Rare Earths

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The rare earths are a moderately abundant group of 17 elements comprising the 15 lanthanides, scandium, and yttrium. The elements range in crustal abundance from cerium, the 25th most abundant element of the 78 common elements in the Earth's crust at 60 parts per million (ppm), to thulium and lutetium, the least abundant rare-earth elements at about 0.5 ppm (Mason and Moore, 1982, p. 46). In rock-forming minerals, rare earths typically occur in compounds as trivalent cations in carbonates, oxides, phosphates, and silicates.

In 2004, world rare-earth production was primarily from the rare-earth mineral bastnäsite. No rare earths were mined in the United States; however, the mine and plant at Mountain Pass, CA, was kept on care and maintenance. Rare-earth ores were mainly supplied by China, with lesser amounts mined in Brazil, India, and Russia. Domestic stocks of previously produced bastnäsite concentrates, intermediate rare-earth concentrates, and separated products were available for purchase from Molycorp, Inc. at Mountain Pass. Consumption was estimated to have decreased as did imports of cerium compounds, rare-earth chlorides, rare-earth metals, and mixed rare-earth compounds. U.S. imports of individual rare-earth compounds, ferrocerium and pyrophoric compounds, and yttrium compounds increased (table 5).

Yttrium consumption increased by about 61% in 2004 compared with that of 2003, according to data from the Port Import Export Reporting Service (PIERS) database of Commonwealth Business Media, Inc. (undated§[1]). Yttrium was used primarily in lamp and cathode-ray tube phosphors; lesser amounts were used in structural ceramics and oxygen sensors.

The domestic use of scandium increased slightly in 2004. Overall consumption of the commodity remained small. Demand was primarily for aluminum alloys used in baseball and softball bats. Scandium alloys, compounds, and metals were used in analytical standards, metallurgical research, and sports equipment. Minor amounts of high-purity scandium were used in semiconductors and specialty lighting.

The lanthanides comprise a group of 15 elements with atomic numbers 57 through 71 that include the following in order of atomic number: lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium. Cerium, which is more abundant than copper (whose average concentration in the Earth's crust is 50 ppm), is the most abundant member of the group at 60 ppm, followed, in decreasing order, by yttrium at 33 ppm, lanthanum at 30 ppm, and neodymium at 28 ppm. Thulium and lutetium, the least abundant of the lanthanides at 0.5 ppm, occur in the Earth's crust in higher concentrations than antimony, bismuth, cadmium, and thallium.

Scandium, whose atomic number is 21, is the lightest rare-earth element. It is the 31st most abundant element in the Earth's crust, with an average crustal abundance of 22 ppm (Mason and Moore, 1982, p. 46). Scandium is a soft, lightweight, silvery-white metal, similar in appearance and weight to aluminum. It is represented by the chemical symbol Sc and has one naturally occurring isotope. Although its occurrence in crustal rocks is greater than lead, mercury, and the precious metals, scandium rarely occurs in concentrated quantities because it does not selectively combine with the common ore-forming anions.

Yttrium, whose atomic number is 39, is chemically similar to the lanthanides and often occurs in the same minerals as a result of its similar ionic radius. It is represented by the chemical symbol Y and has one naturally occurring isotope. Yttrium's average concentration in the Earth's crust is 33 ppm and is the second most abundant rare earth in the Earth's crust. Yttrium is a bright silvery metal that is soft and malleable, similar in density to titanium.

The elemental forms of rare earths are iron gray to silvery lustrous metals that are typically soft, malleable, ductile, and usually reactive, especially at elevated temperatures or when finely divided. Melting points range from 798° C for cerium to 1,663° C for lutetium. The unique properties of rare earths are used in a wide variety of applications. The principal economic rare-earth ores are the minerals bastnäsite, loparite, and monazite and lateritic ion-adsorption clays (table 2).

The rare earths were discovered in 1787 by Swedish Army Lieutenant Karl Axel Arrhenius when he collected the black mineral ytterbite (later renamed gadolinite) from a feldspar and quartz mine near the village of Ytterby, Sweden. Because they have similar chemical structures, the rare earth elements proved difficult to separate. It was not until 1794 that the first element, an impure yttrium oxide, was isolated from the mineral ytterbite by Finnish chemist Johann Gadolin (Weeks and Leicester, 1968, p. 667, 671).

Rare earths were first produced commercially in the 1880s in Sweden and Norway from the rare-earth mineral monazite. Production in Scandinavia was prompted by the invention in 1884 of the Welsbach incandescent lamp mantle, which initially required the oxides of lanthanum, yttrium, and zirconium, with later improvements requiring only the oxides of thorium and cerium. The mantles also used small amounts of neodymium and praseodymium oxides as an indelible brand-name label. The first rare-earth production in the United States was recorded in 1893 in North Carolina; however, a small tonnage of monazite was reportedly mined as early as 1887. South

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

Carolina began production of monazite in 1903. Production of monazite occurred in Brazil as early as 1887, and India began recovery of the ore in 1911.

Production

In 2004, Molycorp, Inc. (a wholly owned subsidiary of Unocal Corporation), remained open on a care-and-maintenance basis and sold from its stockpile of bastnäsite concentrates, intermediate concentrates, and separated compounds previously processed at its open pit operations at Mountain Pass. In 2004, the minerals sector of Unocal reported sales revenue of $60 million (unaudited), an increase of $35 million from the $25 million (unaudited) in 2003 (Unocal Corporation, 2005, p. 30). Unocal's minerals sector included minerals other than the lanthanides [such as carbon, columbium (niobium), and molybdenum] and is undifferentiated in Unocal's report. Part of the increase in revenues in the minerals sector in 2004 was due to the sale of a partial interest in its Brazilian niobium company Companhia Brasileira de Metalurgia e Mineracao (CBMM). Molycorp's interest in CBMM was sold down to 40% from 44.59% for a pretax gain of $15 million (Unocal Corporation, 2005, p. 38). Although the company was not actively mining rare earths, the sales operation remained open, and several lanthanide products were packaged, sold, and shipped. Substantial stocks of lanthanide concentrates and intermediate and refined compounds were available.

Lanthanide products available in 2004 from Molycorp were bastnäsite concentrate, cerium nitrate, lanthanum chloride, lanthanum hydrate, lanthanum-rich nitrate, and the oxides of cerium, erbium, europium, gadolinium, praseodymium, samarium, and yttrium.

Three companies processed intermediate rare-earth compounds to lanthanides in 2004. Grace Davison (a subsidiary of W.R. Grace & Co.) processed intermediate rare-earth compounds to produce cerium- and lanthanum-rich compounds used in making fluid-cracking catalysts for the petroleum industry and processed cerium and zirconia compounds for automotive catalysts and catalyst supports (Grace Davison, 2004§).

Santoku America, Inc. (a subsidiary of Santoku Corporation of Japan) produced rare-earth magnet and rechargeable battery alloys at its operations in Tolleson, AZ. Santoku America produced both types of high-strength permanent magnets, namely neodymium-iron-boron (NIB) and samarium-cobalt magnets. For the rechargeable battery industry, Santoku produced nickel-metal hydride (NiMH) alloys that incorporate specialty rare-earth mischmetals. The plant also produced a full range of high-purity rare-earth metals in cast and distilled forms, foils, and sputtering targets, including scandium and yttrium. Santoku (33%) continued its joint venture Anan Kasei Ltd. with Rhodia Electronics and Catalysis, Inc. (67%). The joint venture operations, located in Anan, Japan, produced fuel additive emission-reduction catalysts, phosphors, polishing compounds, rare-earth-base nontoxic colorants and coatings for plastics, and three way catalytic converter catalysts (Santoku America, Inc., undated§).

Rhodia's operations produced finished rare-earth products from imported materials at its plant in Freeport, TX. Rhodia continued to operate its large-scale rare-earth separation plant in La Rochelle, France, and had additional capacity at its joint venture in Kobe, Japan. These plants provide Rhodia's U.S. operations with a majority of their rare-earth supply. Rhodia produced rare-earth containing catalysts for automotive emission applications including the three-way catalyst (precious metals, alumina, and ACTYLYS™ rare-earth-base catalyst) for gasoline engines and the EOLYS™ fuel additive catalyst for diesel engines (facilitates the regeneration of particulate filters) (Rhodia Electronics and Catalysis Inc., undated§). Rhodia reported sales by market segment to be 56% electronics, 37% catalysis, and 7% new markets.

All commercially produced purified yttrium was derived from imported compounds. The principal source was China.

Two scandium processors operated in 2004. High-purity products were available in various grades, with scandium oxide produced having up to 99.999% purity. Boulder Scientific Co. processed scandium at its Mead, CO, operations. It refined scandium primarily from imported oxides to produce high-purity scandium compounds, including carbide, chloride, diboride, fluoride, hydride, nitride, oxalate, and tungstate.

Scandium also was purified and processed from imported oxides at Aldrich-APL, LLC in Urbana, IL, to produce high-purity scandium compounds, including anhydrous and hydrous chloride, fluoride, iodide, and oxide. The company also produced high-purity scandium metal.

The principal domestic producer of NIB magnet alloys was Santuko America. Leading U.S. producers of rare earth magnets were Electron Energy Corporation, Landisville, PA; Hitachi Magnetics Corporation, Edmore, MI; Hitachi Metals North Carolina, China Grove, NC; and VAC Magnetics Corporation [a subsidiary of Vacuumschmelze GMBH & Co. KG (a division of Morgan Crucible Company plc.)], Elizabethtown, KY. Hitachi Magnetics, planned to close its plant in Edmore, MI, in 2005 as a result of low-cost production from China. Demand for rare earths used in NiMH batteries decreased, and overall demand for rechargeable batteries declined in 2004. Rechargeable batteries are used in camcorders, cellular telephones, PDAs, portable computers, and other portable devices. The principal world markets for rechargeable batteries are laptop computers and cellular phones. Japan, the leading producer of rechargeable batteries, produced an estimated 306 million units of rare-earth-containing NiMH batteries in 2004, a decrease from the 380 million produced in 2003. In comparison, Japan produced an estimated 1,198 million units of lithium-ion batteries in 2004. The average cost of a lithium ion battery was about 2.4 times the cost of a NiMH battery (Roskill's Letter from Japan, 2005a).

Consumption

Statistics on domestic rare-earth consumption were developed by surveying various processors and manufacturers, evaluating import and export data, and analyzing U.S. Government stockpile shipments. Domestic apparent consumption of rare earths increased in 2004 compared with that of 2003.

In 2004, yttrium consumption was estimated to have increased substantially to 619 t from 384 t in 2003. The increase was primarily for lighting phosphors. Yttrium information was based on data retrieved from the PIERS database. Yttrium compounds and metal were imported from several sources in 2004. Yttrium compounds and metals were imported from China (85.4%), the Netherlands (7.74%), Japan (3.72%), Austria (1.41%), Belgium (1.08%), Hong Kong (0.42%), and the Republic of Korea (0.19%). The estimated use of yttrium, based on imports, was primarily in lamp and cathode-ray tube phosphors and electronics (98.8%), alloys (0.89%), and ceramics (0.30%) (Commonwealth Business Media, Inc., undated§).

Stocks

All U.S. Government stocks of rare earths in the National Defense Stockpile (NDS) were shipped in 1998. Periodic assessments of the national defense material requirements may necessitate the inclusion of rare earths, including scandium and yttrium, in the NDS at a future date.

Prices

The prices of rare-earth materials either increased or were essentially unchanged in 2004 compared with 2003. The following estimates of prices were based on trade data from various sources or were quoted by rare-earth producers. All rare-earth prices remained nominal and subject to change without notice. The competitive pricing policies in effect in the industry caused most rare earth products to be quoted on a daily basis from the producers and processors. The average price of imported rare-earth chloride was $2.41 per kilogram in 2004, an increase from $1.50 per kilogram in 2003. In 2004, imported rare-earth metal prices averaged $5.22 per kilogram, a decrease from $6.97 per kilogram in 2003. Mischmetal and specialty mischmetals composed most of the rare-earth metal imports. (Mischmetal is a natural mixture of rare-earth metals typically produced by metallothermic reduction of a mixed rare-earth chloride.) The price of basic mischmetal ranged from $3.14 to $3.87 per kilogram, and low-zinc, low-magnesium mischmetal, from $4.59 to $5.07 per kilogram (metric ton quantities) in 2003, free on board (f.o.b.), China port (China Rare Earth Information, 2004§). The domestic price of mischmetal at $10.00 per kilogram (metric ton quantities), was higher than the Chinese price because of shipping costs related to its classification as a hazardous material since it is pyrophoric. The average price for imported cerium compounds, excluding cerium chloride, increased to $4.67 per kilogram in 2004 from $4.15 per kilogram in 2003. The primary cerium compound imported was cerium carbonate.

The 2004 nominal price for bastnäsite concentrate was $5.51 per kilogram of contained lanthanide oxide ($2.50 per pound of contained lanthanide oxide). The price of monazite concentrate, typically sold with a minimum 55% rare-earth oxide (REO), including contained thorium oxide, f.o.b., as quoted in U.S. dollars and based on the last U.S. import data, was unchanged at $400.00 per metric ton ($0.73 per kilogram of contained rare-earth oxide). In 2004, no monazite was imported into the United States. Prices for monazite remained depressed because the principal international rare-earth processors continued to process only thorium-free feed materials.

The nominal price for basic neodymium metal for metric ton quantities remained around $16.68 per kilogram ($7.57 per pound), f.o.b. shipping point (China Rare Earth Information, 2004§). Most neodymium-iron-boron alloy was sold with additions of cobalt (typically 4% to 6%) or dysprosium (no more than 4%). The cost of the additions was based on pricing before shipping and alloying fees; with the average cobalt price increasing to $52.76 per kilogram ($23.93 per pound) in 2004, the cost would be about $0.53 per kilogram ($0.24 per pound) for each percentage point addition.

Rhodia's quoted rare earth prices, per kilogram, net 30 days, f.o.b. New Brunswick, NJ, or duty paid at point of entry, in effect at yearend 2004, are listed in table 3. No published prices for scandium oxide in kilogram quantities were available. Yearend 2004 nominal prices for scandium oxide were compiled from information provided by several domestic suppliers and processors. Prices for 2004 were essentially unchanged from those of 2003. The 2004 prices were as follows: 99% purity, $500 per kilogram; 99.9% purity, $1,300 per kilogram; 99.99% purity, $2,500 to $6,000 per kilogram; and 99.999% purity, $10,000 per kilogram.

Scandium metal prices for 2004 were essentially unchanged from those of 2003 and were as follows: 99.9% REO purity, metal pieces, distilled dendritic, ampouled under argon, $303 per 2 grams; 99.9% purity, metal ingot, $124 per gram; scandium rod, 12.7-millimeter (mm) diameter, 99.9% (metals basis excluding tantalum), $497 per 10 millimeters; and 99.9% REO purity foil, 0.025-mm thick, ampouled under argon, 25 mm by 25 mm, $141 per sheet (Alfa Aesar, undated§).

Scandium compound prices were unchanged from 2003 and were as follows: scandium acetate hydrate 99.9% purity, $66.30 per gram; scandium chloride hydrate 99.99% purity, $85.00 per gram; scandium nitrate hydrate 99.9% purity, $73.90 per gram; and scandium sulfate pentahydrate 99.9% purity, $65.80 per gram. Prices for standard solutions for calibrating analytical equipment were $25.70 per 100 milliliters of scandium atomic absorption standard solution and $420.30 per 100 milliliters of scandium plasma (ICP/DCP) standard solution (Aldrich Chemical Co., 2002, p. 1639-1641).

Prices for kilogram quantities of scandium metal in ingot form have historically averaged about twice the cost of scandium oxide, and higher purity distilled scandium metal prices have averaged about five times that cost.

Foreign Trade

U.S. exports increased substantially and imports of rare earths increased slightly in 2004 compared with those of 2003. Data in this section are based on gross weight, while data in the tables may be converted to equivalent REO content, as specified. U.S. exports totaled 12,100 t valued at $54.4 million, a 60.2% increase in quantity and a 23.7% increase in value compared with those of 2003 (table 4). Imports totaled 23,500 t gross weight valued at $97.9 million, a 1.4% increase in quantity and a 4.2% increase in value compared with those of 2003 (table 5).

In 2004, U.S. exports of rare earths increased in quantity in all four trade categories. Principal destinations in 2004, in descending order, were Canada, Estonia, Germany, and Japan.

The United States exported 840 t of rare-earth metals valued at $6.05 million, a 38% increase in quantity and an 86% increase in value compared with that of 2003. Principal destinations, in descending order of quantity, were Japan, Indonesia, China, and Germany. Exports of cerium compounds, primarily for glass polishing and automotive catalytic converters, increased by 19.3% to 2,280 t valued at $12.6 million. Major destinations, in descending order of quantity, were the Republic of Korea, India, Mexico, Japan, and Germany.

Exports of inorganic and organic rare-earth compounds increased by 168% to 4,800 t in 2004 from 1,790 t in 2003, and the value of the shipments decreased by 5.0% to $18.9 million. Shipments, in descending order of quantity, were to Canada, Estonia, Germany, and the Republic of Korea.

U.S. exports of ferrocerium and other pyrophoric alloys increased to 4,190 t valued at $16.8 million in 2004 from 3,250 t valued at $10.7 million in 2003. Principal destinations, in descending order of quantity, were Germany, Canada, Netherlands, the United Kingdom, and the United Arab Emirates.

In 2004, U.S. imports of compounds and alloys increased in quantity and value for three out of seven categories and are listed in table 5. China and France dominated the import market, especially for mixed and individual rare-earth compounds, followed by Japan, Russia, and Estonia (figure 1). These five countries accounted for 98.3% of the domestic imports.

Imports of cerium compounds totaled 2,820 t valued at $13.2 million. The quantity of cerium compounds imported decreased by 22.4% as a result of decreased demand for automotive exhaust catalysts and the value declined by 12.6%. China was the major supplier for the 10th consecutive year, followed by Japan, France, and Austria.

Imports of yttrium compounds that contained between 19 and 85 weight-percent (yttrium concentrate) increased by 161% to 226 t in 2004, and the value decreased by 18.9% to $3.51 million. China was the leading supplier of yttrium compounds, followed by Japan and France.

Imports of individual rare-earth compounds, traditionally the major share of rare-earth imports, increased by 18.8% compared with those of 2003. Rare-earth compound imports increased to 15,200 t valued at $64.1 million. The major sources of individual rare-earth compounds, in decreasing order by quantity, were China, France, Japan, Russia, and Estonia.

Imports of mixtures of rare-earth oxides, other than cerium oxide, decreased in quantity by 2.88% to 1,660 t valued at $4.9 million. The principal source of the mixed rare-earth oxides was China, with much smaller quantities imported from the United Kingdom, Japan, and Austria.

Imports of rare-earth metals and alloys into the United States totaled 670 t valued at $3.50 million in 2004, a 9.0% decrease in quantity compared with 2003. The principal rare-earth metal sources, in descending order of quantity, were China, with much smaller amounts from Japan and the United Kingdom.

In 2004, imports of rare-earth chlorides decreased by 31.2% to 2,850 t valued at $6.87 million. Supplies of rare-earth chloride, in descending order of quantity, came from China, with minor amounts from the Republic of Korea, Japan, and the Netherlands. In the United States, rare-earth chloride was used mainly as feed material for manufacturing fluid cracking catalysts.

Imports of ferrocerium and pyrophoric alloys increased to 118 t valued at $1.77 million from 114 t valued at $1.65 million in 2003. Principal sources of these alloys, in descending order of quantity, were France and Austria.

World Review

Australia.—Lynas Corporation Ltd. announced the purchase of 19.92% of AMR Technologies Inc., a Canadian company based in Toronto, Ontario, which operates two rare-earth plants in China and a rare-earth bonded magnetic powder plant in Thailand (AMR Technologies Inc., 2004; Lynas Corporation Ltd., 2004). Lynas continued with development of its Mount Weld rare-earth deposit 30 kilometers (km) south of Laverton, Western Australia. Proposals from mining contractors were received to provide deposit overburden stripping, mining, crushing, and stockpiling. Bids were also received to provide transport of the concentrate from Mount Weld to Leonora by truck and then transfer the ore to rail for transport to the port at Esperance. From Esperance the ore is expected to be shipped to Shandong Province in China for processing (Lynas Corporation Ltd., 2005). Reserves at Mount Weld are 1.2 Mt grading 15.6% REO, and indicated reserves are an additional 5 Mt grading 11.7% REO. Inferred resources are 1.5 Mt grading 9.8% REO (Lynas Corporation Ltd., undated§). The deposit has an expected mine life of at least 20 years based on mining 3.2 million metric tons per year of ore at an average grade of 14.3% REO.

Australia remained one of the world's major potential sources of rare-earth elements from its alkaline intrusive deposit, heavy-mineral sand deposits, and rare-earth lateritic deposits. Monazite is a constituent in essentially all of Australia's heavy-mineral sands deposits. It is normally recovered and separated during processing but, in most cases, is either returned to tailings because of a lack of demand or stored for future sale. In 2004, major producers of heavy-mineral sand concentrates in Australia, in order of production, were Iluka Resources Limited [excluding its interest in Consolidated Rutile Ltd. (CRL)]; Tiwest Joint Venture; CRL; and Bemax Resources N.L.; lesser amounts were produced by Doral Mineral Industries Ltd.; Currumbin Minerals Pty. Ltd.; and Murray Basin Titanium Pty. Ltd. (Mineral Sands Report, 2005a).

Development started at two of Iluka's new heavy-mineral sand mines in Western Australia, the Yoganup West Mine and the Wagerup Mine. Iluka's two east coast mines, the Yarraman and Ibis Mines, were operated by CRL on North Stradbroke Island, New South Wales. Production from the Yarraman Mine in 2004 increased as repairs at the Yarraman dredge were completed and dry-mining of higher grade areas adjacent to the dredge supplemented the feed. The Enterprise dredge was upgraded in 2004 and was scheduled to be moved from the Ibis to the new Enterprise mining area in 2005 (Iluka Resources Limited, 2005§). CRL operated a dry separation plant at Pinkenba, Brisbane, Queensland.

Iluka announced the startup of mining operations at its Douglas heavy-mineral sands project in the Murray Basin in southwestern Victoria. A wet concentrator plant was scheduled for completion in the second quarter of 2005. A $130 million dry heavy-mineral separation plant is planned for completion in Hamilton, Victoria, in the fourth quarter of 2005 (Iluka Resources Limited, undated§).

Iluka's announced the discovery of two heavy-mineral deposits in the Eucla Basin of South Australia, the Jacinth deposit and the Ambrosia prospect (Mineral Sands Report, 2005b). Air-core drilling on the Jacinth delineated an average heavy-mineral grade of 6%, containing an economic heavy-mineral content of 55% zircon, 22% ilmenite, and 7% rutile. Inferred resources at the Jacinth were estimated to be 108 Mt of heavy-mineral ore.

The second deposit, the Ambrosia prospect, is located 2 km north of the Jacinth deposit. Initial drilling indicated a heavily mineralized zone with greater than 11% heavy minerals. The heavy-mineral mineral suite contained 66% zircon, 10% ilmenite, and 6% rutile.

Iluka announced that it will start an environment effects statement for its Kulwin, Woornack, Rownack, Rainlover, and Pirro deposits (KWR project) in Ouyen, Victoria. Production from the KWR heavy-mineral project is scheduled for the second half of 2007 (Iluka Resources Limited, 2004).

In Western Australia, Bemax Resources' wholly owned subsidiary Cable Sands operated the Ludlow and Tutunup Mines and the Bunbury Mineral Separation Plant at North Shore. In 2004, the Ludlow and Tutunup Mines produced 106,165 t of heavy-mineral concentrates (the wet mill at Ludlow Mine started in December 2004). The Bunbury Mineral Separation Plant has a capacity of 750,000 metric tons per year (t/yr) of ore. Cable Sands continued to seek approvals to develop a new heavy-mineral sands deposit, the Gwindinup deposit, 30 km south of Bunbury (Bemax Resources N.L., 2005).

Southern Titanium N.L. changed its name to Australian Zircon NL (AZC) effective December 7, 2004 (deListed, undated§). AZC completed a bankable feasibility study on its Mindarie project and expected to obtain financing to develop the mine and processing plants in the first half of 2005 (Australian Zircon NL, 2005a§). The Mindarie deposit is located in the Murray Basin, a sedimentary basin of Cenozoic age. The Murray Basin is composed of lacustrine (a lake environment) and shallow marine sediments surrounded by igneous and metamorphic rock that weathered and washed into the basin. A series of beach and offshore sand strandlines were deposited in the Murray Basin from 5 million to 2 million years ago. The Pliocene ore is in the Loxton-Parilla sands at 8 to 30 meters (m) depth on an uplifted block of a former strand-plain, while the Tertiary ore is in multiple strand lines of a paleobeach placers (Eco-Minex International Co., Ltd., undated§). AZC upgraded its reserves for the Mindarie project to 60.4 Mt of ore at a grade of 4.21% heavy minerals (2.55 Mt of heavy minerals) (Australian Zircon NL, 2005).

AZC's joint-venture project with Austpac Resources NL, the WIM 150, is located near Horsham in western Victoria. Reserves for the project are 452 Mt of ore grading 5.9% heavy minerals. AZC planned to increase its participation in the project to an 80% share when a bankable feasibility study is completed. Testing was started on a 3.5-t sample of the fine-grained WIM 150 ore to determine the best method for separating the heavy minerals (Australian Zircon NL, 2005b§).

Alkane Exploration Ltd. announced that measured resources at its Dubbo zirconia project in New South Wales were 35.7 Mt of ore grading 1.96% zirconia, 0.75% REO (excluding yttria), 0.46% columbium (niobium) pentoxide, 0.14% yttria, 0.04% hafnia, and 0.03% tantalum trioxide. Inferred resources were an additional 37.5 Mt. Planned capacity of the Dubbo operation was 200,000 metric tons per year (t/yr) of ore producing 3,000 t/yr of zirconia equivalent, 600 t/yr of columbium (niobium)-tantalum concentrate, and 1,200 t/yr of REO (yttria and lanthanide oxides). A decision on development of the Dubbo zirconia project was expected by 2006 (Alkane Exploration Ltd., 2005§).

Brazil.—Reserves of rare earths were 109,000 t contained in various types of deposits, including alkaline intrusives, carbonatites, fluvial or stream placers, lateritic ores, and marine placers. The reserves, comprising measured and indicated quantities of monazite, were distributed in deposits primarily in the States of Rio de Janeiro (24,570 t), Bahia (10,186 t), and Espirito Santo (4,136 t) (Fabricio da Silva, 2005). The main placer reserves were in the States of Minas Gerais (24,396 t), Espirito Santo (11,372 t), and Bahia (3,481 t). In 2001, total reserves of rare earths in Brazil were about 6 Mt grading 0.5% contained REO. Brazil did not produce rare earths (monazite) in 2003, the latest date for which Government data are available.

Canada.—A 5-metric-ton-per-hour (t/hr) pilot plant to recover heavy minerals from oil sand was opened by Titanium Corporation, Inc. in Saskatchewan. The operation planned to recover titanium minerals and zircon. The deposit also contains the rare-earth minerals monazite and xenotime. Feed for the plant is recovered from tailings from Syncrude Canada Ltd.'s oil recovery plant in Alberta. Tailings from Syncrude contain greater than 30% heavy minerals (Mineral Sands Report, 2004).

Tiomin Resources Inc. owns rights to a large heavy-mineral sands deposit in Natashquan in northern Quebec. The Natashquan deposit is a successive sequence that coarsens upward. The sedimentary facies can be subdivided into four groups—predeltaic, prodeltaic and deltaic, shoreface progradation, and recent. These successive sequences can be grouped into two major layers—a lower sequence (predeltaic and prodeltaic and deltaic sequence) and an upper sequence (shoreface progradation and recent). A 116-hole drilling program confirmed resources over a mean thickness of 22 m and a heavy-mineral concentration of 9.9%. The project is on hold until Tiomin's Kwale heavy-mineral sands deposit in Kenya is developed (Tiomin Resources Inc., undated§).

China.—Production of rare-earth concentrates in China was 98,000 t REOs in 2004 (table 6). Production from Inner Mongolia at 58,000 t REO accounted for the majority of the rare earths produced, an increase from the 54,000 t REO in 2003. Jiangxi Province's ion adsorption ores were second with 25,000 t of REO, and other mines in China produced 15,000 t REO (Roskill's Letter from Japan, 2005c).

Gambia, The.—Carnegie Corporation Ltd. of Australia has exclusive prospecting licenses in The Gambia that included three mineral sands deposits—Batukunku, Kartung, and Sanyang. Total measured, indicated, and inferred resources were estimated to be 15.1 Mt containing about 1 Mt of heavy-mineral sands at a cutoff grade of 1%. The heavy-mineral assemblage for these deposits was estimated to contain 71% ilmenite, 15% zircon, 3% rutile, and 11% other heavy minerals, including monazite (Carnegie Corporation Ltd., 2004, p. 7-11).

India.—Indian Rare Earths Ltd. (IRE) produced heavy-mineral sands from its three mining divisions at Chavara, Manavalakurichi, and Orissa. The Manavalakurichi operation, located 25 km north of Kanyakumari near the southern tip of India, was awarded the "Industrial Safety Award" by the Atomic Energy Regulatory Board in 2004 for its production unit (Atomic Energy Regulatory Board India, 2004§). Monazite capacity of the plant is 3,000 t/yr (Indian Rare Earths Limited., 2005§).

At Chatrapur, the Orissa Sands Complex (OSCOM) was awarded the "Green Site Award" by the Atomic Energy Regulatory Board in 2003 for its environmental improvements by planting trees (Atomic Energy Regulatory Board India, 2003§). The large scale complex operates two dredges with capacities of 500 t/hr and 100 t/hr, respectively (Indian Rare Earths Limited, 2005§). OSCOM produces a full-range of heavy minerals, including garnet, ilmenite, monazite, rutile, sillimanite, and zircon.

The Rare Earths Division (RED) plant at Aluva chemically processes monazite to produce mixed and separated rare-earth compounds. RED has a capacity to treat 3,600 t/yr of monazite. The plant also produces an impure thorium hydroxide byproduct that is stored for future use as a nuclear fuel (Indian Rare Earths Limited, 2005§).

Japan.—Japan refined 6,015 t of rare earths in 2004, an increase from the 5,502 t produced in 2003. The rare earths were produced from imported ores and intermediate raw materials. Imports of refined rare-earth products were 26,762 t, an increase from the 25,705 t imported in 2003. The value of imports increased to ¥20.792 billion in 2004 from ¥16.351 billion in 2003. Japanese imports of refined rare-earth products increased for rare-earth compounds, rare-earth metals, and yttrium and decreased for all other categories. Imports of refined rare-earth products from the United States decreased to 217 t in 2004 from 347 t in 2003 (Roskill's Letter from Japan, 2005c).

Production of Japanese rare-earth-bonded magnets in 2004 was 570 t, an increase from the 540 t in 2003 (Roskill's Letter from Japan, 2005c). Shipments of rare-earth-bonded magnets were 598 t valued at ¥7.1 billion in 2004, an increase from the 540 t valued at ¥7.0 billion in 2003 (Roskill's Letter from Japan, 2005b).

Japan also produced an estimated 7,900 t of rare-earth-sintered magnets in 2004, an increase from the 5,506 t produced in 2003 (Roskill's Letter from Japan, 2005c). Consumption of rare-earth-sintered magnets by end-use in 2003, the latest date for which data were available, was as follows: audio, 368 t; electric motors and actuators, 1,785 t; integrated technology, 420 t; magnetic resonance imaging, 735 t; voice coil motors, 1,838 t; and other, 105 t (Roskill's Letter from Japan, 2005d).

Japanese imports of rare earths from China were as follows: cerium oxide, 3,629 t; cerium compounds (other than oxide), 5,581 t; ferrocerium, 59 t; lanthanum oxide, 1,860 t; rare-earth compounds, 5,294 t; rare-earth metals, 6,381 t; and yttrium oxide, 1,370 t (Roskill's Letter from Japan, 2005b). China continued to be the leading source of rare-earth imports for Japan with 24,174 t in 2004, an increase from the 22,743 t imported in 2003.

Japanese imports of rare-earth refined products in 2004 were 26,762 t classified as follows: cerium compounds (other than cerium oxide), 6,381 t; cerium oxide, 4,178 t; ferrocerium, 298 t; lanthanum oxide, 1,915 t; rare-earth compounds, 6,229 t; rare-earth metals, 6,384 t; and yttrium oxide (Roskill's Letter from Japan, 2005c).

Kenya.—Tiomin announced that it had signed a 21-year agreement with the Kenyan Government for exclusive mining rights to the Kwale heavy-mineral deposit. The deposit has reserves of 254 Mt of measured and indicated ore. Planned capacity of the plant is 37,000 t/yr of zircon concentrate and construction was expected to commence in the fourth quarter of 2005 (Tiomin Resources Inc., undated§). The project is expected to begin production in 2007. The Kwale deposit is one of four major heavy-mineral sand deposits that Tiomin has identified in the coastal region of Kenya. The Kilifi, Kwale, Mambrui, and Vipingo deposits are located 6 to 12 km inland from the Indian Ocean with road access in place.

Mozambique.—Kenmare Resources plc began construction of the Moma Titanium Minerals (MTM) Mine. Estimated to cost $450 million, the company broke ground on the project on October 18 (Kenmare Resources plc, 2004). Kenmare expects production from the mine to begin in late 2006. Reserves at the MTM project are 407 Mt of ore grading 4.3% heavy minerals (Kenmare Resources plc, undated§). Rare-earth minerals in the deposit are monazite and xenotime. The MTM project comprises three coastal zones of economic heavy minerals, the Moma, Congolone, and Mocambo deposits.

Russia.—The Silvinit joint-stock company has become the owner of the Lovozero mining and concentration operations, including the Karnasurt loparite mine at Revda, Kola Peninsula. Loparite from the Lovozero operation will be sent for processing to another of Silvinit's companies, the Solikamsk magnesium plant. The Karnasurt Mine is expected to return to production at mid-year 2005. Capacity is expected to be 800 metric tons per month (Karelin, 2005).

Senegal.—Mineral Deposits Limited (MDL) continued to study its Grande Côte Zircon Project (GCZP) on the northwestern coast of Senegal, south of Saint-Louis. Production is scheduled for late 2006. MDL is relocating one of its Australian dredges and a concentrator from its Viney Creek deposit and Hawks Nest dry mill to GCZP. MDL estimated dredgeable ore to be 800 Mt grading 2.6% heavy minerals (Mineral Deposits Limited, undated§).

South Africa.—Richards Bay Minerals was the second ranked company in the production of heavy minerals in the world in 2004 (Mineral Sands Report, 2005c).

Ticor South Africa [a mining venture between Kumba Resources Ltd. of South Africa (60%) and Ticor Limited (40%)] produced about 49,000 t of zircon in 2004 (Mineral Sands Report, 2005c). Zircon production was from Ticor's Hillendale Mine near Richards Bay in KwaZulu-Natal Province. Ticor continued to develop its nearby Fairbreeze deposit and initiated detailed site engineering for the project in July with completion scheduled for mid-2005 (Kumba Resources Ltd., 2005§). Concentrate from the site is to be treated at Ticor's existing dry mill separation plant at Empangeni. Production was scheduled for 2007.

Namakwa Sands Pty. Ltd. (a wholly owned subsidiary of Anglo American plc) was third ranked in the production of heavy-mineral sands in the world in 2004 from its mine at Brand se Baai (Minerals Sands Report, 2005c). At present production rates, Namakwa's mine has a remaining mine life of about 31 years.

Mineral Commodities Ltd. of Australia announced in September that it would initiate the three-stage mining right application for its Xolobeni mineral sands deposit in Eastern Cape Province. Mineral Commodities' application will encompass the preparation of a scoping report, an environmental impact assessment (EIA) and draft environmental plan, and finally a premining monitoring program at the site (Mineral Commodities Ltd., 2004). Xolobeni resource estimates are 313 Mt of heavy-mineral sands ore (Mineral Commodities Ltd., 2003§). Mineral Commodities also announced that it had applied for a prospecting permit in August for its Tormin mineral sands project. The company planned to prepare a limited scoping study and an EIA by November for the Tormin project (Mineral Commodities Ltd., 2004). A bench test of the deposit using a four-stage spiral concentrator produced a 98% heavy-mineral concentrate, containing 65% ilmenite, 16% nonmagnetics (includes rutile and zircon), 17% garnet, and 2% nonheavy minerals.

Outlook

Rare-earth use in automotive pollution control catalysts, permanent magnets, and rechargeable batteries is expected to continue to increase as future demand for conventional and hybrid automobiles, computers, electronics, and portable equipment grows. Rare-earth markets are expected to require greater amounts of higher purity mixed and separated products to meet the demand. Strong demand for cerium and neodymium for use in automotive catalytic converters and permanent magnets is expected to continue through 2010. Future growth is forecast for rare earths in rechargeable NiMH batteries (moderated by demand for lithium ion batteries), fiber optics, and medical applications that include dental and surgical lasers, magnetic resonance imaging, medical contrast agents, medical isotopes, and positron emission tomography scintillation detectors. Long-term growth is expected for rare earths in magnetic refrigeration alloys.

World reserves are sufficient to meet forecast world demand well into the 21st century. Several very large rare-earth deposits in Australia and China (for example Mianning in China and Mount Weld in Australia) have yet to be fully developed because world demand is currently being satisfied by existing production. World resources should be adequate to satisfy demand for the foreseeable future.

Domestic companies have shifted away from using naturally occurring radioactive rare-earth ores. This trend has had a negative impact on monazite-containing mineral-sands operations worldwide. Future long-term demand for monazite, however, is expected to increase because of its abundant supply and its recovery as a low-cost byproduct. In the future, thorium's use as a nonproliferative nuclear fuel is considered a likely replacement for uranium, especially in a world concerned with the threat of terrorism. As demand for thorium increases, monazite would resume its role as a leading source of rare earths. The cost and space requirements to dispose of radioactive waste products in the United States are expected to continue to increase, severely limiting domestic use of low-cost monazite and other thorium-bearing rare-earth ores.

Rare-earth producers worldwide are expected to continue to struggle in competition with China's lower wages, inexpensive utilities, and fewer environmental and permitting requirements. China is expected to remain the world's principal rare earth supplier. Economic growth in several developing countries will provide new and potentially large markets in India, Southeast Asia, and Eastern Europe.

The long-term outlook is for an increasingly competitive and diverse group of rare earth suppliers. As research and technology continue to advance the knowledge of rare earths and their interactions with other elements, the economic base of the rare earth industry is expected to continue to grow. New applications are expected to continue to be discovered and developed, especially in areas that are considered essential, such as energy and defense.

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TABLE 1

SALIENT U.S. RARE EARTH STATISTICS[1]

		2000	2001	2002	2003	2004
Production of rare-earth concentrates, rare-earth oxide (REO) basis[e, 2]	metric tons	W	W	W	--	--
Exports, REO basis:						
Cerium compounds	do.	3,950 r	4,120 r	2,740	1,910	2,280
Rare-earth metals, scandium, yttrium	do.	1,650	884 r	1,300 r	730	1,010
Rare-earth compounds, organic or inorganic	do.	1,650 r	1,600 r	1,340	1,790	4,800
Ferrocerium and pyrophoric alloys	do.	2,250 r	2,500 r	2,830	2,880	3,720
Imports for consumption, REO basis:[e]						
Cerium compounds	do.	4,310 r	3,850 r	2,540	2,430	1,880
Ferrocerium and pyrophoric alloys	do.	118	118	89	102	105
Metals, alloys, oxides, other compounds	do.	17,300	15,300 r	11,600	14,100 r	15,300
Prices, yearend:						
Bastnasite concentrate, REO basis[e]	dollars per kilogram	$5.51	$5.51	$5.51	$5.51	$5.51
Monazite concentrate, REO basis[e]	do.	$0.73	$0.73	$0.73	$0.73	$0.73
Mischmetal, metal basis	do.	$16.00 [3]	$16.00 [3]	$16.00 [3]	$10.00 [4]	$10.00 [4]

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company prorietary data. -- Zero.

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

[2]Includes only the rare earths derived from bastnasite as obtained from Molycorp, Inc.

[3]Source: Elements, TradeTech, Denver, CO.

[4]Source: Hefa Rare Earths Canada Co. Ltd., Vancouver, British Columbia, Canada.

TABLE 2

RARE EARTH CONTENTS OF MAJOR AND POTENTIAL SOURCE MINERALS[1]

(Percentage of total rare-earth oxide)

	Bastnäsite		Monazite			
Rare earth	Mountain Pass, CA, United States[2]	Bayan Obo, Inner Mongolia, China[3]	North Capel, Western Australia[4]	North Stradbroke Island, Queensland, Australia[5]	Green Cove Springs, FL, United States[6]	Nangang, Guangdong, China[7]
Cerium	49.10	50.00	46.00	45.80	43.70	42.70
Dysprosium	trace	0.1	0.7	0.60	0.9	0.8
Erbium	trace	trace	0.2	0.2	trace	0.3
Europium	0.1	0.2	0.053	0.8	0.16	0.1
Gadolinium	0.2	0.7	1.49	1.80	6.60	2.00
Holmium	trace	trace	0.053	0.1	0.11	0.12
Lanthanum	33.20	23.00	23.90	21.50	17.50	23.00
Lutetium	trace	trace	trace	0.01	trace	0.14
Neodymium	12.00	18.50	17.40	18.60	17.50	17.00
Praseodymium	4.34	6.20	5.00	5.30	5.00	4.10
Samarium	0.8	0.8	2.53	3.10	4.90	3.00
Terbium	trace	0.1	0.035	0.3	0.26	0.7
Thulium	trace	trace	trace	trace	trace	trace
Ytterbium	trace	trace	0.1	0.1	0.21	2.40
Yttrium	0.10	trace	2.40	2.50	3.20	2.40
Total	100	100	100	100	100	100

See footnotes at end of table.

TABLE 2—Continued

RARE EARTH CONTENTS OF MAJOR AND POTENTIAL SOURCE MINERALS[1]

(Percentage of total rare-earth oxide)

	Monazite—Continued		Xenotime		Rare earth laterite	
	Eastern coast, Brazil[8]	Mount Weld, Australia[9]	Lahat, Perak, Malaysia[2]	Southeast Guangdong, China[10]	Xunwu, Jiangxi Province, China[11]	Longnan, Jiangxi Province, China[11]
Cerium	47.00	51.00	3.13	3.00	2.40	0.4
Dysprosium	0.4	0.2	8.30	9.10	trace	6.70
Erbium	0.1	0.2	6.40	5.60	trace	4.90
Europium	0.1	0.4	trace	0.2	0.5	0.10
Gadolinium	1.00	1.00	3.50	5.00	3.00	6.90
Holmium	trace	0.1	2.00	2.60	trace	1.60
Lanthanum	24.00	26.00	1.24	1.20	43.4	1.82
Lutetium	not determined	trace	1.00	1.80	0.1	0.4
Neodymium	18.50	15.00	1.60	3.50	31.70	3.00
Praseodymium	4.50	4.00	0.5	0.6	9.00	0.7
Samarium	3.00	1.80	1.10	2.20	3.90	2.80
Terbium	0.1	0.1	0.9	1.20	trace	1.30
Thulium	trace	trace	1.10	1.30	trace	0.7
Ytterbium	0.02	0.1	6.80	6.00	0.3	2.50
Yttrium	1.40	trace	61.00	59.30	8.00	65.00
Total	100	100	100	100	100	100

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

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TABLE 3

RARE-EARTH OXIDE PRICES IN 2004

Product (oxide)	Purity (percentage)	Standard package quantity (kilograms)	Price (dollars per kilogram)	Product (oxide)	Purity (percentage)	Standard package quantity (kilograms)	Price (dollars per kilogram)
Cerium	96.00	25	19.20	Neodymium	95.00	20	28.50
Do.	99.50	900	31.50	Praseodymium	96.00	20	36.80
Dysprosium	99.00	3	120.00	Samarium	99.90	25	360.00
Erbium	96.00	2	155.00	Do.	99.99	25	435.00
Europium	99.99	1	990.00 [1]	Scandium	99.99	1	6,000.00
Gadolinium	99.99	3	130.00	Terbium	99.99	5	535.00
Holmium	99.90	10	440.00 [2]	Thulium	99.90	5	2,300.00
Lanthanum	99.99	25	23.00	Ytterbium	99.00	10	340.00
Lutetium	99.99	2	3,500.00	Yttrium	99.99	50	88.00

[1]Price for quantity greater than 40 kilograms is $900.00 per kilogram.

[2]Price for quantity less than 10 kilograms is $485.00 per kilogram.

Source: Rhodia Electronics & Catalysis, Inc.

TABLE 4

U.S. EXPORTS OF RARE EARTHS, BY COUNTRY[1]

Category[2] and country	2003 Gross weight (kilograms)	2003 Value	2004 Gross weight (kilograms)	2004 Value
Cerium compounds (2846.10.0000):				
Australia	1,680	$14,200	5,830	$7,090
Belgium	41,000	55,500	3,000	27,900
Brazil	50,900	263,000	55,700	311,000
Canada	46,200	336,000	47,800	270,000
France	12,500	224,000	8,390	74,500
Germany	318,000	1,050,000	168,000	832,000
Hong Kong	47,000	416,000	91,200	782,000
India	73,900	436,000	295,000	1,760,000
Japan	106,000	895,000	180,000	1,350,000
Korea, Republic of	104,000	466,000	342,000	1,130,000
Malaysia	126,000	465,000	80,200	252,000
Mexico	235,000	1,140,000	203,000	1,080,000
Netherlands	30,900	220,000	16,000	142,000
Singapore	20,300	118,000	10,600	63,300
South Africa	6,850	142,000	3,230	17,800
Taiwan	30,200	210,000	7,110	72,500
United Kingdom	123,000	566,000	38,700	375,000
Other	533,000	3,090,000	720,000	4,100,000
Total	1,910,000	10,100,000	2,280,000	12,600,000
Total estimated equivalent rare-earth oxide (REO) content	1,910,000	10,100,000	2,280,000	12,600,000
Rare-earth compounds[3] (2846.90.0000):				
Austria	47,900	1,190,000	17,000	454,000
Brazil	418,000	575,000	5,330	146,000
Canada	264,000	3,790,000	1,960,000	3,860,000
China	93,700	92,900	23,100	155,000
Colombia	3,780	9,120	2,840	18,400
Estonia	322,000	201,000	1,800,000	1,030,000
France	36,400	1,460,000	38,100	1,100,000
Germany	145,000	1,320,000	255,000	775,000
Hong Kong	25,600	648,000	29,000	661,000
India	1,980	22,500	3,520	17,200
Italy	5,050	40,500	29,900	600,000
Japan	32,300	7,410,000	80,200	3,850,000
Korea, Republic of	139,000	841,000	145,000	1,150,000
Mexico	20,500	157,000	23,800	160,000
Netherlands	95,300	335,000	12,400	830,000
Poland	--	--	34,600	1,230,000
Russia	--	--	45,800	35,200
Singapore	8,320	141,000	5,290	165,000
Taiwan	35,800	920,000	83,900	1,660,000
United Kingdom	8,200	182,000	29,800	482,000
Other	90,800 r	560,000 r	184,000	530,000
Total	1,790,000	19,900,000	4,800,000	18,900,000
Total estimated equivalent REO content	1,790,000	19,900,000	4,800,000	18,900,000
Rare-earth metals, including scandium and yttrium (2805.30.0000):				
China	6,660	223,000	105,000	1,610,000
France	72	7,990	402	24,300
Germany	1,220	66,200	4,040	214,000
Indonesia	17,500	21,000	159,000	218,000
Japan	550,000	2,170,000	559,000	3,380,000
Korea, Republic of	2,060	104,000	721	78,300
Taiwan	39	4,560	1,460	58,600

See footnotes at end of table.

TABLE 4—Continued

U.S. EXPORTS OF RARE EARTHS, BY COUNTRY[1]

Category[2] and country	2003 Gross weight (kilograms)	2003 Value	2004 Gross weight (kilograms)	2004 Value
Rare-earth metals, including scandium and yttrium (2805.30.0000)- continued:				
United Kingdom	158	20,700	131	31,000
Other	30,500 r	635,000 r	10,800	431,000
Total	609,000	3,250,000	840,000	6,050,000
Total estimated equivalent REO content	730,000	3,250,000	1,010,000	6,050,000
Ferrocerium and other pyrophoric alloys (3606.90.0000):				
Argentina	1,440	$61,700	1,130	$10,700
Australia	48,900	1,740,000	51,300	1,810,000
Brazil	1,440	61,700	--	--
Canada	704,000	3,270,000	654,000	2,560,000
Chile	2,140	27,400	5,460	54,200
China	68,400	93,700	82,800	39,000
Colombia	119	2,890	571	6,160
Egypt	37,500	36,400	115,000	106,000
France	11,400	112,000	56,900	181,000
Germany	957,000	1,300,000	1,110,000	5,780,000
Greece	57,000	108,000	57,100	65,400
Hong Kong	177,000	307,000	166,000	346,000
Israel	48,300	50,600	102,000	149,000
Italy	1,130	15,300	621	21,000
Japan	110,000	1,430,000	151,000	2,760,000
Korea, Republic of	2,150	55,900	1,090	69,300
Kuwait	82,300	71,500	97,000	77,500
Mexico	90,500	163,000	32,400	136,000
Netherlands	134,000	359,000	437,000	908,000
New Zealand	--	--	12,300	21,400
Saudi Arabia	50,000	61,900	83,900	128,000
Singapore	1,480	44,100	13,600	69,000
South Africa	246	6,620	311	7,950
Taiwan	986	64,500	6,820	44,600
Turkey	225	5,890	21,800	161,000
United Arab Emirates	207,000	203,000	259,000	237,000
United Kingdom	251,000	741,000	268,000	457,000
Other	200,000 r	337,000 r	397,000	634,000
Total	3,250,000	10,700,000	4,190,000	16,800,000
Total estimated equivalent REO content	2,880,000	10,700,000	3,720,000	16,800,000

[r]Revised. -- Zero.

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

[2]Harmonized Tariff Schedule of the United States category numbers.

[3]Inorganic and organic.

Source: U.S. Census Bureau.

TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF RARE EARTHS, BY COUNTRY[1]

	2003		2004	
Category[2] and country	Gross weight (kilograms)	Value	Gross weight (kilograms)	Value
Cerium compounds, including oxides, hydroxides, nitrates, sulfate chlorides, oxalates (2846.10.0000):				
Austria	166,000	$677,000	39,000	$371,000
China	3,050,000	7,170,000	2,260,000	4,450,000
France	155,000	2,390,000	190,000	2,500,000
Japan	174,000 r	4,290,000	270,000	5,050,000
Other	80,300	533,000	56,600	777,000
Total	3,630,000	15,100,000	2,820,000	13,200,000
Total estimated equivalent rare-earth oxide (REO) content	2,430,000	15,100,000	1,880,000	25,900,000
Yttrium compounds content by weight greater than 19% but less than 85% oxide equivalent (2846.90.4000):				
China	63,000	941,000	211,000	1,350,000
France	6,330	216,000	3,470	204,000
Japan	8,880	2,870,000	10,900	1,950,000
Other	8,330 r	308,000 r	462	16,700
Total	86,600	4,330,000	226,000	3,510,000
Total estimated equivalent REO content	51,900	4,330,000	136,000	3,510,000
Rare-earth compounds, including oxides, hydroxides, nitrates, other compounds except chlorides (2846.90.8000):				
Austria	76,700	2,690,000	91,300	3,230,000
China	8,210,000	21,000,000	11,100,000	29,400,000
Estonia	520,000	515,000	440,000	428,000
France	2,080,000	15,700,000	1,990,000	13,600,000
Germany	5,010	1,090,000	23,600	714,000
Hong Kong	13,100	241,000	24,600	382,000
Japan	536,000	5,460,000	789,000	9,640,000
Russia	1,020,000	1,860,000	672,000	1,220,000
United Kingdom	185,000	5,860,000	45,800	5,090,000
Other	129,000	1,080,000 r	25,200	349,000
Total	12,800,000	55,500,000	15,200,000	64,100,000
Total estimated equivalent REO content	9,580,000	55,500,000	11,400,000	64,100,000
Mixtures of REOs except cerium oxide (2846.90.2010):				
Austria	11,900	652,000	6,300	307,000
China	1,670,000	4,740,000	1,630,000	3,860,000
Germany	8,800	163,000	--	--
Japan	17,600	458,000	9,540	524,000
Russia	115	16,000	143	91,000
United Kingdom	1,600	12,000	12,900	84,300
Other	3,240	58,800	248	67,100
Total	1,710,000	6,100,000	1,660,000	4,930,000
Total estimated equivalent REO content	1,710,000	6,100,000	1,660,000	4,930,000
Rare-earth metals, whether intermixed or alloyed (2805.30.0000):				
Australia	8,670	814,000	--	--
Austria	461	44,100	5,350	115,000
China	539,000	2,270,000	632,000	2,780,000
Germany	1,000	8,910	2,000	24,500
Italy	2,000	10,400	5,900	30,100
Japan	176,000	1,600,000	13,200	216,000
Russia	1,040	150,000	1,010	119,000
United Kingdom	7,960	226,000	10,400	177,000
Other	125 r	13,100 r	233	36,400
Total	737,000	5,140,000	670,000	3,500,000
Total estimated equivalent REO content	884,000	5,140,000	804,000	3,500,000

See foonotes at end of table.

TABLE 5—Continued

U.S. IMPORTS FOR CONSUMPTION OF RARE EARTHS, BY COUNTRY[1]

Category[2] and country	2003 Gross weight (kilograms)	2003 Value	2004 Gross weight (kilograms)	2004 Value
Mixtures of rare-earth chlorides, except cerium chloride (2846.90.2050):				
Belgium	--	--	13,000	$122,000
China	3,910,000	$3,640,000	2,750,000	2,670,000
France	35,200	522,000	10,900	83,400
India	80,000	75,600	--	--
Israel	100,000	896,000	1,000	879,000
Japan	7,360	499,000	24,500	483,000
Korea, Republic of	1,220	102,000	37,800	2,140,000
Netherlands	5,130	62,900	15,000	83,100
Russia	47	105,000	1,140	222,000
United Kingdom	2,400	26,200	2,400	15,400
Other	1,670 r	280,000 r	259	165,000
Total	4,150,000	6,210,000	2,850,000	6,870,000
Total estimated equivalent REO content	1,910,000	6,210,000	1,310,000	6,870,000
Ferrocerium and other pyrophoric alloys (3606.90.3000):				
Austria	20,300	396,000	18,800	402,000
Belgium	--	--	2,300	39,200
France	93,600	1,230,000	97,100	1,330,000
Japan	261	6,390	211	5,430
Netherlands	543	23,200	--	--
Total	115,000	1,650,000	118,000	1,770,000
Total estimated equivalent REO content	102,000	1,650,000	105,000	1,770,000

-- Zero.

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

[2]Harmonized Tariff Schedule of the United States category numbers.

Source: U.S. Census Bureau.

TABLE 6

RARE EARTHS: ESTIMATED WORLD MINE PRODUCTION, BY COUNTRY[1, 2]

(Metric tons of rare earth oxide equivalent)

Country[3]	2000	2001	2002	2003	2004
China	73,000	80,600	88,000	92,000	98,000
Commonwealth of Independent States[4]	NA r	NA r	NA r	NA r	NA
India	2,700	2,700	2,700	2,700	2,700
Kyrgyzstan:					
Compounds	6,800 r	NA	NA	NA	NA
Metals	7,736 5	3,800	100	NA	NA
Other	2,000	2,000	2,000	2,000	NA
Malaysia	446 5	351 5	240	360 r	250
United States[6]	W	W	W	--	--
Total	92,700 r	89,500	93,000	97,100 r	101,000

[r]Revised. NA Not available. 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]Table includes data available through June 13, 2005.

[3]In addition to the countries listed, rare-earth minerals are believed to be produced in some Commonwealth of Independent States countries besides Kyrgyzstan, and in Indonesia, Nigeria, North Korea, and Vietnam, but information is inadequate for formulation of reliable estimates of output levels.

[4]Does not include Kyrgyzstan; information is inadequate for formulation of reliable estimates for individual producing countries, including Kazakhstan, Russia, and Ukraine.

[5]Reported figure.

[6]Comprises only rare earths derived from bastnaesite.

FIGURE 1
PRINCIPAL SOURCES, BY WEIGHT, OF U.S. IMPORTS OF RARE EARTHS IN 2004