I. C. 6817

January 1935

DEPARTMENT OF THE INTERIOR

UNITED STATES BUREAU OF MINES
JOHN W. FINCH, DIRECTOR

INFORMATION CIRCULAR

ASBESTOS - GENERAL INFORMATION

BY

OLIVER BOWLES

I.C. 6817
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By Oliver Bowles[2]

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1/ The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6817." This paper is the second of a series of reports on the asbestos industry. The first report, I.C. 6790, is entitled "Asbestos - Domestic and Foreign Deposits."

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DEFINITION

"Asbestos" is not the name of a distinct mineral species but is rather a commercial term applied to fibrous varieties of several minerals. The origin and significance of names applied to asbestos by early writers are discussed in the section devoted to sources of supply and terms employed in ancient times.

VARIETIES

The most useful variety of asbestos is chrysotile, a fibrous serpentine the composition of which is expressed by the formula $H_4Mg_3Si_2O_9$. Chrysotile is characterized by a strength and flexibility that permit the use of the longer fibers for spinning. The bulk of the world production of both long and short fibers is of this variety.

Other varieties of asbestos belong to the amphibole group of minerals. Anthophyllite, having the composition $(Fe,Mg)SiO_3$, is the type most abundant in the United States. Usually it is brittle and of low tensile strength and is more resistant to the action of acids and heat than chrysotile. It is used for nonspinning purposes. Amosite, a peculiar variety of iron-rich anthophyllite occurring in Africa, is notable for the length of its fiber. The best-grade material is used for spinning. Fibrous tremolite, $CaMg_3(SiO_3)_4$, actinolite, $Ca(MgFe)_3(SiO_3)_4$, and hornblende, a complex silicate similar in composition to actinolite, generally are regarded as the minerals to which the term "asbestos" was originally applied. Except for Italian tremolite they have little commercial value. Mountain leather and mountain cork are varieties of amphibole consisting of flexible sheets of interlaced fibers. Mountain wood is a compact fibrous mass of amphibole resembling dry wood. The last three varieties are mineral curiosities and have no commercial value. Crocidolite, also called "blue asbestos", having the composition $NaFe(SiO_3)_2FeSiO_3$, is an unusual amphibole occurring in commercial quantities chiefly in Africa. It is used for both spinning and nonspinning purposes.

SOURCES OF SUPPLY AND TERMS EMPLOYED IN ANCIENT TIMES

The word "asbestos", evidently first applied by Pliny to the fibrous mineral now known by that name, was employed erroneously, for in both ancient and modern Greek it refers to quicklime. The Greek word "asbestos" means "inextinguishable" or "unquenchable" - words conveying quite the opposite meaning from "incombustible", a characteristic feature of asbestos. Possibly Pliny had in mind Plutarch's reference to the "perpetual" asbestos lamp wicks used by the Vestal Virgins. "Lithos amiantos", the original term used by the Greeks for asbestos, meant a rock unstained, untainted, or undefiled and doubtless referred to the cleansing of asbestos cloth by throwing it in the fire.

Another common name applied to asbestos was "Karystios lithos" because a well-known source of flexible mineral fiber was near Karystos, southern

Euboea, Greece. Early in the first century Strabo referred to stone from this locality that was carded and woven into handkerchiefs. Solinus and Plutarch also mention a fibrous mineral from this place. These ancient writers evidently knew little of the deposits, but as two exposures of serpentine occur east of Karystos the fiber probably was chrysotile.3/

Pausanius, who lived in the second century A.D., refers to incombustible "Karpasian flax." Some writers think this term indicates that the source of the fiber was Karpasos, northeastern Cyprus, but no asbestos-bearing rock is known in that vicinity. Evans points out that the word "Karpasos" means "cotton" and that probably it was applied to the mineral because of its adaptability to textile use.4/ Cyprus, however, was a well-known source of supply of asbestos in ancient times. Although it is difficult to determine from early references the exact location of the deposit, probably it was southeast of Mount Troodos in a village known as "Amianto", the identity of which is lost. During recent years chrysotile asbestos has been produced in considerable quantities near a town now known as "Amiandos." This is probably the site of ancient Amianto, for it is situated near Mount Troodos 18 miles from the seaport Limasol.

The asbestos used by the Romans doubtless was a long-fibered variety identified as tremolite and occurring in northern Italy. The use of Italian fiber presumably led to the claim widely made in literature that the original "amiantos" consisted of fibrous amphibole (tremolite, actinolite, or hornblende). A recent personal communication from the chief mineral inspector in Rome, however, casts some doubt as to whether Italian fiber used by the ancients was tremolite. A significant excerpt from this communication reads as follows:

> For a long time it was believed that the Italian "amianti" were all the tremolite type because the first examinations of the material were based on samples of tremolite. It was only in recent years that, after further studies, the producers recognized that their products were for the most part chrysotile with a long, flexible fiber.

Marco Polo refers to "amiantos" cloth shown to him during his travels through Siberia. The best-known asbestos of Siberia is chrysotile occurring at Minusinsk near the Mongolian border. Thus it appears that outside of Italy all the known asbestos deposits were sources of chrysotile and not amphibole.

Further evidence that the term "amiantos" as used by the ancients may have applied to chrysotile as well as to amphibole is found in the uses of the material. With the exception of twisted fiber used for lamp wicks practically all the early references are to textile use. Asbestos was woven into handkerchiefs, tablecloths, winding sheets, and similar fabrics. Most

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3/ Evans, John W., The Identity of the Amiantos or Karystian Stone of the Ancients with Chrysotile: Mineralogical Mag. (London), vol. 14, May 1906, pp. 143-43.

4/ Evans, John W., Work cited, p. 143.

varieties of amphibole asbestos are weak and brittle and cannot be spun or woven. The principal exceptions, aside from the tremolite of Italy, are the crocidolite and amosite of South Africa - varieties unknown until comparatively recent years. Chrysotile, on the other hand, is strong, flexible, and silky and well adapted for textiles. Judging from the probable sources of supply it seems reasonable to conclude that it was employed in ancient times in the manufacture of incombustible fabrics.

ORIGIN

Asbestos originates for the most part from rocks consisting largely of olivine, such as peridotite or dunite, or from pyroxenite. Most chrysotile deposits result from alteration of olivine to serpentine, with subsequent prismatic crystallization providing the fibrous structure. The alteration is effected by intense metamorphism. Contact as well as regional metamorphism evidently plays an important part in the process because in various regions, notably the Canadian and Rhodesian fields, intrusive rocks are associated with the deposits and doubtless definitely influenced their development. Prismatic crystallization occurs in fractures. As recrystallization evidently occurs along the vein walls, the veins may be regarded as of the replacement rather than the fissure type.

Chrysotile occurs in two forms - cross fiber and slip fiber. The former is the characteristic occurrence in all replacement veins, the fibers crossing the veins at right angles to the walls. Hence the fiber length is governed in general by the width of the vein. Slip fiber, on the other hand, parallels the vein wall and usually shows the effects of pressure and movement along a fault plane. The chrysotile occurring in sedimentary rocks in Arizona and in the Carolina district of the Transvaal originated in a quite different way. The fiber in these localities is regarded as a product of alteration of magnesian limestone metamorphosed by diabase intrusions. It occurs in cross-fiber veins.

Under some conditions peridotites and pyroxenites are altered to fibrous amphiboles, of which the most common is anthophyllite. In some places it occurs as slip fiber in shear zones, but more commonly the altered rock takes the form of pockets or lenses consisting almost entirely of irregularly arranged bundles of fiber. The rock is called "amphibolite", and the asbestos is of the mass-fiber type.

The crocidolite and amosite of South Africa originated from rocks quite distinct from peridotite or pyroxenite. They were derived from sediments rich in iron and silica, known as "banded ironstones". Prismatic crystallization in cross-fiber veins probably was assisted to some extent by contact metamorphism.

MODE OF OCCURRENCE

From the discussion of origin it is evident that there are three types of asbestos deposits - cross fiber, slip fiber, and mass fiber. Cross-fiber asbestos consists of innumerable strands extending across veins from wall to wall, except where interrupted by longitudinal seams. Most commercial deposits of chrysotile, amosite, and crocidolite are of this type, but anthophyllite rarely, if ever, occurs in cross-fiber veins. In slip-fiber deposits the strands more or less parallel the vein walls. They frequently show slickensided surfaces because they occupy shear zones where the rock has been subjected to movement and pressure. Slip fiber is common in the chrysotile deposits near Eden, Vt., and predominates in the anthophyllite deposits at Pylesville, Md., and near Bedford and Rocky Mount, Va.

In mass-fiber deposits there is no definite orientation of fibers. Almost the entire mass of the rock is composed of bundles of fibers or needles that sometimes show a radiating structure. This type of occurrence is confined almost exclusively to the anthophyllite variety and is well-exemplified by deposits at Sall Mountain, Ga., and Kamiah, Idaho.

PHYSICAL PROPERTIES

Outstanding Characteristics.- The most characteristic properties of asbestos - those that give it commercial value - are fibrous structure and fire resistance. The longest and strongest fibers have qualities possessed by no other mineral, in that they may be spun into yarn or thread, woven into cloth, or felted into sheets and packings in almost the same way as animal and vegetable fibers, but unlike cotton or wool they consist of incombustible matter.

Fibrous Character.- Although all asbestos is fibrous, the quality of the fiber in the various types and in different deposits is quite diverse. Chrysotile, amosite, and crocidolite normally posses high tensile strength, flexibility, and elasticity, but these qualities vary greatly in material from different localities. Chrysotile occasionally is harsh and somewhat brittle. Crocidolite is said to be stronger than chrysotile. The fibers of amosite are exceptionally long. Anthophyllite is generally brittle and of low tensile strength, although the fiber from some deposits has considerable strength and toughness. This type usually is more flexible than fibrous tremolite or actinolite. Tremolite is generally too weak and brittle for textile use; Italian tremolite, however, is said to be of spinning grade.

Length of fiber is important in asbestos strong and flexible enough for spinning and weaving. The fiber is graded on the basis of length, and materials of identical quality may range in price from $20 to $500 a ton, according to grade.

Fineness of Fiber.- Fineness of fiber is measured by the degree of separation accomplished by fiberizing processes. The fibrous structure of asbestos is due to a highly developed prismatic cleavage, the spacings between cleavage planes being infinitesmal or, at least, measurable by the size of the ultimate particle of fiber, which is incalculably small. Subdivision therefore theoretically may be continued almost indefinitely, the fineness that can be attained depending on the delicacy of the tools used and the skill of manipulation.

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Varieties of asbestos and occurrences of the same variety vary markedly in the ease with which they can be fiberized. Some types can be separated readily into slender fibers, while others are divided with difficulty and therefore appear as coarse-fibered material. Merrill has measured anthophyllite fibers down to 0.002 mm in diameter,[5] and the smallest measured diameter recorded by Cirkel is 0.00075 mm.[6] Apart from strength and flexibility the quality of asbestos is measured to some extent by the fineness of fiber attainable and by the amount of processing required to reduce it to the fineness desired.

Color and Luster.- Chrysotile occurs in various shades of green or yellowish green. When fiberized into a fluffy mass all types of chrysotile are practically white, unless stained by impurities. Amosite ranges from gray or yellowish gray to white and if relatively pure is white when fiberized. Crocidolite is lavender-blue, and this color is maintained when the fibers are separated. Anthophyllite and tremolite are gray, greenish gray, or white, and the separated fibers are white unless staining impurities are present. The luster of asbestos usually is silky or pearly.

Heat Resistance.- Cirkel states that Canadian chrysotile withstands temperatures of 2,000° to 3,000° F. and that a temperature of 5,000° F. produces no visible effects on some varieties.[7] It has been found, however, that when chrysotile is heated to a high temperature its water of crystallization is driven off and it becomes brittle. Anthophyllite, tremolite, and amosite contain low percentages of water and withstand higher temperatures than other varieties. However, crocidolite, although having a low water content, is easily fused into a black magnetic mass.

Heat Conductivity.- Asbestos does not have low heat conductivity. Its value for heat insulation is due to its noninflammability and also to its fibrous structure, which adapt it for manufacture into coverings that are nonconductors of heat because of their porous nature.

Acid Resistance.- Tremolite and anthophyllite are highly resistant to acids. It is claimed that crocidolite resists chemicals and sea water remarkably well. Chrysotile is affected more readily by acids and other chemicals than are the amphibole varieties.

Electrical Resistance.- Varieties of chrysotile lowest in iron content are the most suitable for electrical insulation. Arizona chrysotile is superior for this use. Apparently the iron content of amphibole does not affect its use for this purpose because crocidolite, which upon analysis shows a content of about 35 percent FeO, has high electrical resistance. This seeming contradiction may be explained by the fact that iron is present

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5/ Merrill, G. P., Proceedings of the United States National Museum: Vol. 18, 1895, pp. 282-283.

6/ Cirkel, Fritz, Chrysotile Asbestos - Its Occurrence, Exploitation, Milling, and Uses: Canada Dept. Mines, Mines Branch 69, 2d ed., 1910, p. 85.

7/ Cirkel, Fritz, Work cited, p. [illegible].

in crocidolite as a silicate, whereas in chrysotile it commonly appears as iron oxide impurities.

CHEMICAL COMPOSITION

The chemical formulas for the various kinds of asbestos are given in the section on varieties. Theoretical composition as calculated from chemical formulas rarely corresponds with actual composition because more or less impurity is always present. The following table shows analyses of representative commercial fibers.

Analyses of representative asbestos samples, percent

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	H_2O	Total
Chrysotile, Canada1/	40.36	0.21	1.35	0.65	43.86	-----	----	13.45	99.89
Anthophyllite, Georgia2/	56.40	1.15	----	11.40	28.58	0.50	----	1.63	99.76
Crocidolite, Cape Colony3/	51.10	——	----	35.80	2.30	-----	6.90	3.90	100.00
Amosite, [illegible]4/ ...	49.72	5.72	——	37.00	3.77	1.65	----	2.29	100.15
Tremolite, [illegible]tal5/ ..	58.00	6/5.32	——	-----	22.75	10.65	——	.50	93.02

[illegible] C., Chrysotile Asbestos in Canada: Canada Dept. Mines, Mines [illegible] 7, 1931, p. 20.

[illegible] O. B., Asbestos, Talc, and Soapstone Deposits of Georgia: Geol. [illegible] Georgia Bull. 29, 1914, p. 79.

3/ Hall, A. [illegible], Asbestos in the Union of South Africa: Union of South Africa Geol. Survey Mem. 12, 1916, p. 19.

4/ [illegible], p. 22.

5/ [illegible], p. 23.

[illegible] e_2O_3.

USES

[illegible] is of use asbestos falls into two principal classes - spinning and nonspinning fiber. Spinning fiber comprises the longer grades of chrysotile, crocidolite, amosite, and, exceptionally, tremolite. Nonspinning fiber comprises the shorter grades of these varieties and both the long and short grades of [illegible] [illegible]llite and related amphibole varieties.

The la[illegible] use of spinning asbestos is for the manufacture of automobile br[illegible] linings and clutch facings. As much as 70,000,000 feet of brake-band li[illegible]gs have been made in a single year in the United States. Gaskets cons[illegible]ng of asbestos cloth covered with rubber cement consume large [illegible] [illegible]ning fiber. Asbestos of spinning grade is used also for [illegible] of fireproof theater curtains and scenery; blankets; mattresses; [illegible] gloves, and shoes; aprons; mittens; leggings; helmets; [illegible] [illegible]elts for carrying hot materials; braided and woven tapes; [illegible] [illegible]ings; wick; rope; and listings. The use of asbestos in air[illegible] [illegible] increasingly important.

Nonspinning fiber is used principally in the heat-insulation and roofing trades, although large quantities of the better grades are used for making molded brake linings. On account of its heat-insulating and fire-resisting properties asbestos paper, manufactured in the same way as ordinary paper, is used for making three-ply air-cell and similar pipe covering; as sheeting between floors; as lining for stoves, heaters, filing cabinets, soldiers' helmets, mufflers for automobiles, drum controllers in sulphite mills, automobile radiator covers, and tubes for electric wires; and in many other ways. A widely used pipe covering consists of about 15 percent asbestos and 85 percent magnesia. Compressed sheets of asbestos combined with cement are used extensively for corrugated sheeting, wall board, millboard, lumber, and floor tile and as lining for safes, stoves, heaters, electrical switch boxes, garages, hoods of automobiles, and ovens. Asbestos compounds are used to some extent in automobile bodies. Asbestos-cement pipes are finding increasing use for water and gas mains and sewers. They are resistant to acids, noncorrosive, relatively nonconductive of heat and electricity, light in weight, and so elastic that traffic vibrations are unlikely to cause leakage. Moreover, they are easily placed and joined. A standard European pipe consists of 80 percent cement and 20 percent asbestos.

Roofing shingles consisting of about 85 percent portland cement and 15 percent asbestos are used extensively. Large quantities of short fibers are consumed in the manufacture of plastic fireproof cements used for boiler, pipe, and furnace covering. They also are used in fireproof paints, in arc welding, for protecting the surface of metal sheathing, and as a constituent of asphalt-roof coatings. The stronger grades of anthophyllite are used for making acid filters, stoppings in combustion tubes, wicks for producing flames by saturation with mineral salts, fireproof supports and protectors, and other chemical-laboratory equipment. Weak and brittle amphibole asbestos is used in making plastic cements and as an ingredient in acoustical and other wall plaster, cement flooring, and battery boxes, but it cannot be used in shingles and compressed sheets where fiber strength is important. Many industries use asbestos for hundreds of minor purposes.

MINING METHODS

Asbestos deposits in the various localities differ widely in character, and methods of mining depend greatly on conditions of occurrence. In some places the rock is blasted in open quarries and loaded with power shovels in much the same way as limestone or trap rock is quarried for the production of crushed stone. In other deposits elaborate systems of underground mining have been developed. General methods followed in the principal districts are outlined briefly.

Arizona.- In Arizona chrysotile asbestos occurs in relatively thin veins paralleling limestone beds and therefore is mined in drifts and tunnels. As the veins are only a few inches thick much waste rock must be removed to give working space. A typical mining method is to maintain a tunnel roof close to the asbestos zone and to pick the asbestos onto a large canvas. As the mines are far from railroads and markets the short fibers can scarcely be sold at a profit, and crudes constitute virtually the entire output. Several thousand feet of tunnels have been driven in mines on Ash Creek and at other points in the southern part of the State.

Vermont.- The chrysotile asbestos quarries of Vermont are situated at an elevation of 2,500 feet on the south side of Belvidere Mountain approximately 15 miles from Hyde Park, the nearest railway station. As the rock outcrops at this point, very little stripping is necessary. The quarry face is about 125 feet high, and individual benches are 12 to 15 feet high. Blast holes are sunk with hammer drills. An electric power shovel with a 1¼-cubic yard dipper is used for loading into 5-ton side-dump cars that discharge over a grizzly into a 25- by 36-inch jaw crusher at the mill.

Georgia and Maryland.- Mass-fiber anthophyllite, the variety found in Georgia, usually occurs in pockets or lenses confined for the most part to surface zones; it therefore is quarried in shallow open pits. As operations are small, the material is loaded by hand into small cars that convey it to the mill or to the transshipping point. Quarries at Sall Mountain and Hollywood, Ga., are of this type. Slip-fiber anthophyllite, on the other hand, occurs in narrow shear zones, which necessitate excavation in narrow opencuts or underground workings. The Pylesville (Md.) operations are examples.

Quebec.- Stripping is a serious problem in the Quebec district as overburden ranges from 6 or 8 feet to a maximum of 125 feet in depth. For many years, asbestos was obtained from large open-pit quarries served by overhead cableways. About 1927 methods were modified by the introduction of new equipment - cranes or power shovels were introduced for loading, locomotives were used for hauling cars on the quarry floor, and cable hoists removed the cars from the pits up inclined planes or through tunnels. Power-shovel loading, crushing, and subsequent recovery of crude fiber from picking belts are gradually replacing hand cobbing of crudes in the quarry. This method reduces costs but tends to reduce recovery of crude. The principal reasons for the change were (1) decreasing markets for crudes due to the introduction of molded brake linings; (2) increasing supplies of crudes from Rhodesia, the Union of South Africa, and Russia; (3) a decreasing proportion of crudes in the rock; and (4) lower prices for crudes.

A still later development in the Quebec district is the introduction of shrinkage stoping. The stone is drawn through chutes directly into boxes trammed by hand or electric locomotives through tunnels leading to the open pit, from which the material is hoisted by high-speed cableways. The most recent innovation is an elaborate block-caving system at the King mine of the Asbestos Corporation, Ltd., patterned after the system employed in some of the Arizona copper mines. Satisfactory operation has been attained, and mining costs are considerably lower than those recorded for the shrinkage-stoping method. Details of the process have been published.9/

9/ Ross, J. G., Block Caving at the King Mine of the Asbestos Corporation, Ltd., Thetford Mines, Quebec: Canadian Min. and Met. Bull., no. 264, April 1934, pp. 184-216.

Rhodesia.- Two mining methods - quarrying and shrinkage stoping - are used at the Shabani, the largest asbestos mine in Rhodesia.

The quarrying method is peculiar in that the rock is broken in open pits but removed through vertical shafts. Shafts or winzes are sunk in rows 50 to 60 feet apart and connected with crosscuts at a lower level. The rock around them is drilled and blasted and the fiber cobbed from the broken fragments. In order that the fiber may be broken as little as possible light powder charges are fired in shallow holes. The broken rock is thrown into the shafts which are kept nearly full, drawn into cars on the level below, and taken to the mill for extraction of the short fiber or recovery of the long fiber not removed in cobbing. The cobbed fiber is thrown down a separate shaft. The shafts are also employed for disposal of waste and for drainage.

The shrinkage-stoping method was introduced about 1926. The ground is removed in blocks 80 feet square, leaving pillars 20 to 30 feet wide which are subsequently reclaimed.

Union of South Africa.- The largest asbestos mines in the Union of South Africa are those producing chrysotile in the Barberton district of the Transvaal. The asbestos-bearing serpentine occurs in two zones. The upper one, known as the "ribbon reef", contains short-fiber veins, and the lower one provides long fiber. The belt dips 10° to 20°, and underground mining is practised. The ribbon reef is stoped first, and at a later stage the rock carrying long fiber is removed from the footwall.

Two large mines have been developed in this territory. The New Amianthus mine is worked on several levels. In 1928 it extended down the dip a distance of 1,650 feet from the outcrop. In the same year the Munnik-Myburg mine comprised about 3,300 feet of underground workings.

In the Carolina district of the Transvaal chrysotile occurs in cross-fiber veins occupying a 5-foot zone of altered dolomite dipping 8° to 15°. Mines have been operated since 1905 and have reached a depth of 300 feet.

Amosite of the Lydenburg district of the Transvaal occurs in banded ironstones that have been highly folded and contorted. The fiber-bearing beds usually stand at angles ranging from 15° to vertical. As they are unsuited for open-pit working underground mining is generally followed. Where the beds are intersected by transverse valleys tunnels are driven along the strike, and the fiber-bearing rock is stoped out at various levels. Outcrops are numerous over a wide area, and fiber is obtained from many mines worked at relatively shallow depths.

The largest mines are the Egnep and the Amosa situated near Penge. In this region the fiber-bearing zone dips from 15° to 22°. The Egnep mine is worked on seven levels. A vertical shaft 215 feet deep serves the seventh level and is connected with the sixth by a crosscut. The Amosa mine, as described by Hall in 1930, comprised 11 drifts starting from the outcrop and ranging from 80 to 1,140 feet in length down the dip. An inclined shaft 320 feet long corresponds to a vertical depth of 2?0 feet.

Crocidolite (blue asbestos), which is associated with amosite in the territory north of the Olifants River, is mined in small underground workings. Crocidolite also occurs over a wide area in the Prieska and Kuruman districts of the Cape of Good Hope. The veins are irregular and discontinuous, and systematic mining cannot be followed generally. Much of the fiber is obtained from small open pits or from shallow mines worked by natives. A few mines have been worked to depths of 250 feet with drifts over 1,000 feet long.

Hall describes in considerable detail asbestos mining in South Africa.9/

Russia.- The asbestos deposits of the Bajanova district have a thin overburden. Hand methods of removal were first employed, but power shovels or hydraulic methods have superseded them to quite an extent.

More than 20 shallow open quarries were worked for many years. Up to 1929 drilling was the only mechanical process used, all other operations being conducted with hand tools. Owing to inadequate milling facilities, hand picking became an important concentration process, and only one fourth to one fifth of the rock quarried was sent to the mill. The average fiber content of the rock mined was only about 6 percent, but because of the concentration attained by hand picking that sent to the mill was 22 percent.

The first steps toward more complete mechanization were taken in 1929, with the installation of 2- to 4-ton capacity overhead cableways with fixed foot towers and traveling head towers. These were supplemented by inclined haulageways served by electric hoists. The rock was blasted in benches 5 to 6 meters high and classified into crudes, mill feed, and waste.

In 1929 two shafts were sunk and connected with a haulage level at a depth of 50 meters. They were designed for glory-hole mining, which proved uneconomical. This method was supplemented and largely superseded in 1930 by electric-shovel loading in open pits with transport by locomotives to inclined haulageways, up which cars are taken by electric hoists. Mining costs are estimated at about 75 cents a metric ton of rock. Details of quarrying and mining methods have been supplied by Ru Keyser.10/

Cyprus.- Chrysotile asbestos occurs on the slopes of Mount Troodos in irregular veins traversing serpentine formed by alteration of olivine. The expansion accompanying metamorphism of original olivine resulted in excessive fracturing, which makes excavation easy. The workings consist of open-pit terraces reaching a maximum height of 200 feet. Much of the rock is so fractured and decomposed that it can be broken with picks without the aid of explosives. Before 1927, when compressed-air drills were introduced, the harder rock was drilled for blasting by hand methods. When 40-pound hand hammer drills are used 3-inch holes ranging in depth from 8 to 12 feet are sunk at the rate of about 10 feet an hour. The larger masses of barren rock are removed as waste, and fiber-bearing material is turned over to facilitate drying in the hot sun. It is then passed over gravity screens, and that passing

9/ Hall, A. L., Asbestos in the Union of South Africa: Geol. Survey of South Africa Mem. 12, 2d ed., 1930.

10/ Ru Keyser, Walter A., Mining Asbestos in U.S.S.R.: Eng. and Min. Jour., vol. 134, September 1933, pp. 375-381.

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through an 18-mm mesh screen and retained on a 5-mm screen (about one fifth of the total material quarried) is sent to the mills for recovery of the fiber. Oversize rock retained on the upper screen and sand passing the lower screen are trammed to waste heaps. Quarries are worked from March to December. In 1927 approximately 6,000 workers were employed in the quarries, and about 1,500,000 tons of rock were broken. Operations have been conducted on a much smaller scale since that year. Further details of quarry methods are given by Whitworth.11/

Production consisted exclusively of short fiber until 1934 when according to report a small quantity of spinning fiber was shipped.

WORLD PRODUCTION

The following table compiled by the Bureau of Mines shows production of asbestos by countries for 5 years.

11/ Whitworth, H., Cyprus and Its Asbestos Industry: Mining Mag. (London), vol. 39, September 1928, pp. 143-150.

World production of asbestos, 1929-33, in metric tons
(Compiled by M. T. Latus, of the Bureau of Mines)

Country 1/	1929	1930	1931	1932	1933
Africa:					
Portuguese East Africa	------	2/ 16	------	(3/	(3/
Southern Rhodesia	30,677	34,260	21,810	14,302	27,331
Swaziland	------	------	------	5	3/
Union of South Africa.	29,970	17,491	14,221	10,951	14,412
Australia:					
New South Wales	------	------	8	------	3/
South Australia	1	------	6	20	3/
Western Australia	250	144	116	112	3/
Canada 4/	277,647	219,641	149,047	111,562	141,006
China	277	315	264	3/	3/
Cyprus 2/	14,017	5,487	3,628	1,026	3/
Finland	1,563	1,188	581	756	3/
France	750	503	3/	3/	3/
Greece	3/	2	10	3/	3/
India, British	324	34	6	91	3/
Italy	2,847	851	632	1,284	3/
Japan 5/	1,000	1,000	1,000	1,000	3/
Russia	6/29,520	54,083	64,674	3/	7/72,000
Turkey	3/	3/	4	58	3/
United States	2,862	3,848	2,928	3,229	4,305

1/ In addition to the countries listed, Madagascar reported a production of 545 kilograms of asbestos in 1929. No exploitation of the deposits has been reported since that date.
2/ Exports.
3/ Data not available.
4/ Exclusive of sand and gravel, the production of which is reported as follows: 1929, 17,215 tons; 1930, 30,949 tons; 1931, 6,840 tons; 1932, 3,151 tons; 1933, 5,850 tons.
5/ Approximate production.
6/ Year ended September 30.
7/ Estimated production.

These figures include both long and short fibers of all varieties of asbestos. The output in Rhodesia and the Union of South Africa consists principally of spinning fiber and the longer and more valuable grades of mill fiber, because the local demand for short fibers is small and the price too low to justify shipment to foreign markets. Russia, on the other hand, has developed important asbestos-products industries that utilize large quantities of short fiber from the Urals. Canada has small local demand for short fiber, but the industrial centers of the eastern United States provide a ready market, and for this reason the shorter grades constitute a large proportion of the asbestos production.

The output of most countries showed a steady and pronounced decline from 1929 to 1932, but that of countries for which figures are available shows a general increase in 1933. Russia is an exception; its production shows a marked increase from 1929 to 1933. This country is now one of the world's largest producers of asbestos.

WORLD CONSUMPTION

It is more difficult to determine the consumption of asbestos than its production. Production plus imports minus exports of raw asbestos for any year may not give a true picture of consumption because stocks may be held over for some time and reexported, or material consumed may consist of stocks imported in a previous year. The following table taken from Asbestos12/ furnishes interesting data on consumption. The figures were compiled by "Tropag" Asbest-und Erzimport G.M.B.H. Hamburg, Germany, from data supplied by the ministerial and consular offices of the countries concerned.

World consumption of asbestos, 1931-33 (long tons)

Consumption	1931	1932	1933	Consumption	1931	1932	1933
United States..	121,539	86,311	106,735	Norway	1/1,000	784	987
Canada	1/4,800	1/5,000	1/6,500	Sweden	968	1,193	1/1,200
Russia	1/40,000	1/44,000	1/46,000	Estonia	63	21	32
Japan	7,300	7,680	9,000	Finland	62	43	68
England	19,561	17,414	24,386	Latvia	50	35	1/35
France	1/10,000	1/6,000	14,354	Lithuania	80	11	1/50
Belgium	12,609	5,190	11,239	Jugoslavia	1,293	474	303
Italy	5,134	3,791	1/5,000	Rumania	65	65	1/65
Spain	3,277	4,132	6,059	Australia	1/300	1/400	1/750
Portugal	58	1/40	1/60	India)			
Netherlands ...	266	157	522	Africa)	1/1,200	1/1,100	1/750
Denmark	705	730	1/750	South America and)			
Germany	9,803	7,581	12,613	other countries)			
Austria	5,019	3,466	1,267				
Hungaria	2,394	1,597	78[illegible]	Total, long			
Czecho Slovakia	4,878	7,044	2,208	tons..	253,893	205,172	255,093
Switzerland ...	1,145	563	832	Total, metric			
Poland	321	342	529	tons..	257,955	206,462	259,177

1/ Estimated.

For 1931 total consumption as given in the table (257,953 metric tons) approximates closely the world production (259,935 metric tons) as compiled by the Bureau of Mines. The agreement is much closer than would be expected when variations in stocks and material in transit are considered.

12/ Asbestos, June 1934, p. [illegible].

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The United States leads all countries in asbestos consumption. On a tonnage basis, Russia stands second and England third. Other important consuming countries are France, Germany, Belgium, and Japan.

The following table presents an independent compilation of apparent world consumption for 1931. Figures for production were taken from Bureau of Mines Minerals Yearbook, 1932-33 and those for imports and exports from The Mineral Industry of the British Empire and Foreign Countries, 1930-1932, published by the Imperial Institute, London. The figures for apparent consumption agree reasonably well with those of the preceding table.

World consumption of asbestos, 1931 (long tons)

Country	Production	Imports	Exports	Apparent consumption 1/
U ited States ...	2,882	121,751	1,530	123,103
C nada	146,700	-----	142,355	4,345
ssia	63,655	-----	13,030	50,625
pan	984	7,127	-----	8,111
ted Kingdom ..	-----	19,433	770	18,663
nce	(2/)	(2/)	-----	3/ 10,000
gium	-----	12,411	237	12,174
ly	622	5,194	141	5,675
ia	-----	3,225	180	3,045
tugal	-----	79	-----	79
herlands	-----	267	5	262
mark	-----	693	-----	693
many	-----	9,653	553	9,100
tria	-----	4,992	81	4,911
gary	-----	2,356	-----	2,356
hoslovakia ..	-----	5,263	461	4,802
zerland	-----	1,135	9	1,126
nd	-----	395	6	389
ay	-----	978	-----	978
S on	-----	953	2	951
and	572	61	-----	633
Au ralia	128	1,200	-----	1,328
Afr a	35,463	-----	38,533	-----
Ca	260	-----	-----	260
Yug lavia	-----	1,281	-----	1,281
Eg	-----	100	-----	100
Mex o	-----	400	-----	400
tal apparent consumption..	-----	-----	-----	265,390

1/ duction plus imports minus exports.
2/ a not available.
3/ imated.

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POLITICAL AND COMMERCIAL CONTROL

Russia only of the four leading producing countries has important asbestos-products manufacturing plants. The other principal producing countries - Canada, Rhodesia, and the Union of South Africa - utilize a very small proportion of the asbestos they produce. On the other hand, the principal asbestos-consuming countries - the United States, England, France, Germany, Belgium, and Japan - produce no asbestos or only small tonnages. A large proportion of all asbestos mined therefore enters international trade, and all the principal nations are interested in foreign sources of supply and their availability in times of emergency.

Political Control.- Three of the four large asbestos-producing countries of the world - Canada, Rhodesia, and the Union of South Africa - are in the British Empire. Moderately important deposits in Cyprus and Australia and small deposits in India, New Zealand, and Newfoundland also are under British political control.

The largest deposits outside the British Empire are those of the Soviet Union, while others of considerable importance are under the dominion of the United States, Italy, and Finland. Relatively small deposits are controlled politically by Argentina, Austria, Brazil, Bulgaria, China, Mexico, Portugal, Spain, Switzerland, and Turkey.

Commercial Control.- All asbestos-producing companies in the United States, except the Bear Canyon Asbestos Co., Globe, Ariz., apparently are controlled by United States capital. The Bear Canyon Asbestos Co. is a subsidiary of the Keasbey & Mattison Co., Ambler, Pa., the controlling interest of which was acquired in 1933 by Turner & Newall, Ltd., London, England.

Commercial control of the Canadian mines is diverse. The largest company, Asbestos Corporation, Ltd., is controlled by English, Canadian, and United States capital. The Johnson Co., the pioneer operator, probably is controlled by Canadian capital. The Quebec Asbestos Corporation, Ltd., owned by the Philip Carey Manufacturing Co., Cincinnati, Ohio; the Canadian Johns-Manville Co., Ltd., a subsidiary of Johns-Manville, Inc., New York; and the Nicolet Asbestos Mines, Ltd., a small New York firm, are dominated by United States capital. The Bell Asbestos Mines, Inc., operated by the Keasbey & Mattison Co., Ambler, Pa., is now controlled by Turner & Newall, Ltd., London, England. The ownership of the Canadian companies therefore evidently is divided among English, United States, and Canadian capital. The amounts of capital invested by England and the United States are approximately the same, while the Canadian investment is less.

British capital predominates in all the asbestos-producing companies of Rhodesia and the Union of South Africa.

The Soviet Union controls both politically and commercially activities in the asbestos industry of the Urals.

The one company operating in Cyprus is controlled by British capital.

For many years a British company controlled most of the production of Italy, but since 1929 an Italian company has operated the Balangero Mines where the chief production is now centered.

Practically all the deposits of Australia are controlled by English or Australian capital.

FOREIGN TRADE

Imports.- The following table compiled from Bureau of Mines statistics shows imports of asbestos into the United States for 5 years. It includes only the crude and mill fibers that constitute, on the basis of value, the principal international trade in asbestos.

Imports of asbestos into the United States, 1929-33
(Crude and mill fiber only)

Country of shipment	1929		1930		1931	
	Short tons	Value	Short tons	Value	Short tons	Value
Africa	8,304	$2,163,754	3,210	$730,274	1,337	$189,349
Canada	102,033	6,121,330	70,957	3,656,195	47,340	2,123,746
Germany	1,174	361,446	390	83,897	110	10,700
Italy	123	31,257	48	8,752	19	9,855
Soviet Russia.	252	111,290	4,534	660,539	2,188	104,271
United Kingdom	226	65,437	410	113,684	953	166,465
Belgium	348	55,125	-----	-------	-----	------

Country of shipment	1932		1933	
	Short tons	Value	Short tons	Value
Africa	1,326	$117,774	2,324	$234,357
Canada	31,064	1,[illegible]35,799	4[illegible],916	2,337,946
Germany	1	30	6	669
Italy	85	9,027	17	[illegible],929
Soviet Russia.	------	------	176	17,339
United Kingdom	1	399	1	587
Belgium	------	------	------	------

Countries of shipment as given in the preceding table are not necessarily the countries of origin; they may represent the last ports of shipment. To determine the original sources it may be assumed that approximately all the asbestos shipped from Germany is of Russian origin and that the fiber shipped from the United Kingdom and Belgium was produced in Africa.

The following table shows annual imports by countries or origin for 5 years.

Sources of asbestos imported into the United States, 1929-33
(Crude and mill fiber only)

Source	1929 Short tons	1929 Value	1930 Short tons	1930 Value	1931 Short tons	1931 Value
Africa	8,773	$2,234,316	3,620	$843,959	2,290	$[illegible]55,814
Canada	102,033	6,121,330	70,957	3,656,195	47,340	2,122,746
Soviet Russia	1,426	472,736	4,924	744,450	2,298	114,971
Italy	123	31,257	48	9,752	19	9,955
Total	112,360	9,909,639	79,549	5,253,301	51,947	2,604,386

Source	1932 Short tons	1932 Value	1933 Short tons	1933 Value
Africa	1,327	$113,173	2,325	$[illegible],144
Canada	31,064	1,285,709	49,916	2,337,946
Soviet Russia	1	30	192	19,009
Italy	85	9,627	17	9,929
Total	32,477	1,413,629	51,440	2,600,077

The following table shows the percentages of both quantity and value of total annual imports for 5 years.

Percentage of crude and mill-fiber asbestos obtained from each of the principal foreign sources, 1929-33

Source	1929		1930		1931	
	Quantity	Value	Quantity	Value	Quantity	Value
Africa	7.8	25.7	4.6	16.1	4.4	13.7
Canada	90.8	68.7	89.2	69.6	91.1	81.6
Soviet Russia	1.3	5.3	6.2	14.1	4.4	4.4
Italy	.1	.3	.1	.2	.1	.3

Source	1932		1933		Average for the 5 years	
	Quantity	Value	Quantity	Value	Quantity	Value
Africa	4.1	8.4	4.5	9.0	5.1	14.6
Canada	95.6	91.0	95.0	89.9	92.3	80.1
Soviet Russia	----	----	.4	.7	2.5	4.9
Italy	.3	.6	.1	.4	.1	.4

It may be observed that imports from Africa and Russia are much higher in value than in quantity. This is due to the fact that only the higher-priced crude fibers can be imported profitably from such distant sources. On the other hand, the percentage in quantity of Canadian fiber exceeds its percentage in value because the deposits are near consuming centers, permitting the importation of large quantities of the shorter mill fibers.

As many manufacturers of asbestos products are interested chiefly in sources of supply of the higher-grade spinning fibers an attempt has been made to estimate the tonnages received in recent years from the principal producing centers. The following table shows the approximate tonnages of spinning asbestos received annually from 1924 to 1933 from Canada, Africa, and Russia and the percentage of the total imports each country furnished.

Principal sources of spinning asbestos imported into the United States, 1924-33

Year	Canada[1]		Africa		Russia	
	Short tons	Percent of total imports	Short tons	Percent of total imports	Short tons	Percent of total imports
1924	12,463	80	3,051	20	56	(2/)
1925	17,543	79	4,390	20	191	1
1926	17,681	78	4,747	21	349	1
1927	14,953	66	6,096	27	1,782	7
1928	15,165	62	6,778	28	2,339	10
1929	18,363	64	8,778	31	1,426	5
1930	6,473	50	3,621	21	4,924	29
1931	6,770	60	2,290	20	2,396	20
1932	4,380	77	1,327	23	(3/)	(2/)
1933	(4/)	----	2,325	----	182	----

1/ Figures for Canadian tonnages are approximate. The following text explains methods of determination.
2/ Less than 0.5 percent.
3/ Less than 1 ton.
4/ Data not available.

For the purpose of calculation Canadian spinning fiber includes crude no. 1, crude no. 2, crude run-of-mine, and the highest-grade mill fiber, which since 1920 has been designated "spinning fiber." Figures for the production of Canadian asbestos by grades are published annually, but import figures were not segregated by grades until 1927. From 1924 to 1927 it is assumed that imports of spinning fiber bore the same relation to total imports that production of spinning fiber bore to total production. In other words, if 85 percent of the total Canadian production (exclusive of material classed as "sand, gravel, and stone") was imported into the United States, it is assumed that 85 percent of the spinning fiber produced in Canada was shipped to the United States.

Since 1927 the tonnages of crude and mill fiber imported from Canada have been recorded, but spinning fiber still is not reported separately. To determine this tonnage therefore it is assumed that the various grades of mill fibers (spinning, shingle, and paper stock) are imported in the ratio of their production; that is, if 25 percent of the millstock produced is of spinning grade it is assumed that 25 percent of the millstock imported is spinning fiber. The quantity of spinning fiber thus calculated is then added to imports of Canadian crudes to arrive at the total imports of spinning stock from Canada.

Approximately all imports from the other foreign countries are regarded as spinning fiber. Russian imports in 1931, however, were separated into crudes and mill fiber, the latter being regarded as nonspinning.

By referring to the preceding table it may be observed that Canada supplied about 80 percent of the total imports from 1924 to 1926. In 1927, however, this percentage dropped to 66, and in 1930 it was only 50. In 1932 the Dominion again furnished over three fourths of imports, but the total quantity from all sources was exceptionally low.

Africa supplied about 20 percent of the total each year, except during the period 1927-29, when the proportion was considerably higher. Since 1926 imports from Russia have been considerable; in 1930 Russia supplied more than one fourth of the requirements of the United States. Practical cessation of imports from Russia in 1932 may be attributed to the embargo placed on them during an investigation conducted by the United States Tariff Commission. Although the embargo was lifted, imports in 1933 were of no consequence.

A strong movement toward importation from the more distant sources of supply has been evident in 1934. Of crude fibers imported during the first 7 months, Africa supplied 54 percent, Russia 24 percent, and Canada 22 percent.

Exports.- Large quantities of asbestos products are exported from the United States. The statistics also show domestic exports of unmanufactured asbestos as indicated in the following table. Recent exports under this category have consisted mainly of shingle stock of foreign origin blended in the United States and shipped mainly to Japan, Mexico, and Europe. The exceptionally high value of exports in 1958 is due to a large shipment of Russian asbestos to Germany. Statistics of the Department of Commerce also show shipments of about 1,000 tons of foreign crude and unmanufactured asbestos annually under "exports of foreign merchandise." These represent transshipments of Canadian material via American ports.

Asbestos (unmanufactured) exported from the United States, 1924-33

Year	Short tons	Value	Year	Short tons	Value
1924	1,270	$33,165	1929	709	$109,467
1925	1,109	70,846	1930	771	93,018
1926	1,104	85,022	1931	1,714	122,391
1927	309	42,744	1932	1,707	94,936
1928	850	146,623	1933	1,378	88,521

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