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RARE EARTHS [ADVANCE RELEASE]

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Rare Earths

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In 2008, world rare-earth production was primarily from the mineral bastnäsite. Rare earths were not mined in the United States in 2008. Rare-earth ores were primarily mined by China, with smaller amounts mined in India, Brazil, and Russia, listed in order of decreasing production.

Throughout 2008, processing of intermediate rare-earth concentrates took place at the Mountain Pass Mine in California. On September 30, privately held Molycorp Minerals LLC acquired the Mountain Pass rare-earth facility in California from Chevron Mining Inc. Rare-earth consumption was estimated to have decreased in 2008. With the exception of a slight increase of imports and a moderate increase of exports for ferrocerium and other pyrophoric alloys, all other trade categories of rare earths declined (table 1).

Domestic use of scandium decreased in 2008 and overall consumption 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.

Based on import data from the Port Import Export Reporting Service (PIERS) database of Commonwealth Business Media, Inc. (undated), domestic yttrium consumption decreased by 8.9% in 2008 compared with that of 2007. Yttrium was used primarily in fluorescent lamp and cathode-ray tube (CRT) phosphors; lesser amounts were used in structural ceramics and oxygen sensors.

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 (REE) 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.

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 (average concentration in the Earth's crust 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, atomic number 21, is the lightest REE. It is the 31st most abundant element in the Earth's crust, with an average crustal abundance of 22 ppm. 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, atomic number 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 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 ores of the rare earths are the minerals bastnäsite, loparite, and monazite and the lateritic ion-adsorption clays (table 2).

Production

In 2008, the Mountain Pass operation of Molycorp Minerals LLC (formerly Chevron Mining) remained open, although it did not actively mine rare earths. The company processed holdings of lanthanum-rich feedstock contained on site. Production was in the form of lanthanum-rich hydrates and neodymium-praseodymium oxides, which are precipitated as carbonates and then oxalates and finally calcined to oxide form.

Two companies processed intermediate rare-earth compounds to lanthanides in 2008. 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 refining industry. The company also processed zirconia-stabilized ceria compounds for supports for automotive catalysts, fluid catalytic cracking additives, and oxidation of organic compounds in wastewater, and produced several grades of Vitrox and Rareox cerium oxide polishing compounds. Grace Davison's Refining Technologies operating segment's sales were up 13.2% and 13.0% in 2008 and 2007, respectively (Wikinvest, 2009).

Santoku America, Inc. (a subsidiary of Santoku Corporation of Japan) produced rare-earth metals and magnet alloys at its operations in Tolleson, AZ. Santoku America produced two types of alloys used in high-strength permanent magnets—neodymium-iron-boron (NIB) and samarium-cobalt (SmCo)—and was the sole domestic producer of NIB magnet alloys. The plant also produced a full range of high-purity rare-earth metals, including scandium and yttrium, in cast and distilled forms, as foils, and as sputtering targets.

The only U.S. producer of rare-earth permanent magnets was Electron Energy Corp. (EEC) of Landisville, PA. EEC produced SmCo permanent magnets and designed and manufactured magnet assemblies, including actuators, Halbach arrays (magnetic field focusing assemblies), high-speed rotors, and other components.

One scandium processor operated in 2008. Aldrich-APL, LLC in Urbana, IL, purified and processed imported oxides to produce high-purity scandium compounds, including anhydrous and hydrous chloride, fluoride, iodide, and oxide. The company also produced high-purity scandium metal. High-purity products were available in various grades, with scandium oxide having up to 99.999% purity.

Boulder Scientific Co. had scandium facilities on standby at its Mead, CO, operations. Boulder Scientific previously refined scandium primarily from imported oxides and domestic ores to produce high-purity scandium compounds, including carbide, chloride, diboride, fluoride, hydride, nitride, oxalate, and tungstate.

All domestic, commercially produced, purified yttrium products were derived from imported compounds. The principal source was China.

Updated information on mineral reserves and resources of the United States on a regional basis is summarized for Alaska and Utah. Information for Colorado, Idaho, Missouri, Montana, and Wyoming can be found in the 2007 Rare Earths chapter of the U.S. Geological Survey Minerals Yearbook, volume I, Metals and Minerals.

Alaska.—Ucore Uranium Inc. announced the results of pre-drill program surface sampling at the Bokan-Dotson Ridge Rare Earth project in southeast Alaska. Dotson Ridge comprises a southeast-trending structural corridor of multiple rare-earth prospects radial to the southeast margin of the Bokan Mountain peralkaline intrusive complex. The sampling has shown evidence of unusually high concentrations of heavy rare-earth oxides (HREO) to as high as 17% and total rare-earth oxides (TREO) as high as 18%. By Ucore Rare Metals Inc. convention, light rare-earth oxides (LREO) equal oxides for the elements: lanthanum, cerium, praseodymium, neodymium, and samarium. HREO equal oxides for the elements: europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium, and yttrium. TREO equals LREO plus HREO. A drilling program was started at Bokan-Dotson Ridge with a target of 2,000 linear meters of which more than 900 meters was completed (Trading Markets, 2009).

Utah.—Great Western Minerals Group Ltd. (GWMG), of Saskatoon, Saskatchewan, Canada, had a 25% interest and exclusive rights to explore for REEs in the Deep Creek rare-earth-bearing mineral sands deposit in Juab County, Utah. The property covered 17,094 hectares near the community of Callao and was adjacent to power, rail, and roads (Great Western Minerals Group Ltd., 2007). The drilling program at Deep Sands moved toward the objective of completing an NI 43-101-compliant resource estimate, with two drill rigs deployed on this program scheduled for completion by August 2008 (Mining Top News, 2008). GWMG, in its Mine-to-Market business strategy to become a fully integrated global supplier of rare-earth elements and other strategic metals products, acquired Less Common Metals in June 2008 (Yahoo Finance, 2009).

Consumption

Data 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 decreased in 2008 compared with that of 2007.

In 2008, yttrium consumption was estimated to have decreased to 616 metric tons (t) from 676 t in 2007**.** Yttrium information was based on data retrieved from the Port Import Export Reporting Service database. Yttrium compounds and metal were imported from the following sources in 2008: China (85%), Austria (8%), Japan (1%), Hong Kong (2%), and other (4%). The estimated use of yttrium, based on imports, was primarily in fluorescent lamp and CRT phosphors, ceramics, and specialty alloys with a minor amount for metal casting (Commonwealth Business Media, Inc., undated).

Stocks

The last of the U.S. Government stocks of rare earths in the National Defense Stockpile (NDS) was 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 most rare-earth materials, as provided by Rhodia Group of France quoted REO prices, net 30 days, f.o.b. New Brunswick, NJ, or duty paid at point of entry, in effect at yearend 2008, remained the same in 2008 compared with those of 2007 (table 3). All rare-earth prices remained nominal and subject to change without notice. The competitive pricing policies that are in effect for the industry result in most rare-earth product prices being quoted on a daily basis from the producers and processors. Domestic prices were higher than Chinese prices because of shipping costs related to its classification as a pyrophoric hazardous material. Prices for monazite remained depressed from their historical levels because the principal international rare-earth processors continued to process only thorium-free feed materials.

No published prices were available for scandium. Prices in 2008 were estimated to be higher for the high-purity oxides and mid- to ultrahigh-purity oxides than the prices for those materials in 2007.

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 price.

In the following discussion, where necessary, values have been converted from the Chinese Yuan Renminbi to U.S. dollars at exchange rates for the date of posting of each reference cited concerning those nominal values. In China, because of the reputed tight supply of rare-earth raw materials in 2008, prices of rare-earth carbonates remained relatively stable at $1,900 to $2,660 per metric ton (China Rare Earth Information, 2009e). In 2008, the price of neodymium oxide dropped from the highest level of $31 per kilogram at the beginning of 2008 to the lowest point of $9.5 per kilogram in December, down 69%. The price of praseodymium oxide fell from $27 per kilogram to $9.2 per kilogram, down 66%. The price of didymium (a mixture of the rare-earth elements praseodymium and neodymium) oxide dropped from $26 per kilogram to $7.0 per kilogram, down 73%. The price of neodymium metal decreased from $40 per kilogram to $13 per kilogram, down 67%. The price of praseodymium metal slipped from $34 per kilogram to $14 per kilogram, down 59%, and the price of didymium metal dropped from $34 per kilogram to $11 per kilogram, down 68%. In general, prices fell the most in December (China Rare Earth Information, 2009f).

For dysprosium metal, oxide, and dysprosium-iron (DyFe) alloy, at the beginning of January, prices rose from $88 per kilogram, $120 per kilogram, and $94 per kilogram to highs of $99 per kilogram, $135 per kilogram, and $107 per kilogram, respectively, in April. Prices for these materials fell later in the year, and reached lows of $67 per kilogram, $107 per kilogram, and $76 per kilogram for dysprosium metal, oxide, and DyFe alloy, respectively, in December, down 32%, 21%, and 29% (China Rare Earth Information, 2009f).

The price of terbium in China slid downward throughout 2008, from a November high for terbium oxide and terbium metal of $600 to $630 per kilogram and $740 to $760 per kilogram, respectively, to the low point of $260 to $340 per kilogram and $340 to $470 per kilogram, respectively, in December. The largest price drop was 58% and 54%, respectively, within the year (China Rare Earth Information, 2009f).

Foreign Trade

U.S. exports of rare earths increased and imports decreased with regard to quantity in 2008 compared with those of 2007. Data in this section are based on gross weight, while data in the tables may be converted to equivalent rare-earth oxide (REO) content, as specified. U.S. exports totaled 8,260 t valued at $59.6 million, approximately a 9% increase in quantity and a 3% decrease in value compared with those of 2007 (table 4). Imports totaled 20,700 t, gross weight, valued at $186 million, an almost 14% decrease in quantity and a 46% increase in value compared with those of 2007 (table 5).

In 2008, U.S. exports of rare earths decreased in quantity in three out of four trade categories. The United States exported 1,160 t of rare-earth metals valued at $18.6 million, a 6% decrease in quantity and an 8% decrease in value compared with that of 2007. Exports of cerium compounds, primarily for glass polishing and automotive catalytic converters, decreased in quantity by 6% to 1,380 t and increased in value by 10% to $12.2 million.

Exports of inorganic and organic rare-earth compounds decreased by 49% to 663 t in 2008 from 1,300 t in 2007, and the value of the shipments decreased 45% to $7.6 million from $13.8 million.

U.S. exports of ferrocerium and other pyrophoric alloys increased 40% to 5,050 t valued at $21.2 million in 2008 from 3,620 t valued at $16.2 million in 2007.

Mischmetal and specialty mischmetals comprised most of the U.S. rare-earth metal imports. (Mischmetal is a natural mixture of rare-earth metals typically produced by metallothermic reduction of a mixed rare-earth chloride).

In 2008, U.S. imports of compounds and alloys decreased in quantity for six out of the seven categories listed in table 5. China dominated the import market, especially for mixed and individual rare-earth compounds, except for the category of ferrocerium and other pyrophoric alloys where France dominated. In decreasing order of import quantity, the leading supply countries were China, France, Japan, Austria, and Russia (figure 1). These five countries accounted for 99% of the domestic imports.

Imports of cerium compounds totaled 3,100 t valued at $12.8 million. The quantity of cerium compounds imported decreased by 23% as a result of a decreasing demand for automotive exhaust catalysts, and the value increased by 6%. China was the major supplier for the 13th consecutive year, followed by France, Japan, Austria, and the United Kingdom.

Imports of yttrium compounds that contained between 19 and 85 weight-percent yttrium (yttrium concentrate) decreased by 54% to 16.5 t in 2008, and the value increased by 263% to $6.8 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, decreased by 12% compared with those of 2007. Rare-earth compound imports decreased to 11,600 t valued at $119 million, an increase in value of 54%. The major sources of individual rare-earth compounds, in decreasing order by quantity, were China, France, Japan, Hong Kong, Russia, Austria, and South Africa.

In 2008, imports of mixtures of REOs, other than cerium oxide, decreased in quantity by 7% to 2,390 t in 2008 from 2,570 t in 2007, and increased in value 51% to $22.6 million. The principal source of the mixed REOs was China, with much smaller quantities, in decreasing order of tonnage, imported from Italy, Japan, and others.

Imports of rare-earth metals and alloys into the United States totaled 566 t valued at about $4.9 million in 2008, a 13% decrease in quantity compared with that of 2007. The value also decreased 24% from that of the previous year. The principal rare-earth metal source was China, with much smaller amounts, in decreasing order of tonnage, from Japan, the United Kingdom, Russia, and Austria.

In 2008, imports of rare-earth chlorides decreased by 19% to 2,850 t, but the value increased 51% to $17.6 million. Supplies of rare-earth chloride, in descending order by quantity, came from China, with minor amounts from Hong Kong, Taiwan, Germany, Japan, the United Kingdom, and the Republic of Korea. 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 slightly in quantity to 141 t valued at US$2.4 million from 139 t valued at $2.3 million in 2007. Principal sources of these alloys, in descending order by quantity, were France, Austria, and China.

World Review

Global 2008 outputs of sintered NIB magnets and bonded magnets were 63,580 t and 5,400 t, respectively, in 2008, totaling 68,980 t. This represented 92.2% and 7.8% each of the total production volume. Total output value of the two types of magnets amounted to $3.86 billion, of which sintered magnets reached $3.46 billion, representing 89.1% and bonded magnets achieved $421 million, representing 10.9% (China Rare Earth Information, 2009c).

According to China's National Rare Earth Office statistics, output proportions of NIB magnets (including sintered and bonded magnets) by China, Japan, the United States, Europe, and other countries were 6.2%, 20.9%, 0.3%, 1.4%, and 1.2%, respectively. The United States completely ceased production of sintered NIB by the end of 2003. There was a small production of bonded magnets in 2008. Output value of NIB magnets totaled $3.86 billion in 2008, of which $2.24 billion was contributed by China, $1.39 billion by Japan, $154 million by Europe and the United States, and $84 million by other countries. China represented 58% of the total output value, Japan 36%, Europe and the United States 4%, and other countries 2% (China Rare Earth Information, 2009c).

Australia.—Lynas Corporation Ltd. (Sydney) commenced mining in July at its Mount Weld rare-earth deposit in Western Australia (Lynas Corporation Ltd., 2008, p. 10). The company reported approximate market capitalization of $130 million as of January 2009 with a measured resource of 2.21 million metric tons (Mt) at a grade of 14.7% REO (324,000 t of contained REO) along with an indicated resource of 3.84 Mt tons at a grade of 11.5% REO (441,000 t of contained REO) at a 2.5% REO cut-off (Lynas Corporation, 2009).

Alkane Resources Ltd. planned to mine three principal products from its Dubbo Zirconia Project in New South Wales. These products include a range of zirconium products, a niobium-tantalum concentrate, and an yttrium-rare earth concentrate. Alkane expected about 50% of the DZP's revenue to come from the range of zirconium products, 40% to 45% from the niobium-tantalum concentrate, and 5% to 10% from the yttrium-rare earth concentrate. Construction of a pilot plant to produce the three concentrates commenced in late 2007 at Lucas Heights, New South Wales, with completion expected in 2008 (Alkane Resources Ltd., 2008).

Arafura Resources Ltd. continued to develop its Nolans rare earth-phosphate deposit in the Northern Territory. The Nolans deposit is located 135 kilometers north-northwest of Alice Springs, which has the infrastructure to support a mining operation with a gas pipeline, rail access, roads, and provisions. Measured resources of the project are 5.1 Mt grading 3.2% REO, 13.5% phosphate, and 0.57% uranium oxide. Indicated resources at Nolans are 12.3 Mt grading 2.8% REO, 13.4% phosphate, and 0.43% uranium oxide (Arafura Resources Ltd., 2008).

Canada.—Rare-earth exploration and drilling was ongoing at several deposits in the Northwest Territories and Saskatchewan.

Avalon Ventures Ltd's. Thor Lake project is a multielement mineral deposit located near Yellowknife in the Northwest Territories. In 2008, the summer drilling program on the Lake Zone REE deposit concluded, bringing the cumulative totals since drilling commenced in 2007 to 16,640 meters in 85 drill holes. The new results confirmed that the content of HREO as a percentage of TREO in the Basal Zone typically ranges from 15% to 30%. This is the higher grade subzone of the mineralized envelope (Avalon Ventures Ltd., 2008).

Rare-earth minerals at Thor Lake include allanite, bastnäsite, fergusonite, xenotime, and lesser amounts of monazite, parasite, and synchysite. Fergusonite, a rare-earth-iron-tantalum-niobium-titanate mineral, was analyzed for its REO content and was found to contain 29.05% yttrium, 15.6% neodymium, 14.3% gadolinium, 10.4% samarium, 9.80% dysprosium, 4.40% cerium, 4.40% ytterbium, 4.10% erbium, 1.80% terbium, 1.70% praseodymium,1.60% europium, 1.20% holmium, 0.70% lutetium, 0.70% thulium, and 0.30% lanthanum (Avalon Ventures Ltd., 2007).

Great Western Minerals Group reported a new NI 43–101-compliant resource estimate for Hoidas Lake in Saskatchewan, completed by Barr Engineering Company. The company reported that the overall resource estimate increased by 123% to 2.56 Mt from the previous value of 1.15 Mt. This included an increase of more than 1,200% in the measured category to 963,800 t from the previous estimate of 80,000 t, and an increase of 49% in the indicated category to 1.60 Mt from the previous estimate of 1.07 Mt (Yahoo Finance, 2009).

China.—Mine production was primarily from bastnäsite and other rare-earth minerals mined in Inner Mongolia and bastnäsite from Sichuan Province, while ion adsorption ore was produced primarily in the southeastern Provinces of Jiangxi, Guangdong, and Fujian (Grauch and Mariano, 2008).

About one-third of all rare earths produced in China are consumed by the iron and steel industries. Principal products were rare earth-ferrosilicon (rare-earth silicide) and rare earth-magnesium-ferrosilicon, which consumed 25,000 t of equivalent REO. Production in 2006, the latest available, was 180,000 t of rare-earth magnesium silicon alloy and 50,000 t of rare-earth silicide (gross weight). Rare-earth silicide production was located in various areas of China, including Inner Mongolia Autonomous Region, 22,000 t; Sichuan Province, 14,000 t; Shanxi Province, 5,000 t; Henan Province, 4,000 t; and other provinces, 5,000 t (China Rare Earth Information, 2009d).

In 2007, the year of the latest available data, China produced 4,490 t of REO in phosphors for application in electroluminescent phosphors, flat panel displays, fluorescent lighting, long-afterglow phosphors, and various other uses. In 2007, rare-earth phosphors represented 6.2% of total rare-earth consumption (China Rare Earth Information, 2009a).

In 2008, it was reported that rare-earth raw materials were in tight supply in China (China Rare Earth Information, 2009e). Chinese supply of dysprosium and terbium products decreased in 2008, which resulted in higher prices (China Rare Earth Information, 2009f). Exports of DyFe declined owing to the global financial downturn. There was a sharp drop in production of NIB magnets followed by a decline in demand for dysprosium products (China Rare Earth Information, 2009f). Dysprosium is consumed as an alloying agent in the manufacture of NIB magnets.

With the onset of 2008, there was a downward trend in the price of terbium correlated with a sluggish market for many of the rare earths throughout 2008 (China Rare Earth Information, 2009f).

From the statistics of China's National Rare Earth Office, total industrial output value was $3.589 billion and sales income was $3.696 billion in the Chinese rare-earth industry for 2008, which was down 14.72% and 10.33%, respectively, from that of 2007. At yearend 2008, Baotou Steel Rare-Earth (Group) Hi-tech Co., Ltd. was the largest light rare-earth producer in China, with the production capacity of 250,000 t of rare-earth concentrate (50% REO), 60,000 t of separated rare-earth oxides, 10,000 t of rare-earth metals, 5,000 t of magnetic materials, 3,000 t of hydrogen storage materials, 3,000 t of polishing materials, and 120 t of fluorescent-grade europium oxide. In 2008, Baotou Steel produced 53,997 t rare-earth oxides (REO) of different rare-earth products, up 44% from that of 2007, and achieved the sales income of $471.9 million, up 29% compared with that of 2007. From the statistics reported by State Development and Reform Committee, output of rare-earth permanent magnets was 49,300 t in 2008, including 46,000 t of sintered NIB magnets, 2,800 t of bonded NIB magnets, and 500 t of SmCo magnets (China Rare Earth Information, 2009b).

France.—Rhodia was organized into seven enterprises with the rare-earth unit, Rhodia Electronics and Catalysis, and the performance silica unit, Rhodia Silica Systems, under Rhodia Silcea. Rhodia also produced rare-earth-containing catalysts for automotive emission applications; fluid-cracking catalysts for oil refining, desulfurization catalysts, styrene monomer catalysts, chemical catalysts for oxidation, dehydrogenation, and hydrogenation; and polymerization catalysts to promote the drying of paints and produce environmentally friendly tires. Rhodia's other operations produced finished rare-earth products from imported materials at its plant in Freeport, TX, and produced high-purity rare earths at its separation plant in La Rochelle. Additional rare-earth capacity was operated through Anan Kasei in Kobe, Japan.

Japan.—There were three Japanese NIB alloy producers, one of which used neodymium exclusively, and the other two used didymium and a mixture of mostly neodymium and praseodymium.

Japan produced rare earths from imported ores and intermediate raw materials. Japanese imports of rare earths in 2007, the latest year for which data were available, were as follows: rare-earth metals, 9,320 t; cerium oxide, 11,012 t; cerium compounds other than cerium oxide, 8,015 t; rare-earth compounds, 6,261 t; lanthanum oxide, 3,310 t; and yttrium oxide, 1,805 t. China continued to be the leading source of rare-earth imports for Japan. Japanese imports of rare earths from China were as follows: rare-earth metals, 9,296 t; cerium oxide, 9,580 t; cerium compounds other than cerium oxide, 6,373 t; rare-earth compounds, 5,703 t; lanthanum oxide, 3,110 t; and yttrium oxide, 1,720 t (Roskill's Letter from Japan, 2008).

Outlook

Rare-earth use in automotive pollution control catalysts, permanent magnets, and rechargeable batteries are 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. Demand for cerium and neodymium for use in automotive catalytic converters and catalysts for petroleum refining was expected to expand by 6% to 8% per year for the next 5 years if the world economy remains strong. Rare-earth magnet demand was expected to increase by 10% to 16% per year through 2012, increasing to 45,000 t to 50,000 t by 2012 (Kingsnorth, 2008). Future growth was expected for rare earths in rechargeable NiMH batteries, especially those used in hybrid vehicles, increasing to 10,000 t to 20,000 t REO by 2012. NiMH demand was also expected to increase (moderated by increasing demand for lithium-ion batteries) with increased use in portable equipment, such as camcorders, cellular telephones, compact disk players, digital cameras, digital video disk players, laptop computers, and MPEG audio-layer-3 players. Increased rare-earth use was expected in fiber optics, medical applications that include dental and surgical lasers, magnetic resonance imaging, medical contrast agents, medical isotopes, and positron emission tomography scintillation detectors. Future growth potential was projected for rare-earth alloys employed in magnetic refrigeration (Gschneidner and Pecharsky, 2008).

World reserves are sufficient to meet forecast world consumption 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. Existing production is currently not sufficient to meet world demand, and shortages exist for neodymium and dysprosium for magnet alloys and europium and terbium for phosphors. Although the Mountain Pass deposit in the United States contains sufficient resources to meet domestic demand for light-group REEs, the deposit does not contain sufficient heavy-group REEs to meet demand for those elements.

All domestic and most foreign companies have shifted away from using naturally occurring radioactive rare-earth ores. This trend has a negative impact on monazite-containing mineral sands operations worldwide, causing mine closures and reduced revenues. Long-term demand for monazite, however, is expected to increase because of the mineral's abundant supply and low-cost byproduct recovery. Thorium's use as a nonproliferative nuclear fuel is considered a likely substitute for uranium in the future, especially in a world concerned with the threat of nuclear terrorism. If consumption of thorium increases, monazite could resume its role as a major source of rare earths. Storage requirements and permits to dispose of radioactive waste products in the United States are expensive, however, severely limiting domestic use of low-cost monazite and other thorium-bearing rare-earth ores.

Rare-earth producers outside of China, generating less than 5% of the world's supply, were in competition with China's lower wages, inexpensive utilities, and less restrictive environmental and permitting requirements. China was expected to remain a major world rare-earth supplier. Increasing prices, export limits, rising demand within China, and a ban on new mining permits in China were expected to make rare-earth deposits outside of China more economic. Economic growth in several developing countries could provide new and potentially large markets for rare earths in Eastern Europe, India, and Southeast Asia.

The long-term outlook appears to be 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 increase. 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]

		2004	2005	2006	2007	2008
Production of rare-earth concentrates, rare-earth oxide (REO) basis[e, 2]	metric tons	--	--	--	--	--
Exports, REO basis:						
Cerium compounds	do.	2,280	2,220	2,010	1,470	1,380
Rare-earth metals, scandium, yttrium	do.	1,010	636	611	1,470 r	1,390
Rare-earth compounds, organic or inorganic	do.	4,800	2,070	2,700	1,300	663
Ferrocerium and pyrophoric alloys	do.	3,720	4,320	3,710	3,210	4,490
Imports for consumption, REO basis:[e]						
Cerium compounds	do.	1,880	2,170	2,590	2,680	2,080
Ferrocerium and pyrophoric alloys	do.	105	130	127	123	125
Metals, alloys, oxides, other compounds	do.	15,300	13,000	16,000	15,000 r	13,200
Prices, yearend:						
Bastnäsite concentrate, REO basis[e]	dollars per kilogram	5.51	5.51	6.06	6.61	8.82
Monazite concentrate, REO basis[e]	do.	0.73	0.73	0.73	0.73	0.48
Mischmetal, metal basis[3]	do.	5.00–6.00 r	5.00–6.00 r	5.00–6.00 r	7.00–8.00 r	10.00

do. Ditto. [e]Estimated. [r]Revised. -- Zero.

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

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

[3]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)

Rare earth	Bastnäsite: Mountain Pass, CA, United States[2]	Bastnäsite: Bayan Obo, Inner Mongolia, China[3]	Monazite: North Capel, Western Australia[4]	Monazite: North Stradbroke Island, Queensland, Australia[5]	Monazite: Green Cove Springs, FL, United States[6]	Monazite: 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
	Monazite—Continued: Eastern coast, Brazil[8]	**Monazite—Continued: Mount Weld, Australia[9]**	**Xenotime: Lahat, Perak, Malaysia[2]**	**Xenotime: Southeast Guangdong, China[10]**	**Rare earth laterite: Xunwu, Jiangxi Province, China[11]**	**Rare earth laterite: 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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[6]Analysis from RGC Minerals (USA), Green Cove Springs, FL.

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TABLE 3
RARE-EARTH OXIDE PRICES IN 2008

Product (oxide)	Purity (percentage)	Standard package quantity (kilograms)	Price (dollars per kilogram)
Cerium	96.00	20	50.00
Do.	99.50	20	65.00
Dysprosium	99.00	20	160.00
Erbium	96.00	20	165.00
Europium	99.99	20	1,200.00
Gadolinium	99.99	20	150.00
Holmium	99.90	10	750.00
Lanthanum	99.99	20	40.00
Lutetium	99.99	1 or 10	3,500.00
Neodymium	95.00	20	60.00
Praseodymium	96.00	20	75.00
Samarium	99.90	20	200.00
Do.	99.99	20	350.00
Scandium	99.99	NA	NA
Terbium	99.99	20	850.00
Thulium	99.90	5	2,500.00
Ytterbium	99.00	10	450.00
Yttrium	99.99	20	50.00

Do. Ditto. NA Not available.

Source: Rhodia Electronics & Catalysis, Inc.

TABLE 4

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

Category[2] and country	2007 Gross weight (kilograms)	2007 Value	2008 Gross weight (kilograms)	2008 Value
Cerium compounds (2846.10.0000):				
Australia	137	$12,000	--	--
Austria	104,000	687,000	104,000	$708,000
Belgium	1,970	31,100	1,950	28,300
Brazil	60,900	266,000	8,690	65,800
Canada	10,400	152,000	15,300	149,000
China	95,500	918,000	72,400	893,000
Egypt	252,000	882,000	116,000	606,000
France	30,800	271,000	18,100	169,000
Germany	34,900	294,000	120,000	1,040,000
Hong Kong	52,300	521,000	20,200	251,000
India	82,600	490,000	41,700	292,000
Japan	220,000	1,920,000	226,000	1,850,000
Korea, Republic of	3,520	45,500	248,000	288,000
Mexico	152,000	749,000	82,200	423,000
Netherlands	94,900	579,000	48,800	337,000
Singapore	4,440	31,100	--	--
Taiwan	24,600	195,000	77,900	3,290,000
United Kingdom	103,000	888,000	14,500	179,000
Other	139,000	2,200,000	168,000	1,640,000
Total	1,470,000	11,100,000	1,380,000	12,200,000
Total estimated equivalent rare-earth oxide (REO) content	1,470,000	11,100,000	1,380,000	12,200,000
Rare-earth compounds[3] (2846.90.0000):				
Argentina	82	4,140	40	10,000
Austria	--	--	2	12,000
Brazil	40,500	308,000	59,800	258,000
Canada	114,000	689,000	48,200	773,000
China	82,000	880,000	134,000	311,000
Colombia	16,000	47,300	17,100	35,900
Estonia	179,000	154,000	--	--
France	28,000	670,000	50,600	1,340,000
Germany	8,280	446,000	11,700	525,000
Guatemala	160	5,270	2,000	4,910
Hong Kong	19	37,400	10	6,000
India	334	14,600	4,960	47,900
Italy	7,490	34,000	9,730	86,100
Japan	163,000	6,590,000	27,400	1,030,000
Korea, Republic of	119,000	731,000	164,000	857,000
Mexico	269,000	1,510,000	40,800	850,000
Netherlands	1,620	31,400	17,000	197,000
Poland	--	--	309	37,900
Singapore	2,990	68,900	3,880	72,500
Taiwan	15,700	461,000	3,060	246,000
United Kingdom	130,000	612,000	32,600	381,000
Other	119,000	521,000	35,500	530,000
Total	1,300,000	13,800,000	663,000	7,610,000
Total estimated equivalent REO content	1,300,000	13,800,000	663,000	7,610,000

See Footnotes at end of table.

TABLE 4—Continued

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

Category[2] and country	2007 Gross weight (kilograms)	2007 Value	2008 Gross weight (kilograms)	2008 Value
Rare-earth metals, including scandium and yttrium (2805.30.0000):				
Belgium	6,350	$253,000	4,850	$193,000
Brazil	100	15,500	86	64,600
China	127,000	2,100,000	114,000	1,630,000
Germany	21,000	432,000	50,000	398,000
Hong Kong	104,000	250,000	3	5,000
India	7,460	315,000	5,020	285,000
Japan	665,000	10,200,000	479,000	11,400,000
Mexico	1,510	75,200	297	132,000
Switzerland	25	17,000	20	8,600
Taiwan	98,500	2,610,000	40,000	502,000
Other	194,000	3,900,000	465,000	4,010,000
Total	1,230,000	20,200,000	1,160,000	18,600,000
Total estimated equivalent REO content	1,470,000	20,200,000	1,390,000	18,600,000
Ferrocerium and other pyrophoric alloys (3606.90.0000):				
Argentina	60,000	216,000	13,400	74,300
Australia	562	26,300	73,000	167,000
Bahrain	25,100	26,800	--	--
Canada	689,000	2,220,000	667,000	2,470,000
China	462,000	4,490,000	675,000	6,050,000
Egypt	126,000	126,000	29,000	42,600
France	78,100	189,000	48,600	111,000
Germany	649,000	950,000	12	7,040
Greece	44,200	73,400	633	21,600
Hong Kong	127,000	257,000	19,000	439,000
Israel	75,900	559,000	29,400	48,100
Japan	30,500	1,670,000	31,700	1,240,000
Jordan	--	--	124	45,400
Korea, Republic of	115,000	1,580,000	4,000	131,000
Kuwait	49,600	55,000	--	--
Mexico	76,000	351,000	2,640,000	5,470,000
Morocco	63,000	66,300	--	--
Netherlands	74,200	217,000	56,100	180,000
New Zealand	13,400	20,300	27,600	56,100
Portugal	7,530	16,600	7,820	16,600
Russia	59,600	87,300	--	--
Saudi Arabia	131,000	200,000	20	7,740
Singapore	1,680	45,200	12,000	89,300
Taiwan	--	--	4,710	54,200
United Arab Emirates	274,000	298,000	748	29,300
United Kingdom	263,000	2,130,000	365,000	2,840,000
Other	124,000	323,000	348,000	1,570,000
Total	3,620,000	16,200,000	5,050,000	21,200,000
Total estimated equivalent REO content	3,210,000	16,200,000	4,490,000	21,200,000

-- 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.

[3]Inorganic and organic.

Source: U.S. Census Bureau.

TABLE 5

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

Category[2] and country	2007 Gross weight (kilograms)	2007 Value	2008 Gross weight (kilograms)	2008 Value
Cerium compounds, including oxides, hydroxides, nitrates, sulfate, chlorides, oxalates (2846.10.0000):				
Austria	60,600	$356,000	78,700	$734,000
China	3,630,000	7,770,000	2,890,000	9,980,000
France	121,000	1,080,000	36,800	421,000
Hong Kong	16,500	20,600	--	--
Japan	88,700	2,350,000	43,600	1,440,000
Korea, Republic of	2,520	24,700	34	21,600
United Kingdom	48,000	149,000	40,000	112,000
Other	45,000	399,000	13,200	113,000
Total	4,010,000	12,100,000	3,100,000	12,800,000
Total estimated equivalent rare-earth oxide (REO) content	2,680,000	12,100,000	2,080,000	12,800,000
Yttrium compounds content by weight greater than 19% but less than 85% oxide equivalent (2846.90.4000):				
China	29,800	310,000	8,650	202,000
France	815	40,100	916	61,500
Japan	5,070	1,510,000	6,860	6,490,000
Other	--	--	115	10,500
Total	35,700	1,860,000	16,500	6,770,000
Total estimated equivalent REO content	21,400	1,860,000	9,920	6,770,000
Rare-earth compounds, including oxides, hydroxides, nitrates, other compounds except chlorides (2846.90.8000):				
Austria	109,000	4,210,000	67,600	2,980,000
Canada	3,030	105,000	3,460	139,000
China	11,700,000	44,800,000	10,500,000	79,900,000
France	519,000	15,000,000	390,000	19,200,000
Germany	1,550	359,000	1,750	845,000
Hong Kong	220	5,040	234,000	2,320,000
Japan	421,000	10,900,000	234,000	10,900,000
Russia	346,000	547,000	96,300	470,000
South Africa	12,700	120,000	48,400	522,000
United Kingdom	68,300	112,000	4,030	118,000
Other	40,400	1,970,000	94,800	1,510,000
Total	13,200,000	78,100,000	11,600,000	119,000,000
Total estimated equivalent REO content	9,990,000	78,100,000	8,810,000	119,000,000
Mixtures of REOs except cerium oxide (2846.90.2010):				
China	2,510,000	9,090,000	2,300,000	16,000,000
Germany	822	43,200	450	33,300
Italy	44,700	5,420,000	56,200	6,150,000
Japan	7,790	310,000	1,730	312,000
Russia	11	14,300	1	3,800
United Kingdom	67	30,400	5	6,530
Other	4,000	23,000	32,000	56,900
Total	2,570,000	14,900,000	2,390,000	22,600,000
Total estimated equivalent REO content	2,570,000	14,900,000	2,390,000	22,600,000

See footnotes at end of table.

TABLE 5—Continued

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

	2007		2008	
Category[2] and country	Gross weight (kilograms)	Value	Gross weight (kilograms)	Value
Rare-earth metals, whether intermixed or alloyed (2805.30.0000):				
Austria	616	$138,000	1,570	$189,000
China	636,000	5,710,000	540,000	3,740,000
Germany	2	2,250	5	6,750
Japan	8,470	168,000	12,600	458,000
Russia	619	112,000	2,690	226,000
United Kingdom	8,100	333,000	9,010	317,000
Total	653,000	6,470,000	566,000	4,940,000
Total estimated equivalent REO content	784,000	6,470,000	679,000	4,940,000
Mixtures of rare-earth chlorides, except cerium chloride (2846.90.2050):				
China	3,250,000	10,000,000	2,580,000	16,100,000
Germany	589	202,000	5,230	203,000
Hong Kong	147,000	743,000	211,000	618,000
Japan	6,400	102,000	3,940	76,700
Korea, Republic of	54,700	73,800	114	10,500
Russia	101	241,000	38	97,100
Taiwan	40,600	160,000	18,000	170,000
United Kingdom	7,420	98,900	3,220	19,200
Other	43	37,400	34,300	317,000
Total	3,510,000	11,700,000	2,850,000	17,600,000
Total estimated equivalent REO content	1,610,000	11,700,000	1,310,000	17,600,000
Ferrocerium and other pyrophoric alloys (3606.90.3000):				
Austria	16,200	550,000	18,700	356,000
China	4,370	42,200	6,950	124,000
France	116,000	1,680,000	116,000	1,900,000
Other	2,300	47,800	--	--
Total	139,000	2,320,000	141,000	2,380,000
Total estimated equivalent REO content	123,000	2,320,000	125,000	2,380,000

-- 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]	2004	2005	2006	2007	2008
Brazil	402 [4]	527 [4]	527 [4]	645	550
China	98,000	119,000	133,000	120,000	125,000
India	2,700	2,700	2,700	2,700	2,700
Kyrgyzstan:					
Compounds	NA	NA	NA	NA	NA
Metals	NA	NA	NA	NA	NA
Other	NA	NA	NA	NA	NA
Malaysia	800	150	430	380	380
Total	102,000	122,000	137,000	124,000	129,000

NA Not available.

[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 8, 2009.

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

[4]Reported figure.

TABLE 7

MONAZITE CONCENTRATE: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons, gross weight)

Country[3]	2004	2005	2006	2007	2008
Brazil	731 [4]	958 [4]	958 [4]	1,173 [4]	1,200 [p]
India	5,000	5,000	5,000	5,000	5,000
Malaysia	1,683 [4]	320 [4]	894 [4]	682 [r, 4]	700
Total	7,410	6,280	6,850	6,860 [r]	6,900

[p]Preliminary. [r]Revised.

[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 May 10, 2009.

[3]In addition to the countries listed, China, Indonesia, Nigeria, North Korea, the Republic of Korea, and countries of the Commonwealth of Independent States may produce monazite; available information is inadequate for formulation of reliable estimates of output levels.

[4]Reported figure.

FIGURE 1
PRINCIPAL SOURCES BY WEIGHT OF U.S. IMPORTS OF RARE EARTHS IN 2008