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TALC AND PYROPHYLLITE

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Mineral Facts and Problems,
1985 Edition

UNITED STATES DEPARTMENT OF THE INTERIOR

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William P. Clark, Secretary

BUREAU OF MINES

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As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island terrritories under U.S. administration.

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TALC AND PYROPHYLLITE

By Robert A. Clifton[1]

The mineral talc is a soft, hydrous magnesium silicate, $3MgO•4SiO_2•H_2O$. Commercial talcs range from the near theoretical mineral composition to mineral products that have physical properties in common with pure talc but contain very little of the actual mineral. Soapstone is a term used for a massive form of rock containing the mineral talc in quantities ranging from near theoretical to as little as 50%.

Ordinary usuage usally restricts the term "soapstone" to impure massive talcose rock, while the high-purity massive talc is called steatite. All three talc-containing minerals (talc, soapstone, and steatite) will be termed "talc" here. Wherever possible, pyrophyllite will be treated separately. Pyrophyllite is similar to talc in most of its physical characteristics and has the formula $Al_2O_3•4SiO_2•H_2O$.

Production of talc in 1983 was 980,000 tons[2] valued at $19 million. Pyrophyllite production was 87,000 tons valued at $1.3 million. Imports of talc and pyrophyllite combined were 44,000 tons.

The end uses for talc and pyrophyllite are similar but not identical, with talc having a wider end-use range including some higher quality filler applications for which pyrophyllite either does not qualify or is used to only a slight extent. Both are used in significant quantities in ceramics. Other significant uses for talc are in paints, roofing materials, paper, and plastics. Other major uses for pyrophyllite are in refractories and insecticides. Pyrophyllite, at least at present, does not share the expected boom of talc as a plastic filler-reinforcer.

A technologic change likely to increase future demand for talc significantly is replacement of structural steel parts in vehicles with lighter weight fiber-reinforced plastics to conserve energy. This expected increase was delayed over the past 5 years because of the introduction of smaller automobiles. Talc is an economic filler that enhances the properties, including strength, of the plastic matrix.

Supply problems have been mainly local and concerned with the distance between the consuming centers and the talc producing areas. Also, supply problems could develop if the export market were to expand rapidly or if there is a great increase in use in plastics.

The talc industry has an apparent environmental problem, the validity of which is very questionable. Tremolite rock, a desirable component of the talc used for ceramics, is an amphibole whose crystal structure demands that is cleave into elongate particles with parallel sides. Consequently, the ground product has been found to contain up to 20% of particles with an aspect ratio (length to width) of 3:1 or greater. Grinding action cannot manufacture fibers. These elongated particles, however, meet the regulatory definition of fiber and, consequently, they have erroneously been called asbestos and have had the negative health effects of asbestos imputed to them.

Solid waste problems could develop if heightened demand makes recovery and processing of low-grade deposits desirable.

[1] Physical scientist, Division of Industrial Minerals.

[2] The quantities used throughout this chapter are short tons unless otherwise specified.

INDUSTRY STRUCTURE

Background

Soapstone was first used in the United States by the American Indians, who early recognized the ease with which it could be shaped and its heat-retaining qualities and used it for bowls, pots, cooking stoves, and other utensils. These uses furnished the term "potstone," which still is applied to soapstone in some localities. The early European settlers on the North American Continent used heated, cut-soapstone bricks extensively as warning stones in carriages, sleighs, and beds—a practice that survived until recent times. Beginning between 1870 and 1880, tubs, sinks, hearthstones, mantels, fireless cookers, griddles, firebrick, and various utensils were manufactured from soapstone. The first talc-grinding mill was established at Gouverneur, NY, about 1880, and the product was used principally for paper filler.

From 1880 to 1900, inclusive, the annual output of the talc and soapstone industry of the United States was about 88,000 short tons valued at about $1 million. These figures included manufactured soapstone items.

Size and Organization

Talc was produced domestically in 1983 from 26 mines in Arkansas, California, Georgia, Montana, New York, North Carolina, Oregon, Texas, Vermont, Virginia, and Washington. Texas, Vermont, Montana, and New York, in order of volume, were the leading States and, with California, accounted for more than 97% production.

During 1983, pyrophyllite was mined at five sites in North Carolina. Also, two California mines were in operation, and one U.S. company shipped pyrophyllite from its Canadian mine for processing in Philadephia.

The five largest U.S. talc producers jointly provided nearly 75% of the total domestic output. Some of these firms produced talc exclusively. Others were horizontally integrated subsidiaries of diversified organizations. The principal domestic producers of crude talc and pyrophyllite were vertically integrated to some degree in that they operated grinding mills and processed the ground product in plants adjacent to the mines or in separate installations more conveniently located with respect to transportation and major markets. Part of the mineral from California and Montana was ground in Nebraska, Alabama, and New Jersey, and a substantial quantity of Montana talc was processed in Belgium prior to 1983.

Definitions, Grades, Specifications

The mineral talc is a hydrous silicate of magnesium, $3MgO•4SiO_2•H_2O$. In commercial talcs, compositions vary widely. Iron-mineral impurities such as magnetite, pyrite, and limonite can be present. These objectionable impurities are removed for most uses to the extent feasible. The talc of highest purity is derived from sedimentary magnesium carbonate rocks;

Table 1.—World talc and related mineral production, 1983, and capacity, 1983, 1984, and 1990
(Thousand short tons)

	Production	Capacity		
	1983	1983	1984	1990[1]
North America:				
United States	1,066	1,400	1,500	1,800
Other	120	140	170	200
Total	1,189	1,540	1,670	2,000
South America	560	600	700	800
Europe	1,735	1,900	1,900	2,100
Africa	25	30	70	100
Asia and Oceania	4,047	4,800	5,000	6,000
World total	7,553	8,870	9,340	11,000

[1]Forecast.

less pure talc comes from ultrabasic igneous rocks (*1*).[3] Tremolite, an amphibole, $2CaO \cdot 5MgO \cdot 7SiO_2 \cdot H_2O$, is associated with metamorphic rocks and occurs as bladed crystals or fibrous aggregates.

Pyrophyllite is a hydrous aluminum silicate similar to talc in properties and in most applications, its formula is $Al_2O_3 \cdot 4SiO_2 \cdot H_2O$.

Steatite has been used to designate a grade of talc suitable for making electronic tube insulators. Block steatite talc is a massive form of talc that can be machined readily and has a uniform low shrinkage in all directions and high electrical resistivity when fired at high temperature. Phosphate-bonded talc, a synthetic product, is equivalent to natural block.

Lava is a term frequently used in the trade to designate block talc or the finished products made from block talc. French chalk is a soft, massive variety of talc used for marking cloth. Soapstone refers to all massive gray to bluish or greenish talcose rocks, which with few exceptions have a slippery feeling and can be carved by hand.

Wonderstone, a massive block pyrophyllite from the Republic of South Africa, is a compact cryptocrystalline pyrophyllite containing rutile (TiO_2) and carbonaceous impurities. It is used as a pressure-transfer medium in the manufacture of synthetic diamond. It has the ability to maintain structural integrity at the ultrahigh temperatures and pressures required in diamond synthesis. Like lava, it can be easily machined in the green state to close tolerances, as required to accommodate the diamond-synthesis reaction capsule. It also serves as an electrical insulator during the compaction.

Grades of talc are most frequently identified with the end use. Important properties are softness and smoothness, color, luster, high slip tendency, moisture content, low oil and grease absorption, chemical inertness, fusion point, low electrical conductivity, high dielectric strength and high thermal conductivity.

Properties required for specific end uses are as follows:

Ceramics.—Uniform chemical and physical properties are required. Manganese and iron are usually objectionable. For high-frequency insulators, no more than 0.5% CaO, 1.5% iron oxide, and 4% Al_2O_3 can be tolerated.

Paints.—Impurities that grind to colors other than white are highly objectionable. To yield the desired smooth paint film, at least 98.5% must pass through a 325-mesh screen.

Roofing.—A low-grade offcolor and impure talc is acceptable.

Insecticides.—Requirements are chemical inertness with respect to toxicants, satisfactory bulk density, and low abrasive characteristics.

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

Rubber.—Many synthetic rubbers use ground talc as fillers in their compounding formulations. Volume changes, amount of filler, and particle size all affect the stress-strain characteristics of the product.

Paper.—Requirements include chemical inertness, softness, freedom from grit, satisfactory ink acceptance, brightness, and dispersibility in water.

Cosmetic and Pharmaceuticals.—Talc must be grit free, finely sized, chemically pure, and pleasing in color. For cosmetics, talc must have good dry slip characteristics.

As mentioned above, both color and purity are important characteristics of talc. They can be partially described by "brightness," which is a measure of reflectance in terms of percent compared with the reflectance of pure magnesium oxide.

The maximum fineness of talc in a given paint is often determined by the use of a Hegman gage, which consists of a precision steel block into which a wedge-shaped channel, 0.5-inch wide and up to 0.005-inch deep, has been cut and marked with a linear scale. A drop of paint is placed at the deeper end of the channel and scraped toward the end. Fineness is indicated at the point on the scale at which talc particles are seen to protrude above the paint surface. Hegman number and approximate particle size, respectively, are 8—6 micrometers; 7—13 micrometers; 6½—20 micrometers; 6—25 micrometers; 5—40 micrometers; 4—50 micrometers; and 3—65 micrometers.

RESERVES—RESOURCES

Talc deposits exist in every continent and all have similar geology. The geologic settings of these deposits have been summarized as always occurring as a secondary mineral formed in or from preexisting rocks; low-grade regional metamorphism established the conditions of formation of all deposits of economic interest; commerical ore bodies are molded after the shape of the parent material; and that, as far as genesis studies can determine, all talc formation occurred in the Precambrian era (*2*).

The definitions of reserve and reserve base are published in U.S. Geological Survey Circulary 831, "Principles of a Resource/Reserve Classification for Minerals," which is reprinted in the introduction to Mineral Facts and Problems, 1985 Edition.

Although at least 43 countries produced talc and pyrophyllite in 1983, the better commercial deposits were found in Australia, Austria, Brazil, China, Finland, France, India, Italy, Japan, North Korea, the Republic of Korea, the U.S.S.R., and the United States. Preliminary reports indicate that three talc areas in the United States and one in China may soon have expanded production and larger reserves.

The paper of Chidester et al. published in 1964, remains the primary reference on the geology of U.S. talc deposits (*1*). U.S. deposits are of three major types: those associated with sedimentary rocks as exemplified by the California-Nevada deposits and those in Montana, New York, and Texas; those associated with ultramafic igneous rocks, as the Vermont deposits; and those associated with mafic igneous rocks that occur in the Appalachian Mountains and are the source of most of our soapstone.

Winkler in 1974 presented the following reaction as the most probable method of forming pure talc deposits: 3 dolomite + 4 quartz + H_2O = talc + 3 calcite + $3CO_2$ (*3*).

Table 3 gives the composition of minerals often found associated with talc deposits. Note that chemical analyses like those reported in table 2 can point out the presence of specific minerals. The CaO found in both the New York and Georgia talcs, for example, correctly points out tremolitic talc.

Data on domestic reserves of the talc-group minerals are incomplete, but some tentative estimates have been published. In-

Table 2.—Typical chemical analyses of talc ores and products
(Percent)

	Pure talc (Theoretical)	1	2	3	4	5	6
SiO_2	63.36	35.98	59.15	47.92	62.65	59.80	54.92
MgO^2	31.98	32.95	31.34	26.00	30.23	27.45	27.20
Fe_2O_3	-	.65	3.36	6.82	1.51	.05	.46
TiO	-	.02	-	.15	-	-	-
Al_2O_3	-	.43	.26	7.35	.31	.57	-
CaO	-	-	.15	4.14	trace	6.80	5.76
K_2O	-	-	-	-	.05	-	-
Na_2O	-	-	-	-	.15	-	-
CO_2	-	20.45	1.76	-	.27	1.18	-
H_2O	4.75	2.73	4.30	.05	4.87	-	-
MnO	-	.41	-	-	-	.39	-
S	-	.06	-	.09	-	.03	-
NiO	-	.21	-	-	-	-	-
Cr_2O_3	-	.18	-	-	-	-	-
CoO	-	.01	-	-	-	-	-
FeO	-	5.96	-	-	-	.15	-
Less O for S	-	.05	-	-	-	-	-
P_2O_5	-	.01	-	.00	-	-	-
Loss on ignition	-	-	-	7.51	-	4.75	10.76
Total	100.00	100.10	100.32	100.03	100.04	101.17	99.10

1. Average Vermont carbonate ore.
2. Flotation talc, Johnson Mine, Vermont.
3. Roofing granules, Southern Talc Co., Georgia.
4. Steatite, Yellowstone Mine, Montana.
5. Average talc ore, talc Talcville, Gouveneur District, New York.
6. Texas talc.

Table 3.—Approximate composition of minerals present in talc ores
(Percent)

	SiO_2	MgO	CaO	CO_2	Fe_2O_3	Al_2O_3	K_2O	H_2O
Talc	63	32	-	-	-	-	-	3- 7
Serpentine (antigorite)	44	43	-	-	-	-	-	8-13
Chlorite	33	36	-	-	-	18	-	5-14
Anthrophyllite	58	30	2	-	-	-	-	15- 2.2
Tremolite	57	28	13	-	-	-	-	15- 2.3
Actinolite	52	5	9	-	34	-	-	3
Diopside	56	18	26	-	-	-	-	-
Feldspar	65	-	-	-	-	18	17	-
Magnesite	-	48	-	52	-	-	-	-
Dolomite	-	22	30	48	-	-	-	-
Calcite	-	-	56	44	-	-	-	-

formation available in the late 1950's pointed to U.S. reserves approximating 90 million tons (4). Further exploration and delineation have increased that estimate to 150 million tons, and recent reports have indicated that approximately enough new ore is being delineated to make up for that being mined. Much larger quantities could certainly be obtained at prices only moderately higher than those of 1983.

The largest bodies of domestic talc ore now known are those fairly pure ones in Montana and the tremolitic talc in New York State. It is anticipated that additional talc deposits of major importance will be found in Montana and other sections of the United States. Extensive exploration was undertaken recently in Texas and Vermont. Deposits of talc-group minerals of present, past, or potential commercial importance are known to exist in Alabama, Arkansas, California, Georgia, Maryland, Massachusetts, Michigan, Montana, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Pennsylvania, Rhode Island, Texas, Vermont, Virginia, Washington, and Wisconsin.

Pyrophyllite reserves in North Carolina alone are said to total at least 12 million tons, and, although estimates of quantities are not available for California and Pennsylvania, those States also have commerical deposits.

Definite information is limited on talc and pyrophyllite reserves in the rest of the world. However, deposits are known to be widely distributed, and the aggregate available tonnage is great. Immense deposits of talc-group minerals, enough to meet expanded world demand, are known to exist in a number of regions not presently industrialized. It is estimated that the world's reserves and reserve base of talc and pyropyllite are at least one-third of a billion tons and 1.3 billion tons, respectively. Much greater reserves would be available at world prices not markedly higher than those of 1983.

Table 4.—World talc and related minerals reserves and reserve base[1]
(Million short tons)

	Reserves	Reserve base[2]
North America:		
United States	150	600
Other	10	40
Total	160	640
South America	5	20
Europe	60	190
Africa	5	20
Asia and Oceania	120	400
World total	350	[3]1,300

[1]In collaboration with U.S. Geological Survey.
[2]The reserve base includes demonstrated resources that are currently economic (reserves), marginally economic (marginal reserves), and some of those that are currently subeconomic (subeconomic resources).
[3]Data do not add to total shown because of independent rounding.

TECHNOLOGY

Most of domestic talc production comes from open pit mines (*2*). Nevertheless, underground mines continue to be important sources of these minerals. In both types of operation, the extraordinary slipperiness of talc ore imposes unusual, but controllable, problems. Mechanized loaders and haulage units must be provided with special slip-reducing tires or chains, and haulage slopes must be kept to gentle gradients. Cribbing and timbering, when required for underground mining, must be placed with exceptional precision in order to minimize the lateral component of forces acting upon supporting members.

Mining operations for the production of mineral that is to be ground before marketing are usually carried out by conventional drilling and blasting methods, but extremely good housekeeping practices must be employed to avoid reducing the brightness of the talc or the inadvertant introduction of more abrasive materials. The extraction of material for block or lump purposes, for crayon stock, or for dimension stone requires minimum use of explosives. In these cases, masses as large as 4 by 8 by 10 feet are removed by hand equipment or by sawing. Final reduction to desired shapes and sizes is usually accomplished by the use of gang saws.

Technologic advances have freed the United States from dependence upon foreign sources for supplies of block steatite talc suitable for electronic components and other shapes. Synthetic block, meeting all requirements for this purpose and superior to the natural substance in dependable uniformity, can now be manufactured by applying a phosphate-bonding process to higher grades of platey talc that are abundantly available in the United States.

Selective mining and hand sorting are the methods most commonly used for improving the quality of the crude talc-group minerals, but froth flotation is being employed increasingly (figure 1). The softness of talc eases certain mining and processing operations.

Pit-run talc ore to be treated by flotation or to be pulverized before sale usually first passes through jaw crushers and then receives secondary size reduction in rolls or cone crushers. The following stage of grinding, down to 100- to 325-mesh sizes, is usually done in roller mills in closed circuit with air separators. Such mills are sometimes equipped with oil- or gas-fired combustion chambers to permit simultaneous drying and grinding. High-intensity magnetic separators are commonly added to the circuit to achieve a product with minimum content of iron. For the more abrasive ores such as tremolitic talc or ceramic-grade pyrophyllite, this grinding stage may be carried out in quartzite- or silex-lined pebble mills with quartzite pebbles as the grinding medium.

Microgrinding in fluid-energy mills enables talc to compete with alternative materials in the manufacture of paint, paper, plastics, and rubber. An attrition-grinding process, originally developed for the beneficiation of kaolin, has been applied advantageously to talc to yield an ultramicronized product especially suited for cosmetic and pharmaceutical preparations. The Bureau of Mines contributed basic research to this development, and a fourth publication by Stanczyk and Feld summarized the previous three. (*5*).

FLOWSHEET OF A VERMONT TALC MILL

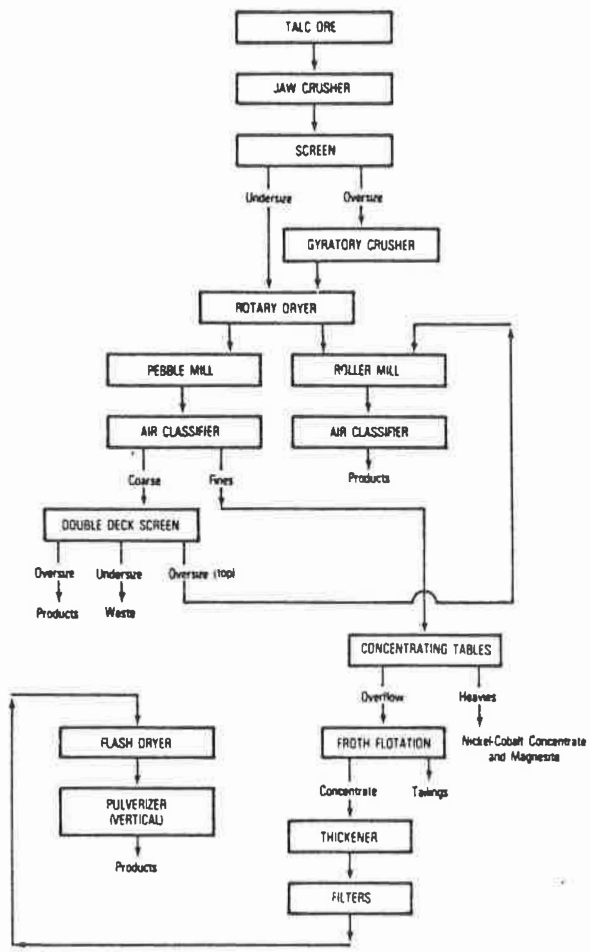

Figure 1.—Flowsheet of a Vermont talc mill.

USES

The members of the talc group are among the most versatile of the inorganic substances available to industry, and few if any minerals provide wider ranges of application. Talc minerals from different sources may present notable differences in properties, and those differences shape the consumption pattern.

The largest use of talc-group minerals is in the manufacture of ceramics—sagger bodies and other kiln furniture, sanitary ware, floor and wall tile, dinnerware, glazes, and electrical porcelains. In this application, addition of talc or pyrophyllite to the usual clay-silica-feldspar body mixtures facilitates the firing of the ware by allowing lower firing temperatures and quicker firing schedules. The quality is improved by the prevention of crazing in the glazes and the production of good white-fired bodies to which glazes of high-brilliance attractiveness can be fitted. The ceramic industry used 35% of the ground talc in 1983 and 32% of the pyrophyllite. Much of the talc used by the ceramic industry is a mixture of platey talc and blocky tremolite.

The second major use of talc minerals is as filler and/or pigment of paints. For these purposes, platey varieties of talc have good hiding power, act as pigments in their own right, and serve to entangle and buoy up particles of other pigments, thus helping to keep them in suspension during prolonged storage.

The important properties of talc to the paint industry are color, fineness, oil absorption, and chemical inertness. This is a major use, 18% of talc but a minor one, 1%, for pyrophyllite.

For roofing materials—tar paper, asphalt shingles, or roll roofing—the addition of talc provides a surface that is nonsticking, chemically inert, fire retardant, and weather resistant. The

Table 5.—End uses for ground talc and pyrophyllite, 1983
(Thousand short tons)

Use	Talc	Pyrophyllite	Total
Ceramics	319	27	346
Cosmetics[1]	50	—	50
Insecticides	5	12	17
Paint	166	1	167
Paper	81	—	81
Plastics	57	1	58
Refractories	2	23	25
Roofing	98	7	105
Rubber	28	—	28
Other[2]	95	13	108
Total	901	84	985

[1]Incomplete data. Some cosmetic talc known to be included in "Other."
[2]Includes art sculpture, asphalt filler, crayons, floor tile, foundry facings, rice polishing, stucco, and other uses not specified.

ease of processing and the low cost of roofing granules from crushed talc make them a desirable component for shingles. The roofing industry used 11% of the talc and 8% of the pyrphyllite in 1983.

Fourth in order among outlets for domestic talc minerals is uses for coating and/or loading of high-quality papers. In this application, high-purity talc helps in obtaining a product with the desired weight and opacity, good ink retention, and superior surface texture. A total of 6% of talc consumption goes to the paper industry. Talc's ability to be preferentially wetted by oily materials in the presence of water makes it a very effective "pitch control" agent in paper manufacturing. Pitch is the residual gum with the cellulose fibers that inhibits good ink acceptance during printing.

The plastics industry, with needs for both reinforcement materials and economic fillers, has recognized talc as both and is now fifth among the users of talc minerals. It uses 6% of the ground talc and 1% of the pyrophyllite. Talc can be used as a filler and/or reinforcer in either thermosetting or thermoplastic resins. It improves chemical and heat resistance, dimensional stability, stiffness, hardness, thermal conductivity, tensile strength, creep resistance, and electrical insulation. Talc also aids in processability, compared with other fillers.

For cosmetic and pharmaceutical uses, talcs must be selected to meet the highest standards of purity, softness, pleasant feel, color, chemical stability, and must be free from grit, irritants, or bacterial contamination.

The characteristics of talc that make it useful to the rubber industry are its retention of slipperiness, even at elevated temperatures, that makes it an inexpensive mold release agent and prevents adjacent rubber pieces from sticking to each other, and its economy as a filler in which application it also provides internal lubrication. The rubber industry used 3% of the talc in 1983.

Use of minerals of the talc group as carriers and/or diluents for insecticides accounts for the eighth largest fraction. Talc minerals are especially useful for this purpose because their chemical inertness makes them compatible with a variety of toxic substances while their physical characteristics facilitate the dispersion and increase the effectiveness of those agents. This use accounts for 14% of pyrophyllite consumption, but is a relatively minor one for talc.

Use of talc minerals in refractories has much the same rationale as their use in ceramics. This is a major outlet, 27%, for pyrophyllite.

The remaining talc uses in the United States are distributed over an extensive range of minor applications as diverse as incorporation in agents for chemical warfare, floor waxes, and shoe polishes—and include uses such as peanut polishing and salami dusting.

SUPPLY-DEMAND RELATIONSHIPS

Approximately 96% of the U.S. supply of talc minerals comes from domestic mines and the remainder is imported. Because producers' stocks are minimal, production follows demand fairly closely. Demand has been quite stable over the past decade, as indicated in table 6, despite minor recessions that occurred during the period. The end-use pattern has also been quite constant, except for the introduction of its use in plastics, an increase in its use in roofing materials, and a decrease in its use in insecticides and refractories.

Substitutes

Many materials, including clays and calcium carbonate, substitute for talc in it's many filler applications, and in roofing, insecticides, and other uses. However, no economic substitutes are available for many applications that depend on its unique properties. These application include ceramics, cosmetics, plastics, and other.

BYPRODUCTS AND COPRODUCTS

The only commercially significant byproducts generated in the course of talc-group mining and milling operations are the chlorite produced in some Western U.S. operations and the sericite produced with the pyrophyllite in North Carolina. Talc is a byproduct of other mining in some Scandinavian countries.

STRATEGIC CONSIDERATIONS

The Government stockpile goal, for steatite block, was only 28 tons in 1984. A Government task force recommended that this material be removed as a stockpile item because advancing technology, particulary in electronics, makes stockpile unnecessary. Domestic resources of talc are adequate for any foreseeable emergency.

ECONOMIC FACTORS

Values received for both crude and processed talc-group minerals, as reported by producers, have remained fairly stable in constant dollars since 1963 except for a decrease during most of the 1970's. Historical data are shown in table 8.

The bulk of the talc and pyrophyllite of commerce is made up of relatively low-unit-value material unable to bear the charges of long-distance transportation. Exceptional grades such as high-purity talc of pharmaceutical, cosmetic, or even papermaking quality are significant items of international trade.

Imports of talc and pyrophyllite are minor and do not exert a decisive influence on the industry. Talc imported into the United States by most favored nations was subject, as of January 1, 1984, to the following rates of duty: crude and not ground, 0.02¢ per pound, ground, washed, powdered, or pulverized, 3.8% ad valorem; cut or sawed, or in blanks, crayons, cubes, disks, or other forms, free; other not specifically provided for, 4.8% ad valorem. Exports, all talc, amounted to 22% of production in 1983. After increasing from 1973, as indicated in table 9, to highs in 1977 through 1981, exports decreased in 1982 and 1983. The decrease in the constant dollar value per ton suggests the exportation of lesser grades of talc. Most exports have been of crude material.

The allowable depletion rates established under the Tax Reform

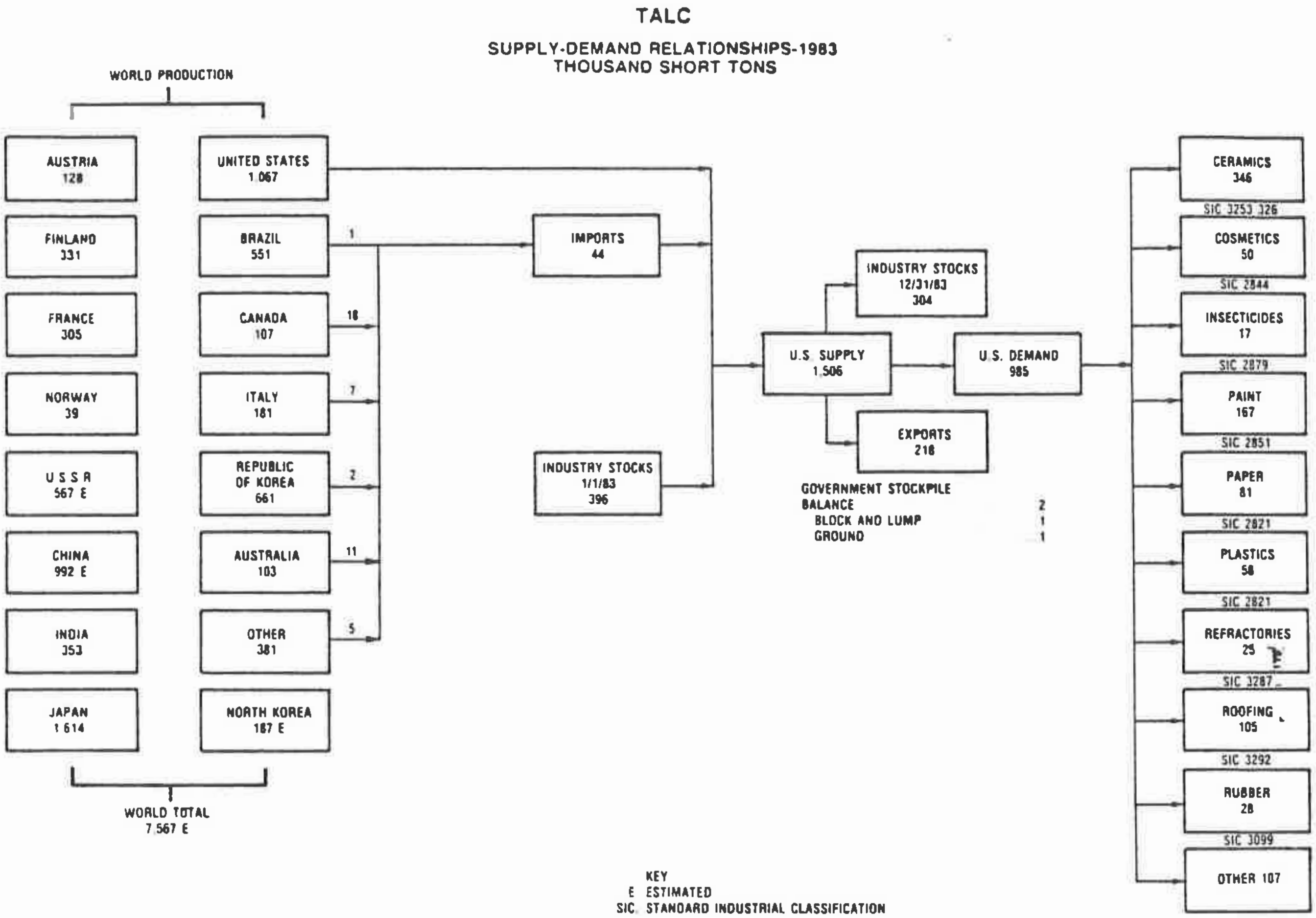

Figure 2.—Supply-demand relationships for talc, 1983.

Table 6.—Supply-demand relationships, 1973–83

(Thousand short tons)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
WORLD PRODUCTION											
United States	1,247	1,290	965	1,092	1,205	1,384	1,453	1,240	1,243	1,135	1,066
Rest of world	4,710	4,994	4,420	4,714	4,995	5,667	6,126	7,060	6,612	6,460	6,487
Total	5,957	6,284	5,385	5,806	6,200	7,051	7,579	8,300	7,955	7,595	7,553
COMPONENTS AND DISTRIBUTION OF U.S. SUPPLY											
Domestic mines[1]	1,247	1,290	965	1,092	1,290	1,384	1,453	1,240	1,343	1,135	1,066
Imports	33	30	23	20	22	19	22	21	27	27	44
Industry stocks, Jan. 1	71	448	521	420	419	370	476	487	428	398	396
Total U.S. supply	1,351	1,768	1,509	1,532	1,731	1,773	1,951	1,748	1,798	1,560	1,506
Distribution of U.S. supply:											
Industry stocks, Dec. 31[e]	448	521	420	419	370	476	487	428	398	396	304
Exports	180	183	158	212	322	267	316	275	311	232	218
Industrial demand	1,004	1,064	931	901	1,039	1,030	1,148	1,045	1,089	932	985
U.S. DEMAND PATTERN											
Ceramics	346	221	185	280	317	274	323	295	387	312	346
Cosmetics	40	35	31	37	75	69	74	59	75	45	50
Insecticides	43	47	42	40	47	40	46	39	42	26	17
Paint	178	158	141	191	211	193	238	198	207	171	167
Paper	80	89	67	60	69	87	105	102	88	79	81
Plastics	([2])	([2])	([2])	60	120	148	113	111	111	55	58
Refractories	54	39	50	62	63	45	62	71	41	24	25
Roofing	60	93	88	95	80	128	132	102	90	104	105
Rubber	32	25	16	19	52	37	40	38	36	22	28
Other	171	364	315	57	5	9	15	30	12	94	108
Total demand	1,004	1,064	931	901	1,039	1,030	1,148	1,045	1,089	932	985

[e]Estimated.
[1]Crude ore mined.
[2]Included in "Other."

Table 7.—Talc stockpile status, March 31, 1984

(Short tons)

Material	Goal	Total inventory	Excess to goal authorized for disposal	Sales 1983
Steatite block and lump	28	1,081	886[1]	—

[1]125,000 pounds as of October 1, 1984.

Table 8.—Time-price relationships for talc-group minerals, 1963-83

	Average annual producer value, dollars per ton			
	Sold by producers[1]		Mine production[2]	
Year	Actual prices	Based on constant 1983 dollars	Reported value	Constant 1983 dollars
1963	23.20	69.82	6.85	20.61
1964	21.98	65.14	6.99	20.72
1965	23.62	68.50	7.35	21.32
1966	22.67	63.70	7.24	20.34
1967	24.86	67.81	7.61	20.76
1968	25.92	67.73	6.95	18.16
1969	29.38	73.01	7.30	18.14
1970	27.41	64.64	7.56	17.83
1971	27.51	61.79	7.36	16.53
1972	31.10	67.07	7.08	15.27
1973	27.22	55.52	7.33	14.95
1974	30.64	57.42	8.75	16.40
1975	19.20	32.91	9.25	15.86
1976	37.68	61.41	9.07	14.78
1977	47.00	72.37	10.86	16.72
1978	56.32	80.74	11.39	16.33
1979	64.64	85.31	13.85	18.28
1980	66.70	80.62	15.68	18.95
1981	80.92	89.43	16.84	18.61
1982	83.57	87.12	18.21	18.98
1983	93.55	93.55	19.01	19.01

[1]Includes both ground and crude.
[2]Crude only.

Table 9.—U.S. talc exports

(Thousand short tons and thousand dollars)

		Value		
Year	Quantity	Actual	Based on constant 1983 dollars	Constant dollars per ton
1973	180	6,618	13,497	75
1974	183	6,711	12,576	69
1975	158	6,338	10,865	69
1976	212	9,034	14,723	69
1977	322	9,166	14,114	44
1978	267	12,359	17,718	66
1979	316	15,210	20,073	64
1980	275	14,963	18,086	66
1981	311	15,095	16,683	54
1982	232	12,957	13,508	58
1983	218	12,916	12,916	59

Act of 1969 remained at 22% for domestic block steatite and 14% for foreign material through 1983.

OPERATING FACTORS

The 1976 Mining in the Parks Act, which put a 4-year moratorium on any further land disturbance by mining at several national parks and monuments, expired in 1980. Talc mining in Death Valley National Monument had been severely limited under this law. Upon its expiration, congress debated whether to extend the act or to ban all mining in national parks. However, no action was taken by Congress.

The mining and processing of talc and pyrophyllite inevitably causes at least a small degree of disruption of the environment and existing ecology. However, these operations take place, for the most part, in localities well removed from major urban concentrations. Landscape disfigurements and land-use conflicts are minor and localized, except in recreation areas.

Waste rock from talc mines is relatively small in volume and is immobile and nontoxic. The washing, milling, and flotation of talc minerals may generate minor quantities of water-contaminating suspensions, but treatment of effluents in thickeners and settling ponds is uncomplicated and effective. Recirculation of plant water is usually easy to accomplish. The mining and milling of talc and pyrophyllite ores often give rise to concentrations of siliceous dusts; again, their effect is usually localized. These dust problems have been resolved at most of the major facilities by standard procedures.

Production of talc is among the least energy-intensive mineral operations. It is the softest of minerals, somewhat easier to mine than most, and a great deal easier to process than most.

Both the talc producers and their customers have been cited by Federal regulating agencies for being in violation of asbestos regulations. This happened because of the imprecision of mineral terminology, which does not distinguish between the fibrous and nonfibrous varieties of several amphiboles, and of monitoring methods that are nonspecific and terms each elongate particle of whatever origin a fiber and, by analogy, asbestos. The resulting publicity and court cases have caused some talc consumers to turn to competing material.

The Bureau of Mines has participated in the development of mineralogical definitions and terminology of particulate materials including asbestos (6) and talc and has contributed to two publications on the subject in the American Society for Testing and Material (ASTM) (*7-8*). In 1976, the Bureau of Mines established its Particulate Mineralogy Unit to help clarify the confusion in particulate-mineral terminology, to develop a solid scientific basis for research into particle-related pollution problems, and to provide technical advice and assistance to regulatory bodies.

Employment in talc and pyrophyllite mines and preparation plants in 1983 was estimated to be equivalent to the services of 800 full-time workers. Despite the growing trend toward mechanization of all major talc-group production facilities, some operations such as sorting, are still by hand, and the productivity ratio, in terms of tons per man-year, has not varied markedly in recent years.

PROBLEMS

During the 1970's, it was noted that the mineral assemblages of some talc deposits contains naturally fibrous minerals, both the asbestos and nonasbestos varieties, which are reported as contaminants in certain ores and products. The problem was exacerbated by the lack of semantic differentiation between some massive amphibole rocks and their asbestos varieties. Tremolite is the only name for both its asbestos and rock forms, which are chemically identical, and give the same pattern when analyzed by X-ray diffraction. Even if, as in the case of serpentine rock and chrysotile asbestos, there is a semantic differentiation, most analyses cannot find the difference. Figure 3 is an X-ray diffraction pattern of a typical talc sample (*5*) taken by Bureau researchers. The peaks identified as serpentine could by chrysotile asbestos, and others identified as tremolite could be either its rock or asbestos form.

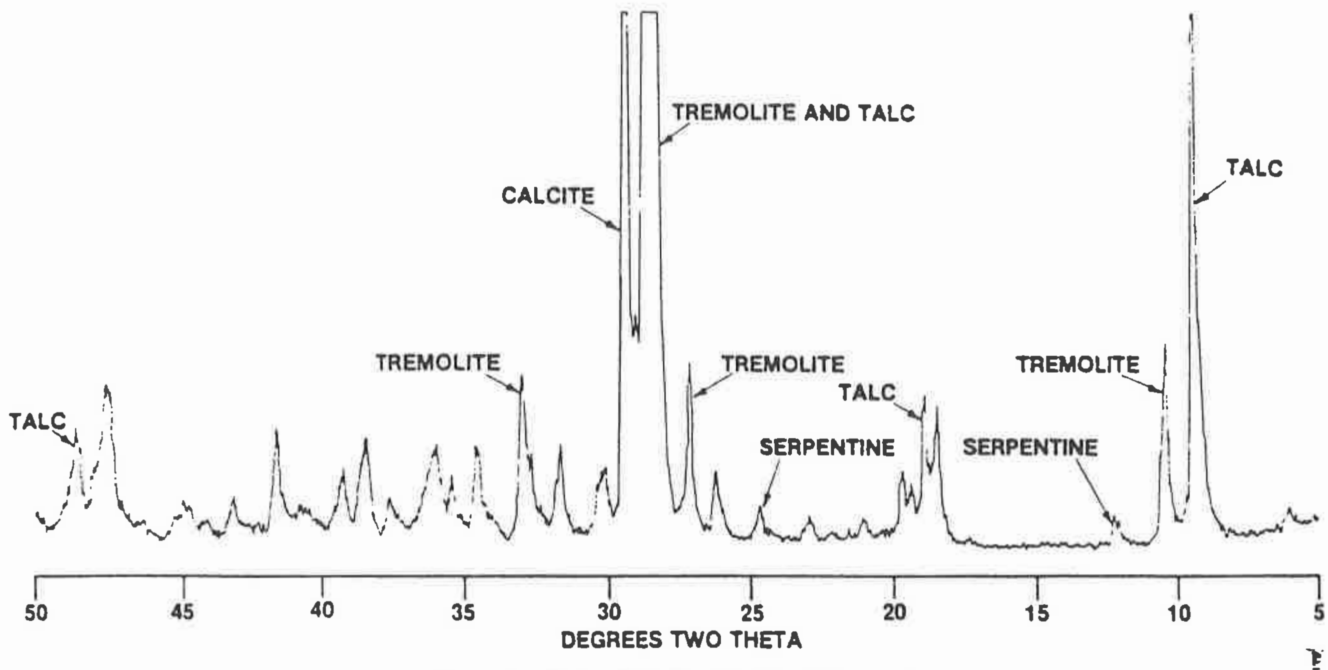

Figure 3.—X-ray diffraction patterns of talc sample.

ASTM is addressing the semantic problem with a new definition for asbestos (*6*). This definition is rigorous enough to exclude those minerals and mineral particles that were never asbestos and describes asbestos as "A term applied to six naturally occurring minerals exploited commercially for their desirable physical properties, which are in part derived from their asbestiform habit. The six minerals are the serpentine mineral chrysotile and the amphibole minerals grunerite asbestos (also referred to as amosite), riebeckite asbestos (also referred to as crocidolite), anthophyllite asbestos, tremolite asbestos, and actinolite asbestos. Individual mineral particles, however processed and regardless to their mineral name, are not demostrated to be asbestos if the length-to-width ratio is less than 20 to 1."

Distance from mine to market and the attendant transportation costs seem to be affecting portions of the talc market. High transportation costs can make talc noncompetitive in low cost filler markets.

OUTLOOK

Demand

Demand for talc and pyrophyllite in the United States in 2000 is expected to be between 1.4 and 4.8 million tons, corresponding to an average growth rate of 5.4% per year during the 1983-2000 period.

Ceramics and Glass.—The statistical projection of 490,000 tons for ceramic uses in 2000 was obtained by regression analysis with the gross private domestic investment (GPDI) as the explanatory variable.

Ceramic products most likely to experience growth rates above that of the GPDI are ceramic items for cookware, other heat-resistant applications including space and aeronautic hardware, and floor and wall tile (high-temperature products), bringing the upper end of the forecast demand range to 950,000 tons for 2000.

For some uses, particularly floor and wall tile, and, to a lesser extent, electronic and other special ceramics, numerous raw materials such as some clays and other industrial minerals that can be used almost interchangeably, compete. The effect of the competing material could be significant on the 2000 demand for talc-group ceramic raw materials bring the low end of the forecast range to 450,000 tons in 2000.

The wide range of ways in which ceramics have and will likely continue to serve present and anticipated cultural and industrial purposes even more widely supports the forecast that the most probable demand for talc minerals in ceramics applications in 2000 would be 700,000 tons.

Cosmetics.—The statistical projection of 170,000 tons was derived from a regression analysis with GPDI as the explanatory variable. Good correlation was also obtained with the Federal Reserve Board (FRB) index for soap and toiletries.

Per capita real income in the United States is expected to increase by 2000, so that spending on luxury and marginally essential items, especially in view of recent vigorous promotion of cosmetics for men, seems likely to increase at a rate exceeding those anticipated elsewhere in the economy. This possibility supplied the rationale for the upper limit of 300,000 tons for this end use by 2000.

Consumption of talc in cosmetics, medicinal articles, and allied products may be restrained, at least temporarily, as the consequence of a health-hazard concern related to talc. The lower extreme of the cosmetics demand forecast range for 2000 was set at 100,000 tons to allow for the possible continuation of this influence.

By counterbalancing these opposing trends, middle of the range, 200,000 tons, was concluded to be the most probable forecast of 2000 demand for talc minerals in cosmetic preparations.

Insecticides.—Use of talc-group minerals as carriers and diluents for insecticides is greatly affected by social and environmental considerations and with the number of consumers. The statistical projection of no market for talc minerals for 2000 was arrived at by correlation with the U.S. population.

The need to guard against further deterioration of ecological balances will possibly lead to increasing restriction of the employment of the pesticide types now current, and either the development of sharply specific single-species poisons or the devising of control methods entirely divorced from toxic substances dispersed incarriers. To allow for these contingencies, the low forecast demand was set at zero.

An optimistic assessment of the possibility of developing regulatory procedure that would permit the continued application of formulations at least similar to those now in use was the basis for the selection of 50,000 tons for the high end of the range and 30,000 tons at the probable level of demand for talc-group minerals in insecticides in 2000.

Paints. —the statistical projection of 260,000 tons of talc-group minerals for use in paint in 2000 was obtained from a regression analysis using the FRB production index for paint as an explanatory variable. Because of new formulations in paint manufacturing that might be expected to increase the use of talc-group minerals in paints significantly, a figure of 400,000 tons was chosen as the high end of the forecast range.

On the other hand, a number of negative influences might depress the future consumption of talc in paint. Many materials, including certain steels, asbestos-cement products, and porcelain enamel panels, do not need to be painted. Also, the new and increasingly popular water-based gloss paints require little or no talc. The lower end of the forecast demand range for 2000 was estimated to be 200,000 tons.

By counterbalancing the additive and detrimental factors likely to affect the furture situation of talc-based paints, 300,000 tons was estimated to be the probable for talc-group minerals in paint manufacturing in 2000.

Paper.—The statistical projection of 180,000 tons of talc for use in paper in the year 2000 was obtained by correlation with the FRB total production index. Good correlation was also obtained with the FRB index of paper and paper products.

Use of talc in papermaking has grown rapidly since the mid-1950's and appears capable of additional expansion because of greater need for its pitch control properties; therefore, the high side of the forecast range for 2000 was established at 300,000 tons.

There has been no significant shift toward alternate materials to take the place of talc for this purpose. With little dropoff in demand expected, 180,000 tons was set as the lower limit of demand.

In view of the steadily increasing involvement of paper in all aspects of present-day life, the ever greater volumes of paper being consumed by duplicating machines and computer printouts, and despite forecasts of a "paperless office," 250,000 tons was estimated to be the most probable forecast of talc demand for papemaking in 2000.

Plastics.—The amount of talc being use in plastics has long been of minor proportions and carried in "Other." The 8-year data now available show a rapid growth through 1978 and a dropoff since then. Projection of these data would give a negative growth rate and no market in 2000. However, the continuing need for lighter weight components in vehicles to conserve fuel supports a positive growth. The high end of the demand forecast range is based on a prediction by Katz and Milewski who expect large uses for plastic filling (9). Much more probable is an annual growth rate of 10% giving a 400,000-ton demand in 2000.

Refractories.—[illegible] mand has decreased [illegible] progressive shift of [illegible] fire clay raw material [illegible] service under increasing [illegible] to mechanical and chemical [illegible] Among the materials finding [illegible] manufacture of refractories [illegible] Use of refractories is indispensable [illegible] trum of industrial processes, and [illegible] the FRB total production index [illegible] was used to obtain the statistical [illegible] of talc-group minerals for refractories [illegible] 2000. The possible development of chemical [illegible] stead of pyrometallurgical ones for the extraction of a number of nonferrous metals, possible recourse by the steel industry to methods involving the direct reduction of iron ore, and long-term low growth because of greater imports in the steel industry dampen prospects for [illegible] refractory markets. These factors plus structural [illegible] in demand pattern in the U.S. economy could reduce demand for talc-group minerals for refractories to below the statistical projection, so that 50,000 tons was taken as the low forecast.

The bricks, shapes, and mortar compositions collectively classified as basic refractories, some of which contain talc, have become increasingly prominent because of a number of major innovations in metallurgical practice. Continuation of those technologic changes is likely, suggesting an upper limit of the demand forecast of 130,000 tons in 2000.

The most probable demand for talc-group minerals for refractories in 2000 was forecast at 100,000 tons.

Roofing.—Demand for talc minerals in this use is closely associated with new construction, but replacement roofing is independent of this activity. Correlation with the gross national product was used to establish the statistical projection of 180,000 tons for 2000.

Talc minerals in the grades suitable for use in roofing can be low in unit cost, and, because of excellent performance and general availability, are subject to only limited competition from other materials in this application. Talc-group minerals, at the expanse of alternate substances, are likely to command a greater share in the roofing materials industry which, because of pent-up demand for housing, appears due for an extended period of expansion. Because of these consideration, it seemed reasonable to place the upper boundary of the demand at 360,000 tons of talc-group minerals for roofing use in 2000.

Probably the most influential restraints on the use of roofing materials are the mounting costs of real estate, labor, and building materials, all factors favoring the construction of large apartment houses of the highrise type, in which the roofing area per person is much smaller than in one-family houses. To allow for these contingencies, the statistical projection was used to establish the lower limit of demand in 2000 at 150,000 tons.

In view of the scant probability of an early decline in building costs and the strong effect of the trend to multifamily housing needing less roofing per family, 200,000 tons was selected as the most probable forecast for the utilization of talc minerals in roofing in 2000.

Rubber Products.—The statistical projection of 47,000 tons of talc minerals for rubber in 2000 resulted from correlation of talc-group demand with projected gross private domestic investment (GPDI). Although a number of alternative substances compete actively as rubber fillers, the

Table 10.—Projection and forecasts for U.S. talc and pyrophyllite demand by end use, 2000

(Thousand short tons)

End use[1]	1983	2000: Statistical projections[2]	Contingency forecast for United States: Forecast range: Low	Forecast range: High	Probable
Ceramics	346	490*	450	950	700
Cosmetics	50	170	100	300	200
Insecticides	17	0	0	50	30
Paint	167	260	200	400	300
Paper	81	180	180	300	250
Plastics	58	—	80	2,000	400
Refractories	25	75*	50	130	100
Roofing	105	180*	150	360	200
Rubber	28	47*	40	60	50
Other	108	—	100	200	200
Total	985	—	1,350	4,750	2,430

[1]Ground only.

[2]Statistical projections, provided by the Branch of Economic Analysis, are derived from regression analysis based on historical time series data and from forecasts of economic indicators such as GNP and FRB index. A statistical projection of zero indicates that demand will vanish at or before the year 2000, based on the historical relationship. Projection equations with a coefficient of determination (R-squared) less than 0.70 are indicated by an asterisk (*).

Table 11.—Summary of forecasts of U.S. and rest-of-world talc and pryophyllite demand, 1990–2000

(Thousand short tons)

	1983	2000 Forecast range: Low	2000 Forecast range: High	Probable: 1990	Probable: 2000	Probable average annual growth rate 1983-2000 (percent)
United States:						
Total	984	1,500	4,800	1,400	2,400	5.4
Cumulative	—	21,100	43,000	8,500	28,000	—
Rest of world:						
Total	6,569	13,900	16,300	9,200	15,000	5.0
Cumulative	—	170,000	187,000	56,000	178,000	—
World:						
Total	7,553	15,400	21,100	10,600	17,400	5.0
Cumulative	—	191,000	230,000	64,500	206,000	—

talc-group minerals will probably continue to command most of their present share of the rubber filler market. The most probable forecast of demand for talc minerals for the manufacture of rubber goods in 2000 was estimated at 50,000 tons.

Other.—Removal of the high growth "Plastics" uses from "Other" uses and considering the historic stability of this category even with new markets, the 2000 demand seems unlikely to exceed 200,000 tons, which was taken as the high end of the range for 2000.

In a number of the end uses making up the "Other" category, the talc-group minerals are subject to active competition from other materials such as asbestos, clays, diatomite, feldspar-silica mixtures, vermiculite, wollastonite, and synthetic products. Other applications may be declining or becoming obsolescent because of changes in construction methods. These contingencies appeared to justify a low demand of 100,000 tons.

Consideration of the diversity of uncommon characteristic possessed by the talc minerals and the possible emergence of new applications for these versatile materials were the principal reasons setting demand in other uses at 200,000 tons in 2000.

The end-use pattern for the talc minerals in most industrialized countries probably conforms in general to that in the United States. Some countries, deficient in high-quality clays suitable for those purposes, use talc-group minerals extensively as fillers for paper, rubber, and other products. In other nations, ceramic applications predominate. In view of the number of countries without abundant competing raw materials, and considering a more rapid growth in underdeveloped countries, the low side of the rest-of-world forecast demand range is not expected to fall below 13.9 million tons in 2000, the figure calculated by relating demand with expected growth rate for gross world product. The estimated high side of the range of talc demand forecast for 2000 is 16.3 million tons, and the rest-of-world probable demand is 15.0 million tons, corresponding to a growth rate of about 5.0% per year. Developing countries have growing needs for ceramics, refractories, paints, etc., that produce exaggerated growth rates for talc and other minerals.

Summation of domestic and rest-of-world figures indicates that worldwide demand for talc-group minerals in 2000 will probably be about 17.5 million tons, the result of a growth rate of 5.0% per year during the remainder of this century.

Forecasts of U.S. and rest-of-world demand for talc-group minerals in 1990 and 2000 are summarized in table 11. Projections and forecasts of U.S. demand for talc-group minerals by end use in 2000 are summarized in table 10.

Table 12.—Adequacy of U.S. and world talc reserves

(Thousand short tons of talc)

	United States	Rest of world	World total
Reserves	150,000	200,000	350,000
Cumulative demand, 1983-2000	28,000	178,000	206,000

Adequacy of Supply

Reserves of talc and pyrophyllite in the United States are at least 150 million tons. The reserve base is much larger, and many times the quantity of the reserves would be available with a moderate advance in prices. Cumulative domestic requirements through 2000 for talc-group minerals, using the probable demand, will be 28 million tons. To maintain the constant ratio of domestic production to domestic demand would require a total cumulative output between 1983 and 2000 of 37 million tons. Domestic reserves are more than adequate to meet the foreseen requirements.

The cumulative demand for talc and prophyllite in the rest of the world, based on the probable demand growth of 5.0% per year, is 178 million tons, bringing the probable world demand for talc-group minerals through the forecast period to 206 million tons.

About 30 countries regularly produce talc or related minerals on a commercial scale, and potential exists for even more widely distributed production in the future (4). Estimates based on the scanty evidence currently at hand indicate that the quantities of talc-group minerals potentially obtainable in the rest of the world might total 200 million tons, and that a moderate increased in the offered price could bring perhaps double that tonnage into the market. The entire rest-of-world reserve base of talc minerals that would be minable at higher prices is probably close to 1 billion tons. This, coupled with the known existence of additional ore workable at moderately higher prices and with the high probability of further discoveries of major new deposits, makes it evident that the supply of talc-group minerals during the forcast period is adequate to meet the forecast demand in the rest of the world.

Possible Supply-Demand Changes

A straight-line projection to 2000 of domestic production during the past 21 years, shown in table 13, suggests that talc and pyrophyllite production in 2000 might be 2.0 millions tons if this historic trend persists. This compares with 2.6 million tons obtained by assuming that the 1983 relationship between production and demand prevails in 2000.

Denial of access to domestic resources could seriously affect future U.S. supply. A major resource area, Death Valley National Monument, was under Congressional restrictions as to further land disturbances, and no increase in production occurred from

Table 13.—Comparison of U.S. talc minerals production and demand, 1963-83, 1990, and 2000

(Thousand short tons)

Year	U.S. demand	U.S. production
1963	794	804
1964	858	890
1965	822	863
1966	838	895
1967	808	903
1968	876	958
1969	941	1,029
1970	948	1,028
1971	979	1,037
1972	942	1,107
1973	1,004	1,247
1974	1,064	1,268
1975	931	965
1976	901	1,092
1977	1,114	1,205
1978	1,136	1,325
1979	1,020	1,453
1980	1,007	1,240
1981	937	1,343
1982	820	1,135
1983	985	1,066
1990	[1]1,400	[2]2,000 [e]1,700
2000	[1]2,400	[2]2,200 [e]2,500

[e]Estimated.
[1]Probable forecast from table 10.
[2]21-year trend projection.

1976 to 1980. This moratorium was not renewed in 1980. The moratorium removal had not, in 1984, had a noticeable effect on Death Valley production. Limitation of access to resources on public recreation or conservation lands could limit the growth rate of the talc industry.

Operation of some open pit talc and pyrophyllite mines may be restricted by environmental concerns. However, some operations probably can be continued indefinitely by switching to underground mining, and improved techniques of landscape rehabilitation will no doubt be applied to minimize the environmental problems faced by those unable to be so converted.

Technologic advances that would best benefit the talc industry in the next two decades would be those that could bring about improvements in mining machinery and development of better and more efficient automatic equipment for the beneficiation and preparation of the mined product for the market, particularly to reduce hand sorting.

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