# Kyanite and Related Materials

By Michael J. Potter[1]

Kyanite, andalusite, and sillimanite are anhydrous aluminum silicate minerals that are alike in both composition and use patterns and have the same chemical formula, $Al_2O_3 \cdot SiO_2$. Related materials include synthetic mullite, dumortierite, and topaz, also classified as aluminum silicates, although the last two additionally contain substantial proportions of boron and fluorine, respectively. All of these kyanite-group substances can serve as raw materials for manufacturing special high-performance refractories in the high-alumina category, but there has been no record in recent years of significant utilization of either dumortierite or topaz for this purpose in the United States.

Although published statistics are not sufficiently complete to be wholly conclusive, it appears that the United States, India, and the Republic of South Africa are the leading world producers of kyanite-group minerals. It can be presumed that the U.S.S.R. and perhaps a few other industrialized nations also produce significant quantities of these materials.

U.S. kyanite production in 1977 was slightly higher in tonnage and value than in 1976. The amount of kyanite-group material exported decreased compared with that of 1976. The tonnage of imported material continued to be small.

**Legislation and Government Programs.**— The allowable depletion rates for kyanite, established by the Tax Reform Act of 1969 and unchanged through 1977, were 22% for domestic production and 14% for foreign operations.

On November 17, 1977, the Federal Government announced the offering of 2,816 tons of kyanite for sale on a sealed-bid basis. On December 5, 1977, 150 tons of kyanite was sold to one company at a total sales value of $41,250. The General Services Administration was conducting bid openings for the sale of the kyanite on the fourth Tuesday of each month.

## DOMESTIC PRODUCTION

Kyanite was produced in the United States in 1977 at three open pit mines, two in Virginia and one in Georgia. Kyanite Mining Corp. operated the Willis Mountain mine in Buckingham County, Va., and the Baker Mountain mine in adjoining Prince Edward County, Va. C-E Minerals, Inc., operated the Graves Mountain mine in Lincoln County, Ga.

Domestic kyanite output in 1977 was slightly higher in tonnage and value than in 1976. Kyanite production statistics for 1977 (as well as for all previous years since 1949) are withheld to avoid disclosing company proprietary data.

Synthetic mullite production showed a slight decrease in both tonnage and value compared with the 1976 figures, and output was largely of the high-temperature sintered variety. The four producers of this material were A. P. Green Refractories Co. at Philadelphia, Pa.; C-E Minerals, Inc., at Americus, Ga.; Harbison-Walker Refractories Co. at Eufala, Ala.; and Taylor Refractories Division, NL Industries, Inc., at Greenup, Ky. Electric-furnace-fused mullite was produced by The Carborundum Co. at Niagara Falls, N.Y.

Table 1.—Synthetic mullite production in the United States

| Year | Quantity (short tons) | Value |
|---|---|---|
| 1973 | r58,180 | $5,211,000 |
| 1974 | r41,510 | 5,895,000 |
| 1975 | r24,150 | 3,350,000 |
| 1976 | r42,230 | 5,453,000 |
| 1977 | 40,280 | 5,283,000 |

rRevised.

## CONSUMPTION AND USES

Conforming to established end use patterns, kyanite and related materials were consumed in 1977 mostly in the manufacture of high-alumina or mullite-class refractories and in lesser quantities as ingredients in some ceramic compositions. Domestic kyanite, already ground to minus 35 mesh as required by the flotation process used in its separation and recovery, was marketed in the raw form or after heat treatment; that is, as mullite, which was sometimes further reduced in particle size before use. In the 35- to 48-mesh range, the mineral was used mostly in monolithic refractory applications such as for high-temperature mortars or cements, ramming mixes, and castable refractories, or with clays and other ingredients in refractory compositions for making kiln furniture, insulating brick, firebrick, and a wide variety of other articles. More finely ground material, minus 200 mesh, for example, was used in body mixes for sanitary porcelains, wall tile, precision-casting molds, and miscellaneous special-purpose ceramics.

## PRICES

Engineering and Mining Journal, December 1977, listed prices for kyanite, f.o.b. Georgia, ranging from $63 to $106 per short ton for bulk shipments and $9 more per ton for bagged material.

Price ranges quoted for kyanite-group materials in Ceramic Industry magazine, January 1978, follow:

| | Per short ton |
|---|---|
| Andalusite | $30-$60 |
| Kyanite | 64-116 |
| Mullite, calcined | 302-313 |
| Mullite, fused | 160-450 |

The December 1977 issue of Industrial Minerals (London) quoted kyanite-group price ranges approximately equivalent to the following (converted from pounds sterling per metric ton to dollars per short ton):

| | Per short ton |
|---|---|
| Andalusite, Transvaal, c.i.f. main European port | $146 |
| Kyanite, Indian, f.o.b | $109- 127 |
| Sillimanite, Indian, natural, bagged, f.o.b | 177 |
| Kyanite, Indian, calcined, f.o.b. Calcutta | 181 |

## FOREIGN TRADE

The quantity of kyanite-group materials exported in 1977 showed a substantial decrease compared with that of 1976 exports. The greater part of the material currently being exported by the United States is probably mullite. (The Bureau of the Census export figures, which are used in table 2, do not distinguish between synthetic mullite and materials that are in part mullite.)

The tonnage of imported material continued to be small. Because of this, the Bureau of the Census is expected to stop collecting data on kyanite imports as a separate category.

**Table 2.—U.S. exports and imports for consumption of kyanite and related minerals**

| | 1975 | | 1976 | | 1977 | |
|---|---|---|---|---|---|---|
| | Quantity (short tons) | Value | Quantity (short tons) | Value | Quantity (short tons) | Value |
| Exports: | | | | | | |
| Argentina | 160 | $14,926 | 325 | $22,686 | 149 | $30,330 |
| Australia | 9,918 | 615,663 | 14,886 | 1,087,338 | 345 | 31,311 |
| Belgium-Luxembourg | 221 | 58,062 | 1,049 | 94,541 | 223 | 41,871 |
| Brazil | 582 | 29,700 | 309 | 32,788 | 371 | 28,900 |
| Canada | 5,175 | 361,361 | 4,857 | 362,709 | 10,242 | 731,084 |
| Colombia | 301 | 20,869 | 58 | 2,934 | -- | -- |
| Denmark | 134 | 11,919 | -- | -- | -- | -- |
| France | 600 | 69,973 | 300 | 45,234 | 676 | 79,490 |
| Germany, Federal Republic of | 65,487 | 3,582,084 | 14,181 | 1,011,056 | 4,351 | 499,491 |
| Haiti | -- | -- | -- | -- | 80 | 4,093 |
| Hong Kong | 48 | 7,262 | -- | -- | 19 | 2,934 |
| Israel | 200 | 11,255 | -- | -- | -- | -- |
| Italy | 13,066 | 921,974 | 6,907 | 600,611 | 3,903 | 403,630 |
| Japan | 30,666 | 1,796,826 | 5,406 | 428,012 | 5,323 | 391,737 |
| Mexico | 3,045 | 318,374 | 4,130 | 391,763 | 3,256 | 287,030 |
| Netherlands | 1,120 | 84,598 | 131 | 11,057 | 63 | 4,245 |
| New Zealand | 20 | 1,690 | 21 | 1,851 | 59 | 5,238 |
| Philippines | 12 | 2,205 | 219 | 24,874 | 473 | 55,885 |
| South Africa, Republic of | 3 | 1,168 | 2 | 1,126 | 19 | 3,874 |
| Spain | -- | -- | 21 | 1,735 | 42 | 3,480 |
| Sweden | 5,755 | 385,925 | 3,028 | 261,251 | 2,186 | 210,376 |
| Taiwan | 49 | 3,542 | -- | -- | 88 | 2,335 |
| U.S.S.R. | 1,734 | 170,182 | -- | -- | -- | -- |
| United Kingdom | 11,110 | 739,346 | 6,940 | 509,519 | 5,993 | 503,448 |
| Venezuela | 850 | 137,230 | 481 | 45,904 | 882 | 82,265 |
| Other | 113 | 9,277 | 78 | 4,699 | 89 | 13,882 |
| Total | 150,369 | 9,355,411 | 63,329 | 4,941,688 | 38,832 | 3,416,929 |
| Imports: | | | | | | |
| El Salvador | -- | -- | -- | -- | 1 | 495 |
| France | -- | -- | -- | -- | 2 | 1,183 |
| India | 65 | 2,849 | -- | -- | -- | -- |
| Mexico | -- | -- | 65 | 7,225 | -- | -- |
| South Africa, Republic of | -- | -- | 45 | 5,172 | 50 | 5,786 |
| Total | 65 | 2,849 | 110 | 12,397 | 53 | 7,464 |

## WORLD REVIEW

**Australia.**—The only production of sillimanite was at Mount Crawford, South Australia. Most of the material being mined was kaolinized sillimanite, with only a comparatively small amount of sillimanite rock being produced as a coproduct. In the Eneabba-Jurien Bay area of Western Australia, some 25,000 tons per year of fine-grained kyanite was being thrown onto tailings dumps. The kyanite is removed from the zircon fraction of the mineral sands. Although it might be recovered economically in the future, it is presently considered to be an impurity.[2]

**Brazil.**—Initial production of kyanite began in mid-1977 at Andrelandia, in Minas Gerais State. Output was expected to be around 15,000 tons per year with an increase in production to around 30,000 tons per year by 1978.[3]

Some activity was taking place at a lump kyanite operation in Goias State, not far from the Federal capital of Brasilia. Reserves were estimated at around 2 million tons of pure lump kyanite averaging 60% $Al_2O_3$ and 10 million tons of a kyanite-quartz rock with the kyanite content ranging from 70% to 90%. Boulders of the pure kyanite were being broken up and stockpiled at a crushing station onsite, and lump material was being transported to the ports of Santos and Rio de Janeiro for shipment. The operating company, Cianita-Serra das Araras Ltda., is controlled by Finapa Assessoria Commercial e Industrial Ltda. of São Paulo in conjunction with an Italian company, Italmineraria S.p.A., which was also providing technical assistance on the project. Methods were being investigated for beneficiating the mixed kyanite-quartz material.[4]

**India.**—Reserves of high-alumina lump kyanite at Lapso Buru were said to be quite limited, and the Indian Government reportedly banned exports of kyanite containing more than 60% $Al_2O_3$.

The Khasi sillimanite deposits in Assam were originally mined by Assam Sillimanite Ltd. but were later taken over by the Government. In recent years, supplies of the lump material had fallen off considerably, but production seemed to be underway again, although the reserve situation was difficult to assess. During the monsoon periods, it is almost impossible to get material to the ports.

Maharashtra State also possesses some high-grade massive kyanite deposits. Material is quarried by hand picking and sorting, as it is at the other deposits. Reserves are difficult to assess.

Apart from the high-grade material, India has large reserves of lower grade quartz-kyanite schists and sillimanite schists, and research was underway to find ways of beneficiating these.[5]

**South Africa, Republic of.**—Andalusite occurs in three main areas, all in Transvaal Province: Groot Marico/Zeerust, northern Lydenburg, and Thabazimbi. Reserves are very large.

One of the three producers in the Groot Marico area, Exandula (Pty.) Ltd., which is owned by Cullinan Minerals (Pty.) Ltd., was producing about 13,000 tons per year. The firm was planning to increase capacity to 22,000 tons per year to meet increased local demand. Another mine, owned by Export Minerals (Pty.) Ltd., was producing from 2,700 to 10,600 tons per year. In spite of excess capacity, plans were underway to increase production capacity to 17,600 tons per year in 1977. The andalusite, with an alumina content of 56% and less than 1% $Fe_2O_3$ in the concentrate, meets requirements for refractory producers in the United Kingdom and Japan.

In the Lydenburg district there were four established andalusite mines, and a fifth was expected to come into operation in mid-1977. One of the established mines, owned by Marico Minerals, had been operating at about 75% of its capacity of 40,000 tons per year in recent years. Plans call for increasing the capacity to about 55,000 tons per year by 1980. Hudson Mining Co. operated a large mine at Annesley, where production capacity was 44,000 tons per year, although actual output had been running at 75% of capacity. During 1977 the company was planning to increase the capacity to 50,000 tons per year, with further increases by 1980 and 1985. At Hudson Mining's other mine it was planned to increase production to 6,600 tons per year in 1977, followed by an increase to 11,000 tons per year by 1980 and 15,000 tons per year by 1985. The mine owned by Hoogenoog Andalusite (Pty.) Ltd. has been in operation only since March 1976. The production capacity of 12,000 tons per year was to be increased to 22,000 tons per year, with most of the output destined for Japan and Australia.[6] Cullinan Minerals was in the process of opening up a large andalusite deposit at Klipfontein in eastern Transvaal. Plant construction started in June 1976; initial capacity was to be around 20,000 tons per year, rising to 40,000 tons per year in the following years.[7] Two grades (both containing less than 1% $Fe_2O_3$) were to be produced: A standard grade with over 54% $Al_2O_3$ for local consumption, and a premium grade with over 58% $Al_2O_3$ for the export market.

In the Thabazimi area, Weedons Minerals was hoping to open its first andalusite mine. Target production was put at 22,000 tons per year of high-grade material, with an unusually low iron content for South African andalusite.

Sillimanite production amounted to 28,000 tons in 1976. There were only two operating mines. Reserves are limited and will only last until 1982 unless new deposits are found.[8]

**Spain.**—Production of kyanite has been around 6,600 tons in recent years. Total reserves were estimated at about 3 million tons. Mining of kyanite was to be expanded to 20,000 tons per year late in 1977, and a new plant was to be installed.[9]

**Table 3.—Kyanite, sillimanite and related materials: World production, by country[1]**

(Short tons)

| Country and commodity[2] | 1975 | 1976 | 1977[p] |
|---|---|---|---|
| Australia: Sillimanite[3] | 648 | 625 | 1,098 |
| Brazil: Kyanite | 254 | 282 | [e]290 |
| France: Kyanite and andalusite[e] | 11,000 | 11,000 | 11,000 |
| India: | | | |
| Kyanite | [r]57,721 | 53,276 | 47,214 |
| Sillimanite | [r]9,125 | 16,379 | 16,418 |
| Korea, Republic of: Andalusite | 117 | 573 | 127 |
| South Africa, Republic of: | | | |
| Andalusite | 85,042 | 85,389 | 124,645 |
| Sillimanite | 18,641 | 28,366 | 17,036 |
| Spain: Andalusite | 5,558 | [e]6,600 | [e]6,600 |
| United States: | | | |
| Kyanite | W | W | W |
| Synthetic mullite | [r]24,150 | [r]42,230 | 40,280 |

[e]Estimate. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Owing to incomplete reporting, the table has not been totaled.

[2]In addition to the countries listed, a number of other countries presumably produced kyanite and related minerals, but output data are not reported and no basis is available for estimates of output levels.

[3]In addition, sillimanite clay (also called kaolinized sillimanite) is produced, but output is not reported quantitatively, and available information is inadequate for the formulation of reliable estimates of output levels.

## TECHNOLOGY

A patent was granted for extracting alumina from kyanite, aluminous clay, low-grade bauxite, or like material. The source material is slurried in concentrated sulfuric acid, heated to form a hard, anhydrous mass containing aluminum sulfate and silica, decomposed in the presence of a carbonaceous reductant at 700°C to 800°C to form an alkali-soluble alumina, and subjected to alkali leaching.[10]

The high strength potential of single-phase mullite under compressive stress-strain and creep testing conditions at 1,400° and 1,500°C was investigated.[11] Although the strength properties of mullite-containing fire clay refractories have been studied extensively, studies on mullite itself have been limited. This work was made possible by recently developed techniques of hot-pressing mullite powders to form a dense polycrystalline mullitic material. Previous materials invariably contained a glass phase, formed during mullitization, which adversely affected strength and creep values.

---

[1]Physical scientist, Division of Nonmetallic Minerals.

[2]Industrial Minerals (London). Sillimanite Minerals-Synthetics Encroaching on Markets. No. 117, June 1977, p. 50.

[3]Page 53 of work cited in footnote 2.

[4]Industrial Minerals (London). World of Minerals (Goias Kyanite). No. 121, October 1977, p. 11.

[5]Pages 47-48 of work cited in footnote 2.

[6]Pages 42-45 of work cited in footnote 2.

[7]Manos, A. Industrial Minerals of South Africa. Industrial Minerals (London). No. 122, November 1977, p. 25.

[8]Pages 45-46 of work cited in footnote 2.

[9]Page 50 of work cited in footnote 2.

[10]Lowenstein, H. M., and A. M. Lowenstein. Alumina Production. Canadian Pat. 1,017,578, Sept. 20, 1977.

[11]Dokko, P. C., J. A. Pask, and K. S. Mazdiyasni. High-Temperature Mechanical Properties of Mullite Under Compression. J. Am. Ceram. Soc., v. 60, No. 3-4, March-April 1977, pp. 150-155.