MCP-6
mineral commodity profiles

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CT-778

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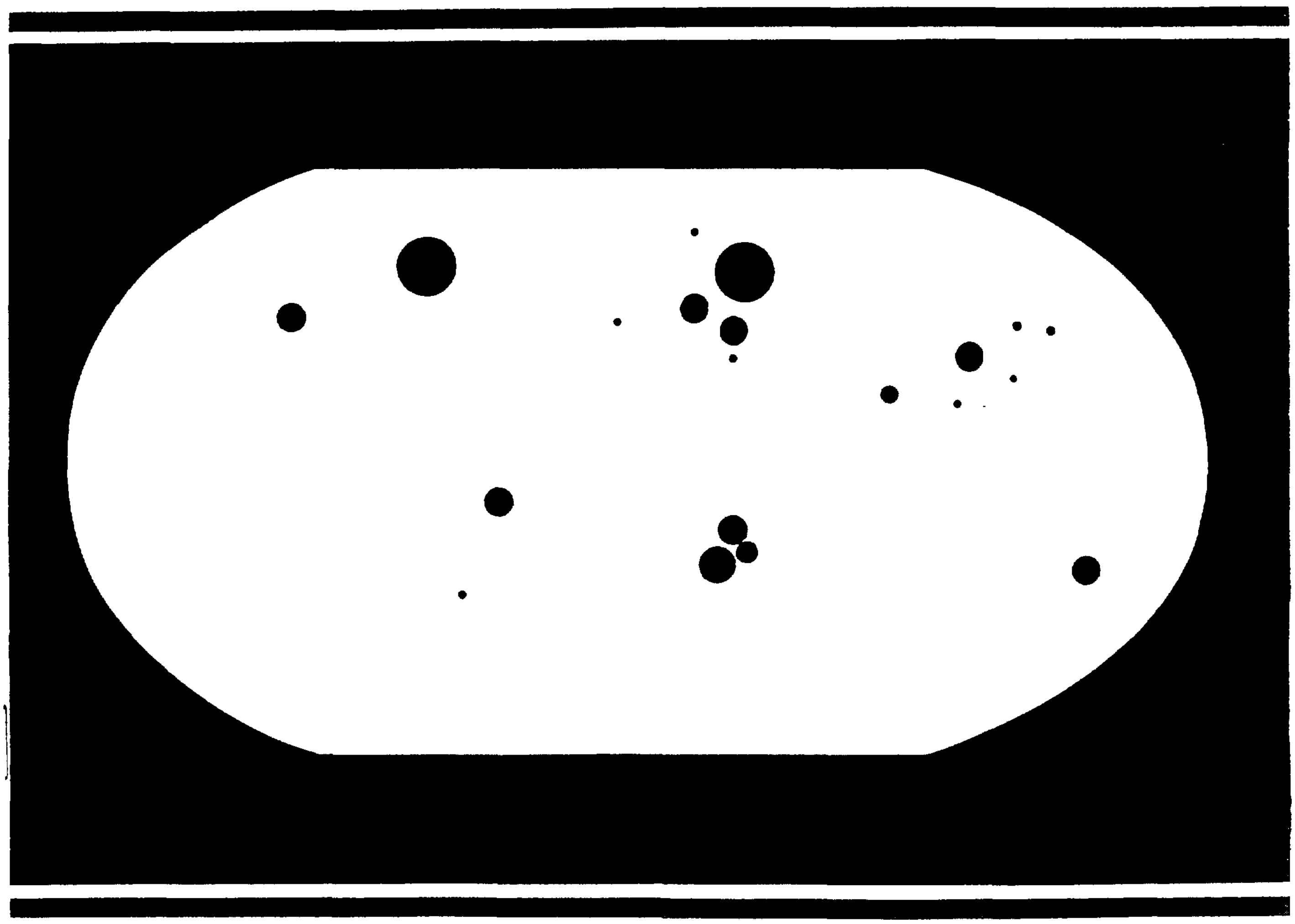

BUREAU OF MINES ★ UNITED STATES DEPARTMENT OF THE INTERIOR
SEPTEMBER 1977

CTD007132

ASBESTOS

MINERAL COMMODITY PROFILES
MCP-6, September 1977

This current report on asbestos has been prepared by the Bureau of Mines, U.S. Department of the Interior to:

1. Provide the latest available data and information on asbestos.
2. Invite comment, revisions, or additional information on the subject.

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CTD007133

This publication has been cataloged as follows:

Clifton, Robert A.

Asbestos-1977/by Robert A. Clifton. [Washington]: U.S. Dept. of the Interior, Bureau of Mines, 1977.

17 p.; diagrams; 27 cm. (Mineral Commodity Profiles; 6)

Bibliography: p.

1. Asbestos. 2. Asbestos industry. I. United States. Bureau of Mines. II. Title. III. Series.

TN1.A2 U5 no. 6 622.06173

CTD007134

ASBESTOS

By Robert A. Clifton[1]

The United States may no longer be the world's largest consumer of asbestos, since the U.S.S.R. probably consumes as much or more (figure 4). The domestic construction industry presently uses the majority of asbestos fibers in products such as asbestos-cement pipe and sheet, roofing products, flooring products, paints, and caulking, and should remain the largest user. U.S. mines produced 17 percent of our consumption needs in 1976. Canada is the leading supplier of asbestos imports (about 95 percent), with the Republic of South Africa second. South Africa supplies all of the U.S. demand for crocidolite and amosite, and the majority of imports from there are these fibers.

The rate of growth in the use of asbestos continues higher in the developing countries. Asbestos reserves could well be in danger of depletion by the year 2000, at the forecast rates of consumption, if the "find" rate of new sources does not increase.

Canada could remain the world's leading producer, in spite of the rise of production in the U.S.S.R., as activity in exploration, evaluation, and development of asbestos deposits remains high. U.S. demand shows some signs of abatement; however, this decline may be attributed to the temporary effects of the economic recession. There are several new inorganic fibers available, but they pose no present serious threat to the major asbestos markets. The present, and possibly chronic, world shortage, coupled with a growing demand-reserve ratio, suggest the need for research to find adequate substitutes.

The health hazards associated with asbestos are undergoing close scrutiny by the Federal and local governments, unions, industry organizations, and concerned environmentalists. Although prolonged controversy seems probable, efforts to minimize the hazard may permit the continuance of important uses of asbestos in the economy.

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INDUSTRY STRUCTURE

Canada, with major activity in the Province of Quebec, leads the world in both total quantity produced and the size of individual mines and mills. The U.S.S.R. is also a major world asbestos producer. The Republic of South Africa, the People's Republic of China, Italy, and the United States mine substantial tonnages and, in combination with Canada and the U.S.S.R., produce over 90 percent of the world's supply. Chrysotile is the variety wanted by over 95 percent of the world's consumers. Most of the data in this report relate to chrysotile, and hereafter the term "asbestos" will mean chrysotile unless otherwise designated.

Total world production in 1975 was an estimated 4.5 million tons of all grades and varieties (table 1). Canada's share, because of a prolonged strike, was just 25 percent; the U.S.S.R produced an estimated 46 percent; the Republic of South Africa, 9 percent; the People's Republic of China, 4 percent; Italy, 4 percent; and the United States, 2 percent. Recent published data on world production do not credit U.S.S.R. production with the lower grades that are not used as fibers.

Geographic Distribution

In 1963, there was only one major asbestos-producing mine in the United States, GAF's Lowell mine in Vermont. During that year, another mine of similar size and output, and three lesser mines began operating in California. In 1974, all of the major producers operated, but in California, the largest mine and a lesser one closed during the year. In 1976, the largest California mine reopened under new ownership. Major domestic production is limited to Vermont and California.

An area roughly 75 miles long and 5 to 6 miles wide, beginning 80 miles east of Montreal, Canada, and continuing eastward con-

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Table 1.—World asbestos production, 1975, and capacity, 1976 and 1980

(Thousand short tons)

	Production[1] 1975	Capacity 1976	Capacity 1980
Chrysotile:			
North America:			
Canada	1,140	2,000	2,600
Mexico	----	----	50
United States	99	125	130
Total	1,239	2,125	2,780
South America:			
Argentina	1	1	1
Brazil	72	75	90
Total	73	76	91
Europe:			
Bulgaria	24	25	30
Finland	3	0	0
Italy	162	173	180
U.S.S.R.	2,090	2,200	2,600
Yugoslavia	14	19	40
Other	----	4	5
Total	2,293	2,421	2,855
Africa:			
Rhodesia	180	180	200
South Africa, Republic of	162	90	100
Swaziland	41	48	55
Other	1	1	1
Total	384	319	356
Asia:			
China, People's Republic of	165	180	200
Cyprus	35	36	40
India	23	25	30
Japan	5	26	25
Korea, Republic of	4	7	7
Taiwan	2	4	4
Turkey	17	18	25
Total	251	296	331
Oceania: Australia	40	73	100
World chrysotile total	4,280	5,310	6,513
Crocidolite:			
South Africa, Republic of	149	194	200
Australia	----	21	21
World crocidolite total	149	215	221
Amosite: South Africa, Republic of	80	120	130

[1] 1975 production, with the exception of Canada and the United States, was at capacity.

tains not only the world's largest mine and mill, but, in toto, the largest concentration of known deposits in the world. Mergers and closings have reduced the number of operating companies to five in this "Eastern Townships" region, stretching from Danville to East Broughton, Quebec. Four of the companies are either totally or partially owned by U.S. corporations, most of which manufacture asbestos-containing products. New Canadian mines continue to be opened. The Asbestos Hill mine of the Asbestos Corp., located in northern Quebec on the Ungava Peninsula, opened in 1973 and continued production, while the even newer United Asbestos Corp. mine in Ontario closed in 1977 because of financial problems. Canadian production in 1976 totaled 1,707,000 short tons; that of the United States totaled 114,842 short tons.

Most Soviet asbestos is used domestically or in other countries that have centrally controlled economies. The large mine and mill complexes in the Bajenova district of the Urals, the Dzhetygara mine in Kazakhstan, and Ak-Dovurak in Tuva are to be joined by the Kiembay combine under construction in Orenburg Oblast and the planned development of the Molodezhnoye and Il'chirsk deposits at Buryat. A new combine in Kazakhstan is to be a joint venture with several centrally controlled economy (COMECON) nations as partners.

Rhodesian chrysotile deposits retain importance in the world market. The generally tight supply would assure this, but the chronic worldwide shortage of spinning grade fibers accentuates it. Although presently available, domestic and Canadian production of these long fibers has not satisfied U.S. demand during most of the past decade. Imports of the low-iron spinning-grade fibers needed in the electrical-insulation and textile segments of the industry are no longer entering due to the 1977 repeal of the "Bryd Amendment," which exempted strategic materials from United Nations sanctions against Rhodesia. Swaziland and the Republic of South Africa are also major producers of chrysotile. South Africa is presently the sole producer of amosite and crocidolite, which are in diminishing demand. "In continent" use of African asbestos is increasing, but the large majority is still sold on the world market.

Five mine and mill operations were run by as many companies to produce asbestos in the United States in 1976. Three of the operations were in California and one each in Arizona, Vermont, and perhaps North Carolina. The California companies are Atlas Mineral Corp., Calaveras Asbestos Ltd., and Union Carbide Corp. Jaquays Mining Corp. operates in Arizona, and Vermont Asbestos Group, Inc., in Vermont. There was some anthophyllite produced domestically in 1976, reported to have come from North Carolina. Total employment in the five firms was 397.

The fully integrated Johns-Manville Corp. is the largest asbestos producer in Canada, and is a major supplier to the world market. Johns-Manville's many manufacturing plants in the United States use large quantities of asbestos as a raw material.

Turner & Newell, Ltd., based in Manchester, England, is another fully integrated company with worldwide operations. Its mines are in Rhodesia, the Republic of South Africa, and Canada. Its Canadian subsidiary, Bell Asbestos Mines, Ltd., has a mine at Thetford, Quebec, and a large minority holding in Cassiar Asbestos Corp., which has mines in British Columbia

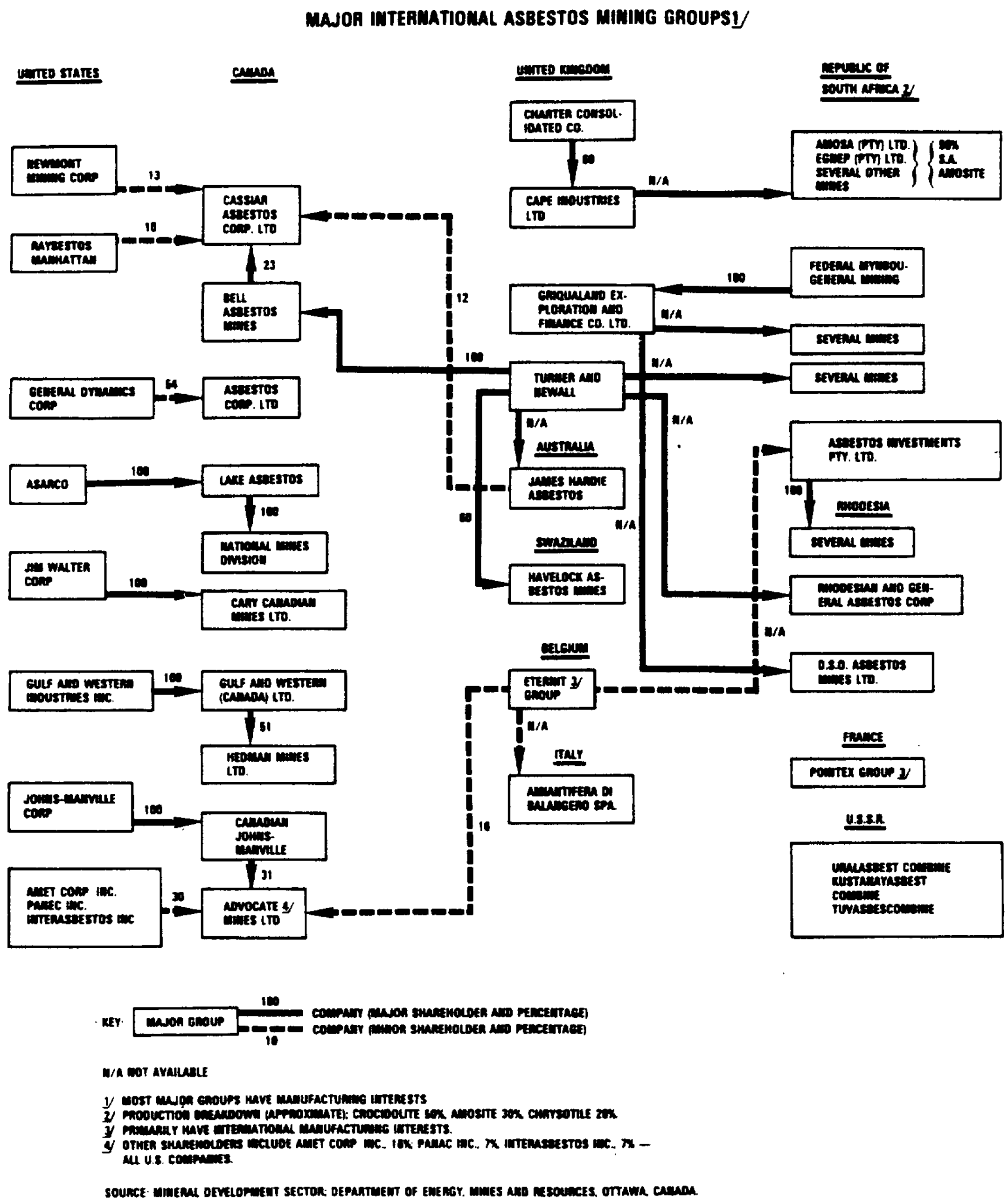

Figure 1.—Major international asbestos mining groups. Figures above arrows indicate percent ownership of company shares.

and the Yukon. Bell acts as selling agent for Cassiar.

Much of the world market for asbestos from the Republic of South Africa is met by the Cape Asbestos Co., Ltd., London. This fully integrated company developed the mines there to feed its asbestos-product plants in Europe and North America.

The larger international asbestos groups and their affiliations are depicted in figure 1 *(20)*[2].

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Definitions and Grades

Asbestos is a name applied to a number of naturally fibrous minerals. The principal variety is chrysotile from the serpentine group, a hydrous magnesium silicate with the theoretical formula $Mg_6Si_4O_{10}(OH)_8$. Other commercial varieties (all amphiboles) are amosite, a trade name for a complex iron-magnesium silicate (mostly cummingtonite-grunerite), $(Mg,Fe^{+2})_7 Si_8O_{22}(OH)_2$; and crocidolite, a sodium-iron hydrous silicate variety of riebeckite, $Na_2Fe_3{}^{+2} Fe_2{}^{+3} Si_8O_{22}(OH,F)_2$. Of minor importance are tremolite asbestos, $Ca_2(Mg,Fe^{+2})_5 Si_8O_{22}(OH,F)_2$, and anthophyllite asbestos, $(Mg,Fe^{+2})_7 Si_8O_{22}(OH,F)_2$ (*1*,*5*).

Chrysotile, the principal variety of commerce, is graded and grouped according to fiber length. Most of the groups are divided into several subgroups to comprise the commercial specifications. One producer alone offers its customers 420 grades of fibers in 1,320 different forms (*16*). For some uses, the chemical composition is important. Thus, for electric insulation, an upper limit for the iron content may be specified. The methods of classification used in the principal producing countries are discussed in detail in another Bureau of Mines publication (*3*).

USES

All uses of asbestos are as processed fiber. The processed chrysotile fibers are placed into the following groupings, which are based upon length of fiber:

Groups 1, 2, and 3.—These groups are composed of the longest fibers; the major end-use products include textiles, clothing, theatre curtains, different types of packings, fireproof textile products, woven brake linings, clutch facings, electrical insulation materials, and high-pressure and marine insulation.

Group 4.—Its major use is in asbestos-cement pipe, which is used mainly in transporting water, such as in municipal waterworks, irrigation, and conservation projects.

Group 5.—This group is used in asbestos-cement sheets, flat and corrugated sheets, low-pressure asbestos-cement pipes, and molded products. It is also used in some paper products such as pipe insulation, wrappings, and other products, including brake linings and gaskets.

Group 6.—The main consumption for this group is in asbestos-cement products, gaskets, brake linings, vinyl sheet backings, and millboard.

Group 7.—The group is used in molded brake linings and clutch facings, as a filler in vinyl and asphalt floor tile, and in asphalt compounds, joint and insulation cements, roof coatings, plastics, and caulking compounds.

Asbestos-product plants are located in 16 States, principally in the eastern, southern and West Coast areas.

Asbestos is adaptable to more than 2,000 uses. Because of its high strength-to-weight ratio and resistance to searing temperatures, it is used in rockets and missiles. Amosite is used for felted insulation in blanket form for high-temperature service up to 900° F. A loosely compacted form is applied as a covering for marine turbines, jet engines, and similar applications. Amosite is also used as a constituent of 85-percent-magnesia insulation and light-weight, fire-resistant marine partition board. Long-fiber crocidolite ("blue asbestos") is woven into fabrics for locomotive-boiler lagging (in Great Britain) and for acid-resistant packings and gaskets. The principal use of the shorter crocidolite fibers is in making asbestos-cement pipe. Tremolite asbestos and anthophyllite asbestos are used for chemical-resistant filters, as welding-rod coatings, and as fillers in various products.

World end-use patterns are not discernible from available data, and projections of U.S. patterns to the rest of the world cannot be justified. In 1970, 70 percent of the world's asbestos was reportedly connected with products used in the construction industry (*12*). This still seems reasonable and can be used for planning purposes. The remaining 30 percent is divided among a myriad of uses.

RESERVES–RESOURCES

Whether the U.S. asbestos reserves shown in table 2 will become resources is debatable. Presently, the economic pressures of remaining competitive while making large capital expenditures to meet environmental regulations are being easily overcome by a buoyant world market in which demand exceeds supply. The strong demand is expected to continue but there is a real anxiety in the industry about proposed regulations that would exceed the technological capability to meet at any cost.

The possible million tons of asbestos fiber at the Copperopolis, Calif., deposit are, under present environmental regulations, economic. The future of the millions of tons of short fibers available in the Coalinga, Calif., area is doubtful, because of low demand and environmental costs.

[1] Italicized numbers in parentheses refer to items in the list of references at the end of this report.

The world reserve picture seems better than the domestic one. In 1973 demand outstripped capacity to produce for the first time in recent years. Johns-Manville's Jeffrey mine, the world's largest, had sold its total annual production by August. In 1974, there was a slight reduction in American consumption and Canadian production. In 1975, the landslide at Jeffrey mine and the 7-month strike at the mines around Thetford Mines reduced Canadian production to 63 percent of that in 1974. During the strike, 55 percent of the normal supply for U.S. consumption was disrupted. This heightened the world demand which, even without this aberration, gave indications that it could seriously threaten world reserves by the year 2000.

Geology

Most chrysotile asbestos deposits, including those of Vermont and California in the United States, Canada, Southern Rhodesia, Swaziland, and Republic of South Africa, and the U.S.S.R., consist of irregular cross-fiber veins (closely packed fibers set at a right angle to the faces of the rock fractures) or slip-fiber zones (shear planes in rock, filled with fiber matted together parallel to the seam) in massive serpentine. Such deposits commonly extend to unknown depths. Those of Arizona, however, consist of more or less horizontal asbestos-bearing serpentine zones in thin-bedded limestone. Such deposits are generally less extensive and less persistent than those in massive serpentine. Amosite and crocidolite of the Republic of South Africa occur in banded ironstones that are so folded and contorted that the veins are very irregular.

TECHNOLOGY

Exploration and Development

Exploration and development are apparently increasing throughout the world because of the increasing demand for asbestos fiber and lack of production capacity to meet that demand. At least one major company is still actively exploring possible sites in the contiguous 48 States. Recently announced asbestos showings in the Eagle Quadrant in Alaska seem to be subeconomic.

Exploration in Canada remains quite active. Some large metal-mining firms are joining the asbestos firms in the search for new asbestos deposits.

Table 2.—Identified world asbestos resources

(Million short tons)

	Reserves [1]	Other resources	Total
North America:			
United States	9	65	130
Other	56		
Total	65	65	130
South America	5	4	9
Europe	52	20	72
Africa	22	14	36
Asia	7	8	15
Oceania	9	4	13
World total	160	115	275

[1] Based on average U.S. price of asbestos in 1975 of $144 per ton.

Mining

In Vermont and in the Copperopolis district in California, the fiber-bearing rock is removed from an open pit. In the Coalinga district of California, the highly sheared ore is simply "plowed" and allowed to air-dry, and the coarse fraction is then screened out from the mill feed. In Arizona, a heading is driven beneath the fiber zone; the zone is later blasted down and milled. The Canadian mines generally are open pits. The chrysotile of Southern Rhodesia, the Republic of South Africa, and Swaziland is obtained from underground mines. Amosite is obtained chiefly from large underground workings, and blue asbestos (crocidolite), from small open pits and shallow mines. The Soviet deposits are worked both in open pits and underground. Cyprus has large open pit workings.

The data (*17*) analyzed by least squares regression analysis and depicted in figure 2 tell a very interesting story about asbestos recovery from established mines over a period of time. In 1951, in the Quebec asbestos mines, 75 percent of the rock mined was milled, and 9.9 percent of that milled was recovered as fibers. About 20 years later (1970), only 32.2 percent of the rock mined was milled, and it yielded 6.1 percent fibers. Trend projection to the year 2000 indicates that only 24.4 percent of the mined rock will be milled, and 2.9 percent of the milled material will be fibers.

Many variables preclude prediction of the point when these trends would produce subeconomic resources, but they certainly portend escalating mining problems and costs.

Processing

Asbestos milling is a complex operation involving primarily the separation of fiber from rock and classification of fiber by length. There has been little change in the basic methods described in a previous Bureau of Mines publication (4).

Special milling techniques have been developed for the matted short-fiber chrysotile of the Coalinga district of California, including grinding and wet-milling.

In Copperopolis, Calif., Vermont, and Canada, the mills are large and complex. The fiber is classified in many grades, such as spinning, cement stock, and paper stock.

In many mills, asbestos fiber is packed under pressure in five-ply paper and/or woven vinyl bags. Each pressure-packed bag contains 100 pounds of asbestos and occupies about 2 cubic feet. With this pressure-packing, the asbestos measures 45 cubic feet per short ton.

Asbestos-producer research and development programs are engaged primarily in lowering mining costs and refining processes. For example, at Johns-Manville's Jeffrey mine in Quebec, 200-ton-capacity trucks are used to haul waste, pit rock, and overburden (*18*). Trucks of 100-ton capacity are used to feed the ore to a primary crusher, which can accept such a truckload from each of two sides simultaneously.

Process refinement research and development has paid dividends in two ways. Techniques have been developed that successfully recover short fibers from waste tailing piles by reprocessing. These also reduce dust levels in the mills, aiding in worker protection.

Automation and computer control of the asbestos milling circuits are not only under study (7) but also in operation. The new No. 6 mill at Jeffrey mine is a crusher-dryer-concentrator complex that is fully computer controlled (*18*).

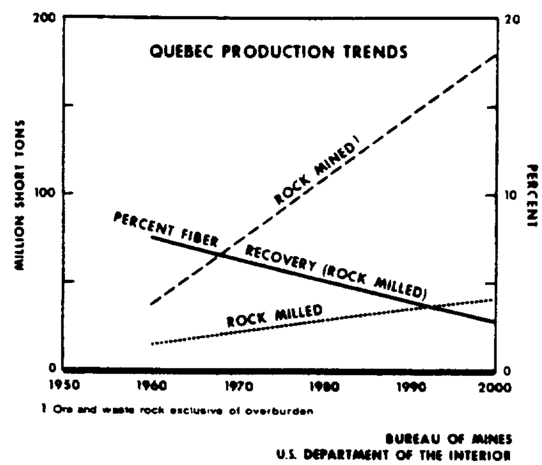

Figure 2.—Quebec production trends, from analysis of 1951–70 data.

Current Research

The largest area of research concerned with asbestos for the last few years has been in connection with the controversial health aspects of the fibers. The National Institute of Environmental Health Sciences, for example, started a multiyear animal-feeding study in 1976 to determine the health effects of ingested asbestos and asbestos-related minerals.

In late 1976, the Bureau of Mines established the Particulate Mineralogy Unit at College Park, Md., to help clarify the present confusion in particulate mineralogy, especially in regard to asbestos, and to develop a solid scientific basis for research into particle-related pollution problems and for the process of decisionmaking by regulatory bodies. The Bureau of Mines no longer has a research program aimed at either synthesizing analogs of the natural fibers or finding substitutes.

There are several synthetic inorganic fibers available commercially and more are becoming available each year. Most efforts seem to be aimed at thermal insulation, which constitutes only a small portion of the asbestos market. The most desirable characteristic of asbestos, its tensile strength, is compared with other fibers in table 3.

Glass-reinforced cement, now available commercially in the United States and Europe, could affect the future of the asbestos industry. The glass used is a high-zirconia, alkali-resistant fiber developed by the United Kingdom's Building Research Station. However, several drawbacks have been reported (*14*): The glass fibers have inferior drainage characteristics; they are formed by a costly spray-suction process; their strength gradually fails with time; and they cost about four times as much as the equivalent asbestos.

The exotic and very expensive inorganic whiskers, such as sapphire (Al_2O_3), are the only synthetic fibers that equal or surpass the strength of asbestos. Even the very newest inorganic fibers available commercially (*11*) are not as strong as glass and cannot be considered seriously competitive with asbestos.

The present shortages and projected demands indicate serious depletion of present reserves by the end of the century. Accelerated research is necessary to find substitute fibers that will have at least some of the attractive asbestos characteristics of strength, chemical inertness, heat resistance, and econony.

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Table 3.—Characteristics of some fibers (6)

Fiber	Tensile strength		Young's modulus		Specific gravity
	Kg/cm^2	$Lb/in^2 \times 10^3$	Kg/cm^2	Lb/in^2	
Crocidolite	35,000	500	172.2×10^4	24.6×10^6	3.2
Amosite	21,000	300	153.3×10^4	21.9×10^6	3.1
Chrysotile	28,000	400	155.4×10^4	22.2×10^6	2.4
Glass	15,500	250	73.0×10^4	8.5×10^6	4.6
Aluminum	1,800	25.6	70.0×10^4	9.9×10^6	2.7
Steel 5137	3,700	52.6	190.0×10^4	27.0×10^6	7.8

SUPPLY-DEMAND RELATIONSHIPS

Components of Supply

During the entire history of the asbestos industry in the United States, domestic sources have been able to meet only a small percentage of U.S. requirements. Vermont and the Copperopolis district of California have been the only consistent U.S. sources of Quebec-type asbestos. Both are predominantly producers of short fiber, but the Vermont asbestos mines produce about 500 to 700 tons per year of spinning-length fiber. Most of it is applied to nonspinning uses.

Canada furnished 96 percent of all the asbestos tonnage imported by the United States (1971–75), but only a small portion (2 percent) was spinning-grade fibers. The comparatively small quantities received from Africa, particularly those formerly received from Rhodesia, are more important than would appear on a tonnage basis because they consist largely of special kinds and qualities unobtainable elsewhere. Under emergency conditions, imports of spinning fibers are of primary importance. Imports of spinning fibers from Canada average about 15,000 tons per year. The longer fibers of chrysotile suitable for spinning represent a small fraction of the total production. Shortages of spinning-grade fibers have previously occurred and seem to be becoming chronic.

Imports of amosite into the United States from 1971 to 1975 averaged about 8,000 tons per year. During the first year of this period, the United States was purchasing for the national stockpile, and imported over 14,000 tons. Government purchasing stopped, and the imports totals were halved for 1972 and 1973. In October 1976, the Federal Preparedness Agency announced a stockpile goal for amosite to be 26,291 short tons. (See "Strategic Considerations.")

Imports of crocidolite advanced from 12,000 tons in 1954 to 24,000 tons in 1966, but averaged only about 10,000 tons per year from 1971 to 1975.

U.S. and World Production

In 1973, U.S. production of asbestos fiber was at an alltime high; however, production in 1974 and 1975 did not reach that level owing to the early 1974 closing of two California mines that represented about 40 percent of the 1973 production. The reopening of the Copperopolis, Calif., mine in 1976 by Calaveras Asbestos Ltd. brought domestic production up to 81 percent of the 1973 record high.

Canadian asbestos production continued to increase until 1974, when there was a small decline in production, followed by an additional 37-percent decrease in 1975. New production capacity will reportedly reach 520,000 short tons by 1980 (9).

A total of 1.15 million tons per year of new capacity is expected to become available in world markets during 1973–80 (9). This includes 300,000 tons of Soviet exports and production from mines in Australia, Colombia, Greece, New Zealand, Mexico, and Brazil.

A mill fire, landslide, and protracted strike combined to reduce Canada's 1975 production to only 1.14 million tons—61 percent of its 1973 high—and prematurely widened the expected gap between supply and demand.

Canadian production (all chrysotile) was 1.69 million tons in 1972, 1.97 million tons in 1974, 1.14 million tons in 1975, and 1.71 million tons in 1976.

The spinning grades of chrysotile asbestos produced in Southern Rhodesia were of great importance during World War II and the early postwar years because they constituted the principal source of low-iron chrysotile suitable for shipboard electric-cable construction. They were of renewed importance each time a spinning-grade shortage appeared. The only new source of asbestos with substantive amounts of spinning-grade fiber that has become available in the postwar years is the low-iron deposit of chrysotile that was opened in 1953 in British Columbia.

Production of amosite in the Republic of South Africa, which increased from an average of 20,000 tons per year during the 1940's to 100,000 tons in 1973, dropped to 88,000 tons in 1975.

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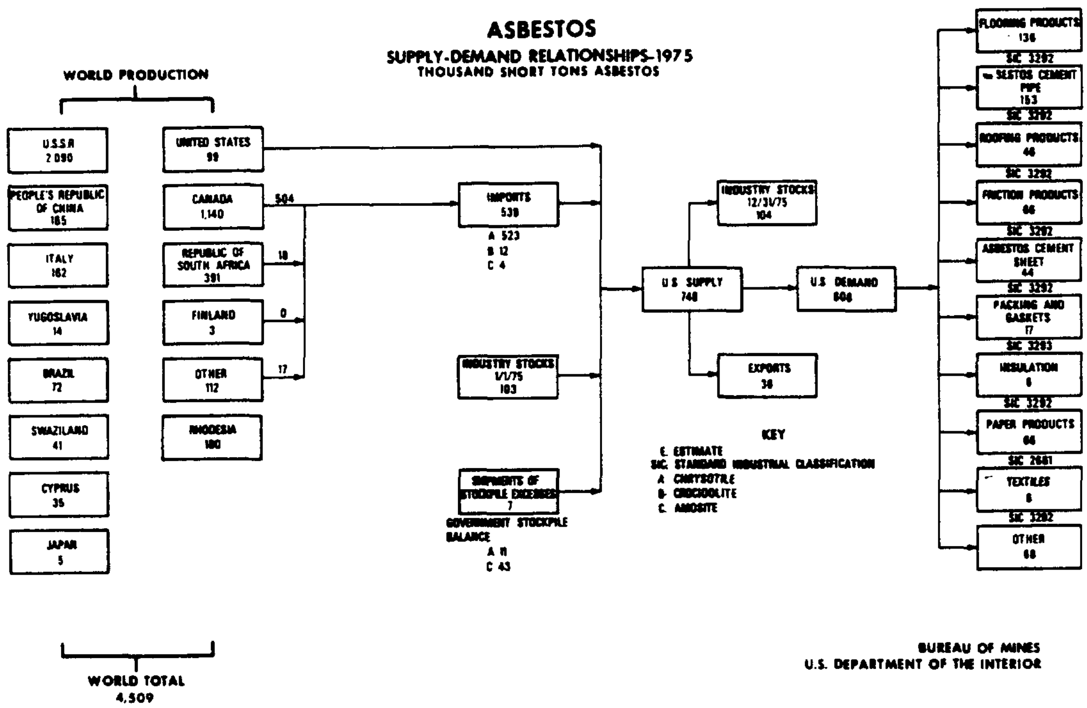

Figure 3.—Supply-demand relationship for asbestos, 1975.

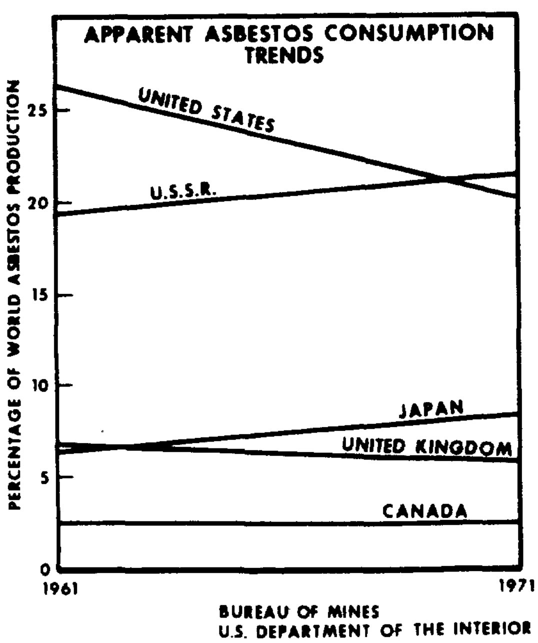

Figure 4.—Apparent national asbestos consumption trends.

Crocidolite is mined only in the Republic of South Africa. African production of crocidolite has increased from an annual average of 10,000 tons during the 1940's to 165,000 tons in 1975.

U.S. and World Consumption

In 1972, the Bureau of Mines began collecting data on domestic asbestos consumption on a greatly revised canvass form that negates efforts at comparison with previous years. Industry cooperation has resulted in more complete data, and further revisions of the form are planned. The data in table 5 have been adjusted to reflect 100 percent of the apparent consumption. The 11 major uses in 1976 were as follows: Roofing products (34 percent), asbestos-cement pipe (19 percent), flooring products (15 percent), friction products (8 percent), paper (4 percent), asbestos-cement sheet (3 percent), plastics (2 percent), packing and gaskets (2 percent), coatings and compounds (2 percent), insulation (1 percent), and textiles (1 percent).

World consumption of asbestos is increasing at a much faster rate than that in the United States (fig. 4). Maintaining the 4.5-percent predicted growth rate may not be possible within the limits of production capacity. The recent economic recession had no apparent effect on world asbestos demand, because the Canadian production troubles in 1975 have masked trend developments.

Table 4.—Asbestos supply-demand relationships, 1967–76

(Thousand short tons)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
World mine production:										
United States	123	121	126	125	131	132	150	113	99	115
Rest of world	3,084	3,170	4,042	3,672	3,816	4,050	4,448	4,423	4,410	*4,885
Total	3,207	3,291	4,168	3,797	3,947	4,182	4,598	4,536	4,509	*5,000
Components of U.S. supply:										
Domestic mines	123	121	126	125	131	132	150	113	99	123
Shipments of Government stockpile excesses	1	1	5	11	8	16	7	29	7	2
Imports, chrysotile	618	703	669	626	660	724	771	747	523	646
Imports, crocidolite	15	14	11	9	7	5	13	11	12	10
Imports, amosite	13	20	15	14	15	7	8	8	4	2
Industry stocks, Jan. 1	19	17	18	23	21	30	98	103	103	104
Total U.S. supply	789	876	844	808	842	914	1,045	1,011	748	887
Distribution of U.S. supply:										
Government acquisition	1	----	----	7	----	----	----	----	----	----
Industry stock, Dec. 31	20	18	24	20	29	46	103	103	104	115
Exports	47	41	36	47	54	59	66	62	36	47
Industry demand	721	817	784	734	759	809	876	846	608	725
U.S. demand pattern:										
Flooring products	179	204	196	184	191	202	218	153	136	113
Asbestos cement pipe	134	155	149	139	144	154	166	222	153	140
Roofing products	71	82	79	73	76	81	87	76	46	253
Friction products	65	74	71	66	68	73	79	80	66	64
Asbestos cement sheet	51	57	56	51	53	57	64	96	44	23
Packing and gaskets	22	25	24	22	23	24	26	29	17	20
Insulation	22	25	24	22	23	24	26	14	6	9
Paper products	14	16	16	15	15	16	18	63	66	31
Textiles	14	16	16	15	15	16	18	20	6	7
Other	145	163	154	147	151	162	174	94	66	65
Total U.S. demand	721	817	784	734	759	809	876	846	608	725

*Estimate.

Table 5.—U.S. asbestos distribution by end use, grade, and type, 1976

(Short tons)

	Chrysotile											
	Gr. 1 and 2	Gr. 3	Gr. 4	Gr. 5	Gr. 6	Gr. 7	Gr. 8	Total chrysotile	Crocidolite	Amosite	Anthophyllite	Total asbestos
Asbestos cement pipe	----	600	86,300	28,800	3,100	200	----	118,800	20,300	2,800	----	140,000
Asbestos cement sheet	----	1,000	2,100	3,600	9,800	5,900	----	22,400	----	200	100	22,700
Flooring products	1,500	1,100	----	6,300	600	104,000	----	113,500	----	----	----	113,500
Roofing products	----	----	----	400	1,900	251,300	----	253,600	----	----	----	253,600
Packing and gaskets	----	1,800	5,900	6,300	700	3,300	----	20,000	100	----	----	20,100
Insulation, thermal	----	----	800	200	1,900	3,600	----	6,500	----	100	----	6,600
Insulation, electrical	----	100	----	100	200	1,900	----	2,300	----	----	----	2,300
Friction products	----	2,800	1,500	21,100	6,800	31,000	200	63,400	----	100	300	63,800
Coatings and compounds	----	----	300	300	100	19,200	----	19,900	----	----	----	19,900
Plastics	----	200	2,800	100	1,200	15,400	----	19,700	700	----	1,100	21,500
Textiles	200	6,900	300	----	----	----	----	7,400	----	----	----	7,400
Paper	----	100	1,600	3,300	22,200	3,500	----	30,700	300	----	----	31,000
Other	----	300	800	2,500	4,400	14,700	----	22,700	----	1,200	----	23,900
Total	1,700	14,900	102,400	72,800	52,900	454,000	200	698,900	21,400	4,500	1,500	726,300

World Trade

If one were to remove from consideration the asbestos produced in the People's Republic of China (nearly all is used domestically) and that produced in the U.S.S.R. (most of which is used domestically or in other COMECON countries), a truer picture of Canadian prominence emerges. In the rest of the world, Canada had 67 percent of the market in 1973; the Republic of South Africa, 12 percent; Italy, 6 percent; and the United States, 5 percent. In 1975 (Canada's low year), Canada had 51 percent of this market; the Republic of South Africa, 17 percent; Italy, 7 percent; and the United States, 4 percent.

Canada's main markets are the United States and Europe, but there is a considerable trade in the Far East. South Africa sells most of its asbestos to European and African companies. The market for Italian asbestos is mainly in Europe.

Recycling

Asbestos fibers cannot be recycled in their common role of reinforcing a host matrix because removal from the matrix would destroy the fibers.

There are few asbestos uses (mainly textile) that have uncombined fibers in the end product. When these products are no longer useful, neither is the asbestos because of the physical and/or chemical changes that have made it a different mineral with less strength or shorter fibers of less value than reclamation costs.

Table 6.—Current stockpile goals and Government inventories as of December 31

(Short tons)

	Stock-pile goals	Total inventories 1975	Total inventories 1976	Sales of excesses 1976
Amosite	26,291	45,293	42,623	2,670
Chrysotile	None	10,956	[1] 10,965	----
Crocidolite	None	2,478	[1] 2,474	----
Total	----	58,727	56,052	2,670

[1] Adjusted figure, Federal Preparedness Agency.

Thus, asbestos is a nonrenewable natural resource with substitutes in only a few of its many uses.

Table 7.—Time-price relationship for asbestos

Year	Average annual price, dollars per short ton: Actual price	Average annual price, dollars per short ton: Constant 1975 dollars
1956	89.78	161.63
1957	88.09	172.38
1958	90.50	174.34
1959	91.17	171.83
1960	94.62	175.35
1961	95.60	175.61
1962	94.85	171.09
1963	92.44	164.31
1964	98.70	172.73
1965	97.92	167.67
1966	100.63	166.82
1967	101.91	164.11
1968	98.93	152.46
1969	110.03	161.46
1970	115.64	161.06
1971	117.54	155.76
1972	116.63	148.42
1973	122.22	147.01
1974	122.27	133.65
1975	144.14	144.14
1976	206.31	197.56

STRATEGIC CONSIDERATIONS

During World War II, controls were in effect to restrict exports of asbestos needed in the military program. These controls were removed by executive order on September 10, 1945. During the Korean war, the supply situation again became acute, and in 1950 and 1951 controls were invoked that required licenses for export of all grades of asbestos. The license requirement was removed for the nonspinning grades in 1953 and for spinning fibers in 1954; however, export licenses are still required for shipments to nations that have centrally controlled economies.

The United States joined the United Nations embargo of Rhodesian products in 1967. By 1969 all Rhodesian asbestos except occasional small lots released from bonded warehouses or the government stockpile had disappeared from the U.S. market. In 1971 an exception to the sanctions for strategic materials, including asbestos, was enacted by Congress. Significant amounts of Rhodesian asbestos were appearing at U.S. ports by the time the sanctions were reimposed early in 1977.

Chrysotile and amosite are the only types of asbestos remaining on strategic stockpile lists, but the present goal for chrysotile has been reduced to zero, although a moratorium on acquisitions and disposals went into effect in February 1977, and there was some chrysotile on hand. The status of the asbestos in the stockpile as of December 31, 1976, is shown in table 6.

The United States is historically dependent upon foreign sources for about 90 percent of its requirements for all grades and types of asbestos. The principal sources of low-iron, spinning-grade chrysotile asbestos are British Columbia in Canada and previously Rhodesia. A small amount of low-iron, long-fiber chrysotile is available from Arizona. The only source of commercial grades and quantities of amosite is a limited area in the Transvaal, Republic of South Africa. The United States is completely dependent on foreign sources for crocidolite. Although the United States is an asbestos-importing country, there is some export trade, because domestic chrysotile producers have significant markets in Japan and Latin America. There are some reexports of foreign fibers.

The Asbestos Corp.'s bulk shipments of concentrate (30 percent fibers) from its Asbestos Hill mine in Canada to its new mill in Nordenham, West Germany, was novel. The operation, started in 1972, may portend other changes in the world market, since it has been singularly successful.

ECONOMIC FACTORS AND PROBLEMS

Prices and Costs

Prices for Canadian asbestos continued to climb, with a 14-percent increase in 1977. Quebec chrysotile fiber prices in 1977, f.o.b. mine, ranged from Can$85 per short ton for 7T, which is the shortest of the regular grades generally produced, to Can$1,700 for the longest of the milled fibers. Crude No. 1 was quoted at Can$4,000 per ton. British Columbia (Cassiar) sold for Can$268 for CZ to Can$3,621 per ton for Crude No. 1.

Vermont chrysotile, produced in grades similar to those in Canada, ranged in price in 1977 from $82 for Group 7 to $477 for Group 4, f.o.b. mine. Arizona fibers ranged in price from $100 for Group 7 to $3,000 per ton for No. 1 crude, f.o.b. Globe, Ariz.

The average price for amosite, f.o.b. U.S. ports in 1976, was $561 per short ton; for crocidolite, prices averaged $579 per short ton.

The total value for the 114,842 tons of asbestos produced in the United States during

1976 was $23,693,000, averaging $206.31 per ton f.o.b. mine site. The imports of asbestos for consumption were valued at $153 million.

Least-square-regression analysis of a 10-year period of Canadian asbestos production (fig. 5) is taken from the 1972 Minerals Yearbook. The marked divergence of the value and production lines shows graphically the inflationary trends. The upward slope of the production and export lines is indicative of the expanding world market. The slight divergence between the production and export lines illustrates that Canada's consumption growth rate exceeds that of production and that an increasing amount of Canadian asbestos is consumed domestically. Reasons for production cost increases (decline in grade of ore) are apparent in figure 2, although table 7, with the exception of 1976 data, indicates a steady decrease in unit value in constant dollars.

Taxes and Tariffs

There are no special taxes on the asbestos industry. Producers are granted a depletion allowance of 22 percent on domestic production and 10 percent on foreign production. Domestic asbestos producers have no tariff protection.

Transportation

The Quebec and Vermont deposits are within easy rail haul to most of the plants manufacturing asbestos products in the industrial areas of the Eastern United States. The African deposits are remote from the principal markets and have high transportation expenses, although African markets are increasing. Transportation from British Columbia, Canada, to any market area is costly. The Arizona producer also has transportation problems. The mines are in the vicinity of Globe, the nearest railhead, with an average haul to the railroad of about 50 miles, compounded by the distance to the major consumption centers in the northeast.

Consumption of asbestos is also growing along the west coast of the United States and other areas where fiber from California would be competitive, in terms of freight rates, with that from Quebec.

Packing for ocean transport, either way, is changing to containerization. South African shippers have developed packaging techniques that conform to our container requirements. Western U.S. producers package their export asbestos in intermodal containers. Rail shipments handle about 80 percent of asbestos shipments, but these are not yet being containerized.

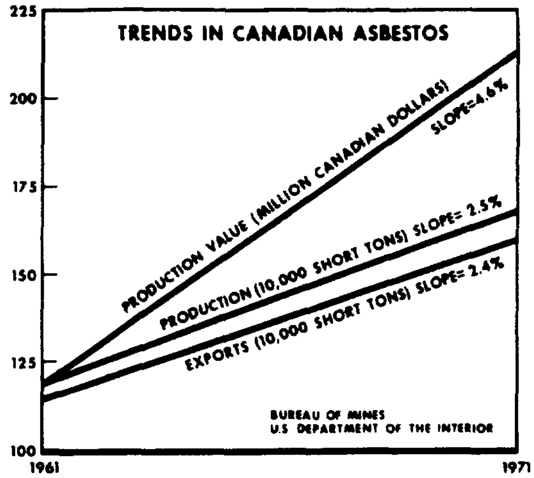

Figure 5.—Trends in Canadian asbestos production, exports, and production value, 1961–71.

Energy Requirements

The Bureau of Mines conducted a comprehensive study of the energy used in the asbestos-mining industry in 1973. The survey covered all producers in Arizona, California, North Carolina, and Vermont.

On a tonnage basis, energy used per ton of usable asbestos was equivalent to 1,500 kilowatt-hours. Estimated cost was $1.7 million, or $11.55 per ton. The ease of mining the Coalinga, Calif., deposit kept these data low.

In contrast to the Bureau of Mines study are the data in table 9, extracted from a University of Illinois study (*15*). They demonstrate the energy costs of a large mine and mill with higher extraction energy requirements than the average U.S. producer. Their energy requirements per ton are equivalent to 2,823 kilowatt-hours. These data compare favorably with a report from Battelle Columbus Laboratories (2), which found the energy used per ton of asbestos produced to be 2,492 kilowatt-hours.

The following table (*8*) demonstrates the need for asbestos by the energy-producing industries during the period 1975–90:

Energy industry	Short tons
Geothermal powerplants	58,532
Nuclear fission powerplants	53,393
Oil and gas refineries, port facilities, liquid natural gas, pipelines	49,449
Fossil fuel powerplants	305
Coal mines and transport	97
Uranium mining and processing	85
Bioconversion	1
Total	161,862

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Table 8.—Energy used by the U.S. asbestos mining industry, 1973

Source and unit	Used in mining	Used in milling	Total used	Total (thousand kilowatt hours)
Heavy fuel oil .... thousand gallons..	852	1,345	2,197	96,358
Natural gas .... million cubic feet..	----	168	168	50,736
Electricity .... thousand kilowatt hours..	2,641	44,974	47,615	47,615
Diesel oil .... thousand gallons..	412	133	545	22,147
Liquid petroleum gas .... do	14	168	182	6,987
Gasoline .... do	52	12	64	2,343
Total energy, thousand kilowatt hours	59,192	166,994	226,186	226,186

OPERATING FACTORS AND PROBLEMS

In 1970, Congress enacted "The Clean Air Act." Among the provisions of that act was that the Administrator of the Environmental Protection Agency (EPA) could designate substances as "hazardous air pollutants." One of three substances named to the first list on March 31, 1971, was asbestos. This was the first Federal agency to address the growing controversy about the effects of asbestos dust upon the health of humans.

There is insufficient space to document the conflicting reports, and insufficient data to evaluate the validity of each. The few areas of consensus are as follows:

1. Prolonged occupational exposure to heavy concentrations of asbestos dust, in the absence of personal protective devices, can measurably increase the chances of a person contracting the type of pneumoconiosis called asbestosis.
2. Exposure to asbestos may increase the chances of contracting the very rare type of cancer called mesothelioma.
3. Asbestos workers exposed to heavy concentrations of dust without respiratory protection, and who are also heavy smokers, have increased chances of contracting lung cancer.
4. The evidence concerning the possible hazard from ingestion of asbestos particles is contradictory and inconclusive (*10*).

There is no consenus about a threshold limit value (an acceptable concentration that would minimize danger from exposure), or even a method of measuring it. EPA says there is no acceptable way to measure asbestos in the ambient air. The Occupational Safety and Health Administration (OSHA) of the Labor Department uses a membrane filter and microscopy method with a present standard of two fibers greater than 5 micrometers in length per milliliter of air. The method used by the Mining Enforcement and Safety Administration (MESA) approaches the OSHA method; one MESA group uses the two fiber level and another uses a five-fiber level, but is currently moving to the two-fiber limit.

The controversial aspects of the matter appear to be of the long lasting variety with no early solutions in sight.

Table 9.—Energy consumed in the production of 1 ton of cleaned and graded chrysotile asbestos [1]

Stage and type of fuel	Amount [2]	Equivalent, thousand Btu
Mining: [3]		
Electric	38 kilowatt-hours	499
Diesel fuel oil	10.09 gallons	1,680
Bunker 6C oil [4]	1.32 gallons	245
Kerosene	0.04 gallon	7
Gasoline	0.46 gallon	70
Total	....	2,501
Primary crushing: Electric	6 kilowatt-hours	79
Secondary crushing: Electric	68 kilowatt-hours	892
Drying:		
Electric	38 kilowatt-hours	499
No. 2 fuel oil [5]	0.49 gallon	82
Bunker 6C oil [4]	13.97 gallons	2,593
Propane [6]	0.11 gallon	12
Total	....	3,186
Milling and grading: Electric ..	226 kilowatt-hours	2,966
Grand total	....	9,624

[1] Mine-plant transportation not included.
[2] Liquids converted from the imperial gallon (imp gal) to U.S. gallon using 1 imp gal = 1.200949 U.S. gal.
[3] Based on a large Quebec mine with a 3-to-1 ore ratio, 6 percent fiber per ton of ore, and 25 to 30 inches of mine precipitation per year.
[4] Based on caloric value of 154,046 Btu/gal.
[5] Based on average caloric value of 5,825,000 Btu per barrel.
[6] Based on average caloric value of 3,843,000 Btu per barrel.

An example of litigation in the controversy is the Reserve Mining Co. case, in which the company was sued by the Federal Government primarily for polluting Lake Superior with asbestos-bearing tailings, and secondarily for air pollution with asbestos fibers. The judgment rendered said there was no indication of harm from ingested asbestos, but that both the water and air pollution must be abated in a reasonable time.

The controversy had no effect in the marketplace in 1973 and 1974, in which years there were record high consumption and production. Any effects in 1975 and 1976 were masked by the shortages attendant to the Canadian production troubles and were not discernible.

Much research was funded by Congress to answer environmental questions. Some of these questions are as follows:

1. Is asbestos by and of itself a true carcinogen?
2. Are there significant differences, under the same conditions of exposure, between the toxicities of different types of asbestos?
3. What is the dose-response relationship to

asbestos dust exposure, or what exactly is a safe level of exposure?

4. Are there any physiological effects from the asbestos in the ambient air?

5. Is there a valid correlation between measurements of asbestos dust by the various methods?

6. Is there any physiological effect from asbestos ingested with food or water?

7. Are there valid correlations between the health effects of conditions of 30 years ago and those of today, or between occupational and incidental exposure to asbestos?

The health problems allegedly connected with exposure to asbestos dust continue to make headlines. Stories about the dangers of asbestos dust from air ducts, brake linings, road abrasion, and the erection and demolition of buildings are just a few of the late ones. These stories, whether valid or not, keep pressure on the regulatory agencies and may be a causative factor in OSHA's late 1975 proposal to reduce the safe exposure level to asbestos from 5 fibers greater than 5 micrometers in length per cubic centimeter to 0.5 fiber per cubic centimeter and the proposal a year later by the National Institute for Occupational Safety and Health to reduce the level even further to 0.1 fiber per cubit centimeter. As of July 1, 1976, OSHA's permissible-exposure level dropped to 2.0 fibers per cubic centimeter. As late as June 1977, no hearings had been held on the 0.5-fiber-per-cubic-centimeter proposal.

OUTLOOK

Demand

Domestic demand for asbestos is expected to increase slowly to between 1,026,000 and 2,000,000 short tons in the year 2000. The low of the range indicates an average annual growth rate of 1.0 percent; the high indicates 3.8 percent.

The forecast was derived by contingency forecasting of the major end use demands, considering possible shifts caused by either changing technology or dwindling resources during the forecast period (table 11).

Much higher than normal growth in demand was experienced by asbestos in the decade between 1940 and 1950. The total increase for that period was 200 percent above the 1940 level, one-half of it occurring during the war years and one-half in the following 5 years. Estimated annual growth rates of between 0.54 and 2.73 percent were obtained by correlation analysis between asbestos demand for the last 20 years and appropriate economic indicators. The quantity of asbestos indicated by this projection method for each end use was modified to obtain a demand range contingent on technologic or other changes in the consuming industries. About two-thirds of the asbestos demand in the United States during 1975 was consumed by the construction industry, and this ratio is expected to persist throughout the forecast period.

The U.S. probable demand for asbestos in 2000 is expected to be about 1.3 times that of the 20-year trend point for 1975. The rest-of-world demand should show a greater growth since the developing countries have a much greater new construction potential. Demand is likely to be limited by capacity to produce. This growth rate is estimated at 4.5 percent. If problems prevent an increase in general living standards in the rest of the world, the consumption of asbestos would represent an annual average growth rate estimated at 3.4 percent. The low of the range would be 8.6 million tons under these conditions. Table 10 summarizes forecast ranges for United States and the rest of the world. Figure 6 shows historical demand in the last 20 years and 10- and 20-year trend projections to the year 2000.

Demand for asbestos for use in the construction industry was projected to the year 2000 at an average annual growth rate of 0.3 to 0.5 percent on the basis of total new construction modified by the 20-year trend. The figures for the year 2000 are believed to be near the minimum that could normally be expected. However, substitution is possible in many of the end uses, particularly in asbestos-cement products, where a variety of alternative ceramic and new plastic materials are available, and in paints and caulking, where asbestos has a wide range of substitutes. The low end of the range for asbestos construction products was obtained by assuming a continuation of the 20-year trend.

On the high side of the demand range, the most apparent opportunities for increases above the forecast base appear to be asbestos-cement products, which compete with lumber and other building products, many of which are increasing rapidly in price. The growth rate for asbestos-cement products could average 4 percent per year and approach the anticipated growth rate for total new construction by the year 2000. Use of asbestos in floor tile has been increasing in recent years because of shortages and higher prices for some competing materials. Paper products are used in electrical appliances as well as in construction,

Table 10.—Summary of forecasts of U.S. and rest-of-world asbestos demand, 1975–2000

(Thousand short tons)

	1975	2000 Forecast range		Probable		Probable average annual growth rate 1975–2000, percent
		Low	High	1985	2000	
United States:						
Total	608	1,026	2,000	880	1,038	[1] 1.1
Cumulative [1]	....	22,600	33,300	8,400	22,900	....
Rest of world:						
Total	3,904	8,578	14,177	5,740	11,040	4.5
Cumulative [2]	....	147,000	200,000	47,500	172,000	....
World:						
Total	4,512	9,604	16,177	6,620	12,078	4.0
Cumulative	....	169,600	233,300	55,900	194,900	....

[1] Calculated from a 20-year U.S. demand trend of 791 for 1975.
[2] Calculated from a 10-year rest-of-world demand trend of 3,696 for 1975.

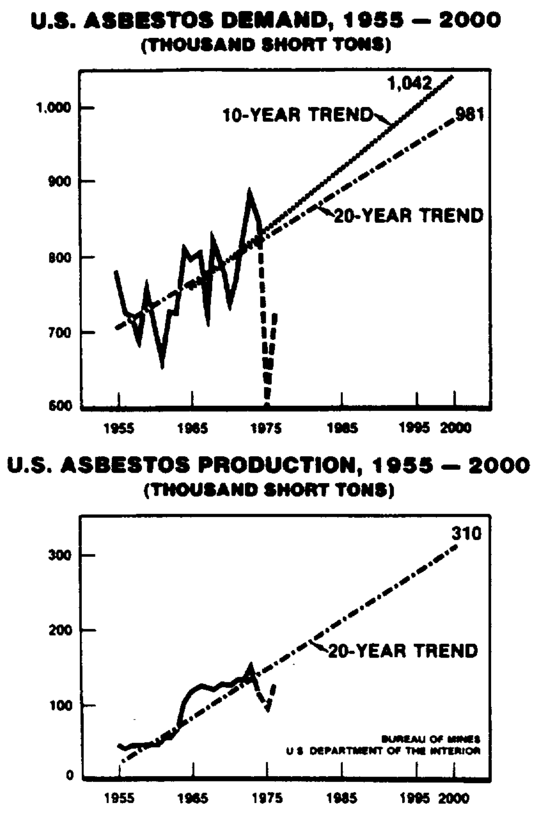

Figure 6.—U.S. asbestos production, demand, and projected trends to 2000.

and although the quantity for such use is relatively small, it is expected to grow more than 1 percent per year.

Asbestos demand for friction products was projected to the year 2000 at an annual rate of 1.5 percent. This figure was based on a formula derived from analysis of total asbestos demand modified by the estimated growth in the automobile industry and economic indicators, which showed the best correlation.

Asbestos is an important part of many types of friction materials for use in automobiles, trucks, and other transportation equipment. Modern industry could scarcely function without asbestos friction materials. In addition to using asbestos in brake linings, automobiles equipped with automatic transmissions get their drive from metal transmission disks, which are covered with a super-tough paper containing crocidolite asbestos. The average automobile with power shift contains from eight to twelve of the paper-lined disks. Although the quantity of asbestos in each transmission is small, the output of more than 8 million automatic transmissions annually requires disk-paper production of hundreds of tons.

A new composition disk-brakeshoe unit containing asbestos has been designed to meet the critical braking requirements for the new 150-mile-per-hour passenger train systems projected for U.S. use.

Based on an estimated forecast of the number of motor vehicles produced in the year 2000, and on the assumption that the use of asbestos per vehicle will remain at present levels, the forecast for asbestos demand in user-operated vehicles is projected to 118,000 tons. An increased number of transportation vehicles and equipment using parts made of asbestos or maintaining the present quantity used per vehicle could result in a demand as high as 189,000 tons.

Demand for asbestos in textiles was projected to 24,000 tons in year 2000 by formula derived from analysis modified by the 20-year trend.

Asbestos textiles are used in the manufacture of yarn and cloth, which is used in products such as safety clothing, packings, brake linings, and filters. Carded fiber filters are 100 pecent asbestos and are used for the clarification of oils and chemicals, and in some countries, for wine and beer. Asbestos lap is a felted form of carded asbestos fiber made for the electric wire and cable industry, as insulation for heater

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Table 11.—Projections and forecasts for U.S. asbestos demand by end use, 1975 and 2000

(Thousand short tons)

End Use	1975	2000: Contingency forecasts for United States: Forecast base [1]	Forecast range: Low	Forecast range: High	Probable
Asbestos cement pipe	153	244	270	527	274
Asbestos cement sheet	44	95	115	224	116
Flooring products	136	323	187	364	189
Roofing products	48	128	92	180	93
Packing and gaskets	17	38	35	68	35
Friction products	66	124	97	189	98
Insulation	6	39	17	33	17
Paper	86	28	76	149	77
Textiles	6	29	24	47	24
Other	68	256	113	219	115
Total	606	....	1,026	2,000	1,038

[1] The forecast base for friction products is derived from statistical analysis on data for 1960–75. All other 2000 forecast base figures are based on data for 1960–73.

cords, fixture wires, and other electrical conductors. Asbestos rovings are used by the electric wire industry to serve as insulation for heater cords, cables, and electrical heating elements. The projected growth of asbestos demand in electrical appliances coupled with design improvements that increase asbestos use could result in increased asbestos demand. On the other hand, there are other materials used as insulation that could replace asbestos for some purposes.

Because of its inherent incombustibility and thermal stability, asbestos cloth is extensively used whenever these properties are essential in a fabric. Many Government specifications requiring pipe insulation to be protected by an outside jacket of asbestos cloth are being revised for alleged health reasons. Many maritime specifications and industrial and utility powerplant specifications required asbestos cloth to hold the insulation in place and to serve as a permanent protection and fireproof jacket over pipe and boiler insulation. These are also being revised. Specially processed lint-free asbestos cloths serve as protective shields in nonradioactive areas adjacent to nuclear reactors.

Competition from other substitute material is not likely to be important, and no competitive factor is considered. Production of asbestos textile yarn, cord, and thread in 1963 was 19.7 million pounds and is assumed to be nearly the same now. Output of asbestos cloth in 1963 was 9.4 million pounds and 11.5 million pounds in 1968. Data for the last 5-year period (1968–73) are not available. Assuming that there will be some increased use of asbestos for such items as electrical appliances and fire-fighting equipment, the high projected demand could be 47,000 tons in the year 2000.

With low-cost, short-fiber asbestos available from domestic sources in large quantities, there should be a significant impact on the mineral filler market for a wide range of end products, particularly in products that must withstand high temperatures or corrosive conditions.

Supply

Domestic resources of chryostile are found mostly in California, Vermont, and Arizona. Although deposits are known to exist also in Montana, Oregon, Wyoming, and a few other States, production from these has been negligible. California has the greatest potential of becoming a substantial producer of short-fiber asbestos. In addition, anthophyllite asbestos is produced in North Carolina.

Nine of the major asbestos-product-manufacturing firms have captive fiber sources through U.S. and Canadian mines, either wholly or partially owned, (*19*). The total present production capacity of these mines exceeds 2 million short tons per year.

The United States has been dependent on foreign supplies of asbestos for certain essential and strategic grades. Canada supplies most of our requirements for chrysotile, with South Africa supplying amosite and crocidolite. The increasing world demand coupled with the forecasted shortfall in foreign supplies should encourage development of domestic resources. Such development of domestic asbestos deposits, if feasible under environmental regulations and coupled with advancing technology in the use of substitutes, could shift our position from heavy reliance on foreign supplies for this mineral.

United States and Canadian chrysotile resources are more than ample to meet the high of the forecast domestic demand for 2000, but could affect Canadian capability for supplying a major part of the demand in the rest of the world. The relationship between Quebec producers and U.S. consumers could be altered if the Provincial Government carries through on

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its announced interest in nationalizing the asbestos industry (*13*).

The relatively small requirements for amosite will continue to come from the Republic of South Africa unless deposits of a similar asbestos are discovered in other countries, or unless adequate substitutes become available at competitive prices, thereby providing acceptable options to the consumers. Crocidolite asbestos will also be obtained from the Republic of South Africa, and perhaps from Australia or Bolivia, so long as it remains competitive with chrysotile, but substitution is practicable in end uses, and continuation of crocidolite supply is not particularly significant.

Demand for asbestos in the United States for domestic consumption in 1976 was 725,000 tons, about 17 percent of which came from domestic sources; most of the balance was obtained from Canada and the Republic of South Africa. Annual requirements for asbestos in the year 2000 are not expected to exceed 2 million tons, the high of the forecast range (table 11). If the 1976 ratio of domestic production to demand prevails in the year 2000, the domestic production component required to meet the maximum expected demand would be 340,000 tons. This production could be accomplished from known resources only by much more extensive use of the low-cost, very-short-fiber Coalinga, Calif., material. Historical and projected domestic production and demand for asbestos are shown in table 12 and figure 6. The trend projections for demand are low compared with the forecast range, which is caused mainly by the time periods chosen for the trend projections. The demand growth for asbestos has averaged about 1.0 percent per year from 1954 to 1973 and about 0.4 percent per year from 1956 to 1975.

Table 12.—Comparison of domestic asbestos production and demand 1954–76, and projected production in 2000 based upon historical trends

(Thousand short tons)

Year	U.S. demand	Domestic production	
1954	724	46	
1955	782	45	
1956	728	42	
1957	724	43	
1958	685	44	
1959	754	46	
1960	709	45	
1961	666	53	
1962	726	53	
1963	724	66	
1964	813	101	
1965	795	118	
1966	805	126	
1967	721	123	
1968	817	121	
1969	784	126	
1970	734	125	
1971	759	131	
1972	809	132	
1973	876	150	
1974	846	113	
1975	608	99	
1976	725	115	
1985	[1] 880	[2] 216	[e] 160
2000	[1] 1,036	[2] 310	[e] 200

[e] Estimated.
[1] Probable forecasts from table 10.
[2] 20-year trend.

Possible Technological Progress

Although asbestos was synthesized in the late 1920's, and much work has been done since that time, an economical method of synthesis has not yet been announced. Technology must come up with competitive synthetic asbestos or asbestiform products and make them available in significant quantities before the end of the century for world demand to be met. The mineral raw materials needed for production of synthetic asbestos and other inorganic fibers are abundant.

Among the factors that should tend to increase asbestos demand within the next decade is the newly developed potential for large-scale production of low-priced asbestos from domestic deposits, which should in time spur research into new uses and into new ways to substitute short-fiber asbestos for the longer, more expensive types. The 1975 shortages drove some manufacturers to try such substitution with a degree of success. The domestic product is being used in asbestos-cement pipe and undoubtedly can be used in other products by adapting the production processes.

Work is underway which is aimed at developing large-scale asbestos uses, even in the face of the shortages. Foremost among these is the potential for use in asphalt paving materials, which must bear up under various difficult conditions. Examples are airport runways and hangar areas, which are subjected to high-temperature, corrosive effects of jet exhausts; street curbing, which must be able to absorb shock and forces from the wheels of motor vehicles; and resurfacing of old roads. Resurfacing requires about 35 tons of asbestos per mile of 40-foot pavement and probably has the greatest potential for large-volume asbestos use. Technological changes in roadbuilding methods could result in capping new highways with asbestos-rich asphalt.

Medical problems connected with asbestos have been under intense study in recent years and undoubtedly will continue to warrant increasing attention in the future. In addition to study and medical treatment of the effects of asbestos on the respiratory system, work should be aimed at improved methods for protecting workers in mines, mills, and fabricating plants. Among the possibilities for solving the problems (in addition to medical study and treatment) are much greater use of automation where feasible, remote control of fabrication processes, improved protective equipment and respiratory devices, and development and strict enforcement of safety procedures.

Remaining Problems

One of the most serious problems confronting the domestic consuming industry is our dependence for the greater part of our supply of asbestos on foreign sources. About 85 percent of the supply of chrysotile and all of the amosite and crocidolite comes from foreign countries. Complete dependence upon foreign supply for strategic grades can be minimized by adequate stockpiles.

Adequate information on the methods of mining and processing asbestos and development of equipment is available, but cost data are lacking. Information is available on the principal end products in which asbestos is utilized; however, there is no information on the wastage that takes place in the manufacturing of the end item.

The number of materials that are economically competitive with asbestos is limited. Although much research has been directed to synthesizing fibers that have properties similar to asbestos, it has met with only limited success. The development of practical technologic advances in this broad area would substantially improve the supply outlook.

Health hazards are present in the whole sequence of mining, processing, and utilizing asbestos, and the expanding use of this material demands continued attention to the problem.

Asbestos is not an energy-intensive mineral; on the contrary, it has a long association with energy-conservation products. Nonetheless, energy-conservation practices need further development in all phases of the mining, milling, and utilization of asbestos.

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