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Selected Annotated Bibliography of Asbestos Resources in the United States and Canada

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 - L



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

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*Contains references on the geology,
mineralogy, and origin of asbestos
resources*



UNITED STATES DEPARTMENT OF THE INTERIOR

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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.
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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 asbestos 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 asbestos 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 serpentinized 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 serpentinized 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 northwestern 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 cobbed, and milled fiber. All non-spinning 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 serpentized. 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 serpentine" float. Most of the asbestos probably occurs as short slip-fiber chrysotile on the flakes of serpentine.

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. [Stock-piling, 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 Asbestes. [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 Kriegszeiten. [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, serpentinization, 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 serpentinization 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 serpentinized 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

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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 $\frac{1}{3}$ 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 asbestos 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_3O_4 . 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 serpentized 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. 386-388.

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 Kiimmel, 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 serpentized 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 serpentization of ultramafic igneous rocks, including several references to origin of chrysotile asbestos. Historical development of theories of serpentization are summarized; characteristics, textures, structures, and composition of serpentinite bodies throughout the world are

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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." Serpentinitization 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 Sweetwater 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 serpentinitization 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.

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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, E., 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, 1951, Structural materials and industrial minerals: British Columbia Dept. Mines Ann. Rept. 1950, 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 serpentized 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.

— 1952, Structural materials and industrial minerals: British Columbia Dept. Mines Ann. Rept. 1951, 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.

— 1954, Structural materials and industrial minerals: British Columbia Dept. Mines Ann. Rept. 1953, 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.

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Byers, A. R., and Dahlstrom, C. D. A., 1954, Geology and mineral deposits of the Amisk-Wildnest Lakes area, Saskatchewan: Saskatchewan Dept. Mineral Resources, Geol. Br. Rept. 14, p. 135-137.

Cross-fiber chrysotile occurs in narrow veinlets cutting serpentinitized 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 $\frac{1}{6}$ to $\frac{3}{4}$ inch, and make up as much as 12 percent of the rock. Geologic map in 8 parts; scale 1 inch= $\frac{1}{2}$ mile, is included.

Cady, 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 asbestosiform 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. Philip 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. 132, 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. R., 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 $\frac{1}{4}$ 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

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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 asbestosiform 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, Cooke 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-

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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 asbestosiform 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. Asbestosiform 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 Danyville 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 serpentinitization 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 serpentinitization 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 Larochelle, 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.

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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 serpentization of the ultramafic rocks are recognized. The first stage is essentially deuterian 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 serpentization. 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 serpentized peridotite. 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 alkalies, 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. 97-108.

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 serpentinized 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 deuterian 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 deuterian 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, Serpentines, 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 serpentinites 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 Peninsula: 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 asbestosiform 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.

McKillip, 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 Lamoille 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 Small's 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 asbestos 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 serpentized 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 asbestos 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 asbestosiform minerals, pulverized minerals (indicating serpentine rock, soapstone, brucite, and serpentized 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=5½ 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., 1905, 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 asbestosiform 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 Twenholfe, 1949.

Reifsneider, 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.

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Retty, 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 Ge⁴⁺ substituted for Si⁴⁺; platy crystals were formed when Al³⁺ substituted for both Si⁴⁺ and Mg²⁺; either platy or tubular crystals were formed when Ni²⁺ substituted for Mg²⁺; however, this is dependent also upon other factors. Serpentine structures were not formed when Mn²⁺, Zn²⁺, Co²⁺, Fe³⁺, Cr³⁺, and Ga³⁺ 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, MgO-SiO₂-H₂O, NiO-SiO₂-H₂O, and MgO-GeO₂-H₂O.

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 Heide, 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 serpentine, 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 asbestos-form 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.

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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 northwestern 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 serpentinite." 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 SiO_2 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-

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tinite 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 Enders' 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 asbestos-form minerals and specific descriptions of the chrysotile deposits in Gila County, Ariz. Chrysotile was deposited in fractures and folds near diabase sills in the serpentized 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 = 1½ 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.

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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 asbestos-form 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.

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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 asbestos 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-

terial 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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