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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 production estimated to be about 93,000 metric tons (t) in 2010 (table 3). 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 were 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 ($3Al_2O_3 \cdot 2SiO_2$). The first three minerals are the primary minerals of what is referred to as the kyanite group, especially in the United States where kyanite is prevalent, but are also known collectively (including natural mullite) as the sillimanite minerals. Mullite typically is the most desired of these minerals because of its superior refractory (heat resistant) properties and high strength, but it is rarely found in nature in quantities that are economical to develop. Mullite can be made by calcining kyanite at a high temperature (for example, above 1,450 ºC), and synthetic mullite typically refers to mullite made by calcining certain mixtures of alumina- and silica-containing minerals and materials, including bauxite and kaolin, at similarly high temperatures.

Production

Kyanite Mining Corp. (KMC), which has been mining the kyanite deposits in central Virginia since 1945, was the sole U.S. producer of kyanite and kyanite-derived mullite. KMC operated two open pit mines, the East Ridge Mine and the Willis Mountain Mine, in Buckingham County, and beneficiated the ore into a marketable kyanite concentrate. The company also had two kilns at its Dillwyn, VA, facility, the Gieseke Plant, at which kyanite was converted into mullite. U.S. production data reported to the U.S. Geological Survey (USGS) were withheld to avoid disclosing company proprietary data. KMC produced one grade of kyanite, Virginia Kyanite, which contains between 55% and 60% Al_2O_3. A second product, Virginia Mullite, which KMC described as "a true mullite, not a synthetic blend," was produced by calcining kyanite (O'Driscoll, 2010b). In 2010, 93,000 t of kyanite was reported produced in the United States; this was an increase of about 34% compared with the reported production of 71,000 t in 2009 and nearing a return to the production level of 97,200 t in 2008 (Lassetter, 2010, 2011). The estimated value of kyanite produced in the United States in 2010 was nearly $28 million, an increase of about 33% compared with a revised estimate of $21 million in 2009. This was based upon an estimated average unit value for raw and worked kyanite that remained at about $300 per metric ton compared with that of 2009. KMC's mullite product contained about 80% mullite (Kyanite Mining Corp., 2006). C-E Minerals, Inc. (part of Imerys SA Group) produced synthetic mullite from calcined bauxitic kaolin near Americus, GA, that contained up to 87% mullite (C-E Minerals, 1997). Based on nongovernment estimates from previous years, U.S. production of synthetic mullite of about 40,000 t in 2010 had an estimated value of about $12 million.

KMC estimated that reserves at its two Virginia mines would last for 50 to 75 years. During the economic slowdown in 2009, KMC reengineered and replaced the iron reduction stage of its beneficiation process to produce a higher quality kyanite through significant removal of the iron in its product while also increasing recovery of kyanite and production capacities (O'Driscoll, 2010b).

In response to increasing demand, C-E Minerals restarted all its kilns in Andersonville, GA, in late 2009, and in early 2010, brought onstream a new sintered mullite rotary kiln, which added 75,000 metric tons per year (t/yr) to the company's existing production capacity (O'Driscoll, 2010a).

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 about 4% to 6% when calcined and can 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 beneficial creep resistance, which limits 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 and unshaped form, in contrast to prefired and preshaped brick products, and may be gunned, hand packed, molded, 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 increased by about 15% and 38%, respectively, in 2010 from that of 2009, following decreases of 7% and 36%, respectively, in 2009 from that of 2008. The leading steel-producing countries and their shares of 2010 steel output of 1.41 billion metric tons were China, 44%; Japan, 8%; the United States, 6%; Russia, 5%; India, 5%; the Republic of Korea, 4%; and Germany, 3%. These countries accounted for more than 1.05 billion metric tons of steel production in 2010, representing a 14% increase in production from the same countries compared with that of 2009 (World Steel Association, 2011a). Other refractories users were the nonferrous metal and glass industries (Sweet, Dixon, and Snoddy, 2006). Other end uses of kyanite and related materials included brake shoes and pads, electrical insulating porcelains, foundry use, precision casting molds, sanitaryware and whiteware, and other products (Kyanite Mining Corp., 2006).

KMC found its traditional markets for kyanite strengthening and gradually coming back from the weakened markets of the economic recession of late 2008 and 2009, and the company was experiencing success in some new markets, such as ceramic foam filters and refractories for aluminum production (O'Driscoll, 2010a).

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 2010 was from France and South Africa and was presumed to be andalusite (table 2). In 2010, imports of andalusite decreased by 55% compared with those of 2009. No U.S. imports of kyanite or sillimanite were reported in 2010.

World Review

South Africa continued to be the leading producing country of andalusite, with an estimated 240,000 t produced in 2010 (table 3). France produced an estimated 65,000 t of andalusite. Although China is thought to be a producer of andalusite, kyanite, and sillimanite, detailed production data have been unavailable since 2003 (O'Driscoll, 2010b). India was the primary producer of sillimanite, with an estimated 16,800 t of sillimanite, and also produced 7,800 t of kyanite in 2010. Countries that are thought 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).

In addition to the steady resurgence in the world's steel industry, a steady decline of inexpensive and readily available refractory bauxite from China contributed to an increasing interest in the development of resources of sillimanite minerals (O'Driscoll, Mike, 2010b).

Peru.—In northern Peru, andalusite resources that were within unconsolidated sand and gravels of the Tablazo Mancora flood plain and other unproven mineral resources were being evaluated. Andalusita S.A. (a subsidiary of Refractarios Peruanos S.A.) began andalusite production at a rate of 30,000 t/yr in 2009 and was expected to reach full capacity of 40,000 t/yr by mid-2010, but further information was not available. The primary andalusite grade being produced for refractory consumers, mainly in Asia, Europe, and North America, contained a minimum of 58% Al_2O_3 and a maximum of 0.8% Fe_2O_3 (O'Driscoll, 2010a).

South Africa.—Andalusite Resources (Pty.) Ltd. mined andalusite near capacity at its Maroeloesfontein Mine in Thabazimbi, Limpopo Province. The mine's full production capacity was 50,000 t/yr with an expected mine life of 20 years. With licenses to mine adjacent properties to the north of the current mine site, the company expected an additional 25 years of production at the same rate. Andalusite Resources' latest drilling program on other adjacent sites found larger reserves than expected, adding an additional 25 years of mine life, bringing the total to 70 years at 50,000 t/yr. Andalusite Resources planned to expand production in the region to 80,000 to 100,000 t/yr by the end of 2012. The company's main markets were in China, Europe, India, and South Africa (O'Driscoll, 2010b).

Outlook

Natural raw materials, such as andalusite and kyanite, continue to be important in refractory manufacturing. They may become increasingly sought after as alternative materials to bauxite in certain refractory applications owing to a decrease in readily available, comparatively inexpensive refractory bauxite from China. Demand for bauxite within China has increased, and the availability of quality bauxite for export has declined in recent years, in part owing to Chinese Government policies that have reduced bauxite (and other mineral) exports. Also, bauxite supplies were affected by government restrictions and closures at several mining and processing locations in China owing to environmental and safety controls (O'Driscoll, 2010b). In general, refractory producers have faced increasing challenges in obtaining the bauxite necessary to produce refractory products (Roberts, 2010).

For durable refractories, technology advances included increased use of synthetic mullite. Continuing improvements in the technologies used in the manufacture of refractories is expected, and the use of synthetic raw materials in the production of refractories also is likely to increase. Other general material use trends could include the increased development and use of monolithic products, as has been the case in Japan's steel industry for more than a decade, and potentially a gradual increase in the use of recycled refractory materials (Semler, 2007b).

China and Japan have been 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, and Southeast Asia (Semler, 2007b).

For Canada, Mexico, and the United States, steel consumption was projected to increase in 2011 by nearly 11% because of stock rebuilding from the drawdown during the recession coupled with an ongoing recovery in the U.S. economy. Because

of efforts by the Chinese Government to moderate growth, especially in its real estate sector, the growth in China's apparent steel use slowed in the latter part of 2010 and was projected to slow to about 5% in 2011. India's steel use was expected to increase by about 13% in 2011. India is on track to become the third leading steel consuming country in the world after China and the United States. World steel consumption was forecast to increase by nearly 6% in 2011 compared with that of 2010 (World Steel Association, 2011b).

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TABLE 1
PRICES OF KYANITE AND RELATED MATERIALS IN 2010

(Dollars per metric ton)

	Price
Kyanite, USA, ex-works, raw, 54% to 60% alumina.	233–332
Kyanite, USA, ex-works, calcined (mullite), 54% to 60% alumina, 22-ton lots	387–456

Source: Industrial Minerals, December 2010, p. 69.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF ANDALUSITE, KYANITE, AND SILLIMANITE[1, 2, 3]

Year	Quantity (metric tons)	Value[4] (thousands)
2009	4,880	$2,060
2010	2,180	938

[1]Most material is andalusite from South Africa. No kyanite or sillimanite imports were reported.

[2]Harmonized Tariff Schedule of the United States code 2508.50.0000.

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

[4]Customs value.

Source: U.S. Census Bureau.

TABLE 3
KYANITE AND RELATED MATERIALS: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country and commodity[3]	2006	2007	2008	2009	2010
Australia:					
Kyanite	1,000	1,000	1,000	1,000	1,000
Sillimanite[4]	300	300	300	300	300
Brazil, kyanite, marketable	600	600	600	600	600
China, unspecified	3,400	3,500	4,000	4,000	4,000
France, andalusite	65,000	65,000	65,000	65,000	65,000
India:					
Kyanite	7,000	7,300	7,500	7,700	7,800
Sillimanite	15,000	15,200	16,000	16,500	16,800
South Africa, andalusite	221,209 [5]	264,645 [5]	216,667 [5]	190,000 [r]	240,000
United States:					
Kyanite	102,000 [6]	118,000 [7]	97,200 [8]	71,000 [9]	93,000 [10]
Mullite, synthetic	40,000	40,000	40,000	40,000	40,000

[r]Revised.

[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 April 29, 2011.

[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) that contains 40% to 48% Al_2O_3 is produced.

[5]Reported figure.

[6]Source: Estimated based on data from Mine Safety and Health Administration, [undated], Mining industry accident, injuries, employment, and production data: Mine Safety and Health Administration (accessed March 9, 2009, via http://www.msha.gov/stats/part50/p50y2k/aetable.htm).

[7]Source: Lassetter, W.L., Jr., 2008, Kyanite, andalusite, sillimanite and mullite: Mining Engineering, v. 60, no. 6, June, p. 44–45.

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[9]Source: Lassetter, W.L., Jr., 2010, Sillimanite minerals: Mining Engineering, v. 62, no. 6, June, p. 74–76.

[10]Source: Lassetter, W.L., Jr., 2011, Sillimanite minerals: Mining Engineering, v. 63, no. 6, June, p. 96–98.