2010 Minerals Yearbook

RARE EARTHS

U.S. Department of the Interior
U.S. Geological Survey

October 2012

Rare Earths

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In 2010, world rare-earth production was primarily from the mineral bastnäsite. Rare earths were not mined in the United States in 2010. Rare-earth ores were primarily mined in China, with smaller amounts mined in India, Malaysia, and Brazil, listed in order of decreasing production. Processing of intermediate rare-earth concentrates took place at the Mountain Pass Mine in California.

Domestic use of scandium remained small in 2010. 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 increased by 43% in 2010 compared with that of 2009. Yttrium was used primarily in linear 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 (also referred to as lanthanoids) 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. At an average concentration in the Earth's crust of 60 ppm, cerium is more abundant than copper, 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.

Rare earths can be classified as either light rare-earth elements (LREE) or heavy rare-earth elements (HREE). This division between the LREE include the lanthanide elements from atomic number 57 (lanthanum) through atomic number 64 (gadolinium), and the HREE include the lanthanide elements from atomic number 65 (terbium) through atomic number 71 (lutetium). The division is based on the lanthanoid LREE having unpaired electrons in the 4f electron shell, and HREE having paired electrons in the 4f electron shell. Gadolinium has a very stable half-filled 4f electron shell with seven unpaired electrons. Proceeding with terbium and continuing along the series through lutetium, paired electrons are progressively added to the 4f electron shell for each respective element in the HREE lanthanoid series until there is a full complement of 14 electrons in the 4f electron shell of lutetium. The division between LREE and HREE lanthanoids falls between gadolinium and terbium. Yttrium is included as a HREE even though it is not part of the lanthanoid contraction series.

Scandium (atomic number 21), a transition metal, is the lightest REE but it is not classified as one of the group of LREE nor one of the HREE. 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 that of 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), a transition metal, is chemically similar to the lanthanides and often occurs in the same minerals as a result of its similar ionic radius. Its atomic radius of 104 picometers in the trivalent state places it in relative size between the ionic radii of holmium and erbium (104.1 and 103, respectively). It is included as one of the HREE. 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 December 2010, Molycorp, Inc. resumed mining at its Mountain Pass operation and was preparing to resume milling operations. During 2010, Molycorp produced more than 3,000 metric tons (t) of rare-earth materials from stockpiled feedstock. A two-phase expansion plan was underway that would increase capacity to 19,100 metric tons per year (t/yr) of rare-earth oxides (REO) by yearend 2012 and 40,000 t/yr by yearend 2013. In July, Molycorp became a publicly traded company. Molycorp conducted additional drilling and exploration work in 2010 with a primary focus on in-fill drilling. The company planned additional drilling and exploration work in 2011. Proven reserves at Mountain Pass were estimated to be about 40,000 t of REO and probable reserves to be about 962,000 t of REO (Molycorp, Inc., 2011, p. 35–39).

Two companies processed intermediate rare-earth compounds to lanthanides in 2010. 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.

In April, Molycorp acquired Santoku America, Inc. (Molycorp, Inc., 2011, p. 7). Santoku America 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 U.S. scandium processor operated in 2010. Sigma-Aldrich Co. 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., another processor, had scandium facilities on standby at its Mead, CO, operation. 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.

Owing to market conditions, several mineral exploration and development projects were underway. Drilling and prefeasibility studies were underway in Alaska, Nebraska, and Wyoming.

In May, Rare Element Resources Ltd. increased the resource estimate for its Bear Lodge project in Wyoming by 50%. The new resource estimate for REO contained in the Bull Hill area of the project was 549,000 t with a 1.5% REO cutoff grade (Rare Element Resources Ltd., 2010b). In November, the company completed a scoping study on its Bear Lodge project. Based on the results of the scoping study, the company planned to begin prefeasibility studies to update the mineral resource estimate and begin more detailed metallurgical testing and engineering studies in 2011 (Rare Element Resources Ltd., 2010a).

Quantum Rare Earth Developments Corp. acquired the Elk Creek niobium-rare earth project in southeastern Nebraska. The Elk Creek property contains an intrusive carbonatite complex containing niobium and rare-earth elements. In 2010, Quantum began an exploration program of the property including a review of the historic exploration of the property during the 1970s and 1980s (Quantum Rare Earth Developments Corp., 2010).

In Alaska, Ucore Rare Metals Inc. conducted a drilling program at its Bokan Mountain-Dodson property to confirm previous drilling results and to examine mineralization at greater depth. A National Instrument (NI) 43–101-compliant resource estimate was expected to be completed in 2011 (Ucore Rare Metals Inc., 2010).

Consumption

Data on domestic rare-earth consumption were developed by surveying various processors and manufacturers and evaluating import and export data. Domestic apparent consumption of rare earths was not calculated in 2010 because data were withheld to avoid disclosing company proprietary data.

In 2010, yttrium consumption was estimated to have increased to 670 t from 468 t in 2009. Yttrium information was based on data retrieved from the PIERS database. The leading source of yttrium compounds and metal in 2010 was China (84%). 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.

Prices

China's actions to restrict exports of REO through quotas and taxes caused prices of rare-earth products to rise significantly. The prices of most rare-earth materials, provided by Rhodia Inc., were higher or the same in 2010 compared with those of 2009 (table 3). On average, REO prices increased by 29% from those in 2009. Scandium oxide prices were slightly higher than those in 2009.

The average yearend rare-earth metal prices from Metal-Pages Ltd. increased more than 200% in 2010 compared with those in 2009. Lanthanum metal (used in nickel-metal hydride batteries) and cerium metal (used in mischmetal and in iron and steelmaking) increased by more than five times to $60.50 and $51.50 per kilogram. Prices for neodymium ($114 per kilogram) and dysprosium ($400 per kilogram), used in permanent magnets, increased by 285% and 171%, respectively, compared with those in 2009.

Prices for scandium metal in ingot form were unchanged at $158,000 per kilogram.

Foreign Trade

Data in this section are based on gross weight, although data in the tables are also converted to REO content. U.S. exports totaled 8,090 t valued at $88 million, an 8% increase in quantity and a 52% increase in value compared with those of 2009. On a gross-weight basis, ferrocerium was the largest export category, accounting for 48% of the total exports (table 4).

U.S. rare earth imports totaled 16,200 t valued at $189 million, approximately an 8% increase in quantity and a 67% increase in value compared with those of 2009. 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, and Japan. These three countries accounted for 94% of the domestic imports.

World Review

Australia.—In New South Wales, Alkane Resources Ltd. continued to develop its Dubbo Zirconia project with planned production of hafnium, niobium, rare earths, tantalum, and zirconium products. In 2010, Alkane Resources continued to optimize separation technologies using a demonstration pilot plant at ANSTO Minerals laboratories near Sydney. A definitive feasibility study based on a potential production of 4,610 t/yr of rare-earth oxides was underway. At yearend, measured resources of REO were 54.9 million metric tons. Production was not expected to begin until 2014 (Alkane Resources Ltd., 2011).

Aurafura Resources Ltd. continued to develop its Nolans Bore mining and beneficiation project in the Northern Territory and its Whayalla processing operation in South Australia. In 2010, Aurafura began a bankable feasibility study and conducted environment and technology demonstration studies for the mine and processing operations. The bankable feasibility study was expected to be completed in 2011, and initial production targeted for 2013. The Whyalla operation was expected to reach full production of 20,000 t/yr of REO by 2014 (Ward, 2010, p. 17).

In Western Australia, engineering and construction of a mineral concentration plant at Lynas Corp. Ltd.'s Mount Weld deposit was 80% complete, and an 18-month stockpile of crushed ore to feed the plant was in place at yearend. Production of concentrate for Lynas Corp.'s Malaysian REO processing operation was scheduled to begin in 2011 (Lynas Corp. Ltd., 2011, p. 2).

Canada.—In the Northwest Territories, Avalon Rare Metals Inc. completed a prefeasibility study on its Thor Lake (Nechalco) project in June. The study was based on an initial production output of 5,000 t/yr of REO and probable mineral reserves of 204,000 t REO (Avalon Rare Metals Inc., 2010b). In September, Avalon announced it had completed a NI 43–101 resource update on the Nechalco deposit. The indicated resource was 359,000 t of REO (Avalon Rare Metals Inc., 2010a).

In Quebec, Matamec Explorations Inc. continued drilling its Kipawa deposit and had SGS Geostat Inc. complete a NI 43–101 resource estimate. The resource was considered under two scenarios—as a resource of rare earths and yttrium with zirconium as a byproduct, and as a resource of zirconium with rare earths and yttrium as a byproduct. SGS Geostat estimated that the indicated resources included up to 30,200 t of REO. In September, Matamec announced that it had contracted Roche Ltd. to assist in the development of NI 43–101-compliant preliminary economic assessment (Matamec Explorations Inc., 2011, p. 11–14).

In Quebec and Newfoundland and Labrador, Quest Rare Minerals Ltd. continued exploration drilling and completed preliminary resource and economic assessments on its Strange Lake property in September. From the assessments, the company determined that the deposit warranted further investigation and development. The operation could produce more than 22,600 t/yr of REO concentrate. Feasibility studies were scheduled to begin in 2011 (Quest Rare Minerals Ltd., 2010).

China.—China continued to dominate the supply of REE, accounting for 97% of global mine production. Mine production was primarily from bastnäsite and other rare-earth minerals in Inner Mongolia-Autonomous Region and Sichuan Province and from ion adsorption ore in the southeastern Provinces of Fujian, Guangdong, and Jiangxi (Grauch and Mariano, 2008).

Citing domestic requirements and environmental concerns, China restricted supply of REE through export quotas and taxes. China's Ministry of Land and Resources set a production quota for rare-earth concentrate at 89,200 t of contained REO. According to figures from the China Rare Earth Society, however, production was actually about 130,000 t (Reuters, 2011). The Ministry of Industry and Information Technology announced that the 2011 production quota for rare-earth separated products would be 90,400 t. Provincial governments were responsible for managing their allocated quotas and assigning the output quota to individual mining companies (Ministry of Industry and Information Technology of the People's Republic of China, 2010).

The Ministry of Finance and the Administration of Taxation announced that the resource tax on bastnasite and monazite would be taxed at 60 yuan per metric ton and that middle and heavy rare earths would be taxed at a rate of 30 yuan per metric ton beginning on April 1, 2011 (Ministry of Finance of the People's Republic of China, 2010, p. 301).

The autonomous government of Inner Mongolia granted Baotou Rare Earth Co. (Baotou), China's leading REO producer, authority to build a stockpile of rare-earth products and to build facilities to store 200,000 t of REO. In 2009, Baotou REO production was estimated to be about 55,000 t, but the regional government limited the company's sales to 50,000 t in 2010. Any production in 2010 beyond the 50,000 t limit was assumed to be incorporated into the stockpile (Reuters, 2010). Baotou moved to expand its rare-earth interest in southern China by investing 232 million yuan ($34.3 million) in three REE companies in Jiangxi Province. In August, Baotou announced plans to acquire 48% interest in Xinfeng Xinli Rare Earths Co., Ltd., 49% interest in a joint venture with Quannan Jinghuan Technology Co., Ltd., and 9.25% interest in Ganzhou Chenguang Rare Earths Co., Ltd. (China Daily, 2010).

Estonia.—Molycorp acquired a 90% interest in Aktsiaselts Silmet, one of two rare-earth processing facilities in Europe. The acquisition doubled Molycorp's REO production capacity to 6,000 t/yr and gave the company the ability to produce didymium metal (Molycorp, Inc., 2011, p. 7).

India.—Toyota Tsusho Corp. and its Indian subsidiary (Toyotsu Rare Earths Orissa Pvt. Ltd.) were promoting a plan to construct a REO processing plant in Orissa. The plan called for 3,000 to 4,000 t/yr of REO derived from monazite produced at Indian Rare Earth Ltd.'s heavy-mineral sands operation. In October, Government officials from India and Japan agreed to collaborate on the development and reuse of rare-earth materials (Toyota Tsusho Corp., 2010).

Japan.—Japan Oil, Gas and Metals National Corp. (JOGMEC) entered into an agreement with Midland Exploration Inc. for rare-earths development near the Quest Rare Minerals Ltd.'s Strange Lake project in the Ytterby region of Canada. Under the agreement, JOGMEC would earn a 50% interest in the project by spending CAD$2.7 million during 3 years. JOGMEC could take products in proportion to the interest and have the right of first refusal on the other party's share of the products (Japan Oil, Gas and Metals National Corp., 2010).

Malaysia.—Lynas Corp. neared completion of its advanced materials processing plant near Kuantan with an initial capacity of 11,000 t/yr of REO. A second phase of construction was scheduled to be completed in 2012 that would double REO production capacity (Lynas Corp. Ltd., 2011, p. 2).

South Africa.— Great Western Minerals Group Ltd. (GWMG) was moving ahead with a project to recommission the abandoned Steenkampskraal mine in the Western Cape owned by Steenkampskraal Monazite Mine Ltd. In June, GWMG appointed SRK Engineers and Scientists of Johannesburg to complete a feasibility study on the project and, in August, agreed to purchase all of the rare-earth materials produced by the mine for a 10-year period. At yearend, GWMG held interest in the Steenkampskraal mine and in six REE properties in North America (Great Western Minerals Group Ltd., 2011).

United Kingdom.—GWMG planned to increase rare-earth metals processing capacity at its subsidiary, Less Common Metals Ltd. (LCM). A new furnace at its Hooton Park operation, Birkenhead, was expected to increase LCM's processing capacity by approximately 50%, and was scheduled to be in production by the third quarter of 2011. The new furnace was designed to provide NdFeB alloys for sintered magnets (Great Western Minerals Group Ltd., 2010).

Vietnam.—The Dong Pao Mine in the northern part of Vietnam has large resources of rare earths. The ownership included six Vietnamese companies. VIMICO (Vietnam National Minerals) and VINACOMIN (Vietnam National Coal-Mineral Industries Group) jointly held 55% of the shares. The mining rights were owned by LARESCO and Lai Chau Rare Earth in a joint venture. Two other Japanese companies—Toyota Tsusho and Sojitz—also held an interest in the Dong Pao Mine (Roskill's Letters from Japan, 2010).

Outlook

Rare-earth use in automotive pollution control catalysts, permanent magnets, and rechargeable batteries is expected to continue to rise as future global demand for conventional and hybrid automobiles, computers, electronics, and portable equipment increases. 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 is expected to trend with refinery and automotive production. REE magnet production was projected to increase to 150,000 t by 2014 from 92,000 t in 2011. Future growth was expected for rare earths in rechargeable NiMH batteries, especially those used in hybrid vehicles, increasing to 62,000 t REO by 2014 (BCC Research, 2010). NiMH demand was also expected to increase (moderated by increasing demand for lithium-ion batteries), with increased use in portable electronic equipment. 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.

Although the rare earth content of world reserves is greater than cumulative world consumption expected well into the 21st century, current annual production is less than current world consumption; there are shortages for neodymium and dysprosium for magnet alloys and europium and terbium for phosphors. Companies are working to develop rare-earth deposits in Australia, Canada, Greenland, South Africa, and the United States.

All domestic and most foreign companies have currently shifted away from using naturally occurring radioactive rare-earth ores. This trend has had 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. 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.

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 southeastern 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]

		2006	2007	2008	2009	2010
Production of rare-earth concentrates, rare-earth oxide (REO) basis[e]	metric tons	--	--	--	--	--
Exports, REO basis:						
Cerium compounds	do.	2,010	1,470	1,380	840	1,350
Ferrocerium and pyrophoric alloys	do.	3,710	3,210	4,490	2,970	3,460
Rare-earth compounds, organic or inorganic	do.	2,700	1,300	663	455	1,690
Rare-earth metals, scandium, yttrium	do.	611	1,470	1,390	4,930	1,380
Imports for consumption, REO basis:[e]						
Cerium compounds	do.	2,590	2,680	2,080	1,500	1,770
Ferrocerium and pyrophoric alloys	do.	127	123	125	102	131
Mixtures of rare-earth chlorides except cerium chloride	do.	2,750	1,610	1,310	411	956
Mixtures of REOs except cerium oxide	do.	1,580	2,570	2,400	4,750	5,480
Rare-earth compounds, oxides, hydroxides, nitrates, other compounds except chlorides	do.	10,600	9,900	8,820	5,080 r	3,980
Rare-earth metals, whether intermixed or alloyed	do.	867	784	679	226	525
Yttrium compounds	do.	168	21	10	7	73
Prices, yearend:						
Bastnäsite concentrate, REO basis	dollars per kilogram	6.06	6.61	8.82 r	5.73 r	6.87
Monazite concentrate, REO basis	do.	0.73	0.73	0.48	0.87 r	0.87
Mischmetal, metal basis[2]	do.	5.00–6.00	7.00–8.00	8.00–9.00 r	8.00–9.00 r	45.00–55.00

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

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

[2]Source: HEFA Rare Earths Canada Co. Ltd., Vancouver, British Columbia, Canada.

TABLE 2

RARE EARTH CONTENTS OF MAJOR AND POTENTIAL SOURCE MINERALS[1, 2]

(Percentage of total rare-earth oxide)

Rare earth	Bastnäsite: Mountain Pass, CA, United States[3]	Bastnäsite: Bayan Obo, Inner Mongolia, China[4]	Monazite: North Capel, Western Australia[5]	Monazite: North Stradbroke Island, Queensland, Australia[6]	Monazite: Green Cove Springs, FL, United States[7]	Monazite: Nangang, Guangdong, China[8]
Yttrium	0.10	trace	2.40	2.50	3.20	2.40
Lanthanum	33.20	23.00	23.90	21.50	17.50	23.00
Cerium	49.10	50.00	46.00	45.80	43.70	42.70
Praseodymium	4.34	6.20	5.00	5.30	5.00	4.10
Neodymium	12.00	18.50	17.40	18.60	17.50	17.00
Samarium	0.8	0.8	2.53	3.10	4.90	3.00
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
Terbium	trace	0.1	0.035	0.3	0.26	0.7
Dysprosium	trace	0.1	0.7	0.60	0.9	0.8
Holmium	trace	trace	0.053	0.1	0.11	0.12
Erbium	trace	trace	0.2	0.2	trace	0.3
Thulium	trace	trace	trace	trace	trace	trace
Ytterbium	trace	trace	0.1	0.1	0.21	2.40
Lutetium	trace	trace	trace	0.01	trace	0.14
Total	100	100	100	100	100	100

Rare earth	Monazite—Continued: Eastern coast, Brazil[9]	Monazite—Continued: Mount Weld, Australia[10]	Xenotime: Lahat, Perak, Malaysia[3]	Xenotime: Southeast, Guangdong Province, China[11]	Rare earth laterite: Xunwu, Jiangxi Province, China[12]	Rare earth laterite: Longnan, Jiangxi Province, China[12]
Yttrium	1.40	trace	61.00	59.30	8.00	65.00
Lanthanum	24.00	26.00	1.24	1.20	43.4	1.82
Cerium	47.00	51.00	3.13	3.00	2.40	0.4
Praseodymium	4.50	4.00	0.5	0.6	9.00	0.7
Neodymium	18.50	15.00	1.60	3.50	31.70	3.00
Samarium	3.00	1.80	1.10	2.20	3.90	2.80
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
Terbium	0.1	0.1	0.9	1.20	trace	1.30
Dysprosium	0.4	0.2	8.30	9.10	trace	6.70
Holmium	trace	0.1	2.00	2.60	trace	1.60
Erbium	0.1	0.2	6.40	5.60	trace	4.90
Thulium	trace	trace	1.10	1.30	trace	0.7
Ytterbium	0.02	0.1	6.80	6.00	0.3	2.50
Lutetium	not determined	trace	1.00	1.80	0.1	0.4
Total	100	100	100	100	100	100

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

[2]Rare earths are listed in order of atomic number.

[3]Johnson, G.W., and Sisneros, T.E., 1981, Analysis of rare-earth elements in ore concentrate samples using direct current plasma spectrometry—Proceedings of the 15th Rare Earth Research Conference, Rolla, MO, June 15–18, 1981: New York, NY, Plenum Press, v. 3, p. 525–529.

[4]Zang, Zhang Bao, Lu Ke Yi, King Kue Chu, Wei Wei Cheng, and Wang Wen Cheng, 1982, Rare-earth industry in China: Hydrometallurgy, v. 9, no. 2, p. 205–210.

[5]Westralian Sands Ltd., 1979, Product specifications, effective January 1980: Capel, Australia, Westralian Sands Ltd. brochure, 8 p.

[6]Analysis from Consolidated Rutile Ltd.

[7]Analysis from RGC Minerals (USA), Green Cove Springs, FL.

[8]Xi, Zhang, 1986, The present status of Nd-Fe-B magnets in China—Proceedings of the Impact of Neodymium-Iron-Boron Materials on Permanent Magnet Users and Producers Conference, Clearwater, FL, March 2–4, 1986: Clearwater, FL, Gorham International Inc., 5 p.

[9]Krumholz, Pavel, 1991, Brazilian practice for monazite treatment: Symposium on Rare Metals, Sendai, Japan, December 12–13, 1991, Proceedings, p. 78–82.

TABLE 2—Continued

RARE EARTH CONTENTS OF MAJOR AND POTENTIAL SOURCE MINERALS[1, 2]

[10]Kingsnorth, Dudley, 1992, Mount Weld—A new source of light rare earths—Proceedings of the TMS and Australasian Institute of Mining and Metallurgy Rare Earth Symposium, San Diego, CA, March 1–5, 1992: Sydney, Australia, Lynas Gold NL, 8 p.

[11]Nakamura, Shigeo, 1988, China and rare metals—Rare earth: Industrial Rare Metals, no. 94, May, p. 23–28.

[12]Jiangxi Province, 1985, Introduction to Jiangxi rare-earths and applied products: Jiangxi Province, China, Jiangxi Province brochure, 42 p.

TABLE 3

RARE-EARTH OXIDE PRICES IN 2010[e, 1]

Product (oxide)	Purity (percentage)	Standard package quantity (kilograms)	Price (dollars per kilogram)
Scandium	99.99	NA	3,500.00
Yttrium	99.99	20	50.00
Lanthanum	99.99	20	38.00
Cerium	96.00	20	30.00
Do.	99.50	20	NA
Praseodymium	96.00	20	60.00
Neodymium	95.00	20	63.00
Samarium	99.90	20	175.00
Do.	99.99	20	NA
Europium	99.99	20	1,400.00
Gadolinium	99.99	20	165.00
Terbium	99.99	20	1,400.00
Dysprosium	99.00	20	310.00
Holmium	99.90	10	750.00
Erbium	96.00	20	165.00
Thulium	99.90	5	1,500.00
Ytterbium	99.00	10	375.00
Lutetium	99.99	1 or 10	2,200.00

[e]Estimated. Do. Ditto. NA Not available.

[1]Rare earths are listed in order of atomic number.

Source: Rhodia, Inc.

TABLE 4

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

Category[2] and country	2009 Gross weight (kilograms)	2009 Value	2010 Gross weight (kilograms)	2010 Value
Cerium compounds (2846.10.0000):				
Australia	1,920	$13,300	9	$8,060
Austria	43,800	437,000	122,000	1,530,000
Belgium	1,800	21,800	5,000	5,000
Brazil	11,400	95,900	7,900	133,000
Canada	15,300	151,000	25,300	284,000
China	72,800	878,000	255,000	2,110,000
France	3,950	47,200	95,300	412,000
Germany	94,800	731,000	124,000	1,110,000
Hong Kong	3,930	128,000	18,100	446,000
India	60,600	402,000	15,700	159,000
Japan	114,000	1,320,000	180,000	3,170,000
Korea, Republic of	15,800	79,400	25,900	214,000
Mexico	192,000	800,000	241,000	1,420,000
Netherlands	43,300	241,000	64,500	364,000
Singapore	10,100	64,600	181	9,500
Taiwan	7,340	96,700	8,490	156,000
United Kingdom	14,200	99,500	14,400	737,000
Other	133,000	2,430,000	151,000	2,080,000
Total	840,000	8,030,000	1,350,000	14,300,000
Total estimated equivalent rare-earth oxide (REO) content	840,000	XX	1,350,000	XX
Ferrocerium and other pyrophoric alloys (3606.90.0000):				
Argentina	29,100	162,000	143	4,920
Australia	19,100	984,000	12,700	2,750,000
Canada	494,000	1,620,000	513,000	2,040,000
China	169,000	1,960,000	100,000	789,000
Egypt	451	77,700	1,260	102,000
France	66,300	1,170,000	35,400	183,000
Germany	342	14,200	7,760	176,000
Greece	888	274,000	639	42,200
Hong Kong	26,100	306,000	9,450	305,000
Israel	75	3,230	1,210	10,700
Japan	17,200	461,000	17,100	504,000
Korea, Republic of	4,240	255,000	1,380	73,100
Mexico	1,890,000	4,200,000	2,300,000	4,840,000
Netherlands	33,100	171,000	229,000	1,180,000
New Zealand	--	--	16,700	55,600
Saudi Arabia	1,020	33,700	268	5,400
Singapore	477	14,500	1,280	40,300
Taiwan	164	5,970	408	13,200
United Arab Emirates	1,680	32,100	--	--
United Kingdom	296,000	14,000,000	168,000	4,790,000
Other	299,000	2,290,000	478,000	1,120,000
Total	3,350,000	28,000,000	3,900,000	19,000,000
Total estimated equivalent REO content	2,970,000	XX	3,460,000	XX

See footnotes at end of table.

TABLE 4—Continued

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

Category[2] and country	2009 Gross weight (kilograms)	2009 Value	2010 Gross weight (kilograms)	2010 Value
Rare-earth compounds[3] (2846.90.0000):				
Austria	491	$3,470	279,000	$616,000
Brazil	13,400	122,000	9,450	248,000
Canada	53,900	479,000	49,600	588,000
China	43,200	488,000	47,000	906,000
Colombia	1,640	$29,200	9,010	$25,500
Congo (Brazzaville)	--	--	69,900	437,000
Estonia	--	--	77,700	220,000
France	28,500	543,000	23,000	442,000
Germany	18,200	502,000	38,200	1,420,000
Hong Kong	2,050	125,000	1,090	69,500
India	4,190	49,600	18,500	127,000
Italy	8,110	89,700	16,300	108,000
Japan	63,900	1,870,000	379,000	13,900,000
Korea, Republic of	74,000	405,000	90,100	940,000
Mexico	43,900	502,000	79,800	1,160,000
Netherlands	9,370	44,400	107,000	1,560,000
Singapore	6,190	94,500	12,000	204,000
Spain	16	22,000	141,000	187,000
Taiwan	1,810	46,800	1,670	407,000
United Kingdom	3,620	229,000	77,400	1,930,000
Vietnam	2,800	31,100	62,500	682,000
Other	75,700 r	542,000 r	103,000	1,060,000
Total	455,000	6,210,000	1,690,000	27,200,000
Total estimated equivalent REO content	455,000	XX	1,690,000	XX
Rare-earth metals, including scandium and yttrium (2805.30.0000):				
Belgium	268	24,600	8	39,700
Brazil	16,800	221,000	84,200	1,290,000
China	365,000	1,370,000	316,000	1,230,000
Germany	4,800	232,000	7,220	317,000
Hong Kong	62,800	283,000	990	190,000
India	3,130	228,000	6,780	380,000
Japan	303,000	5,330,000	639,000	19,800,000
Mexico	150	80,800	675	83,700
Switzerland	48	28,400	1	3,260
Taiwan	1,190	46,600	801	64,700
Turkey	3,190,000	6,220,000	--	--
Other	157,000 r	1,650,000 r	93,300	4,110,000
Total	4,100,000	15,700,000	1,150,000	27,500,000
Total estimated equivalent REO content	4,920,000	XX	1,380,000	XX

[r]Revised. XX Not applicable. -- 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	2009 Gross weight (kilograms)	2009 Value	2010 Gross weight (kilograms)	2010 Value
Cerium compounds, including oxides, hydroxides, nitrates, sulfate, chlorides, oxalates (2846.10.0000):				
Austria	386,000	$1,140,000	131,000	$1,400,000
China	1,720,000	5,030,000	2,010,000	13,500,000
France	17,700	208,000	11,800	685,000
Japan	51,600	1,800,000	139,000	4,700,000
Korea, Republic of	--	--	32,400	275,000
United Kingdom	17,300	68,100	60,100	155,000
Other	49,200	812,000	262,000	1,980,000
Total	2,240,000	9,070,000	2,640,000	22,600,000
Total estimated equivalent rare-earth oxide (REO) content	1,500,000	XX	1,770,000	XX
Ferrocerium and other pyrophoric alloys (3606.90.3000):				
Austria	21,000	457,000	25,400	626,000
China	4,280	90,300	11,900	184,000
France	89,100	2,080,000	110,000	2,290,000
Taiwan	--	--	700	9,530
Total	114,000	2,620,000	148,000	3,110,000
Total estimated equivalent REO content	102,000	XX	131,000	XX
Mixtures of rare-earth chlorides, except cerium chloride (2846.90.2050):				
Australia	--	--	1,930	3,190
Canada	617	2,570	--	--
China	887,000	4,560,000	2,030,000	11,100,000
Estonia	--	--	4,000	126,000
France	21	9,940	10,300	243,000
Germany	129	112,000	336	87,000
Japan	5,550	108,000	19,500	206,000
Russia	59	127,000	138	76,400
United Kingdom	787	10,700	15,000	121,000
Total	894,000	4,930,000	2,080,000	12,000,000
Total estimated equivalent REO content	411,000	XX	956,000	XX
Mixtures of REOs except cerium oxide (2846.90.2010):				
China	4,700,000	19,100,000	5,410,000	33,400,000
France	--	--	56	22,900
Germany	934	108,000	1,270	65,400
Ireland	--	--	34,600	2,830,000
Italy	42,500	4,190,000	18,400	1,790,000
Japan	6,130	64,900	9,310	148,000
Russia	111	66,900	63	35,100
Total	4,750,000	23,500,000	5,480,000	38,300,000
Total estimated equivalent REO content	4,750,000	XX	5,480,000	XX
Rare-earth compounds, including oxides, hydroxides, nitrates, other compounds except chlorides (2846.90.8000):				
Austria	58,200	2,650,000	108,000	4,390,000
Canada	3,000	15,000	--	--
China	5,590,000	38,600,000	4,080,000	55,400,000
France	331,000	13,000,000	542,000	16,600,000
Germany	35,300	304,000	700	208,000

See footnotes at end of table.

TABLE 5—Continued

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

Category[2] and country	2009 Gross weight (kilograms)	2009 Value	2010 Gross weight (kilograms)	2010 Value
Rare-earth compounds, including oxides, hydroxides, nitrates, other compounds except chlorides (2846.90.8000)—Continued:				
Hong Kong	600	$5,990	100	$6,800
Japan	143,000	9,350,000	417,000	17,300,000
Russia	109	95,300	13,200	339,000
South Africa	39,600	426,000	64,100	781,000
United Kingdom	157	49,000	43,800	211,000
Other	565,000	3,060,000	45,800	1,080,000
Total	6,770,000	67,500,000	5,310,000	96,300,000
Total estimated equivalent REO content	5,080,000 r	XX	3,980,000	XX
Rare-earth metals, whether intermixed or alloyed (2805.30.0000):				
Austria	227	36,100	3,610	223,000
Canada	--	--	224	19,700
China	167,000	3,790,000	361,000	12,300,000
Germany	--	--	70	17,600
Hong Kong	--	--	46,400	409,000
India	50	4,000	--	--
Japan	10,800	481,000	13,600	954,000
Korea, Republic of	--	--	53	51,600
Russia	2,110	182,000	3,620	328,000
Spain	31	2,450	--	--
United Kingdom	7,870	368,000	8,480	413,000
Vietnam	--	--	219	4,150
Total	188,000	4,870,000	437,000	14,700,000
Total estimated equivalent REO content	226,000	XX	525,000	XX
Yttrium compounds content by weight greater than 19% but less than 85% oxide equivalent (2846.90.4000):				
China	8,690	136,000	98,000	586,000
France	945	29,800	9,100	589,000
Japan	1,710	362,000	5,100	641,000
Other	190	37,500	10,200	243,000
Total	11,500	565,000	122,000	2,060,000
Total estimated equivalent REO content	6,920	XX	73,500	XX

[r]Revised. XX Not applicable. -- 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]	2006	2007	2008	2009	2010
Brazil	527 [4]	645 [4]	460 [r, 4]	170 [r]	140
China	133,000	120,000	125,000	129,000	120,000
India	2,700	2,700	2,700	2,700	2,800
Kyrgyzstan	NA	NA	NA	NA	NA
Malaysia	430	380	120 [r]	13 [r]	400
Total	137,000	124,000	128,000	132,000	123,000

[r]Revised. 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 October 4, 2011.

[3]In addition to the countries listed, rare-earth minerals are thought 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]Reported figure.

TABLE 7

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

(Metric tons, gross weight)

Country[3]	2006	2007	2008	2009	2010
Brazil	958 [4]	1,173 [4]	1,200	1,200	1,200
India	5,000	5,000	5,000	5,000	5,000
Malaysia	894 [4]	682 [4]	233 [r]	25 [r]	30
Total	6,850	6,860	6,430 [r]	6,230 [r]	6,230

[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 9, 2011.

[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 ouput levels.

[4]Reported figure.