

KYANITE AND RELATED MATERIALS

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Kyanite, andalusite, and sillimanite are anhydrous aluminosilicate minerals that have the same chemical formula, Al_2SiO_5 , but differ in crystal structure and physical properties. When calcined at high temperatures (around $1,350^\circ C$ to $1,380^\circ C$ for kyanite and slightly higher for andalusite and sillimanite), these minerals are converted to mullite, $3Al_2O_3 \cdot 2SiO_2$, and silica, SiO_2 , which are refractory materials. In the conversion to mullite, 1 metric ton (t) of mineral concentrate yields about 0.88 t of mullite. Synthetic mullite is made by heating mixtures of alumina and silica or bauxite and kaolin at around $1,550^\circ C$ to $2,000^\circ C$ (Roskill Information Services, Ltd., 1990). Refractories are heat-resistant materials used in high-temperature applications such as furnaces, boilers, ladles, and kilns, in the metallurgical, glass, chemical, cement, and other industries.

The United States has been the leading producer of kyanite. South Africa has been the leading country in andalusite output, followed by France. Sillimanite has had limited production; India has supplied most of the output of around 12,000 metric tons per year.

Legislation and Government Programs

The Defense National Stockpile contained 136 t of kyanite at yearend 1999, which was being offered for sale on the third Thursday of every month (Defense National Stockpile Center, November 8, 1999, Kyanite, press release, accessed April 13, 2000, at URL <http://www.dnsc.dla.mil/kyanite.htm>).

Production

In 1999, kyanite was mined by Kyanite Mining Corp. at two open-pit mines in Buckingham County, VA. The company also operated beneficiation plants and calcining facilities for the conversion of kyanite to mullite. U.S. output was estimated at 90,000 t (Dickson, 1999); a corresponding value was estimated to be \$12.7 million (before any material was converted to mullite), using a value of \$141 per metric ton (table 1). High-temperature sintered synthetic mullite, made from calcined bauxitic kaolin clay, was produced by C-E Minerals, Inc. near Americus, GA. Production output was estimated at 39,000 t (Dickson, 1999).

Piedmont Minerals Co., Inc., Hillsborough, NC, mined a pyrophyllite/andalusite/sericite deposit. The company sells products containing blends of the three minerals to refractories and ceramics producers. There was no known U.S. output of sillimanite.

Consumption

Kyanite and andalusite, when heated at high temperature, are transformed into mullite and silica or glassy phase. The formation of mullite greatly enhances the refractoriness of a material. Uncalcined kyanite expands on heating, increasing in volume by about 15%. This property can be used to counteract shrinkage of other components in refractories, especially clays. Examples of kyanite- or mullite- containing refractories include ramming mixes, gunning mixes, monolithics, and mortars. Monolithics are refractories made of a single piece or as a continuous structure without separate sections. Kyanite also is used in insulating brick, firebrick, kiln furniture, and refractory shapes (O'Driscoll, 1999, p. 91).

Andalusite expands on heating by about 5%. Andalusite refractories have very good creep resistance and thermal shock resistance. They are used in torpedo ladles, blast furnace stoves, steel ladles, lime kilns, glass furnaces, cement kilns, carbon anode baking furnaces, incinerators, and other applications (O'Driscoll, 1999, p. 91).

Sillimanite was not used in the United States in 1999.

Prices for kyanite and related materials have remained stable during the past year, both in the United States and elsewhere (table 1).

Foreign Trade

The United States exported kyanite, mullite, and synthetic mullite to countries in Europe, Latin America, and the Pacific Rim. In 1999, as in recent years, imports of andalusite have been largely from South Africa (table 2). There were no known U.S. imports of kyanite or sillimanite in 1999.

World Review

Anglovaal Mining Ltd., in South Africa, sold Rhino Minerals (Pty.) Ltd. to Mircal South Africa (Pty.) Ltd., a local subsidiary of the Imerys Group (formerly Imetal Group), of France. Imerys, through its Imerys Refractories Group, is the world's largest producer of andalusite. Through its subsidiaries, Damrec Group in France and Samrec (Pty.) Ltd., in South Africa, Imerys owns all but one of the andalusite mines in South Africa and France (Industrial Minerals, 1999).

Andalusite production in South Africa in 1999 fell to about 130,000 t, compared with about 236,000 t in 1998 (table 3). Consumption of andalusite, which is mainly in refractories, has been affected by reduced activity in world iron and steel

production. Consequently, two South African andalusite mines were mothballed in 1998 and 1999 (Luitingh, 1999).

Outlook

The iron and steel industry continued to be the largest user of refractories in general, both in the United States and worldwide. Although there have been modest increases of iron and steel production in the United States during the past several years, U.S. steel imports have been increasing significantly, especially during the past 2 years. The 1999 import total was higher than any year except 1998 and 14.4% higher than in 1997, the last record year prior to 1998's unprecedented surge (American Iron and Steel Institute, January 31, 2000, Full year 1999: Steel imports exceed 35 million tons total and finished steel imports second highest ever and prices not yet restored, press release, accessed April 14, 2000, at URL http://www.steel.org/news/pr/2000/pr0001_imports.htm). Since 1995, significant imports of steel have come from Brazil, Japan, the Republic of Korea, and Russia. This has been a factor in reduced refractory demand (Semler, 1999).

The move toward monolithic refractories was expected to continue. In Western Europe, the tonnage of monolithics consumed probably will exceed the total for bricks and shapes within 8 to 10 years. In Japan, monolithics make up 60% by weight of the annual refractories production (Briggs, 1999).

Bricks and shapes, on average, cost more than twice as much per ton as monolithic refractories. This factor and the relative speed and ease of installation of monolithics explain why they continue to gain market share at the expense of bricks and shapes (Briggs, 1999).

References Cited

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GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

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Other

- Kyanite and related minerals. Ch. in *Mineral Facts and Problems*, U.S. Bureau of Mines Bulletin 675, 1985.
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¹Prior to January 1996, published by the U.S. Bureau of Mines.

TABLE 1
PRICE OF KYANITE AND RELATED MATERIALS IN 1999

(Dollars per metric ton)

	Price
Andalusite, South Africa, 57.5% alumina, 2,000-metric-ton bulk, f.o.b. 1/	180-220
Andalusite, South Africa, 59.5% alumina, 2,000-metric-ton bulk, f.o.b. 1/	220-230
Kyanite, USA (VA), 54% to 60% alumina, 35-325 mesh, 18-ton lots:	
Raw	140-170
Calcined	250-280

1/ Free on board.

Source: Industrial Minerals, December 1999, no. 387, p. 71.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF ANDALUSITE 1/ 2/ 3/

Year	Quantity (metric tons)	Value 4/ (thousands)
1998	9,610	1,850
1999	6,290	1,320

1/ Most material is from South Africa.

2/ Harmonized Tariff System (HTS) code: 2508.50.0000.

3/ Data are rounded to no more than three significant digits.

4/ Customs value.

Source: Bureau of the Census.

TABLE 3
KYANITE: ESTIMATED WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country and commodity 3/	1995	1996	1997	1998	1999
Australia:					
Kyanite	800	800	800	800	1,000
Sillimanite 4/	100	100	100	100	100
Brazil: Kyanite	600	600	600	600	600
China: Unspecified	2,500	2,500	3,000 r/	3,000 r/	3,000
France: Andalusite	60,000 r/	70,000 r/	67,000 r/	65,000 r/	65,000
India:					
Kyanite	6,772 5/	6,715 5/	6,035 r/ 5/	5,169 r/ 5/	5,000
Sillimanite	9,687 5/	7,521 5/	12,299 r/ 5/	11,936 r/ 5/	12,000
Kenya: Kyanite	(6/)	(6/)	--	--	--
South Africa:					
Andalusite	206,378 5/	233,728 r/ 5/	251,203 r/ 5/	236,200 r/ 5/	129,875 5/
Sillimanite	317 5/	-- 5/	-- 5/	65 r/ 5/	--
Spain: Andalusite	3,500	3,500	3,500	3,000 r/	2,500
United States:					
Kyanite	W	W	W	90,000	90,000
Mullite, synthetic	W	W	W	39,000	39,000
Zimbabwe	875 5/	141 5/	1,113 r/ 5/	3,780 r/ 5/	4,000

r/ Revised. W Withheld to avoid disclosing company proprietary data. -- Zero.

1/ U.S. and estimated data are rounded to no more than three significant digits.

2/ Owing to incomplete reporting, this table has not been totaled. Table includes data available through March 23, 2000.

3/ In addition to the countries listed, a number of other nations produce kyanite and related materials, but output is not reported quantitatively, and no reliable basis is available for estimation of output levels.

4/ In addition, about 7,000 metric tons of sillimanite clay (also called kaolinized sillimanite) is produced annually containing 40% to 48% Al₂O₃.

5/ Reported figure.

6/ Less than 1/2 unit.