substances, one gray metallic and one red, are both believed to be zinc-mercury selenide minerals.

— 1836, On riolite, a supposed biseleniuret of zinc: *Philos. Mag.*, ser. 3, v. 8, p. 261-263.

A mineral from Culebras, Mexico, formerly believed to be a biseleniuret of zinc, was found to be native selenium ore with a variable mixture of zinc, mercury, cadmium, and iron.

Delwig, L. F. *See* Christman and others, 1953.

DeMent, Jack, and Dake, H. C., 1946, *Rarer metals*: Brooklyn, Chemical Pub. Co., p. 251-286.

A summary of the history, mineralogy, occurrence, physical properties, chemical properties, compounds, biological nature, technology, and analysis of selenium.

Derrick, J. J., and Vaes, J. F., 1956, The Shinkolobwe uranium deposit, in *Proceedings of the international conference on the peaceful uses of atomic energy*, v. 6, *Geology of uranium and thorium*: New York, United Nations, p. 94-128.

Ore from certain massive sulfide veins in the Shinkolobwe mine contains minerals with compositions similar to vaesite and siegenite, except that in one mineral 19 percent of the sulfur is replaced by selenium (selenio-vaesite) and in the other 11 percent of the sulfur is replaced by selenium (selenio-siegenite). In the selenio-sulfide veins, which contain a greater variety of minerals than do the selenium-free sulfide veins, the usual accessory minerals are molybdenite, pyrite, chalcopyrite, bornite, digenite, covellite, and gold. In these veins 3 other selenium minerals are found; one is thought to be related to umangite, and 2 are unidentified but are known to be selenides. A mineral almost identical with molybdenite occurs in certain brecciated formations intimately associated with selenio-sulfides, which is thought to be a variety of selenium molybdenite.

de Salas, Susana M., 1947, Selenium in water. III. Selenium content of some Argentine waters: *Rev. obras sanitarias nación*, v. 21, p. 21-24.

No relation between selenium content and the amount of fluorine, vanadium, and arsenic was found in 70 samples of water. The water from 12 purification plants contained 0-5 micrograms per liter selenium. Natural water from 40 different locations contained 0-67 gammas per liter selenium. (Chem. Abs., v. 42, col. 2089.)

Des Cloizeaux, and Damour, A., 1881, Note sur chalcomérite, nouvelle espèce minérale (sélénite de cuivre): *Soc. minéralog. France Bull.*, v. 4, p. 51-55.

Veins containing selenides of lead, silver, and copper are found at Cachenta, southeast of Mendoza, Argentina. The minerals are identified as cachentalite, chalthalite, zorgite, berzellanite, and a new copper selenite mineral, chalcomenite.

Dey, A. K. See Brown, J. C., and Dey, 1955.

Di Franco, S., 1942, Mt. Etna's mineralogy: *Accad. gioenia sci. nat. Catania Atti*, v. 5, mem. 9, p. 1-175.

Minerals found in Mt. Etna's eruptive materials include selenium among some 60 sulfide, oxide, carbonate, and silicate minerals. (Chem. Abs., v. 42, col. 491.)

Dimmick, T. D., 1948, Mineral resources of Australia, Minor metals: *Australia Bur. Mineral Resources, Geology, and Geophysics Summ. Rept.* 35, p. 8-10.

Selenium minerals, uses, prices, and production are discussed. The only commercial source of selenium is anode sludge formed during the electrolytic refining of blister copper. Anode sludge is obtained by Electrolytic Refining and Smelting Company of Port Kembla, New South Wales, and the Mount Lyell Mining and Railway Company at Queenstown, Tasmania. The anode sludges from these companies contain from 1 to 2 percent and 2 percent selenium respectively. Selenium is present in the Mount Morgan ore and one analysis of blister copper from Mount Morgan gave 0.019 percent selenium. The converter flue dust has been found to contain selenium to the extent of 0.04 percent. Selenium is present in small amounts in tellurides at Kalgoorlie and Rothsay, Western Australia, but the occurrences are not of economic importance.

Dios Guevara, Juan de, 1940, The presence of selenium in a sample of Peruvian sulfur: *Soc. Quim. Peru Bol.*, v. 6, no. 1, p. 23-25.

A sample of sulfur from Chachani, Arequipa, contained 99.69 percent sulfur, 0.01 percent selenium, no arsenic, 0.09 percent organic substances, 0.14 percent ash, and 0.07 percent water. (*Chem. Abs.*, v. 34, col. 5603.)

Divers, Edward, and Shimidzu, Tetsukichi, 1883, The red sulphur of Japan: *Chem. News*, v. 48, p. 284.

Orange-red sulfur similar to the selen-sulfur of the Lipari Islands, Naples, and Hawaii, is found among volcanic sulfur deposits in Japan. It has been obtained from Iwoshima; Motoyama, Satsuma, and Tateyama, Etchui; and Oshima. One specimen examined contained 0.06 percent selenium, 0.17 percent tellurium, 0.01 percent arsenic, and a trace of molybdenum. Yellow sulfur also may contain traces of selenium and tellurium.

Djingheuzian, L. E., 1957, Metallurgical developments in the recovery of some of the less common metals in Canada, in *Extraction and refining of the rare metals*: London, Institution of Mining and Metallurgy, p. 72-90.

Selenium and tellurium occur as copper selenides and copper-gold tellurides in the copper-nickel ores of International Nickel Company of Canada. The amount of selenium in the ore is exceedingly small and no attempt is made to determine the amount. Copper anode slimes contain 8-10 percent selenium. Metallurgy of selenium is described.

Doležal, Jan. See Čadek and Doležal, 1957.

Domeyko, J., 1864, Sur quelques nouveaux minéraux du Chili: sélénite double d'argent et de cuivre (eucairite Berz): *Annales Mines [Paris]*, ser. 6, v. 5, p. 458-459.

Specimens of silver-copper selenide mineral (eucairite) were found in Flamenco in the Atacama desert in Chile and in the Province of San Juan, on the other side of the Andes.

——— 1866, Notice sur les sélénites provenant des mines de Cacheuta: *Acad. sci. [Paris] Comptes rendus*, v. 63, p. 1064-1069.

A vein containing selenium minerals was found in the Province of Mendoza, Argentina, near the area of the coal mines of Cacheuta. The vein is similar to the sulfide ores of Chile, being rich in silver near the surface and becoming rich in lead and poor in silver at depth, except that the ore minerals are selenides rather than sulfides. Near the surface the ore mineral is a polyselenide of silver and copper, with a little iron and cobalt, similar to eucairite, in which there is isomorphous substitution of copper for silver at depth. In the deeper parts of the vein the ore is lead selenide, containing very little silver or copper.

Doty, M. F., 1927, *Bibliography on selenium from 1817 to 1925*: New York, New York Public Library, 114 p.

A list of references in the New York Public Library on mineralogy, crystallography, properties, uses, and patents of selenium.

Downie, C. C., 1952, Metallurgical fume and fume dusts: *Mining Mag. [London]*, v. 86, no. 2, p. 80-83.

Brief review of methods of recovery of selenium from refinery fume dusts.

Draize, J. H. *See* Beath and others, 1934a, b.

Dudley, H. C. *See* Robinson, W. O., and others, 1934.

Eakle, A. S., 1914, Minerals of California: California State Mining Bur. Bull. 67, p. 47.

Tiemannite occurs in large masses near Clear Lake and in the Abbott mine, Lake County; in the San Joaquin Ranch mine, Orange County; and in the old Guadalupe mine near New Almaden, Santa Clara County.

Earley, J. W., 1949, Studies of natural and artificial selenides; [Pt.] 1—klockmannite: *Am. Mineralogist*, v. 34, p. 435-440.

Klockmannite from Sierra de Umango, Argentina, was compared with artificial klockmannite and was found to be physically and structurally identical.

——— 1950, Description and synthesis of the selenide minerals: *Am. Mineralogist*, v. 35, p. 337-364.

A study of natural and artificial selenides, mainly by microscopic and X-ray methods, including naumannite, agularite, eucairite, crookesite, berzellanite, umangite, clauthalite, tiemannite, penroseite, guanajuatite, and paraguanajuatite.

Edgington, Glen. *See also* Robinson and Edgington, 1945.

Edgington, Glen, and Byers, H. G., 1942, Selenium content and chemical analyses, pt. 9 of *Geology and biology of North Atlantic deep-sea cores between Newfoundland and Ireland*: U. S. Geol. Survey Prof. Paper 196-F, p. 151-155.

Core samples of sea floor sediments containing volcanic ash were analyzed. Bering Sea core contains 0.25-0.7 ppm selenium; Ocean City, Md., 0.6-2 ppm selenium; North Atlantic, less than 0.1-0.8 ppm. selenium; Caribbean Sea at Bartlett Deep, less than 0.08-0.2 ppm selenium. No evidence of a relation between volcanic activity and selenium accumulation can be drawn from these data.

Edwards, A. B., 1939, Some observations on the mineral composition of Mount Lyell copper ores, Tasmania, and their modes of occurrence: *Australasian Inst. Mining and Metallurgy Proc.*, no 114, p. 61-110.

Selenium occurs as a trace in the Mount Lyell ores, but constitutes 3.9 percent of the final electrolytic slimes from the purification of copper. The amount of selenium in the ore is in the order of 1 part in 124,000. In the North Lyell bornite-chalcopyrite ore body a mineral believed to be berzellanite or eucairite occurs in minute silver-white needle-shaped inclusions in bornite and in chalcocite replacing bornite.

Edwards, A. B., and Carlos, G. C., 1954, The selenium content of some Australian sulphide deposits: *Australasian Inst. Mining and Metallurgy Proc.*, no. 172, p. 31-64.

The possibility of using sulfur-selenium ratios as a method of distinguishing between sulfide deposits of sedimentary or supergene and hydrothermal origin was tested on Australian sulfide ores. Sulfur-selenium ratios of sedimentary pyrites range from 500,000 to 38,000; sulfur-selenium ratios of known hydrothermal pyrites range from 9,000 to 13,000. This investigation shows that

high selenium content is associated with hydrothermal origin, but low selenium content is not positive evidence of sedimentary origin, because some hydrothermal sulfides are low in selenium. The amount of selenium in hydrothermal ore depends on the amount of selenium available to mineralizing solutions and on factors controlling the substitution of selenium for sulfur. On the basis of their sulfur to selenium ratios, the deposits at Nairne, South Australia; Broken Hill, N. S. W.; and Mount Isa, Queensland; are considered to be of hydrothermal origin. In many Australian sulfide ores investigated, the early formed minerals, chalcopyrite, pyrite, bornite, and arsenopyrite, are the most seleniferous; later formed minerals, sphalerite, galena, and tetrahedrite, are less seleniferous; and the low-temperature minerals, stibnite, cinnabar, and barite, are poor in selenium. Tables show sulfur and selenium content of sedimentary, supergene, and hydrothermal pyrite, pyrrhotite, chalcopyrite, sulfates, gossans, molybdenite, sphalerite, galena, stannite, stibnite, cinnabar, tetrahedrite, arsenopyrite, and bornite.

Ellers, A., 1913, Notes on the occurrence of some of the rarer metals in blister copper: *Am. Inst. Mining Metall. Engineers Bull.* 78, p. 999-1000.

The smelter recoveries of selenium from blister copper are: Fairfield, Utah, 2,800 lb. selenium from 5,000 tons blister from Bingham mine; Steptoe, Nev., 3,303 lb. from 3,000 tons blister from Nevada Consolidated mines; Omaha, Neb., 213 lb. from 800 tons blister from Rocky Mountain lead-silver mines; Mountain, Calif., 54 lb. from 150 tons blister; Tacoma, Wash., 336 lb. from 800 tons blister from Pacific coast and Alaska copper ores; Aguascalientes, Mexico, 1,870 lb. from 1,100 tons blister from Mexican gold-silver-copper ores; Cerro de Pasco, Peru, 275 lb. from 2,000 tons blister; Mt. Lyell, Tasmania, 336 lb. from 800 tons blister.

Elkin, E. M. *See also* Schloen and Elkin, 1946, 1950, 1954.

Elkin, E. M., and Margrave, J. L., 1954, Selenium and selenium compounds: *Encyclopedia Chem. Technology*, v. 12, p. 145-163.

A review of physical and chemical properties, analytical methods, metallurgy, inorganic and organic compounds, health and safety factors, and uses of selenium.

Emmons, W. H., and Laney, F. B., 1926, Geology and ore deposits of the Ducktown mining district, Tennessee: *U. S. Geol. Survey Prof. Paper* 139, p. 52-53.

Determinations made by the Tennessee Copper Company of selenium in composite samples of Ducktown primary ores taken in December, 1907, give the following selenium contents: Burra Burra mine, 0.0175 percent; London mine, 0.011 percent; Polk County mine, trace. Six samples of lead-bearing copper ores from the secondary zone contained traces of selenium.

Eppson, H. F. *See* Beath and others, 1934b, 1935, 1937a, b, 1939a, b, 1940, 1941; Beath and Eppson, 1947.

Everett, F. D., and Bauerle, L. C., 1957, Investigation of tuffs near Lysite, Wyo., for selenium: *U. S. Bur. Mines Rept. Inv.* 5296, 30 p.

Exploration work on a seleniferous tuff in the Poison Draw area north of Lysite, Fremont County, Wyo., established that selenium mineralization is

erratically distributed in small irregular bodies and is not confined to any one tuff bed. Of 206 samples assayed from 11 drill holes, only 8 contained more than 0.005 percent selenium. The extent and grade of reserves could not be calculated because of the sporadic nature of the mineralization and the lack of correlation between infrequent showings. Metallurgical research to develop a process to recover high-purity selenium from the tuff included water-leaching, precipitation from pregnant solutions, and direct-volatilization methods. Because of the low tenor of ore and the presence of soluble sulfates and bentonitic clay, all methods of extraction were complicated and expensive.

Fernandez, V., 1877, Ueber Guanajuatit-Frenzelit; Schwefelselenwismuthglanz: Zeitschr. Krystallographie u. Mineralogie, v. 1, p. 499.

Guanajuatite and frenzelite from Santa Catarina mine, Guanajuato, Mexico, are the same mineral.

Fisher, Coleman, Jr., 1849, Examination of the telluret of bismuth, from Virginia: Am. Jour. Sci., ser. 2, v. 7, p. 282-283.

Tetradymite from the White Hall mine, Spotsylvania County, was analyzed and found to contain 7.23 percent selenium, 37.96 percent tellurium, and 54.81 percent bismuth.

Fleischer, Michael, 1955, Minor elements in some sulfide minerals: Econ. Geology, Fiftieth Anniversary Volume, pt. 2, p. 970-1024.

Data in the literature on the selenium content of galena, sphalerite and wurtzite, chalcopyrite, pyrite and marcasite, pyrrhotite, and arsenopyrite are summarized in tables for each mineral. The tables list references, type of analysis, and quantitative determinations by arbitrarily selected concentration ranges.

Fleming, G. A. See also Walsh and others, 1951.

Fleming, G. A., and Walsh, T., 1957, Selenium occurrence in certain Irish soils and its toxic effects on animals: Royal Irish Acad. Proc., v. 58, sec. B, no. 7, p. 151-166.

Analyses were made of rock, soil, and plant samples from certain parts of Counties Limerick, Tipperary, and Meath where chronic selenium poisoning of animals had been reported. The rocks were Upper and Middle Carboniferous Limestone associated with shale and sandstone beds of the Yoredale and Pendle-side series. The source of the selenium was found to be certain shale beds. Soils with the highest selenium content were poorly drained, low-lying, and of high organic matter and molybdenum content. The soils were believed to be of lacustrine origin, the selenium having been carried in by drainage from surrounding areas. As much as 1,200 ppm selenium was found in soils.

Foster, Z. C. See Hough and others, 1941.

Franke, K. W., and Painter, E. P., 1937, Effect of sulfur additions on seleniferous soils; Binding of selenium by soil: Indus. Eng. Chemistry, Indus. Ed., v. 29, p. 591-595.

Sulfur in the form of ground sulfur and gypsum was added to a seleniferous field in Gregory County, S. D., on which wheat and corn were grown. The application of sulfur did not inhibit the absorption of selenium by the plants. Plants appear to absorb less selenium during dry seasons than during rainy seasons.

Franke, K. W., Burris, Robert, and Hutton, R. S., 1936, A new colorimetric procedure adapted to selenium determination: *Indus. Eng. Chemistry, Anal. Ed.*, v. 8, p. 435.

A method is described by which colored precipitates of colloidal fineness can be filtered onto a mat of barium sulfate. This procedure can be used for the estimation of 0.005 to 0.15 mg of selenium with an accuracy of 0.001 to 0.01 mg.

Frebald, Georg, 1927a, Beiträge zur Kenntnis der Erzlagerstätten des Harzes. II. Über einige Selenerze und ihre Paragenesen im Harz: *Zentralbl. Mineralogie, Jahrg. 1927, Abt. A, no. 1*, p. 16-32.

The minerals, clausthalite, tiemannite, naumannite, and umangite, and the mechanical mixtures, lehrbachite (clausthalite and tiemannite), zorgite (clausthalite and umangite), "selenkobaltblei" (clausthalite, "kobaltglanz", hematite), and "seebachite" (clausthalite, umangite, tiemannite), from the Harz are described. The paragenesis of selenium minerals at Clausthal is: pyrite, quartz, calcite, chalcopyrite, clausthalite, tiemannite; at Trogtal: hematite, "kobaltglanz", clausthalite; at Lehrbach: dolomite, clausthalite, tiemannite, umangite, chalcocite, chalcopyrite; at Zorge: quartz, hematite, calcite, clausthalite, tiemannite, umangite; at Tilkerode: pyrite, quartz, dolomite, calcite, chalcopyrite, clausthalite, naumannite, tiemannite.

——— 1927b, Beiträge zur Kenntnis der Erzlagerstätten des Harzes; III Über Berzelianit, Cu_2Se , und ein neues Vorkommen von "Selenkobaltblei" im Harz: *Zentralbl. Mineralogie, Jahrg. 1927, Abt. A, no. 6*, p. 196-199.

Berzelianite from Skrikerum, Sweden, the Caroline mine near Lehrbach, and the Oberjeremiashöhe mine between Zorge and Wieda is described. Seleniferous material identified as a mixture of clausthalite, "kobaltglanz", and an unknown component from a quarry at Trogtal near Lautenthal is also described. In the Harz, the sulfides, pyrite and chalcopyrite, are older than the selenides, which are the last product of hydrothermal deposition.

Frenzel, August, 1874, *Mineralogisches; Selenwismuthglanz: Neues Jahrb. Mineralogie, Geologie u. Palaeontologie, Jahrg. 1874*, p. 679-681.

A bismuth-selenium-sulfur mineral from Guanajuato, Mexico, is described.

Friedel, C., and Sarasin, Edmond, 1881a, Forme cristalline du sélénite de cuivre: *Soc. minéralog. France Bull.*, v. 4, p. 225-228.

Artificial chalcomenite has a different crystal form from natural chalcomenite, although the composition is the same.

——— 1881b, Reproduction de la chalcoménite: *Soc. minéralog. France Bull.*, v. 4, p. 176-178.

Artificial selenite of copper was formed from a solution of potassium selenite precipitated by copper sulfate.

Friend, J. N., and Allchin, J. P., 1941, The selenium and tellurium contents of sulfur from Krisuvik, Iceland: *Mineralog. Mag.*, v. 28, p. 9-10.

Analyses of sulfur indicated 12.5 ppm selenium and 250 ppm tellurium in extracted sulfur; 200 ppm selenium and 4000 ppm tellurium in insoluble residue; and 18.9 ppm selenium and 378 ppm tellurium in crude mineral.

Fromme, Joh., 1890, Eucairit aus Argentinien: Jour. prakt. Chemie, v. 150, new ser. v. 42, p. 57-62.

Description and analysis of eucairite from La Rioja Province, Argentina, are given.

Fron del, Clifford. See Palache and others, 1944.

Gale, H. S., 1908, Carnotite and associated minerals in western Routt County, Colo.: U. S. Geol. Survey Bull. 340, p. 257-262.

Carnotite deposits at the southern foot of Blue Mountain near Skull Creek, 18 miles east of the Colorado-Utah boundary, occur as crusts and impregnations in sheared and brecciated coarse white sandstone of Jurassic age. The deposits are associated with copper sulfates, vanadates, and carbonates, and contain a copper selenite or selenate mineral. This is the first occurrence of a selenite mineral noted in the United States.

Gavelin, Sven, 1939, Geology and ores of the Malånäs district, Västerbotten, Sweden: Sveriges Geol. Undersökning, Ser. C, no. 424, Årsb. 33, no. 4, p. 124, 134.

Cupriferous pyrite ore of the Eastern Bjurfors ore field contains an average of 0.021 percent selenium. The ore of the Middle Bjurfors field contains 0.002 and 0.012 percent selenium.

——— 1954, A telluride assemblage in the Rudtjebäcken pyrite ore, Västerbotten, N. Sweden: Sveriges Geol. Undersökning, Ser. C, no. 536, Årsb. 48, no. 1, 13 p.

Tellurides of lead, silver, and gold are found in pegmatite associated with a compact pyrite-sphalerite-chalcopyrite ore in the Rudtjebäcken mine, Skellefte district, North Sweden. The telluride-bearing pegmatite contains 0.07 percent tellurium and 0.013 percent selenium.

——— 1955, Sulphide mineralization in the Skellefte district, northern Sweden, and its relation to regional granitization: *Econ. Geology*, v. 50, no. 8, p. 814-831.

Minerals of which selenium forms an essential constituent have been identified from only a few deposits in the Skellefte district. Ödman described 2 sulpho-minerals at Boliden which, because of their significant content of selenium, were called selenocosalite and selenokobellite. In the principal sulfides of the ores highly varying values for selenium are obtained from different samples of the same mineral from the same deposit. In pure sulfide minerals values from less than 0.001 to 0.14 percent selenium were obtained. The succession galena-chalcopyrite-sphalerite-pyrite indicates a decreasing selenium content.

Gellmann, Wilhelm, and Biltz, Wilhelm, 1931, Über die Zusammensetzung vulkanischen Schwefels vom Papandajan (West-Java): Zeitschr. anorg. allg. Chemie, v. 197, p. 422-428.

Two kinds of sulfur are found at Papandajan: (a) yellow pure sulfur which coats the ground around active volcanic craters and contains bright red and orange spots; (b) gray less pure sulfur which occurs around sulfur swamps and contains a metallic material like pyrite. The yellow sulfur contains more selenium than the gray, as well as arsenic, lithium, and thallium.

Gellmann, Wilhelm, and Rose, Herm., 1928, Ein neues Selenerzvorkommen bei St. Andreasberg im Harz: Neues Jahrb. Mineralogie, Geologie u. Palaeontologie Beil.-Band, Abt. A, v. 57, pt. 2, p. 785-816.

Selenium deposits in the "Roter Bär" mine, east of St. Andreasberg, Harz, are described and are compared with other selenium ores in the Harz. The minerals clausenthalite, tiemannite, guanajuatite, zinc selenide, naumannite, umangite, and berzelianite are described and their chemical and physical properties are described.

Genth, F. A., 1855, Contributions to mineralogy; [Pt.] 5—Tetradymite: Am. Jour. Sci., ser. 2, v. 19, p. 15-16.

Two samples of tetradymite were examined. The first was associated with gold and quartz and was believed to come from the White Hall mine, Spotsylvania County, Va. The second sample was broad folia of tetradymite implanted in decomposed micaceous slate from the Tellurium mine, Fluvanna County, Va. Only traces of selenium were found in both samples.

——— 1885, Contributions to mineralogy: Am. Philos. Soc. Proc., v. 23, no. 121, p. 30-35.

Joselite from San Jose, Minas Geraes, Brazil, was found to contain a small amount of selenium. Seleniferous galenobismutite from Falun, Sweden, is described and analyses are given.

——— 1891, Contributions to mineralogy, no. 51: Am. Jour. Sci., ser. 3, v. 41, p. 401-403.

Descriptions and analyses are given of: agullarite from the San Carlos mine, Guanajuato, Mexico; seleniferous bismuthinite probably from Guanajuato, Mexico; and guanajuatite (frenzelite) from Germany.

——— 1892, Contributions to mineralogy, no. 54: Am. Jour. Sci., ser. 3, v. 44, p. 381-383.

Descriptions and analyses of agullarite are given.

Gibson, F. H., and Selvig, W. A., 1944, Rare and uncommon chemical elements in coal: U. S. Bur. Mines Tech. Paper 669, 23 p.

Selenium acts very much like arsenic in some qualitative tests. Selenium has been noted in coal from Liège, Belgium, and in coke from England.

Gilbert, C. S. See Beath and others, 1934a, b, 1935, 1937a, b, 1939a, b, 1940, 1941, 1946; Beath and Gilbert, 1936.

Gile, P. L. See Hough and others, 1941.

Giustiniani, E. See Matteucci and Giustiniani, 1897.

Gmelin's Handbuch der anorganischen Chemie, 1942, Selen: 8th ed., Berlin, Verlag Chemie, System-Nr. 10, teil A, Hef. 1, p. 1-75.

History, uses, compounds, and natural occurrence of selenium are discussed.

Goldschmidt, V. M., 1937, The principles of distribution of chemical elements in minerals and rocks: Chem. Soc. London Jour., 1937, pt. 1, p. 655-673.

One percent of the selenium supplied to sea water is present. The amount of selenium which has potentially been supplied to sea water is so great that a

serious poisoning of the ocean would have been caused if some phenomena of elimination had not been in action. Selenium has been removed from aqueous solutions by adsorption on freshly precipitated hydroxides of iron. Considerable concentrations of selenium are in sedimentary iron ores.

Goldschmidt, V. M., 1954, *Geochemistry*: Oxford, Clarendon Press, p. 532-540.

The average abundance of selenium in magmatic rocks is 0.09 ppm; in meteorites, 7 ppm. Pneumatolytic and high-temperature hydrothermal sulfide ores contain more selenium than medium- and low-temperature sulfide ores. Selenium also is markedly associated with gold and silver deposits of the epithermal range. In the cycle of weathering, very little selenium remains in sea water; most is removed with the hydrolyzate sediments, mainly with organic matter, iron and manganese hydroxides, and iron sulfides. Two parts per million selenium was noted in pyritic lead veins of Gilpin County, Colo.; selenium also noted in ores from Mansfeld, Rammelsburg, Bad Grund, and Upper Silesia, Germany, and from St. Agnes, Cornwall, England.

Goldschmidt, V. M., and Heffer, O., 1933, *Zur Geochemie des Selens*: *Gesell. Wiss. Göttingen Nachr., math.-phys. Kl.*, v. 3, no. 35; v. 4, no. 36, p. 245-252.

The similarity of sulfur and selenium suggests that they may be geologically isomorphous, as they are in certain sulfide minerals. Sulfur of volcanic origin contains perceptible amounts of selenium, but in sedimentary rock formations the sulfur is substantially free from selenium. A study of anhydrite, polyhalite, kainite, and kieserite from sea-water deposits shows that in these sulfates the selenium, in proportion to the sulfur, is 10 to 100 times rarer than in eruptive rocks. The higher oxidation potential required for selenium explains the conversion of sulfur to sulfate ion whereas the selenium remains as selenide or native selenium independent of the fate of sulfur. The selenium is therefore removed from the circulating solutions by the reducing action of rocks and minerals and may be expected to accumulate in coal deposits, a conclusion verified by the occurrence of selenium in Yorkshire anthracite. (*Chem. Abs.*, v. 27, p. 4757.)

Goldschmidt, V. M., and Strock, L. W., 1935, *Zur Geochemie des Selens*, II: *Gesell. Wiss. Göttingen Nachr., math.-phys. Kl.*, v. 4, new ser., v. 1, no. 11, p. 123-142.

The selenium content of primary magmatic sulfides was found to be higher than that of other materials, but the selenium-sulfur ratio was highest in sedimentary iron and manganese oxide ores. Sea water, salt beds, and sedimentary rocks are low in selenium. This is because selenium reaching the ocean is not oxidized to selenate, but is absorbed by precipitating iron and manganese hydroxides. The only salt deposit high in selenium is Chilean caliche, formed under oxidizing conditions sufficiently high to convert selenium to selenate. (*Chem. Abs.*, v. 30, col. 1334.)

Goni, J., and Gullemin, C., 1953, *Données nouvelles sur les sélénites et sélénates naturels*: *Soc. française minéralogie et cristallographie Bull.*, v. 76, p. 422-429.

A brief history of the discovery of natural selenite minerals and descriptions of the occurrence and mineralogy of lead selenate from Pacajake, Bolivia, and Cachenta, Argentina; molybdomenite from Cachenta, Argentina, and Trogtal, Lautertal, Hartz, Germany; and ahlfeldite, an alteration product of penroseite,

from Pacajake, Bolivia. The authors consider the existence of cobaltomenite doubtful. The paragenesis of the secondary minerals in limonite at Pacajake is anglesite, cerussite, selenate of lead, chalcocite, and ahlfeldite.

González Reyna, Jenaro, 1956, *Riqueza minera y yacimientos minerales de México*: 2d ed., Internat. Geol. Cong., 20th, Mexico 1956, Banco de México, S. A., Dept. Inv. Indus., p. 301.

No commercially exploitable deposits of selenium minerals exist in Mexico. Selenium occurs associated with silver minerals or forming part of their composition in silver ores associated genetically with andesitic rocks, and is recovered as a byproduct of silver refining. All recent selenium production has been from the State of Guanajuato.

Gordon, S. G., 1925, Penroseite and trudellite: two new minerals: *Acad. Nat. Sci. Philadelphia Proc.*, v. 77, p. 317-321.

A mineral believed to come from the Colquechaca silver mines, Bolivia, was identified as penroseite, a lead-copper selenide with minor amounts of nickel and cobalt. The mineral contained thin veins of goethite or limonite and a white selenide, believed to be clausthalite, and was found in fissure veins in rhyolite.

Gott, G. B. *See* Christman and others, 1953.

Grasselly, Julius, 1948, Analyses of some bismuth minerals: *Univ. Szeged, Acta Mineralog. Petrog., Sec. Sci. Nat.*, v. 2, p. 24-30.

Analyses of joseite, grünlingite, and cosalite from Rézbánya-Baita, all of which contain small amounts of selenium.

Greaves, J. E. *See* Holt and Greaves, 1941.

Grip, Erland, and Ödman, O. H., 1942, The telluride-bearing andalusite-sericite rocks of Mångfallberget at Boliden, northern Sweden: *Sveriges Geol. Undersökning, Ser. C, no. 447, Årsb. 36, no. 4*, 21 p.

Tellurobismuthite at Mångfallberget contains small quantities of selenium substituting for tellurium. Selenium is much rarer here than at Boliden mine.

Grutt, E. W., Jr., 1956, Uranium deposits in Tertiary sedimentary rocks in Wyoming and northern Colorado, in *Contributions to the geology of uranium and thorium by the United States Geological Survey and Atomic Energy Commission for the United Nations International Conference on Peaceful Uses of Atomic Energy*, Geneva, Switzerland, 1955: U. S. Geol. Survey Prof. Paper 300, p. 361-370.

At the Lucky Mc mine, Gas Hills anticline, Fremont County, Wyoming, in the upper Wind River formation, native selenium has been identified in minute particles, and an unknown selenite or selenate mineral occurs in reddish streaks.

Guillemin, C. *See* Goni and Guillemin, 1953.

Hagner, A. F. *See* Beath and others, 1946.

Halen, S., 1921, *Neue Forschungen betreffend das Selen und seine Verbindungen*: *Edel-Erden u. -Erze*, v. 2, p. 105-107.

Bibliography on the sources, extraction, compounds, and uses of selenium.

Hance, F. E., 1939, Report on chemistry: Hawaiian Sugar Planters' Assoc. Proc., Rept. Comm. in Charge Expt. Sta., v. 59, p. 88-100.

Selenium in excess of 10 ppm was not found in Hawaiian agricultural and grazing soils. With the exception of Ekoa, (*Leucaena glauca*), which possesses the property of accumulating selenium, no samples of Hawaiian vegetation contained more than traces of selenium. A sample of the coral-red exudate from Mauna Loa volcano contained 6000 ppm selenium. (Chem. Abs., v. 34, col. 6005.)

Harand, Josef. See Alber and Harand, 1939.

Harloff, C. S., and Johnson, H. F., 1933, The Nichols Series system of electrolytic copper refining: Am. Inst. Mining Metall. Engineers Trans., v. 106, p. 403.

Typical analyses of blister copper treated at Nichols Copper Co. refinery at Laurel Hill, N. Y., showed the following percentages of selenium-tellurium content: Katanga, 0.0002; Rio Tinto, 0.0065; Pyrite, 0.002; Magma, 0.0135; U. V. X., 0.15; Granby, 0.025; Phelps Dodge, 0.03; Tennessee, 0.025; Ducktown, 0.016; Bor, 0.0007; Noranda, 0.20; Nichols blister, 0.02.

Harris, W. E. See Walker and others, 1941.

Hawkes, H. E., 1957, Principles of geochemical prospecting: U. S. Geol. Survey Bull. 1000-F, p. 228, 229, 291, 299.

The abundance of selenium in igneous rocks is 0.09 ppm; its average abundance in fresh water is 8 ppm, and in the mineral residue of fresh water, 55 ppm. The role of selenium in vegetation and the use of indicator plants in prospecting are described briefly.

Headden, W. P., 1907, Some mattes formed in melting zinc-box precipitates—their composition and what it suggests: Colorado Sci. Soc. Proc., v. 8, p. 349-362.

Two analyses of matte from the Camp Bird mine, Ouray, Colo., representing 10 months milling in 1906-07, contained 0.99 percent and 1.500 percent selenium. Selenium in the Camp Bird ore does not occur in pyrites, as is commonly thought, for the pyrites contain only traces of selenium, but is believed to occur in some other mineral which passes into the slimes. No selenium minerals were noted in the Camp Bird ore. Mattes from Cripple Creek contained no selenium.

Hefter, O. See Goldschmidt and Hefter, 1933.

Heier, Knut, 1953, Clausthalite and selenium-bearing galena in Norway: Norsk geol. tidsskr., v. 32, p. 228-231.

Minerals of the isomorphous series clausthalite-galena from Kongsberg silver mines and from Numedal contained 80, 79, and 93 mol. percent of lead selenide. Selenium-bearing galena containing about 10 molecular percent of lead selenide was found also at Åsland and Åslandåsen, North Vinoren, north of Kongsberg.

Heikes, V. C. See Butler and others, 1920.

Hernandez Ortiz, David. See McAllister and Hernandez Ortiz, 1945.

Hershey, A. L., 1945, Some poisonous plant problems of New Mexico: New Mexico Agr. Expt. Sta. Bull. 322, 23 p.

In New Mexico selenium indicator plants are generally found on Cretaceous soils and alluvial formations. Selenium indicator plants and the area of their occurrence in New Mexico are listed. The report contains maps showing the occurrence of formations of Cretaceous age in New Mexico and locations where plants have been collected which contained more than 10 ppm selenium, and areas where common indicator plants of selenium have been collected.

Herzenberg, Robert, and Ahlfeld, Friedrich, 1935, Blockit, ein neues Seleners aus Bolivien: Zentralbl. Mineralogie, Jahrg. 1935, Abt. A, no. 9, p. 277-279.

Blockite (penroseite) was found at the Hiaco silver mine, Pacajake, 30 km northeast of Colquechaca, Bolivia. The mineral was in a siderite vein in quartzite, associated with pyrite, chalcopyrite, naumannite, and barite. Ahlfeldite, a nickel selenite mineral, occurs as an alteration product of blockite. Blockite, a nickel-copper selenide, with lead and cobalt, and 0.022 percent of platinum metals, was believed by the authors to be a different mineral from penroseite.

Hess, F. L., 1909, Selenium: U. S. Geol. Survey Mineral Resources U. S., 1908, pt. 1, p. 715-717.

Brief review of selenium occurrences and uses.

——— 1913, Antimony, bismuth, and selenium in 1912: U. S. Geol. Survey Mineral Resources U. S., 1912, pt. 1, p. 1045.

Selenium production in 1912 was from anode slimes left in the electrolytic refining of copper.

——— 1914, The production of antimony, arsenic, bismuth, selenium, and tellurium in 1913: U. S. Geol. Survey Mineral Resources U. S., 1913, pt. 1, p. 289.

Selenium occurrence in uranium-vanadium-bearing sandstones is mentioned.

——— 1916, Selenium: U. S. Geol. Survey Mineral Resources U. S., 1914, pt. 1, p. 969-974.

Selenium minerals and their occurrences are described. Selenium recovery from blister copper in the United States and foreign countries is discussed, with particular emphasis on the selenium content of blister copper from Butte, Mont., treated at the Anaconda and Great Falls smelters. Potential sources, uses, and field tests are given.

——— 1917, Field tests for selenium: U. S. Geol. Survey Mineral Resources U. S., 1915, pt. 1, Metals, p. 849.

When heated on charcoal or in a closed tube, selenium gives off a fetid odor like "rotten horseradish", and forms a red coating and a silvery-white coating of selenium dioxide.

——— 1925, New and known minerals from the Utah-Colorado carnotite region: U. S. Geol. Survey Bull. 750-A, p. 63-78.

Traces of selenium were noted in analyses of black vanadium-bearing sandstone from Jo Dandy mine, Paradox Valley, Montrose County, Colo., and in rauvite and metatorbernite from Temple Mountain, Utah.

Hess, F. L., 1933, Uranium, vanadium, radium, gold, silver, and molybdenum sedimentary deposits, in *Ore deposits of the western United States*: New York, Am. Inst. Mining Metall. Engineers, chap. 10, pt. 2, p. 450-481.

Discusses selenium in silver ore at the Silver Reef mine near Leeds, Utah, and in asphaltites in Shinarump conglomerate, and the origin of seleniferous uranium-vanadium deposits on the Colorado Plateau. At Silver Reef, the silver occurs as chloride and sulfide above water level, mostly associated with plant remains and carbonaceous matter in Painted Desert sandstone. Silver was originally deposited as silver sulfide and selenide, and reprecipitated above the water table as cerargyrite and selenide. Copper, uranium, and vanadium are associated with the silver ore.

Heusler, F., and Klinger, H., 1885, Ueber Selenide aus den Anden: *Deutsche chem. Gesell. Ber.*, v. 18, p. 2556-2561.

Gives the compositions of lead-copper selenide minerals from the Andes.

Hewett, D. F., Callaghan, Eugene, Moore, B. N., Nolan, T. B., Rubey, W. W., and Schaller, W. T., 1936, Mineral resources of the region around Boulder Dam: U. S. Geol. Survey Bull. 871, p. 28.

Selenium was reported in relative abundance in pyritic ores of the United Verde mine, Jerome district, Yavapai County, Ariz.

Hey, M. H. *See* Bannister and Hey, 1937.

Heyman, A. M. *See* Christman and others, 1953.

Hill, J. M., 1915, Some mining districts in northeastern California and northwestern Nevada: U. S. Geol. Survey Bull. 594, p. 24, 148-149.

Gold-bearing veins in the High Grade, Winters, and Hayden Hill districts, Calif., and the Aurora and Silver Star districts, Nev., belong to one class of late Tertiary mineral deposits and are characterized by white quartz, adularia, and calcite veins with numerous offshoots into highly altered country rock carrying finely distributed free gold, tetrahedrite, pyrite, chalcocopyrite, and frequently selenium in an unknown compound. In the Aurora district the veins are fine-grained quartz banded by dark streaks of quartz, adularia, argentiferous tetrahedrite, pyrite, chalcocopyrite, free gold, and a soft bluish-gray mineral supposed to be a combination of gold and possibly silver with selenium. The similarity between these veins and the quartz-adularia veins carrying gold and selenium at Tonopah, Nev., and Republic, Wash., is discussed.

Hill, W. L. *See* Rader and Hill, 1935.

Hillebrand, W. F., 1905, Tellurium minerals from Colorado: U. S. Geol. Survey Bull. 262, p. 57.

Specimens of tetradymite from a locality near Whitehorn, Fremont County, Colo., contained approximately 0.20 percent selenium.

Hillebrand, W. F., Merwin, H. E., and Wright, F. E., 1914, Hewettite, metahe-wettite, and pascoite, hydrous calcium vanadates: *Am. Philos. Soc. Proc.*, v. 53, no. 213, p. 31-54.

Two selenium minerals accompany metahe-wettite from the Thompsons district, Utah, and have been noticed at Paradox Valley and Henry Mountains,

Utah: (a) Gray hydrous silicate of aluminum, vanadium, and potassium contains inclusions identified as selenium and bituminous matter; (b) A selenium mineral occurs in amounts up to one percent included as specks in gray silicate. The selenium is probably present as elemental selenium and not as a selenide or oxygenated compound.

Hillebrand, W. F., Lundell, G. E. F., Bright, M. S., and Hoffman, J. I., 1953, *Applied inorganic analysis*: 2d ed., New York, Wiley, p. 327-338.

Chemistry of selenium, attack of selenium minerals, and methods of separation and determination of selenium are described.

Hilmoe, R. J. *See* Searight and others, 1946.

Hoffman, J. I. *See* Hillebrand and others, 1953.

Holmes, R. S. *See* Slater and others, 1937.

Holt, W. L., and Greaves, J. E., 1941, The occurrence of selenium in Utah forage plants: *Soil Sci.*, v. 51, no. 4, p. 299-306.

Small non-toxic amounts of selenium are present in most forage plants in the Trout Creek area and in the Pine Valley and Antelope Valley area; plants in the Cache National Forest Reserve area are almost free of selenium. No apparent relationship was observed between the selenium and sulfur content of forage plants.

Holtz, H. C. *See* Howe and Holtz, 1919.

Hopkinson, F. J. *See* Wernimont and Hopkinson, 1940.

Horn, M. J., 1934, Qualitative method for selenium in organic compounds: *Indus. Eng. Chemistry, Anal. Ed.*, v. 6, p. 34-35.

Describes method of testing for selenium requiring very small amounts of material.

Hough, G. J., Gile, P. L., and Foster, Z. C., 1941, Rock weathering and soil profile development in the Hawaiian Islands: *U. S. Dept. Agriculture Tech. Bull.* 752, 43 p.

Exceedingly young soil profiles contained no selenium. Young soil profiles derived from volcanic ash contained from 0.1 to 0.4 ppm selenium in areas of light rainfall and from 1.5 to 6 ppm selenium in areas of heavy rainfall. Old soil profiles derived from middle aged lava contained 0.4 to 4 ppm selenium in areas of light rainfall and 12 to 14 ppm selenium in areas of heavy rainfall. These are among the highest concentrations of selenium encountered in soils that do not produce seleniferous vegetation. It is presumed that selenium is present in these soils as an insoluble ferric selenite.

Howe, J. L., and Holtz, H. C., 1919, *Bibliography of the metals of the platinum group, platinum, palladium, iridium, rhodium, osmium, ruthenium, 1748-1917*: U. S. Geol. Survey Bull. 694, 558 p.

Contains references on selenium compounds with platinum and the influence of selenium on platinum.

Hukki, R. T., and Runolinna, U., 1950, Separation of precious metals from anode slimes by flotation: Am. Inst. Mining Metall. Engineers Trans., v. 187, p. 1131-1132.

Investigation at Outokumpu, Finland, of methods of separation of gold and silver, believed to be in the form of selenides, by flotation from anode slimes.

Huntting, M. T., 1956, Inventory of Washington minerals, part II, Metallic minerals: Washington Div. Mines and Geology Bull. 37, v. 1, p. 282-283; v. 2 (map), p. 46-47.

The properties, uses, production, prices, ore minerals, and geology and occurrences of selenium are described. Selenium occurs in the Blaine Republic, Flag Hill, Golden Valley, Lamefoot, Republic, and Valley mines, Republic district, Ferry County. Mine locations are shown on a map.

Hurd-Karrer, A. M., 1934, Selenium injury to wheat plants and its inhibition by sulfur: Jour. Agr. Research, v. 49, no. 4, p. 343-357.

Selenium injury to plants can be inhibited by the addition of sulfur, either as sulfate or as elemental sulfur. The amount of sulfur required varies with the toxicity of the soil.

——— 1935a, Factors affecting the absorption of selenium from soils by plants: Jour. Agr. Research, v. 50, no. 5, p. 413-427.

Factors affecting selenium absorption are available sulfur, soil type, amount of sand in the soil, method of adding selenium, form of selenium in soil, and growth of previous crops.

——— 1935b, Selenium absorption by plants and their resulting toxicity to animals: Smithsonian Inst. Ann. Rept., 1935, p. 289-301.

Addition of sulfur as sulfate to seleniferous soils retards absorption of selenium by plants. Because of their chemical similarity, sulfur and selenium may be able to play interchangeable roles in plant chemistry.

Hutton, R. S. See Franke and others, 1936.

Imperial Institute, 1937, The sources, production and uses of selenium and tellurium: Imp. Inst. [London] Bull., v. 35, no. 1, p. 56-67.

Properties, uses, and production of selenium, including methods of extraction from pyrites and copper refinery slimes.

Industrial and Engineering Chemistry, 1916, Seleniferous pyrites in the manufacture of sulfite cellulose: Indus. Eng. Chemistry, Indus. Ed., v. 8, p. 278-279.

Some selenium is contained in all pyrites; the ratio between sulfur and selenium in pyrites varies from 10,000:1 to 100,000:1. A method for quantitative determination of selenium in pyrite is described.

Iron Age, 1952, Selenium: Iron Age, v. 170, no. 14, p. 283-284.

Summary of uses, availability, and sources of selenium.

Ishibashi, Masayoshi, 1953, Minute elements in sea-water: Oceanog. Works Japan Rec., new ser., v. 1, no. 1, p. 88-92.

Marine waters collected at Shirahama, Wakayama Prefecture, Japan, contained 4-6 micrograms per liter of selenium. (Chem Abs., v. 48, col. 6175.)

Ishibashi, Masayoshi, Shigematsu, Tsunenobu, and Nakagawa, Yasuharu, 1953, Determination of selenium in sea water: *Oceanog. Works Japan Rec.*, new ser., v. 1, no. 2, p. 44-48.

Selenium content of Japanese coastal waters ranged from 4 to 6 micrograms per liter. (*Chem. Abs.*, v. 49, col. 2250.)

Jacks, G. V., and Scherbatoff, H., 1940, The minor elements of the soil: *Imp. Bur. Soil Sci. [Harpenden] Tech. Commun.* 39, p. 73-81.

Compilation of data on selenium in soils, including the form of selenium in soil, sulfur-selenium relationships of soils, and relationship of plants to content and form of selenium in soils.

Janes, T. H., 1956, Rare, or less common, metals in Canada: *Canada Dept. Mines and Tech. Surveys Mineral Resources Inf. Circ.*, M. R. 21, p. 9.

Selenium is recovered in Canada by Canadian Copper Refiners Ltd., Montreal East, from copper anodes produced at Noranda and Gaspe smelters of Noranda Mines Ltd. and from blister copper produced at Hudson Bay Mining and Smelting Company at Flin Flon. It is also recovered at Copper Cliff refinery of International Nickel Co. of Canada Ltd. as a black, free-flowing, amorphous powder averaging 99.5 percent selenium.

Japan Geological Survey, 1956, Geology and mineral resources of Japan: p. 182.

Selenium is produced mostly as a byproduct from electrolytic copper refineries, and partly from sulfuric acid factories. In 1953, selenium was produced from 10 refineries including Niihama, Saganoseki, Hitachi, Nikko, and from the Miike sulfuric acid factory. Selenium is contained in minerals such as sulfur, pyrite, chalcopyrite, and other sulfide minerals.

Jenney, W. P., 1913, The chemistry of ore deposition, in Emmons, S. F., *Ore deposits*: New York, Am. Inst. Mining Metall. Engineers, p. 325-326.

A discussion of the association of selenium with silver ores at Silver Reef, Utah, and the origin and enrichment of the ores. Selenium usually occurs with minerals believed to have been formed by highly heated vapors and solutions in direct association with igneous disturbances. Its presence at Silver Reef seems to favor the theory of the deposition of silver through fissures. The silver was deposited originally in the sandstone in combination with selenium and probably sulfur by the reducing action of lignitic matter. The ore bodies were later enriched by secondary precipitation of silver sulfides.

Jensen, C. L., *See Peterson and others, 1957.*

Jimbo, Kotora, 1899, Notes on the minerals of Japan: *Tokyo Imp. Univ., Coll. Sci. Jour.*, v. 11, p. 215.

Selenium-sulfur occurs at Tateyama-Jigoku, Province of Etchu, and on the Island of Iwojima near the Province of Osumi.

Johansson, K., 1924, Ett par selenförande mineral från Falu gruva: *Arkiv kemi*, v. 9, no. 9, 23 p.

Describes wittite and seleniferous chiviatite found at Falun with quartz and magnetite in amphibole rock.

Johnson, H. F. *See Harloff and Johnson, 1933.*

Johnson, L. R. *See Thorvaldson and Johnson, 1940.*

Jorisson, A., 1896, Sur la présence du molybdène, du sélénium, du bismuth, etc., dans le terrain houiller du pays de Liège: Soc. géol. Belgique Annales, v. 23, p. 101-105.

Flue dusts recovered from furnaces burning coal from the Sainte-Marguerite mine and from Beyne, Liege, were analyzed and found to contain selenium.

Jornlin, D. F. See Olson and others, 1942a.

Kaiser, E. P., 1954, Selenium in sulfide ores: Geol. Soc. America Bull., v. 65, p. 1379.

More than 50 samples of sulfide ores and their products were analyzed for selenium. Mill concentrates relatively high in selenium are also high in bismuth, cobalt, tin, and zirconium. Minerals containing selenium are almost never recognized in the deposits. Selenium is relatively more abundant in sulfide deposits of certain areas, one of which is the mountainous region of central Arizona. There is no apparent connection between the concentration of selenium in epigenetic ore deposits and its concentration in sedimentary rocks such as the selenium-bearing shales of Cretaceous age in the Great Plains area. These selenium-bearing shales are widespread and probably received their selenium from Cretaceous volcanic materials. Some recent volcanic materials, especially sulfur, are notably rich in selenium.

Keller, Edward, 1914, American progress in the assay of copper bullion: Am. Inst. Mining Metall. Engineers Trans., v. 46, p. 764-788.

Mentions selenium impurities and how they form. Copper bullion that presumably came from Butte, Montana, carries 0.0072 percent selenium and tellurium.

Keys, W. S., and White, R. L., 1956, Investigation of the Temple Mountain collapse and associated features, San Rafael Swell, Emery County, Utah, in Contributions to the geology of uranium and thorium by the United States Geological Survey and Atomic Energy Commission for the United Nations International Conference on Peaceful Uses of Atomic Energy, Geneva, Switzerland, 1955: U. S. Geol. Survey Prof. Paper 300, p. 285-298.

Selenium is particularly abundant in asphaltic ores in the Moss Back member of the Chinle formation in the Temple Mountain mineral belt. An average uranium to selenium ratio of 950:1 was reported from the Campbird No. 7 ore.

Klason, P., and Mellquist, H., 1912a, Determination of selenium in pyrite: Papier-Zeitung, v. 37, p. 767-768.

The selenium content of pyrites from various sources was determined by the iodometric method. Total selenium varied from 4.01 grams per ton in certain Norwegian ores to 90 grams per ton in Falun ore. Pyrites high in copper and lead contain less selenium than pyrites free of these metals. This is also true of sulfur. Louisiana sulfur is mentioned as almost pure, but the selenium content is not given. (Chem. Abs., v. 6, col. 1660.)

— 1912b, Iodometric methods for the quantitative determination of small amounts of selenium in sulfur and pyrites: Zeitschr. angew. Chemie, v. 25, p. 514-518; Papier-Zeitung, v. 37, p. 374-376, 411-412.

Sulfur from Japan and Sicily tested by iodometric methods contained from 1 to 20 grams per ton selenium. (Chem. Abs., v. 6, col. 1578.)

Klein, A. K., 1941, Report on selenium: *Assoc. Official Agr. Chemists Jour.*, v. 24, no. 2, p. 363-389.

Methods for determining selenium are described.

——— 1942, Report on selenium: *Assoc. Official Agr. Chemists Jour.*, v. 25, no. 2, p. 403-410.

Methods for determining selenium are described.

——— 1943, Report on selenium: *Assoc. Official Agr. Chemists Jour.*, v. 26, no. 2, p. 346-352.

Methods of determining selenium are described.

Kleinhampl, F. J. *See* Cannon and Kleinhampl, 1956.

Klinger, H. *See* Heusler and Klinger, 1885.

Klockmann, F., 1891, *Mineralogische Mittheilungen aus der Sammlungen der Bergakademie zu Clausthal: Zeitschr. Krystallographie u. Mineralogie*, v. 19, p. 265-275.

Describes eucalrite and umangite from Argentina.

Knight, H. G. *See also* Byers and Knight, 1935.

Knight, H. G., 1935, The selenium problem: *Assoc. Official Agr. Chemists Jour.*, v. 18, no. 1, p. 103-108.

Review of research on seleniferous soils and selenium poisoning.

Knight, S. H., 1937, The occurrence of selenium and seleniferous vegetation in Wyoming; Pt. 1—The rocks and soils of Wyoming and their relations to the selenium problem: *Wyoming Agr. Expt. Sta. Bull.* 221, p. 3-27.

Selenium occurs in the following formations in Wyoming: Little Medicine tongue of the Dinwoody (basal Chugwater) and the Phosphoria formations of Permian age; Morrison formation of Jurassic age; Pierre, Steele, Niobrara, Lower Cloverly, Mesaverde, Cody, Hilliard, and Upper Cloverly formations of Cretaceous age; and the Wind River, Chadron, Bridger, Uinta, Fort Union, and Ferris formations of Cenozoic age.

Koch, Sandor, 1948, Bismuth minerals in the Carpathian basin; *Univ. Szeged. Acta Mineralog. Petrog., Sec. Sci. Nat.*, v. 2, p. 1-23.

Tetradymite containing small amounts of selenium occurs in all mineral localities of the Carpathian basin. Cosalite from Rézbánya contains 6.57 percent selenium. Csiklovaite, similar to tetradymite, is described.

Koepfel, W. E., and Schellinger, A. K., 1957, Extraction of some less common metals from smelter and refinery intermediates at La Oroya, Peru, in *Extraction and refining of the rare metals: London, Institution of Mining and Metallurgy*, p. 96-103.

Article contains a brief review of physical and chemical properties and the recovery of selenium from copper smelter products. Blister copper at La Oroya contains 0.03 percent selenium and copper anode slimes contain 1.8-2 percent selenium.

Komkov, A. I. *See* Buryanova and Komkov, 1955; Buryanova and others, 1957.

Kovalev, G. A. *See* Buryanova and others, 1957.

Krauskopf, K. B., 1955, Sedimentary deposits of rare metals: *Econ. Geology, Fiftieth Anniversary Volume, pt. I, p. 411-463.*

Most minor metals are more concentrated in shale than in sandstone or limestone, and for most elements, the amounts in shale are close to the crustal abundance. The abundance of selenium in sedimentary rocks is high, possibly because it is supplied to the sediments by volcanic emanations as well as by erosion. The abundance of selenium in the earth's crust is 0.09 ppm; its average concentration in shale is 0.5 to 1 ppm; in sandstone, 1 ppm; in limestone, 0.1 to 1 ppm; in iron oxide sediments, 0.5 to 5 ppm. Iron oxide forms a positive colloid, and anion-forming elements such as selenium tend to concentrate with it. The concentration of selenium in evaporites is far below the crustal average. Selenium is enriched by a factor of 300 in sedimentary pyrites. Selenium is widely disseminated and concentrated in clastic sedimentary rocks in the Rocky Mountain region, where its presence is attributed to volcanic activity and leaching of the selenium chiefly as soluble selenate. It is also present in sandstones of the Colorado Plateau and is said to show a rough correlation with vanadium.

Krilanovich, N. J., *See* McCullough and others, 1946.

Krusch, P. *See* Beyschlag and others, 1914.

Lakin, H. W. *See also* Byers and others, 1936, 1938; Byers and Lakin, 1939; Lovering and others, 1956; Trites and Lakin, 1956; Williams and Lakin, 1935; Williams and others, 1940, 1941.

——— 1956, A field test for selenium: *Internat. Geol. Cong., 20th, Mexico 1956, Resumenes Trabajos Presentados, p. 366-367.*

A small, simple one-piece still for use in rapid field determination of selenium uses 1 gram of material, concentrated sulfuric acid, hydrobromic acid, and bromine. This method can detect as little as 50 ppm selenium immediately and on standing, as little as 10 ppm selenium.

Lakin, H. W., and Byers, H. G., 1941. Selenium occurrence in certain soils in the United States, with a discussion of related topics; sixth report: *U. S. Dept. Agriculture Tech. Bull. 783, 27 p.*

Cretaceous shales of California were examined and found to contain selenium, but not in large amounts. Data on the selenium content of the sea floor of the Gulf of California and of the Pacific Ocean off southern California are given. Investigations of a mildly seleniferous area in Clark County, Nev., of low selenium content of Permian formations of Oklahoma, and of Cretaceous areas of New Jersey, Maryland, and the District of Columbia, which contain minor amounts of selenium, are described. The soils of the Lower Brule Indian Reservation are derived from Pierre shales and contain 0.2 to 16 ppm selenium. The selenium content of atmospheric dust in cities was studied and found to vary from 0.05 to 10 ppm. The source of selenium is probably the pyritic material in coal. A discussion of the modes of accumulation of selenium is presented.

Lakin, H. W., and Byers, H. G., 1948, Selenium occurrence in certain soils in the United States, with a discussion of related topics; seventh report: U. S. Dept. Agriculture Tech. Bull. 950, 36 p.

The report contains analyses of selenium content of soils, minerals, and vegetation of northeastern North Dakota, and areas of Utah, Nevada, Idaho, and Oregon and analyses of 98 samples of pyrite and sulfide ores. Investigation of soils and vegetation of the Park City region, Utah, shows that mine residue slimes deposit selenium in the soils of the valley along Silver Creek. One sample of ore from Park City contained 540 ppm selenium; the slimes contained an average of 70 ppm selenium.

Lakin, H. W., Williams, K. T., and Byers, H. G., 1938, "Nontoxic" seleniferous soils: *Indus. Eng. Chemistry, Indus. Ed.*, v. 30, p. 599-600.

Vegetation grown on soils in Hawaii and Puerto Rico is not seleniferous. Selenium may be present in soils in three forms which become available to plants only by slow processes of hydrolytic action: (a) free selenium, (b) pyritic selenium, and (c) basic ferric selenite. Soils of Hawaii and Puerto Rico are highly ferruginous, and the selenium in such soils is insoluble and does not produce toxic vegetation.

Landergren, Sture, 1935, *Kännedomen om vara sulfidmalms geokemi*: *Geol. fören. Stockholm Förh.*, v. 57, H. 4, p. 626-636.

Two samples of breccia ores from Saxberg and Garpenberg, Sweden, containing 11 percent zinc and much pyrrhotite, contained less than 1 and 100 ppm selenium, respectively.

Laney, F. B. See Bastin and Laney, 1918; Emmons and Laney, 1926; Piper and Laney, 1926.

Lausen, Carl, 1923, Hydrous sulphates formed under fumarolic conditions at the United Verde mine: *Am. Mineralogist*, v. 13, no. 6, p. 203-229.

Minerals formed as the result of a fire at the United Verde mine, Jerome, Ariz., included a black substance which occurs as a coating on fragments of rock beneath iron hoods placed over vents where sulfur dioxide gas issues. The material was found to be sulfide of arsenic with selenium ($As(S,Se)_2$).

Lenher, Victor, 1923, Occurrence, chemistry, and uses of selenium and tellurium (with discussion): *Am. Inst. Mining Metall. Engineers Trans.*, v. 69, p. 1035-1057; *abs.*, *Mining and Metallurgy*, v. 4, p. 32-33.

Discussion of analytical chemistry of selenium including descriptions of methods for oxidized compounds, precipitation tests, qualitative detection in complex mixtures, quantitative methods, separation of selenium and tellurium, and analytical methods practiced at refineries. Brief paragraphs on occurrence and uses.

Levine, V. E., 1915, Biochemical studies of selenium: *New York Acad. Sci. Annals*, v. 26, p. 385-394.

Describes reduction of selenium compounds such as selenious acid, selenic acid, and sodium selenate, by chemical substances, micro-organisms, plant substances, and animal tissues.

Levine, V. E., 1925, The reducing properties of microorganisms with special reference to selenium compounds: *Jour. Bacteriology*, v. 10, p. 217-262.

In the presence of living bacteria, selenious acid, selenic acid, and sodium selenite were reduced to free red selenium. Sodium selenate was not reduced to free selenium. The reduction of selenium is directly proportional to the rate of growth of the organism.

Lindgren, Waldemar, 1905, The copper deposits of the Clifton-Morenci district, Arizona: U. S. Geol. Survey Prof. Paper 43, p. 39, 106.

There is a very small amount of selenium in the ores; fine dust from the Detroit Copper Company's smelters averaged 0.0125 percent selenium-tellurium; matte averaged 0.013 percent selenium-tellurium.

——— 1909, Comments on selenium: *Science*, v. 30, p. 972.

Gold-quartz veins in Tertiary andesitic rocks and tuffs in the Republic district, Wash., contain concentric crusts of quartz, chalcedony, and opal with dark streaks of antimonial tetrahedrite and chalcopyrite. These are rich in gold and carry one percent of selenium, probably combined with the gold. These rare Tertiary selenide veins are similar to those at Tonopah, Nev.

——— 1915, Geology and mineral deposits of the National mining district, Nevada: U. S. Geol. Survey Bull. 601, p. 32.

Tertiary rhyolite flow at the summit of Buckskin Peak shows hot-spring action with the development of chalcedony and silicified rhyolite, in which were found reddish-brown spots giving a strong reaction for selenium.

——— 1933, Mineral deposits: 4th ed., New York, McGraw-Hill, p. 496-498.

Selenium is present in pyritic copper ores of the Mansfeld district, Germany, in small veins in pre-Cambrian rocks at Falun and Skrikerum, Sweden, and in Paleozoic rocks in the Harz, Germany. It occurs more commonly in epithermal quicksilver, silver-lead, and gold-silver veins. Banded veins of gold and selenides, free from other ore minerals, occur in a fine-grained quartz gangue at Republic, Wash., and Radjang Lebong, Sumatra. The gold is finely distributed and the gold selenide has not been positively identified. The veins have probably been deposited close to the surface as colloids.

Loughlin, G. F. *See* Butler and others, 1920.

Love, J. D., 1954, Preliminary report on uranium in the Gas Hills area, Fremont and Natrona Counties, Wyoming: U. S. Geol. Survey Circ. 352, 11 p.

In the Gas Hills area uranium minerals occur in the Wind River formation of early Eocene age in the Thermopolis shale of early Cretaceous age. The uranium is concentrated in clayey and conglomeratic sandstone and in carbonaceous shale. The source of the uranium may have been tuff in the White River formation or younger Tertiary rocks that once overlaid the area. Uranium was carried downward and laterally along sandstone aquifers and was concentrated in favorable host rocks. Eleven samples were analyzed for selenium, and contained from 2 to 80 ppm. The Lysite area, 30 miles north of Gas Hills, is an area of highly seleniferous tuffaceous strata of middle and late Eocene age. The significant feature of the Lysite occurrence is the large amount of water-soluble selenium.

Lovering, T. S., Lakin, H. W., Ward, F. N., and Canney, F. C., 1956, *The use of geochemical techniques and methods in prospecting for uranium, in Contributions to the geology of uranium and thorium by the United States Geological Survey and Atomic Energy Commission for the United Nations International Conference on Peaceful Uses of Atomic Energy*, Geneva, Switzerland, 1955: U. S. Geol. Survey Prof. Paper 300, p. 659-665.

Describes a method for semiquantitative determination of selenium in soils, rocks, and vegetation containing from 2 to 100 ppm selenium. The method, which is not suitable for field use, is a microchemical adaptation of the distillation procedure of Hillebrand and others, combined with Franke's confined spot method of estimation.

Lundell, G. E. F. *See* Hillebrand and others, 1953.

McAllister, J. F., and Hernandez Ortiz, David, 1945, Quicksilver-antimony deposits of Huitzuco, Guerrero, Mexico: U. S. Geol. Survey Bull. 946-B, p. 63.

Tiemannite, onofrite, and other rare selenides of mercury, antimony, and thallium are reported in the Huitzuco ore.

McCaskey, H. D., 1912, Quicksilver: U. S. Geol. Survey Mineral Resources U. S., 1911, pt. 1, p. 914-915.

The Lucky Boy quicksilver mine, 5 miles southwest of Marysville, Piute County, Utah, lies on a steep fault scarp on the east side of the Tushar Range. The commercial ore was mainly onofrite and tiemannite, the sulfo-selenide and selenide of mercury, which occurred in a deposit from 2 to 8 inches thick, following the bedding planes and impregnating impure dark gray limestone. Tiemannite also was present in a vein carrying barite and cinnabar.

McCreary, O. C. *See* Beath and others, 1934a.

McCrosky, C. R. *See* Coleman, W. C., and McCrosky, 1937.

McCullough, J. D., Campbell, T. W., and Krilanovich, N. J., 1946, Analysis of organoselenium compounds: *Indus. Eng. Chemistry, Anal. Ed.*, v. 18, p. 638-639.

Description of method for determining selenium content of organic compounds.

Machatschki, F., and Stradner, E., 1952, Ein Selenid-Mineral vom Spinneltyp: *Österreich. Akad. Wiss., math.-nat. Kl.*, v. 89, p. 211-214.

Crystallographic study of cobalt selenide minerals and selenides of the spinel group.

McNulty, J. S., 1947, Routine method of determining selenium in horticultural materials: *Indus. Eng. Chemistry, Anal. Ed.*, v. 19, p. 809-810.

Description of a method for determining selenium content of organic matter.

Mallet, J. W., 1878, On the chemical composition of guanajuatite, or selenide of bismuth, from Guanajuato, Mexico: *Am. Jour. Sci.*, ser. 3, v. 15, p. 294-296.

Analysis of the mineral guanajuatite gives the formula Bi_2Se_3 , with varying amounts of sulfur replacing selenium.

Margrave, J. L. *See* Elkin and Margrave, 1954.

Marvin, G. G., and Schumb, W. C., 1935, The determination of small quantities of selenium in sulfur: *Indus. Eng. Chemistry, Anal. Ed.*, v. 7, p. 423-425.

Description of a method for determining amounts of selenium ranging from 0.1 to 0.001 percent in sulfur. Commercial sulfur from Texas, crude Louisiana sulfur, and crystal sulfur from Garginti, Italy, contained no selenium; Sicilian selenosulfur of volcanic origin contained 0.054 percent selenium.

Mason, Brian, 1952, *Principles of geochemistry*: New York, Wiley, p. 41, 154, 167, 172, 173, 197, 200.

A review of the cycle of selenium in sea water and its removal by adsorption on freshly precipitated ferric hydroxide, which is shown by the presence of selenium in larger amounts in sedimentary iron ores than its average abundance in the earth's crust. The total amount of selenium supplied to sea water is 0.054 ppm; the amount present is 0.004 ppm. The ability of certain plants to absorb large amounts of selenium is mentioned.

Mathews, J. A., Curl, A. L., and Osborn, R. A., 1937, Report on selenium: *Assoc. Official Agr. Chemists Jour.*, v. 20, no. 2, p. 194-202.

Description of procedures of sample preparation, isolation of selenium, and methods of determining selenium.

Matteucci, R. V., and Giustiniani, E., 1897, Il selenio nei prodotti delle fumarole dell'eruzione Vesuviana del 3 luglio 1895: *Reale Accad. sci. fis. e mat. Napoli, Rend. ser. 3a*, v. 3, p. 100-101.

Analysis of the products of a fumarole on the northwest flank of Vesuvius which erupted on July 3, 1895. In addition to the elements usually found, there were fluorine, phosphorous, boron, and red incrustations of selenium.

Mellor, J. W., 1930, *A comprehensive treatise on inorganic and theoretical chemistry*: London, Longmans, Green and Co., v. 10, p. 693-932.

A treatise on the history, occurrence, extraction and purification, allotropic forms, physical and chemical properties, and compounds of selenium.

Mellquist, H. See Klason and Mellquist, 1912a, b.

Merwin, H. E. See Hillebrand and others, 1914.

Meyer, Julius, and Bratke, Herbert, 1924, Zur Kenntnis der Doppelselenide. 1. Die natürlich vorkommenden Doppelselenide: *Zeitschr. anorg. allg. Chemie*, v. 135, no. 3, p. 289-296.

Analyses are given for umangite, eucairite, zorgite, lehrbachite, and crookesite.

Miesch, A. T., and Connor, J. J., 1956, Distribution of elements, in *Geologic investigations of radioactive deposits—Semiannual progress report*, Dec. 1, 1955, to May 31, 1956: U. S. Geol. Survey TEI-620, issued by U. S. Atomic Energy Comm., Tech. Inf. Service, Oak Ridge, Tenn., p. 128-146.

Report on investigation of the distribution of minor elements in the Salt Wash sandstone member of the Morrison formation to determine which are most useful in tracing patterns of metal dispersion around uranium deposits. Samples were collected in and near the Blitz and Joe Dandy mines in the Henry Mountains mining district, Utah. Most of the samples taken more than a few feet away from the uranium deposits contain less than 1 ppm selenium. Thus, the presence or absence of selenium in rock samples is not a useful guide to uranium ore.

Miller, J. T. *See also* Byers and other, 1938.

———, 1937, Selenium in plants in relation to its occurrence in soils: *Jour. Agr. Research*, v. 55, p. 59-68.

Plants are classified into three types in relation to their tolerance of selenium in the soil: (a) those that absorb selenium readily; (b) that are able to absorb moderate or large amounts of selenium without severe injury; and (c) that have very limited tolerance of selenium and absorb only small quantities.

Miller, J. T., and Brown, I. C., 1938, Observations regarding soils of northern and central Mexico: *Soil Sci.*, v. 46, p. 427-450.

Analyses of soils in northern and central Mexico indicate the presence of selenium only in the Irapuato, Guanajuato, soils, chiefly in the upper 10 inches. Selenium is derived from mine slimes which wash down into the valley. The selenium content averaged from 0.01 ppm at a depth of 144 inches to 1.5 ppm at from 0 to 10 inches.

Miller, J. T., and Byers, H. G., 1935, A selenium spring: *Indus. Eng. Chemistry, News Ed.*, v. 13, p. 456.

Water from a temporary spring in the Niobrara formation in T. 6 S., R. 7 E., Custer County, S. Dak., and soil and vegetation in the neighborhood were analyzed for selenium. The water contained 0.4 ppm selenium, the soil contained 1.5 to 4.0 ppm selenium, the vegetation contained as high as 1600 ppm selenium. Water from another spring in T. 36 N., R. 47 W., contained 0.07 ppm selenium.

Milligan, W. E., 1953, Selenium and tellurium, in *Modern uses of nonferrous metals*: 2d ed., Am. Inst. Mining Metall. Engineers, p. 333-365.

Describes isotopes, occurrence, properties, toxic effects, extraction, economics, and uses of selenium.

Minami, E., 1935, Selen-Gehalte von europäischen und japanischen Tonschiefern: *Gesell. Wiss. Göttingen Nachr., math.-phys. Kl.*, v. 4, new ser., v. 1, no. 12, p. 143-145.

Selenium content of European Paleozoic and Japanese Mesozoic clay shales was determined by the method of Goldschmidt and Strock. The selenium contents varied somewhat, but the atomic ratio of sulfur to selenium was approximately 10,000:1 for all three. (*Chem. Abs.*, v. 30, col. 1335.)

Mining Journal, 1953, Selenium—a scarce by-product metal: *Mining Jour.* [London], v. 241, no. 6185, p. 241-242.

Describes occurrence, uses, recovery processes, and supplies of selenium.

Moore, B. N. *See* Hewett and others, 1936.

Moore, R. T., 1953, Minerals and metals of increasing interest. Rare and radioactive minerals: *Arizona Bur. Mines Bull.* 163, p. 17-19.

A review of the general features, minerals, and occurrence of selenium. At Jerome, Yavapai County, Ariz., crystals of selenium nearly 1 inch long have been found in the fire zone of the United Verde mine. Soils in the vicinity of Camp Verde and also in the upper Tonto Valley are known to contain selenium, but percentages present are not available.

Mosher, M. A., 1933, Recovery of precious and secondary metals from electrolytic copper refining: *Am. Inst. Mining Metall. Engineers Trans.*, v. 106, p. 427-440.

Raw electrolytic lime at Raritan Copper Works, Perth Amboy, N. J., contains 5.31 percent selenium. Selenium recovery plant is capable of producing 3,000 pounds of powdered selenium per month.

Moxon, A. L. *See also* Olson and Moxon, 1939; Olson and others, 1940, 1942a, b; Searight and Moxon, 1945; Searight and others, 1946, 1946-47.

—1937, Alkali disease or selenium poisoning: *South Dakota Agr. Expt. Sta. Bull.* 311, 91 p.

Geological and geographical distribution of selenium in South Dakota and the United States, factors affecting selenium content of soils and plants, and methods of analysis are described. The source of the selenium is believed to be volcanoes of the Cordilleran Geanticline active during the Mesozoic era. Selenium may have been a constituent of the magmas or it may have been conveyed by winds with gases and ash and deposited with sedimentary materials in the Mesozoic seas which covered the Great Plains. In support of this hypothesis is the fact that zones high in selenium also contain bentonite which is presumed to be derived from volcanic ash. In South Dakota, the Pierre and Niobrara formations are the most seleniferous and the soils derived from these formations are heavy clay or gumbo soils. Map and table show distribution and selenium content of Cretaceous formations of South Dakota.

Moxon, A. L., and Rhian, Morris, 1943, Selenium poisoning: *Physiol. Rev.*, v. 23, no. 4, p. 305-337.

Review of literature on the geological distribution of selenium in the Cretaceous formations of Western United States, selenium content of soils, absorption of selenium by plants, and selenium poisoning in animals.

Moxon, A. L., Olson, O. E., and Searight, W. V., 1939, Selenium in rocks, soils and plants: *South Dakota Agr. Expt. Sta. Tech. Bull.* 2, 94 p.

Analyses of seleniferous formations in South Dakota are given. The Niobrara formation is the most consistently highly seleniferous formation. The Sharon Springs member, the upper part of the Virgin Creek member, and the Interior (Mobridge) member of the Pierre formation are also highly seleniferous. Factors determining surface distribution of selenium are width of outcrop, creeping of beds, alluvial deposition, leaching, and secondary deposition. During the formation of soils from bedrock there is considerable loss of selenium by leaching, surface runoff, mixing of parent materials, and topography as it affects surface runoff. Factors determining the availability of selenium to plants are the kind of plants present and their stage of growth, chemical form of the selenium, total selenium content of the soil, climate, and others. Selenium contents of grasses and converter plants in South Dakota are compared. In general, the selenium content of formations determines the type of plants and the selenium content of the plants. A hypothetical selenium cycle is presented.

Moxon, A. L., Olson, O. E., Searight, W. V., and Sandals, K. M., 1938, The stratigraphic distribution of selenium in the Cretaceous formations of South Dakota and the selenium content of some associated vegetation: *Am. Jour. Botany*, v. 25, no. 10, p. 794-809.

Selenium occurs in all Cretaceous formations in South Dakota from the Dakota sandstone through the Pierre formation. Selenium content is low

in the Dakota, Graneros, Greenhorn, and Carlile formations, the Fort Hays member of the Niobrara formation, and the Sully and Virgin Creek members of the Pierre formation; high in the Smoky Hill member of the Niobrara formation and the Sharon Springs member of the Pierre formation; and locally high in thin parts of the Mobridge member of the Pierre formation. There is a close relationship between formation, type of vegetation, and selenium content of vegetation.

Muñoz Reyes, Jorge. *See* Ahlfeld and Muñoz Reyes, 1938, 1939, 1955.

Murdoch, Joseph, and Webb, R. W., 1956, Minerals of California: California Div. Mines Bull. 173, p. 150, 239, 327.

Localities where selenium minerals have been found in California are described. These include naumannite from the Idaho-Maryland mine, Grass Valley, Nevada County; tiemannite from Clear Lake and Abbott mine, Lake County, Helen mine and San Joaquin Ranch mine, Orange County, Guadalupe mine, Santa Clara County, and Socrates mine, Sonoma County; eucairite at Willard Mining Company property, Murphys district, Calaveras County.

Murray, R. M., 1933, Electrolytic copper refining at Mount Lyell, Tasmania: Am. Inst. Mining Metall. Engineers Trans., v. 106, p. 415.

Analyses of tank house materials in 1932 gave 0.031 percent selenium in anodes, 2.83 percent selenium in slimes.

Muthmann, Wilhelm, 1890, Untersuchungen über den Schwefel und das Selen: Zeitschr. Krystallographie u. Mineralogie, v. 17, p. 336-367.

Crystallographic forms of selenium, mixed sulfur-selenium crystals, and metallic selenium are described.

Nakagawa, Yasuharu. *See* Ishibashi and others, 1953.

Newberry, J. S., 1881, The Silver Reef sandstones: Eng. Mining Jour., v. 31, p. 4-5.

Four analyses of ore from Silver Reef, Utah, gave an average of 0.23 percent selenium and 0.26 percent silver. In one specimen the selenium content was 90 ounces per ton.

Noddack, Ida, 1936, Über die Allgegenwart der chemischen Elemente: Angew. Chemie, v. 49, p. 835-841.

A theory that all minerals contain minute amounts of all chemical elements is presented. Mansfeld copper shale contained 0.03 percent selenium and sphalerite from Silesia contained 0.04 percent selenium.

Nolan, T. B. *See* Hewett and others, 1936.

Nordenskiöld, A. E., 1867a, Die Selenmineralien von Skrikerum: Jour. prakt. Chemie, v. 102, p. 456-458.

The minerals eucairite, berzelianite, and crookesite from the copper mine at Skrikerum are described. The thallium content of the minerals is discussed. Eucairite and berzelianite contain very little thallium, while crookesite contains about 16 percent thallium.

Nordenskiöld, A. E., 1867b, Sur les minéraux sélénifères et thallifères de Skrikerum : Soc. chim. France Bull., ser. 2, v. 7, p. 409-414.

First selenium minerals found at Skrikerum copper mine were eucairite and berzelianite. Crookesite was found later by the author.

Nordström, Th., 1879, Mineralanalytiska bedrag; 2—Selenhaltigt mineral från Falun : Geol. fören. Stockholm Förh., v. 4, p. 268.

Description of a bismuth lead selenide mineral found at Falun, Sweden.

——— 1880, Mineralanalytische Beiträge—Selenmineral von Falun: Zeitschr. Krystallographie u. Mineralogie, v. 4, p. 526.

Selenium minerals from Falun, Sweden, are described.

O'Connor, R. See Walsh and others, 1951.

Ödman, O. H. See also Grip and Ödman, 1942.

——— 1938, On the mineral associations of the Boliden ore: Stockholms Högskolas mineralog. inst. Medd., v. 60, no. 2, no. 98, p. 121-146.

A general description of the ore and minerals of the Boliden mine. Selenium is found in varying but small amounts; a number of minerals including selenides are as yet unidentified by the author.

——— 1941, Geology and ores of the Boliden deposit, Sweden: Sveriges Geol. Undersökning, Ser. C, no. 438, Årsb. 35, no. 1, 190 p.

A lead-bismuth-sulfo-selenide mineral occurs in large quantities intergrown with galena in the quartz-tourmaline ore at Boliden. It is called selenocosalite. A mineral similar to kobellite but containing large amounts of selenium also occurs in the quartz-tourmaline veins; it is called selenokobellite.

Olivares S., F. E., and Girón B., I. N., 1956, Recuperación de metales raros en la fundición de la Oroya: Minería [Peru], v. 5, no. 16, p. 2-11.

Selenium recovery at La Oroya smelter of Cerro de Pasco Corp., Peru, is described. Eighty percent of the selenium entering the smelter is in lead concentrates and the remainder is in copper concentrates. The Casapalca mine produces 90 percent of the lead concentrates, which contain 0.09 percent selenium; the copper concentrates come from the Cerro, Yauricocha, and Morococha mines and contain 0.01 percent selenium. A large part of the selenium which enters the smelter in lead concentrates emerges in the residue of the electrolytic refining of copper. The metallurgy of selenium is described and flow sheets showing the recovery of selenium at La Oroya are pictured.

Olsacher, Juan, 1927, Über ein neues Vorkommen von Umangit: Zentralbl. Mineralogie, Jahrg. 1927, Abt. A, no. 5, p. 170-172.

Zorgite from Zorge, Germany, was found to consist of umangite, clausenthalite, and an unknown green mineral; zorgite from Tilkerode, Germany, consisted of umangite and clausenthalite only. "Selenquecksilberkupferblei" from Zorge was found to be composed of clausenthalite, umangite, and tiemannite.

Olson, O. E. See also Moxon and others, 1938, 1939.

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Olson, O. E., and Moxon, A. L., 1939, The availability to crop plants of different forms of selenium in the soil: *Soil Sci.*, v. 47, p. 305-311.

Most of the seleniferous soils in South Dakota are derived from the Pierre formation. The availability of selenium to plants depends on the amount of water soluble selenium, which in turn depends on the amount of selenium in the organic fraction of the soil.

Olson, O. E., Jorndin, D. F., and Moxon, A. L., 1942a, Field studies on methods for determining availability of selenium to plants: *Soil Sci.*, v. 53, no. 5, p. 365-368.

In field studies on naturally seleniferous soils it has been found that no correlation exists between selenium content of *Astragalus* and the total, water-soluble, or base-soluble selenium content of the first foot of soil. Soils in which the leaching of selenium is apparently greater seem to produce plants with a higher selenium content, and it appears that much selenium is absorbed from the subsurface soils.

Olson, O. E., Sisson, L. L., and Moxon, A. L., 1940, Absorption of selenium and arsenic by plants from soils under natural conditions: *Soil Sci.*, v. 50, no. 2, p. 115-118.

No correlation between selenium and arsenic content of soils in South Dakota was noted. Arsenic content of the soils studied was greater than selenium content, but plants grown in the soils contained more selenium. Selenium was present in a more available form than arsenic.

Olson, O. E., Whitehead, E. I., and Moxon, A. L., 1942b, Occurrence of soluble selenium in soils and its availability to plants: *Soil Sci.*, v. 54, no. 1, p. 47-53.

Analyses of plants and soils from T. 107 N., R. 78 W., South Dakota, indicate that soil at 2 or 3 feet in depth, rather than the top 1 foot, is the source of "available" selenium to plants. During weathering of rock to soil, a large part of the selenium is oxidized to the soluble selenate form and is leached from the surface to the subsurface soils, or to soils at lower elevations.

Osborn, R. A. *See* Curl and Osborn, 1938; Mathews and others, 1937.

Otto, Robert, 1890, Eucairit aus Argentinien: *Deutsche chem. Gesell. Ber.*, v. 23, p. 1039-1041.

Eucairite from La Rioja, Argentina, is described with analyses.

Painter, E. P. *See also* Franke and Painter, 1937.

——— 1941, The chemistry and toxicity of selenium compounds, with special reference to the selenium problem: *Chem. Rev. [Baltimore]*, v. 28, p. 179-213.

Review of the forms of selenium in soil and plants, and selenium content of soils and plants. Discusses organic compounds, methods of analysis, and properties of selenium in plants.

Palache, Charles, 1934, Contributions to crystallography: Claudetite; minasragrite; samsonite; native selenium; indium: *Am. Mineralogist*, v. 19, p. 208.

Needles of native selenium were found as incrustations on quartzite and fire-fritted sandstone in the fire-zone of the United Verde mine, Jerome, Ariz. The crystals reach a length of 2 cm and a diameter of 1 mm.

Palache, Charles, 1937, Chalcomenite from Bolivia: *Am. Mineralogist*, v. 22, no. 6, p. 790-795.

A crystallographic study of chalcomenite, hydrous selenite of copper, from the Hlaco lead-silver mine, near Colquechaca, Bolivia. Chalcomenite occurs in cavities lined with limonite together with blockite (penroseite), cobaltomenite (ahlfeldite), and needles of selenolite at the Hlaco mine.

Palache, Charles, Berman, Harry, and Frondel, Clifford, 1944, The system of mineralogy of James Dwight Dana and Edward Salisbury Dana: 7th ed., New York, John Wiley and Sons, v. 1, p. 136-137, 142, 161-167, 178-180, 182-184, 194-195, 204-205, 215-218, 251, 278-279, 294-296, 451, 473-475, 595; v. 2, p. 635, 638-641.

Describes mineralogy and occurrence of selenium, selentellurium, seleniferous sulfur, tetradymite, gruenlingite, joseite, agullarite, naumannite, berzelianite, eucairite, umangite, clausthalite, tilkerodite, zorgite, metacinnabar, guadalcazarite, onofrite, tiemannite, lehrbachite, klockmannite, guanajuatite, penroseite, blockite, wittite, webullite, seleniferous galenobismutite, platynite, chiviatite, ahlfeldite, chalcomenite, cobaltomenite, kerstenite, molybdomenite, and selenolite.

Peacock, M. A., 1941, On joseite, grünlingite, orueteite: *Univ. Toronto Studies, Geol. Ser.*, no. 46, p. 83-103.

Joseite from British Columbia and other areas does not contain selenium, while joseite from San José, Minas Geraes, Brazil, contains from 1.46 to 1.48 percent selenium. Selenium is found in these specimens to substitute for tellurium in a general formula.

Peacock, M. A., and Berry, L. G., 1940, Röntgenographic observations on ore minerals: *Univ. Toronto Studies, Geol. Ser.*, no. 44, p. 47-69.

Guanajuatite from Guanajuato, Mexico, gave X-ray pattern similar to those of bismuthinite and stibnite and very different from that of artificial Bi₂Se₃. Webullite, seleniferous galenobismutite, and seleniferous chiviatite from Falun, Sweden, give varying proportions of lead, bismuth, selenium, and sulfur, with copper and iron. These minerals are shown by polished sections and X-ray powder photographs to be essentially alike, being intimate intergrowths of two undetermined white metallic minerals, with associated chalcopryite.

Penfield, S. L., 1885, Crystallized tiemannite and metacinnabarite: *Am. Jour. Sci.*, ser. 3, v. 29, no. 174, p. 449-454.

Presents crystallographic measurements and chemical analyses of tiemannite from Marysvale, Utah. The mine from which the tiemannite was taken is described by J. E. Clayton as being situated on the east face of a mountain slope and near a profound fault extending north and south. To the east are eruptive rocks including porphyry and trachyte. Underlying the ore beds to the west is quartzite overlaid by 400 feet of gray limestone. The Deertrail vein, carrying gold, silver, lead, and a little copper, is situated at the contact between the quartzite and limestone. In the upper part of the limestone the selenide of mercury is found in a bed of shaly limestone from 15 to 20 feet thick. The vein has been traced north and south about 100 feet along the outcrop and dips into the mountain at an angle of 15°. The ore occurs in masses intermixed with shaly limestone, crystals being very rare. The accompanying minerals are barite, oxide of manganese, quartz, and calcite. The relationship between selenides and sulfides of mercury is discussed.

Petersen, Theodor, 1872, Guadalcasarit, ein neues Mineral (Schwefel-Selen-Zink-Quecksilbererz: Mineralog. Mitt., Jahrg. 1872, no. 2, p. 69-70.

Description of guadalcasarite from Guadalcasar, Mexico, associated with cinnabar in a quartz and barite gangue.

Peterson, H. E. *See also* Sill and Peterson, 1954.

Peterson, H. E., Jensen, C. L., and Anderson, R. G., 1957, A field test for selenium: U. S. Bur. Mines Rept. Inv. 5328, 7 p.

Two methods for qualitative detection of selenium in rocks and soils are described. Both methods are sensitive to 10 ppm selenium and can be made semiquantitative by using suitable standard samples. Fusion with potassium pyrosulfate and a reducing agent can be used if the sample does not contain sulfur or carbonaceous material which, if not oxidized, interfere with the detection of selenium. Caustic fusion with sodium peroxide and sodium hydroxide before fusion with potassium pyrosulfate insures complete oxidation of the sample if sulfur or carbonaceous material are abundant.

Pillipenko, P. P., 1910, Selenium in Altai minerals: Acad. sci. St. Pétersbourg Bull. 1909, p. 1113-1115.

Two specimens of galena contained 1.17 and 1.23 percent selenium, and a specimen of antimony-copper sulfide contained 0.13 percent selenium. (Chem. Abs., v. 4, p. 2787.)

Piper, A. M., and Laney, F. B., 1926, Geology and metalliferous resources of the region about Silver City, Idaho: Idaho Bur. Mines and Geology Bull 11, 165 p.

The silver deposits of the Silver City district are quartz-filled fissure veins and breccia veins. Naumannite and argentite, as they occur in the Silver City district, have identically the same physical properties. It is probable that of the two, naumannite was and is by far the more abundant. Much of the mineral previously called argentite was in reality naumannite. Naumannite is a late hypogene mineral, and may be supergene in some cases. It occurs in the De Lamar, Trade Dollar, Alpine, Banner, and Poorman veins. Clausthalite was found as a minor accessory mineral in the Trade Dollar vein.

Pisani, F., 1879, Sur divers séléniures de plomb et de cuivre de la Cordillère des Andes: Acad. sci. [Paris] Comptes rendus, v. 88, p. 391-392.

Lead-copper selenides found as accessory minerals in an unidentified lead mine of Peru were analyzed. The selenides were of two distinct types and were associated with azurite, malachite, and chrysocolla. Analyses showed selenides corresponding to the formulas (Pb, Cu) Se and (Cu,Pb)₂Se₂ with traces of cobalt, iron and silver.

Powell, A. R. *See* Schoeller and Powell, 1920.

Prichard, G. E. *See* Vine and Prichard, 1954.

Pugsley, C. W., and Cox, T. H., 1937, Selenium problems in South Dakota: Brookings, South Dakota State Planning Board, 30 p.

Properties, occurrence, and distribution of selenium in South Dakota; effects of rainfall on selenium content of soils, poison springs; and selenium convertor plants are discussed. Analyses of soil samples for selenium content show that soils formed from rocks of the Pierre and Niobrara formations are the most

seleniferous. Report also contains results of investigation of selenium in the Fort Randall area and a map showing toxic areas of South Dakota.

Quercigh, Emanuele, 1925, Sul solfoselenio di Vulcano (Isole Eolie): Reale Accad. sci. fis. e mat. Napoli, Rend., v. 31, p. 65-69.

Selensulfur occurs as thin adherent layers in strongly altered siliceous rock. It is amorphous, vitreous, of a brownish-red color, with a conchoidal fracture and reddish streak. The mineral contains traces of arsenic and tellurium. Selensulfur also occurs in an opaque orange-yellow crystal phase which is probably derived from the amorphous phase. Analyses of the soluble portion gave 98.71 percent sulfur, 1.03 percent selenium, 0.18 percent tellurium; and 99.06 percent sulfur, 0.83 percent selenium, and no tellurium. Caution is necessary not to confuse real selensulfur with other products of fumarole activity around Vulcano which have a similar appearance, but which consist mostly of sulfur and arsenic with subordinate amounts of selenium and tellurium. (Chem. Abs., v. 20, p. 2804.)

Rader, L. F., Jr., and Hill, W. L., 1935, Occurrence of selenium in natural phosphates, superphosphates, and phosphoric acid: Jour. Agr. Research, v. 51, no. 12, p. 1071-1083.

Selenium occurs in quantities from less than 0.1 ppm in Tennessee brown phosphate rock to 55 ppm in Wyoming and Algerian phosphates. Phosphate rock from Florida, Tennessee (except Tennessee blue rock), Kentucky, Arkansas, Oklahoma, Australia; light-colored phosphates from Western United States; and apatites from Virginia and Canada contained 1 ppm or less of selenium. Dark-colored phosphates from Western United States and Canada, the majority of Tennessee blue rock and South Carolina phosphates, and Africa and Palestine phosphates contained from 1 to 55 ppm selenium. Larger amounts of selenium occur in pyritiferous phosphates and in phosphates containing greater amounts of organic material. Primary phosphate deposits contain about 5 times as much selenium as secondary phosphate deposits. Permian deposits contain the largest amount of selenium, followed by Miocene, Cretaceous, Jurassic, Eocene, Devonian, and post-Tertiary deposits. Only a small amount of the selenium in raw phosphate rock finds its way into superphosphates and phosphoric acid.

Ramdohr, Paul, 1928, Klockmannit, ein neues natürliches kupferselenid: Zentralbl. Mineralogie, Jahrg. 1928, Abt. A, no. 7, p. 225-232.

Describes analyses of klockmannite from Sierra de Umango, Argentina; Lehrbach, Harz Mountains, Germany; and Skrikerum, Sweden.

——— 1937, Erzmikroskopische Untersuchungen an einigen seltenen oder bisher wenig beachteten Erzmineralen: Zentralbl. Mineralogie, Jahrg. 1937, Abt. A, no. 10, p. 289-293.

Crystallographic description of villamaninite from the Carmenes mine, near Villamanin, Léon, Spain.

——— 1948, Les especes mineralogicas guanajuatite y paraguajuatite: México Com. Directivo Inv. Recursos Minerales Bol. 20, p. 1-15.

Discussion of mineralogy and occurrence at Guanajuato of guanajuatite and paraguajuatite.

Ramdohr, Paul, 1949, *Neue Erzminerale*: Fortschr. Mineralogie, v. 28, p. 69-70. Eskebornite from Tilkerode, Harz Mountains, Germany, is described.

— 1956, Stilleite, ein neues Mineral, natürliches Zinkselenid, von Shinkolobwe, in Lotze, Franz, Geotektonisches Symposium zu Ehren von Hans Stille: Stuttgart, F. Enke, p. 481-483.

A new zinc selenide mineral, stilleite, was found in an ore sample from Shinkolobwe, Belgian Congo, associated with pyrite, linnelite, clausthalite, two unidentified minerals, and dolomite. The mineral is cubic, of the sphalerite type, isotropic, and the color resembles that of tetrahedrite.

Ramdohr, Paul, and Schmitt, Marg., 1955, Vier neue natürliche Kobaltselenide vom Steinbruch Trogtal bei Lautenthal im Harz: Neues Jahrb. Mineralogie, Monatsh., Jahrg. 1955, no. 6, p. 133-142.

Four new cobalt selenide minerals occur in violet to red-brown intergrowths in clausthalite; hematite and secondary native selenium are also present. The minerals are trogtalite (CoSe_2), hastite (CoSe_2 or CoAsSe), bornhardtite (Co_2Se_3), and an unnamed mineral too scarce to study.

Rankama, Kalervo, and Sahama, Th. G., 1949, *Geochemistry*: Chicago, University of Chicago Press, p. 743-755.

Selenium is chalcophile and is enriched in sulfide ore bodies. It forms selenides and sulfoselenides of silver, copper, bismuth, mercury, and lead in hydrothermal rocks; selenites of copper, cobalt, and lead; selenates; and also occurs as native selenium, selen-tellurium, as the oxide, and with volcanic sulfur. Selenium is absorbed in plants, animals, bacteria, and coal. Cycle of selenium: it is removed from sea water with depositing oxidate sediments which are able to adsorb selenium nearly quantitatively from aqueous solutions. During the weathering of seleniferous sulfide deposits selenium is oxidized to selenite; in sediments where the redox potential is very high selenium is oxidized to selenate. Both selenates and selenites are readily reduced to selenium and various selenides.

Rhian, Morris. See Moxon and Rhian, 1943.

Roach, Carl. See Thompson, M. E., and others, 1956.

Roberts, R. J., 1940, Quicksilver deposit at Buckskin Peak, National mining district, Humboldt County, Nev.: U. S. Geol. Survey Bull. 922-E, p. 127.

Selenium is found in small reddish-brown spots in cinnabar-bearing siliceous sinter deposited by hot springs.

Robinson, S. C., 1950, Mineralogy of the Goldfields district, Saskatchewan: Canada Geol. Survey Paper 50-16, 38 p.

Selenium minerals are found in the uranium deposits of the Goldfields district, which are basically veins containing hematite, pitchblende, and gangue. The selenide deposits are unimportant in amount as compared with other types of deposits here, but they are of interest because of their size and because selenium is associated with uranium deposits at Theano Point on Lake Superior and in the Western United States. Selenides are found in the western part of the Goldfields-Martin Lake area only, from the Gil group northward through Martin Lake and Ato Bay to Hal Lake and the Stream fault. The Hal Lake

and Ato Bay deposits are not radioactive and are small bodies of massive selenides which include umangite, klockmannite, and berzelianite, with some clausenthalite, chalcocite, and native copper. The selenides cement and partly replace brecciated host rock and are largely free of gangue minerals. Selenides are associated with pitchblende at Martin Lake mine in the Eagle group and in the Gil group, where they surround and cement fractures in the pitchblende. The selenides are associated with calcite, and where they are plentiful, sulfides are scarce or lacking. The selenides were deposited later than pitchblende, arsenides, or sulfides. The presence of native copper and selenides indicates a temperature of deposition below 200° C. Tiemannite has been found in the Nicholson No. 2 zone, and clausenthalite is abundant in the Ace shaft.

Robinson, S. C., and Brooker, E. J., 1952, A cobalt-nickel-copper selenide from the Goldfields district, Saskatchewan: *Am. Mineralogist*, v. 37, p. 542-544.

A new cobalt-nickel-copper selenium mineral occurring in disseminated grains and small masses and resembling pentlandite was found with umangite, klockmannite, berzelianite, clausenthalite, pyrite, hematite, and chalcocopyrite at the Eagle group of claims and Ato Bay, Beaverlodge Lake, Goldfields district, Saskatchewan. The minerals cement sheared and fractured host rocks. The principal alteration product is chalcocite.

Robinson, W. O., 1933, Determination of selenium in wheat and soils: *Assoc. Official Agr. Chemists Jour.*, v. 16, p. 423-424.

A method for determining very small quantities of selenium in wheat and soil is described. One sample of soil contained 0.3 ppm selenium; 5 and 6 ppm selenium were found in samples of wheat.

— 1936, Selenium content of wheat from various parts of the world: *Indus. Eng. Chemistry, Indus. Ed.*, v. 28, p. 736-738.

Wheat from Saskatchewan, Canada, and South Africa contained from 1 to 2 ppm selenium, indicating seleniferous soils in those areas. Wheat from New South Wales, Australia; Spain; Argentina; and Canterbury, New Zealand contained less than toxic amounts of selenium.

— 1945, Determination of total selenium and arsenic in soils: *Soil Sci.*, v. 59, no. 1, p. 93-95.

A method for determining selenium in soil by quantitative distillation as bromide from strong hydrobromic acid solution. By this method it is possible to detect as little as 1 part of selenium in 10 billion parts of soil.

Robinson, W. O., and Edgington, Glen, 1945, Minor elements in plants, and some accumulator plants: *Soil Sci.*, v. 60, no. 1, p. 15-28.

Variation in selenium content of plants is greater than that of any other element, and ranges from less than 0.1 to 14,900 ppm in *Astragalus racemosus*.

Robinson, W. O., Dudley, H. C., Williams, K. T., and Byers, H. G., 1934, Determination of selenium and arsenic by distillation in pyrites, shales, soils, and agricultural products: *Indus. Eng. Chemistry, Anal. Ed.*, v. 6, p. 274-276. Detailed descriptions of distillation procedures.

Rockenbauer, W., and Schroll, Erich, 1953, Ein empfindlicher spektrochemischer Nachweis von Selen in Erzen: *Österreich. Akad. Wiss., math.-nat. Kl.*, v. 92, p. 192-196.

A spectrochemical method for determining selenium in sulfide minerals is described.

Rockenbauer, W., and Schroll, Erich, 1956, *Spektrochemische Bestimmung des Selens in ostalpinen Pyriten—Dosaggio spettrochimico di selenio in piriti delle alpi orientali*: Soc. mineralog. italiana Rend., v. 12, p. 194.

Sulfide ore minerals of the eastern Alps were analyzed for selenium. The highest value found was 0.01 percent in pyrite from Agordo, Italy.

Rose, Herm. *See* Geilmann and Rose, 1928.

Rossi, Michael. *See* Walker and others, 1941.

Rost, Rudolf, 1935, New minerals for Czechoslovakia from Kladno: *Věsta Přírodní*, v. 16, p. 203-204.

The following occurred on burning heaps of Carboniferous sediments rich in pyrite: rhombohedral γ -selenium, letovicite, mascagnite, α -sulfur, copiapite, epsomite, hexahydrate, pickeringite, lapparentite, and organic substances—anthracene and fluorene. (Chem. Abs., v. 32, col. 885.)

——— 1937, The minerals in the burning shafts at Kladno: *Česká akad. ved. Rozpravy, třída 2*, v. 11, p. 1-19.

Crystals of γ -selenium were found and many organic compounds were formed during the destructive disintegration of coal. (Chem. Abs., v. 33, col. 509.)

Rubey, W. W. *See* Hewett and others, 1936.

Runolinna, U. *See* Hukki and Runolinna, 1950.

Sahama, Th. G. *See* Rankama and Sahama, 1949.

Saito, Tadao, 1953, On minor elements in ore minerals of the Yakumo mine, Hokkaido, Japan: *Hokkaido Univ. Fac. Sci. Jour.*, ser. 4, v. 8, p. 267-276.

The mineralization forming the lead-zinc-manganese deposits of the Yakumo mine in the Neogene Tertiary formation is divided into three stages. The chief minerals are quartz, rhodochrosite, galena, sphalerite, pyrite, and chalcopyrite. Selenium has been detected in rhodochrosite, galena, sphalerite, and in pyrite of the second stage of mineralization. Selenium content tends to increase in later stages in rhodochrosite, to decrease in later stages in sphalerite, to increase in middle stages in pyrite, to decrease in middle stages in galena. Distribution of the minor elements, including selenium, has some relation not only to the chemical character of the ore solution but also to the physical conditions at the time the minerals crystallized.

Sandals, K. M. *See* Moxon and others, 1938.

Sanderson, L., 1940, Selenium: *Canadian Mining Jour.*, v. 61, p. 370-371.

A summary of sources, properties, extraction, and uses of selenium.

Sanford, Samuel. *See* Schrader and others, 1917.

Santmyers, R. M., 1930, Selenium and tellurium: *U. S. Bur. Mines Inf. Circ.* 6317, 23 p.

A summary of chemical properties, uses, identification tests, history, occurrence, minerals, preparation, production, imports, exports, markets, and prices of selenium. Tables show sales of selenium from 1910 to 1927, imports from 1913 to 1928, and monthly prices for 1913 and from 1920 to 1929.

Sarasin, Edmond. *See* Friedel and Sarasin, 1881a, b.

Sargent, J. D., 1954, Selenium: U. S. Bur. Mines Inf. Circ. 7690, 25 p.

Discussion of physical and chemical properties, geology, mineralogy, geographic distribution, domestic and foreign production and consumption, metallurgy, and uses of selenium. Appendix contains lists of selenium minerals, seleniferous formations, indicator plants, United States production and imports, and bibliography.

——— 1955a, Selenium data (Revision of Inf. Circ. 7690): U. S. Bur. Mines Inf. Circ. 7715, 29 p.

Discussion of physical and chemical properties, geology, mineralogy, geographic distribution, domestic and foreign production and consumption, metallurgy, and uses of selenium. Appendix contains tables of selenium minerals, seleniferous formations, indicator plants, United States production and imports, production of electrolytic copper refineries, and bibliography.

——— 1955b, Selenium, *in* Mineral facts and problems: U. S. Bur. Mines Bull. 556, 6 p.

A summary of geographic distribution, geology, metallurgy, reserves, uses, government wartime controls, substitutes, domestic production, consumption, foreign trade, prices, research, outlook, and problems of selenium.

Saunders, A. P., 1900, The allotropic forms of selenium: Jour. Phys. Chemistry, v. 4, no. 6, p. 423-513.

Selenium exists in three forms: (a) liquid (above 220° C.), (b) crystalline red, (c) crystalline gray or metallic. Describes properties and transformations of the different forms of selenium.

Schaller, W. T. *See* Hewett and others, 1936.

Schellinger, A. K. *See* Koepfel and Schellinger, 1957.

Scherbatoff, H. *See* Jacks and Scherbatoff, 1940.

Schloen, J. H. *See also* Clark and Schloen, 1944.

Schloen, J. H., and Elkin, E. M., 1946, Canadian Copper Refiners Montreal East plant: Canadian Inst. Mining and Metallurgy Trans., v. 49, p. 143-190.

Ore from the Noranda and Hudson Bay mines is treated at the Montreal East plant. Ore from Noranda typically contains 0.144 percent selenium, that from Hudson Bay contains 0.117 percent selenium. Selenium plant operation is described.

——— 1950, Treatment of electrolytic copper refinery slimes: Am. Inst. Mining Metall. Engineers Trans., v. 188, p. 764-777.

Analyses are given of selenium in anodes, raw slimes, and treated slimes from Boliden, Sweden; Noranda, Quebec; Electrolytic Refining and Smelting Co., Port Kembla, New South Wales, Australia; Mount Lyell, Tasmania; Norddeutsche Affinerie, Hamburg, Germany; Outokumpu, Finland; and Rhodesia Copper Refineries Ltd., N'kana, Northern Rhodesia. Methods used at the refineries are described. Bibliography on selenium metallurgy.

Schloen, J. H., and Elkin, E. M., 1954, Treatment of electrolytic copper refinery slimes, in *Copper*, by Allison Butts: New York, Am. Chem. Soc. Mon. Ser., Reinhold Pub. Corp., p. 266-269.

Article contains tables giving selenium content of copper anodes, raw slimes, and leached slimes from American Smelting and Refining Co.; Anaconda Co.; Boliden, Sweden; Montreal East and Noranda (Canadian Copper Refiners); Cerro de Pasco, Peru; Port Kembla, New South Wales; Mount Lyell, Tasmania; Copper Cliff, Ontario; Kennecott; Norddeutsche Affinerie, Hamburg, Germany; Phelps Dodge; Outokumpu, Finland; Raritan; N'kana, Rhodesia; and U. S. Metals smelters.

Schmidt, Max, 1925, Beitrag zur Bestimmung kleiner Selenmengen in sulfidischen Mineralien: *Metall u. Erz*, v. 22, no. 19, p. 511-512.

Sulfide minerals contained the following amounts of selenium: sphalerite from Norway, 0.0004 percent; sphalerite from Oberschlesien, Germany, 0.0002 percent; sphalerite from Harz, Germany, 0.0001 percent; galena from Spain, 0.0003 percent; bismuthinite from Schneeberg, Germany, trace; argentite from Freiberg, Germany, 0.001 percent; chalcopyrite from Butte, Mont., 0.005 percent.

Schmitt, Marg. *See* Ramdohr and Schmitt, 1955.

Schoeller, W. R., and Powell, A. R., 1920, Villamaninite, a new mineral: *Mineralog. Mag.*, v. 19, no. 88, p. 14-18.

A new mineral from the Cármenes district near Villamanín, Province of León, Spain, has the formula, $(\text{Cu, Ni, Co, Fe}) (\text{S, Se})_2$, and contains about 1.5 percent selenium. The ores of the district are sulfide minerals of copper, cobalt, and nickel in a dolomite gangue.

Schrader, F. C., 1923, The Jarbidge mining district, Nevada: *U. S. Geol. Survey Bull.* 741, p. 30.

Naumannite occurs with argentite, electrum, and gold in a gangue of quartz and adularia in veins of the Jarbidge district, Nev.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, 1917, Useful minerals of the United States: *U. S. Geol. Survey Bull.* 624, p. 78, 305, 308, 388, 390, 405.

Tiemannite occurs in large masses near Clear Lake and at the Abbott mine in Lake County; at the San Joaquin Ranch mine in Orange County; and at the Guadalupe mine near Los Gatos in Santa Clara County, Calif. Onofrite and tiemannite occur at the Lucky Boy mine near Marysvale, Utah.

Schroll, Erich. *See* Rockenbauer and Schroll, 1955, 1956.

Schumb, W. C. *See* Marvin and Schumb, 1935.

Searight, W. V. *See also* Moxon and others, 1938, 1939.

Searight, W. V., and Moxon, A. L., 1945, Selenium in glacial and associated deposits: *South Dakota Agr. Expt. Sta. Tech. Bull.* 5, 33 p.

Brookings, Kingsbury, Hamlin, Beadle, Day, Clark, Deuel, Grant, Spink, Brown, Codington, and Roberts Counties contain Pleistocene glacial deposits underlain by seleniferous chalk beds of the Mobridge member of the Pierre formation. Selenium occurs in small amounts in all glacial and associated deposits of north-

eastern South Dakota and western Minnesota. Selenium is mostly in silt and clay in Pleistocene deposits, derived from the seleniferous formations over which the glaciers moved. The greatest amount of selenium is in Arlington loess and loesslike silts in poorly drained areas where it has been leached, transported downslope, and redeposited at lower levels.

Searight, W. V., Moxon, A. L., Hilmo, R. J., and Whitehead, E. I., 1946, Occurrence of selenium in Pleistocene deposits and their derivatives in South Dakota: *Soil Sci.*, v. 61, no. 6, p. 455-463.

All Pleistocene glacial tills of northeastern South Dakota contain selenium, averaging less than 1.5 ppm selenium. Loess deposits contain little selenium in upland areas; in depressions they carry noteworthy amounts. The source of the selenium in glacial drift, outwash, alluvium, and loess is bedrock or older drifts over which the glaciers have moved. In South Dakota seleniferous Cretaceous formations underlie Pleistocene glacial deposits.

Searight, W. V., Moxon, A. L., Whitehead, E. I., and Viets, F. G., Jr., 1946-47, Detailed mapping of seleniferous vegetation on soils of Pierre origin: *South Dakota Acad. Sci. Proc.*, v. 26, p. 87-98.

The stratigraphic distribution of selenium sources in the Virgin Creek, Moberly, and Elk Butte members of the Pierre formation in northwestern Lyman County, S. Dak., was mapped by determining the selenium content of western wheatgrass growing on the soils. The selenium source beds are horizontal, so that the ranges of maximum selenium content can be mapped topographically. The authors discuss the possibility of mapping toxic areas on the basis of the topographic position of seleniferous beds.

Selvig, W. A. See Gibson and Selvig, 1944.

Shannon, E. V., 1920a, An occurrence of naumannite in Idaho: *Am. Jour. Sci.*, ser. 4, v. 50, p. 390-391.

Naumannite, a selenide of silver, occurs as nodules in white to bluish clay filling fissures in silver stopes of the De Lamar mine, Silver City district, Owyhee County, Idaho. The mineral resembles argentite and it is possible that much of the silver ore mined was naumannite rather than argentite.

——— 1920b, Boulangerite, bismutoplacionite, naumannite, and a silver-bearing variety of jamesonite: *U. S. Natl. Mus. Proc.*, v. 58, p. 589-607.

Naumannite from the De Lamar mine, Silver City district, Owyhee County, Idaho, contained 22.92 percent selenium and 1.10 percent sulfur.

——— 1925, Tetradyomite from the Hailey quadrangle, Idaho: *Am. Mineralogist*, v. 10, p. 198-199.

Tetradyomite, from near the head of Trail Creek, Hailey quadrangle, Blaine or Custer County, contains small amount of selenium replacing tellurium.

——— 1926, The minerals of Idaho: *U. S. Natl. Mus. Bull.* 131, p. 82, 101-104.

Selenium appears to be confined to, and characteristic of, late Tertiary veins in volcanic rocks. Guanajuatite was found on Kirtley Creek, northeast of Salmon, Lemhi County. Naumannite was found in the Montana and Lucky Boy mines, Yankee Fork district, Custer County; Monument mine, Gravel Range district, and Parker Mountain district, Lemhi County; De Lamar mine, Silver City district, Owyhee County. Clausthalite was found in the Hypotheek mine, Coeur d'Alene district, Shoshone County.

Shcherbina, V. V., 1949, Concentration and dispersion of chemical elements in the earth's surface as a result of oxidative and reductive processes: *Akad. Nauk SSSR Doklady*, v. 67, p. 507-510. [Russian.]

Generalized view of oxidation-reduction reactions as a means of distribution of elements is presented. Oxidations tend to concentrate salts of heavy metals, formed by the oxidation of acids of vanadium, molybdenum, chromium, arsenic, selenium, tellurium, sulfur, and phosphorous. Sulfides, selenides, and tellurides show decreased hydrolyzability on oxidation and their concentration takes place only after reduction reactions. (*Chem. Abs.*, v. 43, col. 8996.)

Shigematsu, Tsunenobu. *See* Ishibashi and others, 1953.

Shimidzu, Tetsukichi. *See* Divers and Shimidzu, 1883.

Short, M. N., 1931, Microscopic determination of the ore minerals: *U. S. Geol. Survey Bull.* 825, p. 79, 80, 83, 85, 86, 93, 94, 104, 105, 167-168.

Determinative tables for selenium minerals, agularite, clausthalite, eucairite, kloekmannite, lehrbachite, naumannite, onofrite, tiemannite, and umangite; tests for selenium.

Shutt, R. *See* Waitkins and others, 1942.

Sill, C. W., and Peterson, H. E., 1954, Iodometric determination of selenium in ores and flue dusts: *U. S. Bur. Mines Rept. Inv.* 5047, 9 p.

A new method is described for direct titration of selenious acid to a starch-iodide end point by adding starch to selenious acid and enough potassium iodide to form a transparent blue color, and then titrating with standard thiosulfate. This method retains the colorless end point of the Norris and Fay method and can be used for determining much larger quantities of selenium than is possible by the McNulty method. Procedures are given for precipitating metallic selenium from flue dust or ore, for oxidizing metallic selenium to selenious acid, and for titrating with thiosulfate.

Sisson, L. L. *See* Olson and others, 1940.

Slater, C. S., Holmes, R. S., and Byers, H. G., 1937, Trace elements in the soils from the erosion experiment stations, with supplementary data on other soils: *U. S. Dept. Agriculture Tech. Bull.* 552, 23 p.

Eleven soil profiles representing 4 of the great soil groups and 3 other soils were examined. The 11 profiles included soils from Wisconsin, Kansas, Iowa, Washington, Missouri, Texas, Ohio, Oklahoma, and North Carolina. Their selenium content ranged from 0.01 to 2.50 ppm. Pierre clay loam and Niobrara sandy clay loam contained 22 and 18 ppm selenium respectively. A relatively high selenium content was found in soils of low silica-sesquioxide ratio, and a tendency for illuviated horizons to have an accumulation of selenium was noted.

Slattery, M. K., 1925, The crystal structure of tellurium and selenium and of strontium and barium selenide: *Phys. Rev.*, ser. 2, v. 25, p. 333-337; *abs.* v. 21, p. 378-379.

Selenium crystallizes in a simple triangular lattice with three atoms grouped at each corner. Strontium and barium selenide have simple cubic structures.

Smith, W., 1915, Estimation of selenium in sulphur: *Indus. Eng. Chemistry, Indus. Ed.*, v. 7, p. 849.

The article describes a method for estimating the amount of selenium in sulfur. Four samples of commercial sulfur from Japan contained 0.045, 0.055, 0.085, and 0.152 percent selenium.

Spencer, A. C., 1917, The geology and ore deposits of Ely, Nevada: *U. S. Geol. Survey Prof. Paper* 96, p. 112.

Ely porphyry copper ores yielded 110 pounds of selenium for each 100 tons of blister copper refined at the Steptoe smelter.

Spurr, J. E., 1905a, Developments at Tonopah, Nevada, during 1904: *U. S. Geol. Survey Bull.* 280, p. 140-149.

Sulfide ore from the Montana vein, Montana Tonopah mine, contained 2.56 percent selenium; oxidized ore from the Valley View mine contained 0.78 percent selenium. Selenium occurs in part as a silver selenide; a selenide of gold is not impossible. The oxidized ore shows that much of the silver selenide is attacked by oxidizing agents. "The oxidized ore of Tonopah is really a modified ore, consisting of an intimate mixture of sulfides and selenides, together with secondary sulfides, chlorides, and oxides."

——— 1905b, Geology of the Tonopah mining district, Nevada: *U. S. Geol. Survey Prof. Paper* 42, p. 92-93, 281, 285.

Analysis of oxidized ore from the 300-foot level of the Valley View vein contains 0.78 percent selenium. Selenium occurs, in part at least, as a silver selenide. There is less than one third as much selenium in the oxidized ore as in the sulfide ore. The primary ores contained quartz, adularia, carbonates, polybasite or stephanite, argentite, chalcopyrite, pyrite, galena, sphalerite, silver selenide, and gold in an undetermined form.

Starrett, W. H. *See* Cannon and Starrett, 1956.

Stoklasa, Julius, 1922, Über die Einwirkung des Selens auf den Bau- und Betriebsstoffwechsel der Pflanze bei Anwesenheit der Radioaktivität der Luft und des Bodens: *Biochem. Zeitschr.*, v. 130, p. 604-643.

Occurrence of selenium in pyrites, radioactive materials, sulfuric acid, and in certain sulfate and phosphate fertilizers is noted. Selenium is released into the air during the roasting of pyrites, smelting operations, and burning of coal. Studies of the biochemical effect of such selenium on plants and seeds in the presence and absence of radioactivity are described.

Stone, J. R., and Caron, P. E., 1954, Selenium in Hampel, C. A., ed., *Rare Metals Handbook*: New York, Reinhold Publishing Corp., p. 347-377.

General treatise containing summary of history, occurrence, methods of recovery, fabrication, toxicity, and uses of selenium. Physical and chemical properties are described in detail.

Stone, R. W. *See* Schrader and others, 1917.

Stradner, E. *See* Machatschki and Stradner, 1952.

Strock, L. W. *See also* Goldschmidt and Strock, 1935.

Strock, L. W., 1935, The distribution of selenium in nature: *Am. Jour. Pharmacy*, v. 107, no. 4, p. 144-157.

Summary of data from paper by Goldschmidt and Strock on the distribution of selenium in products of magmatic origin and of secondary erosion and sedimentation. The distribution of selenium in sulfides is associated with the differentiation and cooling of primary magma. Selenium is richer in the primary sulfide phase of the first differentiation of the magma, such as trolite meteorites and pneumatolytic sulfide ores. Sulfides of magmatic segregation origin contain less selenium, and hydrothermal sulfides which issue from the magma in the last stages of differentiation contain the least selenium. In the erosion cycle a very high oxidation potential is required to oxidize selenide to selenate. Selenium in a very soluble form was present in highly oxidized caliche beds in the Atacama desert, Chile. Selenium does not follow sulfur into sea water but is absorbed by ferric hydroxide-rich marine sediments, thus accounting for seleniferous sedimentary iron ores. Possible sources of selenium in shales and other sedimentary rocks are: (a) erosion of caliche and lignite beds, (b) absorption from water by ferric hydroxide and plants. Sources of selenium in soil are the parent selenium-rich sedimentary rocks, magmatic rocks with sulfide masses, eroding caliche beds, and waters, which have leached other formations, rising to the surface.

Swaine, D. J., 1955, The trace-element content of soils: Commonwealth Bur. Soil Sci. [Harpندن] Tech. Commun. 48, p. 91-99.

Tabulated information on selenium content of soils in Ireland, Russia, Japan, Canada, Mexico, Puerto Rico, Colombia, New Zealand, Hawaiian Islands, and United States—including Wyoming, Oklahoma, South Dakota, Nebraska, Montana, Colorado, Kansas, New Mexico, Arizona, North Dakota, Nevada, Texas, Missouri, Utah, New Jersey, California, and Idaho.

Sweeney, A. See Walsh and others, 1951.

Taber, Stephen, 1913, Geology of the gold belt in the James River Basin, Virginia: *Virginia Geol. Survey Bull.* 7, p. 160.

Tetradymite in gold-bearing quartz veins in quartz-sericite schist at the Tellurium mine, Fluvanna and Goochland Counties, contains traces of selenium.

Taboury, F., 1909, Sur la présence du sélénium dans les eaux minérales de La Roche-Posay, Vienne: *Soc. chim. France Bull.*, ser. 4, v. 5, p. 865-867.

Waters from each of the 3 sources of the spring at La Roche-Posay, Vienne, France, contained 0.2 milligram per liter of selenium.

——— 1932, Sur la présence accidentelle du sélénium dans certains végétaux: *Acad. sci. [Paris] Comptes rendus*, v. 195, p. 171.

Of 3 species of plants growing in a seleniferous spring at La Roche-Posay, Vienne, France, 2 were found to have absorbed selenium in their tissues.

Terada, Shizuo. See Tsuge and Terada, 1950.

Thompson, M. E., Roach, Carl, and Braddock, William, 1956, New occurrences of native selenium: *Am. Mineralogist*, v. 41, nos. 1 and 2, p. 156-157.

Native selenium has been identified in three localities during studies of sandstone-type uranium-vanadium deposits. The selenium occurs as purple-gray

metallic acicular crystals, usually in a felty aggregate of small crystals not more than 2 mm in length. The localities are the Road Hog No. 1A mine, Black Hills, Fall River County, S. Dak., in Lakota sandstone of Early Cretaceous age; Peanut mine, Bull Canyon, Montrose County, Colo., in high-grade ore in Salt Wash sandstone member of the Morrison formation of Late Jurassic age; and Parco No. 23 mine, Thompsons district, Grand County, Utah, in Salt Wash sandstone member of the Morrison formation.

Thompson, R. M., 1954, Naumannite from Republic, Washington: *Am. Mineralogist*, v. 39, p. 525.

Banded quartz from Republic, Washington, contains concentric black metallic bands consisting of argentian tetrahedrite in which small particles of gold, electrum, pyrite, chalcopyrite, and naumannite are embedded.

Thorvaldson, T., and Johnson, L. R., 1940, The selenium content of Saskatchewan wheat: *Canadian Jour. Research*, v. 18, sec. B, p. 138-150.

Analyses are given of 230 composite samples of wheat grown in Saskatchewan. The maximum amount of selenium found was 1.5 ppm, contained by 3.2 percent of the samples; the average amount of selenium found was 0.44 ppm. Wheat grown on soil of glacial lacustrine origin generally contained more selenium.

Trelease, H. M. *See* Trelease and Trelease, 1938.

Trelease, S. F., 1945, Selenium in soils, plants, and animals: *Soil Sci.*, v. 60, no. 2, p. 125-131.

Selenium is present in soil as insoluble ferric selenite, soluble selenates, and organic compounds derived from plant decomposition. Selenium accumulator plants are native range plants rather than cultivated crops or native grasses. Accumulator plants are capable of absorbing selenium from virgin shale soils, converting it into water-soluble forms, and returning it to the soil in a form available for absorption by all types of plants.

Trelease, S. F., and Beath, O. A., 1949, Selenium, its geological occurrence and its biological effects in relation to botany, chemistry, agriculture, nutrition, and medicine: New York, Published by the authors, 292 p.

A general survey of selenium as it is related to agriculture and public health, containing chapters on history of selenium poisoning, selenium indicator plants, distribution in rocks and soils, accumulation of selenium by plants, selenium poisoning in animals, selenium in relation to public health, prevention and control of selenium poisoning, and chemistry. Maps show outcrops of Permian, Triassic, Jurassic, Cretaceous, and Tertiary formations and locations of plant samples containing 50 ppm or more of selenium in the Western United States. A discussion on origin of selenium in rocks and types of selenium-bearing materials is given.

Trelease, S. F., and Trelease, H. M., 1938, Selenium as a stimulating and possibly essential element for indicator plants: *Am. Jour. Botany*, v. 25, no. 5, p. 372-380.

Inorganic selenite used in experiments was found to be essential for growth of indicator plants. Addition of sulfur tended to reduce the intake of selenium by plants growing in environments of low selenium concentration.

Trites, A. F., Jr., 1956, Selenium occurrences in the United States: *Mines Mag.* [Colorado], v. 46, no. 8, p. 43-44.

Selenium occurs associated with uranium in the Gas Hills area, Fremont County, Wyo., in the Temple Mountain and Henry Mountain areas, Utah, and in the Grants area, N. Mex., where it has been released from pyrite by oxidation. Selenides of copper, lead, silver, and mercury are found in many sulfide deposits in the Western United States and Mexico. Selenium is associated with sulfur in volcanoes in Hawaii and Alaska, and at the Vulcan mine, Gunnison County, Colo. It occurs in the phosphate deposits of the northwestern States and in the Upper Cretaceous rocks of the Colorado Plateau and the Western States.

Trites, A. F., Jr., and Lakin, H. W., 1956, Behavior of selenium in the zone of oxidation: *Internat. Geol. Cong., 20th, Mexico 1956, Resúmenes Trabajos Presentados*, p. 377-378.

Selenium released during oxidation of seleniferous sulfide minerals is in less soluble form than sulfur and tends to be concentrated in the oxidized zone. In seleniferous pyrite-bearing sandstone-type uranium deposits of the Colorado Plateau and Wyoming, secondary selenium minerals are concentrated either in mantles overlying unoxidized ore bodies or in haloes enclosing these bodies. The most seleniferous rock is commonly sandstone containing red elemental selenium with varying amounts of hydrous iron oxide containing some basic ferric selenite. Small amounts of selenium are being removed from these deposits by surface and underground water; some of this selenium is retained in the rock as basic ferric selenite, some is absorbed in plants, some enters the atmosphere as gas, some enters streams to be discharged in the ocean and inland basins. Concentrations of selenium are now being built up in bottom sediments in the Gulf of California outward from the mouth of the Colorado River.

Truscott, S. J., 1901-02, The occurrence and mining of gold in the Dutch East Indies: *Inst. Mining and Metallurgy Trans.*, v. 10, p. 52-57.

The Radjang Lebong gold mine in southwestern Sumatra is a reef 1,000 feet long in porphyrite or altered andesite country rock. The ore is hard, close-grained amorphous silica with very little quartz, containing in places a breccia of black silicified slate, and often accompanied by calcite. The gold is finely disseminated throughout, and occurs as free gold and as auriferous silver carrying 1 part of gold to 10 parts of silver. The gold may be associated with tellurium. An analysis of the bullion gives no tellurium, but it contains 4.35 percent selenium. Similar gold-bearing reefs occur at the Lebong Soelit mine, 5 miles west of Radjang Lebong, and at an unnamed reef 7 miles west of Lebong Soelit.

Tsuge, Toshihisa, and Terada, Shizuo, 1950, The selenium content of the pyrites and soils in Japan: *Agr. Chem. Soc. Japan Jour.*, v. 23, no. 10, p. 421-425. [Japanese, English summary.]

Selenium content of pyrites from Japanese mines ranged from 0.2 to 39 ppm, with an average of 12.6 ppm; copper pyrites contained 4 to 39 ppm, with an average of 18.8 ppm; iron pyrites contained 3 to 7 ppm, with an average of 5 ppm; marcasite and pyrrotite contained 0.2 to 0.7 ppm, with an average of 0.45 ppm. Pyrite slags contained 0.2 to 2.5 ppm, with an average of 0.86 ppm. Small quantities of selenium were found in Japanese soils, ranging from 0.4 to 1.2 ppm, with an average of 0.78 ppm. No correlation was found between the sulfur and selenium content of pyrites.

Turner, H. W., 1898, Notes on rocks and minerals from California; tellurium, selenium, and nickel in gold ores: *Am. Jour. Sci.*, ser. 4, v. 5, p. 427-428.

Selenium was found in sulfide ore from a mine on the Mother Lode near Table Mountain in Tuolumne County.

Tyler, P. M., 1952, Selenium: *Natl. Acad. Sci., Natl. Research Council, Rept. no. NMAB-15-M*, 62 p.

The report contains a summary of the selenium supply situation in 1952, including United States requirements and production. Recommendations are made for reducing selenium consumption and expanding production. Increased domestic supplies can be obtained by increasing imports, improving metallurgical practice, and by developing new sources such as nonferrous metal smelting industries, uranium-vanadium plants, iron blast furnace flue dust, sulfuric acid plants, and selenium-bearing rocks and soils. Selenium in iron ore at Iron Mountain, Utah, is described. Uses, geochemistry, and metallurgy of selenium are outlined.

Umpleby, J. B., 1910, Geology and ore deposits of the Republic mining district: *Washington Geol. Survey Bull.* 1, 65 p.

Analyses of mixed specimens of high grade ore from intermediate levels of the New Republic mine, Ferry County, Wash., gave 5.26 percent selenium. Silver is partly in the form of silver selenide; 60 percent of the gold is combined with selenium, probably as a gold-silver selenide.

——— 1913a, Geology and ore deposits of Lemhi County, Idaho: *U. S. Geol. Survey Bull.* 528, p. 55-56, 57, 79, 175.

Strong traces of selenium were detected in ore from the Monument mine at Myers Cove, Gravel Range district. This vein and possibly the similar Parker Mountain and Musgrove deposits are of a rare type of later Tertiary veins enclosed in Tertiary eruptive rocks and characterized by selenium which is found at Tonopah, Nev., and Republic, Wash. Selenium probably occurs at the Monument mine as a selenide of gold or silver. Its source is probably a blue-black mineral which occurs in scattered and bunched grains of microscopic size.

——— 1913b, Some ore deposits in northwestern Custer County, Idaho; *U. S. Geol. Survey Bull.* 539, p. 45-47.

Selenium was noted in post-Oligocene gold-silver ores of the Montana and Lucky Boy mines in the Yankee Fork district, Custer County. The ore is fine-grained quartz containing pyrite, gold, tetrahedrite, chalcopyrite, galena, and enargite. Blue-black specks in the ore contain selenium, gold, lead, bismuth, and copper. The ore veins are in Algonkian schists and quartzites and Miocene tuffs, latites, andesites, basalts, and rhyolites.

(U. S.) National Research Council, Materials Advisory Board, Panel on Selenium, 1956, Report on selenium and possible substitute materials for rectifiers: *Natl. Acad. Sci., Natl. Research Council, Rept. MAB-111-M*, 12 p., app. A-G.

Describes properties of selenium rectifiers and possible substitute materials for rectifiers. Possible sources of additional selenium are phosphate deposits in Idaho, Wyoming, Utah, and Montana; lysite tuffs in Wyoming; high-selenium uranium-vanadium ores; and pyrite-pyrrhotite ore of the United Verde mine, Jerome, Ariz., which contains 0.03 percent selenium and from which 1,131,500 pounds of selenium could be recovered annually for many years.

Vaes, J. F. *See also* Derriks and Vaes, 1956.

Vaes, J. F., 1947, Quelques sulfures de Shinkolobwe: Soc. géol. Belgique Annales, v. 70-B, p. 227-232.

In the Shinkolobwe deposit a mineral similar to vaesite but containing appreciable amounts of selenium was found accompanied by siegenite and small amounts of pyrite and molybdenite. It was called selenio-vaesite. A seleniferous variety of siegenite containing a small amount of tellurium was also found and was called selenio-siegenite.

Vakhrushev, G. V., 1940, Exploration of rare elements in Bashkiriya (southern Ural): Saratov. gos., Univ. Uchenyye zapiski, v. 15, no. 1, p. 124-146. [Russian.]

Selenium content of pyrites is presented: Sibaev, 0.012 percent; Bakyr-Uzyak, 0.012 percent; Bakyrto, 0.013; Yulalin, 0.006 percent. (Chem. Abs., v. 35, col. 65-11.)

Vaupell, C. W., 1938, Mercury deposits of Huitzuco, Guerrero, Mexico: Am. Inst. Mining Metall. Engineers Tech. Pub. 842, 14 p.

Tiemannite and onofrite, with other rare selenides and arsenides of mercury, antimony, and thallium, have been reported in specimens of Huitzuco ores, which are telethermal or epithermal blanket veins and stockworks in brecciated rocks. Geysers later reworked the original minerals and more recent deposits were formed in the extinct geyser and hot spring vents.

Viets, F. G., Jr. *See* Searight and others, 1946-47.

Vine, J. D., and Prichard, G. E., 1954, Uranium in the Poison Basin area, Carbon County, Wyoming: U. S. Geol. Survey Circ. 344, 8 p.

Uranium minerals were found in sandstone of the Browns Park formation of Miocene age in the Poison Basin area, 6 miles west of Baggs. Six ore samples analyzed for selenium contained from 12 to 80 ppm. The occurrence of uranium in the Poison Basin area coincides remarkably with an area known to be high in selenium content. The association of the two elements is probably not due to chemical combination in a specific mineral, but to a common origin. The association may be sufficiently common that prospecting for uranium may be continued in areas of high selenium content.

Vinogradov, A. P., 1945, A chemical study of the biosphere: Pedology, p. 348-354. [Russian, English summary.]

In a geochemical study of the biosphere, analyses were made of soils of the Russian plain from north to south along the 40th meridian. Minimum and maximum selenium contents were, in percentage of dry soil, below 10^{-4} . (Chem. Abs., v. 40, col. 1892.)

Vogt, J. H. L. *See* Beyschlag and others, 1914.

Vokes, F. M., 1957, The copper deposits of the Birtavarre district, Troms, northern Norway: Norges Geol. Undersökelse, no. 199, p. 146.

Sulfide ores occur as closely associated impregnations and breccia types, in zones parallel to the enclosing schists of the Ankerlia series. The chief ore minerals are pyrrhotite, chalcopyrite, sphalerite, and cubanite. Selenium is

found in copper flotation concentrates in amounts of 50 and 100 grams per ton. These figures indicate that selenium follows chalcopyrite; however, the present work cannot be taken as supporting Carstens' conclusion that selenium varies sympathetically with copper content. In specially cleaned samples of ore sulfides, selenium varied from 0.0007 to 0.0014 percent. These figures do not reveal conclusive variations of selenium with either copper or sulfur. The selenium occurs substituting for sulfur in the sulfide lattices. Its presence in the ore is considered as evidence of an epigenetic origin of the deposits.

Waitkins, G. R., Bearse, A. E., and Shutt, R., 1942, Industrial utilization of selenium and tellurium: *Indus. Eng. Chemistry, Indus. Ed.*, v. 34, p. 899-910.

A review of the uses of selenium, including alloys, rectifiers, ceramics, and chemical uses—including oxidizing agents, catalysts, fungicides, insecticides, antioxidants.

Walker, O. J., Harris, W. E., and Rossi, Michael, 1941, Selenium in soils, grains, and plants in Alberta: *Canadian Jour. Research*, v. 19, sec. B, p. 173-178.

Selenium content of 40 samples of soils varied from less than 0.1 to 1 ppm. The underlying strata of much of Alberta are of upper Cretaceous age, but the soil is derived mostly from glacial drift formed from other types of rock, so that the seleniferous area may be much smaller than earlier suspected. Seleniferous areas are more likely to be found in southern Alberta rather than in central Alberta.

Walsh, T. *See also* Fleming and Walsh, 1957.

Walsh, T., Fleming, G. A., O'Connor, R., and Sweeney, A., 1951, Selenium toxicity associated with an Irish soil series: *Nature*, v. 168, p. 881.

Low lying valley soils in a glaciated area underlain by upper Carboniferous limestone in County Limerick contain 30 to 324 ppm selenium. The soils are in an area of poor drainage and high rainfall. Formation of the soils was influenced by wash from the Yoredale beds (Avonian shales), which lie west of the affected area. These beds contain considerable deposits of iron pyrites, which may be the source of the selenium.

Ward, F. N. *See* Lovering and others, 1956.

Warren, H. N., 1888, Detection and estimation of selenium in meteoric iron: *Chem. News*, v. 57, p. 16.

Six specimens of meteoric iron contained quantities of selenium ranging from 0.04 to 0.23 percent.

Washington, H. S. *See* Clarke and Washington, 1924.

Weed, W. H., 1912, Geology and ore deposits of the Butte district, Montana: *U. S. Geol. Survey Prof. Paper* 74, p. 70-71, 79.

Copper ore mined in 1897 contained an average of 0.001 percent of tellurium and selenium; the matte contained an average of 0.01 percent of tellurium and selenium. Matte shipped from Butte smelters in 1897 contained .015, .0021, and .0042 percent tellurium and selenium. The ratio of tellurium to selenium in matte is from 1:1 to 3:1. The constant presence of gold, together with tellurium and selenium, in the blister copper produced by the smelters, suggests the probable presence of minute quantities of some gold-silver telluride.

Weeks, A. D., 1956, Mineralogy of uranium deposits, in *Geologic investigations of radioactive deposits—Semiannual progress report for Dec. 1, 1955 to May 31, 1956*: U. S. Geol. Survey TEI-620, issued by U. S. Atomic Energy Comm., Tech. Inf. Service, Oak Ridge, Tenn., p. 123-127.

Selenium commonly substitutes for sulfur in sulfide minerals in the sandstone type uranium deposits to an extent not previously known. There is no significant difference in selenium content of sulfides, mostly pyrite and marcasite, from barren and mineralized rocks of the Morrison and Chinle formations. In Tertiary sediments, sulfides from mineralized rocks contain 60 times more selenium than sulfides from barren rocks. Selenium in Tertiary sulfides may have been introduced during uranium mineralization, while selenium in Morrison and Chinle formations may have been derived from volcanic debris deposited with the sediments. The highly seleniferous deposits contain clausthalite, eucairite, ferroselite, and cobaltian ferroselite.

Weeks, M. E., 1956, *Discovery of the elements*: 6th ed., Easton, Pa., Jour. Chem. Education, p. 306-319.

A history of the discovery of selenium and selenium minerals. Many localities are listed.

Weibull, M., 1885, Om selenhaltig galenobismutit från Falu grufva: *Geol. fören. Stockholm Förh.*, v. 7, p. 657-666.

Gives analyses of lead bismuth selenides from Falun.

Wells, H. L. *See* Dana and Wells, 1890.

Wernimont, Grant, and Hopkinson, F. J., 1940, Microtitration of selenium: *Indus. Eng. Chemistry, Anal. Ed.*, v. 12, p. 308-310.

Method for volumetric determination of small amounts of selenium.

White, R. L. *See* Keys and White, 1956.

Whitehead, E. I. *See* Olson and others, 1942b; Searight and others, 1946, 1946-47.

Williams, K. T. *See also* Byers and others, 1936, 1938; Lakin and others, 1938; Robinson, W. O. and others, 1934.

——— 1939, Selenium in soils, in *Soils and Men*: U. S. Dept. Agriculture Yearbook, 1938, p. 830-834.

Seleniferous soils develop in semiarid areas and are derived mostly from formations of Cretaceous, Permian, and Triassic age. Soils containing 1 ppm or less of selenium may produce toxic vegetation; irrigation reduces the selenium intake of vegetation.

Williams, K. T., and Byers, H. G., 1934, Occurrence of selenium in pyrites: *Indus. Eng. Chemistry, Anal. Ed.*, v. 6, p. 296-297.

Analyses of pyrites from arid and humid areas in Western and Southeastern United States show a high concentration of selenium in pyrites. In humid areas pyrite is converted to limonitic material, and selenium and sulfur are transformed to soluble forms and are removed from the soil by leaching. In arid and semiarid areas, where there is little leaching, pyritiferous soil parent material forms a soil with high selenium and sulfur content. Analyses are

given of pyrites from Nebraska, Utah, Colorado, Mississippi, Alabama, Georgia, North Carolina, Tennessee, and Virginia.

Williams, K. T., and Byers, H. G., 1935a, Occurrence of selenium in the Colorado River and some of its tributaries: *Indus. Eng. Chemistry, Anal. Ed.*, v. 7, p. 431-432.

Waters taken from the Colorado, Gunnison, and Uncompahgre Rivers above irrigated lands contained very little selenium; waters taken below the entrance of irrigation drainage into rivers contained from 10 to 70 times as much selenium. Drainage waters from irrigated lands contained as much as 2.680 ppm selenium. The soils in this area are derived from seleniferous Mancos shale containing from 2 to 6 ppm selenium.

——— 1935b, Selenium in deep sea deposits: *Indus. Eng. Chemistry, News Ed.*, v. 13, p. 353.

Nine deep sea samples taken in the Bering Sea off the coasts of Alaska and Siberia contained from 0.03 to 0.70 ppm selenium, with an average of 0.27 ppm selenium.

——— 1936, Selenium compounds in soils: *Indus. Eng. Chemistry, Indus. Ed.*, v. 28, p. 912-914.

The chemical form of selenium in the soil determines the amount of selenium absorbed by vegetation. Pyrites carrying insoluble selenium are found in upper Cretaceous shales, particularly in the lower Pierre and upper Niobrara formations. Where iron is present in the soil, selenium may occur as insoluble basic ferric selenite. Water soluble selenates such as calcium selenate are formed in soils low in iron. The presence of selenates in humid soils is very unlikely. Organic matter in soils may contain water-soluble selenium compounds.

Williams, K. T., and Lakin, H. W., 1935, Determination of selenium in organic matter: *Indus. Eng. Chemistry, Anal. Ed.*, v. 7, p. 409-410.

Describes method of determining selenium in air dried vegetation.

Williams, K. T., Lakin, H. W., and Byers, H. G., 1940, Selenium occurrence in certain soils in the United States, with a discussion of related topics; fourth report: U. S. Dept. Agriculture Tech. Bull. 702, 59 p.

Contains methods for determining selenium in coal and animal matter; survey of toxic vegetation and soils in Montana; report on toxic soil in Guanajuato Valley, Mexico, with analyses of soils and vegetation of Chihuahua, Juarez, and Torreon areas; discussion of nontoxic seleniferous soils of Hawaii and Puerto Rico; report on seleniferous areas of the Eagle Ford formation in Texas; report on selenium content of cores from the sea floor between Halifax, Nova Scotia, and Falmouth, England.

——— 1941, Selenium occurrence in certain soils in the United States, with a discussion of related topics; fifth report: U. S. Dept. Agriculture Tech. Bull. 758, 70 p.

Report contains tables showing selenium content of 1,000 samples of wheat from Colorado, Kansas, Nebraska, South Dakota, Wyoming, Montana, and North Dakota. The authors conclude that selenium is present in all wheat; maximum selenium content of wheat found was 25 ppm. The selenium content of 300 samples of corn, oats, and rye was studied. The maximum selenium content was 30 ppm in corn. Selenium content of soils, shales, and vegetation from Cretaceous areas of Alberta, Saskatchewan, and Manitoba is given. Reports on sele-

nium in Montana soil profiles and seleniferous areas of North Dakota are also given. Report on selenium in meteorites shows that selenium content of stony meteorites is higher than that of octahedrite meteorites.

Wootton, W. O. *See* Cahen and Wootton, 1920.

Wright, F. E. *See* Hillebrand and others, 1914.

Zambonini, F., and Coniglio, L., 1925, The presence of soluble compounds of selenium and tellurium as products of the activity of Vesuvius: *Annali osservatorio vesuviano* (3), v. 2, p. 3-6.

A short review is given of the literature on occurrences of selenium and tellurium in volcanic products. A yellow crust at Vesuvius in 1925 consisted of opal, sulfur, chlorides and sulfates of alkali metals with iron, lead, copper, and calcium. An aqueous solution contained 1.25 percent selenium and 0.04 percent tellurium. (*Chem. Abs.*, v. 22, p. 4418.)

Zies, E. G., 1929, The Valley of Ten Thousand Smokes; [Pt.] 1—The fumarolic incrustations and their bearing on ore deposition: *Natl. Geog. Soc. Contrib. Tech. Papers*, v. 1, no. 4, p. 26-27, 40-41.

Selenium is present in sulfur and arsenic pentasulfide incrustations around fumaroles. An incrustation at fumarole 135 contained 0.13 percent selenium.

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Lead Selenate:

- Ahlfeld and Muñoz Reyes 1955
 Goni and Guillemin 1953

Molybdomenite: Ahlfeld and Muñoz Reyes 1955

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- Ahlfeld 1954
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- Ahlfeld 1954
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- Ahlfeld 1954
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- Ahlfeld 1954
 Ahlfeld and Muñoz Reyes 1955

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- Cannon 1952, 1953, 1954, 1956, 1957
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Brazil, San Jose, Minas Geraes, Joseite :
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Burma, Bawdwin mine : Brown, J. C., and Dey 1955

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Cacheuta, Argentina :

- Ahlfeld and Angelelli 1948
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 Mineralogy : Palache and others 1944

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Caliche, Atacama desert, Chile :

- Goldschmidt and Strock 1935
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Orange County :

- Eakle 1914
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- Bradley 1918
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- Bradley 1918
 Eakle 1914
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 Schloen and Elkin 1946

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- Granby, British Columbia: Harloff and Johnson 1933
- Manitoba:
 Byers and Lakin 1939
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- Noranda, Quebec: Schloen and Elkin 1946
- Saskatchewan:
 Byers and Lakin 1939
 Robinson, S. C. 1950
 Robinson, S. C., and Brooker 1952
 Robinson, W. O. 1936
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 Williams and others 1941
- Soils:
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 Byers and Lakin 1939
 Robinson, W. O. 1936
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- Sudbury, Ontario:
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 Schloen and Elkin 1946
- Theano Point, Ontario, uranium: Robinson, S. C. 1950
- Uranium ores: Robinson, S. C. 1950
- Vegetation:
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 Thorvaldson and Johnson 1940
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- Castillite, mineralogy: Palache and others 1944
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Chalcomenite.

- Argentina:
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- Cerro de Cacheuta, Mendoza, Argentina:
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 Damour 1881
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- Goldfields district, Saskatchewan, Canada:
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- Huaco mine, Pacajake, Bolivia:
 Ahlfeld 1954
 Ahlfeld and Muñoz Reyes 1955
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- Huaco mine, Pacajake, Bolivia—Con.
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 Palache 1937
- Mineralogy:
 Friedel and Sarasin 1881a, b
 Palache 1937
 Palache and others 1944
- Chemistry:
 Berzelius 1818
 Gmelins Handbuch anorganischen Chemie 1942
 Hillebrand and others 1953
 Lenher 1923
 Mellor 1930
 Trelease and Beath 1949
- Chile.
 Aguas Blancas, Copiapó, eucarite:
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- Atacama desert, caliche:
 Goldschmidt and Strock 1935
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- Flamenco, Atacama desert, eucarite:
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- Chiviatite.
 Falun, Sweden:
 Johansson 1924
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- Mineralogy:
 Johansson 1924
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- Clausthalite.
 Argentina:
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- Clausthal, Harz, Germany: Frebold 1927a
- Goldfields district, Saskatchewan, Canada:
 Robinson, S. C. 1950
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- Huaco mine, Pacajake, Bolivia:
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- Hypotheek mine, Coeur d'Alene district, Shoshone County, Idaho:
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- Isomorphous with galena:
 Coleman, R. G., and Delevaux 1957
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- Lehrbach, Harz, Germany: Frebold 1927a
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- Tilkerode, Harz, Germany:
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- Trade Dollar mine, Silver City district, Idaho: Piper and Laney 1926
- Trogtal, Harz, Germany:
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- Uranium deposits, Western United States:
 Botinely 1956
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- Zorge, Harz, Germany:
 Frebold 1927a
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- Coal
- Kladno, Czechoslovakia: Rost 1935, 1937
- Liège, Belgium:
 Gibson and Selvig 1944
 Jorisson 1896
- Uranium-bearing, La Ventana mesa, Sandoval County, N. Mex.: Cannon and Starrett 1956
- Cobaltian ferroselite, uranium deposits, Western United States: Weeks, A. D. 1956
- Cobalt-nickel-copper selenide, Goldfields district, Canada: Robinson, S. C., and Brooker 1952
- Cobaltomenite.
- Argentina: Ahlfeld and Angelelli 1948
- Cerro de Cacheuta, Mendoza, Argentina: Bertrand 1882
- Hlaco mine, Pacajake, Bolivia: Palache 1937
- Mineralogy:
 Goni and Guillemín 1953
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- Cobalt selenide minerals.
- Spinel group: Machatschki and Stradner 1952
- Trogtal, Harz, Germany: Ramdohr and Schmitt 1955
- Coke, England: Gibson and Selvig 1944
- Colombia.
- Lelva district soils, State of Boyaca: Ancizar-Sordo 1947
- Soils:
 Ancizar-Sordo 1947
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- Colorado.
- Blue Mountain, Routt (Moffat) County: Gale 1908
- Bull Canyon district, Montrose County: Coleman, R. G., and Delevaux 1957
- Camp Bird mine, Ouray: Headden 1907
- Cortex district, Montezuma County: Coleman, R. G., and Delevaux 1957
- Gilpin County: Goldschmidt 1954
- Gypsum Valley district, San Miguel County: Coleman, R. G., and Delevaux 1957
- Jo Dandy mine, Paradox Valley, Montrose County: Hess 1925
- La Plata Mountains, La Plata County: Coleman, R. G., and Delevaux 1957
- Leadville: Bartlett 1889
- Liberty Bell mine, Telluride: Bastin 1923
- Maybell district, Moffat County: Coleman, R. G., and Delevaux 1957
- Native selenium: Thompson, M. E., and others 1956
- Peanut mine, Bull Canyon, Montrose County: Thompson, M. E., and others 1956
- Placerville district, Montrose County: Coleman, R. G., and Delevaux 1957
- Rico district, Montezuma County: Coleman, R. G., and Delevaux 1957
- Rife district, Garfield County: Coleman, R. G., and Delevaux 1957
- Slack Rock district, San Miguel County: Coleman, R. G., and Delevaux 1957
- Soils:
 Beath 1943
 Beath and others 1939b, 1940, 1941
 Byers 1935, 1936
 Byers and others 1938
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- Uranium, vanadium ores:
 Coleman, R. G., and Delevaux 1957
 Gale 1908
 Hess 1925
 Thompson, M. E., and others 1956
- Uravan district, Montrose County: Coleman, R. G., and Delevaux 1957

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Vegetation :

Beath 1948

Beath and others 1939b, 1940,
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Williams and others 1941

Vulcan mine, Gunnison County, seleni-
ferous sulfur: Trites 1956Wet Mountains, thorium: Christman
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mite: Hillebrand 1905

Colorado Plateau.

Botanical prospecting :

Cannon 1952, 1954, 1957

Cannon and Kleinhampl 1956

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posits :

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Coleman, R. G. 1956

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Miesch and Connor 1956

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Colorado River :

Byers and others 1938

Williams and Byers 1935a

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General :

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DeMent and Dake 1946

Gmelins Handbuch anorganis-
chen Chemie 1942

Halen 1921

Mellor 1930

Painter 1941

Inorganic :

Alber and Harand 1939

Elkin and Margrave 1954

McCullough and others 1946

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Wire, platinum: Howe and Holtz 1919

Copper deposits containing selenium. *See*

Arizona; Australia; Belgian
Congo; Canada; Finland;
Germany; India; Italy; Ja-
pan; Mexico; Montana; Ne-
vada; Northern Rhodesia;
Peru; Spain; Sweden; Tas-
mania; Tennessee; U. S. S. R.;
Utah; Yugoslavia.

Copper refineries, byproduct selenium
analyses :

Benard 1933, 1944

Djingheuzlan 1957

Eilers 1913

Harloff and Johnson 1933

Hess 1913, 1916

Hukki and Runolinna 1950

Imperial Institute 1937

Copper refineries—Continued

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Koeppel and Schellinger 1957

Mosher 1933

Murray 1933

Olivares S. and Girón B. 1956

Schloen and Elkin 1946, 1950,
1954

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Bollden mine, Skellefte district,
Sweden :

Gavelln 1955

Ödman 1941

Mineralogy :

Grasselly 1948

Koch 1948

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Rezbánya-Baita, Hungary :

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Crookesite.

Mineralogy :

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Meyer and Bratke 1924

Palache and others 1944

Skriferum, Sweden: Nordenskiöld
1867a, bCrops. *See* Vegetation.

Crystallography :

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Blanchi 1919

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Muthmann 1890

Palache and others 1944

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Czechoslovakia, Kladno coal: Rost 1935,
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- El Plomo mine, Ojojoma district, Department of Tegucigalpa, Honduras: Dana and Wells 1890
- Mineralogy: Palache and others 1944

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- Coke: Gibson and Selvig 1944
- St. Agnes, Cornwall: Goldschmidt 1954

- Eskebornite, Tilkerode, Harz, Germany: Ramdohr 1949

Eucalrite.

- Aguas Blancas, Copiapó, Chile: Palache and others 1944

Argentina:

- Ahlfeld and Angelelli 1948
- Angelelli 1950
- Fromme 1890
- Klockmann 1891
- Otto 1891

- Cerro de Cacheuta, Mendoza, Argentina: Domeyko 1866

- Flamenco, Atacama desert, Chile: Domeyko 1864

Mineralogy:

- Early 1950
- Fromme 1890
- Klockmann 1891
- Meyer and Bratke 1924
- Otto 1890
- Palache and others 1944
- Short 1931

- Mount Lyell, Tasmania: Edwards 1939
- Skrikerum, Sweden: Nordenskiöld 1867a, b

Uranium deposits, Western United States:

- Coleman, R. G. 1956
- Coleman, R. G., and Delevaux 1957
- Weeks, A. D. 1956

- Willard mine, Murphys district, Calif.: Murdoch and Webb 1956

- Europe, clay shales: Minami 1935

- Ferric selenite in uranium deposits: Trites and Lakin 1956

Ferroselite.

- Tuvinsk Autonomous Territory, U. S. S. R.:

- Buryanova 1956
- Buryanova and Komkov 1955

Uranium deposits, Western United States:

- Coleman, R. G., and Delevaux 1957
- Weeks, A. D. 1956

Finland, Outokumpu copper:

- Hukki and Runolinnä 1950
- Schloen and Elkin 1950, 1954

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- La Roche-Posay, Vienne, mineral waters: Taboury 1909
- vegetation: Taboury 1932

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- Cádek and Dolešal 1957
- Goldschmidt 1937, 1954
- Goldschmidt and Hefter 1933
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- Beath 1936, 1937, 1943
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- Knight, S. H. 1937
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- Bad Grund: Goldschmidt 1954
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- Caroline mine, Harz: Frebold 1927b
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- Mansfeld, copper:**
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- Aurora district, Nev.: Hill, J. M. 1915
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 Radjang Lebong, Sumatra: Lindgren 1933
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- Mineralogy:
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- Germany: Genth 1891
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- Carpathian Basin, csiklovalte, tetrady-
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- Agullarite, De Lamar silver mine,
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Yankee Fork district, Custer County :
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- Argentina:
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- Goldfields district, Saskatchewan, Canada:
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Lehrbachite.

- Hars, Germany: Frebald 1927a
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- Culebras, Mexico: Brush 1881
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Mining Journal 1953
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Schloen and Elkin 1946, 1950,
1954
Stone and Caron 1954
Tyler 1952

Meteorites:

Byers 1938
Goldschmidt 1954
Strock 1935
Warren 1888
Williams and others 1941

Mexico.

Agullarite, San Carlos mine, Guana-
juato: Genth 1891

Bismuthinite, Guanajuato: Genth 1891

Cananea, copper: Sargent 1955

Chihuahua, soil: Williams and others
1940

Culebras quicksilver:

Brush 1881
Del Rio 1828, 1836

General: González Reyna 1956

Guadalcázar, quicksilver:

Brush 1881
Burkart 1866, 1872
Petersen 1872

Guanajuatite, Guanajuato:

Fernandez 1877
Frenzel 1874
Mallet 1878
Peacock and Berry 1940
Ramdohr 1948

Mexico—Continued

Guanajuato, silver:

Aguilero 1901
Byers 1937b
Castillo 1873, 1874
Fernandez 1877
Frenzel 1874
Genth 1891
González Reyna 1956
Mallet 1878
Miller and Brown 1938
Peacock and Berry 1940
Ramdohr 1948
Williams and others 1940

Huitzaco, Guerrero, quicksilver:
de la Peña 1944

McAllister and Hernandez Ortiz
1945

Vaupell 1938

Irapuato, soil:

Byers 1937b
Miller and Brown 1938

Juarez, soil: Williams and others 1940

Metacinnabar:

Brush 1881
Burkart 1866, 1872
de la Peña 1944
McAllister and Hernandez Ortiz
1945
Petersen 1872
Vaupell 1938

Pachuca: Tyler 1952

Paraguanajuatite, Guanajuato: Ram-
dohr 1948

Riolite, Culebras: Del Rio 1828, 1836

San Onofre, quicksilver: Brush 1881

Soil:

Byers 1937b
Miller and Brown 1938
Swaine 1955
Williams and others 1940

Tlemannite:

Brush 1881
de la Peña 1944
McAllister and Hernandez Ortiz
1945

Vaupell 1938

Torreón, soil: Williams and others
1940

Mineralogy:

Borgström 1914-15
Clarke and Washington 1924
DeMent and Dake 1946
Earley 1949, 1950
Goni and Guillemin 1953
Hess 1916
Muthmann 1890
Palache and others 1944
Short 1931

See also various minerals.

Minerals. *See* particular minerals.

Minnesota, glacial deposits: Searight and
Moxon 1945

Missouri, soil :

- Beath and others 1940
 Slater and others 1937
 Swaine 1955

Molybdomente.**Argentina :**

- Ahlfeld and Angelelli 1948
 Bertrand 1882
 Goni and Gullemin 1958

Cerro de Cacheuta, Mendoza, Argentina :

- Bertrand 1882
 Goni and Gullemin 1953

Huaco mine, Pacajake, Bolivia : Ahlfeld and Muñoz Reyes 1955**Mineralogy :**

- Goni and Gullemin 1953
 Palache and others 1944

Trogtal, Harz, Germany : Goni and Gullemin 1953**Montana.****Butte copper ore :**

- Hess 1916
 Weed 1912

Soil :

- Byers 1935, 1936
 Swaine 1955
 Williams and others 1940, 1941

Vegetation :

- Beath and others 1939b, 1940, 1941
 Williams and others 1940, 1941

Native selenium.**Henry Mountains, Utah : Hillebrand and others 1914****Huaco mine, Pacajake, Bolivia :**

- Ahlfeld 1954
 Ahlfeld and Muñoz Reyes 1955
 Block and Ahlfeld 1937

Lucky Mc mine, Fremont County, Wyo. : Grutt 1956**Mineralogy : Palache and others 1944****Paradox Valley, Utah : Hillebrand and others 1914****Peanut mine, Montrose County, Colo. : Thompson, M. E., and others 1956****Road Hog No. 1A mine, Fall River County, S. Dak. : Thompson, M. E., and others 1956****Thompsons district, Utah :**

- Hillebrand and others 1914
 Thompson, M. E., and others 1956

Trogtal, Harz, Germany : Ramdohr and Schmitt 1955**United Verde mine, Jerome district, Ariz. : Palache 1934****Uranium-vanadium deposits, Western United States :**

- Coleman, R. G. 1956
 Coleman, R. G., and Delevaux 1957

Native selenium—Continued**Uranium-vanadium—Continued**

- Grutt 1956
 Hillebrand and others 1914
 Thompson, M. E., and others 1956
 Trites and Lakin 1956

Naumannite.**Argentina :**

- Ahlfeld and Angelelli 1948
 Angelelli 1950

Colquechaca, Bolivia : Bannister and Hey 1937**De Lamar mine, Silver City district, Idaho : Shannon 1920a, b ; 1926****Gravel Range district, Lemhi County, Idaho : Shannon 1926****Huaco mine, Pacajake, Bolivia : Ahlfeld and Muñoz Reyes 1938, 1955****Ahlfeld 1954****Bannister and Hey 1937****Block and Ahlfeld 1937****Herzenberg and Ahlfeld 1935****Idaho—Maryland mine, Grass Valley, Calif. : Murdoch and Webb 1956****Jarbridge district, Nev. : Schrader 1923****Mineralogy :**

- Earley 1950
 Palache and others 1944
 Short 1931

Parker Mountain district, Lemhi County, Idaho : Shannon 1926**Republic district, Wash. : Thompson, R. M. 1954****“Roter Bär” mine, St. Andreasberg, Harz, Germany : Gellmann and Rose 1928****Silver City district, Owyhee County, Idaho :****Piper and Laney 1926****Shannon 1920a, b ; 1926****Tilkerode, Harz, Germany : Frebald 1927a****Yankee Fork district, Custer County, Idaho : Shannon 1926****Nebraska.****Pierre formation : Byers 1935****Soil :**

- Byers 1935
 Swaine 1955

Vegetation :

- Beath and others 1941
 Williams and others 1941

Nevada.**Aurora district : Hill 1915****Buckskin Peak, quicksilver, National district, Humboldt County : Roberts 1940**

Nevada—Continued

Clark County, soil: Lakin and Byers
1941

Comstock Lode, Virginia City, agulla-
rite: Coats 1936

Ely district: Spencer 1917

Jarbridge district, naumannite: Schrader
1923

National district, Humboldt County, hot
springs:

Lindgren 1915

Roberts 1940

Soil:

Lakin and Byers 1941, 1948

Swaine 1955

Tonopah district:

Bastin and Laney 1918

Spurr 1905a, b

Vegetation:

Beath and others 1939b

Lakin and Byers 1948

New Jersey, soil:

Lakin and Byers 1941

Swaine 1955

New Mexico.

Botanical prospecting:

Cannon 1953

Cannon and Starrett 1956

Cretaceous formations: Hershey 1945

Grants area, uranium:

Cannon 1953

Coleman, R. G., and Delevaux
1957

Trites 1956

La Ventana mesa, uranium-bearing coal,

Sandoval County: Cannon and

Starrett 1956

Soil:

Byers 1935, 1936

Byers and others 1938

Hershey 1945

Swaine 1955

Vegetation:

Beath and others 1939b, 1940,
1941

Byers 1936

Hershey 1945

New Zealand.

Great Barrier, Hauraki Goldfields:
Allen 1900

Seleniferous sulfur: Brown, G. V. 1917

Soil: Swaine 1955

North Carolina.

Soil:

Byers 1936

Slater and others 1937

Vegetation: Byers 1936

North Dakota.

Soil:

Lakin and Byers 1948

Swaine 1955

Williams and others 1941

North Dakota—Continued

Vegetation:

Beath and others 1939b, 1940,
1941

Williams and others 1941

Northern Rhodesia, N'Kana, Mufalira,
copper: Schloen and Elda
1950, 1954

Norway.

Birtavarre district, Troms, sulfide
ores: Vokes 1957

Kongsberg and Numedal, clausthalite:
Heier 1953

Leksdals sedimentary pyrite: Carstens
1941a, b, c

Løkken-Grong hydrothermal pyrite:
Carstens 1941a, b, c

North Vinoren: Heier 1953

Occurrence, general:

Beyschlag and others 1914

Caben 1919

Clarke and Washington 1924

DeMent and Dake 1946

Gmellins Handbuch anorgan-
ischen Chemie 1942

Goldschmidt 1954

Halen 1921

Hess 1909, 1916

Hunting 1956

Iron Age 1952b

Lenher 1923

Lindgren 1933

Mellor 1930

Milligan 1933

Mining Journal 1953

Sanderson 1940

Santmyers 1930

Sargent 1954, 1955a, b

Stone and Caron 1954

Trites 1956

Tyler 1952

Ocean. *See* Water.

Ocean floor deposits. *See* Sea-floor deposits.

Ohio, soil: Slater and others 1937

Oklahoma, soil:

Byers 1935

Lakin and Byers 1941

Slater and others 1937

Swaine 1955

Onofrite. *See* Metacinnabar.

Oregon.

Soil: Lakin and Byers 1948

Vegetation: Beath and others 1939b

Oxidation zone:

Coleman, R. G., and Delevaux
1957

Goldschmidt and Strock 1935

Strock 1935

Trites and Lakin 1956

- Paraguanajuatite.**
Guanajuato, Mexico: Ramdohr 1948
Mineralogy:
Barley 1950
Ramdohr 1948
- Penroseite (blockite).**
Colquechaca, Bolivia:
Bannister and Hey 1937
Gordon 1925
Hlaco mine, Pacajake, Bolivia:
Ahlfeld 1954
Ahlfeld and Muñoz Reyes 1938,
1955
Bannister and Hey 1937
Block 1937
Herzenberg and Ahlfeld 1935
Palache 1937
Mineralogy:
Barley 1950
Gordon 1925
Palache and others 1944
- Peru.**
Andes, lead-copper selenides: Pisani
1879
Casapalca, Cerro, Morococha, and Yau-
ricocha mines, Cerro de Pasco:
Olivares S. and Girón B. 1956
Schloen and Elkin 1954
Chachani, Arequipa, sulfur: Dios Gue-
vara 1940
La Oroya smelter:
Koepfel and Schellinger 1957
Olivares S. and Girón B. 1956
- Phosphates.**
General:
Rader and Hill 1935
[U. S.] National Research Coun-
cil, Materials Advisory Board,
Panel on Selenium: 1956
Phosphoria formation: Beath and
others 1937b, 1946
- Platinum compounds, bibliography:** Howe
and Holts 1919
- Platynite, mineralogy:** Palache and others
1944
- Poisoning:**
Knight, H. G. 1935
Milligan 1953
Moxon 1937
Moxon and Rhian 1943
Stone and Caron 1954
Trelease and Beath 1949
- Properties:**
Ancel 1919
Bianchi 1919
Brown, F. C. 1914
Cahen 1919
Cahen and Wootton 1920
DeMent and Dake 1946
Elkin and Margrave 1954
Hunting 1956
- Properties—Continued**
Imperial Institute 1937
Mellor 1930
Milligan 1953
Painter 1941
Sanderson 1940
Santmyers 1930
Sargent 1954, 1955a
Saunders 1900
Stone and Caron 1954
- Puerto Rico.**
Soil:
Byers 1936
Byers and others 1938
Lakin and others 1938
Swaine 1955
Williams and others 1940
Vegetation: Byers 1936
- Pyrites.** *See* Sulfide minerals.
- Quicksilver deposits containing selenium.**
See Argentina; California;
Mexico; Nevada; Utah.
- Riolite, Culebras, Mexico:** Del Rio 1828,
1836
- Seafloor deposits.**
Bering Sea:
Edgington and Byers 1942
Williams and Byers 1935b
Caribbean Sea at Bartlett Deep: Edg-
ington and Byers 1942
Falmouth, England: Williams and
others 1940
Gulf of California: Lakin and Byers
1941
Halifax, Nova Scotia: Williams and
others 1940
North Atlantic: Edgington and Byers
1942
Ocean City, Md.: Edgington and Byers
1942
Pacific Ocean off southern California:
Lakin and Byers 1941
- Sedimentary rocks, concentration in:**
Krauskopf 1955
See also Geochemistry; Geologic forma-
tions; Sulfide minerals.
- Seebachite, Harz, Germany:** Frebold 1927a
- Selenide of iron, hydrous, Hlaco mine,
Pacajake, Bolivia:** Ahlfeld
and Muñoz Reyes 1955
- Seleniferous formations.** *See* Geologic for-
mations, seleniferous.
- Seleniferous galenobismuthite.** *See* Weibul-
lite.
- Seleniferous sulfur.**
Chachani, Arequipa, Peru: Dios Guevara
1940
Garginti, Italy: Marvin and Schumb
1935

Seleniferous sulfur—Continued

- General:
 Kaiser 1954
 Muthmann 1890
- Japan:
 Divers and Shimidsu 1883
 Jimbo 1899
 Klason and Mellquist 1921b
 Smith 1915
- Kilauea, Hawaii: Brown, G. V. 1916, 1917
- Krisuvik, Iceland: Friend and Allchin 1941
- Lipari Island, Italy:
 Brown, G. V. 1917
 Clarke 1924
 Quercigh 1925
- Louisiana: Marvin and Schumb 1935
- Mineralogy: Palache and others 1944
- New Zealand: Brown, G. V. 1917
- Papandajan, West-Java: Gellmann and Biltz 1931
- Sicily, Italy:
 Brown, G. V. 1917
 Klason and Mellquist 1912b
 Marvin and Schumb 1935
- Texas: Marvin and Schumb 1935
- Valley of Ten Thousand Smokes, Alaska: Zies 1929
- Vulcan mine, Gunnison County, Colo.: Trites 1956

Selenoslegentite. *See* Slegentite.

Selenovaesite. *See* Vaesite.

Selenokobaltblei, Harz, Germany: Frebald 1927a

Selenocosalite. *See* Cosalite.

Selenokobellite. *See* Kobellite.

Selenollite

- Argentina:
 Ahlfeld and Angelelli 1948
 Bertrand 1882
- Cerro de Cacheuta, Mendoza, Argentina:
 Bertrand 1882
- Hlaco mine, Pacajake, Bolivia:
 Ahlfeld 1954
 Ahlfeld and Mufios Reyes 1955
 Palache 1937
- Mineralogy: Palache and others 1944

Selenquecksilberkupferblei, Zorge, Germany: Olsacher 1927

Selenotellurium.

- El Plomo mine, Ojojoma district, Tegucigalpa, Honduras: Dana and Wells 1890
- Faczebaja, Hungary: Dana and Wells 1890
- Mineralogy: Palache and others 1944

Slegentite, Shinkolobwe mine, Belgian Congo: Derriks and Vaes 1956

Silver deposits containing selenium. *See* Argentina; Bolivia; Germany; Idaho; Mexico; Nevada; Washington.

Silver-gold selenide.

- Aurora, Nev.: Hill 1915
- Monument mine, Myers Cove, Gravel Range district, Lemhi County, Idaho: Umpleby 1913a
- Republic, Wash.:
 Bancroft 1914
 Umpleby 1910
- Tonopah, Nev.:
 Bastin and Laney 1918
 Spurr 1905a, b

Soils, seleniferous.

- Absorption and content, factors affecting selenium:
 Byers and Knight 1935
 Hurd-Karrer 1934, 1935a, b
 Moxon 1937
 Moxon and others 1939

Analysis:

- Robinson, W. O. 1933, 1945
 Robinson, W. O., and others 1934

Arizona:

- Beath and others 1939b, 1940, 1941
 Byers 1935
 Byers and others 1938
 Moore, R. T. 1953
 Swaine 1955

California:

- Beath and others 1939b, 1940, 1941
 Swaine 1955

Canada:

- Byers 1936
 Byers and Lakin 1939
 Robinson, W. O. 1936
 Swaine 1955
 Walker and others 1941
 Williams and others 1941

Colombia:

- Ancizar-Sordo 1947
 Swaine 1955

Colorado:

- Beath 1943
 Beath and others 1939b, 1940, 1941
 Byers 1935, 1936
 Byers and others 1938
 Swaine 1955

Cuba: Byers 1936

District of Columbia: Lakin and Byers 1941

Form of selenium in:

- Bear 1955
 Beath and Eppson 1947
 Beath and others 1937a, 1939a
 Jacks and Scherbatoff 1940

Soils, seleniferous—Continued**Form of selenium in—Continued**

Lakin and others 1938
 Olson and others 1942a, b
 Olson and Moxon 1939
 Painter 1941
 Trelease 1945
 Williams and Byers 1936

General:

Bear 1955
 Byers 1935, 1936, 1937a
 Byers and Knight 1935
 Byers and others 1938
 Jacks and Scherbatoff 1940
 Knight, H. G. 1935
 Lakin and Byers 1941, 1948
 Miller 1937
 Moxon and Rhian 1948
 Painter 1941
 Robinson, W. O. 1936
 Sargent 1954, 1955a, b
 Swaine 1955
 Trelease and Beath 1949
 Williams 1939
 Williams and others 1940, 1941

Glacial:

Searight and Moxon 1945
 Searight and others 1946
 Walker and others 1941

Hawaii:

Byers and others 1936, 1938
 Hance 1939
 Hough and others 1941
 Lakin and others 1938
 Swaine 1955
 Williams and others 1940

Idaho:

Beath and others 1939b
 Lakin and Byers 1948
 Swaine 1955

Iowa: Slater and others 1937**Ireland:**

Fleming and Walsh 1957
 Swaine 1955
 Walsh and others 1951

Japan:

Swaine 1955
 Tsuge and Terada 1950

Kansas:

Byers 1935, 1936
 Slater and others 1937
 Swaine 1955

Maryland: Lakin and Byers 1941**Mexico:**

Byers 1937b
 Miller and Brown 1938
 Swaine 1955
 Williams and others 1940

Minnesota: Searight and Moxon 1945**Missouri:**

Beath and others 1940
 Slater and others 1937
 Swaine 1955

Soils, seleniferous—Continued**Montana:**

Beath and others 1939b, 1940,
 1941
 Byers 1935, 1936
 Swaine 1955
 Williams and others 1940, 1941

Nebraska:

Beath and others 1941
 Byers 1935, 1936
 Swaine 1955

Nevada:

Beath and others 1939b
 Lakin and Byers 1941, 1948
 Swaine 1955

New Jersey:

Lakin and Byers 1941
 Swaine 1955

New Mexico:

Beath and others 1939b, 1940,
 1941
 Byers 1935, 1936
 Byers and others 1938
 Hershey 1945
 Swaine 1955

New Zealand: Swaine 1955**Nontoxic:**

Byers and others 1936
 Hough and others 1941
 Lakin and others 1938

North Carolina:

Byers 1936
 Slater and others 1937

North Dakota:

Beath and others 1939b, 1940,
 1941

Lakin and Byers 1948

Swaine 1955

Williams and others 1941

Ohio: Slater and others 1937**Oklahoma:**

Byers 1935
 Lakin and Byers 1941
 Slater and others 1937
 Swaine 1955

Oregon:

Beath and others 1939b
 Lakin and Byers 1948

Origin of selenium in soil:

Beath and others 1939a
 Byers 1937a, b
 Byers and others 1936
 Moxon 1937

Pierre soil:

Byers 1934
 Searight and others 1946-47

Puerto Rico:

Byers 1936
 Byers and others 1938
 Lakin and others 1938
 Swaine 1955
 Williams and others 1940

South Africa: Robinson, W. O. 1936

Soils, seleniferous—Continued

South Dakota :

Beath and others 1939b, 1941
 Byers 1935, 1936
 Franke 1937
 Miller and Byers 1935
 Moxon 1937
 Moxon and others 1938, 1939
 Olson and Moxon 1939
 Olson and others 1940, 1942b
 Pugsley and Cox 1937
 Searight and Moxon 1945
 Searight and others 1946, 1946-47
 Swaine 1955

Sulfur, effect on :

Franke and Painter 1937
 Hurd-Karrer 1934, 1935b
 Jacks and Scherbatoff 1940

Texas :

Beath and others 1939b, 1940, 1941
 Byers 1936
 Slater and others 1937
 Swaine 1955
 Williams and others 1940

Trace elements :

Slater and others 1937
 Swaine 1955

U. S. S. R. :

Swaine 1955
 Vinogradov 1945

Utah :

Beath and others 1939b, 1940, 1941
 Byers 1935
 Byers and others 1938
 Lakin and Byers 1948
 Swaine 1955

Vegetation, effect on : Miller 1937

Washington : Slater and others 1937

Western United States :

Beath and others 1939a, b, 1940, 1941
 Byers 1935, 1936
 Trelease and Beath 1949

Wisconsin : Slater and others 1937

Wyoming :

Beath 1936, 1937
 Beath and Eppson 1947
 Beath and Gilbert 1936
 Beath and others 1934a, b, 1935, 1936, 1937b, 1940, 1941, 1946
 Byers 1936
 Knight, S. H. 1937
 Swaine 1955
 Williams and others 1941

South Africa, soils and wheat: Robinson, W. O. 1936

South Dakota.

Cretaceous formations :

Moxon 1937
 Moxon and others 1938, 1939

South Dakota—Continued

Custer County, seleniferous spring : Miller and Byers 1935

Edgemont district, Fall River County, uranium: Coleman, R. G., and Delevaux 1957

Fort Randall area : Pugsley and Cox 1937

General : Pugsley and Cox 1937

Glacial deposits :

Searight and Moxon 1945
 Searight and others 1946

Gregory County, soil: Franke and Painter 1937

Niobrara formation :

Moxon 1937
 Moxon and others 1939
 Pugsley and Cox 1937

Pierre formation :

Byers 1935
 Moxon 1937
 Moxon and others 1939
 Olson and Moxon 1939
 Pugsley and Cox 1937
 Searight and others 1946-47

Road Hog No. 1A mine, Fall River County, native selenium: Thompson, M. E., and others 1956

Seleniferous formations :

Moxon 1937
 Moxon and others 1938, 1939
 Pugsley and Cox 1937

Soil :

Byers 1935, 1936
 Franke and Painter 1937
 Miller and Byers 1935
 Moxon 1937
 Moxon and others 1938, 1939
 Olson and Moxon 1939
 Olson and others 1940, 1942b
 Pugsley and Cox 1937
 Searight and others 1946-47
 Swaine 1955

Stratigraphic distribution :

Moxon and others 1938, 1939
 Searight and others 1946-47

Vegetation :

Beath and others 1939b, 1941
 Miller and Byers 1935
 Moxon 1937
 Moxon and others 1938, 1939
 Olson and Moxon 1939
 Olson and others 1940, 1942
 Pugsley and Cox 1937
 Williams and others 1941

Spain.

Carmenes mine, Villamanin, León, villamaninite:
 Ramdohr 1937
 Schoeller and Powell 1920

Rio Tinto, Huelva, umangite:
 Bateman 1927

Harloff and Johnson 1933

Stilleite: Ramdohr 1956

Sulfide minerals.

Australia: Edwards and Carlos 1954
General:

Čadek and Doležal 1957
 Fielscher 1955
 Kaiser 1954
 Lakin and Byers 1948
 Noddack 1936
 Schmidt 1925

Hydrothermal:

Carstens 1941a, b, c
 Edwards and Carlos 1954
 Saito 1953

Italy: Rockenbauer and Schroll 1956
Japan:

Saito 1953
 Tsuge and Terada 1950

Norway:

Carstens 1941a, b, c
 Vokes 1957

Primary magmatic:

Goldschmidt 1954
 Goldschmidt and Strock 1935
 Strock 1935

Pyrites:

Beath and others 1935
 Byers 1935
 Čadek and Doležal 1957
 Carstens 1941a, b, c
 Edwards and Carlos 1954
 Gavelin 1939
 Industrial and Engineering
 Chemistry 1916
 Klason and Mellquist 1912a
 Lakin and Byers 1948
 Rockenbauer and Schroll 1956
 Tsuge and Terada 1950
 Vakhrushev 1940
 Williams and Byers 1934

Sedimentary:

Beath and others 1935
 Byers 1935
 Carstens 1941a, b, c
 Coleman, R. G. 1956
 Coleman, R. G., and Delevaux
 1957
 Edwards and Carlos 1954
 Weeks, A. D. 1956
 Williams and Byers 1934

Southeastern United States: Williams
 and Byers 1934

Spain: Bateman 1927

Sweden:

Bergenfelt 1953
 Gavelin 1939, 1955
 Landergren 1935

U. S. S. R.: Filipenko 1910

Western United States:

Beath and others 1935
 Byers 1935
 Coleman, R. G. 1956
 Coleman, R. G., and Delevaux
 1957
 Weeks, A. D. 1956
 Williams and Byers 1934

Sulfur, addition to seleniferous soil:

Franke and Painter 1937
 Hurd-Karrer 1934, 1935a, b
See also Seleniferous sulfur.

Sumatra.

Leborg Soelit, gold: Truscott 1901-02
 Radjang Leborg gold mine:
 Beyschlag and others 1914
 Lindgren 1933
 Truscott 1901-02

Sweden.

Bersellanite, Skrikerum:
 Frebald 1927b
 Nordenskiöld 1867a, b
Boliden copper mine, Skellefte district:
 Bergenfelt 1953
 Gavelin 1955
 Grip and Ödman 1938, 1941
Chiviatite, Falun:
 Johansson 1924
 Peacock and Berry 1940
Cosalite, Boliden mine:
 Gavelin 1955
 Ödman 1941
Crookesite, Skrikerum: Nordenskiöld
 1867a, b
Eucalrite, Skrikerum: Nordenskiöld
 1867a, b

Falun:

Atterburg 1874
 Bersellius 1818
 Genth 1885
 Johansson 1924
 Nordström 1879, 1880
 Peacock and Berry 1940
 Weibull 1885

Garpenberg sulfide ores: Landergren
 1935

Klockmannite, Skrikerum: Ramdohr
 1928

Kobellite, Boliden mine: Gavelin 1955;
 Ödman 1941

Malåns district, Västerbotten: Gavelin
 1939

Rudtjebäcken mine, Skellefte district:
 Gavelin 1954

Saxberg, sulfide ores: Landergren 1935
Skellefte district:

Bergenfelt 1953
 Gavelin 1954, 1955
 Grip and Ödman 1942
 Ödman 1938, 1941

Skrikerum:

Frebald 1927b
 Nordenskiöld 1867a, b
 Ramdohr 1928

Sulfide minerals:

Bergenfelt 1953
 Gavelin 1939, 1955
 Landergren 1935

Telluride-bearing pegmatite, Rudtjebäcken: Gavelin 1954

- Sweden—Continued
 Weibullite, Falun :
 Genth 1885
 Peacock and Berry 1940
 Weibull 1885
 Wittite, Falun: Johansson 1924
- Tasmania, Mount Lyell, bersellanite or eucalrite: Edwards 1939
- Tennessee, Ducktown copper ores: Emmons and Laney 1926
- Tetradymite.
 Carpathian Basin, Hungary: Koch 1948
 Mineralogy: Palache and others 1944
 Tellurium gold mine, Fluvanna and Goochland Counties, Va.:
 Genth 1855
 Taber 1913
 Trall Creek, Halley quadrangle, Idaho: Shannon 1925
 White Hall gold mine, Spotsylvania County, Va.:
 Fisher 1849
 Genth 1855
 Whitehorn, Fremont County, Colo.: Hillebrand 1905
- Texas.
 Soil:
 Beath and others 1940
 Byers 1936
 Slater and others 1937
 Swaine 1955
 Williams and others 1940
 Sulfur: Marvin and Schumb 1935
 Vegetation:
 Beath and others 1939b, 1940, 1941
 Byers 1936
 Williams and others 1940
- Thailand, Nong Phai lead mine: Brown, G. F., and others 1952
- Thorium, Wet Mountains, Colo.: Christman and others 1953
- Tiemannite.
 Argentina:
 Ahlfeld and Angelelli 1948
 Angelelli 1950
 California:
 Bradley 1918
 Eakle 1914
 Murdoch and Webb 1956
 Schrader and others 1917
 Germany:
 Frebald 1927a
 Geilmann and Rose 1928
 Olsacher 1927
 Goldfields district, Saskatchewan, Canada: Robinson, S. C. 1950
- Tiemannite—Continued
 Hiaco mine, Pacajake, Bolivia :
 Ahlfeld 1954
 Ahlfeld and Muñoz Reyes 1955
 Lucky Boy mine, Marysville, Piute County, Utah:
 Becker 1888
 Bethke 1956
 Brush 1881
 Butler and others 1920
 McCaskey 1912
 Penfield 1885
 Schrader and others 1917
- Mexico:
 Brush 1881
 de la Peña 1944
 McAllister and Hernandez Ortis 1945
 Vaupell 1938
 Mineralogy:
 Bethke 1956
 Earley 1950
 Palache and others 1944
 Penfield 1885
 Short 1931
- Tilkerodite, mineralogy: Palache and others 1944
- Trogtalite, Trogtal, Harz, Germany: Ramdohr and Schmitt 1955
- Tuff, seleniferous, Wyoming:
 Beath and others 1946
 Everett and Bauerle 1957
 Love 1954
 Tyler 1952
 [U. S.] National Research Council, Materials Advisory Board, Panel on Selenium 1956
- Umangite.
 Argentina:
 Ahlfeld and Angelelli 1948
 Angelelli 1950
 Bodenbender 1902
 Klockmann 1891
 Goldfields district, Saskatchewan, Canada:
 Robinson, S. C. 1950
 Robinson, S. C., and Brooker 1952
- Harz, Germany:
 Frebald 1927a
 Geilmann and Rose 1928
 Olsacher 1927
- Hiaco mine, Pacajake, Bolivia: Ahlfeld and Muñoz Reyes 1938
- Mineralogy:
 Earley 1950
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Utah—Continued

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McCaskey 1912
Penfield 1885
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Moss Back member, Chinle formation:
Keys and White 1956
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Park City region: Lakin and Byers 1948
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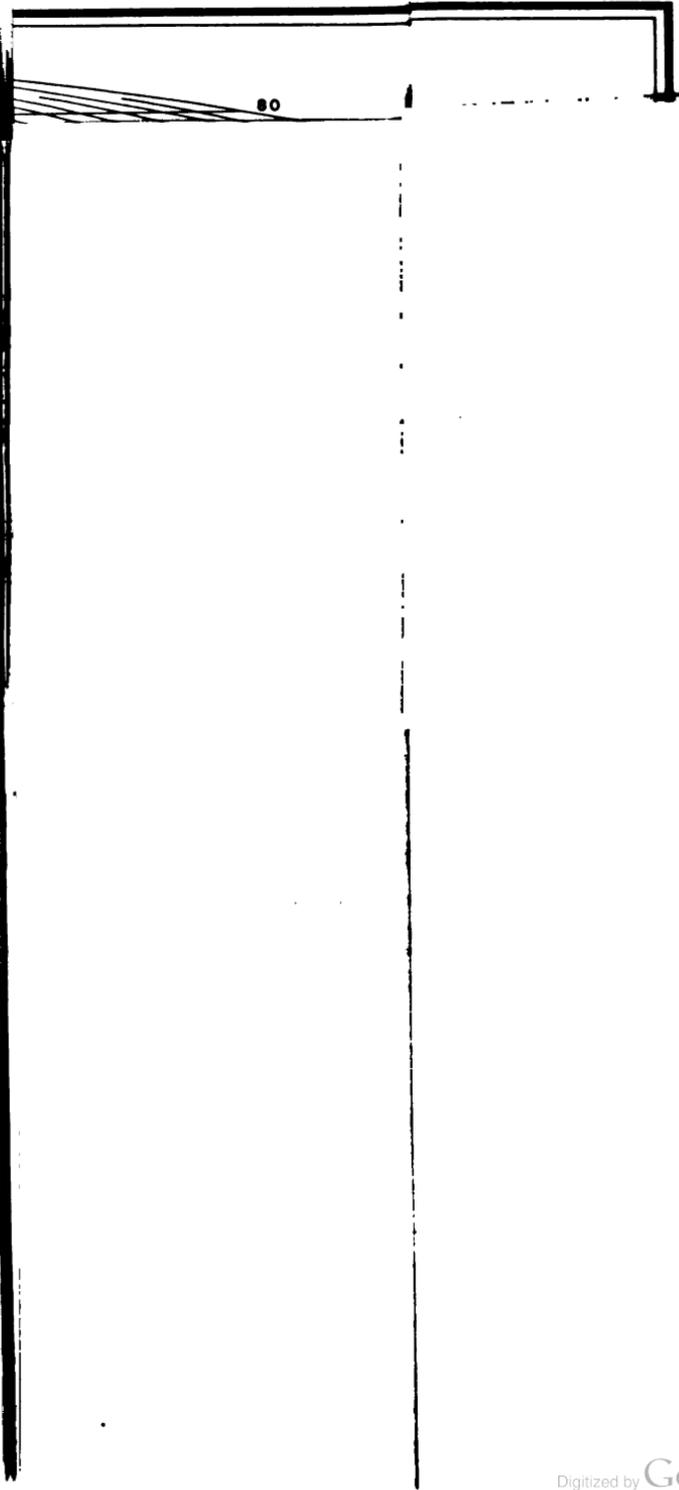
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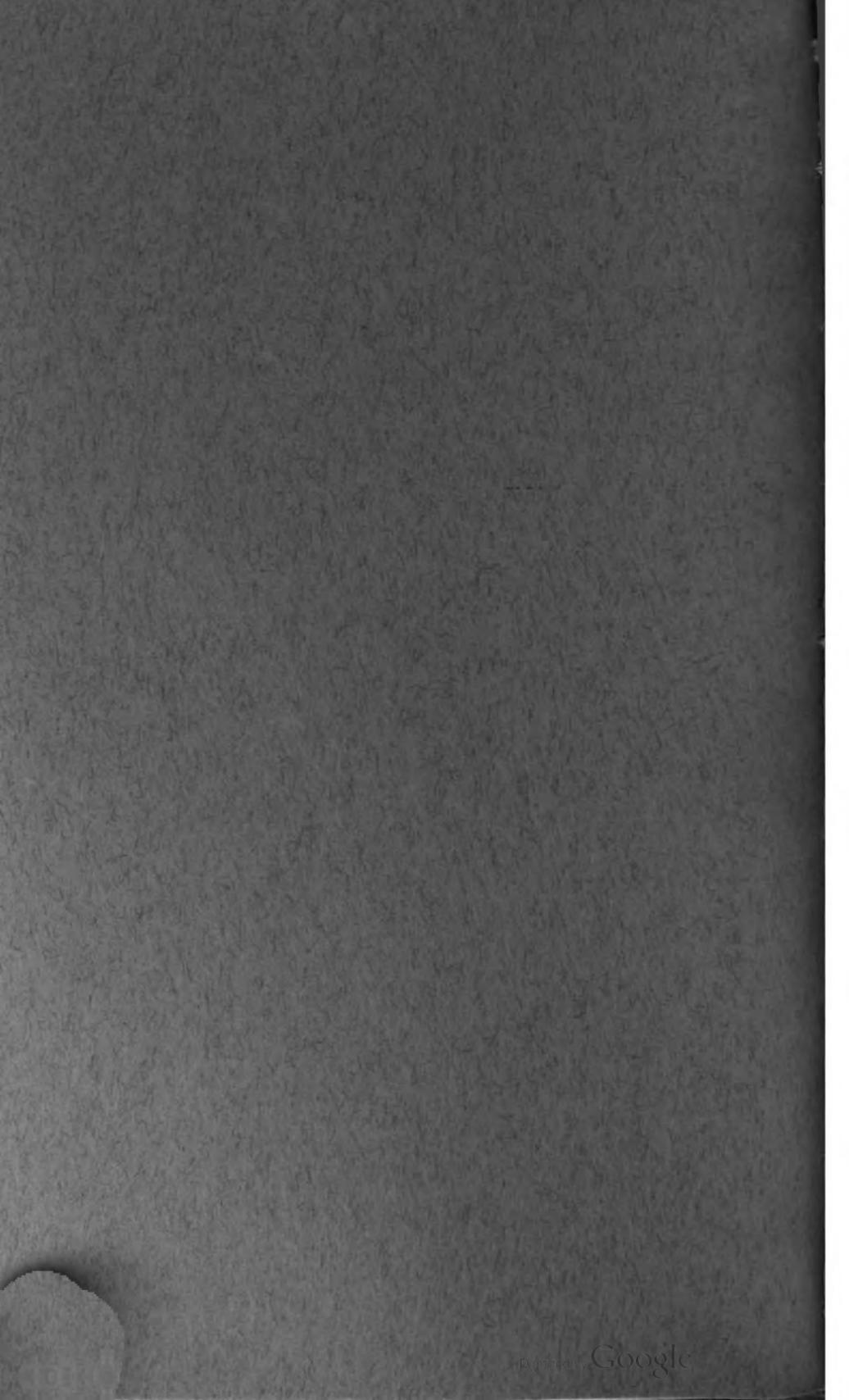
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Selected Bibliography of Andalusite, Kyanite Sillimanite, Dumortierite Topaz, and Pyrophyllite in the United States

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Selected Bibliography of Andalusite, Kyanite Sillimanite, Dumortierite Topaz, and Pyrophyllite in the United States

By AGNES B. GRAMETBAUR

CONTRIBUTIONS TO BIBLIOGRAPHY OF MINERAL
RESOURCES

G E O L O G I C A L S U R V E Y B U L L E T I N 1 0 1 9 - N

*Contains references, to December 31,
1958, on geology, mineral synthesis,
geographic occurrence, and technology
and uses*



UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1959

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

**For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C. - Price 45 cents; (paper cover)**

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ILLUSTRATION

PLATE 6. Map of the United States showing the location of major deposits of the kyanite group of minerals and pyrophyllite..... In pocket

III

CONTRIBUTIONS TO BIBLIOGRAPHY OF MINERAL RESOURCES

SELECTED BIBLIOGRAPHY OF ANDALUSITE, KYANITE SILLIMANITE, DUMORTIERITE, TOPAZ, AND PYROPHYLLITE IN THE UNITED STATES

By AGNES B. GRAMETBAUR

ABSTRACT

The bibliography is a compilation of 566 references on the kyanite, or sillimanite, group of minerals and pyrophyllite to December 31, 1958. The publications are listed alphabetically by author (or authors) with full title and publication data. A brief description of the occurrence of the minerals in the United States and their uses precedes the bibliography.

The index is arranged alphabetically by mineral. Under each mineral the index is further subdivided by geographic areas (State and county) and by subjects, which include general, geology, mineral synthesis, occurrence (geographic), and technology and uses.

A complete list of periodicals and serials examined and a map of the United States, showing the location of major deposits of the kyanite group of minerals and pyrophyllite, are included.

INTRODUCTION

Among the nonclay high-alumina minerals that are most suitable for refractory materials are those of the kyanite group, also called the sillimanite group. These minerals include andalusite, kyanite, and sillimanite, which have the same chemical composition ($\text{Al}_2\text{O}_3 \cdot \text{SiO}_2$) but different crystallographic, physical, and optical properties; and dumortierite ($8\text{Al}_2\text{O}_3 \cdot \text{B}_2\text{O}_3 \cdot 6\text{SiO}_2 \cdot \text{H}_2\text{O}$) and topaz ($[\text{Al}(\text{F},\text{OH})_2]\text{SiO}_4$), which are closely allied in composition and thermal behavior.

All these minerals disassociate upon heating to high temperatures to form mullite ($3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$) and free silica. Kyanite alters at the lowest temperature, $1,100^\circ$ to $1,480^\circ\text{C}$, sillimanite at the highest, $1,550^\circ$ to $1,650^\circ\text{C}$, andalusite at $1,350^\circ$ to $1,450^\circ\text{C}$, dumortierite at $<1,000^\circ$ to $1,250^\circ\text{C}$, and topaz at $<1,000^\circ$ to $1,480^\circ\text{C}$ (Riddle and Foster, 1949, p. 897). Mullite is the only form of silica and alumina that is stable at high temperatures. Pure mullite, which is chemi-

cally inert and stable to about 1,810°C, is an important refractory. The compound derives its name from the Island of Mull, Scotland, where the only natural occurrence of the mineral is known.

The ability of the kyanite group of minerals to form mullite upon firing accounts for their importance as raw materials for the manufacture of high-alumina refractories and ceramic articles. Although they represent a small percentage of the total tonnage of refractories used in the United States, mullite refractories are especially important because they maintain their strength to high temperatures, they have a low rate of thermal expansion and can withstand the effects of rapid temperature changes, and they are resistant to the corrosive action of certain fluxing agents.

All the minerals of the kyanite group have been used for refractory manufacture; kyanite, however, has been most widely used because it is more abundant and more commonly occurs in minable deposits than the other minerals. At present only kyanite is being mined in the United States, and production is expanding rapidly. Although most of the kyanite consumed is used in the refractory industry, its use in the manufacture of heavy-duty nonrefractory ceramics has increased in recent years.

Because domestic kyanite is produced as a fine-grained flotation concentrate that does not bond well, it is unsuitable by itself for making refractory bricks. Massive lump kyanite, designated strategic-grade kyanite, was formerly imported from India, Kenya, and the Union of South Africa for this purpose. In recent years, however, processes have been developed for making synthetic mullite from domestic raw materials. Synthetic mullite, made by fusing or sintering aluminous and siliceous mixtures of appropriate composition, is as good as mullite made from imported strategic-grade kyanite. Materials used in the manufacture of synthetic mullite include low-iron siliceous bauxite, domestic kyanite concentrate and high-alumina clay mixtures, alumina and silica mixtures, and diaspore clay.

Mullite is also a constituent of ceramic materials made from hydrous aluminum silicates, such as pyrophyllite ($\text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2 \cdot \text{H}_2\text{O}$) and kaolinite ($\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$), that contain less alumina than the minerals of the kyanite group. Ceramic articles made from these two minerals have relatively lower refractory properties than materials made from the kyanite group; nevertheless, they form an important branch of the ceramic and refractory industries. Although not a member of the kyanite group, pyrophyllite is included in this bibliography on the basis of similar occurrence and related uses.

About 90 percent of the mullitic material consumed in the United States is used as refractory linings for metallurgical or glass furnaces.

About 50 percent of the mullite refractories are used in the metallurgical industry and 40 percent in the glass industry. The remaining 10 percent is used chiefly in the ceramic industry in manufacturing such articles as kiln furniture, heavy-duty electrical and chemical porcelain, and spark plugs (Gunsallus, 1956).

OCCURRENCE OF ALUMINUM SILICATE MINERALS

ANDALUSITE

Andalusite is characteristically formed in alumina-rich slates and schists by the contact-metamorphic action of large igneous intrusions. In some places it is found in granitic rocks, gneisses, and mica schists. It also occurs as lenses and pockets in pegmatites and as replacement bodies produced by hydrothermal solutions. It commonly occurs as long prismatic crystals with nearly square cross section.

Although andalusite has been found in 24 States, commercial deposits are rare. The only deposits that have been mined are near Mocalno, on the west slope of the White Mountains, Mono County, Calif., and near Hawthorne, Mineral County, Nev.

KYANITE

Kyanite generally occurs as disseminated crystals in schists, quartzites, or gneisses produced by regional metamorphism, but locally it may form coarsely crystalline massive segregations in these rocks. It typically forms long-bladed crystals, often of large size, or coarse interlocking bladed or radiating fibrous aggregates.

Kyanite has been reported from 24 States. Most deposits are of the disseminated type; no minable massive deposits are known. The most important deposits are in the Piedmont belt of crystalline rocks extending from Virginia to Alabama. They occur at Baker Mountain, Prince Edward County, and Willis Mountain, Buckingham County, in Virginia, and at Henry Knob, near Clover, York County, S.C. These are the only deposits now producing kyanite in the United States.

Kyanite and sillimanite are important constituents of the heavy mineral concentrations in some of the beach and dune sands of Florida which are now being exploited for titanium and zircon. Eventually they may be recovered as byproducts.

SILLIMANITE

Sillimanite occurs in schists, gneisses, slates, and hornfels, and is generally formed at high temperatures under conditions of regional or contact metamorphism. In schists it forms long disseminated pris-

matic crystals or radiating fibrous or columnar masses, which may be rather coarse. It occurs less commonly in granites and pegmatites and in lenses, stringers, and nodules near pegmatites.

Sillimanite has been found in 26 States but has been produced only in very small amount in North Carolina (Stuckey, 1937, p. 75). The most promising occurrences are in the Southeastern States, particularly in North and South Carolina and Georgia.

DUMORTIERITE

Dumortierite occurs most commonly in pegmatites that cut aluminous rocks, such as sericite schists or cordierite and corundum gneisses. It also occurs as replacement bodies in association with highly aluminous rocks and as an accessory mineral in granite. Dumortierite commonly occurs as acicular needles or thin blades in fibrous to columnar aggregates; distinct crystals are rare.

Dumortierite has been found in eight States. The deposit in Humboldt Queen Canyon, near Oreana, Pershing County, Nev., however, is the only known commercial deposit in the world. Dumortierite was mined there for about 20 years and was used in the production of spark-plug insulators. Except for a small production of dumortierite in 1949, the mine has been idle since 1945.

TOPAZ

Topaz, like dumortierite, is characteristically a pneumatolytic mineral that is commonly found in veins and cavities in granites and rhyolites or in veins or pegmatites in the contact zones of schists and gneisses surrounding granitic intrusions. It also occurs with other high-alumina minerals, such as pyrophyllite, andalusite, kyanite, and diaspore, in silicified zones in volcanic rocks. In the largest known occurrence of this type, at the Brewer mine, near Jefferson, Chesterfield County, S.C., massive fine-grained topaz is in an irregular silicified zone (carrying gold and pyrite) that has replaced a rhyolitic breccia. The Brewer deposit, which contains the only large topaz reserves known in the United States, was mined during World War II but is no longer producing. Other occurrences of topaz are in California, Colorado, Missouri, North Carolina, and Virginia.

PYROPHYLLITE

Pyrophyllite also is found in metamorphic rocks. It occurs as foliated or compact masses and less commonly as radial fibrous aggregates in irregular, lenticular, or bedded deposits. It is believed to be formed by hydrothermal alteration or metasomatic replacement of

volcanic rocks, such as andesites, rhyolites, and silicic tuffs and breccias; and metamorphic rocks, such as slates and schists.

Pyrophyllite occurrences are known in nine States. The principal production in the United States comes from a belt in the central Piedmont which extends from North and South Carolina to Graves Mountain, Ga. The most important deposits are in Moore, Montgomery, Randolph, Alamance, Orange, and Granville Counties, N.C. North Carolina ranks first in quantity of pyrophyllite produced, followed by California.

EXPLANATION OF BIBLIOGRAPHY AND INDEX

The papers listed in the bibliography were selected from the bibliographic references that follow the chapters "Sillimanite Group," "Pyrophyllite," and "Refractories," respectively, in the first and second editions of "Industrial Minerals and Rocks," published by the American Institute of Mining and Metallurgical Engineers, and from the "Bibliography of North American Geology" to 1956. Articles published from 1957 to December 31, 1958, were obtained from the United States Geological Survey Library in Washington, D.C. A complete list of serials and periodicals included is given on pages 979-983.

The references in the bibliography are listed alphabetically by author (or authors) with full title and publication data.

The index is arranged alphabetically by mineral. Under each mineral the index is further subdivided by geographic areas (State and county) and by subjects, which include general, geology, mineral synthesis, occurrence (geographic), and technology and uses. If no geographic area is given, the subject entries are listed under the mineral before the State entries.

The subject "geology" includes crystallography, chemical and physical properties, chemical analyses, X-ray data, and the formation and geologic occurrence of the minerals. A specific paper may deal with one, several, or all of these subdivisions of "geology."

Under the subject "mineral synthesis" are listed several papers describing laboratory experiments whose primary purpose was to determine the conditions under which the minerals involved are formed in nature.

The author appreciates the help of V. R. Wilmarth and Cleaves L. Rogers, of the Geological Survey, in planning the bibliography and index and the cooperation of the staff of the Geological Survey Library in making the bibliographic material available.

The map of the United States (pl. 6) showing the location of major deposits of the kyanite group of minerals and pyrophyllite is based

on work by Gilbert H. Espenshade, also of the Survey. Additional data for the map were furnished by the United States Bureau of Mines, the California Department of Natural Resources, Division of Mines, the Idaho Bureau of Mines and Geology, the New Mexico State Bureau of Mines and Mineral Resources, the Nevada Bureau of Mines, the North Carolina Department of Conservation and Development, Division of Mineral Resources, and the Geological Survey of Wisconsin.

PERIODICALS AND SERIALS

<i>Abbreviation</i>	<i>Publication</i>
Acad. Nat. Sci. Philadelphia Proc.; Spec. Pub.	Proceedings of the Academy of Natural Sciences of Philadelphia; Special Publi- cation. Philadelphia, Pa.
Alabama Acad. Sci. Jour.....	The Journal of the Alabama Academy of Science. Alabama College, Montevallo, Ala.
Alabama Geol. Survey Bull.....	Geological Survey of Alabama, Bulletin. University, Ala.
Am. Acad. Arts and Sci. Proc.....	Proceedings of the American Academy of Arts and Sciences. Boston, Mass.
Am. Assoc. Petroleum Geologists Bull.	Bulletin of the American Association of Petroleum Geologists. Tulsa, Okla.
Am. Ceramic Soc. Bull.; Jour....	American Ceramic Society Bulletin; Jour- nal. Columbus, Ohio.
Am. Geologist.....	The American Geologist. Minneapolis, Minn.
Am. Geophys. Union Trans.....	Transactions of the American Geophysical Union. Washington.
Am. Inst. Mining Metall. Engi- neers Contr.; Tech. Pub.; Trans.; Year Book.	American Institute of Mining and Metal- lurgical Engineers Contribution; Techni- cal Publications, Transactions; Year Book. New York.
Am. Jour. Sci.....	American Journal of Science. New Haven, Conn.
Am. Mineralogist.....	The American Mineralogist. Washington.
Am. Petroleum Inst. Proj.; Prelim. Rept.	American Petroleum Institute Project, Pre- liminary Report. Columbia University, New York.
Am. Philos. Soc. Proc.....	Proceedings of the American Philosophical Society. Philadelphia, Pa.
Am. Soc. Testing Materials Proc..	American Society for Testing Materials, Proceedings. Philadelphia, Pa.
Annotated Bibliography Econ. Geology.	Annotated Bibliography of Economic Geol- ogy. Urbana, Ill.
Arizona Bur. Mines Bull.....	Arizona Bureau of Mines, Bulletin. Tuc- son, Ariz.
Brick & Clay Rec.....	Brick & Clay Record. Chicago, Ill.
California Dept. Education Bull..	Bulletin of the California State Department of Education. Sacramento, Calif.
California Div. Mines Bull.; Div. Mines and Mining Bull., Min- eral Inf. Service, Mining in California, Spec. Rept.	State of California, Department of Natural Resources, Division of Mines, Bulletin; Division of Mines and Mining Bulletin, Mineral Information Service, Mining in California, Special Report. San Fran- cisco, Calif.

<i>Abbreviation</i>	<i>Publication</i>
California Jour. Mines and Geology.	California Journal of Mines and Geology. San Francisco, Calif.
California Mining Bur. Bull.; Mining in California; Rept. State Mineralogist.	California State Mining Bureau, Bulletin; Mining in California; Report of the State Mineralogist. San Francisco, Calif.
California Univ. Pubs., Dept. Geol. Sci. Bull.	University of California Publications, Bulletin of the Department of Geological Sciences. University of California Press, Berkeley, Calif.
California Univ. Pubs. Math. Phys. Sci.	Publications of the University of California at Los Angeles in Mathematical and Physical Sciences. University of California Press, Berkeley, Calif.
Cement, Mill, & Quarry-----	Chicago, Ill.
Ceramic Abs-----	Ceramic Abstracts. American Ceramic Society, Columbus, Ohio.
Ceramic Age-----	Newark, N.J.
Ceramic Industry-----	Chicago, Ill.
Ceramist-----	The Ceramist. Newark, N.J.
Colorado Geol. Survey Bull-----	Colorado Geological Survey, Bulletin. Boulder, Colo.
Colorado School Mines Quart-----	Quarterly of the Colorado School of Mines. Golden, Colo.
Colorado-Wyoming Acad. Sci. Jour.	The Journal of the Colorado-Wyoming Academy of Science. Bibliographic Center, Denver Public Library, Colo.
Commonwealth-----	The Commonwealth. Virginia State Chamber of Commerce, Richmond, Va.
Connecticut Geol. Nat. History Survey Misc. Ser.; Quad. Rept.	State Geological and Natural History Survey of Connecticut, Miscellaneous Series; Quadrangle Report. Hartford, Conn.
Dissert. Abs-----	Dissertation Abstracts. University Microfilms, Ann Arbor, Mich.
Econ. Geology-----	Economic Geology. Urbana, Ill.
Elisha Mitchell Sci. Soc. Jour-----	Journal of the Elisha Mitchell Scientific Society. Chapel Hill, N.C.
Eng. Mining Jour-----	Engineering and Mining Journal. New York.
Eng. Mining Jour.-Press-----	Engineering and Mining Journal-Press. New York.
Florida Geol. Survey Ann. Rept.; Bull.	Florida State Geological Survey, Annual Report. Bulletin. Tallahassee, Fla.
Forestry-Geol. Rev-----	Forestry-Geological Review, Department of Forestry and Geological Development. Atlanta, Ga.
Geol. Soc. America Bull.; Mem.; Proc.	Bulletin of the Geological Society of America; Memoir; Proceedings. New York.
Georgia Div. Geology Inf. Circ-----	Georgia Department of Forestry and Geological Development, Division of Geology, Information Circular. Atlanta, Ga.

Abbreviation

Publication

Georgia Geol. Survey Bull.; Georgia Mineral Newsletter.	Geological Survey of Georgia, Department of Forestry and Geological Development, Bulletin; Georgia State Division of Conservation, Department of Mines, Mining and Geology, The Geological Survey Bulletin; Georgia Mineral Newsletter. Atlanta, Ga.
Glass Industry-----	The Glass Industry. New York.
Idaho Bur. Mines and Geology Inf. Leaflet; Pamph.	Idaho Bureau of Mines and Geology Information Leaflet; Pamphlet. Moscow, Idaho.
Jour. Geology-----	The Journal of Geology. Chicago, Ill.
Jour. Sed. Petrology-----	Journal of Sedimentary Petrology. Tulsa, Okla.
Maine Geol. Survey Bull.; Rept. State Geologist.	Bulletin, Maine Geological Survey, Department of Development of Industry and Commerce; Report of the State Geologist. Augusta, Maine.
Manufacturers Rec-----	Manufacturers Record. Baltimore, Md.
Massachusetts Dept. Public Works [and] U.S. Geol. Survey, Coop. Geol. Proj. Inf. Circ.	Commonwealth of Massachusetts, Department of Public Works [and] U.S. Department of the Interior Geological Survey, Cooperative Geologic Project, Information Circular. Boston, Mass.
Michigan Geol. and Biol. Survey Pub. (Geol. Ser.).	Michigan Geological and Biological Survey Publication (Geological Series). Lansing, Mich.
Mineralog. Soc. Utah News Bull.---	News Bulletin of the Mineralogical Society of Utah. Salt Lake City, Utah.
Mineralogist-----	The Mineralogist. Portland, Oreg.
Mining and Metallurgy-----	New York.
Mining Eng-----	Mining Engineering. New York.
Mining Sci. Press-----	Mining and Scientific Press. San Francisco, Calif.
Missouri Bur. Geology and Mines State Geologist Bienn. Rept.	Missouri Bureau of Geology and Mines, Biennial Report of the State Geologist. Rolla, Mo.
Montana Acad. Sci. Proc-----	Proceedings of the Montana Academy of Sciences. Missoula, Mont.
Montana Bur. Mines and Geology Mem.; Misc. Contr.	State of Montana, Bureau of Mines and Geology, Memoir; Miscellaneous Contribution. Butte, Mont.
Natl. Acad. Sci.-Natl. Research Council, Minerals and Metals Advisory Board Rept.	National Academy of Sciences-National Research Council, Minerals and Metals Advisory Board Report. Washington.
Nevada Univ. Bull.; Geology and Mining Ser.	University of Nevada Bulletin (Bulletin of Nevada State Bureau of Mines and Mackay School of Mines); Geology and Mining Series. Reno, Nev.
New England Naturalist-----	The New England Naturalist. Boston, Mass.
New Hampshire State Plan. Devel. Comm. Mineral Resource Survey.	New Hampshire Mineral Resource Survey, New Hampshire State Planning and Development Commission. Concord, N.H.

<i>Abbreviation</i>	<i>Publication</i>
New Jersey Dept. Conserv. Econ. Devel., Geol. Ser. Bull.	State of New Jersey Department of Conservation and Economic Development, Geologic Series Bulletin. Trenton, N.J.
New Mexico Bur. Mines and Mineral Resources Bull.	New Mexico Bureau of Mines and Mineral Resources Bulletin. Socorro, N. Mex.
New Mexico Univ. Bull., Geol. Ser.	Bulletin of the University of New Mexico, Geological Series. Albuquerque, N. Mex.
New York Acad. Sci. Trans.....	Transactions of the New York Academy of Sciences. New York.
New York State Mus. Bull.; New York State Mus. and Sci. Service Bull.	New York State Museum Bulletin; New York State Museum and Science Service Bulletin. University of the State of New York, Albany, N.Y.
North Carolina Dept. Conserv. Devel. Bull., Econ. Paper; Div. Mineral Resources Bull., Econ. Paper, Educ. Ser., Inf. Circ.	North Carolina Department of Conservation and Development Bulletin, Economic Paper; Division of Mineral Resources Bulletin, Economic Paper, Educational Series, Information Circular. Raleigh, N.C.
North Carolina Geol. Econ. Survey Bull.; Econ. Paper.	North Carolina Geological and Economic Survey Bulletin; Economic Paper. Raleigh, N.C.
North Carolina Geol. Survey Econ. Paper.	North Carolina Geological Survey Economic Paper. Raleigh, N.C.
North Carolina State Coll. Agriculture and Engineering, Eng. Expt. Sta. Bull.; Dept. Eng. Research Bull.	North Carolina State College of Agriculture and Engineering of the University of North Carolina, Bulletin, Engineering Experiment Station; Department of Engineering Research Bulletin. Raleigh, N.C.
North Carolina State Coll. Rec.....	North Carolina State College Record. Raleigh, N.C.
Ohio State Univ. Studies, Eng. Expt. Sta. Circ.	Ohio State University Studies, Engineering Experiment Station Circular. Columbus, Ohio.
Pit and Quarry.....	Chicago, Ill.
Raw Materials Survey Resource Rept.	Raw Materials Survey, Resource Report. Portland, Oreg.
Rocks and Minerals.....	Peekskill, N.Y.
South Carolina Geol. Survey, ser. 4, Bull.	South Carolina Geological Survey, series 4, Bulletin. Columbia, S.C.
South Carolina Research, Plan. Devel. Board Bull.	South Carolina Research, Planning and Development Board Bulletin. Columbia, S.C.
South Dakota School Mines Bull..	South Dakota School of Mines, Bulletin, Departments of Geology and Mineralogy. Rapid City, S. Dak.
Stanford Univ. Abs. Dissert.....	Stanford University, Abstracts of Dissertations for the Degrees of Doctor of Philosophy and Doctor of Education. Stanford University, Calif.

<i>Abbreviation</i>	<i>Publication</i>
U.S. Bur. Mines Bull.; Inf. Circ.; Minerals Yearbook, preprint; Rept. Inv.	United States Bureau of Mines Bulletin; Information Circular; Minerals Yearbook, preprint; Report of Investigations. Washington.
U.S. Geol. Survey Bull.; Geol. Atlas, Folio; Mineral Inv. Field Studies Map; Mineral Resources U.S.; Missouri River Basin Studies; Prof. Paper.	United States Geological Survey Bulletin; Geological Atlas, Folio; Mineral Investigations Field Studies Map; Mineral Resources of the United States; Missouri River Basin Studies; Professional Paper. Washington.
U.S. Natl. Mus. Proc.-----	Proceedings of the United States National Museum. Washington.
U.S. Tariff Comm., Industrial Materials Ser. Rept.	United States Tariff Commission, Industrial Materials Series Report. Washington.
Utah Acad. Sci. Proc.-----	Proceedings of the Utah Academy of Sciences, Arts and Letters. Salt Lake City, Utah.
Vermont Geol. Survey Bull.-----	Vermont Geological Survey Bulletin. Vermont Development Commission, Montpelier, Vt.
Vermont Geol. Survey State Geologist Rept.	Vermont Geological Survey, Report of the State Geologist. Burlington, Vt.
Virginia Div. Mineral Resources Bull.	Commonwealth of Virginia, Virginia Division of Mineral Resources, Bulletin. Charlottesville, Va.
Virginia Geol. Survey Bull.; Repr. Ser.	Commonwealth of Virginia, Virginia Geological Survey, Bulletin; Reprint Series. University, Va.
Virginia Polytech. Inst., Eng. Expt. Sta. Ser. Bull.; Mineral Industries Jour.	Virginia Polytechnic Institute, Engineering Experiment Station Series Bulletin; Mineral Industries Journal. Blacksburg, Va.
Virginia Univ. Pubs., Philos. Soc. Bull., Sci. Ser.	University of Virginia Publications, Bulletin of the Philosophical Society, Scientific Series. Charlottesville, Va.
Washington Acad. Sci. Jour.-----	Journal of the Washington Academy of Sciences. Washington.
Washington Div. Mines and Geology Bull.	State of Washington, Department of Conservation and Development, Division of Mines and Geology, Bulletin. Olympia, Wash.
Washington Univ. Pubs. in Geology.	University of Washington Publications in Geology. Seattle, Wash.
Wyoming Geol. Survey Bull.-----	The Geological Survey of Wyoming, Bulletin. Laramie, Wyo.

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Seager 1944

Occurrence:

Deer Lodge County:

Emmons and Calkins 1913

Heinrich 1948

Granite County: Kauffman 1952

Park County:

Heinrich 1948, 1949

Kauffman 1952

Riddle and Foster 1949

Seager 1944

Nevada.

General:

Douglas County:

Binyon 1946

McLenegan 1956

Mineral County:

Kerr 1937

McLenegan 1956

U.S. Bureau of Mines 1932-33

Warner and others 1958

Geology:

Humboldt County:¹ Knopf 1917

Pershing County:

Foster 1947

Grawe 1928a

Jenney 1935

Jones 1928

Kerr 1940

Kerr and Jenney 1935

Knopf 1924

Warner and others 1958

Occurrence:

Douglas County:

Binyon 1946

McLenegan 1956

Humboldt County: Knopf 1917

Mineral County:

Foster and others 1952

Funk 1940a

Jensen 1943

Kerr 1937

Ladoo and Myers 1951

McLenegan 1956

McVay and Wilson 1943

Riddle and Foster 1949

U.S. Bureau of Mines 1932-33

Warner and others 1958

Pershing County:

Foster 1947

Funk 1940a

Grawe 1928a

Insley 1933

Jenney 1935

Jones 1928

Kerr 1940

¹ In 1919, the southern part of Humboldt County, which included the Rochester mining district in the Humboldt Range, was incorporated into Pershing County.

Andalusite—Continued

Nevada—Continued

Occurrence—Continued

Pershing County—Continued

Kerr and Jenney 1935

Knopf 1924

Ladoo and Myers 1951

Palmer 1928

Riddle and Foster 1949

Warner and others 1958

Technology and uses:

Mineral County: Foster and others
1952

Pershing County: Palmer 1928

New Hampshire.

Geology: Billings 1955, 1956

Belknap County: Modell 1936

Carroll County: Billings 1928

Cheshire County: Fowler-Billings
1941

Coos County:

Billings 1941

Billings, Chapman, and others
1946Grafton County: Williams and Billings
1938

Occurrence: Billings 1955, 1956

Belknap County:

Myers and Stewart 1956

Modell 1936

Carroll County:

Billings 1928

Meyers and Stewart 1956

Cheshire County:

Fowler-Billings 1941

Hawes 1878

Meyers and Stewart 1956

Coos County:

Billings 1941

Billings, Chapman, and others
1946Billings, Fowler-Billings, and
others 1946

Meyers and Stewart 1956

Grafton County:

Moke 1946

Williams and Billings 1938

Merrimack County:

Hawes 1878

Meyers and Stewart 1956

Rockingham County:

Hawes 1878

Meyers and Stewart 1956

Strafford County:

Bannerman 1941

Hawes 1878

Meyers and Stewart 1956

Sullivan County:

Hawes 1878

Meyers and Stewart 1956

New Mexico.

Geology:

Dona Ana County: Dunham 1935

Lincoln County: Sidwell 1946

Rio Arriba County: Montgomery
1953

Andalusite—Continued

New Mexico—Continued

Geology—Continued

Taos County: Montgomery 1953

Occurrence:

Dona Ana County:

Dunham 1935

Northrop 1942

Lincoln County: Sidwell 1946

Rio Arriba County:

Jahns 1946

Montgomery 1953

Northrop 1942

Talmage and Wootton 1937

Socorro County: Northrop 1942

Taos County:

Montgomery 1953

Northrop 1942

Talmage and Wootton 1937

North Carolina.

Geology: Broadhurst and Council
1954Alamance County: Espenshade and
Potter 1959

Gaston County:

Espenshade and Potter 1959

Potter 1954

Granville County:

Broadhurst and Council 1953

Espenshade and Potter 1959

Lincoln County: Potter 1954

Orange County:

Broadhurst and Council 1953

Espenshade and Potter 1959

Randolph County: Espenshade and
Potter 1959Occurrence: Broadhurst and Council
1954

Alamance County:

Broadhurst 1955

Espenshade and Potter 1959

Gaston County:

Espenshade and Potter 1959

Potter 1954

Granville County:

Broadhurst 1955

Broadhurst and Council 1953

Espenshade and Potter 1959

Stuckey 1958

Lincoln County:

Espenshade and Potter 1959

Potter 1954

Montgomery County: Broadhurst
1955

Moore County: Broadhurst 1955

Orange County:

Broadhurst 1955

Broadhurst and Council 1953

Espenshade and Potter 1959

King 1958

Stuckey 1958

Randolph County:

Broadhurst 1955

Broadhurst and Council 1953

Espenshade and Potter 1959

Andalusite—Continued

Pennsylvania.

Geology:

Chester County: Bascom and Stose 1932

Delaware County:

Bascom and Stose 1932

Dike 1951

Gordon 1922

Lancaster County: Dale and others 1914

Northampton County: Anderson and Chesley 1931

York County: Dale and others 1914

Occurrence:

Chester County: Bascom and Stose 1932

Delaware County:

Bascom and Stose 1932

Dike 1951

Ford 1932

Gordon 1922

McKinstry 1949

Lancaster County:

Agron 1950

Dale and others 1914

Northampton County: Anderson and Chesley 1931

York County:

Agron 1950

Dale and others 1914

South Carolina.

Geology:

Chesterfield County: Espenshade and Potter 1959

Edgefield County: Espenshade and Potter 1959

York County: Espenshade and Potter 1953a

Occurrence:

Abbeville County: Espenshade and Potter 1959

Chesterfield County:

Espenshade and Potter 1959

Peyton and Lynch 1953

Edgefield County: Espenshade and Potter 1959

McCormick County: Espenshade and Potter 1959

York County: Espenshade and Potter 1953a, 1959

South Dakota.

General, Pennington County: Connolly and O'Harra 1929

Geology:

Custer County: Riddle and Peck 1935

Pennington County:

Lincoln and others 1937

Ziegler 1914

Occurrence, Black Hills:

Jensen 1934

Kerr 1937

Andalusite—Continued

South Dakota—Continued

Occurrence, Black Hills—Continued

See also Custer, Pennington, and Lawrence Counties.

Custer County: Riddle and Peck 1935

Lawrence County: Hess 1909

Pennington County:

Connolly and O'Harra 1929

Hess 1909

Lincoln and others 1937

Page and others 1958

Petar 1930

Riddle and Foster 1949

Runner 1918

Ziegler 1914

United States, southeastern.

Geology and occurrence: Espenshade and Potter 1959

Utah.

Geology:

Beaver County: Butler, B. S. 1918

Tooele County: Kemp and Billingsley 1918

Occurrence:

Beaver County:

Butler, B. S. 1918

Butler, B. S., and others 1920

Tooele County:

Kemp and Billingsley 1918

Nolan 1985

Vermont.

Geology and occurrence, Orleans County: Doll 1951

Virginia.

Occurrence:

Fairfax County: Espenshade and Potter 1959

Patrick County:

Dietrich, R. V. 1953, 1954

Espenshade and Potter 1959

Washington.

Geology:

Skamania County:

Clarke, F. W. 1908

Schaller 1905

Spokane County:

Anderson 1928

Collier 1908

Page 1942

Occurrence:

Kittitas County:

Smith and Calkins 1906

Valentine 1949

Pend Oreille County: Valentine 1949

San Juan County:

Kelly and others 1956

McLellan 1927

Valentine 1949

Andalusite—Continued**Washington—Continued****Occurrence—Continued****Skamania County :**

Clarke, F. W. 1908

Kelly and others 1956

Schaller 1905

Valentine 1949

Spokane County :

Anderson 1928

Collier 1908

Kelly and others 1956

Page 1942

Riddle and Foster 1949

Valentine 1949

Stevens County :

Kelly and others 1956

Valentine 1949

Wyoming.**Occurrence :**

Albany County : Osterwald and Osterwald 1952

Fremont County :

Birch 1955

Osterwald and Osterwald 1952

Platte County :

Birch 1955

Clabaugh and others 1946

Osterwald and Osterwald 1952

Dumortierite.**General :**

American Iron and Steel Institute—American Ceramic Society, Inc. 1950

Funk 1940a

Peek 1933

Snedden 1945

U. S. Bureau of Mines 1932-33

Watkins and others 1952

Winston 1944

Geology :

Clarke, F. W. 1908

Douglass 1953

Ford 1932

Grawe 1928b

Jensen 1943

Kerr 1937

Ladoo and Myers 1951

Riddle and Foster 1949

Technology and uses: Foster and others 1952

Arizona.**Geology, Yuma County :**

Bowen and Wyckoff 1926

Diller and Whitfield 1889

Ford 1902

Grawe 1928b

Schaller 1905

Wilson, E. D. 1929

Occurrence: Clarke, F. W. 1908

Yuma County :

Bowen and Wyckoff 1926

Diller and Whitfield 1889

Duke 1957

Ford 1902, 1932

Dumortierite—Continued**Arizona—Continued****Occurrence—Continued****Yuma County—Continued**

Funk 1940a

Galbraith 1947

Grawe 1928b

Ladoo and Myers 1951

Moore, B. N. 1936

Riddle and Foster 1949

Schaller 1905

Wilson, E. D. 1929, 1933

Wilson, E. D., and others 1953

California

General: Riddle and Foster 1949

Geology :**Imperial County :**

Grawe 1928b

Wolf 1930

Merced County: Daviss 1946

Riverside County :

Grawe 1928b

Larsen 1948

Murphy 1930

San Diego County :

Ford 1902

Funk 1940a

Grawe 1928b

Schaller 1905

Stanislaus County: Daviss 1946

Occurrence: Clarke, F. W. 1908

Imperial County :

Dietrich, F. W. 1928

Eakle 1922

Funk 1940a

Grawe 1928b

Jeffery 1943

Murdoch and Webb 1954, 1956

Pabst 1938

Riddle and Foster 1949

Sampson and Tucker 1931, 1942

Tucker 1926

Winston 1944

Wolf 1930

Kern County :

Murdoch and Webb 1956

Reed and Bailey 1927

Merced County: Daviss 1946

Mono County: Woodhouse 1936

Riverside County :

Eakle 1922

Funk 1940a

Grawe 1928b

Jeffery 1943

Kuns 1905

Larsen 1948

Murdoch 1949

Murdoch and Webb 1952, 1954, 1956

Murphy 1930

Pabst 1938

Sampson and Tucker 1931

Winston 1944

San Diego County :

Eakle 1922

Ford 1902, 1932

Dumortierite—Continued

California—Continued

Occurrence—Continued

San Diego County—Continued

- Funk 1940a
- Grawe 1928b
- Jeffery 1943
- Kuns 1905
- Murdoch and Webb 1954, 1956
- Pabst 1938
- Sampson and Tucker 1931
- Schaller 1905
- Winston 1944
- Stanislaus County: Davless 1946

Colorado.

Geology, Fremont County:

- Finlay 1907
- Grawe 1928b

Occurrence, Fremont County:

- Argall 1949
- Finlay 1907
- Grawe 1928b

Montana.

Geology:

- Jefferson County: U.S. Geological Survey 1955
- Madison County: Graham and Robertson 1951, 1952

Occurrence:

- Granite County: Emmons and Calkins 1913
- Jefferson County: U.S. Geological Survey 1955
- Madison County: Graham and Robertson 1951, 1952

Nevada.

General, Pershing County:

- Funk 1940a
- Jeffery 1943
- Jensen 1943
- Kerr 1937
- Ladoo and Myers 1951
- Peck 1926
- Petar 1930
- Riddle and Foster 1949
- Warner and others 1958
- Winston 1944

Geology:

- Humboldt County:
 - Jones 1913
 - Knopf 1917
 - Schaller 1919
 - Schrader 1914
- Nye County: Grawe 1928b
- Pershing County:
 - Bowen and Wyckoff 1926
 - Fairbanks 1926
 - Foster 1947
 - Grawe 1928a, b
 - Jenney 1935
 - Jones 1928
 - Kerr and Jenney 1935
 - Knopf 1924
 - McLenegan 1956

Dumortierite—Continued

Nevada—Continued

Geology—Continued

Pershing County—Continued

- Riddle and Peck 1935
- York 1944

Occurrence: Watkins and others 1952

Humboldt County:

- Clarke, F. W. 1908
- Ford 1932
- Knopf 1917
- Schaller 1919
- Schrader 1914

Nye County:

- Grawe 1928b
- Stoddard 1932

Pershing County:

- Bowen and Wyckoff 1926
- Carpenter 1928
- Fairbanks 1926
- Foster 1947
- Fulton and Smith 1932
- Funk 1940a
- Grawe 1928a, b
- Jeffery 1943
- Jenney 1935
- Jensen 1943
- Jones 1928
- Kerr 1937
- Kerr and Jenney 1935
- Knopf 1924
- Ladoo and Myers 1951
- McLenegan 1956
- Newton 1944
- Palmer 1928
- Peck 1926
- Petar 1930
- Riddle and Foster 1949
- Riddle and Peck 1935
- Snedden 1945
- Stoddard 1932
- Warner and others 1958
- Winston 1944
- York 1944
- Washoe County:
 - Grawe 1928b
 - Stoddard 1932
- Technology and uses, Pershing County:
 - Carpenter 1928
 - Newton 1944
 - Palmer 1928
 - U.S. Bureau of Mines 1932-33

New Mexico.

Geology, Luna County:

- Grawe 1928b
- Schaller 1919

Occurrence:

Luna County:

- Grawe 1928b
- Northrop 1942
- Schaller 1919
- Talmage and Wootton 1937

Rio Arriba County:

- Jahns 1946
- Just 1937
- Northrop 1942

Dumortierite—Continued**New York.****Geology, New York County:**

- Diller and Whitfield 1889
 Ford 1902
 Grawe 1928b
 Riggs 1887
 Schaller 1905

Occurrence, New York County:

- Butler, S. B. 1948
 Chamberlin 1888
 Diller and Whitfield 1889
 Ford 1902, 1932
 Grawe 1928b
 Ladoo and Myers 1951
 Riggs 1887
 Schaller 1905

Washington.**Geology, Skamania County:**

- Ford 1902
 Grawe 1928b
 Schaller 1905

Occurrence: Clarke, F. W. 1908**Skamania County:**

- Ford 1902, 1932
 Grawe 1928b
 Kelley and others 1956
 Schaller 1905
 Valentine 1949

Kyanite.**General:**

- American Iron and Steel Institute—American Ceramic Society, Inc. 1950
 Espenshade and Potter 1959
 Funk 1940a
 Greig 1925
 Gunsallus 1956
 Jeffery 1943
 Kerr 1937
 Norton, F. H. 1949
 Peck 1933
 Riddle and Foster 1949
 Snedden 1945
 U.S. Bureau of Mines 1932-33
 Waggaman 1953
 Watkins and others 1952
 Williamson 1949
 Winston 1944

Geology:

- Clarke, F. W. 1908
 Ford 1932
 Goldsmith 1953
 Hawes 1878
 Heinrich 1952
 Insley 1933
 Jensen 1943
 Ladoo and Myers 1951
 Norton, J. T. 1925a
 Roy and Osborn 1952a, c, 1954
 Sosman 1933
 Taylor 1933

Kyanite—Continued**Mineral synthesis:**

- Clark and others 1957
 Kennedy 1954, 1955
 Roy and Osborn 1952a, 1954
 Schulling 1958
 Yoder 1957

Technology and uses:

- Broadhurst and Council 1953
 Ceramic Industry 1939a
 Galbreath and others 1944
 Gandrud 1935
 Greaves-Walker and others 1937
 Hopkins 1957
 McVay and others 1944
 Newton 1944
 Peck 1924
 Petar 1930
 Prindle and others 1935
 Ralston 1938
 Roy and Osborn 1952b
 Scholes 1938
 Tyler and Heuer 1937, 1949
 Watkins 1932

Alabama.**Geology, Cleburne County: Bowles 1939****Occurrence: Espenshade and Potter 1959****Baldwin County: Havell and McVay 1939****Chilton County:**

- Bowles 1939
 Pallister 1955a, b

Clay County:

- Bowles 1939
 Heinrich and Olson 1953
 Pallister 1955a, b

Cleburne County:

- Bowles 1939
 Heinrich and Olson 1953
 Pallister 1955a, b
 Riddle and Foster 1949

Coosa County:

- Bowles 1939
 Pallister 1955a, b

Randolph County:

- Bowles 1939
 Heinrich and Olson 1953
 Pallister 1955a, b
 Sterrett 1923

Tallapoosa County:

- Bowles 1939
 Heinrich and Olson 1953
 Sterrett 1923

Tuscaloosa County: Pallister 1955a**Technology and uses, Baldwin County: Havell and McVay 1939****Arizona.****Geology, Yuma County:**

- Schaller 1905
 Wilson, E. D. 1929

Kyanite—Continued

Arizona—Continued

Occurrence:

- Coconino County: Wilson, E. D. and others 1958
- Gila County: Wilson, E. D., and others 1958
- Maricopa County:
 - Galbraith 1947
 - Wilson, E. D., and others 1958
 - Wilson and Roseveare 1949
- Mohave County:
 - Galbraith 1947
 - Wilson, E. D., and others 1958
- Yavapai County:
 - Funk 1940a
 - Wilson, E. D., and others 1958
- Yuma County:
 - Duke 1957
 - Ford 1932
 - Funk 1940a
 - Galbraith 1947
 - Moore, E. N. 1936
 - Petar 1930
 - Riddle and Foster 1949
 - Schaller 1905
 - Wilson, E. D. 1929, 1933
 - Wilson, E. D., and others 1953

California.

General:

- Dietrich, W. F. 1928
- Jeffery 1943
- Imperial County:
 - Funk 1940a
 - Henshaw 1942
 - Kerr 1937
 - McLenegan 1956
 - Petar 1930
 - Riddle and Foster 1949
 - Sampson and Tucker 1931, 1942
 - Tucker 1926
 - Winston 1944
 - Wright 1950a, 1957a

Geology:

- Fresno County: Davless 1946
- Imperial County:
 - Barlett 1940
 - Campbell and Wright 1950
 - Melhase 1925
 - Moore, E. N. 1936
- Los Angeles County: Bailey 1940
- Madera County: Davless 1946
- Merced County: Davless 1946
- San Diego County: Crawford, J. J. 1896
- Stanislaus County: Davless 1946
- Occurrence:
 - Murdoch and Webb 1956
 - Tyler and Heuer 1949
 - Watkins and others 1952
- Fresno County: Davless 1946
- Imperial County:
 - Barlett 1940
 - California Division of Mines, Staff 1952
 - Campbell and Wright 1950

Kyanite—Continued

California—Continued

Occurrence—Continued

- Imperial County—Continued
 - Dietrich, W. F. 1928
 - Eakle 1922
 - Funk 1940a
 - Henshaw 1942
 - Jeffery 1943
 - Jenkins and others 1954
 - Jensen 1943
 - Kerr 1937
 - Ladoo and Myers 1951
 - McLenegan 1956
 - McVay and Wilson 1943
 - Melhase 1925
 - Moore, B. N. 1936
 - Murdoch and Webb 1952, 1956
 - Pabst 1938
 - Petar 1930
 - Riddle and Foster 1949
 - Sampson and Tucker 1931, 1942
 - Tucker 1926
 - Watkins 1932
 - Winston 1944
 - Wright 1950a, 1957a
 - Wright and others 1954
- Kern County: Reed and Bailey 1927
- Los Angeles County:
 - Bailey 1940
 - Eakle 1922
 - Sampson and Tucker 1931
- Madera County: Davless 1946
- Merced County: Davless 1946
- San Diego County: Crawford, J. J. 1896
- Stanislaus County: Davless 1946
- Tuolumne County:
 - Eakle 1922
 - Jeffery 1943
 - Pabst 1938
 - Sampson and Tucker 1931
 - Winston 1944
- Technology and uses, Imperial County:
 - Jensen 1943
 - Watkins 1932

Colorado.

- Geology, Park County: Heinrich and Bever 1957
- Occurrence, Park County:
 - Bever 1953
 - Heinrich and Bever 1957

Connecticut.

- Geology, Litchfield County:
 - Barlett 1940
 - Gates 1951, 1954
 - Gates and Bradley 1952
- Occurrence:
 - Fairfield County:
 - Ford 1932
 - Genth 1873
 - Hartford County: Ford 1932
 - Litchfield County:
 - Barlett 1940
 - Ford 1932
 - Gates 1951, 1954

Kyanite—Continued

Connecticut—Continued

Occurrence—Continued

Litchfield County—Continued

Gates and Bradley 1952

Genth 1878

Ladoo and Myers 1951

Florida.

General:

Alachua County: Thoenen and Warne
1949

Baker County: Spencer 1948

Bradford County:

Browning and others 1956

Spencer 1948

Clay County:

Browning and others 1956

Spencer 1948

Thoenen and Warne 1949

Duval County:

Browning and others 1956

Miller, Roswell, III 1945

Spencer 1948

Thoenen and Warne 1949

Escambia County: Miller, Ros-
well, III 1945Highlands County: Thoenen and
Warne 1949Hillsborough County: Miller, Ros-
well, III 1945Indian River County: Miller, Ros-
well, III 1945Lake County: Thoenen and Warne
1949Marion County: Thoenen and Warne
1949Nassau County: Thoenen and Warne
1949Orange County: Thoenen and Warne
1949Putnam County: Thoenen and Warne
1949St. Johns County: Miller, Ros-
well, III 1945Santa Rosa County: Miller, Ros-
well, III 1945

Geology:

Cannon 1950

Martens 1935

Occurrence:

Cannon 1950

Espenshade and Potter 1959

Gunsallus 1956

Alachua County: Thoenen and Warne
1949

Baker County: Spencer 1948

Bradford County:

Browning and others 1956

Spencer 1948

Brevard County: Martens 1935

Broward County: Martens 1935

Clay County:

Browning and others 1956

Calver 1957

Engineering and Mining Journal
1952

Kyanite—Continued

Florida—Continued

Occurrence—Continued

Clay County—Continued

Spencer 1948

Thoenen and Warne 1949

Tyrrell and Klinefelter 1956

Dade County: Martens 1935

Duval County:

Browning and others 1956

Calver 1957

Martens 1935

Miller, Roswell, III 1945

Spencer 1948

Thoenen and Warne 1949

Escambia County:

Miller, Roswell, III 1945

Riddle and Foster 1949

Flager County: Martens 1935

Highlands County: Thoenen and
Warne 1949Hillsborough County: Miller, Ros-
well, III 1945Indian River County: Miller, Ros-
well, III 1945Lake County: Thoenen and Warne
1949Marion County: Thoenen and Warne
1949

Nassau County:

Martens 1935

Thoenen and Warne 1949

Orange County: Thoenen and Warne
1949

Palm Beach County: Martens 1935

Putnam County: Thoenen and Warne
1949

St. Johns County:

Martens 1935

Miller, Roswell, III 1945

Santa Rosa County:

Miller, Roswell, III 1945

Riddle and Foster 1949

Volusia County: Martens 1935

Technology and uses, Clay County:

Engineering and Mining Journal
1952

Tyrrell and Klinefelter 1956

Georgia.

General:

Mattson 1934

O'Meara and Gandrud 1936

Cherokee County:

Furcron and Teague 1945

McVay and Wilson 1947

Dawson County:

Furcron and Teague 1945

McVay and Wilson 1947

Gilmer County:

Furcron and Teague 1945

McVay and Wilson 1947

Habersham County:

Espenshade and Potter 1959

Greene 1935

Riddle and Foster 1949

Smith, R. W. 1932, 1934, 1936a

Kyanite—Continued

Georgia—Continued

General—Continued

Lincoln County: Espenshade and Potter 1959

Pickens County:

Furcron and Teague 1945

McVay and Wilson 1947

Rabun County: Smith, R. W. 1934, 1936a

Geology:

Shell 1949

Stose and Smith 1939

Carroll County: Smith, R. W. 1932

Cherokee County:

Bayley 1928

Espenshade and Potter 1959

Furcron 1950

Prindle and others 1935

Smith, R. W. 1932

Clarke County: Hurst 1953

Dawson County: Furcron 1950

De Kalb County: Herrmann 1954

Fannin County:

Furcron 1950

Hurst 1955

LaForge and Phalen 1913

Prindle and others 1935

Smith, R. W. 1932

Fulton County: Crickmay 1935a

Gilmer County:

Furcron 1950

Smith, R. W. 1932

Gwinnett County: Herrmann 1954

Habersham County:

Crickmay 1952

Furcron 1950

Launer 1952

Prindle and others 1935

Smith, R. W. 1936b

Teague and Furcron 1948

Lincoln County:

Espenshade and Potter 1953b

Furcron 1950

Johnston 1935

Watkins 1942

Watson 1921

Watson and Watson 1912

Pickens County:

Espenshade and Potter 1959

Furcron 1950

Prindle and others 1935

Smith, R. W. 1932

Rabun County:

Crickmay 1952

Espenshade and Potter 1959

Furcron 1950

Prindle and others 1935

Smith, R. W. 1936b

Teague and Furcron 1948

Talbot County:

Clarke, J. W. 1952

Crickmay 1935b

Furcron 1950

Smith, R. W. 1932

Kyanite—Continued

Georgia—Continued

Geology—Continued

Towns County:

Furcron 1950

Prindle and others 1935

Union County:

Furcron 1950

LaForge and Phalen 1913

Prindle and others 1935

Smith, R. W. 1932

Upson County:

Clarke, J. W. 1952

Crickmay 1935b

Furcron 1950

Ingram 1950

Occurrence:

Foster and others 1952

Gunsallus 1956

Kerr 1937

Stose and Smith 1939

Tyler and Heuer 1949

Waggaman 1953

Watkins and others 1952

Carroll County:

Espenshade and Potter 1959

Shearer and Hull 1918

Smith, R. W. 1932

Chatham County: Martens 1935

Cherokee County:

Bayley 1928

Espenshade and Potter 1959

Furcron 1950

Furcron and Teague 1945

McVay and Wilson 1947

Petar 1930

Prindle and others 1935

Riddle and Foster 1949

Smith, R. W. 1932

Clarke County: Hurst 1953

Cobb County: Petar 1930

Dawson County:

Espenshade and Potter 1959

Furcron 1950

Furcron and Teague 1945

McVay and Wilson 1947

Riddle and Foster 1949

De Kalb County: Herrmann 1954

Fannin County:

Espenshade and Potter 1959

Furcron 1950

Greaves-Walker 1930

Hurst 1955

LaForge and Phalen 1913

Prindle and others 1935

Smith, R. W. 1932

Fulton County: Crickmay 1935a

Gilmer County:

Espenshade and Potter 1959

Furcron 1950

Furcron and Teague 1945

McVay and Wilson 1947

Riddle and Foster 1949

Smith, R. W. 1932

Glynn County: Martens 1935

Kyanite—Continued**Georgia—Continued****Occurrence—Continued**

Gwinnett County: Herrmann 1954

Habersham County:

Boyd 1940

Crickmay 1952

Espenshade and Potter 1959

Furcron 1950

Furcron and Teague 1945

Greene 1935

Jensen 1943

Ladoo and Myers 1951

Launer 1952

McVay and Wilson 1943

Petar 1930

Prindle and others 1935

Riddle and Foster 1949

Smith, R. W. 1932, 1934, 1936a, b

Teague and Furcron 1948

Haralson County:

Espenshade and Potter 1959

Shearer and Hull 1918

Harris County: Espenshade and Potter 1959**Lincoln County:**

Espenshade and Potter 1953b, 1959

Furcron 1950

Furcron and Teague 1945

Genth 1873

Johnston 1935

Pratt 1898

Riddle and Foster 1949

Watkins 1942

Watson 1921

Watson and Watson 1912

Lumpkin County:

Espenshade and Potter 1959

Pardee and Park 1948

Nantahala National Forest: Prindle and others 1935**Pickens County:**

Espenshade and Potter 1959

Furcron 1950

Furcron and Teague 1945

McVay and Wilson 1947

Prindle and others 1935

Riddle and Foster 1949

Smith, R. W. 1932

Rabun County:

Crickmay 1952

Espenshade and Potter 1959

Furcron 1950

Furcron and Teague 1945

Prindle and others 1935

Riddle and Foster 1949

Smith, R. W. 1934, 1936a, b

Teague and Furcron 1948

Talbot County:

Clarke, J. W. 1952

Crickmay 1935b

Espenshade and Potter 1959

Furcron 1950

Smith, R. W. 1932

Kyanite—Continued**Georgia—Continued****Occurrence—Continued****Towns County:**

Espenshade and Potter 1959

Furcron 1950

Furcron and Teague 1945

Hash and Van Horn 1951

Prindle and others 1935

Riddle and Foster 1949

Union County:

Espenshade and Potter 1959

Furcron 1950

Greaves-Walker 1930

LaForge and Phalen 1913

Prindle and others 1935

Smith, R. W. 1932

Upson County:

Clarke, J. W. 1952

Crickmay 1935b

Espenshade and Potter 1959

Furcron 1950

Ingram 1950

Petar 1930

Technology and uses:

Foster and others 1952

Ralston 1938

Habersham County:

Boyd 1940

Jensen 1943

McVay and Wilson 1943

Idaho.**General, Shoshone County:** Abbott and Prater 1954**Geology:**

Clearwater County: Hietanen 1956

Shoshone County: Hietanen 1956

Valley County: Schmidt 1958

Occurrence: Foster and others 1952

Clearwater County: Hietanen 1956

Idaho County: Kelly and others 1956

Lemhi County: Waggaman 1953

Shoshone County:

Abbott and Prater 1954

Hietanen 1956

Hubbard 1955

Kelly and others 1956

Valley County: Schmidt 1958

Technology and uses: Foster and others 1952**Maine.****Occurrence, Cumberland County:** Clark and others 1957**Maryland.****Geology:** Dryden and Dryden 1941

Baltimore County: Knopf and Jonas 1929

Calvert County: Miller, Roswell, III 1945

Occurrence:

Dryden and Dryden 1941

Kerr 1937

Kyanite—Continued

Maryland—Continued

Occurrence—Continued

Baltimore County: Knopf and Jonas
1929

Calvert County: Miller, Roswell, III
1945

Massachusetts.

Geology: Franklin, Hampden, Hamp-
shire, and Worcester Counties:
Emercon 1917

Occurrence:

Franklin County: Emerson 1895,
1917

Hampden County:

Emerson 1895, 1917
Ladoo and Myers 1951
Pearre 1956

Hampshire County:

Emerson 1895, 1917
Ford 1932
Petar 1930
Riddle and Foster 1949

Worcester County: Emerson 1917

Montana.

General: Gallatin and Madison Coun-
ties: Heinrich 1948

Geology:

Gallatin County: Heinrich 1949

Madison County:

Heinrich 1949
Reid 1957, 1958

Occurrence:

Gallatin County: Heinrich 1948,
1949

Lewis and Clark County: Kauffman
1952

Madison County:

Heinrich 1948, 1949
Kauffman 1952
Kelly and others 1956
Reid 1957, 1958
Riddle and Foster 1949

New Hampshire.

Geology: Billings 1955, 1956

Grafton County:

Bannerman 1941
Chapman, C. A. 1939
Hadley 1942
Hadley and Chapman 1939
Lyons 1955
Riddle and Peck 1935

Sullivan County:

Chapman, C. A. 1939
Hadley and Chapman 1939

Occurrence: Billings 1955, 1956

Cheshire County:

Fowler-Billings 1949a
Hawes 1878
Heald 1950a
Meyers and Stewart 1956
Moore, G. E., Jr. 1949a, b

Kyanite—Continued

New Hampshire—Continued

Occurrence—Continued

Coos County: Meyers and Stewart
1956

Grafton County:

Bannerman 1941
Chapman 1939
Hadley 1942
Hadley and Chapman 1939
Hawes 1878
Lyons 1955
Meyers and Stewart 1956
Pearre and Calkins 1957
Riddle and Peck 1935

Sullivan County:

Chapman 1939
Hadley and Chapman 1939

New Mexico.

General, Rio Arriba County: Jahns 1946

Geology:

Rio Arriba County:

Barker 1958
Corey 1954
Ellis 1930
Just 1937
Keller and others 1952
Montgomery 1953
Talmage and Wootton 1937

Taos County:

Just 1937
Montgomery 1953

Occurrence:

Rio Arriba County:

Barker 1958
Corey 1954
Ellis 1930
Jahns 1946
Just 1937
Keller and others 1952
Montgomery 1953
Northrop 1942
Petar 1930
Riddle and Foster 1949
Sterrett 1923
Talmage and Wootton 1937

Taos County:

Just 1937
Montgomery 1953
Northrop 1942
Petar 1930
Riddle and Foster 1949

New York.

Geology:

Dutchess County:

Balk 1936
Barth 1936

Putnam County:

Balk 1936
Barth 1936

Occurrence:

Dutchess County:

Balk 1936
Barth 1936

Kyanite—Continued**New York—Continued****Occurrence—Continued****New York County :**

Butler, S. B. 1948

Chamberlin 1888

Putnam County :

Balk 1936

Barth 1936

North Carolina.**General :**

Broadhurst 1955

Greaves-Walker 1980

Buncombe County : Pole and Moore
1938**Yancey County :**

Broadhurst 1955

Espenshade and Potter 1959

Jensen 1943

Kerr 1937

Mattson 1934, 1936, 1937

Murdock 1950

Riddle and Foster 1949

Stuckey 1932, 1937

Trauffer 1936

Geology :

Broadhurst and Councill 1954

Bryson 1928

Greaves-Walker and Riggs 1937

Shell 1949

Stuckey 1935

Stuckey and Conrad 1958

Stuckey and others 1947

Ashe County : Stuckey 1937

Avery County :

Kulp and Brobst 1956

Olson 1944

Stuckey 1937

Buncombe County :

Barlett 1940

Bryson 1930

Espenshade and Potter 1959

Genth 1873

Keith 1904, 1905, 1907b

Overstreet and Griffiths 1955

Stuckey 1932, 1937

Catawba County : Overstreet and
Griffiths 1955**Clay County :**

Bryson 1930

Hash and Van Horn 1951

Stuckey 1937

Cleveland County :

Espenshade and Potter 1959

Keith and Sterrett 1917

Overstreet and Griffiths 1955

Franklin County : Stuckey 1937

Gaston County :Espenshade and Potter 1953a, b,
1959

Furcron 1950

Keith and Sterrett 1917, 1931

Potter 1954

Stuckey 1937

Granville County : Broadhurst and
Councill 1953**Kyanite—Continued****North Carolina—Continued****Geology—Continued****Haywood County :**

Keith 1907b

Stuckey 1937

Iredell County : Stuckey 1937

Jackson County : Stuckey 1937

Johnston County :

Broadhurst and Councill 1953

Dunn 1933

Espenshade and Potter 1959

Furcron 1950

Stuckey 1932, 1937

Lincoln County :Espenshade and Potter 1953a,
1959

Potter 1954

Stuckey 1937

McDowell County : Overstreet and
Griffiths 1955**Macon County :**

Bryson 1932

Hash and Van Horn 1951

Keith 1907a

Stuckey 1937

Mecklenburg County : Stuckey 1937

Mitchell County :

Adler 1950

Brobst 1952

Bryson 1930

Espenshade and Potter 1959

Furcron 1950

Keith 1907c

Kulp and Brobst 1956

Kuns 1888

Olson 1944

Stuckey 1932, 1937

Person County :

Broadhurst and Councill 1953

Espenshade and Potter 1953b,
1959

Stuckey 1935, 1937

Randolph County : Stuckey 1937

Rutherford County :

Espenshade and Potter 1959

Stuckey 1937

Stokes County : Stuckey 1937

Surry County :

Overstreet and Griffiths 1955

Stuckey 1937

Wake County : Steel 1952

Western : Fessler and McCaughey
1929**Wilkes County :**

Bryson 1930

Genth 1873

Stuckey 1937

Yancey County :

Bryson 1930, 1932

Chute 1944

Furcron 1950

Keith 1905

Olson 1944

Payne 1928

Pratt 1898

Kyanite—Continued

North Carolina—Continued

Occurrence :

Broadhurst and Councill 1954
 Foster and others 1952
 Gunsallus 1956
 O'Meara and Grandrud 1936
 Pratt 1901
 Stuckey 1935
 Stuckey and Conrad 1958
 Tyler and Heuer 1949
 Waggaman 1958
 Watkins and others 1952
Alleghany County: Genth and Kerr 1881

Ashe County :

Espenshade and Potter 1959
 Genth 1891
 Greaves-Walker 1945
 Greaves-Walker and Riggs 1937
 Stuckey 1937

Avery County :

Bryson 1928, 1930
 Espenshade and Potter 1959
 Greaves-Walker 1945
 Greaves-Walker and Riggs 1937
 Kulp and Brobet 1956
 Olson 1944
 Petar 1930
 Stuckey 1937

Buncombe County :

Barlett 1940
 Broadhurst 1955
 Bryson 1930, 1938
 Espenshade and Potter 1959
 Genth 1873, 1891
 Genth and Kerr 1881
 Greaves-Walker 1950, 1945
 Greaves-Walker and Riggs 1937
 Hash and Van Horn 1951
 Keith 1904, 1905, 1907b
 King 1958
 Kunz 1907
 Murdock 1950
 Overstreet and Griffiths 1955
 Pole and Moore 1938
 Stuckey 1932, 1937, 1952
 Stuckey and others 1947
 Stuckey and Steel 1953

Burke County: Genth and Kerr 1881

Caldwell County :

Bryson 1928
 Genth 1871, 1891
 Genth and Kerr 1881
 Petar 1930

Catawba County :

Genth 1871, 1891
 Genth and Kerr 1881
 Overstreet and Griffiths 1955

Cherokee County :

Bryson 1928
 Espenshade and Potter 1959
 Genth 1891
 Genth and Kerr 1881
 Petar 1930

Kyanite—Continued

North Carolina—Continued

Occurrence—Continued

Clay County :

Broadhurst 1955
 Bryson 1928, 1930
 Genth 1873, 1891
 Genth and Kerr 1881
 Greaves-Walker 1930, 1945
 Greaves-Walker and Riggs 1937
 Hash and Van Horn 1951
 Petar 1930
 Stuckey 1937
 Stuckey and Steel 1953

Cleveland County :

Broadhurst 1955
 Espenshade and Potter 1953b, 1959
 Hash and Van Horn 1951
 Keith and Sterrett 1917
 Overstreet and Griffiths 1955
 Sterrett 1923
 Stuckey and Steel 1953

Franklin County :

Espenshade and Potter 1959
 Greaves-Walker 1945
 Greaves-Walker and Riggs 1937
 Stuckey 1937
 Stuckey and Steel 1953

Gaston County :

Broadhurst 1955
 Espenshade and Potter 1953a, b, 1959
 Ford 1932
 Furcron 1950
 Genth 1871, 1873, 1891
 Genth and Kerr 1881
 Greaves-Walker and Riggs 1937
 Keith and Sterrett 1917, 1931
 Kunz 1907
 Ladoo and Myers 1951
 Potter 1954
 Sterrett 1923
 Stuckey 1937
 Stuckey and Steel 1953
 Watson 1921

Graham County :

Bryson 1928
 Petar 1930

Granville County :

Broadhurst 1955
 Broadhurst and Councill 1953
 Stuckey 1958

Haywood County :

Bryson 1928, 1930
 Espenshade and Potter 1959
 Genth 1891
 Genth and Kerr 1881
 Greaves-Walker 1930, 1945
 Greaves-Walker and Riggs 1937
 Keith 1907b
 Petar 1930
 Pratt 1906
 Sterrett 1923
 Stuckey 1937

Kyanite—Continued**North Carolina—Continued****Occurrence—Continued****Iredell County :**

Bryson 1928, 1930
 Espenshade and Potter 1959
 Genth 1891
 Genth and Kerr 1881
 Greaves-Walker and Riggs 1937
 Petar 1930
 Pratt 1906
 Stuckey 1937
 Stuckey and Steel 1953

Jackson County :

Bryson 1928, 1930
 Greaves-Walker 1930, 1945
 Greaves-Walker and Riggs 1937
 Hash and Van Horn 1951
 Petar 1930
 Pratt 1906
 Stuckey 1937

Johnston County :

Broadhurst 1955
 Broadhurst and Council 1955
 Dunn 1933
 Espenshade and Potter 1959
 Furcron 1950
 Greaves-Walker 1945
 Greaves-Walker and Riggs 1937
 King 1958
 Stuckey 1932, 1937
 Stuckey and Steel 1953

Lincoln County :

Espenshade, Potter 1953a, 1959
 Genth and Kerr 1881
 Greaves-Walker and Riggs 1937
 Griffiths and Olson 1953a
 Overstreet and Griffiths 1955
 Potter 1954
 Sterrett 1923
 Stuckey 1937

McDowell County :

Bryson 1930
 Genth and Kerr 1881
 Greaves-Walker 1945
 Greaves-Walker and Riggs 1937
 Overstreet and Griffiths 1955

Macon County :

Broadhurst 1955
 Bryson 1930, 1932, 1938
 Genth 1871, 1891
 Genth and Kerr 1881
 Greaves-Walker 1930, 1945
 Greaves-Walker and Riggs 1937
 Hash and Van Horn 1951
 Keith 1907a
 Pratt 1906
 Stuckey 1937
 Stuckey and Steel 1953

Madison County :

Bryson 1930
 Genth 1891
 Genth and Kerr 1881

Kyanite—Continued**North Carolina—Continued****Occurrence—Continued****Mecklenburg County :**

Espenshade and Potter 1959
 Genth 1871, 1891
 Genth and Kerr 1881
 Greaves-Walker and Riggs 1937
 Stuckey 1937

Mitchell County :

Adler 1950
 Brobst 1952
 Bryson 1927, 1928, 1930, 1938
 Espenshade and Potter 1959
 Furcron 1950
 Genth 1871, 1891
 Genth and Kerr 1881
 Greaves-Walker 1930, 1945
 Greaves-Walker and Riggs 1937
 Keith 1907c
 Kulp and Brobst 1956
 Kuns 1888, 1907
 Olson 1944
 Parker 1952
 Petar 1930
 Pratt 1898, 1901
 Stuckey 1932, 1937

Moore County :

Genth 1891
 Genth and Kerr 1881

Nantahala National Forest vicinity :

Mattson 1934

Person County :

Broadhurst 1955
 Broadhurst and Council 1953
 Espenshade, Potter 1953b, 1959
 Genth 1871, 1891
 Genth and Kerr 1881
 Greaves-Walker 1945
 Greaves-Walker and Riggs 1937
 Jonas 1932
 Stuckey 1935, 1937

Randolph County :

Greaves-Walker 1945
 Greaves-Walker and Riggs 1937
 Stuckey 1937, 1938

Rockingham County : Genth and Kerr 1881**Rutherford County :**

Broadhurst 1955
 Espenshade and Potter 1959
 Genth 1873
 Greaves-Walker 1945
 Greaves-Walker and Riggs 1937
 Kuns 1907
 Ladoo and Myers 1951
 Stuckey 1937

Stokes County :

Espenshade and Potter 1959
 Genth 1871, 1891
 Genth and Kerr 1881
 Greaves-Walker and Riggs 1937
 Stuckey 1937

Kyanite—Continued

North Carolina—Continued

Occurrence—Continued

Surry County :

- Espenshade and Potter 1959
- Genth 1871, 1891
- Genth and Kerr 1881
- Greaves-Walker and Riggs 1937
- Overstreet and Griffiths 1955
- Stuckey 1937

Transylvania County :

- Genth 1891
- Genth and Kerr 1881
- Mattson 1934
- Pratt 1906

Wake County :

- Broadhurst 1955
- Espenshade and Potter 1959
- Genth 1891
- Genth and Kerr 1881
- Steel 1952

Watauga County : Genth, Kerr 1881

Western : Fessler and McCaughey 1929

Wilkes County :

- Bryson 1928, 1930
- Espenshade and Potter 1959
- Genth 1871, 1873, 1891
- Genth and Kerr 1881
- Greaves-Walker and Riggs 1937
- Petar 1930
- Stuckey 1937

Yancey County :

- Broadhurst 1955
- Bryson 1927, 1928, 1930, 1932, 1938

Chute 1944

Espenshade and Potter 1959

Ford 1932

Furcron 1950

Genth 1871, 1891

Genth and Kerr 1881

Greaves-Walker 1930, 1945

Greaves-Walker and Riggs 1937

Jeffery 1948

Jensen 1943

Keith 1905

Kerr 1937

Kuns 1907

Ladoo and Myers 1951

McVay and Wilson 1943

Mattson 1934, 1936, 1937

Murdock 1950

Olson 1944

Parker 1952

Payne 1928

Petar 1930

Pratt 1898, 1901

Riddle and Foster 1949

Stuckey 1932, 1937, 1952

Stuckey and others 1947

Stuckey and Steel 1953

Trauffer 1936

Watkins 1932

Kyanite—Continued

North Carolina—Continued

Technology and uses :

- Bryson 1930, 1938
- Foster and others 1952
- Greaves-Walker 1945
- Insley 1933
- Ralston 1938

Yancey County :

- Greaves-Walker 1945
- Jeffery 1943
- McVay and Wilson 1943
- Watkins 1932

Pennsylvania.

Geology :

Chester County : Gordon 1922

Delaware County :

- Dike 1951
- Gordon 1922
- Postel 1941
- Weiss 1949
- Wyckoff 1952

Montgomery County :

- Postel 1941
- Weiss 1949
- Wyckoff 1952

Northampton County : Anderson and Chesley 1931

Philadelphia County :

- Postel 1941
- Weiss 1949
- Wyckoff 1952

Occurrence : Kerr 1937

Bucks County : Gordon 1922

Chester County :

- Gordon 1922
- Ladoo and Myers 1951
- McKinstry 1949

Delaware County :

- Dike 1951
- Gordon 1922
- Ladoo and Myers 1951
- McKinstry 1949
- Petar 1930
- Postel 1941
- Riddle and Foster 1949
- Weiss 1949
- Wyckoff 1952

Lancaster County : Gordon 1922

Montgomery County :

- McKinstry 1949
- Postel 1941
- Weiss 1949
- Wyckoff 1952

Northampton County : Anderson and Chesley 1931

Philadelphia County :

- Gordon 1922
- McKinstry 1949
- Postel 1941
- Weiss 1949
- Wyckoff : 1952

Kyanite—Continued**South Carolina.****General, York County :**

Bule 1949

Espenshade and Potter 1959

Geology :**Cherokee County :**

Espenshade and Potter 1959

Keith and Sterrett 1931

Overstreet and Griffiths 1955

Chesterfield County : Espenshade and

Potter 1959

Edgefield County : Espenshade and

Potter 1959

Greenville County : Sloan 1908**Newberry County : Espenshade and**

Potter 1959

York County :Espenshade and Potter 1953a, b,
1959

Furcron 1950

Keith and Sterrett 1931

Potter 1954

Smith and Newcome 1951

Occurrence :

Tyler and Heuer 1949

Watkins and others 1952

Charleston County : Martens 1935**Cherokee County :**

Espenshade and Potter 1959

Furcron 1950

Keith and Sterrett 1931

Overstreet and Griffiths 1955

Van Horn and others 1949

Chesterfield County :

Espenshade and Potter 1959

Fries 1942

Peyton and Lynch 1953

Watson 1921

Edgefield County : Espenshade and

Potter 1959

Greenville County :

Griffiths and Olson 1953b

Sloan 1908

Sterrett 1923

Newberry County :

Bule 1949

Espenshade and Potter 1959

Richland County : Smith, L. L. 1932**York County :**

Avery 1953a

Brunenkant 1949

Bule 1949

Espenshade and Potter 1953a, b,
1959

Furcron 1950

Gliese and Smith 1958

Gunsallus 1956

Jensen 1943

Keith and Sterrett 1931

Potter 1954

Riddle and Foster 1949

Smith, L. L. 1932

Smith and Newcome 1951

Waggaman 1953

Kyanite—Continued**South Carolina—Continued****Occurrence—Continued****York County—Continued**

Wilson, H. H., Bole, G. A., 1958

Technology and uses, York County :

Avery 1953a

Brunenkant 1949

Gliese and Smith 1958

Gunsallus 1956

Wilson, H. H., Bole, G. A. 1958

United States.South Atlantic States, general : Matt-
son 1934**Southeastern, geology and occurrence :**

Cannon 1950

Espenshade and Potter 1959

Furcron 1950

Stuckey 1953

Utah.Geology and occurrence, Box Elder
County : Crawford, A. L., and
others 1948**Vermont.****Geology :****Orange County :**

Doll 1944

Hadley and Chapman 1939

Jacobs 1944

Windsor County :

Currier 1934

Doll 1944

Lyons 1955

Occurrence :**Orange County :**

Doll 1944

Hadley and Chapman 1939

Jacobs 1944

Windsor County :

Currier 1934

Doll 1944

Hawes 1878

Lyons 1955

Virginia.

General : Peck 1925, 1933

Buckingham County : Jones and
Ellertsen 1954

Charlotte County : Kerr 1937

Grayson County : Stose and Stose
1957**Prince Edward County :**

Corriveau 1955

Espenshade and Potter 1959

Hubbell 1941a

Jensen 1943

Mattson 1934

Riddle and Foster 1949

Sawyer and Whittemore 1941

Geology :

Dryden and Dryden 1941

Shell 1949

Kyanite—Continued

Virginia—Continued

Geology—Continued

Buckingham County:

Espenshade, Potter 1953a, b, 1959
 Jonas 1932
 Taber 1913, 1935

Carroll County:

Furcron 1950
 Jonas 1932
 Stose and Stose 1957

Charlotte County:

Espenshade and Potter 1953a,
 1959
 Jonas 1932
 Taber 1913
 Watson and Watkins 1911

**Goochland County: Taber 1913,
 1935**

Grayson County:

Furcron 1950
 Jonas 1932

**Halifax County: Espenshade and
 Potter 1959**

Henry County: Pegau 1932

Pittsylvania County: Pegau 1932

Prince Edward County:

Espenshade and Potter 1953a, b
 Furcron 1950
 Jonas 1932
 Sawyer and Whittemore 1940
 Stose and Stose 1957

Occurrence:

Dryden and Dryden 1941
 Tyler and Heuer 1949
 Watkins and others 1952

**Amelia County: Dietrich, R. V. 1953,
 1954, 1958**

Buckingham County:

Dietrich, R. V. 1953, 1954, 1958
 Espenshade and Potter 1953a, b,
 1959

Herod 1957

Jonas 1932

Jones and Eilersten 1954

Riddle and Foster 1949

Taber 1913, 1935

Waggaman 1953

Watkins 1932

Watson 1907

Campbell County:

Dietrich, R. V. 1955, 1958
 Espenshade and Potter 1959
 Watkins 1932

Caroline County:

Espenshade and Potter 1959
 Jahns and Griffiths 1953

Carroll County:

Dietrich, R. V. 1953, 1954, 1955,
 1958
 Furcron 1950
 Jonas 1932
 Stose and Stose 1957

Kyanite—Continued

Virginia—Continued

Occurrence—Continued

Charlotte County:

Dietrich, R. V. 1953, 1954, 1958
 Espenshade, Potter 1953a, 1959
 Jonas 1932
 Kerr 1937
 Peck 1925
 Petar 1930
 Taber 1913

Watson and Watkins 1911

**Fairfax County: Espenshade and
 Potter 1959**

**Fluvanna County: Dietrich, R. V.
 1953, 1954, 1958**

Franklin County:

Dietrich, R. V. 1955, 1958
 Sterrett 1923

Goochland County:

Dietrich, R. V. 1953, 1954, 1958
 Espenshade and Potter 1959
 Pardee and Park 1948
 Taber 1913, 1935

Grayson County:

Dietrich, R. V. 1953, 1954, 1955,
 1958

Espenshade and Potter 1959

Furcron 1950

Jahns and Griffiths 1953

Jonas 1932

Stose and Stose 1957

Watkins 1932

Halifax County:

Dietrich, R. V. 1953, 1954, 1958
 Espenshade and Potter 1959

Jonas 1932

Hanover County:

Dietrich, R. V. 1953, 1954, 1958
 Espenshade and Potter 1959
 Jahns and Griffiths 1953
 Watson 1907

Henry County:

Espenshade and Potter 1959

Jahns and Griffiths 1953

Pegau 1932

Louisa County:

Espenshade and Potter 1959
 Jahns and Griffiths 1953

**Lunenburg County: Dietrich, R. V.
 1953, 1954, 1958**

Patrick County:

Dietrich, R. V. 1953, 1954, 1958
 Espenshade and Potter 1959

Watkins 1932

Pittsylvania County:

Espenshade and Potter 1959
 Jahns and Griffiths 1953

Pegau 1932

Prince Edward County:

Avery 1953b
 Bevan 1942
 Corriveau 1955

Kyanite—Continued**Virginia—Continued****Occurrence—Continued****Prince Edward County—Continued**

Dietrich, R. V. 1953, 1954, 1955, 1958

Espenshade, Potter 1953a, b, 1959

Furcron 1950

Gunsallus 1956

Hubbell 1941a, b

Jensen 1943

Jonas 1932

Ladoo and Myers 1951

McVay and Wilson 1943

Mattson 1934

Riddle and Foster 1949

Sawyer and Whittemore 1940, 1941

Stose and Stose 1957

Waggaman 1953

Watkins 1932

Whittemore and Allen 1942

Spotsylvania County:

Dietrich, R. V. 1953, 1954, 1958

Espenshade and Potter 1959

Jahns and Griffiths 1953

Watson 1907

Technology and uses:

Galbreath and others 1944

Inley 1933

Jeffery 1943

Buckingham County: Herod 1957**Prince Edward County:**

Avery 1953b

Gunsallus 1956

Hubbell 1941b

McVay and Wilson 1943

Watkins 1932

Whittemore and Allen 1942

Washington.**Occurrence: Kerr 1937****Chelan County:**

Kelly and others 1956

Valentine 1949

Kittitas County: Kelly and others 1956**Skagit County:**

Kelly and others 1956

Valentine 1949

Wisconsin.**Geology, Iron County:**

Allen and Barrett 1915

Fries 1939

Occurrence, Iron County:

Allen and Barrett 1915

Fries 1939

Hanson 1954

Riddle and Foster 1949

Wyoming.**Geology:**

Albany County: Hagner 1953

Carbon County: Beckwith 1932

Kyanite—Continued**Wyoming—Continued****Occurrence: Kerr 1937****Albany County:**

Birch 1955

Clabaugh and others 1946

Hagner 1953

Osterwald and Osterwald 1952

Carbon County:

Beckwith 1932

Birch 1955

Clabaugh and others 1946

Osterwald and Osterwald 1952

Platt 1947

Riddle and Foster 1949

Platte County:

Birch 1955

Clabaugh and others 1946

Ladoo and Myers 1951

Osterwald and Osterwald 1952

Petar 1930

Riddle and Foster 1949

Pyrophyllite.**General:**

American Iron and Steel Institute—American Ceramic Society, Inc. 1950

Espenshade and Potter 1959

Irving 1956

Ladoo and Myers 1951

Norton, F. H. 1949

Peck 1933

Trelschel 1957

U.S. Bureau of Mines 1932-33

Geology:

Bowen, C. H. 1954

Clarke, F. W. 1908

Ford 1932

Keller 1954

Launer 1952

Roy and Osborn 1952a, c, 1954

Mineral synthesis:

Folk 1947

Gruner 1944

Kennedy 1954, 1955

Roy 1954

Roy and Osborn 1952a, 1954

Yoder 1952

Technology and uses:

Greaves-Walker 1945

Mulryan 1958

Arizona.

Geology, Yuma County: Wilson, E. D. 1929

Occurrence:**Mohave County:**

Galbraith 1947

Wilson, E. D., and others 1953

Yuma County:

Duke 1957

Galbraith 1947

Ladoo and Myers 1951

Wilson, E. D. 1929

Wilson, E. D., and others 1953

Pyrophyllite—Continued

California.

General:

- Inyo County: Wright 1957b
- Mono County: Wright 1950b, 1957b
- San Bernardino County:
 - Wright 1957b
 - Wright and others 1953
- San Diego County:
 - Jahns and Lance 1950
 - Wright 1950b, 1957b

Geology:

- Mariposa County: Kerr, Hamilton, and Pihl 1950
- Mono County: Peck 1924
- San Bernardino County:
 - Bowen, O. E., Jr. 1954
 - Pask and Bowen 1954
- San Diego County:
 - Lance 1950
 - Richard 1935

Occurrence:

- Irving 1956
- Murdoch and Webb 1956
- Alameda County: Eakle 1922
- Butte County: Eakle 1922
- Imperial County:
 - Moore, B. N. 1936
 - Pabst 1938
 - Sampson and Tucker 1942
 - Tucker 1928

Inyo County:

- California Division of Mines 1958
- Eakle 1922
- Jenkins and others 1954
- Murdoch 1949
- Murdoch and Webb 1952, 1956
- Wright 1950b, 1957b

Los Angeles County: Jenkins and others 1954

Madera County:

- Erwin 1934
- Pabst 1938

Mariposa County:

- Bowen and Gray 1957
- Burgess 1949
- Ford 1932
- Kerr, Hamilton, and Pihl 1950
- Pabst 1938

Mono County:

- Foster and others 1952
- Jeffery and Woodhouse 1931
- Jenkins and others 1954
- Kerr 1932
- Ladoo and Myers 1951
- Lemmon 1937
- Pabst 1938
- Peck 1924
- Woodhouse 1936
- Wright 1950b, 1957b
- Wright and others 1954

San Bernardino County:

- Bowen, O. E., Jr. 1954
- Jenkins and others 1954
- Pask and Bowen 1954

Pyrophyllite—Continued

California—Continued

Occurrence—Continued

San Bernardino County—Continued

- Wright 1957b
- Wright and others 1953

San Diego County:

- Burgess 1949
- California Division of Mines 1958
- Gillson 1937
- Jahns and Lance 1950
- Jenkins and others 1954
- Ladoo and Myers 1951
- Lance 1950
- Murdoch 1949
- Murdoch and Webb 1952, 1956
- Richard 1935
- Wright 1950b, 1957b
- Wright and others 1954

Shasta County: Jenkins, others 1954

Tulare County: Jenkins and others 1954

Technology and uses:

- California Division of Mines, Staff 1952
- Jenkins and others 1954
- Inyo County: California Division of Mines 1958
- Mono County: Foster and others 1952
- San Diego County: California Division of Mines 1958

Georgia.

Geology, Lincoln County:

- Espenshade and Potter 1959
- Genth 1873
- Johnston 1935
- Watson and Watson 1912

Occurrence, Lincoln County:

- Burgess 1949
- Espenshade and Potter 1959
- Ford 1932
- Genth 1873
- Johnston 1935
- Ladoo and Myers 1951
- Stuckey 1950
- Watson 1921
- Watson and Watson 1912

Massachusetts.

Occurrence, Franklin County: Emerson 1895

Montana.

Geology and occurrence, Beaverhead County: Perry 1948

Nevada.

General, Mineral County: Warner and others 1958

Geology, Pershing County: Kerr 1940

Occurrence:

- Mineral County: Warner and others 1958

Pershing County: Kerr 1940

Pyrophyllite—Continued

New Mexico.

Occurrence:

Dona Ana County:

Dunham 1935

Northrop 1942

Rio Arriba County:

Just 1937

Montgomery 1953

Northrop 1942

Taos County:

Just 1937

Montgomery 1953

Northrop 1942

North Carolina.

General:

Broadhurst 1955

Engineering and Mining Journal
1938

Greaves-Walker and others 1937

Greaves-Walker and Riggs 1937

Stuckey 1958

Treischel 1957

Alamance County:

Burgess 1949

Espenshade and Potter 1959

Stuckey and others 1947

Chatham County:

Pratt 1900, 1901

Stuckey 1925, 1926, 1927a, 1928

Granville County: Stuckey 1928

Moore County:

Bell and others 1953

Burgess 1949

Emrich 1941

Gower and Bell 1956

Milliken 1938

Pratt 1900, 1901

Stuckey 1925, 1926, 1927a, 1928

Stuckey and others 1947

Randolph County:

Burgess 1936, 1949

Espenshade and Potter 1959

Stuckey 1928

Stuckey and others 1947

Geology:

Broadhurst and Council 1954

Clarke, F. W. 1908

Stuckey 1950

Stuckey and Conrad 1958

Alamance County:

Broadhurst and Council 1953

Stuckey 1928, 1942

Chatham County:

Gillson 1937

Reinemund 1955

Stuckey 1927b, 1935, 1942

Granville County:

Broadhurst and Council 1953

Espenshade and Potter 1959

Stuckey 1942

Johnston County: Espenshade and
Potter 1959

Pyrophyllite—Continued

North Carolina—Continued

Geology—Continued

Lincoln County:

Espenshade and Potter 1959

Potter 1954

Montgomery County:

Broadhurst and Council 1953

Stuckey 1928

Moore County:

Adler 1950

Broadhurst and Council 1953

California Research Corp. 1950

Ceramic Industry 1939b

Davis, D. W., and others 1950

Gillson 1937

Hunt 1950

Keller and others 1952

Kerr and Adler 1950

Kerr, Hamilton, and Pili 1950

Kerr and Kulp 1949

Kerr, Kulp, and Hamilton 1949

Kerr, Main, and Hamilton 1950

Lewis 1950

Main 1950

Mieleze and others 1950

Parmelee and Barrett 1938

Reinemund 1955

Reno and Taylor 1950

Roes and Hendricks 1945

Stuckey 1927b, 1935, 1942

Wheeler and Burkhardt 1950

Orange County:

Broadhurst and Council 1953

Espenshade and Potter 1959

Stuckey 1928

Randolph County:

Broadhurst and Council 1953

Ceramic Industry 1939b

Gillson 1937

Stuckey 1938, 1942

Occurrence:

Broadhurst and Council 1954

Clarke, F. W. 1908

Irving 1956

Stuckey and Conrad 1958

Treischel 1957

U.S. Bureau of Mines 1932-33

Alamance County:

Broadhurst 1955

Broadhurst and Council 1953

Burgess 1949

Espenshade and Potter 1959

Genth 1901

King 1958

Ladoo and Myers 1951

Murdock 1950

Stuckey 1928, 1938, 1942, 1950,

1951, 1958

Stuckey and others 1947

Stuckey and Steel 1953

Valley and others 1958

Chatham County:

Broadhurst 1955

Bryson 1927, 1932, 1938

Pyrophyllite—Continued
North Carolina—Continued
Occurrence—Continued
Chatham County—Continued
 Drane and Stuckey 1925
 Genth 1871, 1873, 1891
 Genth and Kerr 1881
 Gillson 1937
 Greaves-Walker 1945
 Greaves-Walker and Riggs 1937
 Murdock 1950
 Pratt 1900, 1901
 Reinemund 1955
 Stuckey 1925, 1926, 1927a, b,
 1928, 1930, 1935, 1942, 1950
 Stuckey and others 1947
Gaston County:
 Genth 1871, 1873, 1891
 Genth and Kerr 1881
 Watson 1921
Granville County:
 Broadhurst 1955
 Broadhurst and Council 1953
 Bryson 1932
 Bryson and others 1937
 Espenshade and Potter 1959
 Genth 1891
 Greaves-Walker 1945
 Greaves-Walker and Riggs 1937
 King 1958
 Ladoo and Myers 1951
 Stuckey 1928, 1930, 1938, 1942,
 1950, 1958
 Stuckey and Steel 1953
Gulford County: Ford 1932
Johnston County:
 Broadhurst 1955
 Broadhurst and Council 1953
 Espenshade and Potter 1959
 King 1958
 Stuckey 1932, 1937
Lincoln County:
 Espenshade and Potter 1959
 Potter 1954
McDowell County:
 Genth 1871, 1891
 Genth and Kerr 1881
Mecklenburg County:
 Genth 1891
 Genth and Kerr 1881
Mitchell County: Genth, Kerr 1881
Montgomery County:
 Broadhurst 1955
 Broadhurst and Council 1953
 Bryson 1932
 Genth 1871, 1873, 1891
 Genth and Kerr 1881
 Greaves-Walker 1945
 Greaves-Walker and Riggs 1937
 Ladoo and Myers 1951
 Murdock 1950
 Stuckey 1928, 1930, 1938, 1950
 Stuckey and others 1947
Moore County:
 Adler 1950

Pyrophyllite—Continued
North Carolina—Continued
Occurrence—Continued
Moore County—Continued
 Bell and others 1953
 Bray and Stevens 1950
 Broadhurst 1955
 Broadhurst and Council 1953
 Bryson 1927, 1928, 1932, 1938
 Bryson and others 1937
 Burgess 1949
 California Research Corp. 1950
 Ceramic Industry 1939b
 Davis, D. W., and others 1950
 Drane and Stuckey 1925
 Emrich 1941
 Engineering, Mining Journal 1938
 Genth 1871, 1873, 1891
 Genth and Kerr 1881
 Gillson 1937
 Gower and Bell 1956
 Greaves-Walker 1945
 Greaves-Walker and Amero 1941
 Greaves-Walker and others 1937
 Greaves-Walker and Riggs 1937
 Hunt 1950
 Keller and others 1952
 Keller and Pickett 1950
 Kerr and Adler 1950
 Kerr, Hamilton, and Pill 1950
 Kerr and Kulp 1949
 Kerr, Kulp, and Hamilton 1949
 Kerr, Main, and Hamilton 1950
 Ladoo and Myers 1951
 Lewis 1950
 Main 1950
 Mielens and others 1950
 Milliken 1938
 Murdock 1950
 Parmelee and Barrett 1938
 Pratt 1900, 1901
 Reinemund 1955
 Reno and Taylor 1950
 Ross and Hendricks 1945
 Stuckey 1925, 1926, 1927a, b,
 1928, 1930, 1935, 1938, 1942,
 1950, 1951, 1958
 Stuckey and others 1947
 Stuckey and Steel 1953
 Vallye and others 1958
 Wheeler and Burkhardt 1950
Orange County:
 Broadhurst 1955
 Broadhurst and Council 1953
 Bryson 1932
 Bryson and others 1937
 Espenshade and Potter 1959
 Ford 1932
 Genth 1871, 1873, 1891
 Genth and Kerr 1881
 Greaves-Walker 1945
 Greaves-Walker and Amero 1941
 Greaves-Walker and others 1937
 Greaves-Walker and Riggs 1937
 King 1958

- Pyrophyllite—Continued**
North Carolina—Continued
 Occurrence—Continued
 Orange County—Continued
 Stuckey 1928, 1930, 1938, 1950, 1958
 Valley and others 1958
 Randolph County:
 Bishop 1952
 Broadhurst 1955
 Broadhurst and Council 1953
 Bryson 1932, 1938
 Bryson and others 1937
 Burgess 1936, 1949
 Ceramic Industry 1939b
 Engineering and Mining Journal 1943
 Espenshade and Potter 1959
 Genth 1871, 1873, 1891
 Genth and Kerr 1881
 Gillson 1937
 Greaves-Walker 1945
 Greaves-Walker and Amero 1941
 Greaves-Walker and others 1937
 Greaves-Walker and Riggs 1937
 King 1948, 1958
 Ladoo and Myers 1951
 Murdock 1950
 Stuckey 1928, 1930, 1938, 1942, 1950, 1951, 1958
 Stuckey and others 1947
 Stuckey and Steel 1953
 Valley and others 1958
 Zodac 1948
 Richmond County: Genth and Kerr 1881
 Technology and uses:
 Bryson 1938
 Ceramic Industry 1939b
 Greaves-Walker 1945
 U.S. Bureau of Mines 1932-33
 Alamance County:
 Murdock 1950
 Stuckey 1951
 Valley and others 1958
 Chatham County: Stuckey 1930
 Granville County: Stuckey 1930
 Moore County:
 Bray and Stevens 1950
 Bryson 1928
 Bryson and others 1937
 Engineering and Mining Journal 1938
 Keller and Pickett 1950
 Murdock 1950
 Stuckey 1930, 1951
 Valley and others 1958
 Orange County: Valley and others 1958
 Randolph County:
 Bishop 1952
 Bryson and others 1937
 Engineering and Mining Journal 1943
 Murdock 1950
 Stuckey 1930, 1951
 Valley and others 1958

- Pyrophyllite—Continued**
South Carolina.
 Geology, Edgefield County: Espenshade and Potter 1959
 Occurrence:
 Bule 1949
 Burgess 1949
 Abbeville County: Espenshade and Potter 1959
 Chesterfield County:
 Burgess 1941
 Espenshade and Potter 1959
 Ford 1932
 Fries 1942
 Genth 1873
 Ladoo and Myers 1951
 Fardee and Park 1948
 Peyton and Lynch 1953
 Watson 1921
 Zodac 1948
 Edgefield County: Espenshade and Potter 1959
 Newberry County: Espenshade and Potter 1959
 United States, southeastern.
 Geology and occurrence:
 Espenshade and Potter 1959
 Stuckey 1953
 Sillimanite.
 General:
 American Iron and Steel Institute—American Ceramic Society, Inc. 1950
 Espenshade and Potter 1959
 Greig 1925
 Jeffery 1943
 Norton, F. H. 1949
 Peck 1925, 1933
 Riddle and Foster 1949
 Snedden 1945
 U.S. Bureau of Mines 1932-33
 Waggaman 1953
 Watkins and others 1952
 Williamson 1949
 Geology:
 Bowen and Greig 1924
 Clarke, F. W. 1908
 Ford 1932
 Funk 1940a
 Goldsmith 1953
 Heinrich 1952
 Insley 1933
 Jensen 1943
 Keller 1954
 Kerr 1937, 1940
 Ladoo and Myers 1951
 Norton, J. T. 1925b
 Petar 1930
 Posnjak and Greig 1933
 Roy and Osborn 1952a, c. 1954
 Sosman 1933
 Taylor 1933
 Winston 1944

Sillimanite—Continued

Mineral synthesis:

- Clark and others 1957
- Kennedy 1954, 1955
- Morey 1942
- Riddle and Foster 1949
- Roy and Osborn 1952a, 1954
- Schulling 1958
- Smith, R. W. 1932
- Stuckey 1937
- Yoder 1952

Technology and uses:

- Dager and Betteley 1981
- Hunter and White 1946
- Newton 1944
- Palmer 1928
- Roy and Osborn 1952b
- Tyler and Heuer 1937
- Wilson, H. H., Jr. 1952

Alabama.

Occurrence:

Clay County:

- Espenshade and Potter 1959
- Riddle and Foster 1949
- Teague 1950

Cosa County: Pallister 1955a, b

Randolph County:

- Espenshade and Potter 1959
- Riddle and Foster 1949
- Teague 1950

Arizona.

Geology:

- Yavapai County: Anderson, C. A., and others 1955
- Yuma County: Wilson, E. D. 1929

Occurrence:

Coconino County:

- Galbraith 1947
- Wilson, E. D., and others 1953

Gila County:

- Galbraith 1947
- Wilson, E. D., and others 1953

Mohave County:

- Galbraith 1947
- Wilson, E. D., and others 1953

Pinal County: Galbraith 1953

Yavapai County:

- Anderson, C. A., and others 1955
- Galbraith 1947
- Wilson, E. D., and others 1953

Yuma County:

- Wilson, E. D. 1929
- Wilson, E. D., and others 1953

California.

General Mono County: Petar 1930

Geology:

- Los Angeles County:
- Beverly 1934
- Miller, W. J. 1934

Mariposa County:

- Clarke, F. W. 1908
- Rose 1957

Sillimanite—Continued

California—Continued

Geology—Continued

- Merced County: Davless 1946
- Orange County: Larsen 1948
- Riverside County: Larsen 1948
- San Diego County:
- Clarke, F. W. 1908
- Larsen 1948
- Merriam 1946
- Schaller 1905

Occurrence: Murdoch and Webb 1956

Inyo County:

- Eakle 1922
- Jeffery 1943
- Pabst 1938
- Sampson and Tucker 1931
- Winston 1944

Kern County: Miller, W. J. 1931

Los Angeles County:

- Beverly 1934
- Funk 1940a
- Jeffery 1943
- Miller, W. J. 1934
- Pabst 1938
- Winston 1944

Mariposa County:

- Clarke, F. W. 1908
- Eakle 1922
- Jeffery 1943
- Pabst 1938
- Rose 1957
- Sampson and Tucker 1931
- Winston 1944

Merced County: Davless 1946

Mono County: Petar 1930

Orange County: Larsen 1948

Riverside County:

- Funk 1940a
- Larsen 1948

San Bernardino County:

- Eakle 1922
- Jeffery 1943
- Pabst 1938
- Sampson and Tucker 1931
- Winston 1944

San Diego County:

- Clarke, F. W. 1908
- Eakle 1922
- Funk 1940a
- Jeffery 1943
- Larsen 1948
- Merriam 1946
- Murdoch 1949
- Murdoch and Webb 1952, 1956
- Pabst 1938
- Sampson and Tucker 1931
- Schaller 1905
- Waring 1905
- Winston 1944

Tuolumne County:

- Jeffery 1943
- Pabst 1938
- Winston 1944

Sillimanite—Continued**Colorado.****Geology:****Boulder County:**

- Dings 1941
Lovering and Tweto 1958

Chaffee County:

- Crawford, R. D. 1918
Heinrich and Griffiths 1947

Clear Creek County:

- Ball 1908
Harrison and Wells 1956, 1958
Lovering 1935

Custer County:

- Heinrich and Bever 1957
Singewald and Brock 1956

Fremont County:

- Finlay 1907
Hanley and others 1950
Heinrich and Bever 1957

Gilpin County: Slms, others 1955**Park County:**

- Heinrich and Bever 1957
Lovering 1935

Summit County: Lovering 1935**Occurrence:****Boulder County:**

- Argall 1949
Dings 1941
Heinrich and Bever 1957
Lovering and Goddard 1950
Lovering and Tweto 1953

Chaffee County:

- Argall 1949
Crawford, R. D. 1913
Heinrich and Griffiths 1947

Clear Creek County:

- Argall 1949
Ball 1908
Harrison and Wells 1956, 1958
Heinrich and Bever 1957
Lovering 1935
Lovering and Goddard 1950

Custer County:

- Heinrich and Bever 1957
Singewald and Brock 1956

Eagle County:

- Argall 1949
Crawford and Gibson 1925
Pearson and Tweto 1958

Fremont County:

- Argall 1949
Bever 1953
Finlay 1907
Grawe 1928b
Hanley and others 1950
Heinrich and Bever 1957
Riddle and Foster 1949
Sterrett 1923

Gilpin County:

- Lovering and Goddard 1950
Slms and others 1955

Grand County: Heinrich, Bever 1957**Gunnison County:**

- Argall 1949
Heinrich and Bever 1957

Sillimanite—Continued**Colorado—Continued****Occurrences—Continued****Jackson County:**

- Argall 1949
Heinrich and Bever 1957

Jefferson County:

- Heinrich and Bever 1957
Riddle and Foster 1949

Lake County: Heinrich, Bever 1957

- Pearson and Tweto 1958

Larimer County:

- Argall 1949
Thurston 1955

Park County:

- Argall 1949
Bever 1958
Heinrich and Bever 1957

- Lovering 1935

- Lovering and Goddard 1950

- Vanderwilt 1947

Pitkin County: Pearson and Tweto 1958**Summit County:**

- Argall 1949
Lovering 1935

Teller County: Lovering and Goddard 1950**Connecticut.****Geology:**

- Litchfield County: Gates and Bradley 1952

- Middlesex County: Bowen and others 1924

- New London County: Roy and Francis 1953

Occurrence:

- Litchfield County: Gates and Bradley 1952

- Middlesex County: Bowen and others 1924

- Ford 1932

New London County:

- Ford 1932
Ladoo and Myers 1951

- Pratt 1906

- Roy and Francis 1953

Windham County:

- Ford 1932
Ladoo and Myers 1951

Delaware.**Geology, New Castle County:**

- Bascom and Stose 1932
Roy and Francis 1953

Occurrence, New Castle County:

- Bascom and Stose 1932
Ford 1932

- Roy and Francis 1953

Florida.**General:**

- Alachua County: Thoenen and Warner 1949

- Baker County: Spencer 1948

Bradford County:

- Browning and others 1956
Spencer 1948

Sillimanite—Continued

Florida—Continued

General—Continued

Clay County:

Browning and others 1956
 Spencer 1948
 Thoenen and Warne 1949

Duval County:

Browning and others 1956
 Spencer 1948
 Thoenen and Warne 1949

Highlands County: Thoenen and Warne 1949

Lake County: Thoenen and Warne 1949

Marion County: Thoenen and Warne 1949

Nassau County: Thoenen and Warne 1949

Orange County: Thoenen and Warne 1949

Putnam County: Thoenen and Warne 1949

Geology:

Cannon 1950
 Martens 1928, 1935

Occurrence:

Cannon 1950
 Espenshade and Potter 1959
 Gunsallus 1956

Alachua County: Thoenen and Warne 1949

Baker County: Spencer 1948

Bay County: Martens 1928

Bradford County:

Browning and others 1956
 Spencer 1948

Brevard County: Martens 1928, 1935

Broward County: Martens 1935

Clay County:

Browning and others 1956
 Calver 1957
 Engineering and Mining Journal 1952

Martens 1928

Spencer 1948

Thoenen and Warne 1949

Tyrrell and Klinefelter 1956

Dade County: Martens 1935

Duval County:

Browning and others 1956
 Calver 1957
 Martens 1935
 Spencer 1948

Thoenen and Warne 1949

Flagler County: Martens 1935

Gulf County: Martens 1928

Highlands County: Thoenen and Warne 1949

Lake County: Thoenen and Warne 1949

Marion County:

Martens 1928

Thoenen and Warne 1949

Sillimanite—Continued

Florida—Continued

Occurrence—Continued

Nassau County:

Martens 1928, 1935

Thoenen and Warne 1949

Orange County: Thoenen and Warne 1949

Palm Beach County: Martens 1935

Putnam County: Thoenen and Warne 1949

St. Johns County: Martens 1928, 1935

St. Lucie County: Martens 1935

Sarasota County: Martens 1928

Volusia County: Martens 1935

Technology and uses, Clay County:

Engineering and Mining Journal 1952

Tyrrell and Klinefelter 1956

Georgia.

General: Teague 1950

Elbert County:

Espenshade and Potter 1959

Hudson 1946

Hart County:

Espenshade and Potter 1959

Hudson 1946

Teague 1950

Geology: Stose and Smith 1939

Butts County: Hudson 1946

Clarke County:

Hudson 1946

Hurst 1953

Dawson County:

Furcron 1950

Furcron and Teague 1945

De Kalb County:

Herrmann 1954

Hurst 1953

Elbert County:

Furcron 1950

Furcron and Teague 1945

Teague 1950

Gilmer County: Hurst 1957

Gwinnett County: Herrmann 1954

Hart County:

Furcron 1950

Furcron and Teague 1945

Grant 1954, 1958

Griffitts and Olson 1953b

Jasper County: Hudson 1946

Jones County: Hurst 1953

Madison County:

Furcron 1950

Furcron and Teague 1945

Hudson 1946

Teague 1950

Morgan County: Hudson 1946

Newton County: Hudson 1946

Oconee County: Hudson 1946

Oglethorpe County:

Hudson 1946

Hurst 1953

Sillimanite—Continued*Georgia*—Continued**Geology—Continued****Talbot County:**

Clarke, J. W. 1952

Hudson 1946

Towns County:

Furcron 1950

Furcron and Teague 1945

Hash and Van Horn 1951

Upson County: Clarke, J. W. 1952

Walton County: Hudson 1946

Wilkes County: Hurst 1953

Occurrence:

Foster and others 1952

Stose and Smith 1939

Tyler and Heuer 1949

Butts County: Hudson 1946

Chatham County: Martens 1935

Clarke County:

Hudson 1946

Hurst 1953

Dawson County:

Espenshade and Potter 1959

Furcron 1950

Furcron and Teague 1945

De Kalb County:

Herrman 1954

Hurst 1953

Elbert County:

Espenshade and Potter 1959

Furcron 1950

Furcron and Teague 1945

Griffitts and Olson 1953b

Hudson 1946

Peyton 1949

Riddle and Foster 1949

Teague 1950

Gilmer County: Hurst 1957

Glynn County: Martens 1928, 1935

Gwinnett County: Herrmann 1954

Hart County:

Espenshade and Potter 1959

Furcron 1950, 1953

Furcron and Teague 1945

Grant 1954, 1958

Griffitts and Olson 1953b

Hudson 1946

Peyton 1949

Rampacek and others 1945

Riddle and Foster 1949

Teague 1950

Jasper County: Hudson 1946

Jones County: Hurst 1953

Madison County:

Espenshade and Potter 1959

Furcron 1950

Furcron and Teague 1945

Hudson 1946

Peyton 1949

Riddle and Foster 1949

Teague 1950

Sillimanite—Continued*Georgia*—Continued**Occurrence—Continued**

Morgan County: Hudson 1946

Newton County: Hudson 1946

Occonee County:

Hudson 1946

Teague 1950

Oglethorpe County:

Hudson 1946

Hurst 1953

Talbot County:

Clarke, J. W. 1952

Hudson 1944, 1946

Teague 1950

Towns County:

Broadhurst 1955

Espenshade and Potter 1959

Furcron 1950

Furcron and Teague 1945

Hash and Van Horn 1951

Riddle and Foster 1949

Teague 1950

Upson County: Clarke, J. W. 1952

Walton County: Hudson 1946

Wilkes County: Hurst 1953

Technology and uses: Foster and others 1952

Hart County:

Furcron 1953

Furcron and Teague 1945

Rampacek and others 1945

Idaho.

General: Forrester 1942

Geology:

Clearwater County: Hietanen 1956

Latah County: Kelly 1948

Shoshone County: Hietanen 1956

Valley County: Schmidt 1958

Occurrence:

Engel and Shelton 1941

Foster and others 1952

Blaine County: Kauffman 1952

Cassia County: Kauffman 1952

Clearwater County: Hietanen 1956

Latah County:

Forrester 1942

Hubbard 1955, 1957

Kauffman 1952

Kelly 1948

Kelly and others 1956

Riddle and Foster 1949

Skinner and Kelly 1947

Snedden 1945

Shoshone County:

Hietanen 1956

Kauffman 1952

Valley County: Schmidt 1958

Technology and uses:

Engel and Shelton 1941

Foster and others 1952

Latah County: Skinner, Kelly 1947

Sillimanite—Continued

Maine.

General, Knox County: Forsyth 1955

Geology:

Knox County: Houston 1956

Piscataquis County: Philbrick 1936,
1940

Occurrence:

Knox County:

Forsyth 1955

Houston 1956

Piscataquis County: Philbrick 1936,
1940

Maryland.

Geology and occurrence: Dryden and

Dryden 1941

Massachusetts.

Geology:

Franklin County: Emerson 1917

Hampden County:

Emerson 1917

Shannon 1921

Hampshire County: Emerson 1917

Worcester County:

Clarke, F. W. 1908

Emerson 1917

Occurrence:

Franklin County: Emerson 1895,
1917

Hampden County:

Emerson 1895, 1917

Shannon 1921

Hampshire County: Emerson 1895,
1917

Worcester County:

Clarke, F. W. 1908

Emerson 1917

Ladoo and Myers 1951

Montana.

General:

Beaverhead County: Heinrich 1950

Gallatin County: Heinrich 1948

Madison County:

Heinrich 1948, 1950

Reid 1957

Geology:

Beaverhead County:

Heinrich 1949

Sinkler 1942

Gallatin County:

Clabaugh 1952

Clabaugh and Armstrong 1950

Heinrich 1949

Madison County:

Clabaugh 1952

Clabaugh and Armstrong 1950

Heinrich 1949

Hopkins and Taber 1947

Levandowski 1958

Reid 1958

Sinkler 1942

Park County: Heinrich 1948, 1949

Sillimanite—Continued

Montana—Continued

Occurrence:

Beaverhead County:

Heinrich 1949, 1950

Kauffman 1952

Kelly and others 1956

Sinkler 1942

Deer Lodge County:

Emmons and Calkins 1918

Heinrich 1948

Gallatin County:

Clabaugh 1952

Clabaugh and Armstrong 1950

Heinrich 1948, 1949

Kauffman 1952

O'Brien 1947

Granite County: Kauffman 1952

Madison County:

Clabaugh 1952

Clabaugh and Armstrong 1950

Heinrich 1948, 1949, 1950

Hopkins and Taber 1947

Kauffman 1952

Kelly and others 1956

Levandowski 1958

Reid 1957, 1958

Sinkler 1942

Park County:

Heinrich 1948, 1949

Kauffman 1952

Seager 1944

Technology and uses, Gallatin County:

O'Brien 1947

Nevada.

Occurrence:

Mineral County: Riddle and Foster
1949

Nye County: Riddle and Foster 1949

New Hampshire.

Geology: Billings 1955, 1956

Belknap County: Modell 1936

Carroll County:

Billings 1928

Moke 1946

Cheshire County:

Fowler-Billings 1941, 1944,
1949a, b

Heald 1950a

Kurger 1946a

Moore, G. E., Jr., 1949a

Smith, L. L. 1945

Coos County:

Billings 1941

Billings, Chapman, and others
1946

Billings, Fowler-Billings, and
others 1946

Chapman, R. W. 1948

Grafton County:

Bannerman 1941

Billings 1935, 1937

Billings and Williams 1935

Sillimanite—Continued*New Hampshire*—Continued**Geology—Continued****Grafton County—Continued**

Fowler-Billings and Kingsley 1937

Fowler-Billings and Page 1942

Moke 1946

White and Billings 1951

Williams and Billings 1938

Merrimack County :

Chapman, C. A. 1952

Fowler-Billings and Kingsley
1937

Fowler-Billings and Page 1942

Rockingham County : Freedman
1950a, b**Strafford County :** Freedman
1950a, b**Sullivan County :**

Chapman, C. A. 1939, 1952

Fowler-Billings and Page 1942

Heald 1950a

Occurrence : Billings 1955, 1956**Belknap County :**

Meyers and Stewart 1956

Modell 1936

Quinn 1941

Carroll County :

Billings 1928

Meyers and Stewart 1956

Moke 1946

Cheshire County :

Clark and others 1957

Fowler-Billings 1941, 1944,
1949a, b

Heald 1950a, b

Kruger 1946a, b

Meyers and Stewart 1956

Moore, G. E., Jr. 1949a, b

Pearre and Calkins 1957

Smith, L. L. 1945

Snedden 1945

Coos County :

Billings 1941

Billings, Chapman, others 1946

Billings, Fowler-Billings, and
others 1946

Chapman, R. W. 1948

Meyers and Stewart 1956

Merrimack County :

Bannerman 1941

Billings 1935, 1937

Billings and Williams 1935

Fowler-Billings and Kingsley
1937

Fowler-Billings and Page 1942

Meyers and Stewart 1956

Moke 1946

Sterrett 1923

White and Billings 1951

Williams and Billings 1938

Merrimack County :

Chapman, C. A. 1952, 1953

Fowler-Billings and Kingsley
1937**Sillimanite—Continued***New Hampshire*—Continued**Occurrence—Continued****Merrimack County—Continued**

Fowler-Billings and Page 1942

Meyers and Stewart 1956

Rockingham County :

Freedman 1950a, b

Meyers and Stewart 1956

Strafford County :

Freedman 1950a, b

Meyers and Stewart 1956

Sullivan County :

Chapman, C. A. 1939, 1952, 1953

Fowler-Billings and Page 1942

Heald 1950a, b

Meyers and Stewart 1956

Sterrett 1923

*New Jersey.***Geology and occurrence :**

Morris County : Sims 1953, 1958

Passaic County : Hots 1953

Sussex County :

Baker 1955

Sims and Leonard 1952

Warren County : Hots 1954

*New Mexico.***Geology :**Rio Arriba County : Montgomery
1953**Taos County :**

Just 1937

Montgomery 1953

Talmage and Wootton 1937

Occurrence :**Rio Arriba County :**

Jahns 1946

Montgomery 1953

Northrop 1942

Riddle and Foster 1949

Taos County :

Just 1937

Montgomery 1953

Northrop 1942

Riddle and Foster 1949

Talmage and Wootton 1937

*New York.***Geology :****Adirondack Mountains :**

Ailing 1926

Buddington 1929, 1939, 1948

*See also individual counties.***Clinton County :**

Kemp and Ailing 1925

Postel 1952

Dutchess County :

Balk 1936

Barth 1936

Essex County :

Kemp and Ailing 1925

Ogilvie 1905

Jefferson County : Buddington 1934,
1939**Lewis County :** Buddington 1934,
1939

Sillimanite—Continued

New York—Continued

Geology—Continued

Orange County: Hots 1953

Putnam County:

Balk 1936

Barth 1936

St. Lawrence County:

Buddington 1934, 1939

Dale 1935

Dietrich, R. W. 1957

Warren County:

Alling 1926

Ogilvie 1905

Washington County: Alling 1926

Occurrence:

Adirondack Mountains:

Alling 1926

Buddington 1929, 1939, 1943

Engel and Engel 1950

See also individual counties

Clinton County:

Kemp and Alling 1925

Postel 1952

Dutchess County:

Balk 1936

Barth 1936

Essex County:

Kemp and Alling 1925

Ogilvie 1905

Hamilton County: Miller, W. J. 1916

Jefferson County: Buddington 1934, 1939

Lewis County:

Buddington 1934, 1935

Miller, W. J. 1910

Smyth and Buddington 1926

Monroe County: Ladoo, Meyers 1951

Oneida County: Miller, W. J. 1909

Orange County: Hots 1953

Putnam County:

Balk 1936

Barth 1936

St. Lawrence County:

Buddington 1934, 1939

Dale 1935

Dietrich, R. V. 1957

Miller, W. J. 1922

Smyth and Buddington 1926

Warren County:

Alling 1926

Miller, W. J. 1914

Ogilvie 1905

Washington County: Alling 1926

Westchester County:

Ford 1932

Ladoo and Myers 1951

North Carolina.

General:

Hash and Van Horn 1951

Teague 1950

Wilson, H. H., Jr. 1952

Burke County: Hash and Van Horn 1951

Sillimanite—Continued

North Carolina—Continued

General—Continued

Caldwell County:

Hash and Van Horn 1951

Wilson, H. H., Jr. 1952

Gaston County: Espenshade and Potter 1959

Jackson County: Hash and Van Horn 1951

Geology:

Broadhurst 1955

Stuckey and Conrad 1958

Alexander County:

Furcron 1950

Hash and Van Horn 1951

Hunter and White 1946

Buncombe County: Hash and Van Horn 1951

Burke County:

Espenshade and Potter 1959

Furcron 1950

Hunter and White 1946

Overstreet and Griffiths 1955

Caldwell County:

Espenshade and Potter 1959

Furcron 1950

Hunter and White 1946

Catawba County:

Hash and Van Horn 1951

Overstreet and Griffiths 1955

Clay County:

Espenshade and Potter 1959

Furcron 1950

Furcron and Teague 1945

Hash and Van Horn 1951

Hunter and White 1946

Cleveland County:

Espenshade and Potter 1953b, 1959

Furcron 1950

Hash and Van Horn 1951

Hunter and White 1946

Overstreet and Griffiths 1955

Gaston County:

Espenshade and Potter 1953a, b

Potter 1954

Haywood County: Hash and Van Horn 1951

Iredell County:

Furcron 1950

Hash and Van Horn 1951

Hunter and White 1946

Jackson County: Espenshade and Potter 1959

Lincoln County:

Espenshade, Potter, 1953a, 1959

Hash and Van Horn 1951

Potter 1954

Macon County:

Espenshade and Potter 1959

Hash and Van Horn 1951

Rutherford County:

Furcron 1950

Hash and Van Horn 1951

Hunter and White 1946

Overstreet and Griffiths 1955

Sillimanite—Continued

North Carolina—Continued

Geology—Continued

Wilkes County :

- Furcron 1950
- Hash and Van Horn 1951
- Hunter and White 1946

Yadkin County :

- Furcron 1950
- Hunter and White 1946

Occurrence : Stuckey and Conrad 1958

Alexander County :

- Broadhurst 1955
- Espenshade and Potter 1959
- Furcron 1950
- Hash and Van Horn 1951
- Hunter and White 1946
- Murdoch 1950
- Stuckey 1952
- Stuckey and Steel 1953
- Teague 1950
- Wilson, H. H., Jr. 1952

Buncombe County :

- Espenshade and Potter 1959
- Hash and Van Horn 1951
- Hunter and White 1946
- Murdoch 1950
- Teague 1950
- Wilson, H. H., Jr. 1952

Burke County :

- Broadhurst 1955
- Espenshade and Potter 1959
- Furcron 1950
- Genth and Kerr 1881
- Hash and Van Horn 1951
- Hunter and White 1946
- Murdoch 1950
- Overstreet and Griffiths 1955
- Pratt 1906
- Stuckey 1951, 1952
- Stuckey and others 1947
- Stuckey and Steel 1953
- Teague 1950
- Wilson, H. H., Jr. 1952

Caldwell County :

- Broadhurst 1955
- Espenshade and Potter 1959
- Furcron 1950
- Griffitts and Olson 1953a
- Hash and Van Horn 1951
- Hunter and White 1946
- Murdoch 1950
- Stuckey 1952
- Stuckey and Steel 1953
- Teague 1950
- Wilson, H. H., Jr. 1952

Catawba County :

- Broadhurst 1955
- Griffitts and Olson 1953a
- Hash and Van Horn 1951
- Overstreet and Griffiths 1955

Clay County :

- Broadhurst 1955
- Bryson 1932
- Espenshade and Potter 1959

Sillimanite—Continued

North Carolina—Continued

Occurrence—Continued

Clay County—Continued

- Furcron 1950
- Furcron and Teague 1945
- Hash and Van Horn 1951
- Hunter and White 1946
- Murdoch 1950
- Riddle and Foster 1949
- Stuckey 1937, 1951, 1952
- Stuckey and Steel 1953
- Teague 1950
- Wilson, H. H., Jr. 1952

Cleveland County :

- Broadhurst 1955
- Espenshade, Potter 1953b, 1959
- Furcron 1950
- Griffitts and Olson 1953a
- Hash and Van Horn 1951
- Hunter and White 1946
- Murdoch 1950
- Overstreet and Griffiths 1955
- Stuckey 1952
- Stuckey and Steel 1953
- Teague 1950
- Wilson, H. H., Jr. 1952

Gaston County :

- Espenshade and Potter 1953a, b, 1959
- Griffitts and Olson 1953a
- Potter 1954

Granville County : Broadhurst 1955

Haywood County :

- Espenshade and Potter 1959
- Hash and Van Horn 1951
- Hunter and White 1946

Iredell County :

- Broadhurst 1955
- Espenshade and Potter 1959
- Furcron 1950
- Hash and Van Horn 1951
- Hunter and White 1946
- King 1958
- Murdoch 1950
- Stuckey 1952
- Stuckey and Steel 1953
- Teague 1950
- Wilson, H. H., Jr. 1952

Jackson County :

- Broadhurst 1955
- Espenshade and Potter 1959
- Hash and Van Horn 1951
- Stuckey 1951, 1952
- Stuckey and Steel 1953

Lincoln County :

- Broadhurst 1955
- Espenshade and Potter 1953a, 1959

- Griffitts and Olson 1953a
- Hash and Van Horn 1951
- Potter 1954
- Teague 1950

Macon County :

- Broadhurst 1955
- Espenshade and Potter 1959

Sillimanite—Continued

North Carolina—Continued

Occurrence—Continued

Macon County—Continued

- Ford 1932
- Hash and Van Horn 1951
- Stuckey 1951, 1952
- Stuckey and Steel 1953

Madison County: Hash, Van Horn 1951

Rutherford County:

- Broadhurst 1955
- Espenshade and Potter 1959
- Furcron 1950
- Griffitts and Olson 1953a
- Hash and Van Horn 1951
- Hunter and White 1946
- King 1958
- Murdock 1950
- Overstreet and Griffitts 1955
- Stuckey 1951, 1952
- Stuckey and others 1947
- Stuckey and Steel 1958
- Teague 1950
- Wilson, H. H., Jr. 1952

Stokes County: Overstreet and Griffitts 1955

Surry County:

- Overstreet and Griffitts 1955
- Stuckey 1951, 1952
- Stuckey and others 1947
- Stuckey and Steel 1958

Wilkes County:

- Broadhurst 1955
- Furcron 1950
- Hash and Van Horn 1951
- Hunter and White 1946
- Murdock 1950
- Stuckey 1952
- Stuckey and Steel 1958
- Teague 1950
- Wilson, H. H., Jr. 1952

Yadkin County:

- Furcron 1950
- Hunter and White 1946
- Murdock 1950
- Stuckey 1952
- Wilson, H. H., Jr. 1952

Yancey County: Hash, Van Horn 1951

Pennsylvania.

General, Delaware County: Greig 1925

Geology:

Chester County:

- Bascom and Stose 1932
- Gordon 1922
- Roy and Francis 1958

Delaware County:

- Bascom and Stose 1932
- Bowen and Greig 1924
- Bowen and others 1924
- Gordon 1922
- Navias and Davey 1925
- Postel 1941
- Weiss 1949
- Wyckoff 1952
- Wyckoff and others 1926

Sillimanite—Continued

Pennsylvania—Continued

Geology—Continued

Montgomery County:

- Postel 1941
- Weiss 1949
- Wyckoff 1952

Philadelphia County:

- Postel 1941
- Weiss 1949
- Wyckoff 1952

Occurrence:

Chester County:

- Bascom and Stose 1932
- Gordon 1922
- McKinstry 1949
- Roy and Francis 1953

Delaware County:

- Bascom and Stose 1932
- Bowen and Greig 1924
- Bowen and others 1924
- Ford 1932
- Gordon 1922
- Greig 1925
- Ladoo and Myers 1951
- McKinstry 1949
- Navias and Davey 1925
- Postel 1941
- Wyckoff 1952
- Wyckoff and others 1926

Montgomery County:

- McKinstry 1949
- Postel 1941
- Wyckoff 1952

Philadelphia County:

- Gordon 1922
- McKinstry 1949
- Postel 1941
- Wyckoff 1952

South Carolina.

General: Teague 1950

- Anderson County: Bule 1949
- Greenville County: Hudson 1946
- Spartanburg County: Bule 1949

Geology: Shell 1949

Anderson County:

- Hudson 1944, 1946
- Teague 1950

Cherokee County: Overstreet and Griffitts 1955

Greenville County:

- Furcron 1950
- Hudson 1944
- Sloan 1908
- Smith, L. L. 1943, 1945
- Teague 1950

Laurens County: Hudson 1946

Spartanburg County:

- Dosh 1950
- Furcron 1950
- Hickman 1947
- Hudson 1944, 1946
- Smith, L. L. 1943, 1945
- Teague 1950

Sillimanite—Continued*South Carolina*—Continued**Geology—Continued**

York County: Espenshade and Potter
1959

Occurrence: Tyler and Heuer 1949

Anderson County:

Bule 1949

Espenshade and Potter 1959

Furcron and Teague 1945

Hudson 1944, 1946

Overstreet and Griffiths 1955

Rampacek and others 1945

Riddle and Foster 1949

Teague 1950

Charleston County: Martens 1935

Cherokee County:

Bule 1949

Espenshade and Potter 1959

Keith and Starrett 1917

Overstreet and Griffiths 1955

Greenville County:

Bule 1949

Espenshade and Potter 1959

Furcron 1950

Hudson 1944, 1946

Overstreet and Griffiths 1955

Rampacek and others 1945

Riddle and Foster 1949

Sloan 1908

Smith, L. L. 1943, 1945

Teague 1950

Laurens County:

Espenshade and Potter 1959

Hudson 1946

Teague 1950

Oconee County: Overstreet and Griffiths 1955

Spartanburg County:

Bule 1949

Doah 1950

Espenshade and Potter 1959

Furcron 1950

Hickman 1947

Hudson 1944, 1946

Overstreet and Griffiths 1955

Rampacek and others 1945

Riddle and Foster 1949

Smith, L. L. 1943, 1945

Teague 1950

York County: Espenshade and Potter
1959

Technology and uses:

Anderson County:

Espenshade and Potter 1959

Furcron and Teague 1945

Rampacek and others 1945

Greenville County:

Espenshade and Potter 1959

Rampacek and others 1945

Spartanburg County:

Espenshade and Potter 1959

Rampacek and others 1945

Sillimanite—Continued*South Dakota*.

General: Connelly and O'Harra 1929

Geology:

Custer County:

Page and others 1953

Riddle and Peck 1935

Sheridan 1955

Pennington County: Lincoln and
others 1937

Occurrence:

Foster and others 1952

Smith, R. W. 1932

Black Hills: Jensen 1943

Custer County:

Connolly and O'Harra 1929

Page and others 1953

Riddle and Foster 1949

Riddle and Peck 1935

Sheridan 1955

Pennington County: Lincoln and
others 1937

Technology and uses: Foster and others
1952

United States.

Occurrence: Petar 1930

Southeastern, geology and occurrence:

Cannon 1950

Espenshade and Potter 1959

Furcron 1950

Stuckey 1953

Teague 1950

Vermont.

Geology and occurrence:

Orange County:

Doll 1944

Jacobs 1944

Orleans County: Doll 1951

Windsor County: Doll 1944

Virginia.

Geology:

Dryden and Dryden 1941

Espenshade and Potter 1959

Goochland County: Pegau 1932

Occurrence:

Dryden and Dryden 1941

Espenshade and Potter 1959

Amelia County:

Dietrich, R. V. 1953, 1954, 1958

Lemke and others 1953

Caroline County: Jahns and Griffiths
1953

Goochland County:

Jahns and Griffiths 1953

Pegau 1932

Hanover County: Jahns and Griffiths
1953

Louisa County: Jahns and Griffiths
1953

Powhatan County: Jahns and Griffiths
1953

Sillimanite—Continued

Virginia—Continued

Occurrence—Continued

Spotsylvania County: Jahns and Griffiths 1953

Washington.

Geology, Spokane County:

Anderson 1928

Collier 1908

Page 1942

Occurrence:

Chelan County: Kauffman 1952

Kittitas County: Kauffman 1952

Pend Oreille County:

Kauffman 1952

Valentine 1949

San Juan County: Kauffman 1952

Skagit County: Kauffman 1952

Skamania County: Kauffman 1952

Spokane County:

Anderson 1928

Collier 1908

Kauffman 1952

Kelly and others 1956

Page 1942

Riddle and Foster 1949

Valentine 1949

Stevens County: Kauffman 1952

Wyoming.

Geology, Albany County: Hagner 1953

Occurrence:

Albany County: Hagner 1953

Carbon County:

Birch 1955

Osterwald and Osterwald 1952

Topaz.

General:

American Iron and Steel Institute—American Ceramic Society, Inc. 1950

Peck 1933

Riddle and Foster 1949

Geology:

Clarke, F. W. 1908

Ford 1932

Penfield and Minor 1894

Technology and uses:

Hopkins 1957

Meyer 1942

California.

Occurrence, Mono County:

Jeffery and Woodhouse 1931

Kerr 1932

Lemmon 1937

Murdoch and Webb 1956

Riddle and Foster 1949

Woodhouse 1951

Colorado.

Geology, Gunnison County:

Eckel 1933

Staats and Trites 1955

Topaz—Continued

Colorado—Continued

Occurrence, Gunnison County:

Eckel 1933

Heinrich and Bever 1957

Riddle and Foster 1949

Staats and Trites 1955

Missouri.

Geology and occurrence, Madison County:

Singewald and Milton 1929

Tolman 1933

North Carolina.

Geology: Broadhurst and Council 1954

Gaston County: Espenshade and Potter 1959

Granville County:

Broadhurst and Council 1953

Espenshade and Potter 1959

Johnston County: Espenshade and Potter 1959

Occurrence: Broadhurst and Council 1954

Gaston County: Espenshade and Potter 1959

Granville County:

Broadhurst 1955

Broadhurst and Council 1953

Espenshade and Potter 1959

Stuckey 1958

Johnston County: Espenshade and Potter 1959

Orange County:

Broadhurst and Council 1953

Espenshade and Potter 1959

Randolph County: Broadhurst and Council 1953

South Carolina.

General, Chesterfield County:

Bradley and others 1940

Burgess 1941, 1942

Espenshade and Potter 1959

Fries 1942

Jensen 1943

Ladoo and Myers 1951

Payton and Lynch 1953

Riddle and Foster 1949

Stuckey and Amero 1941

U.S. Bureau of Mines 1932-33

Geology, Chesterfield County:

Glass 1937

Pardee and others 1937

Pardee and Park 1948

Occurrence, Chesterfield County:

Bradley and others 1940

Burgess 1941, 1942

Espenshade and Potter 1959

Fries 1942

Galbreath and others 1944

Glass 1937

Jensen 1943

Topaz—Continued

South Carolina—Continued

Occurrence, Chesterfield County—Con.

- Ladoo and Myers 1951
- McVay and others 1944
- McVay and Wilson 1943
- Norton, F. H. 1949
- Pardee and others 1937
- Pardee and Park 1948
- Peyton and Lynch 1953
- Pole 1944
- Ralston 1942
- Riddle and Foster 1949
- Stuckey and Amero 1941

Technology and uses, Chesterfield County:

- Galbreath and others 1944
- McVay and others 1944

Topaz—Continued

South Carolina—Continued

Technology and uses, Chesterfield County—Continued

- McVay and Wilson 1943
- Norton, F. H. 1949
- Pole 1944
- Ralston 1942

Virginia.

Geology, Amelia County: Glass 1950

Occurrence:

Amelia County:

- Dietrich 1958
- Geehan 1953
- Glass 1935
- Lemke and others 1952
- Pegau 1932

Buckingham County: Espenak and Potter 1959



VERMONT—Continued

County, and Kings Mountain deposit, Cleveland

County
County, and Clay Counties

NORTH CAROLINA

County, and Laurens Counties

County
County

GEORGIA

County

County

FLORIDA



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