Kyanite and Related Minerals

By J. Robert Wells[1]

Kyanite, andalusite, and sillimanite are anhydrous aluminum silicate minerals that are closely akin in both composition and use patterns and have the same chemical formula, $Al_2O_3.SiO_2$. Closely related materials include synthetic mullite, dumortierite, and topaz, also classed as aluminum silicates. The latter two additionally contain boron and fluorine, respectively. All of these substances have the capability of serving as materials for the manufacture of special-duty refractories of the high-alumina category. There has been no record in recent years, however, of significant utilization of either dumortierite or topaz for this purpose in the United States.

Although not enough statistics are published to be wholly conclusive, it appears that the United States, India, and the Republic of South Africa hold the lead among world producers of kyanite-group minerals and that they may be not far from evenly matched in that regard. Presumably, the U.S.S.R. and some other industrialized nations also produce significant quantities of these materials.

Domestic production of kyanite plus synthetic mullite dipped moderately in tonnage in 1972, the first such downturn since 1968. Total value of these two materials, which showed a steep drop in 1971 from the peak reached in 1970, sagged again in 1972, though less sharply. These declines may have resulted from the slackness in shipments of finished brick and shape kyanite-mullite refractories that was noted in the 1971 Minerals Yearbook chapter, a trend that was even more marked in 1972. Total value of shipments of mullite brick and shapes made predominately of kyanite-group minerals or synthetic mullite (exclusive of molten-cast products) was 10% lower in 1971 and 28% lower in 1972 than in 1970. Mullite-based mortars, ramming mixes, and castable refractories presumably held up well, because total value of all nonclay refractories followed a 6% decline in 1971 with a 12% increase in 1972.[2] In ample compensation for any reduction in domestic consumption of the mullite refractories, exports of kyanite and allied materials scored a spectacular increase in 1972 with regard to both quantity and total value. Kyanite imports, meanwhile, fell to their lowest level in over 30 years.

Legislation and Government Programs.—The 1970 revision of the list of strategic materials for stockpiling excluded kyanite-mullite. At that time Government holdings totaled approximately 4,800 short tons of that commodity, and Congress authorized the stepwise disposal of the entire quantity by public sale. Notices dated November 23, 1971, January 19, 1972, June 27, 1972, and October 27, 1972, invited bids for the as-is sale of portions of this material, but no acceptable offers were received.

The Office of Minerals Exploration offered to grant Government loans up to 50% of approved costs for the exploration of eligible kyanite deposits, but no loans for that purpose were made in 1972.

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[1] Physical scientist, Division of Nonmetallic Minerals.

[2] U.S. Department of Commerce, Bureau of the Census. Current Industrial Reports, Series: MQ–32C; Summary for 1971; First, Second, Third, and Fourth Quarters 1972.

DOMESTIC PRODUCTION

Kyanite was produced in the United States in 1972 from three open pit mines, two in Virginia and one in Georgia. In addition to the hard-rock production, a minor quantity of kyanite-sillimanite concentrate was recovered in the process of extracting titanium and zirconium minerals from a beach sand deposit in Florida. 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. E. I. du Pont de Nemours & Co., Inc., operated the Trail Ridge mine and mill in Clay County, Fla.

Domestic kyanite output in 1972, as measured by the quantity sold or used, was fractionally lower in both tonnage and total value than in 1971. Specific kyanite production statistics for 1972 (as well as for all previous years since 1949) are withheld because the predominant position of the two major producers would make publication of even national totals a disclosure of each firm's confidential data.

Synthetic mullite, produced in 1972 by eight companies at operations in seven States, amounted to 16% less in tonnage than in 1971 and 18% less in total value. The 1972 output consisted predominantly of high-temperature sintered material, the average unit value of which was substantially below that reported for fused material. Leading in tons produced were Babcock & Wilcox Co., Richmond County, Ga.; Mullite Corp. of America, Sumter County, Ga.; H. K. Porter, Inc., Fairfield County, Conn.; and Charles Taylor & Sons, Inc., Greenup County, Ky.; whose combined outputs amounted to 86% of the 1972 national total.

Table 1.—Synthetic mullite production in the United States

(Short tons and thousand dollars)

Year	Quantity	Value
1968	36,014	5,758
1969	48,588	6,847
1970	55,516	8,840
1971	55,077	4,945
1972	46,389	4,080

CONSUMPTION AND USES

Kyanite and related minerals, conforming to the established end-use pattern, were consumed in 1972 mostly in the manufacture of high-alumina or mullite class refractories and in lesser quantities as ingredients in some ceramic compositions. Imported Indian kyanite was calcined in its natural lump form, after which it was usually separated into designated particle-size ranges for use chiefly as a grog. Domestic kyanite already ground to minus 35 mesh, as required by the flotation process used in separating it from the accompanying quartz gangue, was marketed in the raw form or after heat treatment, as mullite, which was sometimes further reduced in particle size. In the 35- to 48-mesh range, the mineral was employed mostly in refractories applications such as for high-temperature mortars or cements, ramming mixes, and castable refractories, or with clays and other ingredients in refractory compositions for the making of kiln furniture, insulating brick, firebrick, and other refractory articles of a wide variety of types. More finely ground material, minus 200 mesh for example, was used especially in body mixes for sanitary porcelains, wall tile, precision casting molds, and miscellaneous special-purpose ceramics.

PRICES

Engineering and Mining Journal, December 1972, listed the following prices per short ton (unchanged from December 1971 quotations) for kyanite, f.o.b. Georgia, in bags (bulk shipments $2.00 less per ton):

	Per short tons
35 mesh	$58
48 mesh	62
100 mesh	65
200 mesh	73
325 mesh	Nominal

Prices and price ranges for kyanite-group minerals quoted by Industrial Minerals (London), December 1972, were as follows (after conversion from pounds sterling per long ton to dollars per short ton):

	Per short ton
Andalusite, Transvaal, c.i.f. main European port	$51–$56
Kyanite, Indian, c.i.f. main European port	65–79
Sillimanite, Indian, natural, f.o.b. Calcutta	83
Silimanite, Indian, calcined, f.o.b. Calcutta	94

FOREIGN TRADE

An impressively larger quantity of kyanite-group material was exported from the United States in 1972 (to a total of 23 countries) than in any previous year. Large shipments by sea in the year's last quarter, especially from Savannah, Ga., helped to bring the total tonnage to the highest point in history, more than double the 1971 figure. The average unit value of 1972 exports, $50 per short ton, compared with $65 to $70 per ton in recent years, hinted that a greater proportion of the material than in previous years may have been mullite derived from high-temperature calcination of clays, rather than by treatment of kyanite or by synthesis from SiO_2 and Al_2O_3 materials.

Kyanite-group imports in 1972 continued the downward slant that became evident in the early 1950's and declined to less than one-tenth of the 1971 figure and to less than one-fortieth of that of a decade ago, virtually ceasing to be an item of consideration in the U.S. trade balance. For the first time in may years, India was listed as the sole supplier.

Tariff regulations applicable throughout 1972 provided for the duty-free importation of kyanite, sillimanite, andalusite, and dumortierite. The duty on mullite, which amounted to 10% ad valorem in 1970, was reduced to 9% ad valorem on January 1, 1971 and to 7½% ad valorem on January 1, 1972.

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

	1970		1971		1972	
	Short tons	Value	Short tons	Value	Short tons	Value
Exports:						
Argentina	245	$18,375	257	$20,404	112	$7,797
Australia	715	55,642	565	45,434	357	26,468
Belgium-Luxembourg	739	48,004	221	18,658	2,177	140,756
Canada	6,765	443,911	5,698	412,310	5,708	419,689
Colombia	--	--	661	37,791	312	19,399
Denmark	12	630	--	--	1,094	96,133
France	285	34,240	717	80,584	492	56,116
Germany, West	2,707	170,246	1,502	92,571	18,292	840,785
Italy	2,996	229,425	9,961	533,850	8,477	435,069
Japan	2,168	167,869	2,166	180,319	25,338	1,035,628
Mexico	2,435	164,591	1,877	128,057	1,775	118,482
Netherlands	--	--	2,635	187,840	6,561	262,610
Philippines	75	5,877	170	17,635	189	19,359
South Africa, Republic of	41	6,044	157	8,230	17	1,083
Sweden	1,217	72,775	2,609	163,405	731	42,542
Taiwan	309	8,823	--	--	9	570
Thailand	61	3,800	10	834	--	--
United Kingdom	2,213	122,757	1,461	103,652	1,446	107,996
Venezuela	780	46,437	583	41,597	558	52,485
Other	r 261	22,587	304	24,096	266	54,094
Total	24,024	1,622,033	31,554	2,097,267	73,911	3,737,061
Imports:						
France	1	290	1	1,612	--	--
India	1,178	55,264	1,301	60,743	124	5,773
South Africa, Republic of	--	--	41	2,891	--	--
Total	1,179	55,554	1,343	65,246	124	5,773

r Revised.

WORLD REVIEW

Although in most cases little or no statistical information is available, significant production of kyanite-group minerals and materials in recent years has been reported in Australia, Brazil, France, India, Kenya, Malawi, Mozambique, Rhodesia, Republic of South Africa, Republic of Korea, Spain, Territory of South-West Africa, the United Kingdom, and the United States. Interest has been expressed in kyanite deposits in Canada and Norway also, but no commercial production has yet been recorded in those countries. The U.S.S.R. and others among the more industrialized countries doubtless either produce or consume substantial quantities of the kyanite minerals, but pertinent data have not been made public.

Australia.—The annual totals for Australian sillimanite production in the fiscal years ending June 30, 1969, 1970, and 1971, amounted to 2,137, 1,295, and 1,255 short tons, respectively.[3] Recovery of commercial quantities of kyanite and a number of other coproduct minerals is expected to be feasible when full-scale development is reached at a Du Pont sponsored ilmenite-rutile operation at Eneabba, 150 miles north of Perth in Western Australia. Discovery was announced of a potentially valuable kyanite deposit, also in Western Australia, and plans were made to establish facilities for its exploitation.

Canada.—Dumortierite was one of the minerals found to occur in significant amounts in a quartz-feldspar porphyry dike abutting the ore body at Canada's second-largest copper mine on the north end of Vancouver Island, British Columbia. Plans for commercializing the discovery were not mentioned.[4]

Germany, West.—Imports by West Germany of sillimanite minerals (including andalusite and kyanite) amounted to 43,000 tons in 1970 and 30,000 tons in 1971.

India.—Production of Indian kyanite decreased from 131,171 tons in 1970 to 92,638 tons in 1971. Production of sillimanite declined also, although less markedly, from 5,029 tons in 1970 to 4,722 tons in 1971. Exports accounted for 54% and 41% of the 1971 kyanite and sillimanite outputs, respectively. The United Kingdom, West Germany, Italy Japan, and the Netherlands were the principal recipients of the exported material. The Government of India announced that, as of April 1, 1972, all exports of sillimanite will be channeled through the state-owned Minerals and Metals Trading Corp. Mines in the Khasi Hills district of India's remote state of Assam are the world's foremost source of sillimanite, which is valued for the manufacture of special-purpose refractories that are denser and more resistant to abrasion and thermal shock than those based on synthetic mullite. High cost and limited supply, both occasioned by the inaccessibility of the deposits and the expense of transportation (first for long distances over difficult roads, then by river boat down the Brahmaputra to Calcutta) are cited as the principal influences restricting utilization of this mineral.

Israel.—An industrial journal published an article describing the installations and operations of Koors Industries, Hasin-Esh division, which manufactures mullite-type refractories from raw materials mined in Israel's Negev Desert. The resulting products are mostly consumed by the domestic steel, cement, chemical, and ceramic industries.[5]

South Africa, Republic of.—Output of kyanite-group minerals in 1971, the last year for which complete data are available, amounted to 49,020 tons of andalusite and 19,246 tons of sillimanite. Comparable figures for 1970 were 46,872 tons and 23,690 tons, respectively. Exports in 1971 accounted for 41% of the output of andalusite and exceeded that of sillimanite by 7%. Exports in 1970 amounted to 56% and 88% of the respective outputs.

United Kingdom.—The Highlands and Islands Development Board issued a report cataloguing observed mineral occurrences on Scotland's Isle of Skye and mainland Ross and Cromarty County. Kyanite was one of the minerals specifically listed, but no information was released concerning possibilities for commercial development.

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[3] Industrial Minerals (London). Australian Production of Industrial Minerals. No. 64, January 1973, p. 27.

[4] Mining Magazine (London). Island Copper Project. V. 127, No. 4, October 1972, pp. 344–345, 347.

[5] Svec, J. J. Israeli High Alumina Refractories at Home and Abroad. Brick & Clay Record, v. 160, No. 2, February 1972, pp. 32–33.

TECHNOLOGY

In its annual review of materials for ceramic processing, an industrial journal presented informative thumb-nail studies of the kyanite-group minerals and their contributions to modern technology.[6] The research program of the Bureau of Mines included an investigation of beneficiation procedures applicable to kyanite-bearing materials from Idaho. A patent was issued for a process by which kyanite or other aluminosilicate ores can be treated with chlorine to volatilize undesired iron and titanium, leaving residues enriched in aluminum and silicon that can be smelted to produce alloys of these two elements.[7]

Mullite, synthesized from pure silica and Bayer-process alumina (at least 99% Al_2O_3) and then shaped into spheres, was the refractory catalyst-support base selected for a catalytic-cracking process for the production of synthetic pipeline gas.[8] A tabulation was published listing the physical, mechanical, and electrical properties, maximum recommended service temperatures, and practical applications of certain special-purpose ceramics of the refractory mullite type.[9]

A series of articles in a British journal presented a wide-ranging study of modern refractories and of the technology of their production and utilization. Prominently featured among the materials discussed were the kyanite–mullite group of refractories. Included in one of the reports was a useful world-wide listing of principal refractories manufacturers.[10]

A number of articles were published dealing with theoretical and experimental considerations of potential importance for the future development of kyanite–mullite refractories technology.[11]

An article reviewed technologic criteria for choosing types of refractories for a specified application. Considerations discussed for mullite and other applicable materials included thermal conductivity, thermal expansion, specific heat, emissivity, bulk density, porosity-permeability, thermal-shock resistance, creep, and crushing strength and modulus of rupture at different temperatures. More briefly treated were the topics of refractory life expectancy and comparative costs.[12]

The installations, equipment, and methods in use by a major producer of mullite refractories were subjects dealt with in a two-part magazine article.[13] New facilities for the development of refractories technology were placed in service by a leading industrial refractories manufacturer, Kaiser Refractories. The Clay-Alumina Development and Applications section of the new facility specializes in research on aluminosilicate materials, including mullite.[14]

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[6] Ceramic Industry Magazine. V. 100, No. 1, January 1973; Andalusite, p. 39; Dumortierite, p. 62; Kyanite, p. 74; Mullite, p. 88; Sillimanite, p. 102; and Topaz, p. 111.

[7] Hildreth, C. L. (assigned to Ethyl Corp.). Chloridizing Alumina-Containing Ore. U.S. Pat. 3,704,113, Nov. 28, 1972.

[8] Ceramic Age. Mullite Balls Help Produce SNG. V. 89, No. 1, January 1973, p. 4.

[9] Materials Engineering. Mechanical and Electrical Ceramics-Fired Parts. V. 76, No. 4, September 1972, p. 366.

[10] Industrial Minerals (London). An Introduction to Refractories. No. 58, July 1972, pp. 9–23.
———. Refractory Raw Materials—The Producers Reviewed. No. 59, August 1972, pp. 9–19.
———. The UK Refractories Industry. No. 61, October 1972, pp. 9–31.
———. Refractories in the USA. No. 62, November 1972, pp. 9–11, 13–14, 17, 19–23, 25, 27.

[11] Davis, Robert F., Ilhan A. Aksay, and Joseph A. Pask. Decomposition of Mullite. J. Am. Ceram. Soc., v. 55, No. 2, February 1972, pp. 98–101.
Davis, Robert F., and Joseph A. Pask. Diffusion and Reaction Studies in the System Al_2O_3-SiO_2. J. Am. Ceram. Soc., v. 55, No. 10, October 1972, pp. 525–531.
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[12] Russell G. A., Jr. Selection of Refractories for Modern Blast Furnace Stoves. Iron and Steel Eng., v. 49, No. 2, February 1972, pp. 42–48.

[13] Jeffers, P.E. CE Refractories—Part 1, A Profile on Progress; Part 2, An Organization of Specialists. Brick & Clay Record, v. 161, Nos. 1 and 2, July and August 1972, pp. 31–37, 43–44; and 17–21, respectively.

[14] Jeffers, P. E. Kaiser Consolidates Research in New $25-Million Lab. Brick & Clay Record, v. 160, No. 3, March 1972, pp. 26–27.