



# 2008 Minerals Yearbook

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## KYANITE AND RELATED MATERIALS

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# KYANITE AND RELATED MATERIALS

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The United States continued to be the world's leading producer of kyanite and mullite (calcined kyanite) with an estimated production of 115,000 metric tons (t) in 2008. Production of synthetic mullite in the United States was an estimated 40,000 t. Andalusite was mined and marketed as part of a mineral mixture at one U.S. operation, but data are withheld to avoid disclosing company proprietary data. There was no reported U.S. production of sillimanite. Refractory products continued to be a major end use for kyanite and related materials.

This report includes information on andalusite, kyanite, and sillimanite (all of which have the formula  $Al_2SiO_5$ ), and mullite and synthetic mullite ( $3Al_2O_3 \cdot 2SiO_2$ ). Mullite, a refractory (heat resistant) material, can be made by calcining kyanite at high temperature (for example, above 1,450° C). By contrast, synthetic mullite in this report refers to mullite that is made by calcining at high temperature certain mixtures of alumina- and silica-containing minerals and materials, such as bauxite and kaolin.

## Production

Kyanite Mining Corp. (KMC), the sole U.S. producer of kyanite and kyanite-derived mullite, 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 mullite from kyanite. Reported U.S. production data collected by the U.S. Geological Survey (USGS) are withheld to avoid disclosing company proprietary data. Production was estimated using employment data provided by the Mine Safety and Health Administration (MSHA) and nongovernment estimates from previous years. An estimated 115,000 t of kyanite was produced in the United States in 2008, a decrease of about 3% compared with the reported production of 118,000 t in 2007 (Lassetter, 2008). The estimated value of the kyanite produced in the United States in 2008 was \$21 million, a decrease of 17% compared with the 2007 total. The decrease in total value was partially the result of a 14% decrease in the average unit price compared with the average unit price for 2007. KMC's mullite product contained about 80% mullite (Kyanite Mining Corp., 2006). Synthetic mullite, made from calcined bauxitic kaolin and sold by C-E Minerals, Inc., contained up to 87% mullite and was produced near Americus, GA (C-E Minerals, 1997). Based on nongovernment estimates from previous years, estimated U.S. production of synthetic mullite was about 40,000 t in 2008; the estimated value for the material was about \$10 million.

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

## Consumption

Kyanite increases in volume by 16% to 18% when calcined to mullite and can be used in its raw concentrate form in a refractory mixture to offset the shrinkage on firing of other components, especially clays. Andalusite expands irreversibly by only about 4% to 6% when calcined, and can, therefore, be used directly in refractories in its raw state (Dickson, 2006; Lassetter, 2007). 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. Mullite is resistant to abrasion and penetration of deleterious dusts, gases, and slags. It also has good creep resistance, which is resistance to physical deformation under load at high temperatures (Roskill Information Services Ltd., 1990, p. 56, 63).

Examples of refractories that contain andalusite, kyanite, or 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.

Monolithic refractories are supplied in unfired, generally unshaped form, in contrast to prefired, preshaped brick products. They may be gunned, hand packed, moulded, poured, pumped, rammed, or vibrated into place (Moore, 2004).

Iron and steel production continued to be the leading user of refractories. World and U.S. crude steel output decreased by about 1% and 7%, respectively, in 2008 from that of 2007 (World Steel Association, 2009a). Other refractories users were in the nonferrous metal and glass industries (Sweet, Dixon, and Snoddy, 2006). Other end uses of kyanite and related materials include brake shoes and pads, electrical porcelain, foundry use, precision casting molds, sanitaryware, and other products (Kyanite Mining Corp., 2006).

## Foreign Trade

An estimated one-third of U.S. kyanite and mullite output was exported. Most of the material imported into the United States in 2008 was from France and South Africa and was presumed to be andalusite (table 2). In 2008, imports of andalusite increased compared with the amounts imported in 2007 and 2006. No known U.S. imports of kyanite or sillimanite were reported in 2008.

## World Review

South Africa continued to be the leading producing country of andalusite with an estimated production of 260,000 t in 2008 (table 3). France produced an estimated 65,000 t of andalusite. Although China appears to be a producer of kyanite and related minerals (Dickson, 2006), detailed production data have not been obtained. Using available data, India has

been the dominant producer of sillimanite with an estimated production of 16,000 t of sillimanite and 7,500 t of kyanite in 2008. Countries that are said to be producers of synthetic mullite (sintered mullite and/or fused mullite) include Brazil, China, Germany, Hungary, and Japan (Taylor, 2005).

For refractories markets in China, India, and Japan, the steel industry used 70% to 75% of the tonnage. Two of the world's largest refractories companies reported that the steel industry accounted for about 60% of their annual sales worldwide (Semler, 2007a).

**China.**—Xinjiang Bazhou Yilong Andalusite Mineral Co. opened a mine in the Ku'erle andalusite deposit in western China in March 2004. Three grades of andalusite were to be produced, ranging from 53% to 59% alumina (Al<sub>2</sub>O<sub>3</sub>) and from 0.7 to 1 % iron oxide (Fe<sub>2</sub>O<sub>3</sub>). The crystal size of the andalusite was reported to include sizes of 1.0 to 6.0 millimeters (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, 2004). Imerys acquired a 65% stake in Xinjiang Bazhou Yilong Andalusite Mineral Co. and it planned to increase andalusite capacity to 40,000 metric tons per year (t/yr) from 15,000 t/yr by July 2009 which would double China's estimated annual andalusite production (Industrial Minerals, 2008). China was the largest refractory producing country in the world. The country has emphasized the need for improved energy conservation in the production of refractories, which could include developments in energy saving production processes and new types of furnaces and kilns (Tran, 2007).

**United Kingdom.**—DSF Refractories & Minerals Ltd. was planning to expand the production capacity of its Friden plant in Derbyshire. The new fuel-efficient kiln was expected to come online in spring 2009 and decrease the delivery times for its mullite orders (Industrial Minerals, 2009).

## Outlook

Natural raw materials, such as andalusite and kyanite, continue to be important in refractory manufacturing. For even more durable refractories, technology advances have included increased usage of such processed raw materials as synthetic mullite. As the technology for manufacturing refractories continues to improve, the use of synthetic raw materials in the production of refractories could continue to grow. Other general material use trends could include the increased development and use of monolithic products and a gradual increase in the use of recycled refractory materials (Semler, 2007b).

China and Japan have been seen as major locations for the production and consumption of refractories. Opportunities for market expansion could exist in other areas, such as the Commonwealth of Independent States, Eastern Europe, the Middle East, Russia, and Southeast Asia (Semler, 2007b).

Global crude iron and steel production, the leading consumer of refractories, decreased by about 1% in 2008, but world steel production was more than 1.3 billion metric tons for the second consecutive year. The leading steel-producing countries and their share of 2008 steel output were China, 38%; Japan, 9%; the United States, 7%; Russia, 5%; India, 4%; and the Republic of Korea, 4%. These countries accounted for 885 million metric

tons of steel in 2008, which was a slight decrease in production compared with that of 2007 (World Steel Association, 2009a).

For Canada, Mexico, and the United States, steel consumption was projected to decrease by 37% in 2009. China's apparent steel use was projected to decrease by 5% in 2009, and Japan may experience a 20% decrease. World steel consumption (excluding China) was forecast to decrease by 20% in 2009 (World Steel Association, 2009b).

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## GENERAL SOURCES OF INFORMATION

### U.S. Geological Survey Publications

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- 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.

TABLE 1  
PRICE OF KYANITE AND RELATED MATERIALS IN 2008

(Dollars per metric ton)

	Price
Andalusite, free on board, Transvaal, South Africa, 57% to 58% alumina, 2,000-metric-ton bulk lots	295–334
Kyanite, USA, ex-works, raw, 54% to 60% alumina.	184–341
Kyanite, USA, ex-works, calcined (mullite), 54% to 60% alumina, 22-ton lots	325–466

Source: Industrial Minerals, no. 495, December 2008, p. 89.

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)
2007	1,760	\$646
2008	5,580	1,930

<sup>1</sup>Most material is andalusite from South Africa. No known kyanite or sillimanite imports were reported.

<sup>2</sup>Harmonized Tariff Schedule of the United States 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 MATERIALS: ESTIMATED WORLD PRODUCTION, BY COUNTRY<sup>1,2</sup>

(Metric tons)

Country and commodity <sup>3</sup>	2004	2005	2006	2007	2008
Australia:					
Kyanite	1,000	1,000	1,000	1,000	1,000
Sillimanite <sup>4</sup>	300	300	300	300	300
Brazil, kyanite, marketable	600	600	600	600	600
China, unspecified	3,300	3,400	3,400	3,500	4,000
France, andalusite	65,000	65,000	65,000	65,000	65,000
India:					
Kyanite	6,200	6,800	7,000	7,300	7,500
Sillimanite	14,500	15,000	15,000	15,200 <sup>r</sup>	16,000
South Africa, andalusite	234,625 <sup>s</sup>	228,265 <sup>s</sup>	221,209 <sup>s</sup>	264,645 <sup>r,5</sup>	260,000
United States:					
Kyanite	109,000 <sup>r,6</sup>	112,000 <sup>r,7</sup>	112,000 <sup>r,7</sup>	118,000 <sup>r,8</sup>	115,000
Mullite, synthetic	40,000 <sup>6</sup>	40,000	40,000	40,000	40,000
Zimbabwe, kyanite	210 <sup>5</sup>	--	--	--	--

<sup>r</sup>Revised. -- Zero.

<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 12, 2009.

<sup>3</sup>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.

<sup>4</sup>In addition, about 7,000 metric tons 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, 2006, Sillimanite minerals, *in* Countries and commodities report: Mining Journal (Accessed March 17, 2006, via <http://www.mining-journal.com>).

<sup>7</sup>Estimated based on the part 50 report published by the Mine Safety and Health Administration (Accessed March 9, 2009, via <http://www.msha.gov/stats/part50/p50y2k/aetable.htm>).

<sup>8</sup>Source: Lassetter, W.L., Jr., 2008, Kyanite, andalusite, sillimanite and mullite: Mining Engineering, v. 60, no. 6, June, p. 44–45.