ZIRCONIUM AND HAFNIUM

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Zirconium is commercially produced from two minerals. The principal economic source of zirconium is the zirconium silicate mineral zircon (ZrSiO₄). The mineral baddelevite, a natural form of zirconium oxide also known as zirconia (ZrO₂), is a distant second to zircon in its economic significance. Zircon is the primary source of all hafnium. Zirconium and hafnium are contained in zircon at a ratio of about 50:1. Zircon is a coproduct or byproduct of the mining and processing of heavymineral sands for the titanium minerals ilmenite and rutile or the tin minerals cassiterite and stannite. The major end uses of the mineral zircon 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 nuclear fuel cladding, chemical processing equipment (pipes, valves, pumps), heat exchangers, and as an alloy ingredient in various specialty

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 2001 was estimated to be essentially the same as in 2000. Data on U.S. production and consumption of zircon concentrates were withheld to avoid disclosing company proprietary data. Domestic production of zircon decreased slightly because markets for most products declined. In 2001, production of milled zircon increased from that of the previous year. The United States was a net exporter of zirconium ore and concentrates, according to U.S. Census Bureau trade statistics. U.S. imports of zirconium ore and concentrates decreased by 7%, and domestic exports of zirconium ore and concentrates decreased by 8% compared with 2000.

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 data.

Production

Data for zirconium and hafnium materials are developed by the U.S. Geological Survey from a voluntary survey of domestic operations. Of the 43 operations surveyed for 2001, 21 responded. Data for zircon concentrates are developed by a second voluntary survey of domestic operations. In 2001, the two domestic zircon producers, which have three mining and processing operations, responded. Data for nonrespondents were estimated on the basis of prior-year levels. Data on domestic production and consumption of zircon concentrates were withheld to avoid disclosing company proprietary data.

In 2001, domestic production of milled zircon increased by 5% and production of zirconium oxide decreased by 6% from their 2000 levels (table 1).

Zircon is normally produced as a byproduct of the mining and processing of heavy-mineral sands containing the titanium minerals ilmenite and rutile. In 2001, 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 Ltd.). DuPont produced zircon from its Highland and Maxville heavy-mineral sands 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 Inc. company), Albany, OR, and Western Zirconium (a subsidiary of Westinghouse Electric Co.), Ogden, UT. Primary zirconium chemicals were produced by Wah Chang and Magnesium Elektron Inc., Flemington, NJ. Secondary zirconium chemicals were produced by about 10 companies, and zirconia was produced from zircon sand at plants in Alabama, New Hampshire, New York, Ohio, and Oregon.

Iluka continued to increase production at its Old Hickory Mine in Stony Creek, VA. The original zircon production capacity at Stony Creek was 30,000 metric tons per year (t/yr). Phase one of a \$100 million company production expansion, which was announced in 1999 by Iluka Resources Ltd., will be at the Old Hickory Mine in Virginia and phase two at the Green Cove Springs Mine in Florida (Mineral Sands Report, 2001d). The feasibility study for phase one was completed in 2000.

Altair International Inc. announced in September that its pilot plant in Camden, TN, had successfully produced titanium minerals and zircon. Recovery rates were reported to be 80% for the titanium minerals and 90% for zircon. Altair's deposits contain an estimated 490 million metric tons (Mt) grading 3.6% heavy minerals. The company was considering development options, including a joint venture partner to provide financial, engineering, and market resources (Altair International Inc., 2001§¹).

Consumption

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

Zircon, which is used for facings on foundry molds, increases resistance to metal penetration and gives a uniform finish to

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

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 simulant for diamonds and colored gemstones.

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

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

Prices

In 2001, the decreased demand for zircon concentrates resulted in a decrease in price. The average value of imported ore and concentrates decreased by 16% to \$356 per metric ton in 2001 from \$396 per ton in 2000, according to U.S. Census Bureau trade statistics. Domestic prices of standard- and premium-grade zircon were essentially unchanged as a result of a tightening of supply, especially for premium grades. Published prices for imported grades of zircon were higher than those of 2000. Published and unpublished prices for zirconium and zirconium oxide products were unchanged while those for hafnium were slightly lower (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 2001. U.S. exports of zirconium ore and concentrates were 66,900 metric tons (t), an 8% decrease from that of 2000 (table 3). The United States was a net exporter of zirconium and hafnium metal in 2001. U.S. exports of unwrought zirconium metal, waste, and scrap were 186 t, a 3% increase in tonnage compared with those of 2000. U.S. exports classified as "other zirconium metal, waste, and scrap" were 1,190 t, a 15% increase from the 2000 level.

U.S. imports of zirconium ore and concentrates were 60,600 t, a decrease of 4,560 t from those of 2000 (table 4). Australia and South Africa supplied about 97% of the imports of ores and concentrates. Imports of unwrought zirconium metal and waste and scrap amounted to 717 t, a 31% decrease compared with

those of 2000. The leading import sources of unwrought zirconium, in descending order of quantity, were France, Germany, and Mexico. Domestic imports of ferrozirconium alloys were 240 t in 2001, a 15% decrease from the 281 t imported in 2000. Imports originated primarily from Brazil, with a minor quantity from Germany. U.S. imports of unwrought hafnium metal and waste and scrap were 5 t, a 54% decrease compared with those of the previous year. Principal unwrought hafnium import sources, in descending order of quantity, were France and Germany.

World Review

Excluding U.S. production, world production of zirconium mineral concentrates in 2001 was estimated to be 797,000 t, a minor increase compared with that of 2000 (table 5). Australia and South Africa supplied about 83% of all production outside the United States. World reserves of zircon were estimated to be 36 Mt of ZrO₂, while the world reserve base of zircon was 65 Mt of ZrO₂. During 2001, 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 Resouces Ltd. was the world's largest producer of zircon in 2001, with mines in Australia and the United States. Other major zircon producers, in order of decreasing production, were Richards Bay Minerals (RBM) of Australia, 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 the largest producer of zircon concentrates in the world (table 5). In 2001, major producers of zircon concentrates, in order of estimated zircon production, in Australia were Iluka Resources Ltd., Tiwest, Consolidated Rutile Ltd. (CRL) (43% owned by Iluka Resources Ltd.), and RZM/Cable Sands Ltd. (CSL). Australian zircon production for 2001 was as follows: Iluka, 226,000 t (excluding CRL); Tiwest, 81,000 t; CRL, 43,000 t; CSL, 33,000 t (estimated); Mineral Deposits Ltd. (MDL), 7,000 t; Currumbin Minerals Pty. Ltd., 5,000 t; and Murray Basin Titanium Pty. Ltd., 3,000 t (Mineral Sands Report, 2002a). Total Australian production in 2001 was estimated to be 397,000 t, a 1% increase from the revised 2000 level of 393,000 t.

Worldwide production from Australian-based Iluka was 345,900 t of zircon in 2001, an increase of nearly 10% from the 315,000 t in 2000 (Iluka Resources Ltd., 2002a, p. 1). The company operated eight mines in Australia and two in the United States in 2001. Iluka's Australian subsidiary, WA Titanium Minerals, operated six mines in Western Australia, two of which opened in 2000. The company operated the Capel North West Mine near Capel, Western Australia. WA Titanium operated the North Mine and Newman concentrator near Eneabba, Western Australia. Other mining operations were the South Mine near Eneabba and the Yoganup, Yoganup Extended, and Busselton mines in the southwestern region. Iluka's two East Coast mines, in which it has a 48.9% interest, were operated by CRL on North Stradbroke Island, Queensland. CRL's 2001 zircon production was 43,000 t, down 3,300 t from the previous year's level.

Iluka upgraded the resources by 28% at three of its Murray Basin tenements in northwestern Victoria. The deposits included Boulka in Ouyen, the Snapper in Pooncarrie about 120 kilometers (km) north of Mildura, and the Dispersion, about 70 km east of Mildura. Iluka reported grades of greater than 22% heavy minerals with mineral zones containing up to 27% rutile and 15% zircon at Dispersion (Iluka Resources Ltd., 2002b).

BeMaX Resources NL and Probo Mining Pty. Ltd. announced they would begin development of their joint venture 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 t/yr ilmenite, 76,000 t/yr leucoxene, 53,000 t/yr rutile, and 32,000 t/yr zircon (Mineral Sands Report, 2002b; BeMaX Resources NL, 2002).

BeMaX reported inferred resources at its joint-venture Snapper deposit in the northern Murray Basin, New South Wales, to be 104 Mt grading 4.8% heavy minerals. The BIP joint venture between BeMaX (75%) and Probo Mining (25%) controls the Snapper and the Ginkgo heavy mineral deposits (Mineral Sands Report, 2001f). The Snapper deposit is located 10 km southwest of the Ginkgo deposit. According to BeMaX, the Ginkgo deposit has a resource of 252 Mt grading 2.8% heavy minerals. The heavy mineral zircon content of the Ginkgo deposit ranges from 7% to 16% (BeMaX Resources NL, 2001§).

Exploration company Metal Sands Pty. Ltd. released the results of its drilling in southwestern Western Australia. The resource had an estimated 3.37 Mt of ore grading 2.38% ilmenite, including 1.85 Mt grading 0.08% zircon (Metal Sands Pty. Ltd., 2002).

In April, Iluka announced that it had discovered additional heavy-mineral sands resources in Western Australia. Measured, indicated, and inferred resources were increased to 88 Mt of heavy minerals. This resource is split between Western Australia's southwest region, which includes Capel at 48 Mt, and the midwest region, which includes Eneabba at 40 Mt. Iluka's heavy-mineral sand resources in its rest-of-world category, including other parts of Australia, were as follows: Murray Basin, Victoria, Australia, 9 Mt; North Stradbroke Island, Queensland, Australia, 15 Mt; Sri Lanka, 119 Mt; and the United States, 25 Mt (Mineral Sands Report, 2001d).

Australian Zirconia Ltd. (a wholly owned subsidiary of Alkane Exploration Ltd.) announced that it is making minor adjustments to its pilot plant to produce a marketable zirconium oxide and hafnium oxide product from its Dubbo hard-rock zirconium-bearing deposit in New South Wales. Another production run of the plant was planned for December to produce a first run niobium-tantalum product (Alkane Exploration Ltd., 2001). The multimineral deposit is located on the Toongi alkaline intrusive that contains hafnium, lanthanides, niobium, tantalum, yttrium, and zirconium in the igneous rock trachyte. Measured resources at the Dubbo deposit are 42 Mt grading 1.91% zirconium oxide, 0.04% hafnium oxide, 0.449% niobium oxide, 0.027% tantalum oxide, 0.138% yttrium oxide, and 0.713% rare earth oxide (Australian Zirconia Ltd., 2000).

Basin Minerals Ltd. announced it had acquired a loan to

proceed with a final feasibility study of the Douglas heavy-mineral sands deposit in the Murray Basin in western Victoria. Basin Minerals' Douglas deposit covers an area of 5,860 square kilometers and has a resource of 22.4 Mt of heavy minerals. The area contains the Acapulco, Bondi, Bondi East, and Echo strandline deposits containing 11.3 Mt of ilmenite (including leucoxene), 1.26 Mt of rutile, and 1.62 Mt of zircon. Basin Minerals also filed an environmental effects statement with the Victoria Government and obtained a contract for the future sale of its zircon concentrate (Mineral Sands Report, 2002d).

Basin Minerals Ltd. has estimated an inferred resource for the Culgoa deposit, in the Murray Basin, to be 11.8 Mt at 16.8% heavy minerals with a cut-off grade of 3% heavy minerals. Culgoa has 1.985 Mt of heavy mineral concentrate with a waste-to-ore ratio of 2:1. The high grade mineralization is between 60 and 140 meters (m) wide and averages 4 m in thickness over a strike of 17.6 km. Culgoa's heavy mineral content averages 79% valuable heavy mineral and consists of 68% ilmenite, 7% leucoxene, 2% rutile, 2% zircon, and the remaining 21% gangue (TZ Minerals International, [undated]§).

MDL announced it had received approval to proceed with an extension of its dredging at Fullerton, New South Wales. The 14-km extension should extend the minelife by about 10 years at present mining rates. Part of the extension extends onto aboriginal lands, for which MDL has obtained leases from the Worimi Land Council (Mineral Sands Report, 2001h).

Iluka purchased a 4.8% share of Basin Minerals, which has several heavy mineral sands holdings in the Murray Basin that included the Douglas deposit (Mineral Sands Report, 2001c).

Iluka announced a takeover bid for its 43%-owned subsidiary CRL. Through its subsidiary Iluka Corp. Ltd., Iluka Resources offered \$A1.00 per share for all the outstanding stock, a 21% premium to the stock price at the time of offer (Mineral Sands Report, 2001b).

Sons of Gwalia (SOG) increased its share of BeMaX to 19.9%. SOG held a 16.82% equity in BeMaX prior to the sale of 5.1 million shares. Imperial One Ltd. (IOL), the largest shareholder, increased its share of BeMaX to 24.36%. IOL was BeMaX's original joint-venture partner when the exploration company started (Mineral Sands Report, 2001k).

Brazil.—Production of zircon concentrates was 29,805 t in 2000, an increase from the 27,160 t produced in 1999. The leading producer of concentrates was Millennium Inorgânica Chemicals do Brazil S/A, which operated its Mataraca heavymineral sands mine at Guaju, Paraiba State. Investments in upgrades at the mine are expected to improve recoveries and lower overall operating costs in 2002. Millennium Inorgânica Chemicals do Brasil S/A produced 64% of the zircon concentrates mined in Brazil in 2000, totaling about 19,100 t. Total Brazilian production of zircon in 2000, the latest available reported data, was 29,805 t (Fabríco da Silva, 2001).

Other zircon producers in Brazil are operated by Industrias Nucleares do Brasil S/A (INB) (a wholly owned subsidiary of Comissa Nacional de Energia Nuclear). INB produced about 10,700 t of zircon concentrates from its mines in Buena and Delta Paraíba in Rio de Janeiro, Cumuruxatiba in Joacema, and Alcobaca in Bahia.

Canada.—Tiomin Resources Inc.'s Natashquan heavy mineral sand deposit is on a care and maintenance basis while

the company focuses on development of the Kwale deposit in Kenya. The Natashquan deposit, on the north shore of the St. Lawrence River in Quebec, contains ilmenite, magnetite, and zircon. Only a small portion of the deposit has been drilled and resources are estimated to be 2.1 billion metric tons (Gt) of ore grading 5.9% heavy minerals. The dredgeable resource at Natachquan has been calculated using geologic modeling to be about 770 Mt grading 9.0% heavy minerals for the north zone and 890 Mt grading 7.19% heavy minerals for the south zone. A 116-hole drilling program confirmed the modeling resource estimate (Tiomin Resources Inc., [undated]§).

India.— In December, V.V. Minerals (VVM) announced that it had discovered mineral sands resources of 23.9 Mt of ore containing 9.45 Mt of heavy minerals. VVM has been a producer of garnet with byproduct production of ilmenite. With its drilling program in Tamil Nadu, VVM is expecting to produce greater quantities of ilmenite and byproduct rutile and zircon. Additional drilling in 2002 at closer intervals is expected to further delineate its heavy-mineral deposit (Mineral Sands Report, 2002c).

Indian Rare Earth Ltd. (IRE) operates three heavy mineral sand mines at Chavara in Kerala State, at Manavalakurichi in Tamil Nadu State, and at the Orissa Sands Complex in Orissa State. In 2000, the latest year for which data are available, zircon production was 27,000 t, an increase from the 22,000 t produced in 1999. The 2000 production was divided into 22,000 t of intermediate grade zircon used in ceramic and refractory products and 5,000 t of lower grade zircon (high TiO₂) from Orissa used in foundry sand (Mineral Sands Report, 2001e).

Kenya.—Tiomin Resources Inc. is exploring four heavymineral sands deposits in the coastal region between Mambrui and Shimoni. The deposits from north to south are the Mambrui, Kilifi, Vipingo, and Kwale. Located 6 to 12 km inland from the coast, the deposits are in the Magarini Formation of Pliocene age. The Mambrui has a resource of 700 Mt grading 3.7% heavy minerals. Two high-grade zones were delineated with 273 Mt grading 2.3% ilmenite and 0.2% rutile and zircon. The Kilifi deposit has a resource estimated to be 1.7 Gt grading 2% ilmenite and 0.63% nonmagnetic heavy minerals, which include rutile, zircon, and kyanite. The Kilifi dunal system is believed to be aeolian in origin. The Kwale deposit is the most advanced of Tiomin's properties, although it is the smallest of the group. The deposit consists of two large dunes located 10 km from the coast and only 65 km from the city of Mombasa. Kwale's resources are 200 Mt of heavy mineral sands containing 3.8 Mt of ilmenite, 1.1 Mt of rutile, and 0.6 Mt of zircon (Tiomin Resources Inc., [undated]b§).

Japan.—Sumitomo Osaka Cement Co. Ltd. (SOC) and Tosoh Corp. (TC) announced plans to increase zirconia powder production in 2001. SOC stated that it planned to triple production to 3,000 t/yr. TC announced it would double its production of zirconium powder to 1,300 t/yr at its Nanyo operation in Yamaguchi Prefecture (Mineral Sands Report, 2001g).

Madagascar.—Rio Tinto Iron and Titanium Inc. (RIT) announced that its three deposits near Fort Dauphin graded 4.5% to 5.5% heavy minerals. The heavy-mineral suite reportedly is ilmenite-rich with a 75% to 80% content but with a

correspondingly small zircon and rutile content (Mineral Sands Report, 2001j).

Mozambique.—RIT announced the discovery of heavymineral 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 an inferred resource of 70 Mt of ilmenite and other heavy minerals, including zircon. Additional drilling on the deposit is planned (Mineral Sands Report, 2002e).

Kenmare Resources plc of Dublin, Ireland, completed its feasibility study of the Moma titanium minerals project, which indicated the project was viable. Exploratory drilling proved the deposit is capable of supporting a 625,000 t/yr heavymineral sands operation for 20 years (Kenmare Resources plc, 2001).

Russia.—MDM Group, through its member company Mineral Chemical Co., purchased 24.8% of the shares of AO Kovdorsky GOK, a producer of iron ore, apatite, and baddeleyite in the Kola Peninsula. The purchase increased MDM's share of Kovdorsky to 75%. In 2001, Kovdorsky expected to produce about 3 Mt of iron ore, 1.5 Mt of apatite, and 6,000 t of baddeleyite concentrate (Metals-Russi@.com, 2001§).

Kovdorsky issued an analysis of its baddeleyite concentrate produced from its Kovdor open pit mine and processing facility. A typical chemical analysis of the concentrate graded 98.2% zirconium oxide plus hafnium oxide, 0.11% ferric oxide, 0.54% silicon dioxide, 0.25% magnesium oxide, 0.39% calcium oxide, 0.2% phosphate, 0.13% titanium dioxide, 0.08% sulfur trioxide, 0.014% aluminum oxide, and a uranium and thorium content of 415 parts per million (ppm) and 59 ppm, respectively (AO Kovdorsky GOK, 2002§).

Chepetsky Mekhanichesky Zavod (Chepetsky Mechanical Plant) (ChMP) in Glazov, Rupublic of Udmurtia, was the leading zirconium producer in Russia. The plant produced zirconium and zirconium alloy ingots ranging in size from 1,000 to 3,500 kilograms, tubing for nuclear and chemical applications, rods, alloy wire, and alloy sheet. ChMP also produced zirconium compounds [dioxide (monoclinic), yttriastabilized dioxide, carbonate, and sulfate], high purity grinding media, and refractory ceramics (Chepetsky Mekhanichesky Zavod, [undated]§).

Sierra Leone.—CRL announced it had sold its 50% share of Sierra Rutile Holdings Ltd. in April. The mine and plant had been closed since 1995 when a civil war forced the closure of the operation. MIL (Investments) S.A.R.L. of Luxembourg and U.S. Titanium of the United States joint ventured to purchase the 50% share for \$13.25 million (Mineral Sands Report, 2001a).

South Africa.—Foskor Ltd., which ceased production of baddeleyite in June 1999 as a result of declining ore grades, announced it had reached an agreement for the exclusive marketing rights of the Russian baddeleyite at Kovdor. Foskor acquired the exclusivity rights from GMF Trading of Russia (the parent company of AO Kovdorsky GOK) (Industrial Minerals, 2002).

Ticor Ltd. of Australia announced it would acquire 40% of the shares in Iscor's IHM Hillendale project in KwaZulu Natal Province. The remaining 60% is owned by Kumba Resources Ltd. (a subsidiary of Iscor Ltd.). The IHM project, which was renamed Ticor South Africa in August, consists of three deposits—the Hillendale and Fairbreeze in KwaZulu Province and the Gravelotte in Northern Province, which total 16 Mt of heavy minerals. Mining using water jets was used for the project because traditional dredging was determined to be inadequate (Ticor Ltd., 2000§). The Ticor South Africa mine and concentrator were commissioned in June 2000 with production from the deposit beginning in April 2001. The mine initially produced 196,000 t of ore with the concentrator producing 8,500 t of heavy-mineral concentrate. A heavy-mineral dry separation plant at Empangeni also commenced production. The Ticor South Africa mining operation officially opened in September (Australian Mining, 2002§).

Namakwa Sands (a wholly owned subsidiary of Anglo American plc) continued to increase producion of heavymineral sands as a result of an expansion (phase two) at its mine at Brand-se-Baai. The phase two expansion increased ore capacity to 12 million metric tons per year (Mt/yr) from 4 Mt/yr. Capacity to produce zircon concentrates correspondingly increased to 133,000 t/yr. Zircon production increased from 91,900 t in 1998 to 106,800 t in 2000 to 114,000 t in 2001 (Mineral Sands Report, 2001i).

Palabora Mining Co. Ltd. completed the construction phase of the zirconium basic sulphate (ZBS) upgrade plant in December. The ZBS plant was expected to be completed in the first quarter of 2002 (Palabora Mining Co. Ltd., 2002, p. 11, 17). Production of zirconium concentrate ceased in August with the closure of the heavy-minerals plant. The closure was the result of decreased production from the open pit mine and decreasing zirconium oxide (baddeleyite) ore grades. Production of zirconium concentrate in 2001 was 1,574 t. Sales of zirconia products were 7,090 t in 2001, a decrease from the 8,443 t produced in 2000 (Palabora Mining Co. Ltd., 2002, p. 13-14, 59).

Outlook

The global demand for zirconium was expected to increase by 2% to 3% per year over the next few years, and new deposits are expected to come online. Exploration has continued to find new zircon-bearing deposits, and companies are expected to continue to search for new sources. Prices were forecast to rise in the near term in response to higher energy costs. During the next few years, however, the supply and demand of zircon 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 first decade of the 21st century.

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TABLE 1 SALIENT U.S. ZIRCONIUM STATISTICS 1/

(Metric tons)

	1997	1998	1999	2000	2001
Zircon:					
Production:					
Concentrates	W	W	W	W	W
Milled zircon	55,700	55,700	55,600	56,200	59,100
Exports	44,300	41,000	69,500	72,900	66,900
Imports for consumption 2/	62,400	89,500	57,600	65,200	60,600
Consumption, apparent 2/	W	W	W	W	W
Stocks, December 31, dealers and consumers 3/	29,300	32,000	24,700	25,100	37,700
Zirconium oxide:					
Production 4/	15,900	17,300	17,100	22,900	21,500
Exports 5/	1,970	1,540	1,680	2,220	2,400
Imports for consumption 5/	4,220	3,900	3,140	3,950	2,950
Consumption, apparent	W	W	W	W	W
Stocks, December 31, producers 4/	982	985	W	818	2,150

- 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		2000	2001
Zircon:			
Domestic, standard-grade, bulk 1/	dollars per short ton	340.00	340.00
Domestic, 75% minimum quantity zircon and aluminum silicates, bulk 1/	do.	267.00	NA
Domestic, premium-grade zircon, bulk 1/	do.	497.00	360.00
Imported sand, ceramic application, free on board (f.o.b.), bulk 2/	dollars per metric ton	345.00-375.00	375.00-400.00
Imported sand, refractory application, f.o.b., bulk 2/	do.	340.00-370.00	350.00-390.00
Imported sand, foundry sand application, f.o.b., bulk 2/	do.	340.00-370.00	350.00-390.00
Baddeleyite, imported concentrate: 3/			
98% to 99% ZrO2, minus 100-mesh, cost, insurance, freight (c.i.f.) Atlantic por	ts dollars per pound		NA
Over 99% ZrO2, minus 100-mesh, c.i.f. Atlantic ports	do.	0.98	NA
Zirconium oxide: 4/			
Powder, commercial-grade, drums, 2,000-pound minimum	do.	3.00-6.60	NA
Electronic, same basis	do.	3.66-7.50	3.66-750
Insulating, stabilized, 325° F, same basis	do.	4.00	4.00
Insulating, unstabilized, 325° F, same basis	do.	4.00	4.00
Dense, stabilized, 300° F, same basis	do.	4.20	4.20
Zirconium:			
Powder 5/	do.	75.00-150.00	NA
Sponge	do.	9.00-12.00 5/	9.00-14.00
Sheets, strip, bars 5/	do.	20.00-50.00	20.00-50.00
Hafnium, sponge	do.	75.00-95.00 5/	54.00-64.00
NA Natavailable Zara			

NA Not available. -- Zero.

- 1/ Domestic average price.
- 2/ Industrial Minerals, no. 399, December 2000, p. 75; no. 411, December 2001, p. 83.
- 3/ American Vermiculite Corp. baddeleyite price lists.
- 4/ Chemical Market Reporter, v. 258, no. 25, December 18, 2000, p. 29; v. 260, no. 24, December 24-31, 2001, p. 19. 5/ American Metal Market, v. 108, no. 250, December 29, 2000, p. 9; v. 109, no. 250, December 28, 2001, p. 6.

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

	2000		2001		
	Quantity	Value	Quantity	Value	
Class and country	(metric tons)	(thousands)	(metric tons)	(thousands)	
Ore and concentrates:	_				
Afghanistan	137	\$61			
Argentina	507	281	777	\$444	
Australia	73	43	59	29	
Belgium	6,190	2,400	1,520	734	
Brazil	910	417	1,710	913	
Canada	6,420	2,920	6,060	3,320	
Chile	431	257	156	90	
China	872	390	56	55	
Colombia	2,430	1,480	3,050	1,880	
Dominican Republic	215	162	254	160	
Ecuador	957	495	638	369	
France	1,000	657	1,060	643	
Georgia			34	22	
Germany	993	1,210	481	391	
Guatemala		59	98	64	
Guyana		4	133	69	
Hong Kong		37	68	32	
India	— 49	24	2	5	
Indonesia	215	108	726	402	
Ireland	124	118	102	116	
Israel	329	467	45	59	
Italy	23,000	7,600	18,200	7,000	
Japan	1,510	778	4,010	2,190	
Korea, Republic of	1,560	208	314	292	
Mexico	14,800	3,710	5,620	2,320	
Netherlands	5,130	1,710	11,000	4,250	
Pakistan		333	547	310	
Panama		6	<u></u>		
Peru	4	16	39	24	
Philippines	178	103	117	67	
Portugal	36	44	36	44	
South Africa			144	71	
Spain			3,880	1,570	
Sri Lanka			20	10	
Sweden		22	70	45	
Switzerland		22	17	11	
Taiwan		106	20	21	
Thailand		24	38	44	
United Kingdom	3,790	7,040	4.040	6,550	
Uruguay	_ 3,770	7,040	20	0,550	
Venezuela	900	543	1,450	858	
Vietnam		138	234	153	
Other	1/9 r			25	
Total	_	34,000	66,900	35,700	
Unwrought zirconium and waste and scrap:		34,000	00,900	33,/00	
Italy		110	1.4	127	
	_	119	14	136	
Japan United Kingdom	_ 48	1,010	60	1,040	
United Kingdom	- 111	1,550	86	1,230	
Other	19 r			751	
Total r/ Revised Zero.	180	3,620	186	3,160	

r/ Revised. -- Zero.

Source: U.S. Census Bureau.

 $^{1/\,\}text{Data}$ are rounded to no more than three significant digits; may not add to totals shown.

 ${\bf TABLE~4} \\ {\bf U.S.~IMPORTS~FOR~CONSUMPTION~OF~ZIRCONIUM~AND~HAFNIUM,~BY~CLASS~AND~COUNTRY~1/}$

	2000		2001	
	Quantity	Value	Quantity	Value
Class, harmonized code, and country	(metric tons)	(thousands)	(metric tons)	(thousands)
Zirconium ore and concentrates: (2615.10.0000)				
Australia	31,600	\$9,020	31,000	\$9,840
Belgium		43		
Canada		58	73	76
China	41	136	251	583
Germany	391	510	204	175
India			27	152
Italy	2,330	1,390	44	56
Japan	553	3,420	181	2,540
Mexico	240	189	378	272
Netherlands	120	82	39	25
Russia	42	105	162	395
South Africa	29,400	9,410	28,000	6,830
United Kingdom	394	1,320	204	605
Other	18	119	3	17
Total	65,200	25,800	60,600	21,600
Zirconium, unwrought and waste and scrap: (8109.10.3000, 8109.10.6000, 8109.90.0000)		222		-
Argentina	_ 21	333	11	56
Canada	_ 56	4,030	15	1,780
China	_ 17	314		
France	_ 665	26,600	360	26,100
Germany	179	20,200	154	22,800
Japan	_ 79	458	41	1,970
Mexico			82	702
Spain			16	139
United Kingdom			12	137
Other	24	664	25	751
Total	1,040	52,700	717	54,500
Hafnium, unwrought and waste and scrap: (8112.91.2000)	_			
Canada	_ 1	340		
China	_		(2/)	5
France	8	1,440	4	931
Germany	1	415	1	330
Japan	1	38	(2/)	15
Russia	(2/)	11		
United Kingdom			(2/)	17
Total	11	2,240	5	1,300
7				

⁻⁻ Zero

Source: U.S. Census Bureau.

^{1/} Data are rounded to no more than three significant digits; may not add to totals shown.

^{2/} Less than 1/2 unit.

 ${\it TABLE~5}$ WORLD PRODUCTION OF ZIRCONIUM MINERAL CONCENTRATES, BY COUNTRY 1/2/

(Metric tons)

Country	1997	1998	1999	2000	2001 e/
Australia	416,000 r/	369,000 r/	359,000 r/	393,000 r/	400,000
Brazil 3/	19,252	20,132 r/	27,160 r/	29,805 r/	19,500 4/
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	105	231	250	250 e/	250
Malaysia	4,050	3,057	1,763	3,642 r/	2,000
Russia 5/	5,745	6,293	6,800	6,500 e/	6,500
South Africa 6/	265,300	265,000 e/	219,000	253,000 r/	260,000
Sri Lanka	12,450	8,814			
Thailand		e/		100 r/	
Ukraine e/	65,000	65,000	69,000	75,000	75,000
United States	W	W	W	W	W
Total	822,000 r/	772,000 r/	717,000 r/	795,000 r/	797,000

- 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.
- 2/ Includes data available through May 9, 2002.
- 3/ Includes production of baddeleyite-caldasite.
- 4/ Reported figure.
- 5/ Production of baddeleyite concentrate averaging 98% ZrO2.
- 6/ Includes production of byproduct zircon from titanium sands mining and 15,000 to 20,000 tons per year baddeleyite from Palabora Mining Co. Ltd.