



# 2007 Minerals Yearbook

---

## KYANITE

---

# KYANITE AND RELATED MATERIALS

By Michael J. Potter

**Domestic survey data and tables were prepared by Elsie D. Isaac, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.**

The United States continued to be the world's leading producer of kyanite and mullite (calcined kyanite) with an estimated production of 90,000 metric tons (t) in 2007 (table 3). Production of synthetic mullite in the United States was an estimated 40,000 t. There was no reported U.S. production of sillimanite. 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. 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 ( $Al_6SiO_{13}$ ). 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. The estimate of U.S. kyanite production of 90,000 t was based on nongovernment estimates from previous years; the estimated value of the material in 2007 was about \$19 million. 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 87% mullite and was produced near Americus, GA (C-E Minerals, undated). Based on nongovernment estimates from previous years, estimated U.S. production of synthetic mullite was about 40,000 t in 2007; 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. U.S. crude steel output decreased by about 1% in 2007 from that of 2006 (International Iron and Steel Institute, 2008). Other refractories users were 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 to countries in Europe, Latin America, the Pacific rim, and other areas. Most of the material imported into the United States in 2007 was from France and South Africa and was presumed to be andalusite (table 2). The decrease in imports in 2007 may be the result of stronger market demand outside of the United States and a temporary supply shortage from the larger andalusite producer in South Africa (O'Driscoll, 2007b). No known U.S. imports of kyanite or sillimanite were reported in 2007.

## World Review

South Africa continued to be the leading producing country of andalusite, with an estimated 220,000 t in 2007. 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 predominant producer of sillimanite, with an estimated 14,000 to 15,000 t/yr in recent years. 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 was using 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.**—Jungar Mengsheng New Materials Co. Ltd. was a new producer of sintered mullite. The company was located in the northern Chinese Province of Inner Mongolia about 120 kilometers southwest of Hohhot. Ore deposits at the site included kaolin and bauxite. The typical grades of the sintered mullite produced contained 60% to 70% alumina. Current and planned markets included the domestic refractory sector and overseas customers (O'Driscoll, 2007a).

China is 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).

**Japan.**—Since 1993, demand for monolithic (unshaped) refractories has exceeded that for shaped refractories. In 2006, unshaped refractories accounted for about 67% of the refractory tonnage produced in Japan. In the steel industry, unshaped refractories apparently are cheaper, easier to install, more easily repaired, and result in time savings (Semler, 2007b).

**South Africa.**—Andalusite Resources (Pty.) Ltd. (ARL) is a relatively new producer of andalusite and is the only alternative supplier of the South African material outside the Damrec group. In March 2007, ARL increased production from about 2,000 metric tons per month (t/mo) to more than 3,000 t/mo. ARL was supplying shaped and unshaped refractory producers in Asia, Europe, and South Africa (Industrial Minerals, 2007).

## 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 used 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 CIS, Eastern Europe, the Middle East, Russia, and Southeast Asia (Semler, 2007b).

Global crude iron and steel production, the largest consumer of refractories, increased by about 7% in 2007. The four leading steel-producing countries and their share of 2007 steel output

were China, 36%; Japan, 9%; the United States, 7%; and Russia, 5% (International Iron and Steel Institute, 2008).

For Canada, Mexico, and the United States, steel consumption was projected to increase by 4% in 2008. China's apparent steel use was projected to grow by 11.4% in 2007 and 11.5% in 2008, and was expected to account for 35% of the world total. World steel consumption (excluding China) was forecast to increase by 4.4% in 2008 (International Iron and Steel Institute, 2007).

## References Cited

- C-E Minerals, [undated], Mulcoa@calcines: C-E Minerals. (Accessed June 2, 2008, at <http://www.ceminerals.com/calcine.html>.)
- Dickson, Ted, 2006, Sillimanite minerals, in Countries and commodities reports: London, United Kingdom, Mining Journal, 7 p. (Accessed March 17, 2006, via [http://www.mining-journal.com/Annual\\_Review.aspx](http://www.mining-journal.com/Annual_Review.aspx).)
- Industrial Minerals, 2007, Andalusite in action: Industrial Minerals, no. 475, April, p. 70-71.
- International Iron and Steel Institute, 2007, IISI short range outlook: International Iron and Steel Institute, October 8. (Accessed October 9, 2007, at <http://www.worldsteel.org/?action=newsdetail&jaar=2007&id=213>.)
- International Iron and Steel Institute, 2008, World crude steel output increases by 7.5% in 2007: International Iron and Steel Institute, January 23. (Accessed March 17, 2008, at <http://www.worldsteel.org/?action=newsdetail&jaar=2008&id=228>.)
- Kyanite Mining Corp., 2006, Virginia Mullite™ is very low in impurities compared to other traditionally sintered mullite: Kyanite Mining Corp. (Accessed June 2, 2008, at <http://www.kyanite.com/mullite.html>.)
- Lassetter, W.L., Jr., 2007, Kyanite, andalusite, sillimanite, and mullite: Mining Engineering, v. 59, no. 6, June, p. 40-41.
- Moore, Paul, 2004, Refractory monolithics: Industrial Minerals, no. 445, October, p. 43-49.
- O'Driscoll, Mike, 2007a, Mullite in Mongolia: Industrial Minerals, no. 476, May, p. 68-69.
- O'Driscoll, Mike, 2007b, Refractories' double-edged sword: Industrial Minerals, no. 475, April, p. 23.
- Roskill Information Services Ltd., 1990, The economics of kyanite 1990: London, United Kingdom, Roskill Information Services Ltd., 118 p. plus appendices.
- Semler, C.E., 2007a, The refractories world today—An overview: Industrial Minerals, no. 475, April, p. 55-61.
- Semler, C.E., 2007b, Update on refractories in Japan: Refractories Applications and News, v. 12, no. 5, September/October, p. 5-7. (Accessed October 9, 2007, at <http://www.ranews.info/ran/ran2007/ranso07.pdf>.)
- Sweet, P.C., Dixon, G.B., and Snoddy, J.R., 2006, Kyanite, andalusite, sillimanite, and mullite, in Kogel, J.E., Trevedi, N.C., Barker, J.M., and Krukowski, S.T., Industrial minerals and rocks (7th ed.): Littleton, CO, Society for Mining, Metallurgy, and Exploration, Inc., p. 553-560.
- Taylor, Lindsey, 2005, Clays on fire: Industrial Minerals, no. 458, November, p. 30-39.
- Tran, Alison, 2007, Chinese refractory output soars 31%: Industrial Minerals, no. 477, June, p. 29.

## 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.

TABLE 1  
PRICE OF KYANITE AND RELATED MATERIALS IN 2007

(Dollars per metric ton)

	Price
Andalusite, free on board, Transvaal, South Africa, 57% to 58% alumina, 2,000-metric-ton bulk lots	234–277
Kyanite, USA, ex-works, raw, 54% to 60% alumina.	215–279
Kyanite, USA, ex-works, calcined (mullite), 54% to 60% alumina, 22-ton lots	331–402

Source: Industrial Minerals, no. 483, December 2007, p. 77.

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)
2006	4,350	\$1,580
2007	1,760	646

<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 MINERALS: ESTIMATED WORLD PRODUCTION, BY COUNTRY<sup>1, 2</sup>

(Metric tons)

Country and commodity <sup>3</sup>	2003	2004	2005	2006	2007
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	3,200	3,300	3,400	3,400	3,500
France, andalusite	65,000	65,000	65,000	65,000	65,000
India:					
Kyanite	6,000	6,200	6,800	7,000	7,300
Sillimanite	14,000	14,500	15,000	15,000	15,000
South Africa, andalusite	164,921 <sup>5</sup>	234,625 <sup>5</sup>	228,265 <sup>r, 5</sup>	221,209 <sup>r, 5</sup>	220,000
United States:					
Kyanite	90,000	90,000	90,000	90,000	90,000
Mullite, synthetic	40,000	40,000 <sup>6</sup>	40,000	40,000	40,000
Zimbabwe, kyanite	745 <sup>5</sup>	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 April 13, 2008.

<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 reports: Mining Journal. (Accessed March 17, 2006, via <http://www.mining-journal.com>.)