Selected Bibliography of Andalusite, Kyanite Sillimanite, Dumortierite Topaz, and Pyrophyllite in the United States

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GEOLOGICAL SURVEY BULLETIN 1019-N

Selected Bibliography of Andalusite, Kyanite Sillimanite, Dumortierite Topaz, and Pyrophyllite in the United States

By AGNES B. GRAMETBAUR

CONTRIBUTIONS TO BIBLIOGRAPHY OF MINERAL RESOURCES

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Contains references, to December 31, 1958, on geology, mineral synthesis, geographic occurrence, and technology and uses

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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 ($Al_2O_3 \cdot SiO_2$) but different crystallographic, physical, and optical properties; and dumortierite ($8Al_2O_3 \cdot B_2O_3 \cdot 6SiO_2 \cdot H_2O$) and topaz ($[Al(F,OH)]_2SiO_4$), which are closely allied in composition and thermal behavior.

All these minerals disassociate upon heating to high temperatures to form mullite ($3Al_2O_3 \cdot 2SiO_2$) and free silica. Kyanite alters at the lowest temperature, 1,100° to 1,480°C, sillimanite at the highest, 1,550° to 1,650°C, andalusite at 1,350° to 1,450°C, dumortierite at <1,000° to 1,250°C, and topaz at <1,000° to 1,480°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 sileceous 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 ($Al_2O_3 \cdot 4SiO_2 \cdot H_2O$) and kaolinite ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$), 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 columar 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

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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

Abbreviation	*Publication*
Acad. Nat. Sci. Philadelphia Proc.; Spec. Pub.	Proceedings of the Academy of Natural Sciences of Philadelphia; Special Publication. 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; Journal. Columbus, Ohio.
Am. Geologist	The American Geologist. Minneapolis, Minn.
Am. Geophys. Union Trans	Transactions of the American Geophysical Union. Washington.
Am. Inst. Mining Metall. Engineers Contr.; Tech. Pub.; Trans.; Year Book.	American Institute of Mining and Metallurgical Engineers Contribution; Technical 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, Preliminary 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 Geology. Urbana, Ill.
Arizona Bur. Mines Bull	Arizona Bureau of Mines, Bulletin. Tucson, 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., Mineral 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 Francisco, Calif.

Abbreviation	*Publication*
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.

Abbreviation	*Publication*
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.

Abbreviation	*Publication*
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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