

# KYANITE AND RELATED MATERIALS

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U.S. kyanite output was an estimated 90,000 metric tons (t) in 2004; the United States was the world's leading producer of this mineral (table 3). Production of synthetic mullite in the United States was an estimated 40,000 t (Dickson, 2004). There was no reported U.S. production of sillimanite. Iron and steel production continued to be the largest user of refractories worldwide. U.S. iron and steel shipments increased about 6% in 2004 from those of the previous year (American Iron and Steel Institute, 2004<sup>1</sup>). World production of steel increased by 8.8% in 2004 compared with that of 2003 (International Iron and Steel Institute, 2004§).

This report includes information on kyanite, andalusite, sillimanite (all of which have the formula  $Al_2SiO_5$ ), and synthetic mullite ( $Al_6SiO_{13}$ ). Trade data in this report are from the U.S. Census Bureau. Quantities are reported in metric units unless otherwise noted.

## Production

Kyanite Mining Corp. operated two open pit mines in Buckingham County, VA, and beneficiated the ore into a marketable kyanite concentrate. The company also had two kilns at its Dillwyn, VA, facility for production of calcined kyanite (mullite). Reported U.S. production data collected by the U.S. Geological Survey (USGS) are concealed to avoid disclosing company proprietary data. Estimated U.S. kyanite production, based on nongovernment estimates from previous years, was about 90,000 metric tons per year (t/yr) in 2004 with a value of about \$13 million (before conversion to mullite). High-temperature sintered synthetic mullite, made from calcined bauxitic kaolin and sold under the trade name Mulcoa 70, was produced by C-E Minerals, Inc. near Americus, GA. Washington Mills Electro Minerals Corp., Niagara Falls, NY, is the sole U.S. producer of fused synthetic mullite, but it is not known if there was production in 2004. Estimated U.S. production of synthetic mullite was about 40,000 t/yr (Dickson, 2004) with an estimated value of about \$9.7 million.

Piedmont Minerals Co., Inc. in Hillsborough, NC, mined a deposit containing andalusite combined with pyrophyllite and sericite. The company sells products containing blends of the three minerals to producers of refractories and ceramics.

## Consumption

Andalusite expands irreversibly by only about 4% to 6% when calcined and can therefore be used directly in refractories in its raw state. The small volume increase can be beneficial: calcining the refractory in service can result in tight-fitting refractory linings. Kyanite increases in volume by 16% to 18% when calcined and can be used in its raw concentrate form in a refractory mixture to counteract the shrinkage on firing of other components, especially clays (Dickson, 2004). In other refractory applications, kyanite concentrate is calcined to mullite before being added to refractory mixes if the volume increase of the kyanite is not required in the mix (Roskill Information Services Ltd., 1990, p. 56).

Examples of refractories that contain andalusite, kyanite, and/or synthetic mullite include insulating brick, firebrick, kiln furniture, refractory shapes, and monolithic refractories (made of a single piece or as a continuous structure) including castables (refractory concrete), gunning mixes, mortars, plastics, and ramming mixes. The interlocking grain structure of andalusite, kyanite and mullite gives added mechanical strength to refractories and other nonrefractory ceramic articles. Other end uses of kyanite and related materials include brake shoes and pads, electrical porcelain, floor and wall tile, foundry use, precision casting molds, sanitaryware, and other products (Kyanite Mining Corp., 2001§).

Monolithic refractories are supplied in unfired, generally unshaped form in contrast to prefired, preshaped brick products. They include a wide variety of products that may be gunned, hand packed, moulded, poured, pumped, rammed, or vibrated into place. Monolithic refractories are used in many of the same consuming industries as brick, including aluminum furnaces, foundry (both ferrous and nonferrous), incineration, iron and steel production, petrochemicals, power generation, and other applications (Moore, 2004).

## Foreign Trade

The United States exported kyanite and synthetic mullite to countries in Europe, Latin America, the Pacific rim, and other areas. Most of the material imported into the United States in 2004 was from South Africa and was presumed to be andalusite (table 2). No U.S. imports of kyanite or sillimanite were reported in 2004.

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<sup>1</sup>References that include a section mark (§) are found in the Internet References Cited section.

## World Review

South Africa continued to be the leading producing country of andalusite, with an estimated 165,000 t in 2004. France produced an estimated 65,000 t of andalusite. Although China appears to be a producer of kyanite and related minerals (Dickson, 2004), the USGS has not obtained official production data. Using available data, India has been the predominant producer of sillimanite, with an estimated 12,000 t/yr to 14,000 t/yr in recent years.

The refractories industry has continued to seek high-quality, high-performance minerals to meet the increasingly stringent demands of the refractories market. As a result, use of so-called “synthetic” minerals, such as sintered and fused mullites, has increased. Sintered synthetic mullite is made by sintering (heating below the melting point) bauxitic kaolin, or blends of alumina, bauxite, and kaolin. Fused synthetic mullite is made by fusing (melting) high-purity alumina and silica or certain blends of alumina, bauxite, and refractory kaolins (for example, as done in China). There are relatively few producers of mullites. Countries that have at least one producer of sintered mullite are Brazil, China (several), Germany, India, Japan, and the United States. Countries that have at least one producer of fused mullite include Brazil, China, Germany, Hungary, Japan, and the United States (O’Driscoll, 2004c).

**China.**—A new andalusite source in western China came onstream in March 2004: Xinjiang Bazhou Yilong Andalusite Mineral Co. commissioned its 50,000-t/yr andalusite plant in Xinjian Province. Three grades of andalusite were to be produced, ranging from 53% to 59% alumina ( $\text{Al}_2\text{O}_3$ ) and from 0.7% to 1% iron oxide ( $\text{Fe}_2\text{O}_3$ ). The crystal size of the andalusite was reported to include sizes of 1.0 millimeter (mm) to 6 mm, 0.8 mm, and 0.1 mm. In addition to export markets, the andalusite was slated for domestic markets, including steel and nonferrous metal production (Industrial Minerals, 2004b).

**France.**—The Imerys group signed an agreement with Materis group to acquire 100% of Lafarge Refractaires Monolithiques, a leading monolithics producer. The acquisition was subject to competition authorities’ approvals, and a completion date was set for early 2005. Imerys has focused mainly on supply of raw materials, including refractory materials such as andalusite and mullite. However, in 1996, Imerys acquired Plibrico International SA, based in Luxembourg. Plibrico is a leading European producer of monolithic refractories and prefabricated shapes. The company deals with certain sectors within the cement, iron and steel, and power generation markets (O’Driscoll, 2004a).

**India.**—Tata Refractories Ltd., the leading refractories producer in India in 2004, consumed a wide variety of refractory minerals, including andalusite, kyanite, sillimanite, and sillimanite sand. Sillimanite sands are readily available in India, and a large potential in growth is the conversion of this sand to synthetic 60% alumina aggregate. Also, other high-alumina raw materials are being increasingly produced combining, for example, sillimanite and china clay or sillimanite sand and calcined alumina. There has been a trend to use higher purity materials such as synthetic minerals and more high-performance materials (Chattopadhyay, 2004).

**Iran.**—With continuing growth in production of cement, ceramics, nonferrous metals, petrochemicals, and steel, Iran was facing a refractories shortage. In 2004, production of refractories amounted to about 250,000 t, representing 40% of the country’s domestic demand. The rest was imported. Production of refractories in 2004 was 295,000 t. In responding to the situation of domestic development, producers identified certain areas to address: investment in high-quality raw materials development, initiation of joint ventures with established foreign refractories companies to develop Iran’s resources and refractories output, and cooperation among Iran’s refractory producers to improve efficiencies and effectiveness. This last factor was underscored by the merger in 2004 of the four leading refractories companies in Iran. The conclusion of the merger was expected to take several months (Industrial Minerals, 2004a; O’Driscoll, 2004b, p. 34, 37; 2004d).

## Outlook

As the largest user of refractories worldwide, iron and steel production is an indicator of consumption of refractories and corresponding raw materials. Crude steel output in Asia was about one-half of the world total in 2004. China was the leading producer of crude steel, accounting for about 26% of world output (International Iron and Steel Institute, 2004§). As China’s economy develops, there is potential for China’s steel production to increase further (Industrial Minerals, 2004c).

The refractories industry remains in transition and continues to face a number of issues, including strong global and local competition; consolidation and downsizing; dealing with government regulations on the environment, health, and safety; resistance to refractory price increases from buyers of refractories; and the need to focus on adding value and services instead of quantity (Industrial Minerals, 2004c).

## References Cited

- Chattopadhyay, A.K., 2004, Refractories: Industrial Minerals, no. 446, November, p. 86.  
Dickson, Ted, 2004, Sillimanite minerals, in Industrial minerals annual review supplement: London, United Kingdom, Mining Journal Ltd. CD-ROM.  
Industrial Minerals, 2004a, Iranian refractories merger: Industrial Minerals, no. 441, June, p. 23.  
Industrial Minerals, 2004b, New andalusite source in Xinjiang: Industrial Minerals, no. 439, April, p. 17.  
Industrial Minerals, 2004c, Refractory industry still in transition: Industrial Minerals, no. 440, May, p. 23-24.  
Moore, Paul, 2004, Refractory monolithics: Industrial Minerals, no. 445, October, p. 43-49.  
O’Driscoll, Mike, 2004a, Imerys expands refractories arm: Industrial Minerals, no. 447, December, p. 6-8.  
O’Driscoll, Mike, 2004b, Iran—Window of opportunity: Industrial Minerals, no. 446, November, p. 28-41.  
O’Driscoll, Mike, 2004c, Mullite makes good: Industrial Minerals, no. 445, October, p. 32-41.  
O’Driscoll, Mike, 2004d, Refractories—The talk of Tehran: Industrial Minerals, no. 442, July, p. 20-21.  
Roskill Information Services Ltd., 1990, The economics of kyanite 1990: London, United Kingdom, Roskill Information Services Ltd., 118 p. plus appendices.

## **Internet References Cited**

American Iron and Steel Institute, 2004, 2004 yearend steel shipments rise 5.8% over 2003, Press Release, accessed March 15, 2005, via URL <http://www.steel.org>.  
International Iron and Steel Institute, 2004, World produces 1.05 billion tonnes of steel in 2004, Press Release, accessed March 15, 2005, via URL <http://www.worldsteel.org>.  
Kyanite Mining Corp., 2001, How our minerals are used, accessed February 6, 2002, at URL <http://www.kyanite.com/howused.html>.

## **GENERAL SOURCES OF INFORMATION**

U.S. Geological Survey Publications.

Kyanite and Related Minerals. Ch. in *Mineral Commodity Summaries*, annual.

Kyanite and Related Minerals. Ch. in *United States Mineral Resources*, Professional Paper 820, 1973.

## **Other**

Kyanite and Related Minerals. Ch. in *Mineral Facts and Problems*, U.S. Bureau of Mines Bulletin 675, 1985.

Sillimanite Group—Kyanite and Related Minerals. Ch. in *Industrial Minerals and Rocks*, Society for Mining, Metallurgy, and Exploration Inc. (6th ed.), Carr, D.D., ed., 1994.

TABLE 1  
PRICE OF KYANITE AND RELATED MATERIALS IN 2004

(Dollars per metric ton)

	Price
Andalusite, free on board, Transvaal, South Africa, 57% to 58% alumina, 2,000-metric-ton bulk lots	241-281
Kyanite, USA, ex-works, calcined (mullite), 54% to 60% alumina, 18-ton lots	248-295

Source: Industrial Minerals, no. 446, December 2004, p. 73.

TABLE 2  
U.S. IMPORTS FOR CONSUMPTION OF ANDALUSITE,  
KYANITE, AND SILLIMANITE<sup>1, 2, 3</sup>

Year	Quantity (metric tons)	Value <sup>4</sup> (thousands)
2003	4,480	\$1,090
2004	4,010	1,420

<sup>1</sup>Most material is andalusite from South Africa.

<sup>2</sup>Harmonized Tariff Schedule (HTS) code 2508.50.0000.

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

<sup>4</sup>Customs value.

Source: U.S. Census Bureau.

TABLE 3  
 KYANITE AND RELATED MINERALS: ESTIMATED WORLD PRODUCTION, BY COUNTRY<sup>1,2</sup>

(Metric tons)

Country and commodity <sup>3</sup>	2000	2001	2002	2003	2004
Australia:					
Kyanite	1,000	1,000	1,000	1,000	1,000
Sillimanite <sup>4</sup>	100	100	300	300	300
Brazil, kyanite	600	600	600	600	600
China, unspecified	3,100	3,150	3,200	3,200	3,300
France, andalusite	65,000	65,000	65,000	65,000	65,000
India:					
Kyanite	5,000	5,500	6,000	6,000	6,200
Sillimanite	12,000	13,000	14,000	14,000	14,500
South Africa, andalusite	182,674 <sup>5</sup>	193,225 <sup>5</sup>	165,000 <sup>5</sup>	164,921 <sup>r,5</sup>	165,000
Spain, andalusite	2,500	2,500	7	2,500	2,500
United States: <sup>6</sup>					
Kyanite	90,000	90,000	90,000	90,000	90,000
Mullite, synthetic	40,000	40,000	40,000	40,000	40,000
Zimbabwe, kyanite	10,970 <sup>5</sup>	9,682 <sup>5</sup>	5,657 <sup>5</sup>	745 <sup>r,5</sup>	500

<sup>r</sup>Revised.

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

<sup>2</sup>Owing to incomplete reporting, this table has not been totaled. Table includes data available through March 15, 2005.

<sup>3</sup>In addition to the countries listed, small amounts of kyanite were produced in Kenya in 2000; 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.

<sup>4</sup>In addition, about 7,000 metric tons per year of sillimanite clay (also called kaolinized sillimanite) that contains 40% to 48% Al<sub>2</sub>O<sub>3</sub> is produced.

<sup>5</sup>Reported figure.

<sup>6</sup>Source: Dickson, Ted, 2004, Sillimanite minerals, *in* Industrial minerals annual review supplement: London, United Kingdom, Mining Journal Ltd. CD-ROM.