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ASBESTOS

BY

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ASBESTOS[1]

By Oliver Bowles[2]

INTRODUCTION

The mineral asbestos, because of its unique fibrous character, is allied to cotton and wool but has the advantage of heat and fire resistance; therefore, it supplies many industrial needs for which no substitutes are yet available. This report covers the essential features of the asbestos industry, including occurrence, production, mining, milling, utilization, international trade, and marketing. The United States leads all countries in the manufacture of asbestos products, but domestic sources furnish only a small fraction of the raw material required. As the United States is dependent to so great an extent on foreign supplies of raw materials, the bulletin deals at length with the asbestos industry in foreign lands.

Several reports now available deal with the industry in individual countries. Among them are Chrysotile Asbestos in Canada, by J. G. Ross; Asbestos in the Union of South Africa, by A. L. Hall; and a series of articles on the Russian industry, by Walter A. Ru Keyser. These have been drawn upon freely, and full acknowledgment is hereby made for the helpful information thus secured. The file of the magazine Asbestos also has furnished many valuable data touching all phases of the industry. Many other books and articles listed in the bibliography at the end of this bulletin have been utilized and have been supplemented by the author's intimate acquaintance with the industry for about 20 years. The intent is to present a concise, world-wide, historical, technical, and economic treatment of the asbestos industry.

DEFINITION

"Asbestos" is not the name of a distinct mineral species but is, rather, a commercial term applied to fibrous varieties of several minerals. These minerals differ widely in composition, and the fibers are diverse in strength, flexibility, and consequent usefulness.

VARIETIES

The following varieties of asbestos are generally recognized:

Chrysotile is a hydrous magnesium silicate, a fibrous serpentine, represented by the chemical formula $H_4Mg_3Si_2O_9$. It has the same composition as massive serpentine, with which it is always associated. Chrysotile is characterized by a strength and flexibility that permit

[1] Work on manuscript completed Jan. 26, 1937.
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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 variety of iron-rich anthophyllite occurring in Africa, has unusually long fibers. The best-grade material is used for spinning.

Crocidolite, also called "blue asbestos", having the composition $NaFe(SiO_3)_2FeSiO_3$, occurs in commercial quantities chiefly in Africa. It is used for both spinning and nonspinning purposes. Crocidolite occurring in quartz is sold as the semiprecious "tiger-eye."

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 applied originally. 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.

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 possess 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 length.

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 infinitesimal 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.

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,[3] and the smallest measured diameter recorded by Cirkel is 0.00075 mm.[4] 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 effect on some varieties.[5] 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.

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[3] Merrill, G. P., Proceedings of the United States National Museum: Vol. 18, 1895, pp. 282–283.
[4] Cirkel, Fritz, Chrysotile Asbestos—Its Occurrence, Exploitation, Milling, and Uses: Canada Dept. Mines, Mines Branch 69, 2d ed., 1910, p. 85.
[5] Cirkel, Fritz, Work cited, p. 30.
[6] Dana, E. S., System of Mineralogy: Sixth ed., New York, 1911, p. 671.

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

SPECIFIC GRAVITY

The specific gravity of chrysotile, as given by Dana,[6] is 2.22, but that of the commercial fiber is always higher because of the presence of impurities. Canadian chrysotile ranges from 2.54 to 2.59, and the Arizona fiber, being lower in iron, has a specific gravity of 2.47. Anthophyllite ranges from 3.1 to 3.2 and crocidolite is still heavier, ranging from 3.2 to 3.3.

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:									
Canada [1]	40.36	0.21	1.35	0.66	43.86	------	------	13.45	99.89
Arizona [2]	41.56	1.27	------	.64	42.05	------	------	14.31	99.83
Barberton [3]	40.05	1.90	1.60	.40	38.35	0.15	[4] 0.40	16.60	99.70
Shabani [3]	40.96	1.70	------	2.44	38.73	------	[4] .10	16.07	100.00
Russia [5]	39.28	1.75	.40	5.37	40.05	1.74	------	11.52	100.11
Anthophyllite: Georgia [6]	56.40	1.15	------	11.40	28.68	.50	------	1.63	99.76
Crocidolite: Cape Colony [7]	51.10	------	------	35.80	2.30	------	6.90	3.90	100.00
Amosite: Penge [8]	49.72	5.72	------	37.00	3.77	1.65	------	2.29	100.15
Tremolite: Natal [9]	58.80	[10] 5.32	------	------	22.75	10.65	------	.50	98.02

[1] Ross, J. G., Chrysotile Asbestos in Canada: Canada Dept. Mines, Mines Branch 707, 1931, p. 20.
[2] Diller, J. S., Mineral Resources of the United States, 1919. Pt. 2, p. 302.
[3] Hall, A. L., Asbestos in the Union of South Africa: Union of South Africa Geol. Survey Mem. 12, 1918, p. 31.
[4] Includes K_2O.
[5] Ru Keyser, Walter A. Chrysotile Asbestos in the Bajenova District, U. S. S. R.: Eng. and Min. Jour., vol. 134, no. 8, August 1933, p. 338.
[6] Hopkins, O. B., Asbestos, Talc, and Soapstone Deposits of Georgia: Geol. Survey of Georgia Bull. 29, 1914, p. 79.
[7] Hall, A. L., Work cited, p. 19.
[8] Hall, A. L., Work cited, p. 22.
[9] Hall, A. L., Work cited, p. 23.
[10] Includes Fe_2O_3.

Varieties of amphibole asbestos, except tremolite, contain iron combined chemically as an essential constituent of the mineral. Iron may be present in any variety of asbestos as an impurity, chiefly in the form of an oxide that may be detrimental for some uses. The iron impurity in Arizona fiber is considerably lower than that of Canadian, African, or Russian chrysotile.

SYNTHETIC ASBESTOS

Various attempts have been made to manufacture a product similar to natural asbestos. Products known as mineral wool, rock wool, slag wool, and glass wool have some of the properties of chrysotile asbestos but lack its flexiblity and strength. Special forms of glass wool made in 1936 and later are said to have flexibility comparable with that of asbestos and are capable of being woven and spun. A German inventor claimed in 1932 that he had made an artificial product of the same composition and physical properties as Canadian chrysotile and at a cost lower than asbestos mining costs in Canada.

HISTORY [7]

EARLY RECORDS

The peculiar property of incombustibility combined with a fibrous structure attracted attention to asbestos more than 2,000 years ago. Small amounts were used by the Romans for winding sheets to preserve the ashes of the dead when bodies were cremated, but the "immortal linen" was so difficult to weave that only the most distinguished patricians and kings were honored with asbestos shrouds. A specimen of cremation cloth containing ashes was found in 1702 in a Roman sarcophagus and was deposited in the library of the Vatican. According to tradition, the ancient Chinese and Egyptians wove asbestos into mats. In ancient temples, asbestos was used for lamp wicks and to protect altar fires.

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 into 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

[7] Some of the historical data on this and following pages was obtained from a series of articles on the history of the asbestos-manufacturing industry that appeared in the August, October, and November 1935 and January, May, and August 1936 issues of the magazine Asbestos.

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.[8]

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.[9] 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. William Lithgow, a Scotsman, writing about the minerals of Cyprus early in the seventeenth century, referred to "the admirable stone Amiante, whereof they make Linnen cloth that will not burn, being cast into the fire, but serveth to make it neat and white."

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 letter to the author from the chief mineral inspector in Rome, however, casts some doubt as to whether all 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.

A tremolite asbestos glove examined by the writer in the Museum of Natural History, London, England, in 1935 did not appear to consist of strong fiber. A piece of so-called "asbestos" cloth of unknown origin in this museum is not a fabric; it is a felted sheet that may be a natural mountain leather.

Very little mention of asbestos was made throughout the Middle Ages. According to report, Charlemagne, who reigned from 768 to 814, had an asbestos tablecloth, which he would throw into the fire for cleansing. To mystify his guests was apparently the only reason for its use.

Marco Polo refers to "amiantos" cloth shown to him during his travels through Siberia in 1250. He was told by the superstitious people of that region that it was made of the skin of salamanders, but he was too scientifically minded to accept such statements. After much questioning and search, he learned how the fibers were obtained

[8] Evans, John W., The Identity of the Amiantos or Karystian Stone of the Ancients with Chrysotile: Mineral. Mag. (London), vol. 14, May 1906, pp. 143–48.
[9] Evans, John W., Work cited, p. 143.

and prepared. His description of the process of preparation, which consisted of pounding in a mortar to eliminate impurities, suggests that the fiber was chrysotile, and this conclusion is substantiated by the fact that the best-known asbestos of Siberia is chrysotile occurring at Minuisinck near the Mongolian border.

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 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.

The next important reference to asbestos was in 1676 when, at a meeting of the Royal Society, a Chinese merchant exhibited a handkerchief of "salamander's wool" or "linum asbesti." An asbestos napkin belonging to Ferdinand III was exhibited in Vienna in 1679.

Asbestos was discovered in the Ural Mountains of Russia between 1710 and 1720, and the first factory for making asbestos products was operated during the reign of Peter the Great. Textiles, socks, gloves, and handbags were made here for 50 or 60 years, but the enterprise failed, through lack of demand and poor transportation facilities.

HISTORY OF COMMERCIAL PRODUCTION

The utilization of asbestos on a commercial scale had its real beginning in Italy. About 1808, a noblewoman of Valtellina sponsored studies and experiments that brought her many honors and led to the manufacture of asbestos thread, fabrics, and paper of high quality. Several companies were formed between 1860 and 1875. No serious problems were involved in the manufacture of rope packings and heat-insulating board, but much difficulty was encountered in devising suitable machinery for the fabrication of spun products. Exhibits at the Universal Exposition in Paris in 1878 gave wider publicity to the products then manufactured.

In 1860 asbestos was discovered near St. Joseph in Quebec, Canada, and a specimen of fine silky fiber from this region was exhibited in London in 1862. The deposits were few and small, and attempts to work them profitably failed. A new era in the asbestos industry began with the discovery, in 1877, of the famous deposits near Thetford Mines and Coleraine. Mining began in 1878 and 50 tons were produced in that year. The fiber could be worked more easily than Italian asbestos, and its popularity in London, together with the easy availability of a growing market in the United States, led to rapid development. Seven quarries with an aggregate production of 1,400 tons a year were reported in 1885. The highest-grade fiber sold for only $80 a ton in that year, but by 1900 the price had advanced to $300 a ton. Thereafter, owing to depressed prices and to wasteful and costly hand methods of mining and preparation, the industry languished for several years. Prosperity returned when mechanical methods of fiber recovery were introduced.

An occurrence of blue asbestos on the Orange River of South Africa was discovered in 1815. The name "crocidolite", meaning a stone with a woolly appearance, was proposed by Hausmann in 1831. No development took place, however, until the interest shown by Francis Oats led to the establishment of the Cape Asbestos Co., Ltd., in 1893.

Amosite was discovered in central Transvaal about 1907. The name "amosite", given to the fiber in 1918, was taken from the initial letters of the Asbestos Mines of South Africa, the company chiefly interested in its production. Commercial production began about 1916.

Interest in Rhodesian chrysotile was first centered in the Mashaba deposits about 1907. Ground was pegged by a prospector named Gath, and a large mine in the district still bears his name.

Chrysotile was discovered in the Shabani area of Rhodesia about 1906, but no interest was shown in it until 1915. Since that date the growth of the industry has been phenomenal.

HISTORY OF ASBESTOS PRODUCT MANUFACTURE

The spinning and weaving of asbestos for textile manufacture were begun in America more than 50 years ago. The early products were chiefly fireproof garments, such as coats, shoes, gloves, and helmets. Disastrous theater fires led to the use of asbestos curtains, but it was not until the advent of the automobile that asbestos fabrics were produced in quantity. Asbestos brake linings for automobiles were first made in England in 1896, but 1906 seems to be the earliest date that asbestos was used for this purpose in the United States. A severe test of an asbestos brake band and one made of leather was conducted in 1907. The leather was burned to charcoal, whereas the asbestos was unaffected. Thereafter, woven asbestos brake linings were used almost universally until 1924. The advent about that year of the four-wheel internal brake led to the development of molded brake linings, which were found to be more suitable than woven linings for internal brakes. Molded linings have now become almost as important as the woven kinds.

The first asbestos packing employed industrially for steam glands was made in 1871.[10] It consisted of carded Italian fiber enclosed in an outer covering of cotton, but unfortunately gritty grains in the fiber worked through the cotton and scored the piston rods and valve spindles. The next step was to free the asbestos of all gritty impurity.

Another packing made about the same time consisted of cotton wicking saturated with lard oil and coated with powdered anthophyllite, then known as "southern" asbestos. Although scarcely falling within the category of asbestos packings it at least helped to emphasize the value of asbestos for such use.

Shortly thereafter packings of much better quality were made by using asbestos rope covered with a cotton "sock." Between 1877 and 1880, when high-grade spinning asbestos became available from Canada, the cotton covering was replaced by one of asbestos cloth.

[10] Asbestos, Work cited, No. 5, 1935, pp. 2–6.

With the addition of rubber cores to give strength and resiliency, these packings began to assume a modern form. With the advent of high pressures and temperatures, the requirements, as to quality, shape, and size, became more exacting, and today the manufacture of packings is a highly specialized and complicated process.

Asbestos paper was known as early as 1700, when a certain Professor Bruckmann used it for his writings, but the object of obtaining an imperishable document was defeated because, although the paper would withstand the fire, the printing would not. The same result is recorded by Pontoppidian, Bishop of Bergen, in his Natural History of Norway published in 1750. About the middle of the last century asbestos boards were used for book covers in Italy, and shortly thereafter a vain effort was made to induce the Italian Government to manufacture asbestos banknotes. Other early uses of asbestos paper were for ornamental wallpaper and carpet linings.

Asbestos paper is now a very important product, but its present uses as a fireproofing and heat-insulating material were not contemplated by the pioneer investigators or manufacturers. It was first made in America at Waltham, Mass., about 1878. Italian fiber was used until 1879, when the shorter grades of Canadian asbestos were tried and found to be quite satisfactory. Its principal use at that time was to protect hair-felt insulation from the heat of steam pipes. The value of asbestos paper for heat insulation was speedily recognized and the industry grew rapidly. At present, a number of large factories make, in all, more asbestos paper in a day than was made in an entire year 25 years ago.

The most important development of recent years is the manufacture of pre-shrunk paper. It does not absorb moisture and, therefore, when used as a pipe covering it does not shrink under the influence of heat. Thus, gaps in the covering, through which heat might escape, do not appear.

The heavier and thicker product, known as millboard, was also made in the early days of paper manufacture.

Heat insulators constitute an important branch of the asbestos-products industries. Asbestos, in the form of a mixture of fiber and silicate of soda, was first used for heat insulation in 1866. Asbestos cement, containing 15 percent fiber, was tried first as a boiler covering about 1870. Canvas-covered sectional magnesia pipe covering appeared in 1885. Shredded rope and silk noils were first used as binders, and just when the change was made to asbestos fiber is not known. Modern sectional pipe coverings have painted or lacquered surfaces instead of canvas, which improves the appearance and gives better insulation. The first air-cell covering was produced in Brooklyn in 1898.

The manufacture of asbestos-cement products is comparatively recent. Asbestos-cement roofing was first made in Austria about 1900 by the laminated or "Eternit" process, known also as the Hatschek process, after Ludwig Hatschek, its inventor. A pressure-filtration process was developed by C. L. Norton at Nashua, N. H., about 1905. He first produced 36- by 48-inch sheets several inches thick. Much larger sheets were made later. In 1908, a second process was developed for making thin sheets suitable for roofing shingles. However, asbestos-cement shingles were first introduced in the United States by Dr. R. V. Mattison at Ambler, Pa., in 1903. Within recent years the coloring of shingles has attained higher refinement, and asbestos-cement siding shingles have been developed. Flat sheeting for siding and roofs came into use shortly after 1903, and corrugated sheeting was first made in 1905. Production of this great group of building materials has attained large proportions during the past 15 or 20 years.

Asbestos-cement pipes were first manufactured at Genoa, Italy, in 1913 by the Eternit process. Their manufacture began in America in 1929 and the first shipment was made in 1930.

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. 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. More detailed discussions of origin will be found in later sections describing asbestos deposits by State and country.

Chrysotile occurs in two forms—cross fiber and slip fiber. The former is the characteristic occurrence in all fissure-filled veins, the fibers crossing the veins approximately at right angles to the walls. In some veins the fibers cross from wall to wall, hence the fiber length is governed by the width of the vein. In others the fibers may be broken into two or more lengths by partings parallel with the vein walls. Slip fiber, on the other hand, parallels the vein wall and usually shows the effects of pressure and movement along a fault plane. Figure 1 shows typical cross-fiber veins of Canadian asbestos.

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. In the irregular belt of olivine- and pyroxene-bearing rocks that extends from the Gaspé Peninsula in Canada to southern Georgia the alteration was principally into massive serpentine and chrysotile in the northern part, that is, in the area lying in Quebec, Canada, and in Vermont; but in its southern extension only sporadic occurrences of chrysotile are found because the alteration was more generally to anthophyllite and talc.

The softest and most easily fiberized anthophyllite occurs generally near the surface of the deposits; with increasing depth the fiber becomes harsher, more brittle, and less easily worked into a fluffy mass. The development of the best fiber therefore appears to depend upon

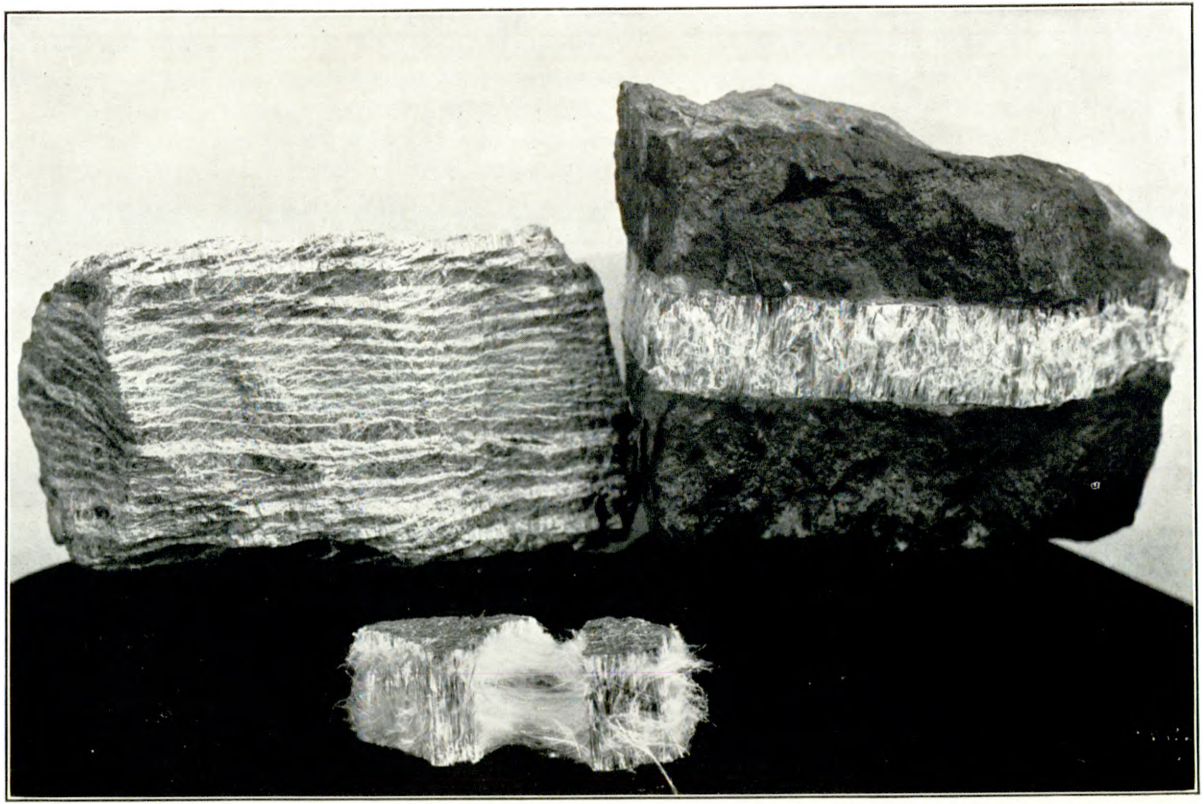

FIGURE 1.—Typical cross-fiber veins of Canadian asbestos.

the action of weathering agencies. Consequently, deposits of soft, easily worked anthophyllite tend to take the form of pockets or lenses of limited depth, and if workings are to be confined to fiber of this character the limitation of reserves must be considered with care. If, however, the harsher, more solid asbestos masses can be fiberized successfully into marketable products, the reserves may be much more extensive. Most of the deposits that have been developed show little promise of large reserves.

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 iron stones. 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.

USES

The uses of asbestos are so numerous and important that one could write a book on that subject alone. On the basis 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 anthophyllite and related amphibole varieties. Spinning asbestos is used for weaving into textiles, but under the general classification of textile uses are included prepared yarns, listing, tape, rope, cord, wick, and thread. The largest use of asbestos textiles is for the manufacture of automobile brake-band linings and clutch facings. As much as 70,000,000 linear feet of brake-band lining has been made in a single year in the United States. Asbestos cloth treated with rubber is made into gaskets for use between the abutting or flange ends of pipes, or between adjoining surfaces, such as manhole and handhole plates, to make the joints tight enough to prevent passage of air, steam, or oil. Asbestos cloth is used, also, for the manufacture of fireproof theater curtains and scenery; blankets; mattresses; firemen's suits, gloves, and shoes; aprons; mittens; leggings; helmets; awnings; conveyor belts for carrying hot materials; and woven sheet-packings. Braided and twisted packings are closely related to textiles.

An important use for nonspinning asbestos is for compressed packings consisting of felted masses of fiber combined with rubber or other binders. They are of various forms known as compressed sheet, coil, spiral, and high-pressure packings.

Another large group of uses is for heat insulation; in fact, asbestos is one of the most important fireproofing and heat-insulating materials known. Among the best-known products is 85-percent magnesia pipe covering. Asbestos paper is used for making 3-ply air-cell and similar pipe covering; as sheeting between floors; lining for stoves, heaters, filing cabinets, soldiers' helmets, mufflers for automobiles, drum controllers in sulphite mills, automobile radiator covers; tubes for electric wires; table mats, pads, stove mats, and other household appliances; and in many other ways. Asbestos paper is also used extensively in the manufacture of asbestos felt roofing and built-up roofs and in making asbestos-protected metal roofing. Millboard is used not only as a building material but as a joint packing for steam pipes and as a lining for safes, stoves, electric switch boxes, hoods of automobiles, and ovens, where a material of greater thickness than paper is required. An important use of millboard is for gaskets on automobiles and steam machinery. Asbestos is used for lagging steam boilers to prevent heat radiation. Large quantities of the shorter fibers are used in plastic fireproof cements for boiler, pipe, and furnace covering. An asbestos-cement coating is sometimes applied to the surface of wallboard for both heat insulation and fireproofing. Numerous household appliances, such as pot holders, mats, and table covers, may be classed in the group of heat-insulating materials.

Large quantities of the shorter grades of asbestos are used in the manufacture of building materials. Roofing shingles made of portland cement and asbestos are used extensively. Compressed sheets of asbestos combined with cement are used for corrugated sheeting, wallboard, millboard, lumber, and floor tile. Corrugated asbestos sheets have special merit in constructing chemical plants or other buildings exposed to a corrosive atmosphere. Asbestos-cement wall tiles in a wide range of colors were introduced about 1930. Asbestos-cement products are used increasingly in Europe as roofing, ceilings, partitions, paneling, linings of interior and exterior walls, water pipes, and gutters. It is claimed that the pipes and gutters are waterproof, require no painting, and compare favorably in strength with cast iron. It has been found that wooden flooring may be nailed to a subflooring consisting of concrete to which about 10 percent of asbestos has been added. Asbestos-composition products are becoming popular for floor tile in homes and on ships.

Miscellaneous uses are innumerable and diverse. There is a marked tendency toward a more extensive use of molded brake bands in automobiles. Of the brake bands made in 1929, about 84 percent were woven and 16 percent molded. In 1931, 70 percent were woven and 30 percent molded, and in 1933 these percentages were, respectively, 59 and 41. This trend indicates a relatively wider use of nonspinning asbestos at the expense of spinning grades. However, in

1935 there was a slight reversal of the trend, 61 percent being woven and 39 percent molded.

Asbestos-cement pipes are being used increasingly 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. They are particularly advantageous for carrying solutions that must be kept free from iron rust. A standard European pipe consists of 80 percent cement and 20 percent asbestos.

Asbestos is used in fireproof paints, in arc welding, for protecting the surface of metal sheeting, as a constituent of asphalt roof coatings, for covering fire hose, and in the manufacture of gas burners. A process has been perfected whereby asbestos may be cemented to steel by means of metallic adhesives. Commercialization of this process will promote wider use of asbestos-protected metals.

Asbestos paper and millboard are used for electrical insulation. Short-fiber asbestos mixed in proportions of 4 to 6 percent with asphalt improves the surface of roads.

Asbestos is used as a polishing agent. A rough asbestos cloth is suitable for common scouring, and an acid-refined asbestos cloth for imparting a high luster.

In the chemical laboratory asbestos is used for acid filters, for stoppings in combustion tubes, for fireproof supports and protectors, and for wicks which when saturated with various mineral salts will produce colored flames. A filter cloth in which noncorrosive wires are combined with the fiber has an advantage over the all-asbestos cloth of greater strength, and also of lower cost because the wire reinforcement permits the use of lower grades of asbestos. Metals such as iron, Monel, nickel, and lead-coated steel are used for the wires, the choice depending on the nature of the solution to be filtered and operating conditions.

Asbestos is used as a filler in insulators and various other molded articles in which a bituminous binder such as gilsonite is used. Asbestos compounds are used to some extent in automobile bodies.

The uses of anthophyllite are limited because of its lack of strength. It is too weak for spinning purposes, and it cannot be used for asbestos-cement shingles or other products to which a high tensile strength of the fiber imparts essential qualities. However, because of its superior resistance to acids, it is well suited for use in chemical laboratories. The stronger grades are used for chemical filters. A tough slip fiber occurring near Pylesville, Harford County, Md., is the most suitable for filter use of any yet found in the United States. Italian tremolite is also used for filters. Anthophyllite and tremolite may be employed for other chemical-laboratory uses mentioned in a previous paragraph.

The principal uses known for anthophyllite are for making plastic cements to cover boilers, pipes, and furnaces, as a filler in rubber and battery boxes, and as an admixture in cement and plastic flooring, acoustical and other wall plasters, and stucco. Its use as a substitute for mineral wool in house insulation is contemplated. No large, consistent market for it has yet been developed, and production has never exceeded a few hundred tons a year.

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Many industries use asbestos in hundreds of minor ways. The catalogs of some asbestos-product companies contain lists of several hundred articles in which asbestos is a more or less essential ingredient.

From the foregoing enumeration of uses, it is apparent that large quantities of asbestos are employed in making brake bands, clutch facings, gaskets, packings, and insulation for automobiles. Therefore, fluctuations in automobile production are likely to be reflected in the amount of asbestos consumed. A second important field of utilization is for heat insulators, roofing, siding, millboard, wallboard, lumber, paper, and roof coatings, all of which are used extensively in the building trades. Asbestos consumption, therefore, is influenced greatly by the volume of building construction. Figure 2

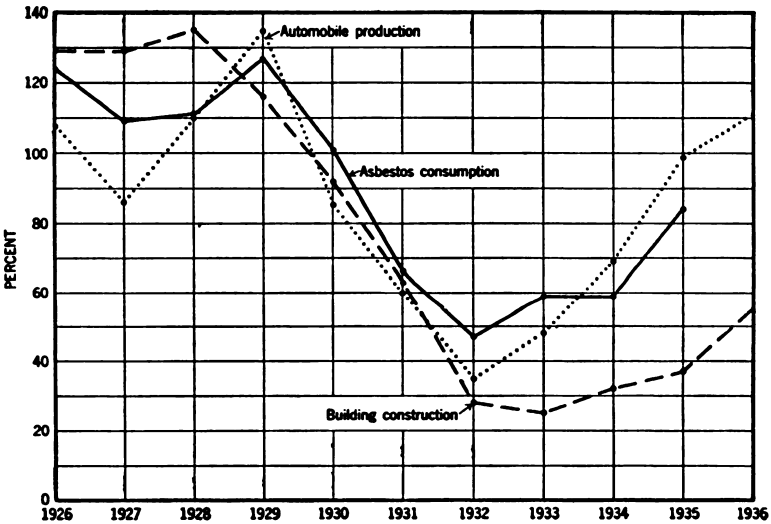

FIGURE 2.—Asbestos consumption compared with automobile production and building construction, 1926–36. Unlike units are reduced to percentages of the 1923–25 average. Statistics of asbestos are from the Bureau of Mines, automobiles from the U. S. Bureau of the Census, and building contracts from the Federal Reserve Board.

shows the relation that exists between asbestos consumption and these two important industrial activities.

The chart indicates that during the depression years 1930 to 1933 asbestos consumption stood at a relatively higher level than either automobile production or building construction. Doubtless, this is due to the fact that during these years asbestos building materials were used in considerable quantities for the repair and maintenance of existing buildings and that a substantial volume of brake-band linings and clutch facings was used to recondition old cars and trucks.

GENERAL DISTRIBUTION

The United States has never attained importance as a producer of asbestos, the domestic output being only $1\frac{1}{2}$ to 4 percent of the quantity required to supply raw material for its extensive asbestos-product manufacturing industries. Production is centered in four principal countries—Canada, Rhodesia, Union of South Africa, and the Soviet Union. Since asbestos first became an important commercial commodity the Province of Quebec, Canada, has led in tonnage produced, but a large proportion of the output of this Province is of the shorter, nonspinning grades. Since 1916, the Union of South Africa and Rhodesia have become increasingly important as sources of the higher-grade spinning fibers. Before the World War, Russia ranked next to Canada as a producer of asbestos, but during the revolutionary period the industry in that country was almost at a standstill. In 1926, however, activity was revived, and each year since then production and exports have increased greatly.

Smaller quantities of asbestos are produced in Cyprus, Australia, Finland, and several other countries.

Chrysotile is the leading product in all the producing countries, but substantial quantities of blue (crocidolite) and amosite asbestos also are produced in the Union of South Africa. Minor quantities of anthophyllite and similar amphibole varieties are mined in the United States, Italy, Bulgaria, Finland, and several other countries.

PRODUCTION AND CONSUMPTION

HISTORY OF PRODUCTION IN THE UNITED STATES

Scattered deposits in California and other Western States furnished a limited tonnage of asbestos many years ago. Georgia has supplied small quantities of anthophyllite, and the same or similar fiber has been produced at times in other States. Chrysotile is produced principally in Arizona and Vermont. The Arizona deposits contain considerable reserves of high-grade spinning fiber, but they are not favorable for low-cost mining, and transportation is difficult and costly. Arizona has produced a small tonnage annually with some interruptions since 1913. The Vermont deposits are extensive but furnish short fiber almost exclusively. Vermont has produced intermittently since 1908.

The following table, compiled from data reported by producers to the United States Geological Survey until 1924 and thereafter to the United States Bureau of Mines, shows the history of production since 1880.

Asbestos sold in the United States, 1880–1936

Year	Short tons	Value	Year	Short tons	Value	Year	Short tons	Value
1880	150	$4,312	1899	681	$11,740	1918	998	$118,687
1881	200	7,000	1900	1,054	16,310	1919	1,161	248,265
1882	1,200	36,000	1901	747	13,498	1920	1,648	678,231
1883	1,000	30,000	1902	1,005	16,200	1921	831	336,968
1884	1,000	30,000	1903	887	16,760	1922	67	10,120
1885	300	9,000	1904	1,480	25,740	1923	227	9,626
1886	200	6,000	1905	3,109	42,975	1924	300	42,526
1887	150	4,500	1906	1,695	28,565	1925	1,258	51,700
1888	100	3,000	1907	653	11,899	1926	1,358	134,731
1889	30	1,800	1908	936	19,624	1927	2,981	336,882
1890	71	4,560	1909	3,085	62,603	1928	2,239	351,178
1891	66	3,960	1910	3,693	68,357	1929	3,155	351,004
1892	104	6,416	1911	7,604	119,935	1930	4,242	289,284
1893	50	2,500	1912	4,403	87,959	1931	3,228	118,967
1894	325	4,463	1913	1,100	11,000	1932	3,559	105,292
1895	795	13,525	1914	1,247	18,965	1933	4,745	130,677
1896	504	6,100	1915	1,731	76,952	1934	5,087	158,347
1897	580	6,450	1916	1,638	180,994	1935	8,920	292,927
1898	605	10,300	1917	1,958	291,014	1936	11,012	309,994

The following table shows sales for a series of years by varieties of fiber. For the period 1926 to 1928, inclusive, and, again, subsequent to 1931, the number of operators reporting was so small that separation by varieties could not be done without revealing individual figures.

Asbestos sold by producers in the United States, 1921–31, by varieties

Year	Chrysotile		Amphibole		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
1921	438	$313, 268	393	$23, 700	831	$336, 968
1922	25	3, 320	42	6, 800	67	10, 120
1923	69	4, 433	158	5, 193	227	9, 626
1924	173	33, 941	127	8, 585	300	42, 526
1925	93	40, 750	1, 165	10, 950	1, 258	51, 700
1926	(1)	(1)	(1)	(1)	1, 358	134, 731
1927	(1)	(1)	(1)	(1)	2, 981	336, 882
1928	(1)	(1)	(1)	(1)	2, 239	351, 178
1929	1, 983	317, 584	1, 172	33, 420	3, 155	351, 004
1930	3, 653	273, 292	589	15, 992	4, 242	289, 284
1931	2, 857	111, 708	371	7, 259	3, 228	118, 967

[1] Bureau of Mines not at liberty to publish figures.

WORLD PRODUCTION

The following table, compiled by the Foreign Mineral Service Division, United States Bureau of Mines, shows production of asbestos by countries for 5 years.

World production of asbestos, 1931–35, in metric tons [1]

[Compiled by M. T. Latus, Foreign Mineral Service Division]

Country	1931	1932	1933	1934	1935
Argentina	------	[2] 7	------	------	------
Australia:					
New South Wales	8	------	------	------	------
South Australia	6	20	13	------	36
Western Australia	116	112	270	157	143
Bulgaria	------	------	------	3	3
Canada [3]	149, 047	111, 562	143, 667	141, 502	190, 931
China	264	250	236	290	(4)
Chosen	------	------	12	4	6
Cyprus [5]	3, 628	1, 626	4, 640	7, 712	7, 634
Czechoslovakia	(4)	(4)	1, 200	2, 100	2, 600
Finland	581	756	1, 340	1, 735	1, 742
France	500	300	400	[6] 400	(4)
Greece	10	9	14	30	(4)
India, British	6	91	------	25	64
Italy	632	1, 284	3, 267	2, 252	(4)
Japan [6]	1, 000	1, 000	1, 000	1, 000	1, 000
Southern Rhodesia	21, 810	14, 303	27, 381	29, 224	38, 644
Swaziland	------	5	------	------	------
Turkey	4	58	120	4	104
Union of South Africa	14, 221	10, 950	14, 411	15, 960	20, 683
U. S. S. R. (Russia)	64, 674	59, 800	71, 700	92, 200	95, 500
United States (sold or used by producers)	2, 928	3, 229	4, 305	4, 615	8, 092

[1] In addition to countries listed, Bolivia, Brazil, and Madagascar are reported to produce small quantities of asbestos.
[2] Rail and river shipments.
[3] Exclusive of sand and gravel, production of which is reported as follows: 1931, 6,540 tons; 1932, 3,151 tons; 1933, 5,850 tons; 1934, 4,238 tons; 1935, 2,744 tons.
[4] Data not available.
[5] Exports.
[6] Approximate 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 better grades of mill fiber, because the local demand is small and the value of the very short fibers 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 reached a low level in 1932 but has shown a rapid increase since that date. The Russian industry experienced only a minor decline during the depression, and a substantial increase in output from year to year since 1932 is indicated.

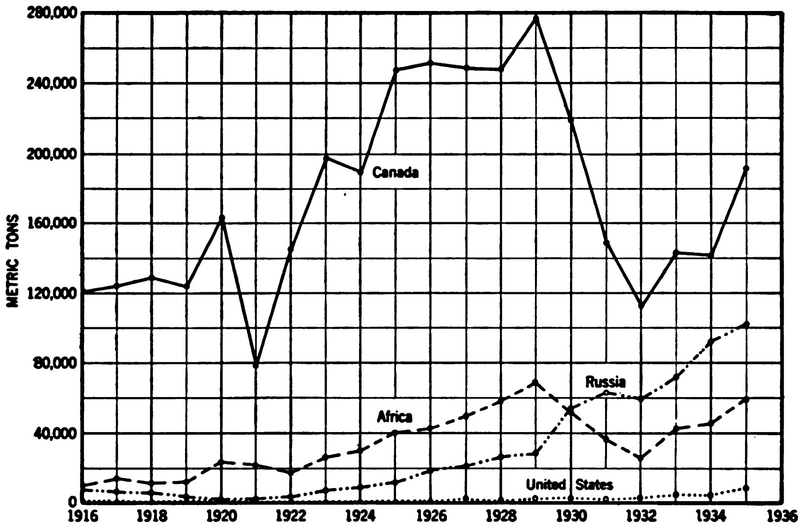

FIGURE 3.—Asbestos production in the three leading foreign centers and in the United States, 1916–35.

Figure 3 shows production in the three leading foreign centers and in the United States for a 20-year period. Canadian production indicated in the chart does not include the lowest grade product designated "sand, gravel, and stone (waste rock only)." For other districts the entire marketed production is included.

The minor importance of the United States among world producers, the leading position of Canada, and the recent rapid gain in prominence of Russia are apparent. On the basis of value of output, Africa and Russia hold a relatively stronger position than is indicated on the chart, because Canada produces a preponderance of the lower-priced short fibers.

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 Asbestos,[11] 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	106,756	Poland	321	342	529
Canada	[1] 4,800	[1] 5,000	[1] 6,500	Norway	[1] 1,000	784	987
Russia	[1] 40,000	[1] 44,000	[1] 48,000	Sweden	968	1,193	[1] 1,200
Japan	7,300	7,680	9,000	Estonia	63	21	32
England	19,561	17,404	24,386	Finland	62	42	68
France	[1] 10,000	[1] 6,000	14,354	Latvia	50	35	[1] 35
Belgium	12,609	5,190	11,239	Lithuania	80	11	[1] 50
Italy	5,134	3,791	[1] 5,000	Jugoslavia	1,292	474	303
Spain	3,277	4,132	6,059	Rumania	65	65	[1] 65
Portugal	58	[1] 60	[1] 60	Australia	[1] 300	[1] 400	[1] 750
Netherlands	266	157	522	India, Africa, South America and other countries	[1] 1,200	[1] 1,100	[1] 750
Denmark	705	736	[1] 750				
Germany	9,808	7,581	12,613				
Austria	5,018	3,466	1,267				
Hungaria	2,394	1,597	781				
Czechoslovakia	4,878	7,044	2,208	Total, long tons	253,893	205,179	255,095
Switzerland	1,145	563	832	Total, metric tons	257,955	208,462	259,177

[1] Estimated.

The difference in total consumption for 1933, as given in this table (259,177 metric tons), and total world production in that year, as compiled by the United States Bureau of Mines (276,140 metric tons), may be explained by variations in stocks and materials in transit.

The following table presents a compilation of apparent world consumption for 1934 based on production plus imports minus exports. Because of variations in stocks, the figures are approximate only. For instance, Canadian consumption as shown in this table is a negative quantity because, with a steadily increasing market demand, exports were drawn from stocks as well as from current production. Canadian consumption ranges from 3,000 to 6,000 tons a year. As indicated in the world totals, consumption balances reasonably well with production.

World consumption of asbestos, 1934

[In metric tons]

Continent and country	Production [1]	Imports [2]	Exports [2]	Apparent consumption
Asia:				
China	290	584		874
Chosen	4	90		94
Cyprus	[3] 7,712		7,712	
India, British	25	966		991
Japan	[4] 1,000	20,515		21,515
Manchuria		1,291	96	1,195
Netherland India		14		14
Turkey	4			4
Total, Asia	9,035	23,460	7,808	24,687

[1] Compiled by Foreign Mineral Service Division, U. S. Bureau of Mines.
[2] Figures as given in The Mineral Industry of the British Empire and Foreign Countries, Statistical Summary, published by The Imperial Institute, London.
[3] Exports.
[4] Approximate production.

[11] Asbestos, vol. 15, no. 12, June 1934, p. 16.

World consumption of asbestos, 1934—Continued

[In metric tons]

Continent and country	Production	Imports	Exports	Apparent consumption
Africa:				
Algeria		37		37
Egypt		97		97
Southern Rhodesia	29, 224		29, 085	139
Union of South Africa	15, 960		15, 815	145
Total, Africa	45, 184	134	44, 900	418
North America:				
Canada	141, 502		143, 557	−2, 055
United States	4, 615	109, 165	1, 514	112, 266
Total, North America	146, 117	109, 165	145, 071	110, 211
South America:				
Brazil		38		38
Chile		27		27
Colombia		38		38
Total, South America		103		103
Australia	157	2, 511		2, 668
Europe:				
Austria		1, 178	86	1, 092
Belgium Luxemburg		10, 797	816	9, 981
Bulgaria	3	3		6
Czechoslovakia	2, 100	4, 938	554	6, 484
Denmark		1, 039		1, 039
Estonia		23		23
Finland	1, 735	85		1, 820
France	[5] 406	10, 220		10, 626
Germany		20, 154	190	19, 964
Greece	30	76		106
Hungary		627		627
Italy	2, 252	8, 421	505	10, 168
Latvia		22		22
Netherlands		288		288
Norway		757		757
Poland		810		810
Portugal		345		345
Rumania		122		122
Spain		4, 702		4, 702
Sweden		1, 703		1, 703
Switzerland		783		783
U. S. S. R. (Russia)	[5] 92, 461	116	33, 813	58, 764
United Kingdom		26, 972	425	26, 547
Yugoslavia		880		880
Total, Europe	98, 987	95, 061	36, 389	157, 659
Total by continents:				
Asia	9, 035	23, 460	7, 808	24, 687
Africa	45, 184	134	44, 900	418
North America	146, 117	109, 165	145, 071	110, 211
South America		103		103
Australia	157	2, 511		2, 668
Europe	98, 987	95, 061	36, 389	157, 659
Total, world	299, 480	230, 434	234, 168	295, 746

[5] Estimate by Imperial Institute, London.

DOMESTIC DEPOSITS

CHRYSOTILE

ALASKA

Asbestos has been found near Shungnak and in the Jade Hills in far northwestern Alaska, and several attempts have been made to develop the deposits.

The Shungnak occurrences are close to the Kobuk River, between 150 and 200 miles from its mouth. According to Smith and

Mertie,[12] the asbestos occurs in small veins in close association with greenstone and serpentine. The veins, which are most abundant on the east side of Dahl Creek, consist mostly of short fiber, although some long fiber has been found. Samples of the latter were submitted to manufacturers some years ago, and they reported that the color was good but the fibers were too weak for high-grade uses. However, samples of strong, flexible chrysotile more than 6 inches long and apparently of very high grade were obtained in 1932 from a deposit in this locality. The asbestos appears to be of the slip-fiber type; therefore, it may be confined to shear zones. Stewart[13] states that three thin veins, the largest of which is about 3 inches wide, were uncovered at one point, and that some veins have been traced for at least a quarter of a mile. The deposit is undeveloped. Water transportation is available during the summer months.

The Jade Hills lie north of the Kobuk River not far from its mouth. The asbestos deposits in these hills were worked in a small way for a short time many years ago, and in 1925 and 1926 interest in them was revived and a trader at Kotzebue financed some new prospecting in the region. No definite information is available as to the kind or quality of asbestos found, but it probably is similar to that occurring at Shungnak.

ARIZONA

Asbestos was first discovered in Arizona by Charley Newton in 1872. He, with a small force of pioneers, fought a band of Indians, and during the engagement came upon an asbestos outcrop 3 miles northeast of Chrysotile on Ash Creek, Gila County, where the largest asbestos mine in Arizona is now located. No interest was taken in the deposit for many years. About 1900, chrysotile asbestos was discovered in the Grand Canyon and small quantities were mined on the north side opposite Grand View, about 20 miles west of Grand View, and at other points. After these discoveries interest reverted to the Gila County occurrences, and in 1912 and 1913 many claims were staked. Asbestos was found in numerous localities over an area 60 miles long and 25 miles wide, most of which lies west of the San Carlos and Apache Indian Reservations.

The asbestos occurs in the Apache formation, which, in the Salt River region, is represented chiefly by beds of quartzite and limestone. It apparently originated as an alteration product of the Mescal (Cambrian) dolomitic limestone due to metamorphism by diabase intrusions. It is associated with greenish and mottled serpentine. It occurs in cross-fiber veins, which are most abundant throughout the limestone close to the contact surfaces. Places where the limestone is much broken by the diabase intrusions are particularly favorable for the formation of asbestos. The veins reach a maximum thickness of about 6 inches. The fibers may extend across the full width of the vein or they may be broken into two or more lengths. The veins are erratic and are not persistent for long distances. Intervals between them on the vertical face commonly vary

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[12] Smith, Philip S., and Mertie, J. B., Jr., Geology and Mineral Resources of Northwestern Alaska: U. S. Geol. Survey Bull. 815, 1930, pp. 344–345.

[13] Stewart, B. D., Mining Investigations and Mine Inspection in Alaska: Biennium Ending Mar. 31, 1933, pp. 21, 22.

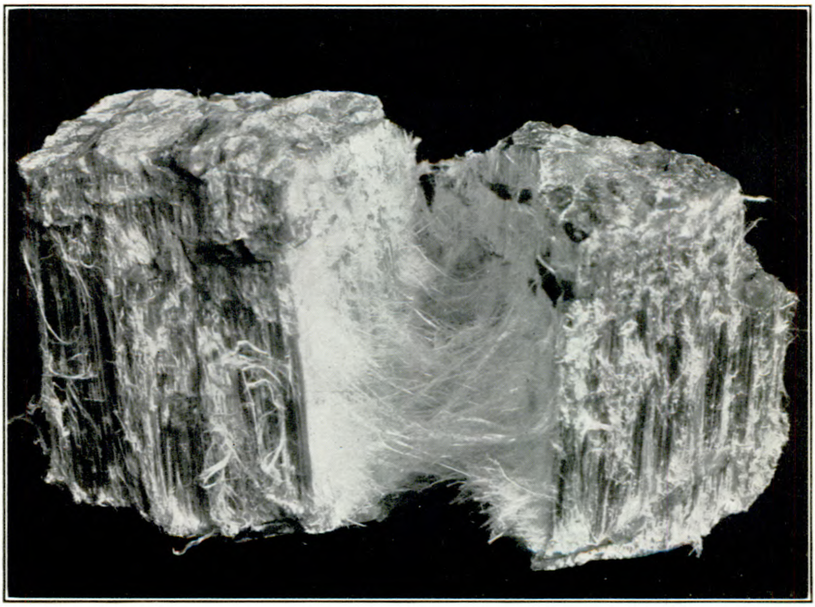

FIGURE 4.—Crude chrysotile asbestos from Arizona. ("Asbestos.")

from 2 to 6 feet. Conditions are most favorable for mining where several veins are close enough to each other to be worked from one tunnel. Usually much barren rock must be mined to recover the fiber-bearing seams. The occurrences are quite different from the Canadian deposits, where fiber veins traverse massive serpentine irregularly.

The highest-grade fiber, shown in figure 4, is soft and silky, has high tensile strength, and is excellent for spinning purposes. A harsher, less desirable fiber, however, is associated with the soft in many places. Arizona chrysotile is very low in iron, therefore it is generally considered more suitable for electrical insulation than chrysotile from other regions. According to Melhase,[14] the asbestos deposits of Gila County may be grouped in five well-defined districts, as follows:

1. Mogollon Rim district at the northern boundary of the county. It contains some interesting occurrences that are too remote to encourage development.
2. Cherry Creek district, comprising about 75 square miles along the canyon of Cherry Creek. The southern end of the district is about 25 miles north of Globe. Considerable mining has been done, notably at the Riga, Triangle, and Aileen properties.
3. Sierra Ancha district, comprising about 60 square miles adjoining the western boundary of the Cherry Creek district. The principal properties in this area are the Clark, Riga, and American ores.
4. Chrysotile district, including about 100 square miles on both sides of Salt River. Chrysotile, where the Johns-Manville mine, the largest asbestos mine in the State, is located, lies 24 miles north-northeast of Globe. Other important properties are the Regal, the Arizona Asbestos Co., and the Bear Canyon Asbestos Co. More than a dozen other properties have been developed to varying degrees.
5. Globe district, covering about 60 square miles, extending from Copper Hill, 4 miles north of Globe, eastward toward the San Carlos River. The Apache mine is the most important in this area.

The location of the deposits, most of which are many miles from a railroad, and the long and costly rail haul to eastern markets have confined mining chiefly to the highest-grade crude fibers. Haulage charges from most of the mines in the Chrysotile district, the most productive area in Arizona, to Globe range from \$22 to \$35 a ton. Very few of the properties have produced during recent years. Production began in 1913 and has never exceeded a few hundred tons a year, attaining a maximum of 1,200 tons in 1920. A new highway, constructed in 1933, from Springerville to Globe lowers the cost of transportation and may encourage enlarged development.

CALIFORNIA

Asbestos occurrences in California are numerous but the history of their development has been disappointing. The first reference to chrysotile in the Mineral Resources chapters of the United States Geological Survey was in 1901. In that year a small production was

[14] Melhase, John, Asbestos Deposits in Arizona: Eng. and Min. Jour. Press, vol. 120, no. 21, Nov. 21, 1925, pp. 805–10.

reported in Riverside County and occurrence in Calaveras County was mentioned. A small output was reported from Placer County in 1905; but, although several new deposits were recorded between 1906 and 1911, none of them bore promise of a large supply. Slip fiber was found in Sierra County in 1912. Samples of chrysotile obtained in Shasta and Napa Counties in 1913 were not of promising quality. Up to 1914, asbestos had been reported in 12 counties. Production in Shasta, Placer, Calaveras, and Alameda Counties aggregated 65 tons in 1914. In 1915, a manufacturer of asbestos pipe covering and shingles at Oakland reported purchase of 80 tons of fiber in Placer, Alameda, and Contra Costa Counties. Three carloads of nonspinning fiber were shipped to Oakland from near Sims in Shasta County in 1916. The asbestos is said to occur in cross-fiber veins, in serpentine, which would indicate that it is chrysotile, but shipments from this locality in 1922 were reported as amphibole.

The most productive deposit in California is 2½ miles northwest of Washington, Nevada County, where the fiber occurs in a large area of serpentine. Mining was begun about 1917. A 300-foot tunnel was driven into a serpentine hill on a 6-percent upgrade and a 150-foot raise was put through to the surface. The rock was mined by a glory-hole method, dropped through the raise, and trammed through the tunnel. A mill having a capacity of 100 tons a day was equipped with stamps, screens, fiberizers, and air-suction pipes. Short fiber and a small quantity of spinning fiber were produced, but activity ceased with the sale in 1923 of a small tonnage of fiber milled in 1921. Much of the output was used in the manufacture of flooring in San Francisco. A deposit that bears promise of commercial importance was reported in the Chicago Park district in 1937.

Another property that attained some prominence is about 6 miles east of Copperopolis, Calaveras County, in a serpentine belt having a maximum width of 2,700 feet. Prospecting and developing conducted in 1920 and 1921 revealed a commercially mineralized area about 1,400 feet long and 400 feet wide. In some places the serpentine rock carries 12 to 15 percent asbestos in cross-fiber veins, but the average of workable rock is much lower. A 5-percent recovery is recorded for one period of mill operation. The fiber is of paper-stock grade or shorter. A small crushing and fiberizing mill, capable of handling about 30 tons of ore a day, began operation in 1921. Underground workings consist of several tunnels, the longest of which was driven 278 feet into the hill. Very little fiber was produced, and no activity has been reported since 1923.

A deposit was developed about 1920 and a mill built in 1921 on a property 2½ miles from Hernandez in southern San Benito County. A small tonnage of fiber was produced from 1923 to 1926, and thereafter activity ceased.

A large asbestos deposit was reported in Napa County, and plans were under way for a $20,000 mill in 931, but the project did not materialize. Small quantities of asbestos were produced 9 miles southwest of Monticello in 1932, and a mill was built in 1933.

In 1931, asbestos occurring in irregular veins in dark-green serpentine was mined in an open-cut near Carrville, Trinity County. Several tons of chrysotile of good quality and averaging ¾ inch in length were obtained.

In 1928, 7 or 8 tons of asbestos were obtained 10 miles from Middletown, Lake County.

Asbestos of good quality was reported from a deposit 27 miles northwest of Coalinga, Fresno County, in 1918. A small tonnage produced in 1918 and 1919 was sold in 1925.

Small quantities were produced 2½ miles east of Ione, Amador County, in 1917, and near Valley Springs, Calaveras County, and in Alameda County in 1918.

Asbestos deposits have been reported at Towle, Iowa Hill, and 3½ miles from Cisco, Placer County; at Goodyears Bar, Sierra County; Edgewood, Siskiyou County; and Tolon, Monterey County. The maximum production in any one year was 410 tons reported by the State mineralogist in 1921. The following table[15] shows production in California, by years, since 1887. The figures in this table represent both chrysotile and amphibole. The entire output prior to 1900 was classed as amphibole.

Asbestos production in California, 1887–1935

Year	Tons	Value	Year	Tons	Value	Year	Tons	Value
1887	30	$1,800	1903	--------	--------	1919[1]	131	$6,240
1888	30	1,800	1904	10	$162	1920[1]		
1889	30	1,800	1905	112	2,625	1921	410	19,275
1890	71	4,260	1906	70	3,500	1922	50	1,800
1891	66	3,960	1907	70	3,500	1923	20	200
1892	30	1,830	1908	70	6,100	1924	70	4,750
1893	50	2,500	1909	65	6,500	1925[1]	25	1,650
1894	50	2,250	1910	200	20,000	1926[1]		
1895	25	1,000	1911	125	500	1927[1]	13	1,160
1896	--------	--------	1912	90	2,700	1928[1]		
1897	--------	--------	1913	47	1,175	1929[1]		
1898	10	200	1914	51	1,530	1930[1]	219	6,175
1899	30	750	1915	143	2,860	1931	--------	--------
1900	50	1,250	1916	145	2,380	1932[1]	309	3,274
1901	110	4,400	1917	136	10,225	1934[1]		
1902	--------	--------	1918	229	9,903	1935	--------	--------

[1] Annual details concealed under "unapportioned."

MONTANA

A deposit of asbestos near Cliff Lake, Madison County, close to the Idaho line, was developed to some extent between 1917 and 1923. The chrysotile occurs with serpentine in limestone, a similar association to that found in Arizona. The asbestos-bearing zone is closely associated with diabase intrusions. Samples sent to the United States Bureau of Mines in 1929 were found to be weaker and more brittle than fiber from Canada or Arizona. A mill was begun in 1923 and additional machinery was delivered in 1926, but production has been almost negligible.

OREGON

Chrysotile asbestos, apparently of good quality, is reported from Malheur County.

The Montbestos Co. (formerly United Asbestos Products Corporation) operated the mine in 1934 but made no sales. Samples submitted to buyers during that year were said to be satisfactory.

[15] California Mineral Production and Directory of Mineral Producers for 1934: State of California Div. of Mines Bull. 111, August 1935, p. 78.

VERMONT

Although asbestos was discovered in Vermont in 1824, no interest was taken in it until M. E. Tucker found a chrysotile vein while felling trees on the eastern side of Belvidere Mountain in 1892 or 1893. Its resemblance to the Canadian fiber was recognized immediately, and it was later found to occur over a considerable area in Lamoille and Orleans Counties.

The Vermont fiber is chrysotile similar in character and occurrence to that found at Thetford Mines, Quebec, the deposit being regarded as a southward extension of the well-known Canadian belt. The asbestos is of two kinds—cross-fiber veins passing irregularly through serpentine and slip fiber lying parallel to slickensided surfaces. Most of the cross-fiber veins are narrow, those over three-fourths inch in width being uncommon. Keith and Bain,[16] after a detailed study of the veins, decided that the asbestos had been introduced as a vein-filling material in torsion cracks and crush fractures. Matched structures on opposite walls of the veins are common. They found little evidence in support of a replacement theory. The slip fiber ranges from a fraction of an inch to 3 or 4 inches long and is somewhat coarser than the cross fiber; however, it is not suitable for spinning. The claim has been made that the proportion of fiber to rock runs 8 to 12 percent, which is somewhat greater than in the Canadian field. The yield of spinning fiber, however, is very small.

Asbestos-bearing rocks occur in four prominent localities in Lamoille and Orleans Counties. The first occurrence, which is undeveloped, is about 2 miles northeast of Lowell. It consists of numerous cross-fiber veins and some slip fiber in serpentine. The second deposit, northwest of Lowell in the vicinity of Westfield, is in the form of a belt several miles long and a mile wide. Considerable slip fiber and cross fiber occur in places, but none has been mined. In the third locality, which is southwest of Lowell near Mount Belvidere, slip fiber predominates. A mill was erected in this district in 1902 by the New England Asbestos Mining & Milling Co., but was operated only 6 months. The fourth serpentine area, extending about 2 miles eastward from the third, occupies a prominent bluff on the shoulder of Belvidere Mountain. Both slip-fiber and cross-fiber veins occur, the latter providing a small amount of crude asbestos. On this property, in 1907, the Lowell Lumber & Asbestos Co. erected a mill with a daily capacity of about 200 tons of rock. Production was first recorded in 1908, and in 1909 the industry was so active that Vermont became the chief asbestos-producing State. In 1910, the output increased 24 percent over that in 1909. In 1911 the total production of the United States, 7,604 tons, was largely from Vermont. During that year considerable no. 2 crude was obtained. In 1912, Vermont, with a production of 4,403 tons, had the distinction of being the only asbestos-producing State in the Union, but for several years thereafter no activity was noted.

The industry was revived in 1920 by the Asbestos Corporation of America but not in the location formerly most productive. Since then operations have been confined to the opposite side of the deposit

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[16] Keith, Stanton B., and Bain, George W., Chrysotile Asbestos. I. Chrysotile Veins: Econ. Geol., vol. 27, no. 2, 1932, pp. 169–188.

at the former quarry site of the New England Asbestos Mining & Milling Co. Slip fiber predominates in this region, there being little or no spinning fiber. The reserves of asbestos-bearing rock are evidently extensive. A mill was built and experimental runs were made but there was no commercial production until 1929. In 1928, the company was reorganized under new ownership as the Vermont Asbestos Corporation of America. The new company quickly put the plant in operation, producing 1,049 tons of mill fiber in 1929, and more than doubled that quantity in 1930. Although depressed markets led to some reduction in output thereafter, since 1932 production has increased substantially. In February 1936 the properties were acquired by Vermont Production Co., Inc., subsequently named the Vermont Asbestos Corporation, a subsidiary of The Ruberoid Co., and with plant additions and improvements an increase in output is anticipated. In 1934, the former operators produced 6 grades of asbestos. The longest grade was shingle stock testing 0–2–10–4. One important use is for manufacture of molded brake linings. It is employed, also, in asbestos-cement shingles, asbestos paper, pipe covering, paint, and boiler covering. The present owners use part of the output in their own products and sell the remainder to other asbestos-product manufacturers.

WYOMING

A small production of chrysotile was reported from Wyoming in 1892 and from 1906 to 1912. Asbestos occurs in a serpentine area of approximately 4½ square miles on Casper Mountain about 8 miles south of Casper and in the Smith Creek area of about 7 square miles 20 miles southeast of Casper, both in Natrona County. The mineral occurs principally as cross-fiber veins, few of which are more than an inch across, but a minor quantity of slip fiber appears in places. In 1910, the Wyoming Consolidated Co. operated a small mill in the Smith Creek area, handling about 30 tons of ore a day. A mill was built on Casper Mountain in 1911. Very little fiber has been produced in either locality, but the Patee Asbestos Shingle Co. reported production of 200 tons in 1934 from its Casper Mountain property.

Occurrences of spinning-grade asbestos near Lander and Atlantic City, Fremont County, were reported in 1919, but the properties have not been developed. A small quantity was obtained at Wheatland, Platte County, in 1920. Chrysotile has been found in several other places, but most of the occurrences throughout the State are relatively low-grade, short fibers.

OTHER OCCURRENCES

Although amphibole is the prevailing type of asbestos in North Carolina, chrysotile also occurs in several places. Chrysotile veins 2 inches wide were found near North Wilkesboro, Wilkes County, in 1902. An open-cut 100 feet long was made, but no production has been reported. Other occurrences have been noted 8 miles west of Spruce Pine, in Yancey County; near Glenville and Sapphire, in Jackson County; on the western slopes of Rich Mountain, Watauga County; and near Elk Creek, Ashe County.

A deposit near Round Hill, Loudoun County, Va., was reported in 1894. Small stringers of asbestos also occur in massive serpentine near Great Falls, Fairfax County.

Chrysotile was found in 1902 near Ishpeming, Marquette County, Mich., and some development work was done.

AMPHIBOLE

ALASKA

Asbestos said to be of the amphibole variety occurs on Admiralty Island and at Chitina on the Copper River. A little development work has been done, but the low price of amphibole fiber discourages development so far from markets.

CALIFORNIA

As early as 1882 asbestos deposits were worked in San Bernardino, San Diego, Calaveras, and Placer Counties, and in 1883 and 1884 occurrences in Butte, Fresno, Los Angeles, Tulare, Mariposa, and Inyo Counties were noted and some of them were developed. Production in 1882 was 1,200 tons; in 1883, 1,000 tons; and in 1884, 1,000 tons. In 1885, a small mine was opened at Windsor in Sonoma County, and fiber of good quality was reported from Del Norte and Yolo Counties. Sales of asbestos in the United States of 30 tons in 1889, 71 tons in 1890, and 66 tons in 1891 were credited entirely to California. In 1892 most of the production was from Wyoming, with small quantities from Oregon and California, but again in 1893 California, with an output of 50 tons, was the only producing State. The mines were idle in 1894 but produced 90 tons in 1895. A small and gradually decreasing output was noted from 1897 to 1900. All the production up to the latter year was classed as amphibole asbestos. Evidently it was used chiefly in San Francisco and Oakland for making pipe and boiler coverings, packings, and roofing.

A slip-fiber anthophyllite was mined for several years near Sims, Shasta County, but no activity has been noted since 1923.

A deposit of amphibole asbestos associated with serpentine near Chandlers, Kern County, was developed in 1928. Several short tunnels and open-cuts were made, but evidently the operation has not passed the development stage. Production during recent years has been almost negligible, and there is no prospect at present of the industry attaining importance.

GEORGIA

Occurrences of amphibole asbestos in Georgia are of two kinds: (1) Mass fiber, consisting of aggregations of short fibers representing a complete alteration of the original igneous rock; and (2) long-fibered asbestos, occurring in veins associated with partly altered peridotite, talc, chlorite, and serpentine.

Georgia has been the most consistent producer of amphibole asbestos of any of the States. The largest quantity has been obtained from deposits on or near Sall Mountain in the vicinity of Helen, Santee, Cleveland, and Nacoochee, White County. These deposits have produced with some interruptions since 1894 and possibly in a small way during earlier years. The asbestos is of the mass-fiber anthophyllite type. It is claimed that 90 to 95 percent of the rock quarried is fiber. The best asbestos is near the surface, where weathering has made it soft and flexible. The solid, unweathered rock is less desirable and requires different treatment. Resources of the best fiber, therefore, are relatively limited, and most of the available high-grade material is exhausted. The fiber is prepared for use in a mill at Gainesville about 27 miles from the deposits. It is employed principallv for fireproofing, for insulation, and in paint manufacture.

Another production center of some importance, particularly from 1924 to 1927, is Hollywood, Habersham County. The mass fiber, which occurs in a deposit about 90 feet wide, is harsher and less silky than that at Sall Mountain. After much experimental work, hammer-mill methods of fiberizing were introduced and several grades of asbestos were prepared. The products were sold for heat insulation and as filler for composition flooring, plaster, battery boxes, and rubber. Little or no production has been recorded since 1927. A large deposit of mass-fiber anthophyllite occurs in this county about 11 miles northwest of Clarkesville. It is 8 to 9 miles by road from Nacoochee, White County, the nearest railway station.

From 1923 to 1927 a small output of anthophyllite was reported from a property on Bear Creek 1½ miles northeast of Statham, Barrow County. It was used principally for filtering acids.

Asbestos was mined about 1880, 2 miles northwest of Burton, Rabun County. The mineral is long-fibered and woody. It resulted from alteration along fracture zones of an extensive peridotite intrusion. Many other occurrences are known in the county.

Fiber 6 to 7 inches long occurs in an 18-inch vein in soapstone about 2 miles southeast of Moreland, Coweta County.

Long slip fiber occurs in talcose rock north of Luthersville, Meriwether County.

Many other undeveloped deposits in the State have been described by Hopkins.[17]

IDAHO

The only asbestos deposit in Idaho that has been developed commercially is in Idaho County about 14 miles southeast of Kamiah. The deposit consists of brittle mass-fiber anthophyllite occurring in lenticular masses, some of which are 200 feet long and 35 feet thick. It is regarded as an alteration product of dunite. The Kamiah Asbestos Manufacturing Co. produced in a small way for a number of years prior to 1918. In September 1921 the property was purchased by the Western Mineral Co. of Kamiah, but no production was reported by this company. The Panhandle Asbestos Co. of Lewiston, Idaho, acquired the property in 1923 and reported small shipments in 1925. No sales have been recorded since that year. According to a press report in 1930, the Diatom Products Co. of Seattle, Wash., purchased the plant. The mill, that was apparently last operated in 1925; had a capacity of 240 tons of ore a day and was equipped

[17] Hopkins, Oliver B., Asbestos, Talc, and Soapstone Deposits of Georgia: Geol. Survey of Georgia Bull. 29, 1914, pp. 142–189.

with crusher, rolls, screens, and air separators. The fiber was used for pipe and boiler covering, in wall plaster and paint, and as a binder in cements and asphalts. In 1922 equipment was installed for sawing fire blocks and insulating brick, but the project did not materialize.

MARYLAND

Asbestos occurrences were noted in western Maryland as early as 1883, but no production worthy of mention was recorded until 1917. In that year a slip-fiber anthophyllite deposit was developed near Pylesville, Harford County. The asbestos occurs in gneissoid schists that have been softened by weathering. The veins generally are small, and the usable fiber is confined to a zone near the surface. The good asbestos extends to greatest depths along shear zones where movement and pressure have been greatest. Mining has been conducted to a depth of about 50 feet.

The fiber is unusually strong and tough, and is especially adapted to making acid filters; therefore, it is more valuable than anthophyllite from other localities. It is prepared for market by the Powhatan Mining Co. at Woodlawn, a suburb of Baltimore. Before this deposit was discovered, supplies of acid-filter fiber were obtained from Italy.

A little long-fiber anthophyllite, said to be similar to that mined at Pylesville, is found associated with talc in the Harford Talc & Quartz Co. quarry near Dublin, Harford County.

MONTANA

A deposit of anthophyllite asbestos, said to be extensive, in Gallatin County, about 17 miles south of Gallatin Gateway, is worked for a small production of insulating material. The fiber occurs in a dense, hard form but breaks down readily to a soft, fluffy mass. Occasional pockets and lenses contain strong, silky fiber, much of which is an inch or more in length. It is of spinning quality and is the only amphibole of such grade in the United States known to the Bureau. Peter F. Karst operated the property for several years, but in 1936 it was acquired by The Karstolite Co. This firm mines the asbestos and manufactures it into a wall and ceiling insulation sold under the trade name "Karstolite."

A small shipment of anthophyllite was recorded in 1928 from a property on Rainey Creek, 7 miles northeast of Libby, Lincoln County.

NORTH CAROLINA

About 1928 a mill that would handle 35 tons of ore a day was built at Minneapolis, Avery County, for treatment of mass-fiber anthophyllite occurring in that region. The mill equipment was improved considerably in 1935, and steps were taken to develop a market for prepared asbestos to be used in home insulation and in many other ways. A deposit near Plumtree, in this county, was developed some years ago, but very little fiber has been produced.

A mill was built near Otto, Macon County, in 1928 but has not produced. A small output was reported in 1919 from a deposit of mass-fiber anthophyllite at Cane River, Yancey County. Deposits of anthophyllite occur also near Warlick, Burke County; on the

Nantahala River, Macon County; near Bakersville, Mitchell County; near Todd, Ashe County; Brevard, Transylvania County: and in Caldwell County.

OREGON

Sixty-four tons of amphibole asbestos produced in Oregon were sold in 1892. In 1917 a small mine was operated a few miles north of Mount Vernon, Grant County. Asbestos occurring near Hereford, Baker County, was described in 1922 as a soft, long-fibered tremolite. Development work on the property was reported in 1925, and in 1926 a 310-foot tunnel was driven. A small production for experimental purposes was reported in 1929.

TEXAS

Amphibole asbestos approaching tremolite in composition occurs in cross-fiber veins traversing serpentine in four localities in Llano and Gillespie Counties. The veins are very irregular, but there is promise of a considerable supply. The occurrence of cross-fiber veins is unusual in amphibole-asbestos deposits. Further information is supplied by Sellards and Baker.[18]

VIRGINIA

Anthophyllite asbestos occurs about 12 miles south of Bedford, Bedford County. The prevailing associated minerals are hornblende and olivine. Unlike the mass-fiber deposits of Georgia and Idaho, the best asbestos is the slip-fiber type, occurring in veinlike masses occupying shear zones. Several veins have been noted, and one 18 inches thick supplied considerable fiber from 1904 to 1911. A mill for treating the asbestos was erected in Bedford in 1903. The available supply is probably small, as very little has been produced since 1911. A small quantity has been used in the manufacture of Tenax, a preparation used by dentists.

A deposit of slip-fiber amphibole occurs also at Rockymount, Franklin County. A shaft was sunk to a depth of 40 feet, and 40 tons were obtained from this mine in 1907. Deposits have been noted also near Boyce, Clarke County, and 8 miles from Roanoke, Roanoke County.

WASHINGTON

The Asbestos-Talc Products Co. developed a property near Burlington, Skagit County, and has produced a small tonnage of mixed talc, serpentine, and asbestos since 1930. The milled product is used in boiler coverings, roofing, and acoustic plaster. The company also manufactures "Asbesto-Fill", a heat-insulating building material, and "Asbestocite", a compound of asbestos fiber and talc used in roofing paints and plastics.

Asbestos has been mined near Pateros, Okanogan County, for use in paints. Deposits have been reported near Leavenworth, Chelan County, near Hamilton, Lyman, and at other points in Skagit County; and 8 miles north of Chewelah, Stevens County.

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[18] Sellards, E. H., and Baker, Charles Laurence: Economic Geology of Texas, part 3, 1935, p. 252.

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OTHER OCCURRENCES

Many other occurrences of amphibole asbestos were known from 1880 to 1905. The following localities, mentioned in early records, evidently had small importance as sources of supply: Staten Island and Long Island, N. Y.; New Brunswick, N. J.; Media and Colerain, Pa.; Lawrence County, S. Dak.; Stevens Point, Wood County, Wis.; Six Mile and Pickens, S. C.; Baraga County, Mich.; and New Hartford, Conn., where a small mill was operated in 1903. From 1901 to 1906 a small output of asbestos was reported near Dalton, Mass. It was first thought to be chrysotile but was identified definitely as anthophyllite in 1906. Blue asbestos (crocidolite) occurs at Beacon Pole Hill near Manville, Providence County, R. I., but not in commercial quantities.

FOREIGN DEPOSITS

CANADA

The asbestos deposits in the eastern townships of the Province of Quebec, Canada, have been famous since 1878. They are situated 100 to 175 miles from Montreal and somewhat nearer Quebec, occupying a stretch of high ground known as the Notre Dame Hills—an extension into Canada of the Green Mountains of Vermont. The hills continue northeastward to the Gaspé Peninsula, and serpentine is exposed in many places throughout their length. An asbestos deposit was developed at Port Daniel on the Gaspé Peninsula in 1919. Commercial asbestos occurs in two places—the Thetford Mines district, described later, and the Eden (Vt.), district, which has been covered in the discussion of domestic deposits.

The Quebec area, about 70 miles long and a maximum of 5 or 6 miles wide, lies between Danville and East Broughton. Within this section are six producing centers—East Broughton, Robertson, Thetford Mines, Black Lake, Coleraine, and Danville. The geology of the district has been covered in detail by Cirkel.[19] The asbestos, a chrysotile of exceptionally high quality, occurs in a very extensive serpentine formation of Cambrian age appearing in places as mountain masses rising 700 to 1,000 feet above the surrounding country. It is said to be the largest area of serpentine near the eastern coast of North America. The serpentine is regarded as an alteration product of the ultrabasic rock dunite, which consists essentially of olivine and chromite. In the process of alteration, serpentinization takes place first along irregular cracks in the olivine, and the wavy contortions of the filaments led to application of the name "serpentine." As alteration of olivine to serpentine involves an increase in volume of more than 30 percent, progressive disruption and fracturing would occur. Cirkel[20] attributed the origin of the chrysotile to columnar crystallization of serpentine in cracks and fissures. The process is somewhat obscure, but he presumed that the serpentine, which thus takes the form of bundles of extraordinarily fine filaments, crystallized from aqueous solutions acting upon the vein walls.

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[19] Cirkel, Fritz, Chrysotile Asbestos—Its Occurrence, Exploitation, Milling, and Uses: Mines Branch, Canada Dept. of Meins, 2d ed., 1910.

[20] Cirkel, Fritz, Work cited, pp. 92–95.

FIGURE 5.—Veins of asbestos on drift face 500 feet below surface, Thetford Mines, Quebec.

Cirkel[21] outlines the successive steps of formation of the asbestos as follows:

1. Intrusion of olivine (dunite) through the earth crust from below.
2. Gradual alteration of the rock to serpentine through hydration, and perhaps loss of silica, increase in volume.
3. Slow readjustment of the rock masses, resulting in the formation of joints and slickensides.
4. Subsequent formation of fissures as receptacles for asbestos fiber, through shrinkage of the rock and also through injection of granite dikes.
5. Infiltration of serpentinous solution from the sides of the wall through process of segregation, and subsequent slow crystallization of chrysotile.

Cooke[22] has made the most comprehensive study of the origin of chrysotile asbestos veins in Quebec. Three hypotheses as to origin have been advanced: (1) Replacement of massive serpentine by asbestos, (2) fissure-filling by circulating solutions, and (3) solutions or vapors penetrating through pores of the wall rock and depositing asbestos in tight fissures, the growth of the fibers pushing the walls apart. Although some objection may be raised to the last-mentioned theory, Cooke concludes that it furnishes the most adequate explanation of the conditions existing throughout the region. The most serious objection to the theory of fissure-filling by circulating solutions is the numerous occurrence of closed veins showing no connection with channels through which solutions could flow.

In some places the fiber is very soft and flexible, while in others it is somewhat harsh and brittle. To determine a reason for this harshness, Cooke[23] made very careful analyses of purified fibers of both varieties. He concluded from the results that the harshness is due primarily to the presence of talc. Keep[24] reached a similar conclusion regarding Rhodesian chrysotile.

Almost the entire output of the Black Lake, Thetford, and Danville areas is derived from cross-fiber veins ranging in width from hair lines to 4 or 5 inches and, rarely, even wider. The bulk of the production is obtained from veins ¼ to ½ inch across. Width of veins is important because it governs largely the length of fiber. Fortunately the fiber as a rule breaks easily from the wall rock. Figure 5 shows a typical occurrence of asbestos veins in the Quebec district.

Slip fiber originating along slickensided fault planes as a result of slow readjustment of the rock masses at a later time forms the chief product of the East Broughton area. The fibers are matted together more or less in parallel position, and therefore appear to be longer than they really are. Slip fiber, as a rule, is less valuable than cross fiber.

The percentage of fiber in the rock is low. According to Ross,[25] 6,208,970 tons of rock were mined in 1929 and total fiber recovery (excluding asbestic) was 311,204 tons. The yield was 5 percent of the total rock mined and 7.7 percent of the rock milled. The value

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[21] Cirkel, Fritz, Work cited, p. 101.
[22] Cooke, H. C., Asbestos Deposits of Thetford District, Quebec: Econ. Geol., vol. 31, no. 4, June–July 1936, pp. 355–376.
[23] Cooke, H. C., The Composition of Asbestos and Other Fibres of Thetford District, Quebec: Trans. Roy. Soc. Canada, 3d ser., vol. 29, sec. 4, May 1935, pp. 7–19.
[24] Keep, F. E., Geology of the Shabani Mineral Belt, Belingwe District: Geol. Survey, So. Rhodesia, Bull. 12, 1929.
[25] Ross, J. G., Chrysotile Asbestos in Canada: Mines Branch, Canada Dept. Mines Bull. 707, 1931, table 1, p. 60.

of the asbestos recovered was $2.12 per ton of rock mined and hoisted. Fiber classed as crude constituted only 1½ percent of the asbestos recovered. The output of spinning fiber, including crudes and the highest-grade mill fiber, was 24,415 tons (7.8 percent of the gross yield). Figures for other years vary little from those given above. The average recovery of fiber from milled rock is about 6 percent. Although Canada produces substantial quantities of spinning fiber, considerably more than 90 percent of its production consists of the shorter (consequently, relatively cheap) grades for which, fortunately, an extensive market exists in the United States.

The reserves of asbestos in Quebec are very large. Some of the workings are more than 400 feet deep, and core drilling has revealed an abundant supply of fiber, at depths of more than 1,700 feet, as high in quality as that near the surface.

The following table shows the annual production and value of asbestos in Quebec since the industry was first established.

Annual production (shipments and sales) of asbestos in Quebec, 1878–1935 [1]

Year	Production	Total value	Average value per ton	Year	Production	Total value	Average value per ton
1878	50	----------	----------	1907	61,985	$2,455,919	$39.62
1879	300	$19,500	$65.00	1908	65,157	2,551,596	39.16
1880	380	24,700	65.00	1909	64,965	2,296,584	35.35
1881	540	35,100	65.00	1910	80,605	2,667,829	33.10
1882	810	52,650	65.00	1911	102,224	3,026,306	29.60
1883	955	68,750	72.00	1912	111,175	3,059,084	27.52
1884	1,141	75,097	65.81	1913	136,609	3,830,504	28.04
1885	2,440	142,441	58.37	1914	107,401	2,895,935	26.96
1886	3,458	206,251	59.65	1915	113,115	3,544,362	31.34
1887	4,619	226,976	49.55	1916	133,339	5,182,905	38.87
1888	4,404	255,007	57.90	1917	137,242	7,198,558	52.45
1889	6,113	426,554	69.77	1918	142,375	9,019,899	63.35
1890	9,860	1,270,240	128.82	1919	135,862	10,932,289	80.47
1891	9,279	999,878	107.75	1920	179,891	14,749,048	81.99
1892	6,082	390,462	64.16	1921	87,475	5,199,789	59.44
1893	6,331	310,156	48.99	1922	160,339	6,053,068	37.75
1894	7,630	420,825	55.15	1923	216,804	7,364,260	33.97
1895	8,756	368,175	42.04	1924	208,762	6,561,659	31.37
1896	10,892	423,066	38.84	1925	273,522	8,976,645	32.82
1897	13,202	399,528	30.26	1926	278,689	10,095,487	36.22
1898	15,893	496,340	31.23	1927	274,798	10,621,571	38.65
1899	15,571	581,667	37.36	1928	273,033	11,238,361	41.16
1900	21,408	719,416	33.60	1929	306,055	13,172,581	43.04
1901	33,466	1,274,315	38.70	1930	242,113	8,390,164	34.65
1902	30,634	1,161,870	37.92	1931	164,297	4,812,886	29.29
1903	29,261	916,970	31.94	1932	122,977	3,039,721	24.72
1904	35,479	1,186,970	33.43	1933	158,367	5,211,177	32.90
1905	48,960	1,476,450	30.16	1934	155,980	4,936,326	31.65
1906	61,675	2,143,653	34.76	1935	210,467	7,054,614	33.52

[1] Figures for 1878–1922 from The Quebec Asbestos Industry, by Norman R. Fisher: Canadian Min. Jour., Aug. 17, 1923, p. 651. Figures for 1923–35 published by the Quebec Dept. of Colonization, Mines, and Fisheries, Bureau of Mines.

Until 1891, virtually the entire Canadian output was crude fiber. but thereafter both crude and milled asbestos were produced. This change in the character of products is reflected in the sharp drop in average value in 1892 compared with the previous year. The exceptionally high average values from 1918 to 1920 may be attributed to the abnormally high prices obtained for crude fiber on account of war conditions. Crude No. 1, for example, sold for more than $3,000 a ton during part of this period.

The largest asbestos producer in Canada is Asbestos Corporation, Ltd., operating the King and Beaver pits at Thetford Mines, the

Consolidated at Black Lake, the Maple Leaf between Thetford and Black Lake, the Vimy Ridge at Coleraine, the asbestos mine at East Broughton, and several other smaller mines as the occasion demands. The company operates six mills having an aggregate capacity of 500 tons of rock an hour. Bell Asbestos Mines, Inc., now owned by Turner & Newall, Ltd., of England, operates a large mine and mill at Thetford Mines. Johnson's Co., which began mining in 1878, is the pioneer in the district. It operates a large pit and mill at Thetford Mines and another similar operation at Black Lake. The Quebec Asbestos Corporation, Ltd., controlled by the Philip Carey Manufacturing Co. of Cincinnati, Ohio, operates a mine and mill near East Broughton. The Canadian Johns-Manville Co., Ltd., conducts a large open-pit power-shovel operation at Asbestos, about 5 miles from Danville. A mill for treatment of the ore and an asbestos-products factory are situated near the quarry. The Nicolet Asbestos Mines, Ltd., operates a pit and mill about 7 miles east of Asbestos. The mills of the district have a combined capacity of over 1,000 tons of rock an hour, and the capital employed in mines and mills is estimated at nearly $22,000,000.

The Canadian deposits occupy an exceptionally favorable position, as they are within easy reach of extensive markets in the United States. The Quebec industry doubtless will maintain its advantage indefinitely in the short-fiber market, because high freight charges on relatively low-priced products discourage transoceanic competition. The future of the spinning-fiber industry in Canada is not so bright because the price per ton of this type is high enough to give it a world-wide market range, and competition with South Africa and Soviet Russia has become increasingly severe. As early as 1919 the writer [26] pointed out the danger to Canadian supremacy in United States markets of increasing imports of African fiber into this country, but it was not until 5 years later that active steps were taken by the industry to meet this competition by consolidating companies and exercising economies in mining, manufacture, and marketing. Such consolidations and cost reductions were forced upon the industry by economic conditions, because with the loss of markets to African competitors the struggle for diminishing trade led to price-cutting that was carried to a point where several companies were reduced to bankruptcy, and the margin of profit obtained by any company was extremely small. Since then the industry has been established on a better competitive basis, but with the rapidly increasing output of Russian mines and the concentration of Rhodesian production in the hands of one powerful company, foreign competition is still a serious problem for producers in Quebec whose mines supply substantial quantities of spinning asbestos. Canada made great progress toward placing her products on a better marketing basis by establishing, in 1931, a uniform classification of asbestos.

From 1916 to 1924 some interest in the development of an asbestos industry in Ontario was aroused. Good-quality chrysotile was obtained at two points in Doloro Township south of the gold-producing area of Porcupine. A maximum production of 172 tons valued at $91,900 was recorded in 1924. The plant was dismantled later, and

[26] Bowles, Oliver, Mineral Industry during 1919 (chapter on Asbestos): McGraw-Hill Book Co., New York, 1920, pp. 41–42.

no subsequent activity has been reported except the sale of 2 tons valued at $901 in 1926.

In 1935 considerable development work was done by the Rahn Lake Mines Corporation, Ltd., of North Bay, Ontario, on a chrysotile deposit near Matachewan, Ontario, Bannockburn Township, about 30 miles southeast of Timmins in the Porcupine gold area. Erection of a mill is contemplated.

Occurrences of chrysotile asbestos of good quality have been reported near Lytton, Revelstoke, and North Kootenay, British Columbia, but samples from Lytton proved to be weak, brittle amphibole.

Although most Canadian asbestos is exported, the manufacture of asbestos products within the country is assuming increasing importance. Before 1921 only one company manufactured asbestos products in Canada; by 1923 there were three plants in Quebec and one in Ontario; in 1932 there were five plants in Quebec, six in Ontario, one in Nova Scotia, and one in British Columbia; and in 1933, four in Quebec, five in Ontario, and one each in Nova Scotia and British Columbia. Products manufactured in 1932 were valued at $1,067,801 and in 1933 at $757,626, compared with a maximum of $2,301,924 in 1930. Capital employed by the companies operating in 1933 totaled $1,777,975.

RHODESIA

The growth of the asbestos industry in Rhodesia has been almost phenomenal. From an initial output of only 55 tons in 1908 it reached more than 42,000 tons in 1929, when of all the minerals produced in the country the value of the output of asbestos was second only to that of gold. Annual production since the beginning of activity is shown in the following table:

Annual production of asbestos in Rhodesia, 1908–36

Year	Short tons	Value	Year	Short tons	Value	Year	Short tons	Value
1908	55	£552	1918	8,574	£158,684	1928	39,960	£970,327
1909	272	2,722	1919	9,798	425,240	1929	42,634	1,186,627
1910	332	3,320	1920	18,823	459,572	1930	37,765	1,070,847
1911	460	6,397	1921	19,528	795,698	1931	24,042	386,494
1912	----------	----------	1922	14,249	577,699	1932	15,766	197,092
1913	290	5,224	1923	20,364	626,898	1933	30,182	555,993
1914	487	8,612	1924	26,141	603,423	1934	32,214	402,745
1915	2,010	32,190	1925	34,349	765,926	1935	42,598	646,658
1916	6,157	99,059	1926	33,344	726,835	1936	56,346	836,469
1917	9,562	189,890	1927	33,176	794,215			

The fiber is of the chrysotile variety occurring in serpentine. It is similar in character and occurrence to that found in Canada and Soviet Russia. There are three producing districts—the Bulawayo, the Victoria (Mashaba), and the Lamagundi, all in southern Rhodesia. Deposits in other localities are known but have not attained commercial importance.

The Bulawayo district is the most important. Its largest mine, the Shabani, opened in 1916, is a prolific producer, in prosperous years providing as much as 1,200 tons of fiber a month. Other important mines in the area are the Birthday, the Nil Desperandum, and the Pangani. The Croft mine at Filibusi has attained some importance.

The asbestos deposits of the Shabani area occur in the central part of a serpentine mass about 10½ miles long and 1 to 3 miles wide. The zone of fiber-bearing serpentine has a length of 2½ or 3 miles and a maximum width of about 200 yards. The serpentine resulted from alteration of dunite, probably under the influence of a granite intrusion. The asbestos veins are best developed in a zone of serpentine 20 to more than 200 feet thick close to the contact of a talc schist that forms the footwall. In the hills, the dip of the contact ranges from 25° to 45°, but where the formation is found in the flat country the dip is only 5° to 10°. The fiber-bearing zone extends down the dip to an unknown distance beyond the practical working limit. The fiber, which occurs in seams as much as 6 inches wide, is rarely more than 3 inches long, because one or more longitudinal partings occur in most veins, except those that are quite narrow. The fiber seams generally parallel the dip of the contact but are continuous for only short distances; they consist of a series of short, irregular, overlapping veins. Ore reserves were estimated at 7,000,000 tons in 1928.

For many years the district was handicapped seriously by difficult transportation; 400 wagons and 7,000 oxen were used for conveying supplies and products many miles over poor roads. In 1928 this hindrance was overcome when a 63-mile railway from Shabani to Somabula was completed.

The earliest Rhodesian production was in the Mashaba district 46 miles east of Shabani and 26 miles west of Victoria. The principal mines, the King's and Gaths', have been large producers for many years. The fiber is similar in occurrence to that of the Shabani area. A small production has been recorded from the Ethel mine in the Lomagundi district more than 200 miles north of Victoria. Here flexible and brittle fibers occur closely associated, and their separation requires a complex milling system.

In Rhodesia the percentage of long fiber is relatively high; it is estimated that 25 to 30 percent of the fiber produced may be classed as spinning grade, whereas only about 7.8 percent of the Canadian output is of this grade. The difference, however, is not as great as these figures indicate, because short fibers that constitute between 50 and 60 percent of the Canadian production are regarded as waste in Rhodesia.

Highly efficient mills for treating the fiber are operated in conjunction with the larger mines. In 1929 all the important mines were consolidated under a single company. The industry is thus placed in a strong competitive position and before 1930 was highly prosperous. Profits of the largest company were 20 percent from 1925 to 1927, 25 percent in 1928, 30 percent in 1929, 11¼ percent in 1930, 5 percent in 1931, 3¾ percent in 1932, and 5 percent in 1933. Most of the fiber is exported to Europe and America, chiefly by way of the port of Beira, Portuguese East Africa. Owing to the remoteness of the region from consuming centers, only the spinning and higher-grade mill fibers are sold. Medium grades classed as shingle stock are sold principally in Europe and Australia for building purposes. Very little Rhodesian asbestos of lower grade than spinning stock reaches the American market.

The advantage of unified control was demonstrated in 1931, when rapidly increasing exports from Russia, combined with decreasing demand throughout the world, threatened the continued prosperity of the Rhodesian industry. Turner & Newall, Ltd., who control virtually the entire output of Rhodesia as well as a large part of that from the Union of South Africa, negotiated an agreement with Soviet Russia whereby a fair proportion of the Continental market was preserved for each.

UNION OF SOUTH AFRICA

More kinds of asbestos are produced in the Union of South Africa than in any other country in the world. Blue asbestos (crocidolite) is produced in large quantities in the Cape of Good Hope, chrysotile and tremolite are mined in small quantities in Natal, while three varieties—chrysotile, crocidolite, and amosite—are mined in the Transvaal. As the last two varieties mentioned are produced commercially in negligible quantities elsewhere in the world, it is interesting to review the quantities sold in South Africa during recent years. The following table shows production by kinds.

Production of asbestos in the Union of South Africa, by kinds, 1926–35, in short tons

Kind	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
Amosite	2,940	5,093	6,748	9,260	3,281	2,087	1,391	3,090	3,757	4,684
Blue asbestos	4,024	4,873	5,144	6,030	5,481	3,651	2,964	3,225	2,811	2,495
Chrysotile	7,133	12,174	12,162	17,747	10,519	9,938	7,715	9,572	11,025	15,620
Total	14,097	22,140	24,054	33,037	19,281	15,676	12,070	15,887	17,593	22,799

The output of amosite recorded in the foregoing table is exclusively from the Transvaal; the blue variety comes principally from Cape Province, with minor quantities from the Transvaal, while the chrysotile originates almost exclusively in the Barberton district of the Transvaal.

The following table shows annual production, by Provinces, from 1910 to 1936.

Production of asbestos in the Union of South Africa, by Provinces, 1910–36, in short tons[1]

Year	Cape of Good Hope	Transvaal	Natal	Total	Value	Year	Cape of Good Hope	Transvaal	Natal	Total	Value
1910[2]	680	10	3	693	£10,801	1924	3,001	4,240		7,241	£110,075
1911	1,254		13	1,267	20,893	1925	2,540	7,628		10,168	152,115
1912	1,217		3	1,220	18,882	1926	3,993	10,104		14,097	216,466
1913	938		24	962	16,028	1927	4,827	17,313		22,140	343,301
1914	1,160	30		1,190	20,087	1928	5,078	18,976		24,054	399,550
1915	2,083	56		2,139	35,899	1929	6,030	26,984	23	33,037	497,393
1916	4,228	407	21	4,656	83,070	1930	5,481	13,800		19,281	340,795
1917	2,999	3,193	28	6,220	87,364	1931	3,651	12,025		15,676	246,583
1918				3,674	54,037	1932	2,964	9,106		12,070	116,401
1919	3,204	631	98	3,933	66,426	1933	3,225	12,662		15,887	197,120
1920	3,526	3,541	45	7,112	114,195	1934	2,810	14,783		17,593	203,033
1921	3,467	1,593	62	5,122	103,067	1935	2,420	20,379		22,799	226,771
1922	2,991	1,392	6	4,389	81,230	1936	2,960	21,646		24,606	
1923	4,317	4,076		8,393	121,453						

[1] Figures for 1910–17 from Asbestos in the Union of South Africa: Union of South Africa Geol. Survey Mem. 12, 1918, p. 134; figures for 1918–36 from statistics of U. S. Bureau of Mines.
[2] Last 7 months.

CAPE OF GOOD HOPE

The fiber resources of Cape Province consist of blue asbestos, which was first discovered between 1803 and 1806. The name "crocidolite" ("woolly stone") was proposed by J. F. L. Hausmann in 1831. Asbestos occurs in northern Cape of Good Hope in an extensive belt of banded ironstones of sedimentary origin stretching from a point 20 miles south of Prieska northward beyond Kuruman for a total distance of about 240 miles. The maximum width is about 30 miles. The lavender-blue crocidolite occurs in interbedded cross-fiber veins that are widely distributed throughout the entire length of the belt. As the asbestos is derived from folded sediments with variable dip and strike, a knowledge of the geology is essential to intelligent prospecting and development. The deposits are described in detail by Hall.[27]

Asbestos is obtained from numerous small pits and from several large underground mines. The fiber ranges from less than one-half inch to 1 or 2 inches in length, rarely attaining a length of 4 inches. The proportion of spinning fiber is relatively high. Hall [28] states that 20 percent of the fiber produced by the leading company in 1917 and about 14 percent of that produced in 1929 was spinning grade. A highly silicified, pale brown, semiprecious variety, known as "tiger-eye" or "cat's-eye", occurs in the Hay district. The lighter-colored varieties are obtainable in slabs 9 to 12 inches long, and the darker kinds in pieces only one-half to three-fourths inch across. In 1935, 9,000 pounds of "tiger-eye" was marketed.

The Cape Asbestos Co. undertook active mining north of Prieska in 1893 and in 1929 was operating 13 mines. Its activities have been consistently successful. A dividend of 15 percent was paid in 1928; in 1932 it dropped to 4 percent but recovered to 6 percent in 1934.

Many workings have been developed northward to points beyond Kuruman. The Dominion Blue Asbestos Mines, Ltd., a subsidiary of Turner & Newall, Ltd., is an active producer in the northern section of the belt. Amosite and Blue Asbestos, Ltd., is another recent producer.

The area is so large and fiber veins are distributed so generally throughout it that reserves are doubtless very great. Transportation is difficult, as the nearest railway line is 100 to 130 miles from the workings. Much study and experimentation have been devoted to fiberization and preparation of blue asbestos, with the result that it is used extensively in Europe, but generally it has not been regarded with favor in America. It is applied to both spinning and nonspinning uses.

TRANSVAAL

CHRYSOTILE

Carolina district.—Asbestos was first produced in the Transvaal about 1905 from a deposit of chrysotile 20 to 25 miles east of Carolina. In origin and occurrence it is similar to that found in Arizona. Cross-fiber veins occupy a 5-foot zone of altered dolomite overlying a diabase sill. The veins parallel the bedding, which dips 8° to 15° northwest. From 40 to 60 percent of the fiber marketed is over

[27] Hall, A. L., Asbestos in the Union of South Africa: Union of South Africa Geol. Survey Mem. 12, 2d ed., 1930.
[28] Hall, A. L., Work cited, p. 87.

1 inch long; that less than one-half inch long is rejected. Mines have been operated at various times, but production has never been large.

A second deposit of chrysotile in the Carolina district occurs on the farm Kalkloof, 3 miles south of the Komati River and 47 miles by road from Carolina. This occurrence is of the usual type—cross-fiber veins in serpentine derived from ultrabasic igneous rock. The fiber occurs in many closely spaced, parallel thin seams inclined at a steep angle. The asbestos is of good quality, but a large proportion of it is short mill fiber. Evidently reserves are extensive. A mill was in operation in 1929, but production has been small.

Barberton district.—In 1918 Hall [29] directed attention to a chrysotile deposit near Barberton in eastern Transvaal, but serious development did not take place until after 1921. The deposit occurs in a belt of serpentine bounded by quartzites lying about 3 miles from Kaapsche Hoop and 14 to 17 miles by road from Godwin River station. The asbestos-bearing portion of the serpentine has been traced for a length of 3 and a width of 2 miles. Further exploration may extend its boundaries considerably. Underground mines have been developed extensively near both the eastern and western ends of a 2-mile zone containing large reserves of fiber.

The New Amianthus Mines, Ltd. (subsidiary of Turner & Newall, Ltd.), operates near the western end. Here the most productive fiber belt is known as the "ribbon rock" or "ribbon line." In a typical section, the upper 7 feet contains narrow parallel fiber seams so numerous and closely spaced that the fiber content may run as high as 40 percent of the entire rock mass. Beneath this band is a 6-foot mass of serpentine, in which the chrysotile veins are fewer and thicker, providing fiber up to 6 inches long. Figure 6 shows the abundance of fiber veins. The veins dip 10° to 20°. The fiber is of high quality and is easily separated from the massive serpentine. Records for one period show that fiber recovered from the upper beds amounted to 30 percent of the rock mined, while from the lower beds it was 10 percent or less. In 1930, the average recovery for the mine was 15 to 17 percent. In that year about 8 percent of the output was of spinning grade, and 92 percent was classed as shingle stock. The mine is a steady producer, furnishing about 1,000 tons of fiber a month in 1930.

The Munnick-Myburgh mine occupies the eastern end of the serpentine area. The fiber seams are more or less parallel and resemble those at the western end already described. Thin seams are close together, and the thicker seams are more widely spaced. A majority of the seams worked range from one-sixteenth to one-half inch in width. Operations began about 1920, and in 1930 the mine was producing about 200 short tons of fiber a month.

For some years the products of the mines were transported 18 miles to Godwin River station in wagons hauled by oxen or mules. The completion in 1929 of a 5.9-mile aerial tramway over a 2,000-foot escarpment to Elandshoek made possible a reduction in haulage cost to about one-eighth of the amount formerly paid. From this point the asbestos is carried by a short-rail haul to Lourenco Marques, Portuguese East Africa, the port of shipment.

The extent of the area, the high percentage of fiber of superior quality in the rock, and the easy access to a seaport make the Bar-

[29] Hall, A. L., Asbestos in the Union of South Africa: Union of South Africa Geol. Survey Mem. 12, 1918, p. 59.

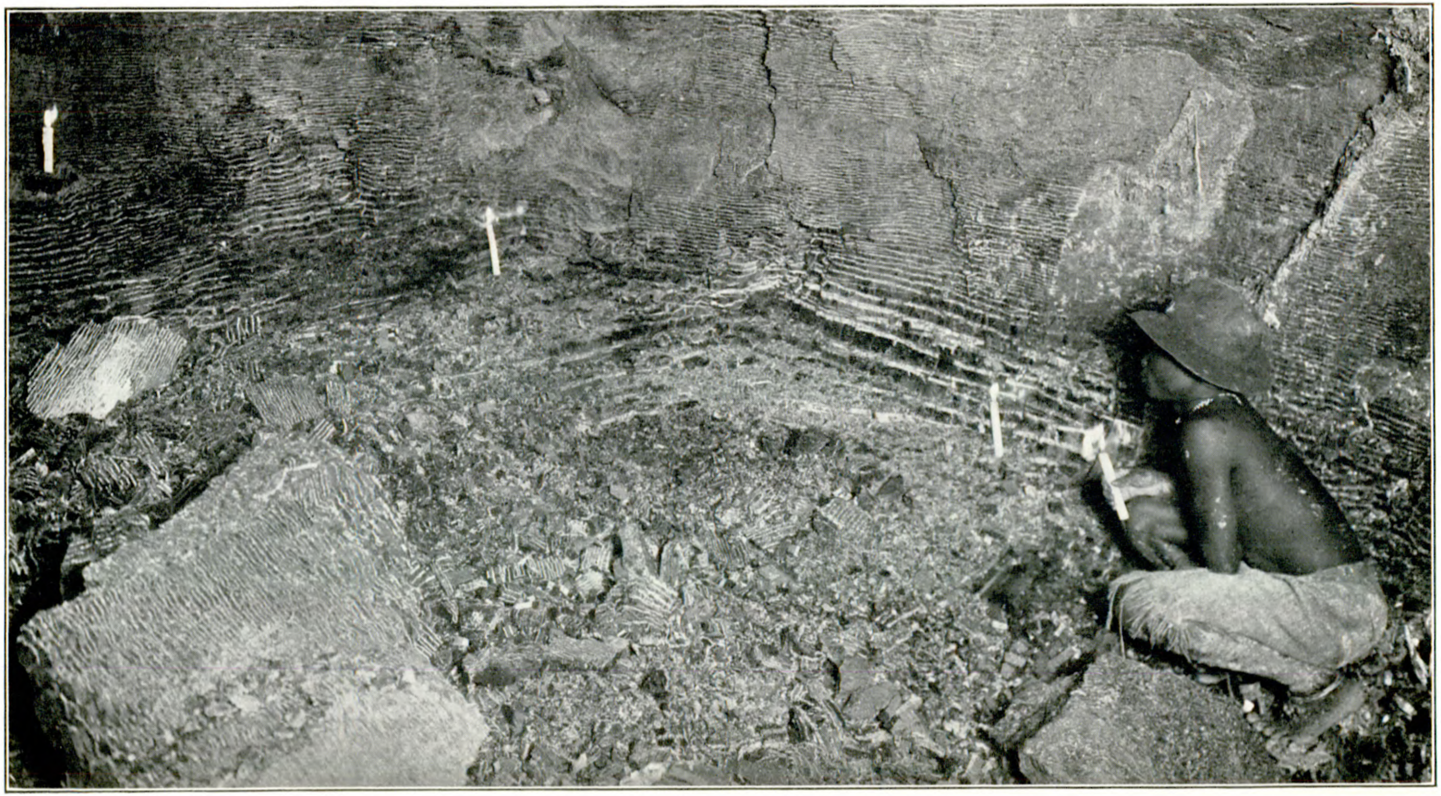

FIGURE 6.—Asbestos veins in the New Amianthus Mines, Ltd., Barberton district, Transvaal, South Africa.

berton district one of the most important asbestos centers in the world. The development of mines in this region is reflected in the rapid increase in production of the Transvaal, beginning in 1923, as shown in the table of production in the Union of South Africa by Provinces.

AMOSITE

This unique variety of asbestos occurs most prominently near Penge, about 30 miles north of Lydenburg in northeastern Transvaal. The belt extends from the Steelpoort River northwestward along the basin of the Olifants River, thence westward to Chuniespoort. The asbestos occurs in cross-fiber veins interbedded with siliceous ferruginous slates associated with intrusive diabase sills. The principal mines, the Egnep and Amosa, about 1½ miles apart, are situated near Penge. Fiber is obtained from surface workings and from several levels underground. A number of smaller mines and open-pit workings have been operated in the western part of the belt near the Malips River. The fiber veins show remarkable continuity over long distances, and reserves are extensive.

The most notable feature of the asbestos is its length, which attains a maximum of approximately 11 inches and averages about 6 inches for the commercial product. When the material was first marketed difficulties were encountered, because standard equipment for manufacturing asbestos products was not well adapted for fiber of such great length. With subsequent adjustments, the material was prepared extensively for spinning, magnesia pipe covering, and manufacture of other asbestos products.

The future of amosite is uncertain. The claim is made that the relatively large production recorded for 1928 and 1929 was stimulated chiefly by a shortage of chrysotile. As a similar shortage is unlikely to occur again for many years, future activity in the amosite fields will depend primarily on the serviceability of this type of fiber.

CROCIDOLITE

Crocidolite occurs in the western part of the amosite belt, a region designated as the Pietersburg district. It is associated closely with amosite, both varieties being obtained from some of the workings. The blue asbestos is obtained chiefly from open pits near and east of the Malips River. The maximum length of fiber is about 3 inches. Production never has been large. In 1928, the last year for which it was recorded, the output was 66 tons.

ANTHOPHYLLITE

Anthophyllite occurs in the Zoutpansberg district, 50 miles west of Waterpoort Siding. The fibrous structure has evidently been developed under the influence of weathering, therefore the persistence of usable fiber at depth is doubtful. Asbestos taken from pits not exceeding 30 feet deep was used some years ago for boiler covering, but there has been little recent production.

NATAL

The most important asbestos deposit in Natal is in the Tugela River Valley east of Kranz Kop, Zululand. Chrysotile asbestos occurs here in vertical cross-fiber veins near contacts of aplite dikes with green serpentine. Most of the fiber is short and inferior. Production since 1910 has ranged from 2 to 62 tons a year.

A deposit of brittle tremolite asbestos has been worked near the Klip River, 45 miles from Dundee, a region where transportation is very difficult. The small amount of material obtained was used for the manufacture of asbestos brick and for insulation.

OTHER AFRICAN OCCURRENCES

Asbestos has been reported at various other points in Africa. The fiber occurs in Bechuanaland, Nyasaland, and in serpentine in the northwest corner of Swaziland. The latter deposit is evidently not far from the productive Barberton district of the Transvaal. Anthophyllite occurs at Morogoro in what was formerly German East Africa, and chrysotile was reported near Macequece, Portuguese East Africa, in 1929.

SOVIET RUSSIA

Before the World War, Russia ranked next to Canada as an asbestos-producing country. During the revolutionary period the industry was almost at a standstill, but since then it has been revived on an extensive scale. The following table shows production since 1913. The figures were obtained from the annual chapters on asbestos in Mineral Resources of the United States, published by the United States Geological Survey until 1924 and thereafter by the United States Bureau of Mines, and from the corresponding chapters in the Minerals Yearbook, published by the Bureau of Mines.

Asbestos production in Russia, 1913–36

Year	Metric tons	Year	Metric tons	Year	Metric tons
1913	17,494	1921	2,604	1929	[2] 29,520
1914	15,691	1922	3,215	1930	54,083
1915	9,779	1923	[2] 4,780	1931	64,674
1916	8,192	1924	[2] 8,456	1932	59,800
1917	(1)	1925	[2] 12,330	1933	71,700
1918	(1)	1926	[2] 18,334	1934	92,200
1919	(1)	1927	[2] 21,156	1935	95,500
1920	1,478	1928	[2] 26,492	1936	

[1] Data not available. [2] Year ended Sept. 30.

The great increase since 1929 does not affect world markets as much as might be expected, because increasingly large quantities are used for home consumption. According to recent figures,[30] the percentage of Russian asbestos exported dropped from 51.1 in 1922–23 to only 20.5 in 1931. This condition reflects the rapidly expanding manufacture of asbestos products in Soviet Russia. However, these figures tell only part of the story, for they do not indicate the percentage of spinning and higher-grade mill fibers exported. The 50 to 80 percent of the production remaining in the country may consist largely of the shorter fibers, which are of minor importance in world trade.

The asbestos region providing the major part of Russian production comprises what is known as the Bajenova district in the Urals. Prin-

[30] Economic Review of the Soviet Union, Oct. 15, 1932, p. 365.

cipal production is at Asbest, about 90 kilometers northeast of Sverdlovsk (Ekaterinburg). Minor production in this district is obtained from the Alapaevsk area in the north and from the Neviansk area in the northwest. The largest mine in the latter is the Kramouralsk. Outside the Bajenova district the only notable production is from Minusinsk, on the Yenisei River in eastern Siberia near the Mongolian border. Here the deposits, said to be of the same general character as those of Arizona, have been worked in a small way, a production of 1,490 tons being reported in 1905. Asbestos also occurs in serpentine in various parts of the Altai Mountains southwest of Minusinsk.

A chrysotile asbestos deposit on the Laba River in the Maikop district of the Caucasus, about 98 kilometers from a railway, has recently been described.[31] The mineral occurs in veins in serpentine which have been intruded by granite. In general, the fibers range in length from 2 to 7 mm, with a maximum of 25 mm (10 inches). The asbestos is said to be of good quality, but the reserves are not extensive. The deposit has been worked in a small way since 1930 and a larger development is anticipated.

A small output was reported from the Katun River district from 1907 to 1909.

Chrysotile has been reported in other parts of Russia, as follows: In a peridotite-serpentine belt in the Province of Transbaikalia, southern Siberia; on the upper course of the Yenisei River in the far north; near the source of the Kuban River east of the Crimea; and in Turkestan.

At Asbest, in the Bajenova district, where the asbestos industry is now centered, 20 or more open pits are worked. They have been under control of the State since 1918 and have been operated by the Uralasbest Trust since 1921. Asbestos was first discovered here about 1710, and systematic development under direction of Baron Girard began in 1885. The asbestos-bearing serpentinized intrusion is about 21 kilometers long and 200 to 1,200 meters wide. It consists of peridotites, which are bounded by schist or slate on the west and by granite on the east. The asbestos is confined to ellipsoidal masses of serpentine, some of which attain a length of 3,500 feet and a width of 1,000 feet. The highest percentage of asbestos is found in the central parts of these masses. The cross-fiber veins generally run north and south with a vertical dip. Slip fiber appears in places. Russian asbestos usually is regarded as being higher in iron than the Canadian fiber, but Ru Keyser [32] has pointed out that Canadian asbestos is high in ferric iron, whereas in the Russian fiber ferrous iron predominates. This probably accounts for the greater discoloration of the Ural asbestos upon weathering. Russian asbestos deposits have a comparatively shallow overburden and are therefore weathered quite extensively, which may account for the somewhat harsher and less silky condition of the fiber compared with the Canadian. Asbestos occurring below the 50-foot level more nearly resembles that obtained in Quebec. While the percentage of spinning fiber in the Russian deposits is a little higher than that in the Canadian, the percentage of total commercial fiber is about the same.

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[31] Tatarinov, P., The Laba (Beden) Deposit of Chrysotile Asbestos in the North Caucasus: Neues Jahrb. Mineral. Geol., Referate II, 1936, pp. 249–250.

[32] Ru Keyser, W. A., Chrysotile Asbestos in the Bajenova District, U. S. S. R.: Eng. and Min. Jour., August 1933, p. 338.

Extensive and systematic core-drilling indicates a reserve for the entire Bajenova district of more than 3,000,000 metric tons of fiber within 50 feet of the surface. This estimate is based on only a 2-percent recovery; with a probable 4½-percent recovery this quantity would be more than doubled. As the deposits extend far below the 50-foot level it is apparent that the reserves are very great. The reserves of asbestos in the Soviet Union were estimated on January 1, 1934, at 19,400,000 tons.

Much of the upper rock is soft enough to be mined with picks and shovels. Before the revolution, crude methods of mining and fiber recovery were practiced, and only the longest grades of fiber—crudes, spinning, and shingle stock—were recovered. However, with increased mechanization and development of markets for the shorter grades, most of the fiber in the rock mined is now separated and sold. As the flow of water is heavy below the 50-foot level, the workings consist principally of broad, shallow, open pits, although some underground development has taken place. A narrow-gage railway was built from Asbest to Bajenova (34 km) in 1927, making possible more intensive development.

There are three major groups of mines in this district. The most northerly, known as the "Proletariat", produces shorts almost exclusively. The two major producing groups are the October (central) and the Ilyinski (southern). Several mills with very crude equipment have been operated for many years. Since 1931, newer and more efficient mills have been built and new equipment has been installed in some of the old ones. A large asbestos-products industry has been established in Russia, and crudes and spinning fibers which in former years constituted a large part of the output have been supplemented by mill products similar to those produced in Canada.

ITALY

Italy is called "the cradle of the asbestos industry", because the mining of asbestos and the manufacture of its products began on an industrial scale in that country. Italy also is unique in that much of the fiber produced in early years consisted of tremolite, a variety of amphibole asbestos little used elsewhere. Before discovery of the Canadian deposits, Italy was the chief source of supply of asbestos for both Europe and America. After the Quebec deposits were developed, the Italian industry experienced little growth. Production from 1898 to 1934 is shown in the following table:

Annual production of asbestos in Italy, 1898–1934, in metric tons

Year	Tons	Year	Tons	Year	Tons
1898	131	1911	170	1924	2,160
1899	81	1912	169	1925	2,105
1900	126	1913	175	1926	2,900
1901	243	1914	171	1927	3,840
1902	243	1915	163	1928	4,950
1903	202	1916	82	1929	2,847
1904	182	1917	85	1930	851
1905	220	1918	60	1931	632
1906	209	1919	98	1932	1,284
1907	359	1920	165	1933	3,267
1908	359	1921	420	1934	2,252
1909	190	1922	540		
1910	175	1923	1,538		

One important deposit is in the Susa Valley region of western Torino near the French border. Here tremolite asbestos, which is particularly well-adapted to the manufacture of acid filters, is mined in the mountains 8,000 to 9,000 feet above sea level. A second deposit is along the Aosta Valley near Ivrea in northeastern Torino, about 46 miles from Turin. Tremolite asbestos has been mined in the mountains in this locality since 1865, but there has been little activity since 1905. The fibers are long and highly resistant to acids and heat, but owing to the difficulty of separating them, they are not well-adapted to weaving. A third source of supply of tremolite asbestos is near Sondrio in northern Lombardy. This asbestos also is a long-fibered variety similar to that of the Torino deposits.

The Balangero mine situated in Torino about 20 kilometers north of Turin has been the chief producer during recent years. The asbestos of this district is chrysotile, the output of which was about 2,000 tons in 1925 and nearly 5,000 tons in 1928, the year of greatest production. In 1928, modern mechanical mining equipment was introduced. The fiber is said to be inferior to Canadian chrysotile for spinning purposes. It commands prices ranging from $75 to $150 a ton and is used chiefly for the manufacture of artificial stone.

Asbestos was produced in Sardinia in 1926, and deposits are reported in Corsica.

Italy is both an importer and an exporter of asbestos. Practically all the fiber required for textile use and considerable quantities of the shorter grades are imported, while small quantities of filter asbestos and other nonspinning grades are exported.

CYPRUS

The chief asbestos deposits of Cyprus occur at Amiandos, on Mount Troodos in the west-central area. A peridotite plug consisting largely of olivine is altered to serpentine on the periphery. Short-fiber chrysotile asbestos occurs in the serpentine in irregular veins that have a maximum thickness of about one-half inch. Faulting and shearing evidently have exerted a definite influence on development of the fibrous structure. The asbestos content of the rock runs only 1 to 2 percent. The deposit is evidently extensive, but no information on reserves is available.

The fiber is of the chrysotile variety and generally too short for spinning, but small shipments of spinning fiber were reported in 1934. Milled fiber is graded into three classes—standard, shorts, and fines. The standard grade, designated "shingle stock", is said to comprise about 90 percent of production.

About 1925 an aerial ropeway 18 miles long was constructed for conveying the asbestos from Amiandos to the seaport at Limasol. The construction cost was about £2,320 a mile. The cost of transporting asbestos by means of the ropeway, including interest on investment and complete amortization of the equipment in 10 years, was given as 6s. 9d. a ton, whereas motor-wagon or animal transport formerly employed on the 37-mile winding road cost 20 to 25s. a ton.

The industry attained considerable importance from 1926 to 1929, but thereafter the demand fell off greatly. It is reported that operations were conducted at a substantial loss in 1932, but the industry recovered greatly in following years.

Production has been in the hands of a single company. The Cyprus Asbestos Co., Ltd., operated for several years prior to 1927, but in that year the Cyprus Trading Corporation, Ltd., was organized and absorbed the former company. In 1932, the newer firm was reorganized as Cyprus & General Co., a British organization, and in 1936 the assets of the latter company were acquired by the Tunnel Asbestos Cement, Ltd., a subsidiary of The Tunnel Portland Cement Co. of West Thurrock, England. The asbestos is used by the company for manufacture of asbestos-cement products in England.

As there are no local asbestos-products plants, the entire output is exported, principally to European countries. Exports began in 1906. Figures for tonnage and value of exports over a period of years are shown in the following table:

Asbestos exported from Cyprus, 1922–36

Year	Long tons	Value	Year	Long tons	Value	Year	Long tons	Value
1922	2,285	£22,899	1927	10,904	£207,562	1932	1,600	£27,214
1923	2,115	57,115	1928	11,579	231,692	1933	4,604	[1] 44,088
1924	4,372	80,070	1929	13,796	292,971	1934	7,590	[1] 73,562
1925	3,290	54,639	1930	5,400	116,092	1935	7,514	50,174
1926	6,331	121,857	1931	3,571	66,381	1936	9,506	80,343

[1] Reported by Cyprus & General Asbestos Co., Ltd.

Of the fiber exported during 1934, 2,889 tons were reported as destined for the United States.

The following table, taken from the Annual Report of the Inspector of Mines and Labour, 1934, indicates the scope of recent operations and the ratio of fiber to rock.

Rock mined, rock treated, and fiber produced in Cyprus, 1931–34, in long tons

	1931	1932	1933	1934
Rock mined	113,738	155,765	354,178	711,646
Rock treated	25,966	36,819	76,784	153,865
Asbestos fiber produced	1,138	1,520	3,494	7,081

OTHER FOREIGN DEPOSITS

Asbestos deposits of minor commercial importance at present are covered in the following pages, by countries, arranged in alphabetical order.

ARGENTINA

Deposits of asbestos are reported at Alta Gracia, Cordoba; Sierra de la Cortadera, Mendoza; Fiambala, Catamarca; and in the Provinces of San Luis and San Juan. The fiber is said to be too short for spinning or weaving and production has been very small. The only available figures show an output of about 42 short tons in 1926 and of less than a ton in 1927.

AUSTRALIA

WESTERN AUSTRALIA

The most important recent development in Western Australia is the Sherlock property, in the Roebourne district, about 24 miles from the port of Balla Balla. Here chrysotile asbestos occurs in veins that are restricted to a relatively narrow zone. Two main veins, separated by a dolerite dike, have been proved for a length of 1,000 feet. The percentage of fiber 2 inches long and over is said to be much higher than in the principal producing regions of the world, and is of good quality. Up to 1934, about 1,000 tons of fiber had been mined by contract laborers and shipped to Europe, but no systematic mining had been followed. Shaft sinking and the erection of a pumping plant were started in 1934.

Other producing areas are Lionel in the Nullagine district, and Soansville and Cooglegong in the Marble Bar district. These deposits are all in the Pilbarra Goldfield area. At Soansville chrysotile occurs in veins up to 30 inches wide with a maximum fiber length of 6 inches. The veins have been proved over a length of 1,200 feet. Fiber from this area shipped to London commanded a price of £120 to £150 a ton.

Asbestos was discovered in the Marble Bar area in 1909. A large deposit has been reported 15 miles west of Cooglegong. Chrysotile veins range from threads up to 6 inches wide.

The following table compiled by Elford, [33] shows production in Western Australia for a period of years.

Production of asbestos in Western Australia, 1921–32

Year	Quantity, tons	Value,	Locality where mined	Year	Quantity, tons	Value,	Locality where mined
1921	202	£12,221	Lionel.	1927	10.8	£304	Lionel.
	32	1,360	Cooglegong.	1928	11.7	782	Soansville and Lionel.
1922	179	7,350	Lionel.				
	2.5	250	Cooglegong.	1929	191	8,568	Sherlock.
1923	111	3,865	Lionel.		63	6,113	Soansville.
	3	150	Cooglegong.	1930	65	4,228	Pilbarra.
1924	73	2,206	Lionel.		17	500	West Pilbarra.
1925	50	1,619	Do.	1931	108	1,446	Roebourne.
1926	91	2,436	Do.	1932	110	1,762	Do.
	14	292	Roebourne.				

SOUTH AUSTRALIA

A promising deposit of crocidolite occurs 10 miles north of Hawker, about 248 miles north of Adelaide. Apparently it is derived from magnesian limestone. The maximum length of the fiber is about 2 inches, but most of the asbestos is short and matted. Two shafts 40 feet apart have been sunk to a depth of 26 feet and connected with a drift. Unfortunately, the ore body is faulted at the 26-foot level, and nothing is known of its continuation. Bluish gray crocidolite occurs as bunches and veins in dolomitic limestone at Robertstown, 83 miles from Adelaide. It is said to have excellent heat-insulating

[33] Elford. Harold S., Australian Nonmetallic Minerals. II. Asbestos: Chem. Eng. and Min. Review, vol. 25, Sept. 5, 1933, p. 396.

qualities. Other occurrences have been noted at Kapunda, Truro, Mount Baker, Gumeracha, and Williamstown.

Chrysotile of good quality occurs at Mimbric near Cowell. Veins attaining a maximum width of 2 inches appear in serpentine traversing marble. According to report, the asbestos-bearing rock would yield 0.5 percent crude and 15 to 20 percent mill fiber. Annual production ranging from 5 to 21 tons has been noted in South Australia for various years.

QUEENSLAND

Asbestos has been noted in many localities in Queensland, mainly within the serpentine belt northeast and north of Rockhampton, extending from Balnagowan near the Fitzroy River to Marlborough. The deposits at Princhester and Marlborough appear to be the most important, though little is yet known of their quality or extent. A small amount of fiber has been mined, and it is reported that it sold for £25 a ton. On Marlborough Creek near its junction with the Fitzroy River well-defined veins having a maximum fiber length of 1½ inches are reported. Queensland asbestos is said to be coarse in texture and of low strength. It is well adapted for asbestos-magnesite flooring, for boiler covering, and as an ingredient of paints.

NEW SOUTH WALES

A chrysotile-asbestos deposit was worked in a small way near Barraba for several years following 1918. Short-fiber chrysotile occurs in a belt of serpentine about ½ mile wide. The area is greatly faulted, which makes mining difficult. A small mill, similar to those in Quebec, was operated for a time, and fiber recovery is said to have been 5.75 percent of the rock treated. Crocidolite occurs near Gundagai and Broken Hill, but the percentage of recoverable fiber is said to be low.

TASMANIA

An occurrence of asbestos at Beaconsfield was discovered more than 30 years ago, a production of 200 tons being recorded in 1899. It is of the chrysotile variety, occurring in irregular and noncontinuous veins in a serpentine belt 2 miles long and 1½ miles wide. The fiber rarely reaches 1 inch in length; commonly, it is ⅛ inch long. The asbestos-bearing area is not very large, and the veins so far uncovered are too scattered and irregular to encourage deep working. A limited production of asbestos of fair quality is possible. The fiber has a higher iron content than Canadian asbestos. A mill for ore treatment was erected in 1917, but very little fiber has been produced.

A promising deposit of asbestos in serpentine is reported on the western shore of Macquarie Harbor, 16 miles south of Strahan. It is undeveloped.

AUSTRIA

Short-fibered amphibole, known as "microasbestos", is mined in Austria near the Hungarian frontier. It is mixed with both asphalt and concrete used for road surfaces.

BRAZIL

An amphibole-asbestos deposit is reported near Rio Branco, Pernambuco, and asbestos of uncertain type occurs in Minas Geraes.

BULGARIA

Amphibole asbestos of the anthophyllite type occurs over a large area in the eastern Rhodope Mountains of southern Bulgaria. A production of several hundred tons was reported unofficially in 1933.

CHINA

Asbestos said to be of the chrysotile variety occurs in a number of Provinces in China, including Chihli, Jehol, Chahar, Suiyuan, Shensi, Szechuan, Hupeh, and Kwangtung. The most important deposits are in the Laiyuan district, Chihli (Hopeh) Province. (The spelling "Hopei" in the footnote reference is not now recognized.) Here the asbestos occurs in numerous generally parallel cross-fiber veins in limestone. Maximum fiber length is about 1½ inches. The asbestos has evidently resulted from metamorphism of a siliceous magnesian limestone under the influence of granite intrusions, therefore it is similar in origin to the Arizona deposits. The deposits have been described by Hou.[34] Reserves in the area are estimated at 400,000 tons. The longer grades are of spinning quality. The deposit has been worked since 1914. Production in 1927 was 180 metric tons. The fiber is conveyed on horseback to Yiksian (106 kilometers) and from there to Tientsin by train. It supplies manufacturing plants in the latter city. Four such plants were reported in 1927. Their products are mostly for domestic consumption, though some are shipped to Japan.

Asbestos mines about 5 miles from Chinchu, Manchuria, have been worked in a small way for more than 20 years. The output has been shipped to factories at Osaka and Tokyo, Japan.

CZECHOSLOVAKIA

According to the Bureau of Foreign and Domestic Commerce,[35] the sole producer of asbestos in the country is "Asbest" Gewinnung und Verwertung von Asbest Gesellschaft m. b. H. at Dobsina. An output of 2,600 metric tons in 1935, 2,100 in 1934, and 1,200 in 1933 has been reported. No data are available as to the nature or quality of the product, nor has the Bureau of Mines any previous record of an asbestos occurrence in this country.

FINLAND

Asbestos production is confined to a locality in Tuusniemi Parish, east-central Finland, where 1,000 to 1,500 tons of amphibole fiber were mined annually until recent years, when production has evidently increased. According to a British report on Finland by Keith Jopson, production in 1934 was 14,000 metric tons, compared with 9,200 tons in 1933 and 6,000 tons in 1932. According to an analysis reported by Borgström [36] Finnish asbestos is of the following chemical composition: SiO_2, 56.57; Al_2O_3, 1.02; FeO, 5.72; MgO, 30.78; CaO, 0.57; H_2O+, 4.89; H_2O-, 0.14. This corresponds closely with

[34] Hou, T. F., Notes on the Asbestos Deposit of Laiyuan District, Hopei Province (in English): Nat. Geol. Survey China Geol. Bull. 25, March 1935, pp. 39–43.
[35] Bureau of Foreign and Domestic Commerce, Foreign Metals and Minerals: Circ. 3, Apr. 15, 1936, p. 9.
[36] Borgström, L. H., Finnish and Foreign Asbestos: Tek. Fören. Finland Förh., vol. 55, 1935, pp. 105–107.

the analysis of Georgia anthophyllite shown on page 4. The product of the mines, together with imported chrysotile fiber, is used in a factory at Helsingfors for the manufacture of asbestos board, Eternit tiles, packings, clothing, and gloves. A small quantity of actinolite has been mined in northern Finland.

FRANCE

Although France uses large quantities of asbestos in its manufacturing plants, a very small production of raw fiber has been recorded. It is interesting to note, therefore, that plans have been made to open an asbestos quarry in the Chateau-Ville-Vieille-et-Chateau-Queyras Commune in the Guil Valley at an altitude of about 2,000 meters.[37]

A deposit of asbestos in Corsica was reported in 1921.

GERMANY

Discovery of a greenish white chrysotile in Bayerischer Wald, East Bavaria, was reported in 1935. This is said to be the only asbestos occurrence known in the country and is exceedingly important from the German standpoint because of increasing demands for home consumption. Imports of raw fiber to supply German asbestos-products plants increased from 7,582 tons in 1932 to 20,154 in 1934.

INDIA

The Hassan district of Mysore State has been the most productive area in India. Both chrysotile and amphibole fibers are available. A maximum production of over 1,700 long tons was obtained in 1920, but no output has been recorded since 1929. A small production has been noted from Seraikela State, Bihar and Orissa from 1921 to 1932. The material is evidently tremolite. Asbestos occurs in many other parts of India; but no estimates of reserves are available and none of the deposits seems capable of a large production of high-grade fiber. The development of a substantial asbestos-producing industry in India will depend largely upon the establishment of domestic asbestos-products plants that will absorb the short fibers. The following table, compiled from data assembled by Coulson,[38] shows production from 1906 to 1934.

Asbestos production in India, 1906–34

Year	Long tons	Value	Year	Long tons	Value	Year	Long tons	Value
1906	20.6	--------	1920	1,818.0	£7,272	1928	156.5	£1,622
1908	18.0	--------	1921	315.5	884	1929	318.4	1,206
1910	3.0	£6	1922	242.0	701	1930	33.2	88
1914	5.0	23	1923	247.0	659	1931	6.0	5
1916	5.0	22	1924	125.3	1,354	1932	90.0	677
1917	148.0	303	1925	16.0	361	1933	--------	--------
1918	357.0	965	1926	58.4	786	1934	24.6	--------
1919	388.0	1,439	1927	67.7	1,011			

[37] Bureau of Foreign and Domestic Commerce, Foreign Trade Notes: Vol. 4, no. 5, May 27, 1935, p. 4.

[38] Coulson, A. L., Asbestos in the Ceded Districts of the Madras Presidency: With Notes on Its Occurrence in Other Parts of India: Mem. Geol. Survey of India, vol. 64, pt. 2, 1934, p. 249.

IRELAND

An asbestos deposit at Avoca, County Wicklow, was reported in 1931. No data are available on variety, quality, or extent.

MEXICO

An unusually good sample of mountain cork—a variety of spongy, matted, amphibole asbestos—was obtained by the Bureau of Mines in 1931 from an undeveloped deposit near San Luis Potosi. According to report, surface exposures indicate that it is extensive. Asbestos has also been reported from the State of Puebla.

NEWFOUNDLAND

A deposit of chrysotile asbestos discovered near Port au Port is thought to represent a continuation of the Quebec belt. No data are available as to its quality or extent.

NEW ZEALAND

Chrysotile asbestos in veins as wide as 3 inches occurs in a serpentine area at least 3 miles long near Mount Arthur in the upper Takaka district of New Zealand. Both cross fiber and slip fiber are available. The cross-fiber veins occur principally in shells 6 to 30 inches thick surrounding cores of massive serpentine with few or no veins. The fiber yield of the shells is estimated at 10 to 25 percent. The deposit evidently is extensive and is undeveloped.

PHILIPPINE ISLANDS

A deposit of amphibole asbestos occurs in Ilocos Norte Province, Luzon Island. A considerable quantity was mined about 1920 for pipe covering and similar uses.

In 1936 the Bureau of Mines received samples of asbestos from this deposit, which, upon examination, proved to be chrysotile of fair strength and flexibility. Some of it probably could be classed as spinning fiber, although it is not as strong as Canadian or Arizona asbestos. No data are available as to the extent or location of the deposit.

PORTUGAL

Asbestos of uncertain quality, probably in deposits of limited extent, is reported from two places in the Beja district, Province of Alemtejo, southern Portugal. No production is recorded.

SPAIN

Two occurrences of chrysotile asbestos in Spain were reported in 1920—one in the Pyrenees and the other in the Cantabrian Mountains. A production of 165 metric tons was recorded for that year, but no later activity has been noted.

SWITZERLAND

Asbestos occurs in the Cantons of Grisons, Tessin, Valais, and Graubunden, Switzerland, but production is small; a maximum of about 400 tons was obtained under the war stimulus of 1918 and 1919. The most important deposits are at Poschiavo, Canton of

Grisons, where a small amount of chrysotile of spinning quality is available. Both chrysotile and tremolite are said to occur in Graubunden.

TURKEY

A small quantity of asbestos has been produced near Kutaia, western Turkey. An output of 58 tons was recorded for 1932, with a value of about $24 a ton. Very promising samples of cross-fiber chrysotile were obtained by the Bureau of Mines in 1934 from a deposit said to occur near Sarikamis, Province of Kars, Turkish Armenia. The samples indicated that the percentage of fiber to rock runs very high and that a fair proportion of crude asbestos is obtainable. No details as to the extent of the deposit or its availability are known.

VENEZUELA

A deposit of chrysotile asbestos apparently of good quality occurs about 8 miles from Tinaquillo, State of Cojedes, about 145 miles from Caracas. The nearest railhead is Valencia, 40 miles distant, and the nearest seaport is Puerto Cabello, 65 miles away.

The occurrence is unusual, as the fiber is associated with clay and shattered rock. A little development work has been done and small shipments have been made, but much systematic exploratory work must be conducted before the commercial value of the deposit can be determined.

OTHER COUNTRIES

Asbestos occurrences have been reported in Bolivia; Gorbea, Chile; Chosen (Korea), Japan; Madagascar; Spitzenbergen; and near Alexandretta, Syria.

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, China, Czechoslovakia, Spain, Switzerland, Turkey, and Venezuela.

COMMERCIAL CONTROL

All asbestos-producing companies in the United States apparently are controlled by United States capital.

Commercial control of the Canadian mines is diverse. The largest company, Asbestos Corporation, Ltd., is controlled by English, Canadian, and United States capital. Johnson's Company, 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 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 if Australia are controlled by English or Australian capital.

INTERNATIONAL TRADE

The United States is the largest consumer of asbestos in the world and imports over 95 percent of its supplies. Normally 70 to 75 percent of Canadian production enters the United States. Because of its proximity to the extensive United States markets, Canada enjoys a distinct advantage over all other countries in the field of short fibers. For many years England, France, Germany, and Belgium imported most of their supplies from Canada. Africa now furnishes much of England's needs. Other European countries are securing increasing quantities from Russia, and fluctuating supplies are obtained in Canada and Africa.

EXPORTS FROM PRINCIPAL PRODUCING COUNTRIES

A recent report from Irving N. Linnell, American consul general in Johannesburg, shows the distribution of African asbestos by country of destination during 1934 and 1935. The following table shows exports from the Union of South Africa. It may be observed that in 1935 about 52 percent of the total quantity was shipped to the United Kingdom, nearly 22 percent to other European countries, and the remaining 26 percent to countries outside of Europe. The United States received less than 5 percent of the total, but paid considerably more per ton than any other country, due to the fact that the United States imports from this source only the higher-grade fibers.

Exports of asbestos from the Union of South Africa, 1934 and 1935

Country of destination	1934		1935	
	Short tons	Value	Short tons	Value
United Kingdom	8,652	£113,019	12,284	£138,736
Belgium	559	7,625	1,124	10,737
France	1,028	17,301	1,195	17,335
Germany	903	16,860	1,493	26,381
Holland	365	7,107	455	7,672
Italy	1,139	20,562	666	12,652
Spain	624	7,938	250	3,641
Sweden	50	736	5	119
Denmark			2	39
Portugal			10	239
Japan	1,327	23,195	2,301	30,497
United States	715	13,884	1,114	23,043
Canada	9	133	26	369
Australia	1,692	24,133	2,206	29,775
India	289	1,777	298	1,817
Algeria			20	389
Chile	73	925	253	3,562
Uruguay	24	447	24	[1] 447
Argentine			10	199

[1] Estimated.

The following table shows similar data for Rhodesia, but the figures are somewhat uncertain because a large percentage of the fiber is shipped through Portuguese East Africa and the ultimate destination is unknown. Evidently 85 percent or more of the 1935 exports reached European ports. The small figures recorded in this table for European countries outside of the United Kingdom indicate that most or all of their requirements of Rhodesian fiber are included under Portuguese East Africa or Optional Ports. Only about 3 percent of the shipments reached the United States. However, that shipped to the United States averaged about $145 a ton, whereas European shipments averaged about $90 a ton.

Exports of asbestos from Rhodesia, 1934 and 1935

Country of destination	1934		1935	
	Short tons	Value	Short tons	Value
United Kingdom	11,764	£212,014	13,120	£206,995
Australia	1,100	20,051	1,450	26,437
India	850	11,625	780	11,986
Portuguese East Africa [1]	15,395	291,830	19,028	335,254
Japan	1,721	26,515	1,075	23,743
Dutch East Indies			50	682
Chile	47	423	97	971
United States	1,076	24,276	1,418	40,955
Union of South Africa [2]	154	1,665	366	3,968
Holland	27	384		
Italy	2	34		
Germany	5	60		
Belgium	46	567		
Sweden			600	9,552
Optional Ports [3]			7,305	132,193

[1] Most of that entering Portuguese East Africa is destined to the Continent of Europe, but ultimate country of destination is unknown at time of shipment.
[2] Probably for reshipment, but destination unknown.
[3] Destined for Continent of Europe, but ultimate country of destination unknown.

As indicated in the following table of exports from Russia, nearly 50 percent of the total is consigned to Germany. Other European countries, Japan, and, during recent years, the United States are substantial buyers. The decline in exports in 1935 compared with 1934 may be due to the pronounced expansion in the domestic asbestos-products manufacturing industries, which consume increasing quantities of the raw asbestos produced. Exports of asbestos from Russia to the United States as shown in this table do not check closely with figures for imports into the United States from Russia as compiled by the Bureau of Foreign and Domestic Commerce. The great increase in Russian production has not affected world trade as much as might be expected, because Russia is developing an important asbestos-products-manufacturing industry and thus uses a great deal of its raw material in its own plants.

Exports of asbestos from U. S. S. R. (Russia),[1] 1934–35

[Compiled by B. B. Waldbauer, Foreign Mineral Service Division]

Country of destination	1934		1935	
	Metric tons	Rubles [2]	Metric tons	Rubles [2]
Austria	136	19,000	44	6,000
Belgium and Luxemburg	3,565	336,000	1,881	139,000
Czechoslovakia	410	43,000		
Denmark	104	10,000	72	5,000
Finland	43	6,000	15	1,000
France	1,045	109,000	944	84,000
Germany	14,741	1,492,000	12,018	1,265,000
Italy	3,464	379,000	1,862	187,000
Japan	3,550	310,000	2,417	146,000
Mongolia	2	200	4	1,000
Netherlands	147	18,000	118	10,000
Norway	77	9,000		
Poland	74	11,000	15	2,000
South America	268	25,000		
Sweden	771	80,000	690	60,000
Switzerland	49	6,000		
Turkey	16	500	14	1,000
United Kingdom	1,647	149,000	1,453	148,000
United States	3,040	192,000	3,099	181,000
Other	566	53,300	463	41,000
Total	33,715	3,248,000	25,109	2,277,000

[1] As given in Foreign Trade (Vneshnayo Torgovlya) Statistical Summary, Moscow.
[2] During these years 1 ruble was worth about 87 cents.

The following table shows exports of Canadian asbestos, by country of destination, in 1934 and 1935. In 1934, 71 percent in quantity and 58 percent in value of the total exports were destined to the United States. In 1935, the figures were 77 and 66 percent, respectively. Exports from Canada to the United States as given in this table differ only by a small amount from the figures for imports from Canada into the United States as compiled by the Bureau of Foreign and Domestic Commerce. The trans-Atlantic trade in short fibers is relatively small, because the price obtainable is too low to justify a heavy transportation expense.

Exports of asbestos from Canada, 1934–35 [1]

[Compiled by B. B. Waldbauer, Foreign Mineral Service Division]

1934

Country of destination	Fiber		Sand and waste		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
Australia	998	$49,859			998	$49,859
Belgium	3,548	191,519	455	$8,968	4,003	200,487
France	3,969	243,416	540	10,075	4,509	253,491
Germany	5,436	441,188	2,497	50,787	7,933	491,975
Italy	618	58,090			618	58,090
Japan	18,489	679,723			18,489	679,723
Netherlands	734	35,800	579	11,541	1,313	47,341
Spain	162	7,887			162	7,887
United Kingdom	4,618	316,468	2,080	44,620	6,698	361,088
United States	44,542	1,996,915	68,171	964,429	112,713	2,961,344
Other	153	8,326	656	9,885	809	18,211
Total	83,267	4,029,191	74,978	1,100,305	158,245	5,129,496

1935

Country of destination	Fiber		Sand and waste		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
Australia	2,004	$99,632			2,004	$99,632
Belgium	4,814	270,606	833	$14,407	5,647	285,013
France	3,781	254,142	320	6,200	4,101	260,342
Germany	4,913	438,062	1,438	28,805	6,351	466,867
Italy	806	74,435			806	74,435
Japan	15,597	628,597			15,597	628,597
Netherlands	1,671	110,725	700	14,776	2,371	125,501
Spain	710	37,328			710	37,328
United Kingdom	4,584	290,569	3,594	75,516	8,178	366,085
United States	61,059	3,079,366	92,810	1,440,995	153,869	4,520,361
Other	247	16,714	330	4,782	577	21,496
Total	100,186	5,300,176	100,025	1,585,481	200,211	6,885,657

[1] As given in The Trade of Canada, Ottawa.

IMPORTS INTO THE UNITED STATES

The following table, compiled from Bureau of Mines statistics, shows imports of asbestos into the United States for 6 years. It includes only the crude and mill fibers that constitute, on the basis of value, the principal international trade in asbestos. Figures for earlier years may be found in the Minerals Yearbook and in Mineral Resources of the United States, published by the Bureau of Mines.

Imports of asbestos into the United States, 1930–35 (crude and mill fiber only)

Country of shipment	1930		1931		1932	
	Short tons	Value	Short tons	Value	Short tons	Value
Africa	3,210	$730,274	1,337	$189,349	1,326	$117,774
Canada	70,957	3,656,195	47,340	2,123,746	31,064	1,285,799
Germany	390	83,897	110	10,700	1	30
Italy	48	8,752	19	9,855	85	9,627
Soviet Russia	4,534	660,559	2,188	104,271		
United Kingdom	410	113,684	953	166,465	1	399
Belgium						

Imports of asbestos into the United States, 1930–35—Continued

Country of shipment	1933		1934		1935	
	Short tons	Value	Short tons	Value	Short tons	Value
Africa	2,324	$234,557	1,794	$198,479	2,128	$294,231
Canada	48,916	2,337,946	43,053	2,026,161	60,032	3,015,247
Germany	6	669				
Italy	17	8,929	16	9,775	22	11,464
Soviet Russia	176	17,339	657	26,434	4,632	213,698
United Kingdom	1	587	22	5,016	202	23,451
Morocco					22	2,131

Countries of shipment as given in the preceding table are not necessarily the countries of origin. Asbestos shipped from Germany was chiefly of Russian origin, and fiber shipped from the United Kingdom, Belgium, and Morocco originated chiefly in Africa.

The following table shows imports, by countries of origin, for 6 years. For Africa and Russia the figures are approximate only, because the origin of fiber shipped from nonproducing countries cannot be traced exactly. Also, for both this table and the one following, relative to short fibers, shipments of small quantities from unusual sources have been disregarded.

Sources of asbestos imported into the United States, 1930–35 (crude and mill fiber only)

Source	1930		1931		1932	
	Short tons	Value	Short tons	Value	Short tons	Value
Africa	3,620	$843,958	2,290	$355,814	1,327	$118,173
Canada	70,957	3,656,195	47,340	2,123,746	31,064	1,285,799
Soviet Russia	4,924	744,456	2,298	114,971	1	30
Italy	48	8,752	19	9,855	85	9,627
Total	79,549	5,253,361	51,947	2,604,386	32,477	1,413,629

Source	1933		1934		1935	
	Short tons	Value	Short tons	Value	Short tons	Value
Africa	2,325	$235,144	1,816	$203,495	2,352	$319,813
Canada	48,916	2,337,952	43,053	2,026,161	60,032	3,015,247
Soviet Russia	182	18,008	657	26,434	4,632	213,698
Italy	17	8,929	16	9,775	22	11,464
Total	51,440	2,600,033	45,542	2,265,865	67,038	3,560,222

The following table shows the percentages of both quantity and value of imports of crudes and mill fibers obtained from each foreign source during recent years.

Percentage of crude and mill-fiber asbestos obtained from each of the principal foreign sources, 1930–35

Source	1930		1931		1932	
	Quantity	Value	Quantity	Value	Quantity	Value
Africa	4.5	16.1	4.4	13.7	4.1	8.4
Canada	89.2	69.6	91.1	81.6	95.6	91.0
Soviet Russia	6.2	14.1	4.4	4.4		
Italy	.1	.2	.1	.3	.3	.6

Source	1933		1934		1935	
	Quantity	Value	Quantity	Value	Quantity	Value
Africa	4.5	9.0	4.0	9.0	3.5	9.0
Canada	95.0	89.9	94.5	89.4	89.5	84.7
Soviet Russia	.4	.7	1.4	1.2	6.9	6.0
Italy	.1	.4	.1	.4	.1	.3

It may be observed that imports from Africa 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 a distant source. 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 lower-priced 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 Canada, Africa, and Russia, and the percentage of the total imports each country furnished.

Principal sources of spinning asbestos imported into the United States, 1924–35

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	8,473	50	3,620	21	4,924	29
1931	6,770	60	2,290	20	2,298	20
1932	4,380	77	1,327	23	(3)	(2)
1933	(4)		2,325		182	
1934	(4)		1,816		657	
1935	(4)		2,352		4,632	

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 mill stock produced is of spinning grade, it is assumed that 25 percent of the mill stock 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 small, but by 1935 they were again almost as large as in the peak year 1930.

Unfortunately, comparison with Canada cannot be made for the years subsequent to 1932, because since that year Canadian statistics for mill fiber are not broken down by classes. Apparently Canada is holding its position because African imports in 1935 were less than one-third of the 1927–29 average.

The following table shows sources of imports into the United States of the shorter grades of asbestos classed as "stucco and refuse." Until recently Canada supplied nearly 100 percent of the short fibers, but since 1932 Cyprus, Soviet Russia, Finland, and Italy together have furnished 4 to 5 percent of the total.

Imports into the United States of asbestos classed as "stucco and refuse", 1930–35

Source	1930		1931		1932	
	Short tons	Value	Short tons	Value	Short tons	Value
Canada	129, 111	$1, 810, 588	82, 767	$1, 108, 936	63, 606	$827, 744
Soviet Russia	2	84	1, 619	35, 423		
Italy			27	315	629	7, 719
Africa	17	469			43	1, 108
Total	129, 130	1, 811, 141	84, 413	1, 144, 674	64, 278	836, 571

Source	1933		1934		1935	
	Short tons	Value	Short tons	Value	Short tons	Value
Canada	63, 999	$854, 647	70, 007	$1, 000, 402	94, 204	$1, 470, 865
Soviet Russia	831	40, 503	1, 938	63, 005	181	834
Cyprus	2, 274	37, 395	2, 463	43, 611	4, 628	87, 844
Italy	939	7, 764	246	1, 774	523	5, 202
Finland	37	1, 404	38	1, 920	11	446
Africa	11	339	100	1, 417		
Total	68, 091	942, 052	74, 792	1, 112, 129	99, 547	1, 565, 191

EXPORTS FROM THE UNITED STATES

Very little unmanufactured asbestos is exported from the United States. Recent exports, shown in the following table, have consisted principally 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 1928 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, 1924–36

Year	Short tons	Value	Year	Short tons	Value	Year	Short tons	Value
1924	1, 270	$93, 163	1929	709	$108, 467	1934	1, 669	$94, 182
1925	1, 109	70, 846	1930	771	95, 318	1935	850	87, 896
1926	1, 104	85, 922	1931	1, 714	122, 391	1936	3, 744	310, 197
1927	309	48, 744	1932	1, 707	94. 936			
1928	850	346, 632	1933	1, 378	88, 521			

Although little unmanufactured asbestos is exported, foreign trade in asbestos products is extensive. The following table shows exports by kinds in 1934 and 1935. Brake linings and textile yarns and packings are the largest items.

Manufactured asbestos products exported from the United States 1934–35, by kinds

Product	1934		1935	
	Quantity	Value	Quantity	Value
Brake lining:				
Molded and semimolded	(1)	$607, 193	(1)	$651, 338
Not molded ... linear feet	1, 641, 333	255, 018	1, 426, 520	231, 381
Paper, millboard, and rollboard ... short tons	602	96, 154	767	130, 578
Pipe covering and cement ... do	1, 389	[2] 126, 190	1, 233	143, 357
Textiles, yarn, and packing ... do	619	[2] 594, 625	715	662, 321
Magnesia and manufactures ... do	1, 277	241, 410	922	146, 068
Asbestos roofing ... squares	26, 457	75, 254	31, 141	106, 678
Other manufactures ... short tons	[2] 799	146, 670	921	190, 208

[1] Quantity not recorded. [2] Revised figure.

PROSPECTING AND EXPLORATION

Asbestos is usually associated with serpentine, a mineral easily recognized by its green or yellowish green color and greasy luster; therefore, the formations in which asbestos occur are traced easily. Asbestos is so resistant to weathering that outcrops frequently occupy knolls or ridges above the level of the surrounding country. The exposure may be widened by stripping or trenching, and the quality of the fiber judged by visual inspection. Surface fiber may be discolored by weathering, but such effects usually are confined to a depth of a few inches only. Exploration at depth may be conducted with diamond- or shot-core drills. Deposits are commonly explored by means of test pits which are enlarged into active quarries or mines if favorable results are obtained. Estimation of the fiber content of an asbestos-bearing rock is difficult, and satisfactory results can be secured only by making actual mill runs.

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 the asbestos occurs in veins in the Mescal limestone near diabase intrusions. The veins pinch and swell irregularly and are so erratic in size and direction that development cannot be planned as definitely as in the mining of many other minerals. The fiber is mined in drifts and tunnels, and conditions are most favorable where two or more veins of workable size are close enough to be worked in one tunnel. The soft, flexible fiber is most desired, but veins of harsher, more brittle asbestos may be associated closely with the softer variety.

Modified room-and-pillar mining methods are followed. Much of the waste rock in each room is built up in dry walls about every 10 feet for roof support. Excess waste and fiber-bearing rock are wheeled to chutes. Cobbing and sorting are done in the stopes on a contract basis. Two grades of fiber are usually produced, and contractors are paid 2 cents a pound more for the long than for the short fiber recovered. Mexican labor is found to be most satisfactory.

Several thousand feet of tunnels have been driven on Ash Creek and at other points in the southern part of the State. Production costs at the best mines are said to be about 40 cents per pound of fiber produced. From 25 to 60 pounds of asbestos are recovered for each running foot of a 4½- by 7-foot tunnel.

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. Whatever overburden is encountered is removed in stoneboats drawn by horses because of the steep slope of the mountainside. The quarry face is about 150 feet high, and individual benches are 12 to 15 feet high. Blast holes are sunk with hammer drills. Two electric power shovels with 1¼-cubic yard dippers are used for loading into 3 motor trucks with 10-ton steel rear-dump bodies. The trucks dump the rock into a chute, which feeds a 28- by 36-inch jaw crusher.

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; therefore it 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.

CANADA

Stripping is a serious problem in the Quebec district, as overburden ranges from 6 to 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 also tends to reduce recovery of crude. The principal reasons for the change were (1) decreasing markets for crudes

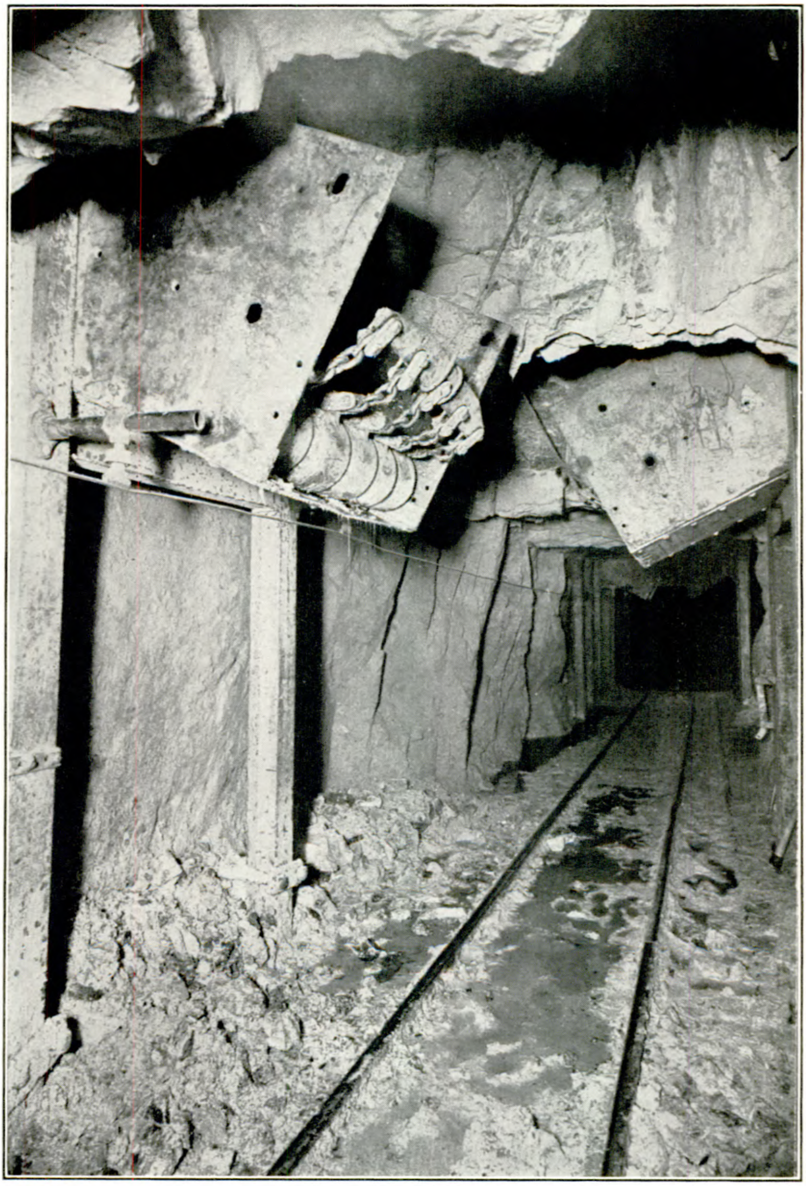

FIGURE 7.—Steel chutes and chain-chute gates, Asbestos Corporation, Ltd., mine, Thetford Mines, Quebec.

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. A haulage level is established 500 feet below the surface. The overlying fiber-bearing rock is worked in blocks 160 feet square. Four grizzly drifts 40 feet apart are driven beneath the block 40 feet above the haulage level. The drifts are timbered and are provided at 20-foot intervals with heavy steel-rail grizzlies with 16-inch openings. "Finger raises" are driven upward at each side of the drift, and 20 feet above the drifts the block is undercut completely by driving drifts and blasting out the intervening pillars. The finger raises are funneled to permit access to large pieces of rock that must be broken at the grizzlies. The boundaries of the block are weakened by projecting raises and connecting drifts. The entire block sinks and is broken up by its own weight. Rock is worked through the grizzlies until the block is exhausted. Satisfactory results have been attained, and mining costs are considerably lower than by the shrinkage-stoping method. Details of the process have been published.[39] Figure 7 shows loading chutes on the haulage level.

The glory-hole method also is used. Raises are driven to the surface from an established level, and the rock is broken down in a funnel-shaped opening at the top of the raise. Broken rock is drawn off into cars and removed through a tunnel.

Most drilling is done with hammer drills held in the hands, but tripod drills are used for flat breast holes and for steep bench holes. Tripod drill holes range up to 18 feet deep. Heavy equipment is sometimes employed to sink holes to depths of 40 feet or more. Wet drilling is impractical because the fiber forms a spongy mass that tends to clog the drill hole.

If the fiber-bearing rock is quarried in shallow pits, loaded cars may be hauled in trains directly from the face. An elaborate spiral track lay-out is in use at one pit.

Mining costs are variable, depending upon the percentage of fiber in the rock, hardness of rock, quarry conditions, and many other factors. Ross[40] gives a direct mining and milling cost of $10 to $15 per ton of fiber where the rock is loaded with power shovels, and where recovery is 8 to 12 percent of gross quarry output. Where the rock is hand-sorted, shoveled into boxes, and elevated with crane or cableway hoists, the direct operating costs may range from $20 to $60 per ton of fiber produced.

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[39] Ross, J. G., Block Caving at the King Mine of the Asbestos Corporation, Ltd., Thetford Mines, Quebec: Canadian Min. and Met. Bull. 264, April 1934, pp. 184–218.

[40] Ross, J. G., Chrysotile Asbestos in Canada: Canada Dept. of Mines Bull. 707, 1931, p. 57.

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 is 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 practiced. 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 290 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.[41]

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, 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.[42]

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 the original olivine resulted in excessive fracturing, which makes excavation easy. The workings consist of open-pit terraces reaching a maximum height of 250 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

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

[42] Ru Keyser, Walter A., Mining Asbestos in U. S. S. R.: Eng. and Min. Jour., vol. 134, September 1933, pp. 375–381.

drills are used, 3-inch holes ranging in depth from 8 to 12 feet are sunk at a rate of about 10 feet an hour. The larger masses of barren rock are removed as waste. Fiber-bearing material is turned over to facilitate drying in the hot sun, and it is then passed over gravity screens. That passing 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. The 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 were still more extensive in 1928 and 1929, decreased greatly during the depression years, but recovered substantially in 1934 and 1935. Further details of quarry methods are given by Whitworth.[43]

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

CHINA

Primitive methods are followed in the Laiyuan district. The mining tools used are hammers, chisels, picks, and shovels. No machinery or explosives are employed. Small inclined tunnels are sunk along the veins to a maximum depth of about 30 meters. The fiber is cobbed and sorted by hand. Mining costs are said to range from $96 to $137 a ton of fiber produced.

MILLING METHODS

CLASSIFICATION OF FIBER

A brief discussion of the method of classifying asbestos fibers is a necessary preliminary to a description of milling methods.

Canadian and Vermont asbestos fibers are divided into three main groups—crudes, mill fibers, and shorts. The term "crude" is applied to fiber of spinning grade, measuring three-eighths inch or longer, that is hand-cobbed and not passed through a mill. Mill fibers are obtained by crushing and beating the fiber-bearing rock until the asbestos is freed, and then removing the fiber from the rock by screening or air separation. Shorts are the lowest grades of mill products.

Russian asbestos also is classed as crudes and mill fibers, but the term "crude" is applied somewhat loosely; it apparently includes some spinning fiber that has been prepared mechanically.

The term "crude" is not generally applied to African products. Spinning fibers comparable in quality with Canadian crudes are prepared by hand-cobbing alone or in conjunction with simple mechanical crushing, disintegrating, and screening processes. A much larger proportion of the African long fibers has been prepared mechanically during recent years. Mill fibers of the shorter grades constitute the largest part of the tonnage.

Virtually all of the asbestos produced in Cyprus is classed as mill fiber.

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[43] Whitworth, M., Cyprus and Its Asbestos Industry: Mining Mag. (London), vol. 39, September 1928, pp. 143–150.

GENERAL FEATURES OF MILLING METHODS

As pointed out on preceding pages, the two major types of chrysotile occurrences are (1) deposits derived from alteration of peridotite-pyroxenite rocks and (2) deposits derived from dolomitic limestone intruded by diabase. The first type is the principal source of asbestos in Vermont, Quebec, the Ural Mountains, Rhodesia, and the Transvaal. The second type, which represents a small fraction of the world output, occurs in Arizona; Minusinsk, Siberia; and the Carolina district of South Africa. The principal gangue material associated with asbestos of the first type is serpentine, and the materials with the second type are serpentine and limestone. As chrysotile also is serpentine, differing only in structure from the gangue, it is obvious that the milling of chrysotile must differ from all other forms of ore concentration. As the valuable mineral and the gangue consist of the same material, neither chemical composition nor specific gravity can be utilized as the basis for separation. The property that makes mechanical separation of chrysotile possible is its fibrous structure, which permits it to be opened or divided by impact into separate filaments, thus making it amenable to separation from the gangue by air suction and screening.

The value of chrysotile asbestos depends largely on the length of the fiber. When fiber three-eighths inch long is worth $100 a ton, fiber three-fourths inch long is worth approximately $400 a ton. Thus, it is apparent that breaking fibers in half destroys approximately three-fourths of their value. The most important principle underlying the milling of asbestos, therefore, is the separation of fiber from rock with minimum breakage of fibers. The best machines spare the fiber unnecessarily rough treatment and at the same time break the rock effectively. Modern mills are designed to remove the separated fiber after each crushing process, to separate the sand as soon as it is formed, and to keep hard, barren rock out of the mill. If fiber already freed from rock enters the next crushing unit along with sand and rock fragments, it will be broken into shorter grades. Asbestos milling consists essentially of coarse crushing, drying, and recrushing in stages, each step being followed by screening and air separation of fiber from rock.

Another peculiarity of asbestos milling is the absence of any known method of testing the quality of mill feed. A rock that appears to contain little fiber may yield a fair return; conversely, one that appears promising may show a disappointingly low recovery. As both the valuable mineral and the gangue are serpentine, an assay is useless. A laboratory-scale crushing and fiber-separating unit might give results that differ widely from those of a commercial mill operating on the same rock. Although the percentage of recoverable fiber in a rock cannot be determined in advance, the actual yield can be calculated from the mill output. A fair estimate of the value of a fiber-bearing rock can be obtained only by making a test run in a commercial mill.

In the following discussion of milling methods throughout the world, Canadian practice is considered first because Canadians were the pioneers in the asbestos industry, and their methods have established a basis for practice in other countries.

CANADA

PREPARATION OF CRUDES

In Canada the associated rock is broken free of the larger-fiber veins by sledging, and the masses of fiber are sorted by hand. The fiber with some adhering rock is dried on steam coils and then taken to the cobbing sheds, where the fiber veins are flattened with a hand hammer, freeing them from adhering rock. The separated rock, dust, and short fibers are dropped into a receptacle under the bench, and the remaining high-grade fibers are classed as Crude No. 1, material three-fourths inch long and over, and Crude No. 2, material three-eighths to three-fourths inch long. To separate further the short fiber and rock dust, Crude No. 1 is screened on a flat shaking screen with three-eighths-inch holes and No. 2 on one with three-sixteenths-inch holes. After being screened, the fibers are bagged in jute bags of 100 pounds capacity. Five to twenty percent of rock fragments, dust, and short fiber still remain in the crudes as sold, and these impurities are separated at the factory where asbestos products are manufactured. Rejects accumulated in preparing crudes are utilized as mill fibers or sold as screenings. Crudes constitute a small proportion of the recoverable fiber but are the most valuable products.

Ru Keyser [44] has developed a process of preparing long fiber mechanically, by which rolls are used instead of hand hammers. The fibers are graded on screens that are so operated that the fibers are held in a horizontal plane. The claim is made that fibers thus prepared are superior in grade and purity to hand-cobbed crudes.

MILLING PRACTICE

Mechanical means of preparing fiber began in Quebec in 1888, and by 1896 important tonnages of milled fiber were sold. The principal processes involved in milling are crushing, drying, storing, fiberizing, screening, air separating, and grading.

PRELIMINARY CRUSHING

Rock from the quarries or mines is dumped into a so-called "sluice" that holds several carloads. The sluice may have a railroad-rail-grizzly bottom that provides a bypass for fines. The primary-crusher feed from the sluice is controlled by finger gates—that is, suspended rails that may be moved up or down. A jaw crusher with a 36-inch by 24-inch opening set for a 4- to 6-inch discharge is the most popular primary breaker. Larger or smaller units may be employed as needed. Crushers discharge to picking belts, where liberated crudes are removed by hand.

DRYING

The quarry rock contains considerable moisture, in winter even snow and ice, and it must be dried for proper milling. Standard rotary driers generally are used. The shells are 40 to 60 feet long, 4 to 6 feet in diameter, and inclined at an angle of 7°. The material is lifted by a series of blades and allowed to fall through the cur-

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[44] Ru Keyser, Walter A., Mechanical Cobbing of Chrysotile Asbestos: Eng. and Min. Jour., vol. 134. no. 6, June 1933, pp. 235–237.

rent of hot air that circulates through the cylinder. Capacities range from 30 to 60 tons of rock an hour and costs from 4 to 18 cents a ton.

Stack driers also are used and are said to be much more economical. Rock is elevated to the top of a 50-foot stack 7 feet in diameter and allowed to fall through a rising current of hot air. Grid bars interrupt the speed of the descent.

STORAGE

A large supply of rock in storage insures regular mill feed. Rock is fed to the mill on belt conveyors carried in concrete tunnels beneath the storage bins. By drawing rock from several gates at the same time material of comparatively uniform size and fiber content is obtained. Bins having capacities of 25,000 to 150,000 tons are in use.

FIBERIZING

Although crushing, drying, and storing methods are fairly uniform throughout the Canadian district, milling methods vary greatly. No flow sheet can be applied generally because milling must be modified to suit the rock. A method suitable for hard rock would be too severe for fiber enclosed in soft rock. Secondary crushing may be done with jaw or gyratory crushers, rolls, Symons cones, or hammer mills. A straight impact that frees and fluffs the fiber is preferred to a grinding or shearing action. Therefore, rolls are less desirable than impact mills.

The following flow sheet, given by Ross,[45] probably represents the best modern practice.

Grizzly in rock sluice.
Jaw crusher.
Drier.
Grizzly, fines to screens fitted with suction.
Gyratory crusher.
Screens with suction.
Rolls.
Screens with suction.
Jumbo.
Screens with suction.
Jumbo.
Screens with suction.
Jumbo.
Screens with suction.
Jumbo.
Screens with suction.
Rotary graders and flat cleaning screens.
Floats bin.
Sand to dump.

It will be observed that the principle of removing the fiber after each stage of crushing is followed strictly.

According to this flow sheet, crushing beyond the primary stage is accomplished with gyratory crushers and Jumbo machines. The Jumbo, which is manufactured locally, is a horizontal drum 6 to 8 feet long and 24 to 30 inches in diameter. Beaters attached to a horizontal shaft consist of arms that support manganese-steel hammers. The beaters are set at intervals of 6 or 8 inches along the

[45] Ross, J. G., Chrysotile Asbestos in Canada: Canada Dept. of Mines Bull. 707, 1931, p. 42.

shaft and clear the inside of the shell by about ½ to 1 inch. They are turned at an angle to direct the broken rock toward the discharge end. The shaft rotates at 400 to 800 revolutions per minute, according to the nature of the rock treated. Instead of the Jumbo machine, some mills employ various types of cyclones, which beat the rock to a powder. The Laurie cyclone consists of a cast-iron chamber in which two beaters shaped like ship propellers are driven in opposite directions at a speed of 1,700 to 2,000 revolutions per minute. In the Pharo cyclone the beaters revolve in the same direction and the rate of discharge is controlled by gates. The Torrey cyclone is somewhat like the Jumbo, except that the axis of the beater arms is vertical.

SCREENING

Shaking screens actuated by eccentrics generally are used, although vibrating screens of the Hum-mer type also are employed. Usual sizes are 3 to 5 feet wide and 8 to 12 feet long. Perforated steel plates are more generally used than wire mesh. Screens with holes up to three-eighths of an inch and larger are used for scalping, and smaller openings down to one thirty-second of an inch for the very fine materials. Wire screens ranging from 3 to 24 meshes to the inch are commonly used for cleaning fiber.

Fines pass through the openings, but the coarser rock fragments and longer fibers remain on the screen. The shaking action brings the fiber to the surface of the bedded-rock fragments, and it is removed by air-suction equipment that will be described later. Thus, each screen furnishes three products—fines that pass through as waste, coarse rock fragments discharged at the end, and fiber collected by suction. Oversize rock fragments pass to the next fiberizing unit.

AIR SUCTION

Fiber segregated on the surface of a layer of rock fragments on the screen is removed through suction hoods that operate on the principle of a vacuum cleaner. The opening of the suction hood is 3 to 4 inches wide and extends across the full width of the screen at its lower end. The cross-section area of the narrow opening is the same as that of the pipe into which it converges, which ranges from 12 to 20 inches in diameter. Large fans produce the necessary vacuum. A 10- to 15-horsepower motor is required to drive a fan giving the necessary lifting power through a pipe 15 inches in diameter. The air current sweeps the fiber from the screens, carries it through pipes, and aspirates it in collecting chambers, where the diminished rate of the air current permits it to fall. The dust-laden air from the fans is blown into dust chambers, and the fine materials that settle there are returned to the mill, where the longer fibers are separated and the extremely short grades are bagged and sold as "floats."

WET PROCESS

Considerable progress has been made in developing a wet process for treating Canadian asbestos. Some claim that wet treatment involves less breakage of fiber and a higher recovery. Experiments were begun in 1921, and a testing plant was built in 1923, but commercial usage has not been attempted.

GRADING

Fiber is graded according to length in trommels about 8 feet long and 28 inches in diameter fitted with woven-wire cloth. Paddles clamped to a central shaft agitate the fiber and force the shorter grades through the screen. One type of machine consists of a stationary trommel in which the paddles rotate at 400 to 900 revolutions per minute. The tips of the paddles are twisted at a small angle, which causes the fiber to travel through the machine. Other machines are so designed that the trommel rotates in one direction at 5 revolutions per minute and the paddles rotate in the opposite direction at 180 to 250 revolutions per minute. Some trommels make only one finished grade—that passing through the screen—and the oversize is conducted to a second trommel for further grading. Thus, several trommels may operate in series. At one of the newer mills the trommel is equipped with two sizes of screen cloth, which make one oversize and two undersize grades. Any number of grades may be made, and special grades may be obtained by blending. Sand and dust are removed from the graded fiber on flat cleaning screens. Finished fiber lifted from the cleaning screen by air suction is conveyed to the store room for bagging.

CLASSIFICATION

Methods of grading asbestos fiber by length have been described. To determine with reasonable accuracy the quality of fiber in each grade and thus be able to modify grading methods accordingly, a standard testing machine is used. The purchaser can rely on the standard test and thus avoid any confusion that might ensue from dependance upon trade names or designations. A description of the standard testing machine [46] follows:

The machine consists of a nest of four wooden boxes measuring 24½ by 14¾ inches and 3½ inches in depth. The boxes, which are superposed one above the other, are numbered, from the top down, 1, 2, 3, and 4. The bottoms of boxes 1, 2, and 3 are made of metallic screen of the following specifications: Box 1: ½-inch opening, diameter of wire, 0.105 inch. Box 2: 4-mesh wire, 0.063 inch. Box 3: 10-mesh wire, 0.047 inch. Box 4 is a receptacle for the fines that fall through the three other boxes. The nest of four boxes or trays rests on a table to which an eccentric with a throw of $\frac{25}{32}$ inch gives a movement of $1\frac{9}{16}$-inch travel.

To make a test, 16 ounces of asbestos is put on the top tray, which is covered. The machine is run at the rate of 300 revolutions per minute at the shaft of the eccentric, and by means of an automatic device this is kept going for exactly 2 minutes, giving the nest a horizontal shaking movement. At the end of this time the asbestos that remains on each tray is weighed. This gives the grades of the asbestos fiber; the longest fiber naturally stays on the top tray, whereas the shorter fiber, according to its length, remains on screens 2 and 3 or drops into the pan or lowest tray. The more fiber retained on the first screen and the less fiber in the pan, the higher the grade and, therefore, the greater its value. If, for instance, a

[46] Ross, J. G., Work cited, p. 49.

customer buys spinning fiber of the specification 4–7–4–1, it means that in a sample of 16 ounces, representing the average of the lot shipped, 4 ounces will remain on the top screen, 7 on the second, 4 on the third, and, finally, 1 ounce will go through all the screens into the pan. He will evidently pay more for this material than for paper stock testing 0–0–10–6. This indicates that out of 16 ounces tested, nothing is retained on the first two screens, 10 ounces remain on the third, and 6 ounces go through the latter into the pan. It is evident that the figures of the test represent the proportion, in ounces, of the different lengths of fiber in a pound of asbestos.

Samples for testing usually are taken at the grading machines every half hour. Owing to unavoidable variations in fiber as it comes from the pit, the quality of mill-run fiber usually is maintained a little higher than its designation.

For many years each Canadian company graded its fiber according to its own standards and sold the products under its own trade designations. This practice led to much confusion in marketing because different mills employed similar marks for grades quite unequal in quality and value. It was frequently necessary for buyers to have samples tested before placing orders. In 1931, producers in Quebec agreed upon a uniform classification of fibers whereby they are divided into nine groups, and each group was divided into grades. Crude asbestos was defined as "hand-selected cross-vein material essentially in its native or unfiberized form", and milled asbestos as "all grades produced by mechanical treatment of asbestos ore." Except for the very lowest grades, which are based on the weight per cubic foot, all milled grades are based on the results of tests in the standard testing machine previously described. Ross [47] gives a complete description of the standard grades of Canadian asbestos as agreed upon in 1931:

Crude asbestos

Class	Standard designation of grade	Description
Group no. 1	Crude No. 1	Consists basically of crude ¾-inch staple and longer.
Group no. 2	Crude No. 2	Consists basically of crude ⅜-inch staple up to ¾-inch.
	Crude run-of-mine	Consists basically of unsorted crudes.
	Crudes sundry	Consists of crudes other than above specified.

Milled asbestos

Class	Standard designation of grade	Description
Group no. 3	Spinning or textile fiber	Consists of fiber testing 0–8–6–2 and over.
Group no. 4	Shingle fiber	Consists of fiber testing below 0–8–6–2 to and including 0–1½–9½–5.
Group no. 5	Paper fiber	Consists of fiber testing below 0–1½–9½–5 to and including 0–0–8–8.
Group no. 6	Waste, stucco or plaster	Consists of material testing below 0–0–8–8 to and including 0–0–6½–9½.
Group no. 7	Refuse or shorts	Consists of material testing 0–0–5–11 and below, including material testing below 0–0–1–15 and specified as weighing 35 pounds or less per cubic foot, loose measure.
Group no. 8	Sand	Consists of such asbestos mill products as sand weighing over 35 pounds per cubic foot, loose measure, and under 75 pounds per cubic foot, loose measure, and containing a preponderance of rock.
Group no. 9	Gravel and stone	Consists of such asbestos mill products weighing 75 pounds and over per cubic foot, loose measure.

[47] Ross, J. G., Work cited, pp. 50–51.

Subdivision of the groups of milled asbestos

Group no.	Standard designation of grades	Guaranteed minimum shipping test
No. 3. Textile and spinning fibers	3D	8-6-1-1.
	3F	7-7-1½-½.
	3K	4-7-4-1.
	3M	2-9-4-1.
	3R	2-8-4-2.
	3T	1-9-4-2.
	3Z	0-8-6-2.
No. 4. Shingle fibers	4D	0-5-10-1.
	4F	0-3-12-1.
	4K	0-4-9-3.
	4M	0-4-8-4.
	4R	0-3-9-4.
	4T	0-2-10-4.
	4Z	0-1½-9½-5.
No. 5. Paper fibers	5D	0-½-10½-5.
	5F	0-½-9½-6.
	5K	0-0-12-4.
	5M	0-0-11-5.
	5R	0-0-10-6.
	5T	0-0-9-7.
	5Z	0-0-8-8.
No. 6. Waste, stucco, or plaster	6D	0-0-7-9.
	6F	0-0-6½-9½.
No. 7. Refuse or shorts	7D	0-0-5-11.
	7F	0-0-4-12.
	7H	0-0-3-13.
	7K	0-0-2-14.
	7M	0-0-1-15.
	7-20	20 pounds per cubic foot, loose measure.
	7-25	25 pounds per cubic foot, loose measure.
	7-30	30 pounds per cubic foot, loose measure.
	7-35	35 pounds per cubic foot, loose measure.
No. 8. Sand	8-40	40 pounds per cubic foot, loose measure.
	8-45	45 pounds per cubic foot, loose measure.
	8-55	55 pounds per cubic foot, loose measure.
	8-75	75 pounds per cubic foot, loose measure.
No. 9. Gravel and stone	9	75 pounds and over per cubic foot, loose measure.

The fiber is packed in jute bags of 100 or 125 pounds capacity marked with the grade letter or number and the manufacturer's name.

ARIZONA

The high cost of transportation to railways and heavy freight charges to markets render the sale of shorter Arizona fibers unprofitable. Spinning fibers are therefore the principal products of the Arizona deposits. The smaller mines produce hand-cobbed crudes almost exclusively. The rock is mined and cobbed by the same workers on a contract basis. Cobbing is conducted in much the same way as in Canada.

Three of the larger mines have milling facilities. The largest mill, equipped with crushers, cyclones, and screens, produces No. 1 mill fiber ¾ to 2½ inches long; No. 2, ⅜ to ¾ inch long; No. 3, ⅛ to ⅜ inch long; and No. 4, ⅛ inch and less. The products are graded according to tests made with a standard Canadian testing machine.

In one of the smaller mills the rock first passes through a jaw crusher followed by two sets of rolls. Two grades of fiber are separated by an impact screen. The shorter asbestos is treated with a small fiberizing machine and is cleaned and graded in a trommel 16 feet long and 4 feet in diameter.

Another small mill produces five grades of spinning fibers and a shingle stock. No grades shorter than shingle stock can be sold profitably.

A considerable quantity of rock containing spinning-fiber veins, which are difficult to cob by hand, are treated in these mills and yield what is known as mechanically cobbed crude fiber, an anomalous designation, according to the Canadian definition of crude, which includes only hand-cobbed fiber. The claim is made, however, that the crude fiber can be graded by machine more accurately than by hand.

VERMONT

The asbestos-bearing rock quarried near Eden, Vt., first is crushed to 5- or 6-inch size in a 28- by 36-inch jaw crusher and then discharged to a 36-inch belt conveyor, which carries the material to a 1,000-ton storage bin. When taken from storage, it is crushed to 3-inch size in a 13- by 30-inch jaw crusher. The product is split to two 4½- by 40-foot rotary driers. A trommel with ¾-inch openings precedes the final crushing unit—a 5½-foot Symons cone. The material that passes through the trommel is combined with the crusher product and conveyed to a second storage bin. The product of the tertiary crusher is treated in a series of Jumbos or fiberizers like those used in Quebec, and the fiber is recovered by screening and air suction. Oversize material passing the hoods is conveyed to a second series of fiberizers. The fiber picked up by air suction in the collectors is further screened, passed through dust removers and graders, dropped into bins according to length, and sacked in 100-pound burlap bags. The principal products manufactured are shingle stock testing 0–2–10–4; millboard, paper, and molded brake-lining fiber testing 0–0–10–6 or 0–0–8–8; and material suitable for roofing, paints, plastics, molded products, and boiler covering testing 0–0–5–11. Equipment was installed in 1936 for salvaging the shorter grades not heretofore recovered, and additional grades now marketed include 0–0–2–14, 0–0–1–15, 0–0–0–16, "no test" and "floats." Special brake-lining fibers are prepared at times. Virtually no crude or spinning fibers are produced. The mill capacity is upward of 100 tons of rock an hour. The demand for the products has more than tripled during the past 4 years. Figure 8 shows the mill as it appeared in 1936.

UNION OF SOUTH AFRICA

CHRYSOTILE

At the New Amianthus mine, Barberton district, Eastern Transvaal, long-fibered chrysotile is hand-sorted and graded by natives as A and B, fiber over 1⅛ inches long and fiber ¾ to 1⅛ inches long, respectively; both are designated as crudes. A third grade, E, consisting of hand-selected fiber down to ½ inch long might be classed as crude.

Rock bearing the shorter fibers is crushed, dried, and reduced by rolls. The product of each set of rolls is sieved over 10-mesh screens, the fines going to waste. After passing through four sets of rolls the product is virtually pure fiber except for dust adhering to it. The

FIGURE 8.—Mill of the Vermont Asbestos Corporation near Eden, Vt.

asbestos is passed through a fiberizer to beat out the dust, then over a dust sieve, and finally over grading sieves. Two principal mill grades are made: F, one-fourth to one-half inch; and G, one-fifth to one-fourth inch. Grade F corresponds to Canadian fiber testing 0–4½–10–1½. The milled fibers are principally shingle and paper stocks. The mill has a capacity of 6,000 tons of rock a month.

At the Munnik-Myburgh mine in the same district four grades of hand-cobbed chrysotile fiber are designated as follows: IXL, over three-fourths inch; XL, one-half to three-fourths inch; X, one-fourth to one-half inch; and XX, one-eighth to one-fourth inch. Hand-cobbed fiber is graded in shaking screens.

Short fiber is treated in a mill with an elaborate flow sheet. Dried and crushed rock is passed through a series of rolls followed by grading screens. All five products obtained are passed through a regrading plant. The grades and their values, as shown on a Canadian standard testing machine, are as follows:

M1	2–11–2–1	M4	0–0–8½–7½
M2	0–8½–6–1½	M5	0–0–4½–11½
M3	0–3–10–3		

The milled grades constitute about 95½ percent of the total fiber recovery.

CROCIDOLITE

Methods of milling and grading crocidolite vary greatly in different localities. In the Southern Belt of the Cape Provinces the workings are numerous, and many are relatively small. At the smaller workings the fiber is all hand-cobbed. In many places it is hand-sorted into grades according to length, but at the larger workings the hand-cobbed asbestos is graded by machinery. A hand-turned trommel made of perforated sheet iron or covered with wire netting usually is employed. The cobbed fiber from a series of workings may be shipped to a central screening plant where all asbestos one-half inch long or over is recovered, and the minus one-half-inch product is taken to a mill for further crushing and grading. At one mill the rolls travel at slightly different speeds so as to subject the fiber to a tearing action. Double grading trommels sometimes are used. The inner cylinder has one-fourth-inch holes and the outer one-eighth-inch. Material passing the outer cylinder is waste; the oversize from the outer cylinder is designated grade SS and the oversize from the inner cylinder is grade S. The following grades are produced:

E. Over 2-inch cobbed fiber.
D. 1¾-inch to 2-inch cobbed fiber.
C. 1¼-inch to 1¾-inch cobbed fiber.
B. ⅞-inch to 1¼-inch cobbed fiber.
A. ½-inch to ¾-inch cobbed fiber.
S. ¼-inch to ½-inch milled fiber.
SS. Shorts, ⅛-inch to ¼-inch milled fiber.

In the Northern Belt, material over three-fourths inch long is hand-cobbed. For many years the mill grades were not standardized and the companies had difficulty in marketing their products. Later, a large mill was erected at Kuruman, and the grades manufactured there were established standards that offered such decided marketing advantages that other producing companies adopted them. In this mill, rock carrying the shorter fibers is passed through crushers, heavy rolls, and disintegrators. The fiber thus separated is classified on grading screens. The following grades are made:

ES. Over 1¼-inch hand-cobbed fiber.
No. 1. ¾-inch to 1¼-inch hand-cobbed fiber. Also, 2 grades of plus ¾-inch discolored fiber.
No. 2. ⅜-inch to ¾-inch milled fiber.
No. 3. ⅜-inch, or under, milled fiber.

Of the total fiber recovered, about 13½ percent is hand-cobbed and 86½ percent milled. In both the Northern and Southern Belts about 9 percent of the total fiber is of spinning grade.

Crocidolite of the Pietersburg district, Transvaal, is passed through rolls, fiberizers, and grading trommels. Four grades are produced:

B. Over 1¼ inch.
A. ⅝ inch to 1¼ inch.
S. ¼ inch to ⅝ inch.
Paper grade, ⅛ inch to ¼ inch.

AMOSITE

Because of its unusual length, most of the amosite produced is hand-cobbed. The fiber thus freed from adhering rock is passed through a series of rolls and disintegrators and then graded on shaking screens or trommels, usually into three grades. No. 1 is spinning fiber; no. 2 is used in the manufacture of rope, felts, and similar products; and no. 3 is used for asbestos-cement products such as roofing slates and corrugated sheathing. The fiber is classified both according to length and color. The colors range from whitish gray to yellowish; the gray shades are considered the best. Most of the mills are small.

RHODESIA

The Rhodesian asbestos industry is centered at the large chrysotile mines of Shabani. To avoid damage to the fiber, as much of it as possible is separated from the rock close to the working face; hence, the hand-cobbing and bagging of crude fiber is an important part of quarrying and mining operations. Each cobbing boy recovers about 1,500 pounds of fiber a shift in open quarries and 1,000 pounds a shift in stopes. The cobs are said to average 40 to 50 percent fiber.

The quarry rock first is broken in jaw crushers and rolls, and the products are sorted on picking belts into three groups: (1) Rock containing little or no fiber, (2) rock containing large seams of fiber, and (3) fines and rock carrying small seams of fiber. Product 1 is left on the belt and conveyed to the waste heaps, product 2 is carried on a second belt to the cobbing sheds, and product 3 is conveyed by a third belt to the mill. Hand cobs from both the cobbing sheds and the quarries or stopes are fiberized and graded in one mill, and the fiber-bearing rock is reduced in another.

Some maintain that when fiber-bearing rock is kept wet until it reaches the mill it suffers less damage and is in better condition for milling than when it is handled and rehandled dry. After primary crushing in the mill, the rock is dried either with steam-heated equipment or in rotary driers in which the products of combustion from wood fires are in direct contact with the rock. The dried rock is reduced in a series of small grinding pans operating like pug mills. Fiber is separated from rock with shaking screens and air suction in the same manner as in Canada. Undesirable brittle fiber is ground in the pans and passes through the screens with the waste rock. Fiber carried in the air current is deposited in a centrifugal settler, and the air passes on through the exhaust fan and dust trap to an outlet. The asbestos is taken to a grading mill, where it is cleaned further from dust and separated into the various market grades. Grading is done in hexagonal trommels.

Cobbed asbestos is fiberized, cleaned, and graded in a mill in which the equipment is modified to handle longer fiber.

In the Shabani area, the tonnage of cobbed fiber ranges from 2½ to 3¼ percent of the total rock mined. Total milled and cobbed fiber averages about 4 percent of the rock quarried. One must not infer that the rock is leaner than in Quebec, where recovery is about 6 percent, because short-fiber material amounting to many thousand tons in Quebec is discarded as waste in Rhodesia.

Few data are available on the grades produced at Shabani or on the proportion of each grade. From 25 to 30 percent is spinning fiber, and most of the remainder is shingle stock. Fiber shorter than paper stock cannot be handled profitably because of the heavy transportation expense to markets. The longest spinning fibers, nos. 1 and 2, are the only grades quoted in the United States market reports.

At the King's and Gaths' mines in the Mashaba district the asbestos is recovered by hand-cobbing only. The tonnage of marketable fiber obtained is 0.7 to 1.2 percent of the rock quarried.

RUSSIA

In Russia, crude asbestos is sorted in the quarry and cobbed as in Canada; but, with increasing mechanization, hand cobbing has declined and a larger proportion of the fiber is prepared mechanically. For many years the fiber was concentrated by hand-sorting in the quarries. Although recoverable fiber averages about 4½ percent of total rock quarried, the elimination of barren rock by hand-sorting so raised the grade that mill feed averaged about 22 percent of the fiber. During recent years mechanical mining equipment has replaced hand methods to a large extent and the fiber is concentrated by hand-sorting on picking belts after the rock is crushed.

The preliminary stages of rock treatment are exemplified best in one of the newer mills, the "Gigant", which began operation in 1932. Rock from the quarry is conveyed to a storage bin and from that to a no. 9 Gates gyratory crusher, which reduces it to about 6-inch size. It discharges to a picking belt, where about 20 percent of the primary feed containing too little fiber to justify milling is thrown out as waste rock. The asbestos-bearing rock is reduced to 1½- to 2-inch size in two no. 7 Gates gyratory crushers discharging to heavy shaking screens. The oversize from the screens passes to picking belts, where more barren rock is eliminated. The good rock from the picking belt is reduced to about 1-inch size in a jaw crusher and joins the undersize from the shaking screens in a wet-storage bin, whence it passes to three rotary driers, which reduce the water content from about 8 to 1 or 2 percent. The product is conveyed to the dry-storage bin.

The most noteworthy feature of the preliminary milling stage is the concentration on picking belts. Because the serpentine tends to break cleanly along the fiber veins, effecting a more or less distinct separation of barren and fiber-bearing rock, conditions particularly favor this method of concentration. Of the original mill feed, consisting of 2,400 tons a day, about 1,440 tons are eliminated as waste, leaving only 960 tons for the later milling processes. Thus, picking belts save operators a great deal of useless milling.

In the more advanced milling stages the dried rock is passed over heavy shaking screens, from which four products are obtained: (1) Fiber removed by suction fans, (2) oversize rock conveyed to a set of rolls, (3) middlings that bypass the rolls and are carried to the next screen, and (4) fines conveyed to a Humboldt disintegrator. By means of a series of such rolls, screens, suction pipes, and disintegrators, virtually all of the fiber is recovered. Fiber from the collecting hoppers is sent to a series of shaking screens for cleaning. The cleaned fiber is collected again by suction fans and classified by length in slowly rotating grading trommels.

The older mills employed a typically Russian method of milling. The rock was reduced in a series of rolls, and part of the fiber was separated from rock with trommels; the major separation, however, was made on inclined planes provided with suitable gaps. The fiber dropped through the gaps, and the rock fragments jumped over them. Ru Keyser[48] has described milling processes in some detail.

A large new mill designed to handle 2,000,000 tons of rock annually and produce 80,000 tons of fiber in six grades was nearing completion in 1934. This mill will give Russia a total milling capacity of approximately 175,000 tons of fiber a year.

Little information is available regarding the grades produced and the percentage of each grade. Estimates made in 1931 indicated that fiber one-third inch or more in length constituted about 30 percent of the total output. Since that date, with increasing factory capacity for the manufacture of asbestos products, probably a larger proportion of the shorter grades is produced. Grades entering the German market in 1929 were designated as follows:

Grade 0. 1½ inch or longer.
Grade 1. ¾ inch to 1½ inches.
Grade 2. ⅝ to ¾ inch.
Grade 3. ⅜ to ⅝ inch.
Grade 4. ⅛ to ⅜ inch.
Grade 5. Less than ⅛ inch.

Price quotations for Russian fiber in the American market include Crude No. 1, Crude No. 2, Crude No. 3, and shingle stock. Beginning July 1935, a new grade, designated Crude AA, was placed on the market. Evidently it is the highest grade produced, because it was quoted at $450 a ton.

[48] Ru Keyser, Walter A., Asbestos Milling in the Urals: Eng. and Min. Jour., vol. 134, no. 10, October 1933, pp. 415–419.

CYPRUS

In Cyprus, the rock bearing chrysotile asbestos is so decomposed that it breaks down readily into small sizes. Small quantities of hand-cobbed fiber are obtained. Rock reduced in the quarry by hand methods is screened to eliminate barren material over 18 mm (7/10 inch) and fines under 5 mm (1/5 inch); the intermediate product, which averages about one-sixth of the total quarry output, is sent to the mills. The mill feed is crushed and passed over flat shaking screens and the fiber recovered by air suction. It is treated further to remove dust and to classify it according to length. The asbestos recovered constitutes about 3½ percent of the mill feed, and virtually the entire production is short fiber.

Milled asbestos is graded into three classes—standard, shorts, and fines. The standard grade, designated "shingle stock", is said to include about 75 percent of the production. The entire output is exported. Twelve mills were reported in operation in 1935. Their aggregate capacity is 25,000 tons of fiber a year of 6 working months. They are operated during the dry season only.

AUSTRALIA

The Lionel plant in Australia produces four grades, which are numbered in the reverse order from that generally practiced; the smaller numbers are applied to the shorter fibers. No. 1, the lowest grade produced, includes fibers about ¼-inch long; No. 2, about ½-inch; No. 3, about 1 inch; and No 4, 2 inches and over.

ANTHOPHYLLITE MILLING

Anthophyllite, a variety of amphibole asbestos, has been mined in a small way in the United States for many years. Small mills have been operated in Georgia, Montana, North Carolina, Oregon, Virginia, and Washington. As a large percentage of the rock treated is asbestos, fiberization and classification are the principal milling processes. The fiber is much weaker than chrysotile, and therefore severe treatment is to be avoided.

In one mill operated a few years ago the dried rock was broken in a gyratory crusher, whence it went to a hammer mill equipped with air suction for carrying off the loose fiber. This process was followed by reduction in a double-cage mill, the cages running in opposite directions. The fiber was removed by air suction; an enlargement in the suction pipe retarded the velocity of the air current, permitting heavy fragments of unopened fiber to fall. These fragments were returned through a trap to the cage mill in closed circuit. The fiber was classified with vibrating screens.

In another mill the dried rock is first reduced with a jaw crusher, followed by a set of rolls. The crushed asbestos rock is fiberized in a hammer mill equipped with an air separator. Coarse material is returned to the fiberizer, dust is collected in a dust chamber, and the fiber is conveyed to a bin that feeds into a packer. The fiber is packed in 100- or 200-pound sacks. Modifications of these processes are employed in other mills.

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Anthophyllite mined in Harford County, Md., is peculiarly suited for the manufacture of filters that resist the action of chemicals. It undergoes special treatment, including careful hand selection and washing in acids.

MARKETING

Asbestos is used in so many diverse products that its markets are numerous and widespread. It is used extensively in the United States, England, France, Germany, Belgium, Italy, Netherlands, Spain, Russia, and Japan. The last country has become an important buyer of roofing-grade asbestos. Russia at one time exported almost its entire production, but recently it has become an important manufacturer of asbestos products. Many other countries use smaller quantities. With greater diversity in use, expansion of automobile production, development of new types of building materials, and stronger demands for heat-insulation material, the consumption of asbestos has increased steadily. In recent years, mineral, slag, and glass wools have increased in importance as insulation, and although generally used in fields other than those in which asbestos is employed, they are replacing asbestos to some extent.

Some fiber is handled by agents or jobbers, but most of it is shipped direct from mine to consumer. Usually samples are submitted and fiber length and quality are guaranteed. The larger manufacturers of asbestos products have their own testing machines and can check the producer's classification. The producer should be familiar with manufacturing conditions in order that he may prepare the material to suit each particular use.

Canadian asbestos generally is preferred by users in the United States, although African and Russian fibers may be substituted for many uses. Considerable quantities of the latter fibers are mixed with the Quebec product.

The principal Canadian producers sell direct to consuming industries and also to dealers and agents who distribute it to consumers. Sales frequently are made to consumers only after they have examined and approved samples submitted by dealers or producers. Canadian firms sometimes supply European customers with trial consignments of several tons, particularly if they are introducing new products.

Asbestos is sold in 100-pound or 125-pound bags on a short-ton basis, bags included. Quotations are f. o. b. mines. The weight of a given volume varies with the length of fiber as the longer fibers are bulkier. The volume of a short ton ranges from 60 to 90 cubic feet. A minimum carload of fiber is 20 tons, and of refuse and shorts, 30 tons. Settlements usually are made on the basis of 2 percent discount within 10 days, or 30 days net.

Before the World War, Hamburg was the principal marketing center, but since that time New York has become the most important. The larger producers now have offices in New York, Hamburg, London, and other large cities.

Market requirements are based principally on fiber length, but strength, flexibility, color, chemical composition, and cleanliness may have an important bearing on use. The principal market outlets are indicated in the following brief summary of uses.

The longer and more valuable asbestos crudes and fibers, ranging upward from about $70 a ton, are used in manufacturing woven brake linings, textile fabrics, and asbestos packing. The next lower grades, ranging from about $25 to $70 a ton, are used in manufacturing rigid asbestos-cement shingles, lumber, and corrugated sheathing. Still shorter fibers are used in manufacturing paper and millboard, and the lowest-grade fibers are employed in heat-insulating cements, cold molded products, and fillers.

European imports from Africa are handled principally by dealers or agents. The importers pay cash or open a credit in South Africa and sell on credit to manufacturers. The latter concerns do not buy directly from producers because they are accustomed to buy on 3 to 6 months' credit, and importations are not made easily on such a basis. The Canadian standard testing machine is used to some extent in Africa.

Several of the largest asbestos organizations are of the vertical type; that is, they mine and mill the raw materials and fabricate finished products. At least three large companies in the United States are of this type, each having mines in Canada and factories in the United States. Turner & Newall, Ltd., controls nearly all of the asbestos production of Rhodesia and much of that of the Union of South Africa. The company has 20 large asbestos-products factories in England. The Russian industry is also of this type; the State controls both production of raw materials and manufacture of finished products. Because of this condition, a substantial part of Russian production never enters the open market.

Most of the world supply of raw asbestos is in exceptionally strong hands, and distribution is conducted in close and sympathetic collaboration with buyers, many of whom are also strong, well-organized concerns. Hence, new producers and new sales organizations are not likely to dislocate the market seriously. Furthermore, new organizations sometimes have difficulty in finding a market because consumers of asbestos ordinarily place orders 12 to 18 months in advance of actual needs. Centralized control by large units also makes possible the establishment of marketing agreements. Turner & Newall, Ltd., having control of virtually the entire output of Rhodesia, was able in 1931 to consummate an agreement with Russia whereby orders were apportioned between European consumers and the market stabilized on a basis satisfactory to all concerned.

PRICES

Prices of Canadian asbestos have fluctuated greatly during the past 15 years. In 1920, because of war stimulation, prices skyrocketed to unprecedented heights, Crude No. 1 selling for more than $3,000 a ton. In 1921, the price dropped to less than half that amount, and by 1925 the highest grades were selling for only about one-eighth of the price received in 1920. The following table shows, except for 1933 to 1936, the average price per short ton, f. o. b. mine, received by producers as reported to the Quebec Bureau of Mines. Since 1932 the Canadian figures, unfortunately, are not presented in enough detail to show values by grades, and for these later years average price quotations as given in Mineral and Metal Markets are used. The latter figures, however, are generally very much higher than figures for actual sales as given by the Quebec Bureau of Mines.

Average value per short ton of asbestos sold in Canada, 1921–36 [1]

Year	Crude No. 1	Crude No. 2	Spinning fibers	Shingle stock	Millboard and paper stock
1921	$1,281.32	$446.91	$263.09	$101.75	[2] $31.19
1922	648.68	265.32	207.71	81.00	[2] 21.65
1923	472.60	237.29	123.37	57.05	[2] 22.01
1924	365.97	215.27	110.81	45.12	[2] 19.84
1925	364.96	206.12	106.43	50.78	31.03
1926	371.51	229.62	130.22	58.62	33.88
1927	423.65	249.59	129.32	64.80	37.82
1928	534.87	296.65	148.71	73.80	38.73
1929	557.38	331.82	177.30	75.26	38.56
1930	480.44	285.44	141.52	70.64	35.33
1931	431.46	216.35	107.22	58.72	[3] 34.66
1932	396.94	192.43	91.36	49.64	[3] 30.84
1933	457.50	206.25	100.20	52.71	[3] 32.71
1934	450.00	212.50	112.50	55.00	[3] 35.00
1935	500.00	212.50	112.50	60.00	[3] 35.00
1936	550.00	212.50	118.75	60.00	[3] 35.00

[1] Figures for 1921–32 from Quebec Bureau of Mines; for 1933–36, average of quotations, Mineral and Metal Markets.
[2] Paper and others.
[3] Paper only.

Price trends are shown graphically in figures 9 and 10.

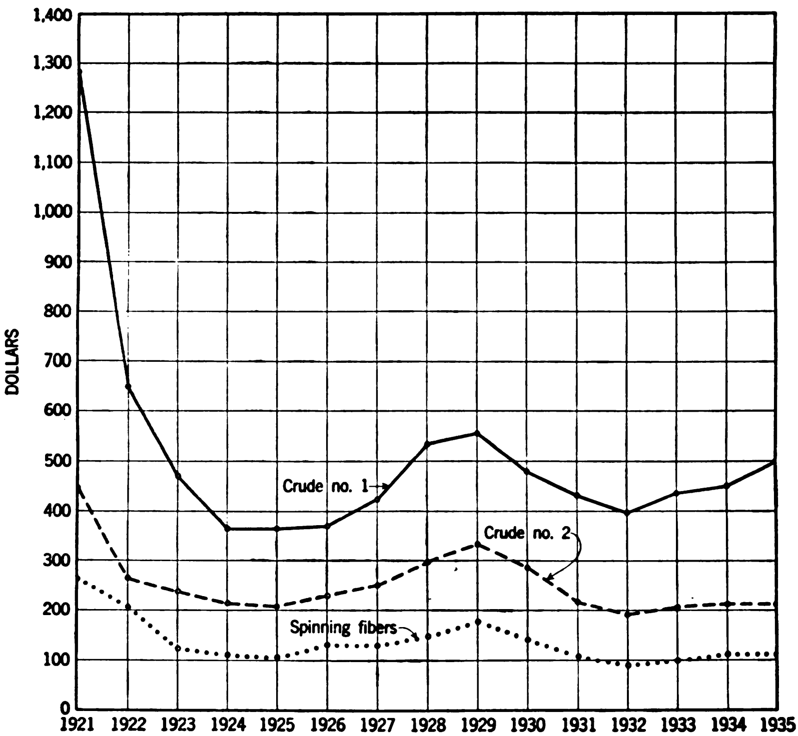

FIGURE 9.—Average value per short ton of Canadian crudes and spinning fibers, 1921–35. Data for 1921–32 from value of sales compiled by the Bureau of Mines, Province of Quebec. Data for 1933 to 1935 from price quotations in Mineral and Metal Markets.

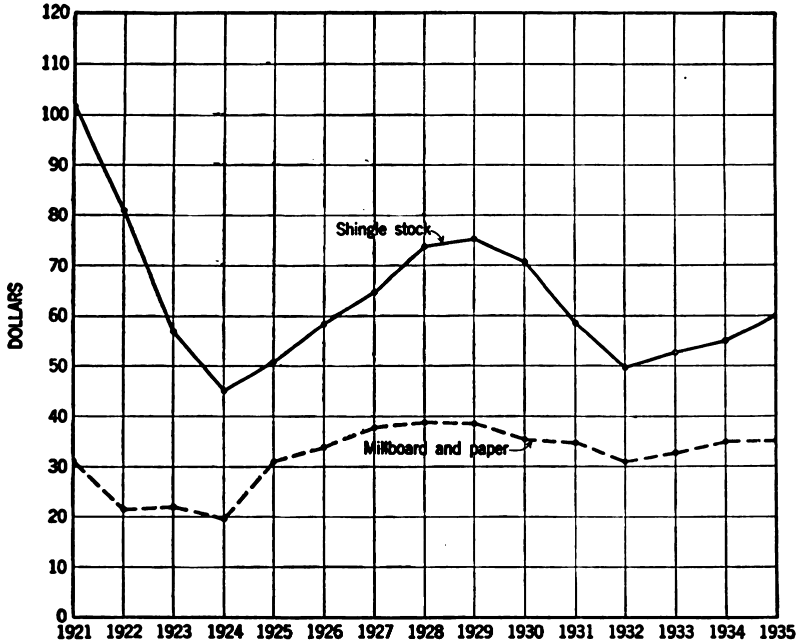

FIGURE 10.—Average value per short ton of Canadian shingle, millboard, and paper stocks, 1921–35. Data for 1921–32 from value of sales compiled by the Bureau of Mines, Province of Quebec. Data for 1933 to 1935 from price quotations in Mineral and Metal Markets. Figures for millboard and paper prior to 1925 represent paper and others.

Average quotations for Vermont asbestos, as given in Mineral and Metal Markets, are shown in the following table. Prices are per short ton, f. o. b. mines.

Prices of Vermont asbestos, 1931–36

Year	Shingle stock	Paper stock	Cement stock	Year	Shingle stock	Paper stock	Cement stock
1931	$50.71	$35.00	$20.00	1934	$45.00	$35.00	$23.00
1932	42.92	32.92	20.00	1935	46.25	35.00	23.00
1933	42.92	32.71	20.25	1936	47.50	35.00	23.00

The following table shows prices of Rhodesian and Russian asbestos per short ton, average quotations for the year, as shown in Mineral and Metal Markets. All prices are c. i. f. New York.

Average price quotations per ton of foreign asbestos

Year	Rhodesian		Russian			
	No. 1	No. 2	Crude No. 1	Crude No. 2	Crude No. 3	Shingle stock
1923	$361.11	$227.77				
1924	313.75	193.75				
1925	292.50	222.91				
1926	325.00	250.00				
1927	402.08	322.91				
1928	450.00	350.00				
1929	450.00	350.00				
1930	383.33	300.00	$210.00	$160.00	$50.00	
1931	304.17	204.17	227.50	184.17	113.54	
1932	187.50	131.25	213.54	163.54	125.00	
1933	186.67	136.67	212.50	162.50	125.00	$55.00
1934	210.00	160.00		162.50	128.75	55.00
1935	210.00	172.50	192.50	167.50	130.00	52.50
1936	210.00	185.00	220.00	186.00	130.00	55.00

Beginning July 1935 a new grade of Russian asbestos designated Crude AA was quoted regularly at $450 a ton until February 1936, and at $475 a ton for the remainder of the year.

MANUFACTURE OF ASBESTOS PRODUCTS

A WIDESPREAD AND DIVERSIFIED INDUSTRY

The fire resistance of asbestos combined with its fibrous character adapt it admirably for the manufacture of flexible, heat-insulating products, packings, and gaskets for use in places where fabrics of animal or vegetable origin would be less enduring and would create fire hazards. The addition of asbestos to various fireproof building materials gives them strength and flexibility; and, furthermore, manufacturers of many miscellaneous products find that asbestos, when used as an ingredient, imparts superior qualities. Thus many large industries have grown up in recent years for the manufacture of innumerable products of which asbestos is a major or an essential constituent.

The Bureau of Mines deals primarily with economic, technologic, and safety problems pertaining to raw materials of mineral origin; but, as the manufacture of asbestos products is very important in the United States, while the production of raw asbestos is a small industry, more space than usual is given in this report to manufacturing processes and their resulting products.

ASBESTOS-PRODUCTS PLANTS

UNITED STATES

The United States leads all countries in the manufacture of products of which asbestos is an essential or important constituent. The Bureau of the Census listed 238 establishments in the United States that made asbestos products in 1929, 208 in 1931, 187 in 1933, and 196 in 1935. The industry is centered chiefly in the North Atlantic States, notably in the Philadelphia (Pa.) and eastern New Jersey areas. Important factories are operated, also, in Cincinnati (Ohio), Chicago (Ill.), St. Louis (Mo.), and other midwestern cities; in the

Southern States; and on the Pacific coast. Most of the output enters the domestic market; less than 5 percent, in value, is exported.

The following table shows the quantity and value of the principal asbestos products manufactured in the United States in recent years, as given in the Biennial Census of Manufactures. The articles listed as "other products" are very numerous; some manufacturing companies sell more than 200 different articles. Many products included under the last four items in the table consist of various materials, including wood, steel, copper, cork, and rubber, in addition to asbestos, which may form a very small proportion of the total.

Asbestos products manufactured in the United States, 1929–35

[Data from Bureau of Census]

	1929		1931		1933		1935	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Asbestos textiles and textile products:								
Brake linings......feet	110, 246, 479	$16, 447, 438	56, 059, 659	$8, 367, 492	35, 472, 491	$4, 545, 006	36, 679, 944	$4, 686, 701
Clutch facings......pieces	38, 096, 113	3, 910, 727	21, 340, 773	1, 796, 761	18, 857, 760	1, 601, 934	26, 516, 094	2, 697, 182
Yarn......pounds	15, 378, 407	5, 173, 568	9, 512, 686	2, 471, 388	8, 487, 342	1, 551, 909	8, 042, 599	1, 843, 979
Cloth......do	6, 666, 589	2, 767, 049	4, 629, 158	1, 413, 959	4, 648, 677	1, 069, 751	7, 301, 389	1, 790, 756
Tape, listings, and tubular lagging......do	2, 225, 852	1, 202, 231	2, 350, 548	880, 538	1, 735, 925	580, 948	2, 014, 871	739, 791
Packing......do	8, 623, 281	3, 845, 710	6, 747, 122	2, 333, 956	4, 971, 327	1, 883, 940	7, 979, 797	2, 315, 266
Gaskets......do	3, 012, 335	1, 726, 804	1, 441, 325	644, 385	1, 400, 192	577, 177	1, 859, 552	813, 453
Other textiles		1, 088, 466		630, 770		812, 535		1, 184, 626
Total textiles and products		36, 161, 993		18, 539, 249		12, 623, 200		16, 071, 754
Asbestos building materials:								
Shingles......squares	894, 164	5, 277, 308	565, 997	3, 266, 054	408, 256	1, 826, 279	1, 171, 095	5, 234, 727
Lumber......square feet	35, 395, 194	3, 094, 426	16, 907, 820	1, 563, 135	14, 193, 900	1, 032, 313	18, 287, 729	1, 503, 660
Other building materials		2, 051, 884		818, 343		620, 546		1, 413, 877
Total building materials		10, 433, 618		5, 647, 532		3, 479, 138		8, 152, 264
Other asbestos products:								
Brake lining, molded......feet	22, 410, 872	2, 534, 646	24, 180, 184	2, 823, 738	24, 373, 952	3, 422, 593	23, 068, 575	4, 569, 814
Brake linings (kind unrecorded)		5, 484, 654		3, 116, 045		3, 270, 159		
Pipe and boiler covering, air-cell......feet	67, 331, 323	4, 657, 666	39, 083, 826	2, 755, 354	19, 554, 455	1, 137, 283	22, 804, 499	1, 818, 833
Pipe and boiler covering other than air-cell......do	27, 686, 503	2, 516, 009	8, 797, 834	938, 149	8, 461, 631	851, 826	7, 530, 951	1, 608, 149
Pipe and boiler covering, 85 percent magnesia......do	23, 959, 209	3, 045, 324	19, 323, 303	2, 511, 795	10, 818, 354	1, 457, 211	12, 153, 486	1, 781, 904
Molded blocks, 85 percent magnesia......board feet	21, 479, 103	2, 457, 337	11, 740, 953	1, 209, 015	9, 711, 170	852, 844	13, 747, 150	1, 072, 823
Millboard......pounds	7, 280, 221	345, 375					8, 479, 173	398, 934
Insulating cements......do	68, 472, 386	917, 846	39, 100, 027	602, 853	35, 856, 231	630, 204	28, 486, 049	423, 370
Table mats and protectors......do	1, 615, 631	766, 222					700, 082	371, 933
Other products [1]		5, 206, 078		3, 485, 101		2, 778, 323		4, 560, 772
Gaskets other than asbestos textile [2]		15, 741, 964		10, 153, 121		9, 005, 392		12, 351, 135
Metallic and semimetallic packings		3, 066, 578		2, 110, 725		1, 845, 437		2, 767, 830
Steam and other packing other than asbestos textile [3]		7, 932, 758		2, 272, 013		2, 363, 242		2, 865, 909
Total other products		54, 672, 457		31, 977, 909		27, 614, 514		34, 591, 406
Grand total		101, 268, 068		56, 164, 690		43, 716, 852		58, 815, 424

[1] Asbestos paper and miscellaneous products; includes millboard in 1931 and 1933.
[2] Includes some gaskets that contain little or no asbestos.
[3] Excludes leather packings.

CANADA

For many years Canada exported almost its entire production of raw asbestos, but lately it has developed an important asbestos-products industry. In 1934, 11 plants were engaged in this line of manufacture. Four of them, in the center of the asbestos-mining district in Quebec, accounted for 46 percent of the total production. There were also six plants in Ontario and one in Nova Scotia. The principal products are brake-band linings, boiler and pipe coverings, packings, paper, and roofing.

The following table, compiled from data furnished by the Dominion Bureau of Statistics, shows the extent of the industry during recent years:

Asbestos products plants in Canada, 1925–35

Year	Number of plants	Capital employed	Cost of materials at works	Selling value of products at works
1925	12	$2, 624, 260	$783, 063	$1, 344, 097
1926	14	2, 773, 433	750, 907	1, 530, 094
1927	13	2, 860, 945	797, 975	1, 663, 300
1928	14	3, 064, 164	925, 661	2, 050, 432
1929	12	2, 949, 712	1, 348, 460	2, 286, 638
1930	11	2, 316, 645	1, 327, 025	2, 301, 924
1931	13	1, 112, 141	729, 771	1, 308, 183
1932	13	2, 682, 882	559, 673	1, 067, 801
1933	11	1, 777, 975	331, 062	757, 626
1934	11	1, 391, 873	387, 074	910, 983
1935	13	1, 703, 301	518, 994	1, 130, 282

GREAT BRITAIN

The manufacture of asbestos products is an important industry in Great Britain. In 1929, 57 factories were operated by 35 companies and the estimated value of their output was $28,163,000. Of the raw asbestos used, 44 percent came from Rhodesia, 28½ percent from the Union of South Africa, 21½ percent from Canada, and small amounts from Cyprus, the United States, Italy, and Russia. The range of products is much the same as in the United States. About one-fourth of the total output is exported.

GERMANY

In 1929, 32 factories in Germany made asbestos products, 17 of which were devoted chiefly to spinning, weaving, and braiding. Four factories made corrugated sheeting, pipe, roofing tile, and other asbestos-cement products. The raw asbestos is obtained chiefly from Russia, although substantial quantities are imported from Canada and Africa. As asbestos has not been produced in Germany, the quantity used annually in German asbestos-manufacturing plants, except for fluctuation in stocks, is identical with net imports, which have increased from 7,580 tons in 1932 to 12,600 tons in 1933, 20,000 tons in 1934, and about 22,000 tons in 1935.

AUSTRIA

In Austria, the original home of "Eternit", nine asbestos-products factories were operated in 1929. Asbestos-cement tile was the principal product of four factories.

FRANCE

In 1929, four factories in France produced asbestos-cement roofing tiles and similar products; nine plants were devoted chiefly to the manufacture of spun, woven, and braided products; four factories made high-pressure packings; and two factories made asbestos brake linings.

BELGIUM

Belgium has imported from Canada, Africa, and Russia between 1,200 and 3,000 metric tons of asbestos annually during recent years. Nine factories were in operation in 1929, but only five were reported in 1936. These firms consume over 90 percent of the imports of raw fiber. The principal products made are asbestos-cement shingles, tiles and pipes, and asbestos insulation. The output of millboard and woven products is small. No brake linings are made in the country. A large percentage of the imports of fiber are of shingle grade.

ITALY

In Italy, three large factories and numerous small ones manufactured principally asbestos-cement tiles and sheets in 1929. Thread, cards, cartons, textiles, and filter paper also are made in considerable quantities. Two plants manufacture "Eternit" products. The annual value of Italian asbestos products was estimated in 1932 at 25 million lire (about $2,061,775 on the basis of the 1935 rate of exchange).

CZECHOSLOVAKIA

In 1929, three factories in Czechoslovakia were devoted to asbestos spinning, weaving, and braiding; one made asbestos board; four, high-pressure packings; and several, asbestos-cement tile. Eight companies manufactured asbestos-cement roofing tiles in 1936. In that year the three largest companies concluded a cartel agreement whereby prices for domestic sales were increased substantially. The claim is made that the new price of 15 crowns (about 62 cents) a square meter gives the companies a small margin of profit.

NETHERLANDS

A plant for making "Eternit" cement-asbestos gas and water conduits was built at Goor, Netherlands, in 1936.

FINLAND

One factory established at Helsingfors, Finland, in 1923 manufactures "Eternit" products, packings, insulating materials, and fabrics. Both domestic and foreign asbestos are used.

SCANDINAVIA

Norway imports 100 to 200 metric tons a year of asbestos from Finland. It is used chiefly for heat insulation. Two factories manufacture asbestos packings, but their requirements of raw fiber are small. Similarly, few asbestos products are manufactured in

Sweden. The country imports about 1,000 metric tons of fiber annually, chiefly from Finland and Russia. It is used principally for heat insulation. A small asbestos-products industry exists in Denmark. In 1934, 1,040 metric tons of unmanufactured asbestos were imported.

AUSTRALIA

There are quite a number of factories in Australia devoted to the manufacture of asbestos products. They are located chiefly in Sydney, Brisbane, Melbourne, and Perth, and their principal products are asbestos-cement sheet siding and roofing and asbestos-cement pipe. Sheet-metal roofing is used widely in Australia, and a substantial substitution of asbestos-cement sheets is anticipated.

Asbestos production in Australia is small, hence most of the raw asbestos required is imported. The Union of South Africa and Canada are the chief sources of supply. The most recent available figures show annual imports of about 3,500 tons valued at about £60,000.

RUSSIA

According to recent data, about two-thirds of the Russian output of asbestos is used in domestic factories devoted to the manufacture of asbestos products. Russia, therefore, is becoming an important factor in this industry. One very large factory at Leningrad makes asbestos-cement products, fabrics, paper, and insulating materials. As a result of research conducted at Leningrad by the Asbestos Institute, several new products and processes of manufacture have been developed. The Yaroslave Rubber Combinate has started mass production of molded asbestos brake linings.

OTHER COUNTRIES

There are several asbestos factories in Poland, Hungary, Spain, and Switzerland. Several establishments in Japan make asbestos textiles, insulating materials, and asbestos-cement products. Evidently roofing is becoming an important branch of the industry in that country, because recently there has been an unusually large demand for shingle-stock fiber.

FABRICATION OF ASBESTOS PRODUCTS

The manufacture of asbestos products involves many diversified and complex processes. Only a brief summary of the principal operations is presented herein because this report pertains primarily to raw materials.

FABRICS

Crude fiber delivered to the manufacturing plant usually is crushed in a chaser mill, fiberized, and freed from rock impurities by screening and air separation. It is then ready to enter the various successive stages of manufacture into fabrics. Milled spinning fibers prepared by producers need not undergo this preliminary treatment.

The processes involved in the manufacture of fabrics follow in general those employed in spinning and weaving cotton, wool, or silk. Asbestos fibers differ from those of organic origin mainly in the nature of the surface. Wool fibers are covered with scaly bands known as imbrications, and cotton fibers are rough, twisted, and irregular. On the other hand, asbestos fibers have no nodules, twists, or irregularities on the surface that will enable one fiber to cling to another. They are more nearly akin to silk but are smoother and more rodlike. This smooth, slippery condition creates such difficulties in spinning that the manufacture of a 100-percent asbestos yarn is slow and costly; therefore a percentage of some other fiber, usually cotton, is added to act as a vehicle to carry the asbestos through the manufacturing processes. The proportion of cotton added varies with the character of the asbestos and with the nature of the finished product. It rarely exceeds 20 percent, and with long-fibered Canadian asbestos may be as low as 2 percent.

Asbestos used in the manufacture of fabrics may consist of a mixture of varieties from different localities. The proportions depend upon the cost and quality of raw materials and the requirements of the finished product. Most manufacturers in America prefer Canadian fiber as a base, although many products now are made of African fiber alone. The blended fibers, together with the necessary addition of cotton, are mixed thoroughly with revolving beaters. Some manufacturers, however, introduce the cotton at a later stage.

Carding is the next step in the process of manufacture. Carding rolls are covered with leather and fitted with sharp steel bristles. They comb the fibers parallel and remove short fibers, bits of rock, and dust. After passing a succession of carding rolls the fiber emerges as a loose blanket, which may be turned 90° and passed through another carding machine. The blanket then is separated into rovings, which are gathered in a roll on a Jack spool and spun into yarn, as in ordinary textile mills.

Yarns are made in various sizes; a "5-cut" yarn measures about 500 yards to the pound and a "30-cut" yarn about 3,000 yards. When twisted exceptionally hard, it is known as asbestos thread and used in sewing gas mantles, asbestos theater curtains, and asbestos clothing. The spindles of single-ply yarn are transferred to twisting machines and twisted into two- or three-ply yarn, which is wound on spools. Asbestos cord and rope are made by twisting together a greater number of strands.

Where yarn is to be used for brake bands or packings, it usually is reinforced with fine copper, brass, or lead wire. Thus, for brake bands three strands of single-ply yarn and two strands of brass wire of gage nos. 0.006, 0.007, or 0.008 may be twisted together. For packings, a single lead wire or one to three strands of brass wire are twisted with two or three strands of asbestos yarn. Products prepared in this way are known as "metallic yarns."

Yarns are woven into fabrics by well-known processes employed in cotton- or woolen-textile mills. Asbestos cloth is used for theater curtains, fireproof clothing, and many other textile products. Single-ply asbestos yarn also is braided into tape. For electrical insulation it should contain not more than 7 percent carbon and not more than 14 percent cotton. Metallic yarn containing about 16 percent cotton is woven into strips for brake-band linings. Standard widths range from 1 to 6 inches and standard thicknesses from one-eighth to three-eighths inch. They are processed with rubber and other ingredients. The manufacture of brake-band linings for automobiles is the most important branch of the asbestos-products industry. As indicated in the table on page 84, strips woven for this purpose in 1929 totaled more than 20,000 miles.

Asbestos packings are made in various ways. The yarn may be twisted or braided into valve-stem packings, the braided forms may be compressed into rings, or asbestos cloth may be cut into gaskets or other desired forms. They may be coated or impregnated with rubber compounds, oil, or flake graphite. Metallic yarn is used in some packings.

SHINGLES AND LUMBER

Roofing shingles are made of a mixture of approximately 75 percent portland cement and 15 percent shingle-grade asbestos. When manufactured by the so-called "dry process", the cement, asbestos, and coloring agent are mixed dry in a cylindrical mixer provided with paddles. The mixture is spread evenly on an 18-inch conveyor belt and sprayed with water at 180° F. Rollers compress it to the required thickness, and a rotary cutter separates it into individual shingles. The shingles are piled in stacks separated by steel pallets and squeezed in a hydraulic press at a pressure of 20,000 pounds per square inch, after which they are cured, trimmed, and punched for nailing.

Shingles are also made by the wet process described in the following paragraph:

Asbestos lumber and shingles may be made by the laminated or "Eternit" process first used in Austria. Cement, shingle-grade fiber, and coloring matter are mixed with a large quantity of water, agitated thoroughly with a beater, and pumped to a paper machine that builds up the sheets in successive laminations to the desired thickness. Portland cement thus mixed with a large quantity of water does not lose its capability of setting at a later stage when most of the water is removed. For shingle manufacture, thin sheets are made. Lumber consists of thicker and larger sheets. Corrugated sheets are made by crimping flat sheets. The laminated process is used also for making cement-asbestos pipes, but the building up of tube-shaped articles is more complicated and requires special equipment.

Asbestos lumber is also made by the dry process described previously, but more time is needed for compression and curing than is required for the thin sheets used for roofing.

PAPER AND MILLBOARD

Asbestos of paper-stock grade is mixed with a large amount of water to make a thin slurry, which is agitated thoroughly by 5-foot drums covered with slats. Starch, flour, or size and sodium silicate, derived partly from the overflow squeezed out of the paper at a later stage, are added to the slurry. This is then conveyed to a paper machine similar to that used in the manufacture of paper from rags or wood pulp. All particles of stone or other impurities are eliminated in a sand-catching and knot-removing machine. The sheets of paper pass between rollers to remove most of the water and are dried in hot cylinders and wound in rolls. If a two-ply paper is desired, one side of a sheet is coated lightly with sodium silicate, and the two sheets are run together over several hot rolls. Crimped paper is made by passing it over corrugated rolls. In the manufacture of air-cell pipe covering, the tips of the corrugations are coated with sodium silicate, and a flat sheet is added. When this process is repeated, a two-ply, three-ply, or thicker air-cell covering may be made.

Millboard is generally classed with paper because it is manufactured by the same general process. It is simply a thick paper; it bears the same relation to asbestos paper that cardboard bears to wrapping paper. The board usually is built up on rectangular screens rather than on drums.

The manufacture of millboard gaskets is important. The high speeds, temperatures, and pressures attained in modern automobiles and other machinery demand very exacting qualities in the millboard used. It must have uniform density and high strength, and variations in thickness in any part of the sheet must not exceed two one-thousandths of an inch.

COMPOUNDED PACKINGS

Certain types of asbestos packing are made by mixing clean, well-opened fiber with fillers, such as clay, barite, magnesia, iron oxide, graphite, or cellulose, and binding materials, such as gums, resins, lac, or rubber dissolved in benzine. High-quality sheets contain about two parts asbestos to one part filler. The mixture is molded into sheets of the desired thickness. Several sheets may be glued together and reinforced with copper or lead foil.

MAGNESIA INSULATION

For the so-called "85-percent-magnesia" pipe covering a good grade of asbestos—chrysotile, blue asbestos, or amosite—ranging from 0–6–6–4 to 0–5–8–3 is used. Approximately 15 percent of fiber is mixed with 85 percent of basic magnesium carbonate derived from dolomite, magnesite, or bitterns at salt works. These ingredients are mixed thoroughly with water and filter-pressed into cakes, which are dried for 3 days in steam-heated kilns. The blocks are then trimmed, cut in lengths, and bored to form hollow cylinders; these are sawed lengthwise, and the half-cylinder sections are rolled in pairs in glued canvas jackets. For ordinary use the walls have a maximum thickness of about 2½ inches.

ASBESTOS CEMENT

A covering used widely for boiler insulation consists of short-fiber asbestos and a cementing material such as plastic clay. The ingredients are mixed with water to form a paste, which is applied with a trowel.

COLD-MOLDED ARTICLES

Increasing quantities of short-fiber asbestos are used in the manufacture of electrical fittings and household appliances. Mixtures of asbestos, gilsonite, cement, and oil are ground together and compressed in molds; these are baked in ovens, polished, and lacquered. Gilsonite imparts a brown color; if gray is desired the gilsonite is omitted.

NONCORROSIVE FILTERS

Amphibole asbestos, which in general is more resistant to chemicals than chrysotile, is washed, thoroughly fiberized, and otherwise prepared for use in Gooch crucibles or for other filtering processes that employ strong acids and alkalies.

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