

2013 Minerals Yearbook

KYANITE AND RELATED MINERALS [ADVANCE RELEASE]

KYANITE AND RELATED MINERALS

By Arnold O. Tanner

Domestic survey data and tables were prepared by Elsie D. Isaac, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

In 2013, the United States continued to be the world's leading producer of kyanite and mullite (calcined kyanite), with a combined estimated production of 110,000 metric tons (t); all production was from Virginia (Virginia Department of Mines, Minerals and Energy, 2014) (tables 1, 7). World production of kyanite and related minerals-andalusite, kyanite, and sillimanite—was estimated to be at least 460,000 t (tables 1, 7). Domestic production of synthetic mullite (calcined aluminous and siliceous minerals and clays) was estimated to be 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. No U.S. production of sillimanite was reported. Refractory products continued to be the dominant end use for kyanite and related minerals. Of the refractory usage, an estimated 65% was in ironmaking and steelmaking, the remainder in the manufacture of chemicals, glass, nonferrous metals, and other materials.

This report includes information on the minerals and alusite, kyanite, and sillimanite, all with a formula of Al₂SiO₅, and on calcined kyanite and synthetic mullite with the chemical formula Al₆Si₂O₁₃. Andalusite, kyanite, and sillimanite are the primary minerals that make up the kyanite group of minerals, especially in the United States where kyanite is prevalent, but are also known collectively as the sillimanite minerals where that mineral is more common, particularly in India. For most end uses of these aluminosilicate minerals, mullite is the preferred mineral because of its superior refractory (heatresistant) properties (it is stable to 1,800 °C) and high strength, but it is rarely found in nature in minable quantities. In the United States, the term mullite generally refers to mullite that is produced by calcining kvanite (to a temperature of 1,450 °C or more), whereas synthetic mullite typically refers to mullite made by calcining certain mixtures of alumina- and silicacontaining minerals and materials, including bauxite and kaolin, at similarly high temperatures.

Production

In 2013, the production of kyanite and mullite in the United States was estimated to increase to about 110,000 t from that of 2012 (Virginia Department of Mines, Minerals and Energy, 2014) (tables 1, 7). The value of kyanite and mullite produced in the United States in 2013 was estimated to be about \$33 million (table 1).

A U.S. Geological Survey (USGS) voluntary survey was sent to the sole U.S. producer of kyanite and kyanite-derived mullite in 2013, the Kyanite Mining Corp. (KMC), but these data are withheld to avoid disclosing company proprietary data. KMC has mined kyanite deposits in central Virginia since 1945. The company operated the East Ridge and Willis Mountain open pit mines in Buckingham County, and beneficiated the ore into a marketable kyanite concentrate product. An estimated 15% to 20% of this kyanite concentrate was further processed and converted by calcination into mullite; more than 90% of this conversion was at the company's Gieseke Plant (East Ridge) and the remainder at the Willis Mountain plant, just south of Dillwyn, VA. KMC's concentrate graded 92% to 96% kyanite containing between 55% and 60% alumina (Al_2O_3); the derived mullite product contained about 80% mullite.

An agreement was reached in June 2013 and finalized in August, to resolve a legal dispute brought by KMC's minority stockholders regarding KMC's management of company assets and unfair treatment of minority shareholders. The Disthene Group, Inc., the holding company for KMC, acquired the minority owners' shares in the Group for a total settlement of \$78 million (Council, 2013). Operation of the mine continued without disruption throughout the litigation process.

C-E Minerals (a subsidiary of Imerys SA) produced synthetic mullite from calcined bauxitic kaolin clays near Americus, GA, including various products that contained 65%, 77%, and 87% mullite (C-E Minerals, 2013). Estimated U.S. production of synthetic mullite in 2013 was about 40,000 t with an estimated value of about \$12 million (table 1).

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

Consumption

Accounting for as much as 90% of consumption, the dominant end use for kyanite and related minerals was refractories and refractory products. Of the refractory usage, an estimated 65% was in the production of iron and steel, the remainder in the manufacture of chemicals, glass, nonferrous metals, and other materials. When calcined to mullite, kyanite increases in volume, depending upon particle size, typically by 3% for very fine particles (325 mesh) to as much as 25% for coarser particle fractions (35 mesh) and thus can be used as a raw concentrate 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 (Lassetter, 2012). In refractory applications where the volume increase of kyanite is not required, kyanite concentrate is first calcined to mullite and added to refractory mixes. Mullite is resistant to abrasion and penetration by deleterious dusts, gases, and slags and 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).

The iron and steel industry continued to be the leading user of refractories, including those containing kyanite and mullite. Although world crude steel output increased by 3.5% in 2013 from that of 2012, U.S. crude steel output decreased by nearly 2%. Decreased U.S. steel output resulted, in part, from an oversupply of steel, steel company bankruptcies, and less expensive imports from China in the market. The leading steelproducing countries, which also would be leading consumers of refractory products, included China, accounting for 48% of the world's steel production in 2013; Japan, 6.9%; the United States, 5.4%; India, 5.1%; Russia, 4.3%; the Republic of Korea, 4.1%; and Germany, 2.7%. These countries accounted for nearly 77% of world steel production in 2013 (World Steel Association, 2014a). Other prominent refractories users were the nonferrous metal and glass industries.

Other end uses of kyanite and related minerals and materials included abrasive products such as motor vehicle brake shoes and pads and grinding and cutting wheels; ceramic products such as electrical insulating porcelains, sanitaryware, and whiteware; foundry products and precision casting molds; and other products (Kyanite Mining Corp., 2006).

Prices

Based on data received in the USGS survey of domestic kyanite production, the unit value of raw kyanite concentrate and calcined kyanite (mullite) (largely dependent on grade sizing) increased slightly, but the actual data have been withheld to avoid disclosing company proprietary data. Published prices for kyanite and andalusite serve only as a general guide; these prices were unchanged as of December 2013 from those of 2012 and are shown in table 2.

Foreign Trade

Nearly 45% of U.S. kyanite and mullite (calcined kyanite or synthetic, unspecified) output was exported in 2013 (tables 1, 3, and 4). Exports of kyanite (excluding mullite) increased 16% overall to 42,400 t, valued at about \$13 million and were shipped to 36 countries (table 3). Exports of mullite decreased by about 7% to 23,100 t, valued at nearly \$10 million and were shipped to 17 countries (table 4). China, Germany, the United Kingdom, the Netherlands, Mexico, Japan, and the Republic of Korea (in descending order) combined, received nearly 71% of U.S. kyanite exports (table 3), and 87% of U.S. mullite exports went to Canada, Germany, Mexico, and the United Kingdom, in descending order of quantity (table 4).

U.S. imports of kyanite group minerals (mostly andalusite) increased by 26% to 4,110 t, valued at \$1.61 million in 2013 (tables 1, 5). Of these imports, nearly 85% was from South Africa, 7% from Peru, and about 6% from France (table 5). Imports of mullite (calcined kyanite or synthetic, unspecified)

decreased by 7% to 5,820 t, with a 43% decrease in value to about \$5.2 million from \$9.2 million. The disproportionate decline in import values was largely attributed to the reduced customs value of material from Canada and Germany. The leading sources of mullite imports were Canada with 45%; China, 25%; Brazil, 12%; and Germany, 10% (table 6).

World Review

South Africa continued to be the leading producing country of andalusite, and India was the leading producer of sillimanite (table 7). Countries thought to be producers of synthetic mullite included Brazil, Canada, China, Germany, Guyana, Hungary, Japan, and Russia.

Continued growth in the world steel industry and the sporadic availability of inexpensive refractory-grade bauxite from China served to increase the demand in refractory production for alternate raw materials such as andalusite. The leading andalusite producers, China, Peru, and South Africa, continued to expand operations. Conversely, production of low-iron, refractory-grade bauxite was reported from mines in Brazil, Guyana, and Russia, potentially representing competition for the kyanite group minerals, especially andalusite (Saxby, 2013a).

China.—Although China was thought to produce kyanite group minerals, detailed production data have been unavailable since 2003. A production capacity of 40,000 metric tons per year (t/yr) was reported for Damrec SA (a subsidiary of Imerys) at its Yilong Andalusite Mineral Co. facilities in the Xinjiang Uyghur Autonomous Region of northwestern China (Dyson, 2012).

Peru.—Andalucita S.A. continued development and production from its mine in northwestern Peru, 20 kilometers (km) from the deep seaport of Paita, including a plant upgrade to enable an annual production capacity of 42,000 t. The planned addition of another screen would increase the plant's capacity to 60,000 t/yr (Carmichael and Lismore-Scott, 2013). A primary andalusite product grading 59% to 60% Al_2O_3 and a maximum of 0.85% iron oxide was produced for refractory consumers. About 50% was sold for use in steel manufacturing and 50% for cement, glass, and aluminum products. Most of the andalusite products were shipped to customers in Europe, North America, and South America (Dyson, 2012).

Latin Resources Ltd. (Perth, Western Australia, Australia) continued exploration and development of its most advanced project, the Guadalupito iron and mineral sands project, near the port town of Chimbote on the eastern inland portion of the coastal plain of northern Peru. In December, Latin Resources received unrestricted and exclusive surface rights to the land overlying the estimated 1.1-billion-ton heavy-mineral sand Los Conchales resource, 25 km by established roadway to Peru's leading steelmaker. The Los Conchales mineral sands deposit, which covers 1,350 hectares of the Guadalupito project, is mostly and alusite (21% to 24%) and magnetite (22% to 25%). The Los Conchales resource is more than 90% below the water table, making it amenable to dredging. Latin Resources was seeking joint-venture partners to invest in the project's development (Ollett, 2013; Latin Resources Ltd., 2014; Proactive Investors Australia Pty Ltd., 2014)

South Africa.—Andalusite Resources (Pty.) Ltd. mined andalusite at its Maroeloesfontein Mine in Thabazimbi,

Limpopo Province. In 2013, the company's annual production capacity was about 70,000 t/yr. Depending upon market growth, the company planned to expand to as much as 120,000 t/yr by 2015; current production was near capacity (Carmichael and Lismore-Scott, 2013; Dyson, 2012).

Damrec produced about 70% of the andalusite in South Africa at four mines, which had a combined capacity of 195,000 t/yr of andalusite and planned to increase output to about 250,000 t/yr over the next few years. Rhino Minerals (Pty.) Ltd. operated three of Damrec's four mines in South Africa, the Annesley, Havercroft, and Rhino Mines in Limpopo Province. Samrec (Pty.) Ltd. operated the fourth mine, the Krugerspost Mine near Lydenburg, Mpumalanga Province (Carmichael and Lismore-Scott, 2013; Modiselle, 2012, p. 203).

Vietnam.—Significant deposits of kyanite and sillimanite were reported in the country. One of two kyanite deposits in northern Vietnam, the Thanh Son kyanite in Phu Tho Province, had reported reserves of 60,000 t. In tests, highalumina refractory bricks were successfully manufactured from kaolin plus Thanh Son kyanite. In southern Vietnam, the Hung Nhuong sillimanite deposits in Quang Ngai Province were reported to have total reserves of slightly more than 100,000 t. No production of kyanite or sillimanite was reported (Phuong, 2012).

Outlook

Natural raw aluminosilicate minerals, such as andalusite and kyanite, have become increasingly sought after as alternative materials to bauxite in certain refractory applications. Rising production and energy costs for bauxite ore and the nearly exclusive licensing of metallurgical-grade bauxite mines by the Chinese Government since 2003 may lessen the availability of refractory-grade bauxite (Saxby, 2013b). When compared with raw materials with higher alumina content, andalusite is expected to be an increasingly attractive alternative because it requires firing at a lower temperature than most alternative materials when used to produce a dense and shrinkage-resistant refractory aggregate. This reduces energy consumption and greenhouse gas emissions (Feytis, 2011).

In the United States, apparent consumption of steel, the leading industrial market for refractories, was projected to increase by 4% in 2014 and by 3.7% in 2015, after declines in 2012 and 2013 that resulted in part from slower than expected growth in manufacturing and construction (World Steel Association, 2014b). The improving global economy, continued momentum in the automotive markets and energy sectors, and stronger, more consistent growth in the construction sector indicate that the demand for and consumption of steel is expected to grow, and with this the need for more refractories (Zacks Investment Research, Inc., 2014).

World steel consumption is expected to stabilize and increase by about 3% in 2014 and by more than 3.5% in 2015, after a slower 1.2% increase in 2013. Because of continuing efforts by the Chinese Government to moderate domestic growth, especially in its real estate sector, and to rebalance its economy, China's steel consumption was expected to increase by 3.0% in 2014 and 2.7% in 2015, following an increase of 6.1% in 2013 (World Steel Association, 2014b). China's more than 2-billion-metric-ton-per-year cement industry also continued to require raw materials such as kyanite group minerals for the manufacture of refractory products. Continued growth was expected in China's cement industry, as evidenced by the building of a significant number of new kilns, all of which require refractories.

The dependence on bauxite for refractory production may lessen, depending on the ability of refractories producers to use or substitute and alusite, kyanite, and similar raw materials for bauxite in refractory applications; the quantities and prices of andalusite and similar materials produced at new and expanded mines; and the quantities of bauxite available for mullite production from such projects as mine expansion and kiln construction in Guyana. Additionally, inexpensive refractory-grade bauxite that becomes available for export from developments in Brazil, Guyana, and Russia may become competitive with andalusite and kyanite in some applications, such as steel furnaces and industrial boilers (Saxby, 2013a). For durable refractories, technological advances are likely to include increased use of synthetic mullite. Available and alusite supplies are expected to increase owing to mine expansions and new mines in France, Peru, South Africa, and possibly Spain.

The Asia-Pacific region is the largest market for refractories, and China is anticipated to remain the single leading market, comprising the majority of global consumption. Above-average growth is expected to take place in India. For the next several years, increases in the market for refractories are likely to continue in Eastern Europe, North America, and Western Europe. Growth in the refractory market in North America, in the longer term, may lag behind the global average, in part owing to a shift in steel production to developing countries. Finding and procuring a consistent supply of refractory raw materials, especially at affordable prices, is likely to remain a challenge for refractory producers, particularly those in Europe and the Western Hemisphere (Deneen, 2011). Another challenge for producers in Europe, Japan, and North America is an increased use of higher quality, longer lasting refractories with longer inservice life cycles leading to reductions in consumption per ton of steel. In these regions, consumption of refractories per ton of steel in recent years has decreased, in the range of 8-10 kg per ton, less than one-half that of China. However, during the next 5 years or more, current consumption levels of refractories per ton of steel are expected to decline as developing countries shift to similar refractory materials and more advanced steelmaking practices (O'Driscoll, 2013).

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Other

		2009	2010	2011	2012	2013
Production						
Kyanite:						
Quantity ²	metric tons	71,000	93,400	98,200	98,500	110,000
Value ^e	thousands	\$21,000	\$29,000	\$31,000	\$31,000	\$33,000
Synthetic mullite: ^e						
Quantity	metric tons	40,000	40,000	40,000	40,000	40,000
Value	thousands	\$10,000	\$12,000	\$12,000	\$12,000	\$12,000
Exports: ³						
Quantity	metric tons	25,800	37,900	38,100	36,400	42,400
Value ⁴	thousands	\$7,510	\$11,300	\$11,600	\$11,700	\$13,100
Imports for consumption: ³						
Quantity	metric tons	4,880	2,180	5,390	3,260	4,110
Value ⁵	thousands	\$2,060	\$938	\$2,230	\$1,610	\$1,610
Consumption, apparent ⁶	metric tons	90,100	97,200	105,000	105,000	112,000
World, production ^{e, 7}	do.	341,000 ^r	399,000 ^r	411,000 ^r	427,000 ^r	464,000

TABLE 1 SALIENT U.S. KYANITE AND RELATED MINERALS STATISTICS¹

^rRevised. ^eEstimated. do. Ditto.

¹Data are rounded to no more than three significant digits.

²Source: Virginia Department of Mines, Minerals and Energy, 2014, DMM report TNPR.06—Comparison of annually reported tonnage data: Charlottesville, VA,Virginia Department of Mines, Minerals and Energy. (Accessed April 2, 2014, via http://www.dmme.virginia.gov/DMM/miningdata.shtml.)

³Source: U.S. Census Bureau.

⁴Free alongside ship (f.a.s.) value.

⁵Customs value.

⁶Includes kyanite and synthetic mullite production plus imports minus exports.

⁷A number of countries produce kyanite and related materials, but output is minimal in some countries and is not reported quantitatively and cannot be included in the world total.

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

TABLE 2
PRICES OF KYANITE AND RELATED MINERALS IN 2013

Material		Price
Andalusite, South Africa, 57% to 58% alumina, 2,000-metric-ton bulk lots	euros per metric ton	235-280
Andalusite, free on board, South Africa, 55% to 59% alumina, 2,000-metric-ton bulk lots, European port	do.	350-425
Kyanite, United States, ex-works, raw, 54% to 60% alumina	dollars per metric ton	247-353
Kyanite, United States, ex-works, calcined (mullite), 54% to 60% alumina, 22-ton lots	do.	411-484
do. Ditto.		

Source: Industrial Minerals, December 2013, p. 52-54.

	201		2013		
	Quantity	Value ³	Quantity	Value ³	
Country	(metric tons)	(thousands)	(metric tons)	(thousands)	
Argentina	140	\$37	160	\$45	
Australia	425	130	492	142	
Belgium	2,640	812	2,610	817	
Canada	2,410	816	2,600	840	
Chile	60	14	120	29	
China	3,960	1,100	7,810	2,210	
Egypt	280	70	400	109	
Germany	5,700	1,820	6,490	2,070	
Hungary	264	77	40	13	
India	481	122	389	102	
Indonesia	118	31	80	19	
Italy	1,650	454	1,320	411	
Japan	3,510	1,270	3,080	1,130	
Korea, Republic of	2,740	942	2,740	896	
Malaysia	220	53	380	95	
Mexico	2,300	774	3,270	1,120	
Netherlands	3,360	1,030	3,360	866	
Poland	352	90			
South Africa	386	299	12	3	
Spain	420	118	486	145	
Slovenia			204	43	
Sweden	928	263	896	263	
Taiwan	638	231	700	172	
Thailand	360	91	338	86	
Turkey	682	169	694	179	
United Kingdom	2,040	720	3,550	1,180	
Other	373 ^r	146 ^r	164	143	
Total	36,400	11,700	42,400	13,100	

TABLE 3U.S. EXPORTS OF KYANITE, BY COUNTRY^{1, 2}

^rRevised. -- Zero.

¹ Harmonized Tariff Schedule of the United States code 2508.50.0000 for kyanite concentrate.

 $^{2}\mbox{Data}$ are rounded to no more than three significant digits; may not add to totals shown.

³Free alongside ship (f.a.s.) value.

Source: U.S. Census Bureau.

TABLE 4 U.S. EXPORTS OF MULLITE, BY COUNTRY^{1, 2}

	201	12	2013		
	Quantity	Value ³	Quantity	Value ³	
Country	(metric tons)	(thousands)	(metric tons)	(thousands)	
Belgium	389	\$182	271	\$124	
Brazil	340	125	238	96	
Canada	10,500	2,990	9,410	2,680	
China	1,950	596	907	353	
Germany	3,870	2,230	5,400	3,430	
Hungary	132	56 ^r			
Italy	64	27	66	29	
Mexico	3,630	1,720	4,330	2,160	
Netherlands	519	287	839	378	
South Africa			240	25	
Taiwan	34	19	152	66	
United Kingdom	3,090	1,530	1,050	525	
Other	285 r	130 ^r	207	103	
Total	24,800	9,890	23,100	9,960	
^r Revised Zero.					

¹Harmonized Tariff Schedule of the United States code 2508.60.0000 for mullite (calcined kyanite or synthetic).

²Data are rounded to no more than three significant digits; may not add to totals shown.

³Free alongside ship (f.a.s.) value.

Source: U.S. Census Bureau.

TABLE 5 U.S. IMPORTS FOR CONSUMPTION OF ANDALUSITE, KYANITE, AND SILLIMANITE^{1, 2, 3}

	201	2	2013		
	Quantity	Quantity Value ⁴		Value ⁴	
Country	(metric tons)	(metric tons) (thousands)		(thousands)	
France	183	\$137	236	\$176	
Peru	342	155	302	131	
South Africa	2,530	1,220	3,490	1,260	
Other	208	103	76	49	
Total	3,260	1,610	4,110	1,610	

¹Most material is thought to be andalusite.

²Harmonized Tariff Schedule of the United States code 2508.50.0000 for kyanite concentrate.

³Data are rounded to no more than three significant digits; may not add to totals shown.

⁴Customs value.

Source: U.S. Census Bureau.

 TABLE 6

 U.S. IMPORTS FOR CONSUMPTION OF MULLITE^{1, 2}

	201	2	2013		
	Quantity	antity Value ³ Quantity		Value ³	
Country	(metric tons)	(thousands)	(metric tons)	(thousands)	
Brazil	481	\$439	698	\$744	
Canada	3,600	3,360	2,610	2,070	
China	223	89	1,450	571	
Germany	1,560	4,720	557	1,150	
Hungary	397	489	449	554	
Japan	9	39	49	67	
Other	11	20	8	20	
Total	6,280	9,160	5,820	5,180	

¹Harmonized Tariff Schedule of the United States code 2508.60.0000 for mullite, calcined kyanite or synthetic, unspecified.

 $^2\mathrm{Data}$ are rounded to no more than three significant digits; may not add to totals shown.

³Customs value.

Source: U.S. Census Bureau.

TABLE 7 KYANITE AND RELATED MINERALS: WORLD PRODUCTION, BY COUNTRY^{1, 2}

(Metric tons)

Country and commodity ³	2009	2010	2011	2012 ^e	2013 ^e
Brazil, kyanite ^e	600	600	600	600	500
France, andalusite ^e	65,000	65,000	65,000	65,000	70,000
India:					
Kyanite	5,276 ^r	5,839 ^r	4,537 ^r	4,800 r	4,800
Sillimanite	33,691 ^r	45,010 ^r	55,728 ^r	58,000 r	58,000
Total	38,967 r	50,849 r	60,265 r	62,800 r	62,800
Peru, andalusite		262	276	375 4	322 4
South Africa, and alusite	165,217	189,185	186,242	200,000	220,000
United States, kyanite ^{5, 6}	71,000	93,400	98,200	98,500 ⁴	110,000
Grand total ^e	341,000 r	399,000 r	411,000 r	427,000 r	464,000

^eEstimated. ^rRevised. -- Zero.

¹Grand total, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

²Includes data available through October 9, 2014.

³Australia and China produce kyanite and related materials, but output is not reported quantitatively, and no output levels.

⁴Reported figure.

⁵Excludes synthetic mullite.

⁶Source: Virginia Department of Mines, Minerals and Energy, 2014, DMM report TNPR.06—Comparison of annually reported tonnage data: Charlottesville, VA, Virginia Department of Mines, Minerals and Energy. (Accessed April 2, 2014, via http://www.dmme.virginia.gov/DMM/miningdata.shtml.)