ZIRCONIUM AND HAFNIUM

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Zirconium is produced from two ore minerals, zircon and baddeleyite. The principal economic source of zirconium is the zirconium silicate mineral zircon ($ZrSiO_4$). Only a relatively small quantity of baddeleyite, a natural form of zirconium oxide or zirconia (ZrO_2), was mined in 2002. In May 2002, Palabora Mining Company, Inc. ceased production of baddeleyite at its open pit mine in South Africa. The sole remaining baddeleyite producer is at Kovdor, Russia. Zircon, the principal ore material, was mined at many locations worldwide.

Zircon is the primary source of all hafnium. Zirconium and hafnium are contained in zircon at a ratio of about 50 to 1. Zircon is a coproduct or byproduct of the mining and processing of heavy-mineral sands for the titanium minerals ilmenite and rutile or tin minerals. The major end uses of zircon in descending order of quantity are refractories, foundry sands (including investment casting), and ceramic opacification. Zircon is also marketed as a natural gemstone, and its oxide is processed to produce cubic zirconia, a diamond and colored gemstone simulant. Zirconium metal is used in chemical piping, nuclear fuel cladding, pumps, and valves in corrosive environments, heat exchangers, and various specialty alloys.

The principal uses of hafnium are in nuclear control rods, nickel-based superalloys, nozzles for plasma arc metal cutting, and high-temperature ceramics.

World production of zirconium mineral concentrates in 2002, excluding U.S. production, was estimated to have decreased a minor amount in 2002 when compared with the 2001 level. Data on U.S. production and consumption of zircon concentrates were withheld to avoid disclosing company proprietary data. Domestic production of zircon decreased slightly although demand for zircon increased. In 2002, production of milled zircon and zirconium oxide decreased from that of the previous year. According to U.S. customs trade statistics, the United States was a net exporter of zirconium ore and concentrates. In 2002, U.S. imports of zirconium ore and concentrates decreased by 42%, and domestic exports of zirconium ore and concentrates decreased by 30% compared with 2001. The major declines were the result of poor economic conditions and slow demand in the U.S. in 2001.

With the exception of prices and referenced data, all survey data in this report have been rounded to no more than three significant digits. Totals and percentages were calculated from unrounded numbers.

Production

Data for zirconium and hafnium manufactured materials are developed by the U.S. Geological Survey (USGS) from a voluntary survey of domestic operations. Of the 49 operations surveyed, 19 did not respond. Data for nonrespondents were estimated on the basis of prior-year levels.

Data for zircon concentrates are developed by a second voluntary survey of domestic mining operations. The two domestic zircon producers, which have three mining and processing operations, responded. Data on domestic production and consumption of zircon concentrates were withheld to avoid disclosing company proprietary data.

Domestic production of milled zircon decreased by 37% and production of zirconium oxide decreased by 18% from their 2001 levels (table 1). Domestic production of zircon concentrate decreased in 2002 from the previous year's level.

Zircon is normally produced as a byproduct of the mining and processing of heavy-mineral sands containing the titanium minerals ilmenite and rutile. In 2002, U.S. mine producers of zircon were E.I. du Pont de Nemours and Co. (DuPont) and Iluka Resources, Inc. (a subsidiary of the Australian company Iluka Resources Limited). DuPont produced zircon from its Highland and Maxville heavy-mineral sand deposits near Starke, FL. Iluka produced zircon from its heavy-mineral sand operations at Green Cove Springs, FL, and Stony Creek, VA.

U.S. producers of zirconium and hafnium metal were Wah Chang (an Allegheny Technologies company), Albany, OR, and Western Zirconium (a subsidiary of Westinghouse Electric Company), Ogden, UT. Primary zirconium chemicals were produced by Wah Chang and Magnesium Elektron Inc., Flemington, NJ. Secondary zirconium chemicals were produced by 10 companies, and zirconia was produced from zircon sand at plants in Alabama, New Hampshire, New York, Ohio, and Oregon.

In Florida, Iluka reported lower production from its Green Cove Springs operations in 2002 resulting from slow market conditions, a revised dredge path with lower grades, and wet weather conditions in the third and fourth quarters (Iluka Resources Limited, 2003§[1]).

In Virginia, production from the Old Hickory Mine in Stony Creek also was lower due to the startup of an expansion project coupled with a severe water shortage created by drought conditions. An expansion project at the Old Hickory Mine included a new mine site, mining unit, concentrator, zircon finishing plant, and additional heavy-mineral sands separation capacity (Iluka Resources Limited, 2003a).

[1]References that include a section mark (§) are found in the Internet References Cited section.

Iluka announced the start of a $36 million expansion of its operations into northern Florida and Georgia. Development of the Lulaton deposit will replace heavy-mineral sands production from the Green Cove Springs Mine. Iluka planned to decommission its floating dredge concentrator at Green Cove Springs by mid-2003 and relocate its mobile concentrator in early 2003 to an adjacent lease area, where it would continue to operate until 2005 (Mining Australia, 2003§). A new 1,000-metric-ton-per-hour concentrator and mining unit was planned to develop the Lulaton deposit in southern Georgia and was expected to come online in 2003.

Altair International, Inc. announced on July 18 that it had changed its name to Altair Nanotechnologies Inc. The name change reflects the company's refocus of its core business to nanotechnology processes (U.S. Securities and Exchange Commission, 2002). Altair Nanotechnologies continues to hold the rights to the Camden, TN, heavy-mineral sands deposit.

Consumption

Approximately 95% of the consumption of zirconium is as zircon, zirconium oxide, or other zirconium chemicals. The remainder is consumed as zirconium metal and zirconium-containing alloys.

Zircon, used for facings on foundry molds, increases resistance to metal penetration and gives a uniform finish to castings. Milled or ground zircon is used in refractory paints for coating the surfaces of molds. Zircon, in the form of refractory bricks and blocks, is used in furnaces and hearths for containing molten metals. Glass tank furnaces use fused-cast and bonded alumina-zirconia-silica-base refractories. Baddeleyite is used principally in the manufacture of alumina-zirconia abrasive and in ceramic colors and refractories.

Stabilized zirconium oxide exhibits high light reflectivity and good thermal stability and is primarily used as an opacifier and pigment in glazes and colors for pottery and other ceramic products. Yttria-stabilized zirconia (YSZ) is used in the manufacture of oxygen sensors that control combustion in furnaces and automobile engines. YSZ is also used in the manufacture of a diverse array of products, including high-temperature, high-strength structural ceramics, heat- and break-resistant shirt buttons, golf shoe cleats, golf putters, fiber optic connector components, coatings for the hot sections of jet engines, and cubic zirconia, a gemstone simulant for diamonds and colored gemstones.

Because of its low thermal neutron absorption cross section, hafnium-free zirconium metal is used as cladding for nuclear fuel rods. Commercial-grade zirconium, unlike nuclear grade, contains hafnium and is used in the chemical process industries because of its excellent corrosion resistance.

Hafnium is used in nuclear control rods because of its high thermal neutron absorption cross section. However, the largest end use for hafnium metal is as an alloy addition in superalloys.

Prices

In 2002, increased demand for zircon concentrates generally resulted in increased prices. The average value of imported ore and concentrates increased by 11.5% to $397 per metric ton in 2002 from $356 per ton in 2001. The average value of zircon ore and concentrates exports decreased by 2% to $523 per ton from $533 per ton in 2001. Domestic prices of standard- and premium-grade zircon were higher as a result of a tightening of the domestic supply and an increase in global demand. The greatest demand was from foreign markets for ceramics, especially those in China and Europe.

Published prices for bulk grades of zircon, free on board, were unchanged or lower (Industrial Minerals, 2002i). Ceramic-grade Australian zircon prices narrowed to between $360 per ton and $390 per ton at yearend 2002 from between $350 per ton and $410 per ton, while United States prices were unchanged at $375 per ton to $400 per ton. Australian zircon, foundry-grade, increased in price to between $320 per ton and $370 per ton at yearend 2002 price from between $280 per ton to $360 per ton, while United States foundry sand remained unchanged at $350 per ton to $390 per ton. U.S. refractory-grade zircon was also unchanged at $350 per ton to $390 per ton (table 2).

Foreign Trade

According to U.S. Census Bureau trade statistics, the United States was a net exporter of zirconium ore and concentrates in 2002. U.S. exports of zirconium ore and concentrates were 47,100 metric tons (t), a 30% decrease from that of 2001 (table 3). The United States was a net exporter of zirconium and hafnium metal in 2002. U.S. zirconium metal exports are classified under two new Harmonized Tariff Schedule of the United States (HTS) tariff numbers—8109.20.0000, "Unwrought zirconium powder," and 8109.30.0000, "Zirconium waste and scrap." The previous HTS tariff number 8109.10.0000, "Unwrought zirconium, waste and scrap," was discontinued. In 2002, U.S. exports of unwrought zirconium (powder) were 109 t, and exports of zirconium waste and scrap were 99 t. U.S. exports classified as "Other zirconium metal, waste and scrap" were 1,430 t, a 20% increase from the 2001 level.

U.S. imports of zirconium ore and concentrates were 35,300 t, a decrease of 42% from the 60,600 t imported in 2001 (table 4). Australia and South Africa supplied 91% of the imports of ores and concentrates. Imports for the new category HTS 8109.20.0000, "Unwrought zirconium powder" were 47.7 t in 2002, and the leading sources, in descending order of quantity, were Canada and Germany. Imports for the other new trade category HTS 8109.30.0000, "Zirconium waste and scrap" were 33.8 t in 2002, and the leading sources, in descending order of quantity, were Japan, the United Kingdom, and India. The trade category HTS number 8109.10.6000, "Unwrought zirconium, waste and scrap, powders, other," was discontinued. Domestic imports of ferrozirconium

alloys were 167 t in 2002, a 31% decrease from the 240 t imported in 2001. In 2002, ferrozirconium imports originated entirely from Brazil. U.S. imports of "Unwrought hafnium, including powder," which were imported under a new trade category, HTS number 8112.02.2000, were 4.87 t, and principal import sources, in descending order of quantity, were Canada, France, and China.

World Review

Excluding U.S. production, world production of zirconium mineral concentrates in 2002 was estimated to be 756,000 t, a minor decrease compared with that of 2001 (table 5). An Australian publication estimated world zirconium mineral production to be 1.09 million metric tons (Mt), which includes the additional production estimated for the United States (Mineral Sands Report, 2003d, p. 5). Australia and South Africa supplied about 87% of all production outside the United States. World reserves of zircon are estimated to be 37 Mt of ZrO_2, while identified world resources of zircon were about 72 Mt of ZrO_2. During 2002, the zirconium industry continued to be active in the exploration and development of mineral deposits on a global basis, particularly in Australia, Kenya, Mozambique, South Africa, and the United States. Iluka Resources Limited was the world's largest producer of zircon in 2002, with mines in Australia and the United States. Iluka had an estimated 30% of the world's production. Other major zircon producers, in order of decreasing production, were Richards Bay Minerals (RBM) of South Africa, Namakwa Sands (Pty.) Ltd. of South Africa, DuPont of the United States, Tiwest Joint Venture of Australia, and Consolidated Rutile Ltd. (CRL) of Australia.

Australia.—Australia was one of the two largest producers of zircon concentrates in the world (table 5). In 2002, major producers of zircon concentrates, in order of estimated zircon production, in Australia were Iluka Resources, Tiwest, CRL, and RZM/Cable Sands Ltd. (CSL). Australian zircon production for 2002 was as follows: Iluka, 259,000 t (excluding its interest in CRL); Tiwest, 78,000 t; CRL, 39,000 t; CSL, 16,000 t; Mineral Deposits Ltd. (MDL), 8,000 t; Currumbin Minerals Pty Ltd., 4,000 t; and Murray Basin Titanium Pty. Ltd., 8,000 t (Mineral Sands Report, 2003c). Total Australian production in 2002 was estimated to be 416,000 t, a 4.8% increase from the revised 2001 level of 397,000 t (Mineral Sands Report, 2003c). The USGS estimated 2002 Australian production to be 408,000 t (table 5).

Worldwide production from Australian-based Iluka was 361,000 t of zircon in 2002, an increase of about 4.4% from the 345,900 t in 2001 (Iluka Resources Limited, 2003b, p. 35). The company operated eight mines in Australia (six on the west coast and two on the east coast) and two in the United States. Iluka's Australian subsidiary, WA Titanium Minerals, operated six mines and a zircon finishing plant (Narngulu) in Western Australia in 2002. Two new mines near Eneabba, Western Australia—the South Tails and the Depot Hill deposit—are planned for development in the first half of 2003 (Iluka Resources Limited, 2003§). High zircon grades at Iluka's South Tails deposit (zircon grade is 20% of the heavy-mineral suite) was expected to increase future zircon production rates. Iluka's other mining operations were the North West Mine near Capel, the North Mine and South Mine near Eneabba, and the Yoganup, Yoganup Extended, and Busselton Mines in the southwestern region. Mining of the remnants of the Yoganup Extended Mine were scheduled to begin in early 2003.

Iluka's 50%-owned two east coast mines, the Yarraman and Ibis, were operated by CRL on North Stradbroke Island, New South Wales. CRL's 2002 zircon production was 39,000 t, down 4,000 t from the previous year's level. Zircon production was lower due to lower grades at Yarraman and operating problems with the tailings circuit (Iluka Resources Limited, 2003§). The tailings circuit was upgraded in late 2002 with improved production rates and recoveries expected in 2003. CRL's Ibis Mine was scheduled for closure as the company shifted production to its Enterprise deposit in New South Wales. The dredge and infrastructure at Ibis are scheduled for shipment to the Enterprise location in 2003. CRL's overall production for 2003 was expected to be lower due to the move. CRL operated a dry separation plant at Pinkenba, Brisbane, Queensland.

Iluka upgraded its total heavy-mineral resources by 15% while its net heavy-mineral reserves increased by 14% (Iluka Resources Limited, 2003§). In the Murray Basin deposit area of New South Wales and Victoria, Iluka upgraded its resources of titanium minerals and zircon by 28% (Iluka Resources Limited, 2002§). The increase is primarily due to the three new deposits—Boulka (near Ouyen), Dispersion, and Snapper. The Dispersion deposit in New South Wales has a resource of 7.3 Mt grading 22% heavy minerals with a 15% zircon content. The 10 Ouyen deposits have a reported total resource of about 60 Mt grading 15.7% heavy minerals with a 9% zircon content. The Snapper deposit has a resource of 5.111 Mt grading 13.8% heavy minerals with a 10% zircon content (Iluka Resources Limited, 2002).

Iluka purchased a 100% interest in Basin Minerals Limited (BML) in the Murray Basin (Iluka Resources Ltd., 2003a, p. 5). Iluka paid $A139 million in June for BML's extensive heavy-mineral sands interests including the Culgoa and Douglas deposits. BML's major deposit includes the Douglas mineral-sands project in southwestern Victoria. Iluka planned initial development of the Douglas deposit in the last half of 2003. The Douglas deposit covers an area of 5,860 square kilometers and has a resource of 22.4 Mt of heavy minerals. Five strandline deposits within the Douglas deposit contain 11.3 Mt of ilmenite (including leucoxene), 1.26 Mt of rutile, and 1.62 Mt of zircon (Mineral Sands Report, 2002a).

BeMaX Resources N.L. and Probo Mining Limited announced they would begin development of their Ginkgo Mineral Sands Project (Ginkgo) in the Murray Basin near Pooncarie, New South Wales. Reserves are 184 Mt of ore grading 3.2% heavy minerals. Production from the Ginkgo deposit was expected to commence in late 2003 with shipments emanating in early 2004. Production rates are proposed to be 124,000 metric per tons per year (t/yr) of ilmenite, 76,000 t/yr of leucoxene, 53,000 t/yr of rutile, and 32,000 t/yr of zircon (BeMaX Resources N.L., 2002; Industrial Minerals, 2002d).

Southern Titanium N.L. reported that it was acquiring working capital to develop its recently acquired Mindarie deposit in the Murray Basin (Industrial Minerals, 2002c). Funding was to be used to complete a bankable feasibility study, bonds for purchasing

mine and plant equipment, and other obligations. Southern obtained 100% of the Mindarie deposit from Steiner Holdings Pty. Ltd. Production from the Mindarie was expected to begin in 2004 (Huleatt, Jaques, and Towner, 2002, p. 7)

Joint-venture partners BeMaX (75%) and Probo Mining Pty. Ltd. (25%) announced they had obtained mining leases for the Ginkgo mineral-sands deposit (Industrial Minerals, 2002b). A bankable feasibility study that was completed by the partners and approval to develop the deposit was received from the New South Wales Minister of Planning (Industrial Minerals, 2002d). The deposit is 120 kilometers (km) north of Mildura, Victoria, in the Murray Basin area of New South Wales. Resource estimates for the Ginkgo were increased by 21% to a revised 40 Mt with a mine life of 25 years. The mine was expected to be commissioned in 2003 with shipments of heavy-mineral sands (including zircon) commencing in 2004.

Australia Zirconia Ltd. (AZL) (a wholly owned subsidiary of Alkane Exploration Ltd.) revised its resource estimate for the Dubbo zirconia deposit in New South Wales to 37.5 Mt. The alkaline intrusive ore, an altered trachyte, grades 1.96% zirconium oxide, 0.04% hafnium oxide, 0.46% niobium oxide, 0.03% tantalum oxide, 0.14% yttrium oxide, and 0.745% rare-earth oxides (Industrial Minerals, 2002g).

Doral Mineral Sands Pty. Ltd. opened its $30 million Dardanup Mine in Western Australia on October 8 (Huleatt, Jaques, and Towner, 2002, p. 7). Capacity at the operation, 15 km east of Bunbury, was 120,000 t/yr of titanium minerals and 10,000 t/yr of zircon.

Brazil.—Two companies produced zircon in 2001—Millennium Inorgânica Chemicals do Brazil S/A from its heavy-mineral sands Mataraca Mine at Guaju, Paraiba State, and Indústrias Nucleares do Brasil S/A (INB) from its mine in São Francisco, Rio de Janeiro. In 2001, Millenium produced about 11,300 t of zircon, and INB produced about 9,700 t. Zircon resources in Brazil are in the States of Amazonas, 1,657 t; Bahia, 92,400 t; Minas Gerais, 94,300 t; Paraíba, 210,000 t; Rio de Janeiro, 115,500 t; Rio Grande do Norte, 40,000 t; São Paolo, 9,300 t, and Espírito Santo, 5,700 t. Total Brazilian production of zircon in 2001, the latest year for which preliminary data were available, was 21,000 t, a decrease from the 30,000 t produced in 2000 (Sumário Mineral, 2002, p. 124-125).

Gambia.—Australian joint-venture partners Astron Limited and Carnegie Corporation Limited agreed to process and ship a zircon concentrate from an existing zircon-rich waste stockpile at Brufut. The stockpile reportedly contains 50,000 t of treatable material (Globemedia, 2002a§). Astron guaranteed to purchase the first 12,000 t for $85 per ton and the remaining zircon concentrate for $65 per ton (Globemedia, 2002b§).

India.—Heavy minerals, including zircon, occur in many coastal States. Reserves of zircon for the States of Orissa and Andhra Pradesh were 4.93 Mt in ore grading 10% to 35% total heavy minerals (THM). In the State of Tamil Nadu zircon reserves were 7.63 Mt in ore grading 7% to 39% THM. Reserves in the State of Kerala were 5.22 Mt of zircon in ore grading 7% to 64% THM. Combined reserves of the States of Bengal, Bihar, and Maharashtra were 0.47 Mt of zircon. Total Indian reserves of zircon were reported to be 18.25 Mt. Recoverable reserves were estimated to be 30% less based on losses in mining, processing, and areas unavailable due to "socio-legal restrictions" (Indian Department of Atomic Energy, 2003§).

Rare Earths Ltd. (IRE) was the eleventh largest producer of zircon in the world from its mine at Chavara. IRE produced an estimated 15,000 t of zircon in 2002 (Mineral Sands Report, 2003d, p. 5). The corporate offices of IRE were in Prabhadevi, Mumbai.

Ticor Ltd. of Australia announced it would not exercise its option to fund a prefeasibility study of mineral sands deposits in Tamil Nadu (Industrial Minerals, 2002h). In a joint-venture agreement with MDL in 2001, Iscor Ltd. (which spun off its mining operations to Kumba Resources Ltd.) signed a memorandum of understanding to form an alliance to develop two heavy-mineral sands deposits in Tamil Nadu State. The Tamil Nadu deposits at Kudiraimozhi and Navaladi-Sattankulam contain 1 billion metric tons of ore grading 6.2% ilmenite, 0.4% rutile, and 0.7% zircon (Mineral Deposits Limited, 2003b§). Ticor announced that the project's economics were not compelling under the current market conditions. Ticor retained an interest in the project though its 15.4% stake in MDL, whose interests in India are controlled through its subsidiary companies Ausind Sands Limited and Mauritius Titanium Limited and its Indian partnership with WSIL Mineral Sands India Pvt. Limited. An application for approval to advance exploration to close-spaced drilling and detailed ore exploration was completed. MDL reported the inferred resource of the Navaladi deposit at 123.4 Mt of ore grading 17.3% heavy minerals and 0.7% zircon [with only 50% of the area tested to a depth of 6 meters (m)]. The lower grade Kudiaramozhi deposit has 216.6 Mt of ore grading 8.61% heavy minerals and 0.34% zircon. MDL has a 74% interest in the Navaladi deposit and a 72% interest in the Kudiraimozhi deposit (Mineral Deposits Limited, 2003a§).

Kenya.—Tiomin Resources Inc. of Toronto, Ontario, Canada, filed a motion in court in Kenya to dismiss an injunction issued in 2001 blocking development of the Kwale heavy-mineral sands deposit. The motion was based on the fact that the original suit was filed by 3 farmers who falsely claimed they represented 203 farmers in the region. Many regional farmers were unaware their names had been used in the lawsuit, and 150 of the 203 requested that their names be removed (Industrial Minerals, 2002e).

Mozambique.—Rio Tinto Iron and Titanium Inc., a subsidiary of Rio Tinto plc, announced the discovery of heavy-mineral sands deposits in the provinces of Gaza and Inhambane. The placer deposits are in a coastal dunal system representing a fossil shoreline. Initial drilling indicated a total resource of 120 Mt of ilmenite (Rio Tinto plc, 2003, p. 19). Additional drilling on the deposit is planned (Mineral Sands Report, 2002b, p. 2).

Kenmare Resources PLC announced it had obtained contracts for all of the zircon it initially planned to produce from its Moma deposit (Mineral Sands Report, 2003b, p. 3). Kenmare received all the required permits from the Government of Mozambique to commence construction of the heavy-mineral sands project.

Russia.—Foskor Ltd. of South Africa announced it had signed an agreement with GMF Trading Ltd., the parent company of A.O. Kovdorsky GOK (Kovdor), for the exclusive marketing of its baddeleyite to certain markets (Industrial Minerals, 2002a). Foskor ceased production of baddeleyite from its Palabora Mine in South Africa in June 1999 as a result of declining ore grades. The exclusive rights granted to Foskor include areas in the Middle East, the Far East, and South America. With the closure of the open pit at Palabora Mining Co.'s operations at Phalaborwa in 2002, Kovdor became the world's sole producer of baddeleyite.

Saudi Arabia.—Mining exploration company Tertiary Minerals PLC of the United Kingdom was awarded an exploration license to investigate a tantalum-zirconium deposit. Located in northwestern Saudi Arabia, the Ghurayyah deposit is about 900 m in diameter and 250 m deep with an inferred resource of 385 Mt (Tertiary Minerals plc, 2002§). The zirconium oxide in the deposit grades 8.915 kilograms per metric ton (Industrial Minerals, 2002f).

South Africa.—RBM was the second largest producer of zircon in the world with 260,000 t in 2002, up from 245,000 t produced in 2001 (Mineral Sands Report, 2003d).

Ticor South Africa [a mining venture between Kumba Resources Ltd. of South Africa (60%) and Ticor (40%)] produced about 55,000 t of zircon in 2002 (Mineral Sands Report, 2003c). The project consists of three deposits—Fairbreeze, Gravelotte, and Hillendale. The Hillendale was the first mine Ticor developed in KwaZulu-Natal Province. Anglo American plc owns a 20.1% stake in Kumba Resources Ltd., and Kumba Resources holds a 50.12% interest in its partner, Ticor, which owns a 15.4% stake in Australian mineral sands producer MDL (Mineral Sands Report, 2003a).

In August 2001, Palabora Mining Co. Ltd. [owned by shareholders Rio Tinto plc (46.4%) and Anglo American (28.7%)] closed the heavy-minerals plant and ceased production of zirconium concentrate and uranium oxide at its mine at Phalaborwa, Limpopo Province (Palabora Mining Co. Ltd., 2003, p. 10-11). Reduced production from the open pit and a declining zirconium ore grade as mining progressed towards the center of ore body made operations uneconomic. Palabora produced 1,574 t of baddeleyite in 2001. The company completed construction of a zirconium basic sulfate (ZBS) plant in December 2001 (Palabora Mining Co. Ltd., 2003, p. 8). Palabora operated the ZBS plant with imported feedstock.

Namakwa Sands Pty. Ltd. (a wholly owned subsidiary of Anglo American) was ranked by Mineral Sands Report as the third largest producer of zircon in the world in 2002 from its mine at Brand-se-Baai. Zircon concentrate produced from its dry mill at Koekenaap was 105,000 t in 2002, a decrease from the 114,000 t produced in 2001 (Mineral Sands Report, 2003e). Zircon capacity at Namakwa was 133,000 t/yr with a remaining minelife of about 33 years.

Ukraine.—Heavy-mineral sands producer Vilnohirsk State Mining & Metallurgical (VSMMP) was ranked by Mineral Sand Report as the world's eighth largest zircon producer in 2002. Producing about 4% of the world's total at 34,000 t, VSMMP mined the Mayshev mineral sand deposit at Vilnohirsk, Dnipropetrovsk Oblast in central Ukraine (Mineral Sands Report, 2003d). The heavy-mineral assemblage at Vilnohirsk includes chromite, ilmenite, kyanite, leucoxene, rutile, sillimanite, staurolite, tourmaline, and zircon. The deposit grades 8% to 12% heavy minerals.

Outlook

The global demand for zirconium materials increased in 2002. Growth was expected to increase by 3% to 5% per year during the next few years, and new deposits are expected to come online. Prices were forecast to rise in the near term in response to higher energy costs. The increased demand relative to the available supply will contribute to continued price increases in the short term. During the next few years, however, the zircon supply and demand is expected to be in closer balance as new deposits and plant expansions come online, especially in the United States and Australia. Expansions in supply are expected in Mozambique and South Africa, and further exploration and development efforts are underway in Australia, Canada, India, Kenya, South Africa, Ukraine, and the United States. Production of zircon in the United States is expected to increase during the next 5 to 10 years.

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TABLE 1
SALIENT U.S. ZIRCONIUM STATISTICS[1]

(Metric tons)

	1998	1999	2000	2001	2002
Zircon:					
Production:					
Concentrates	W	W	W	W	W
Milled zircon	55,700	55,600	56,200	59,100	37,000
Exports	41,000	69,500	72,900	66,900	47,100
Imports for consumption[2]	89,500	57,600	65,200	60,600	35,300
Consumption, apparent[2]	W	W	W	W	W
Stocks, December 31, dealers and consumers[3]	32,000	24,700	25,100	37,700	21,600
Zirconium oxide:					
Production[4]	17,300	17,100	22,900	21,500	17,600
Exports[5]	1,540	1,680	2,220	2,400	1,950
Imports for consumption[5]	3,900	3,140	3,950	2,950	2,900
Consumption, apparent	W	W	W	W	W
Stocks, December 31, producers[4]	985	W	818	2,150	1,530

W Withheld to avoid disclosing company proprietary data.

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

[2]Includes insignificant amounts of baddeleyite.

[3]Excludes foundries.

[4]Excludes intermediate oxides associated with metal production.

[5]Includes germanium oxides and zirconium dioxides.

TABLE 2
PUBLISHED YEAREND PRICES OF ZIRCONIUM AND HAFNIUM MATERIALS

Specification of material	2001	2002
Zircon:		
Domestic, standard-grade, bulk, per short ton[1]	$340.00	$350.00
Domestic, 75% minimum quantity zircon and aluminum silicates, bulk, per short ton[1]	NA	NA
Domestic, premium-grade zircon, bulk, per short ton[1]	360.00	410.00
Imported sand, ceramic application, free on board, bulk, per metric ton[2]	375.00-400.00	375.00-400.00
Imported sand, refractory application, free on board, bulk, per metric ton[2]	350.00-390.00	350.00-390.00
Imported sand, foundry sand application, free on board, bulk, per metric ton[2]	350.00-390.00	350.00-390.00
Baddeleyite, contract price, cost, insurance, and freight main European port[3]		
Refractories/abrasive grade	2,200-2,600	2,000-2,400
Ceramic grade (98% ZrO_2 and HfO_2)	2,600-3,800	2,600-3,800
Zirconium oxide:[4]		
Powder, commercial-grade, drums, 2,000-pound minimum, per pound	NA	NA
Electronic, same basis, per pound	3.66-7.50	3.66-7.50
Insulating, stabilized, 325° F, same basis, per pound	4.00	4.00
Insulating, unstabilized, 325° F, same basis, per pound	4.00	4.00
Dense, stabilized, 300° F, same basis, per pound	4.20	4.20
Zirconium:		
Powder, per pound[5]	NA	NA
Sponge, per pound	9.00-14.00 [5]	NA
Sheets, strip, bars, per pound[5]	20.00-50.00	NA
Hafnium, sponge, per pound	54.00-64.00 [5]	NA

NA Not available.

[1]Domestic average price.

[2]Source: Industrial Minerals, no. 411, December 2001, p. 83; no. 423, December 2002, p. 71.

[3]Source: Mineral Price Watch, issue 97, January 2003, p. 11.

[4]Sources: Chemical Market Reporter, v. 260, no. 24, December 24-31, 2001, p. 19; v. 262, no. 22, December 16-30, 2002, p. 26.

[5]Source: American Metal Market, v. 109, no. 250, December 28, 2001, p. 6.

TABLE 3
U.S. EXPORTS OF ZIRCONIUM, BY CLASS AND COUNTRY[1]

Class and country	2001 Quantity (metric tons)	2001 Value (thousands)	2002 Quantity (metric tons)	2002 Value (thousands)
Ore and concentrates:				
Argentina	777	$444	811	$500
Australia	59	29	45	26
Belgium	1,520	734	805	449
Brazil	1,710	913	2,270	1,090
Canada	6,060	3,320	4,780	3,270
Chile	156	90	--	--
China	56	55	832	473
Colombia	3,050	1,880	2,680	1,600
Dominican Republic	254	160	264	173
Ecuador	638	369	464	269
France	1,060	643	586	438
Georgia	34	22	17	11
Germany	481	391	6,040	2,870
Guatemala	98	64	59	45
Guyana	133	69	1	3
Hong Kong	68	32	22	11
Hungary	--	--	19	42
Indonesia	726	402	7	8
Ireland	102	116	128	147
Israel	45	59	128	214
Italy	18,200	7,000	14,600	5,750
Japan	4,010	2,190	1,210	1,320
Korea, Republic of	314	292	113	367
Mexico	5,620	2,320	3,080	1,170
Netherlands	11,000	4,250	5,000	1,980
Pakistan	547	310	1,030	608
Peru	39	24	113	73
Philippines	117	67	58	34
Portugal	36	44	73	88
South Africa	144	71	3	15
Spain	3,880	1,570	--	--
Sri Lanka	20	10	--	--
Sweden	70	45	52	34
Switzerland	17	11	--	--
Taiwan	20	21	116	387
Thailand	38	44	19	21
United Kingdom	4,040	6,550	1,100	702
Uruguay	20	11	--	--
Venezuela	1,450	858	351	256
Vietnam	234	153	234	158
Other	8 r	24 r	21	45
Total	66,900	35,700	47,100	24,600
Unwrought zirconium and waste and scrap:				
Italy	14	136	--	--
Japan	60	1,040	--	--
United Kingdom	86	1,230	--	--
Other	26	751	3	9
Total	186	3,160	3	9

rRevised. -- Zero.

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

Source: U.S. Census Bureau.

TABLE 4

U.S. IMPORTS FOR CONSUMPTION OF ZIRCONIUM AND HAFNIUM, BY CLASS AND COUNTRY[1]

Class (harmonized code) and country	2001 Quantity (metric tons)	2001 Value (thousands)	2002 Quantity (metric tons)	2002 Value (thousands)
Zirconium ore and concentrates: (2615.10.0000)				
Australia	31,000	$9,840	14,500	$4,850
Canada	73	76	884	456
China	251	583	1,360	2,000
Germany	204	175	147	142
India	27	152	10	72
Italy	44	56	207	135
Japan	181	2,540	9	93
Mexico	378	272	181	125
Netherlands	39	25	--	--
Russia	162	395	298	698
South Africa	28,000	6,830	17,700	5,330
United Kingdom	204	605	40	94
Other	3	17	1	5
Total	60,600	21,600	35,300	14,000
Zirconium, unwrought and waste and scrap:[2]				
(8109.90.0000, 8109.20.0000)				
Argentina	11	56	3	39
Belgium	--	--	37	311
Canada	15	1,780	44	3,170
France	360	26,100	395	30,200
Germany	154	22,800	32	3,850
Japan	41	1,970	1	7
Mexico	82	702	--	--
Spain	16	139	--	--
United Kingdom	12	137	1	42
Other	25	751	19	1,040
Total	717	54,500	532	38,700
Hafnium, unwrought and waste and scrap:[3]				
(8112.92.2000)				
Canada	--	--	2	296
China	(4)	5	1	65
France	4	931	1	296
Germany	1	330	--	--
Japan	(4)	15	1	10
United Kingdom	(4)	17	--	--
Total	5	1,300	5	668

-- Zero.

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

[2]Harmonized Tariff Schedule (HTS) 8109.10.3000 and 8109.10.6000 (2001), HTS 8109.20.000 (2002).

[3]HTS 8112.91.2000 (2001), HTS 8112.92.2000 (2002).

[4]Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 5

ZIRCONIUM MINERAL CONCENTRATES: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country	1998	1999	2000	2001e	2002e
Australia	369,000	359,000	393,000	400,000	408,000 [3]
Brazil[4]	20,132	27,160	29,805	20,553 [r, 3]	20,500
China[e]	15,000	15,000	15,000	15,000	15,000
India[e]	19,000	19,000	19,000	19,000	19,000
Indonesia	231	250	250 [e]	250	250
Malaysia	3,057	1,763	3,642	2,000	2,000
Russia[5]	6,293	6,800	6,500 [e]	6,500	6,500
South Africa[6]	265,000 [e]	219,000	253,000	262,000 [r]	250,000
Sri Lanka	8,814	--	--	--	--
Thailand	-- [e]	--	100	--	--
Ukraine[e]	25,000 [r]	25,000 [r]	30,000 [r]	33,600 [r]	34,300
United States	W	W	W	W	W
Total	732,000 [r]	673,000 [r]	750,000 [r]	759,000 [r]	756,000

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in total. -- Zero.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes data available through May 9, 2003.

[3]Reported figure.

[4]Includes production of baddeleyite-caldasite.

[5]Production of baddeleyite concentrate averaging 98% ZrO_2.

[6]Includes production of byproduct zircon from titanium sands mining and 15,000 to 20,000 metric tons per year of baddeleyite from Palabora Mining Co. Ltd.