Rare Earth Elements

Rare Earth Elements - Special Mineral Feature

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Rare Earth Elements – Special Mineral Feature

INTRODUCTION

The 17 elements that make up the group of rare earth metals are as diverse in their applications as they are challenging to pronounce. The rare earths comprise the 15 lanthanide minerals (lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium), as well as yttrium and scandium. Yttrium and scandium, while not true rare earth elements (REE), are often included in the REE categorization as they exhibit many similar properties and characteristics of REE and are geologically found in the same mineral deposits. Promethium exhibits radioactivity, has no stable isotopes, and is not naturally present in orebodies.

REE are typically contained in the minerals bastnaesite, monazite, xenotime, eudialyte, apatite, and loparite. While REE are moderately abundant in the earth's crust, most are not concentrated sufficiently to make them economically exploitable. This geographic concentration of global rare earth production raises important issues of supply vulnerability.

REE are often divided into two categories, "light rare earth elements" and "heavy rare earth elements," according to each element's electron configuration. The light rare earth elements (LREE) include lanthanum (atomic number [Z] = 57) through to and including gadolinium (Z = 64). The heavy rare earth elements (HREE) include terbium (Z = 65) through to and including lutetium (Z = 71). Although yttrium (Z = 39) is the lightest REE, it is grouped with the HREE to which it is chemically and physically similar. The chemical and physical differences that exist within the REE group arise because of small differences in ionic radius and generally result in segregation of REE into deposits enriched in either light or heavy lanthanides plus yttrium. Scandium is also trivalent; however, its properties are not similar enough to classify it as either a LREE or HREE.[1]

GLOBAL IMPORTANCE

Over the past several decades, science has uncovered many of the properties of the rare earth elements, and their increasing use in industrial products has made them critical to many applications. Rare earth materials are used in most of the world's high-technology products. Because of their ability to readily release or accept electrons, REE have become uniquely indispensable to many electronic, optical, magnetic, and catalytic applications. From i-Pods to catalytic converters, to wind power generators, solar cells, computer disc drives and hybrid electric vehicles, rare earths are ubiquitous to high-technology applications and critical to the overall economic well-being of the global community. They are extensively used as fluid cracking catalysts in petroleum production and are considered indispensible in various military systems, such as missiles and precision-guided weapon systems.

Comprising only 3% of REE production by weight, the REE phosphor market is considered the most important in terms of dollar value. Colour television manufacturers stimulated demand for REE phosphors based on their use of yttrium and europium. More recently, REE phosphors have been used for signal amplification in fibre optics.

Permanent magnets can generate a stable magnetic field without the need for an external power source. As such, they are key components in the production of lightweight, high-powered motors and generators. Neodymium and samarium-cobalt are the two main types of permanent magnets. Of the two, neodymium magnets generate the strongest magnetic field while samarium-cobalt magnets are the most resistant to oxidation and high temperatures. According to Roskill Information Services Ltd., permanent magnets represent a rapidly growing market for rare earths.

The manufacture of permanent magnets includes the use of neodymium, praseodymium, and small amounts of dysprosium, samarium, and terbium. Permanent-magnet generators are used in the manufacture of wind turbines, allowing wind energy to be converted into electricity. Permanent-magnet motors are also used in electric vehicles and hybrid electric vehicles, allowing the energy stored in the vehicles' battery to be converted into mechanical power used for vehicle propulsion. REE used in permanent magnets have the capacity to significantly reduce the weight and size of the motor or generator. According to a 2011 *Critical Materials Strategy* report released by the U.S. Department of Energy, the trend towards wind turbines is to operate them at slower speeds, thus allowing electricity generation to occur at much lower wind speeds. The slower-speed turbines are achieved through direct-drive mechanics where the rotating blades directly couple to the generator. The lack of auxiliary gearing in the drive train reduces maintenance costs and is advantageous in remote or offshore locations. Large-capacity wind turbines increasingly use rare earth permanent-magnet generators. While rare earth permanent-magnet-containing wind turbines currently occupy a relatively small segment of the marketplace, their market share is likely to increase as the demand increases for larger wind turbine projects.

Cerium oxide-based powders are used to create a finished surface for glass products and glass-based electrical components. Polishing produces a smoothness on the glass such that light can pass through it without disturbances by surface irregularities. The use of rare earths in the polishing process involves a chemical reaction with the glass surface. Cerium oxide is slurried in a water solution to be used as the polishing agent. This results in a series of reactions, including dissolution of glass constituents such that the surface of the glass is removed or transformed during this polishing process.

Cerium is also useful as a de-colourizing agent in glass production. The presence of iron in the silica sand typically used to produce glass acts as a strong blue-green or brown-yellow colourant. The addition of cerium serves to oxidize the iron present in the silica, converting the iron into a low-adsorption colourless ferric form.

The use of REE as a catalyst accounts for roughly 18% of global use. A catalyst is a substance that increases the rate of a chemical reaction without undergoing any permanent chemical change itself. Rare earths are used in a wide range of catalytic applications due to their unique chemical characteristics. Cerium is widely used in the production of automotive catalytic converters to remove pollutants from vehicle emissions. Cerium, used in the platinum-based automotive catalysts, promotes the oxidization of unburnt hydrocarbons, allowing the conversion of carbon monoxide into carbon dioxide and reducing the release of nitrous oxide.

Rare earths are also used in the process of fluid catalytic cracking (FCC) in the refining of crude oil to produce lighter, more valuable fractions. The use of lanthanum in FCC catalysts provides the largest global market for this rare earth element and, together with cerium, enhances the oil refining separation process.

Rare earths are also used in a variety of metallurgical applications, including the production of metal alloys for nickel-metal hydride battery manufacture, as an additive in "super-alloys" of nickel-based or cobalt-base alloys used in aircraft turbine engines, and in the production of high-temperature aluminum alloys.

A range of rare earths (yttrium, cerium, lanthanum, praseodymium, gadolinium, and neodymium) are used in the production of advanced ceramic applications to improve hardness, strength, and corrosion resistance. Examples of specific applications include ceramic crucibles, resistors, humidity sensors, high-temperature cutting tools, and ceramic capacitors.

Other applications where REE are used include a variety of products such as computers, aircraft, monitors, television displays, radar systems, health care equipment, and clean water production.

In summary, REE use, as of 2012, is distributed in the following percentages: magnets (20%), metal alloys (19%), catalysts (18%), polishing (16%), phosphors (8%), glass (7%), ceramics (6%), and other uses (6%).[2]

GLOBAL SUPPLY AND DEMAND, 2011-16

Market experts[3] forecast growing demand for all REE over the next 5-10 years with their burgeoning use in high-technology applications and clean energy products.

The manufacture of permanent magnets is seen as one of the fastest growing markets for REE use. Global demand for rare earths in permanent magnets is expected to grow by 10-15% per year between 2011 and 2016. In 2012, the global market for permanent magnets was over US$7.4 billion and was predicted to grow to more than US$17 billion by 2020 with China taking an increasing share to account for nearly 75% of the market.

Neodymium-iron-boron (Nd-Fe-B) magnets will continue to be used over other types of permanent magnets in applications where high performance, high efficiency, small size, and cost are paramount. Samarium-cobalt magnets will continue to dominate in specialty high-temperature applications within the industrial, military, and aerospace industries where technical advantages in thermal stability and corrosion resistance outweigh other considerations. Growth in the rare earth permanent-magnet market will continue to come from traditional applications, mainly small electronic devices such as small motors, actuators, and sensors in automobiles as electrification of car systems increases, and from consumer electronics such as hard disk drives and CD-ROMs and DVDs. Growth will also come from the increased production of electronic bicycles in Asia and other geographic regions.

The use of Nd-Fe-B magnets in new “clean energy” technologies such as hybrid electric vehicle motors and generators, and permanent magnets for wind power turbines, could have a positive impact on growth from 2011. These technologies have not yet been fully established, but where Nd-Fe-B magnets are used, they are often consumed in larger tonnages than in more traditional magnet applications. These new markets will benefit from increasing regulatory controls on carbon emissions and from the fiscal stimuli being put in place by governments coming out of the economic downturn.

Forecast[4] non-China demand for REE is expected to increase from roughly 35 000 tonnes per year (t/y) in 2012 to more than 55 000 t/y by 2016. Non-China production of REE is forecast to increase tenfold over the same timeframe. Global demand for REE in 2020 is forecast to be between 200 000 and 240 000 tonnes (t) with the non-China demand roughly 70 000-90 000 t. With new production imminent from Molycorp’s Mountain Pass mine and Lynas’s Mount Weld mine, the non-China market should soon be self-sufficient in LREE. There will, however, remain a shortage of HREE. In 2008, China highlighted a potential shortfall in HREE supply within 10 years. No new sources of HREE have been brought on-line since that time and, with the rampant illegal mining and processing of rare earths in China largely focused on the “heavies,” resource depletion may be more serious than was earlier believed.[5]

China’s dominance in the international REE supply chain is the result of decades of strategic action to enhance its market position over these resources. Over a 30-year period, China has sought to develop, maintain, expand, and secure its REE monopoly. Until the mid-1990s, the United States was one of the principal producers of REE. China, with its ability to produce REE in abundance at very low prices, overtook global production as the privately owned U.S.-based mine was unable to economically compete. In 2008, China announced its inability to continue to produce REE for the global community and imposed export restrictions that encouraged the rest of the world to undertake exploration for rare earths. While China has large LREE resources, it has a limited resource supply of HREE. Its supply of HREE arises primarily from ionic clay deposits in the southern regions of the country, which may be depleted by 2018-20. As many of these heavy rare earths are critical in the manufacture of high-technology applications, China was able to use access to REE as an incentive to attract foreign manufacturers to relocate production to China.

China’s “de facto” monopoly on the production of REE has caused concern in many countries whose manufacturing base requires the use of these materials. In the absence of access to a stable supply of rare earths outside China, some companies have been forced to relocate a fraction of their production value chain to China in order to secure access to what has become a controlled resource. These concerns become more pronounced in industries that provide component parts for defence-related equipment, which may have national security implications.[6] While the amount of rare earths used in various applications is often relatively small, their availability and security of supply will often override monetary considerations. In these instances, governments may choose to intervene in the supply chain to secure a stable, essential source of these valued minerals.

IMPORTANCE TO CANADA

Canada has interests, both direct and indirect, in securing access to REE. While it directly imports small tonnages of the rare earth compounds of cerium and lanthanum for use in glass polishing and petrochemical metallurgy, the most significant impacts on Canada are related to imports of rare earth permanent magnets, or components that contain permanent magnets, for use in clean energy technologies and high-technology product applications. Canadian industries vulnerable to secure access to REE include: clean energy (wind turbines/solar cells), automobile and hybrid vehicle production, aerospace applications, defence applications, energy-efficient lighting, the electronic industries, and nuclear and medical applications. Many of Canada’s manufacturers in high-profile sectors are deeply integrated within supply chains involving producers in allied countries. In several high-profile sectors, Canadian manufacturers have sub-contracted component parts production to China for the assurance of guaranteed REE supply. While this loss of Canadian manufacturing may not be significant to Canada’s economy, the implications for relocated production are of concern to larger economies and the potential for the loss of complete product lines is considered real.

Wind Turbines

As of 2011, Canada operated 2858 wind turbines generating a total of 4820 megawatts (MW) of installed capacity. Roughly 600 of these wind turbines were produced using REE permanent magnets. Wind turbines driven by permanent magnets eliminate the need for internal gearboxes, thereby allowing the blades to turn at the same speed as the generator. Typically, the larger the wind turbine, the more likely is the use of REE technology due to operational efficiencies, lower maintenance requirements, and less downtime over a generator’s 20-year lifespan. Offshore turbine projects are large by design and almost always incorporate REE and permanent magnets. A shortage or unavailability of critical REE could necessitate an entire retooling and construction redesign to accommodate less efficient induction motor technology.

Automotive Uses

Canada is home to 10 vehicle assembly plants owned by 5 manufacturing companies producing 29 models of automobiles. Each of these vehicles uses REE permanent magnets for various components, motors, or ancillary equipment within the product line. In addition, all vehicles contain a catalytic converter that transforms carbon monoxide and ozone into carbon dioxide and oxygen. REE coatings on the catalyst surface play a critical role in the chemical reactions within a converter and enable the reactions to occur at high temperatures.

Hybrid and electric vehicles (EV) use significantly larger percentages of REE permanent magnets than traditional internal combustion automobiles. Hybrid and EV reduce hydrocarbon consumption by replacing or supplementing the internal combustion engine with a battery-powered electric traction drive. REE are used within the nickel-metal hydride battery, the electric traction motor, and the regenerative braking system. A typical hybrid vehicle contains approximately 28 kilograms of REE. While there is currently limited manufacture of hybrid and/or EV in Canada, consumer demand is expected to increase significantly as technology evolves and prices decline.

Aerospace/Aircraft Applications

Canada's aerospace industry includes more than 90 companies regrouped within the Aerospace Industries Association of Canada. Many of these companies are internationally recognized, leading manufacturers of aircraft and aerospace products and are active in developing, designing, assembling, and manufacturing various components, parts, and in some instances, aircraft for the global aerospace industry. REE are indispensible in the manufacture of many component parts used in these high-technology aerospace applications. Secure access to a constant and consistent supply of REE is required for design and production needs. Within this unique sector, many of the component parts manufactured for use in new-age aircraft for military, civilian, or aerospace use involve cutting-edge technologies where the protection of intellectual property becomes paramount. In these circumstances, manufacturers are legitimately concerned that sub-contracting the manufacture of component parts to companies operating in foreign countries opens up an opportunity for intellectual property to be compromised.[7] Direct purchase of the REE guarantees the security of intellectual property for some component parts.

Defence Industries

A special case for REE use involves the defence industry. Many countries remain deeply concerned about their reliance on REE-containing component parts sourced from foreign countries that may be installed in critical defence-related products. The following is a partial listing of critical REE-related defence applications. None of these defence systems can be sustained without reliable REE technology supply chains.[8]

- **Electronics** (REE use: Nd, Dy, Tb, Eu, Y): for energy storage, density amplification, and capacitance in jamming devices, electromagnetic railguns, area denial systems, metal-hydride batteries, and long-range acoustical devices.

- **Optical Systems (**REE use: Eu, Y, Tb): for amplification, colour and useful life in advanced lighting, avionics, computer displays, night vision, and fibre optics.

- **Power, Stealth, Fuel Efficiency (**REE use: Nd, Pr, Sm, Dy, Tb): for compactness and permanent magnets in electric drive motors (selected examples include hub-mounted electric traction drives, future combat hybrid power systems, joint strike fighter aircraft, electric aircraft, integrated starter generators, and stealth technologies).

- **Surveillance and Detection (**REE use: Nd, Y, La, Lu, Eu): for amplification and enhanced resolution of signals in radar, sonar transducers, multi-purpose integrated chemical agent alarms, and enhanced gamma-ray radiation detection.

- **Communications (**REE use: Nd, Pr, Dy, Tb, Eu, Y): for actuators and amplifiers in computer disc drives, voice coil motors for audio, satellite communications, microwave communications, and traveling wave tubes.

- **Lasers (**REE use: Y, Eu, Tb): for amplification of energy and resolution in laser targeting, sabershot photonic disruptors, Boeing's laser avenger (for countering improvised explosive devices [IEDs]), air-based lasers, and future combat systems vehicles with laser weapons.

Within this defence sector, many Canadian manufacturers are, at times, active in supplying various components to foreign country defence industry contractors as part of global supply chains. As a policy, several countries are insisting that the future supply of REE-containing components be sourced from secure supply channels. This directive may place increased pressure on the Canadian aerospace sector to secure alternative sources of supply for REE-containing components.

Miscellaneous Applications

There is a host of other applications that require access to and use of REE that may have either a direct or indirect impact on Canada

- **High-Technology Miniaturized Products:** High-technology applications characterize the modern era, with digital products contributing to every part of modern life. REE facilitate this technology with new materials and novel applications that enable the use of more efficient, higher-performance materials that meet the demand for faster, smaller, and lighter products with longer battery life. REE permanent magnets are installed in all computer hard drives, CD-ROM drives, and DVDs. The voice coil motor that controls the arm that reads and writes information onto the disk requires an REE permanent magnet to provide better control, allowing thinner tracks and more information storage. In portable electronics, tiny permanent magnets are used to drive the speakers in earphones, resulting in smaller, lighter speakers with faster base response and lower overall distortion. Such technology would not be possible without the role played by REE.

- **Lasers:** Yttrium-aluminum-garnet crystals are used in the production of solid-state lasers used in eye surgery for repairing damage and removing cataracts. Tumours can be treated in certain areas of the body with lasers and ruptured blood vessels can be sealed.

- **Nuclear:** REE are used in nuclear reactors due to their ability to absorb neutrons and remain stable at high temperatures. Neutron absorbers are used to lower high levels of radioactivity, particularly during the initial use of fresh fuel. REE are also used in the manufacture of various nuclear control rods.

- **Electron Microscopes:** Lanthanum is used as the cathode in generating the electron beam in an electron microscope. Lanthanum emits electrons with densities 10 times greater than those produced by tungsten, which is the typical material used in the production of microscopes. The use of lanthanum allows higher thermal stability, lower vapour pressure, smaller electronic function, higher brightness, and lower energy spread.

- **Medical Applications:** Gadolinium is used as a contrast agent to enhance images taken by magnetic resonance image (MRI) scanners. The use of gadolinium improves the effectiveness of an MRI scanner fortyfold over traditional contrast agents. Solutions of gadolinium complexes are applied intravenously to the patient, where they collect in abnormal brain or body tissues, improving the clarity of the MRI.

In summary, the highest growth in demand for REE in Canada is expected to be in magnets and metal alloys for use in clean energy technologies and high-technology applications. These will include automobiles, hybrid and electric vehicles, aerospace, wind turbines, solar cells, and lighting applications. Progress in these fields will increase competition for global access to REE. While alternatives to REE are being evaluated, no substitutes have yet been found that provide an equivalent standard of performance. For Canada and many allied trade partners, REE form the economic and technical foundation upon which to build a more fuel-efficient, technologically advanced nation. Given the widespread use of REE and their unique properties, it appears that the world's appetite for REE will continue to grow. As such, it is in Canada's best interests to work with like-minded countries to secure a long-term, stable supply of REE without being dependent upon any one country.

Canada also has upstream manufacturing interests as a potential future supplier of REE deriving from the mining industry.

CANADIAN MINES OVERVIEW

The REE situation in Canada remains quite promising. While Canada does not currently produce any rare earths, there are more than 200 exploration projects targeting REE, and they are successfully attracting investment dollars to further their exploration work. The number of exploration projects has more than doubled in the past year consequent to the heightened media attention focused on REE. Canada has long been recognized as having a strong junior mining sector, and the robustness of this sector is exemplified in the REE marketplace. Many of the junior exploration companies have leveraged recent media attention surrounding the export restrictions being imposed by China and the critical need for rare earths in clean energy technologies, and have recast their exploration focus to include REE. While it is unlikely that many of these 200 projects will ever produce or even discover economical concentrations of the lanthanide metals, they have successfully leveraged global attention to attract financial investments in their companies. These exploration investment inputs will undoubtedly lead to the discovery of some resource materials, if not explicitly rare earth elements.

The process of exploring for, discovering, and ultimately bringing a mineral resource to the marketplace can take many years. There are, however, a number of Canadian rare earth exploration companies that have been active in this field for many years and whose mining projects are at an advanced level of development.

For all stages of development, the distribution of REE projects across Canada is: Quebec, 73; Ontario, 39; British Columbia, 38; Newfoundland and Labrador, 21; Saskatchewan, 9; New Brunswick, 8; Manitoba, 7; Nova Scotia, 4; the Yukon, 3; the Northwest Territories, 2; and Nunavut, 2.

Quebec accounts for 35% of the projects, Ontario for 19%, British Columbia for 18%, Newfoundland and Labrador for 10%, and all other provinces and territories for less than 10%. Alberta and Prince Edward Island have no projects.

It is not only the geological factors that influence the number of rare earth projects in a jurisdiction. A lack of infrastructure and/remoteness tend to increase costs, thereby reducing the number of projects, but jurisdictions with larger areas have greater potential for favourable geological environments.

Project-Development Stages

The stages of development from early geological reconnaissance to the life cycle of development and operation are:

- Grassroots exploration
- Exploration
- Advanced exploration
- Prefeasibility/scoping
- Feasibility
- Building or construction
- Operation
- Closure

As companies progress through these stages, money and effort are spent over time to reduce uncertainty. Most grassroots exploration is eventually abandoned without development and many sites are never drilled. Exploration effort is expended to characterize the mineralization to the point where a resource level may be established. Economic scenarios and development strategies are used to evaluate the potential profitability of the mineralization. Only if the economics have the potential to be profitable and the mineralization is sufficiently rich and extensive can the project pass to the next stage of development.

CANADIAN ADVANCED REE PROJECTS

Of the more than 200 exploration projects in Canada, there are 14 that may be classified as “advanced” in that they have a defined level of mineral resources or mineral reserves.

Avalon Rare Metals Inc. - Nechalacho-Thor Lake Deposit

Avalon Rare Metals Inc. is developing the Nechalacho-Thor Lake deposit in the Northwest Territories. It contains approximately 28% HREE. Target production of roughly 10 000 t/y is projected to commence in 2016/17. A bankable feasibility study is to be completed by 2013 and construction could begin in 2014. Avalon is considering integrating its own REE separation plant with a facility in Louisiana, United States, to produce individual rare earth oxides. Capital costs for an integrated mine, mill, and metallurgical plant could exceed US$890 million. Avalon has identified some 14.5 million tonnes (Mt) of probable reserves at its Thor Lake deposit grading 1.53% total rare earth oxides. Recoverable by-product minerals include zirconium, niobium, and tantalum. Information on the Thor Lake geology is available on the Internet at http://avalonraremetals.com/projects/thor_ lake/thor_lake_intro/NR_ 10-09_Probable_Mineral_ Reserves.pdf and at www.avalonraremetals.com/projects/thor_lake/prefeasibility_study/. Avalon’s technical report can be viewed at www.avalonraremetals.com/_resources/reports/SWRPA_Avalon_Thor_ Lake_43-101.pdf.

Commerce Resources Corporation - Ashram Project

Commerce Resources Corporation is an exploration and development company with a particular focus on deposits of rare metals and rare earth elements. The company is specifically focused on the development of its Upper Fir tantalum and niobium deposit at the Blue River project in British Columbia and its Ashram rare earth project in Quebec. Commerce Resources has successfully completed preliminary economic assessments for both the Blue River project and the Eldor property, which contains the Ashram project.

The Eldor property is located in the Nunavik region of Quebec approximately 130 kilometres (km) south of Kuujjuaq and is only accessible by float plane or helicopter, or by snowmobile in the winter months. In 2012, Commerce Resources completed a preliminary economic assessment on the Ashram project that showed 29 Mt of measured and indicated resources and 219 Mt of inferred resources averaging 1.88% total rare earth oxides at a cut-off grade of 1.25%, of which roughly 9% was heavy and middle REE. The rare earth minerals are primarily monazites and, to a lesser extent, bastnaesite and xenotime. Commerce Resources estimates an annual production of 16 000-17 000 t of rare earth oxides over a mine life of 25 years. Further information on the Ashram project is available on the company's Internet site at www.commerceresources.com/s/Eldor.asp.

DNI Metals Inc. - Buckton Project

DNI Metals Inc. holds a 2720-square-kilometre (km^2) (272 000 hectares [ha]) land position in northeastern Alberta, 120 km north of Fort McMurray, over polymetallic black shales that are locally enriched with molybdenum, nickel, uranium, vanadium, zinc, copper, cobalt, silver, gold, lithium, specialty metals (e.g., scandium and thulium), and REE. The Alberta land position was assembled during 2007-09. DNI has advanced one of the mineralized systems, the Buckton Mineralized Zone, to an initial NI 43-101 technical report that classified inferred resources representing 227 t of mineralized black shale grading 0.03% total REE. The resource also contains concentrations of molybdenum, nickel, uranium, vanadium, zinc, copper, cobalt, and lithium. Further information on the Buckton project can be obtained from the company's web site at www.dnimetals.com.

GéoMéga Resources Ltd. - Montviel Project

GéoMéga Resources Ltd. is a Canadian-based exploration company focused on the discovery and development of mineral deposits in the Quebec region. GéoMéga's exploration projects include seven graphite deposits and the Montviel rare earth project. The Montviel project is located north of the Abitibi mining region in Quebec, which is 45 km west of the Cree First Nation of Waswanipi and 97 km north of Lebel-sur-Quévillon. A 2011 NI 43-101 resource estimate noted 183.9 Mt of indicated resources grading 1.453% total rare earth oxides with a cut-off grade of 1.00% and containing less than 1% HREE content. The estimate noted a further 66.7 Mt of inferred resources grading 1.460% total rare earth oxides using a 1.00% cut-off grade. A 2012 drilling program revealed a HREE enrichment zone located on the southern periphery of the Core Zone. Disclosure of an updated NI 43-101 resource estimate is scheduled for release in early 2013. Further information concerning GéoMéga and its Montviel project can be found on the company's web site at www.ressourcesgeomega.ca.

Great Western Minerals Group Limited - Hoidas Lake Project

Great Western Minerals Group, a Canadian-based company, holds a 100% interest in the Hoidas Lake project in Saskatchewan. The company is an integrated rare earth processor whose specialty alloys are used in the battery, magnet, and aerospace industries. Great Western Minerals has operating production facilities in the United States and the United Kingdom. The Hoidas Lake project is 100% owned by Great Western Minerals. It has one of the highest proportions of neodymium present in any known rare earth deposit (22%), making it strategically important to the permanent magnet industry.

Resource estimates include measured resources of 0.983 Mt grading 2.568% rare earth oxides, indicated resources of 1.597 Mt grading 2.349% rare earth oxides, and inferred resources of 0.286 Mt grading 2.139% rare earth oxides. Great Western Minerals has focused on the metallurgy of Hoidas Lake with the goal of designing an optimal concentration/leaching process for the ore. The project could proceed through the preliminary feasibility stages with a goal of being in production by 2016/17. Further information on the Hoidas Lake project can be obtained on the company's web site at www.gwmg.ca/html/projects/hoidas-lake/index.cfm.

IAMGOLD Corporation - Niobec Project

IAMGOLD Corporation is a Canadian-based mid-tier gold producer with five operating gold mines on three continents. In Quebec, Canada, the company operates Niobec Inc., which is one of the world's leading producers of niobium, and owns an REE resource close to its niobium mine. The Niobec property contains a carbonitite complex and is located 13 km north of Ville de Saguenay (Chicoutimi) in the limits of the municipality of St-Honoré, Quebec. Based on a 2011 drill program, a NI 43-101 technical report indicated inferred resources of 466.8 Mt at a grade of 1.65% total rare earth oxides, including 0.031% heavy rare earth oxides. This corresponds to approximately 98.1% LREE and 1.9 % HREE. IAMGOLD anticipates conducting a scoping study to be published in 2013 that will define the significance of the rare earth resource and foresees a funding strategy that would include joint-venture partners and strategic alliances. Further information on this property can be found on the company's web site at www.iangold.com.

Matamec Explorations Inc. - Kipawa Project

Matamec Explorations Inc. is a junior mining company whose main focus is developing the Kipawa deposit for the production of REE and zirconium. In parallel, the company is exploring in the Kipawa Alkalic Complex for rare earths-yttrium-zirconium-niobium-tantalum mineralization on its Zeus property. Matamec is also exploring for gold, base metals, and platinum group metals. Its gold portfolio includes the Matheson joint-venture property located in close proximity to the Hoyle Pond mine in the prolific mining camp of Timmins, Ontario. In Quebec, Matamec is exploring for lithium and tantalum on its Tansim property and for precious and base metals on its Sakami, Valmont, and Vulcain properties. As well, together with Northern Superior Resources Inc., it is exploring for gold on the Lespérance/ Wachigabau property.

Matamec has established a partnership with Toyota Rare Earth Canada Inc., a subsidiary of Toyota-Tsusho Corporation, to collaborate to accelerate development of the Kipawa deposit. According to the agreement, Toyota can acquire a 49% undivided interest in the Kipawa deposit with an offtake agreement to buy 100% of the mixed rare earth concentrate. Toyota will arrange with Matamec the financing for the mine through to production. This agreement effectively secures for Toyota a HREE supply for the production and marketing of hybrid vehicles.

The Kipiwa deposit contains an estimated mineral resource of 19 Mt of indicated and inferred resources grading 0.428% total rare earth oxides with a 36% concentration of HREE plus yttrium. Production of roughly 5000 t/y is estimated to begin by 2016. Further information on Matamec's Kipiwa deposit can be viewed on the company's web site at www.matamec.com/2011/06/matamec-announces-63850-tonnes-of-indicated-and-17780-tonnes-of-inferred-treo-at-kipawa/.

Orbite Aluminae Inc. - Grande-Vallée Project

Orbite Aluminae Inc. is a Canadian exploration company that is developing a technology for the production of smelter-grade alumina, high-purity alumina, and high-value elements, including rare earths and rare metals, from a variety of sources such as aluminous clay and bauxite without generating the toxic red mud residue that the traditional Bayer process produces. Orbite also owns exclusive mining rights over a total of 60 984 ha, including the 6665-ha Grande-Vallée property, which is the site of an aluminous clay deposit in Quebec. Importantly, REE are to be considered as by-products arising from the production of alumina. A 2012 NI 43-101 compliant report identified over 1 billion t of aluminous clay in this deposit containing roughly 600 000 t of total rare earth oxides, of which close to 16% are HREE plus yttrium. Orbite has begum construction activities at the high-purity alumina plant located in Cap-Chat, Quebec, and expects to achieve production by the second quarter of 2013. Orbite has the capacity to produce roughly 1000 t/y of rare earth oxides. Further information on Orbite can be obtained on its web site at www.orbitealuminae.com.

Pele Mountain Resources - Eco Ridge Project

Pele Mountain Resources' Eco Ridge mine is located in Elliot Lake, Ontario, and is the only Canadian mining camp to have ever achieved commercial REE production. The Eco Ridge mine was formerly operated by Rio Algom and Denison Mines from 1956 to 1996. The mining operation recovered REE as a by-product of uranium production. Pele's recent NI 43-101 preliminary economic assessment provided an assessment of 48.7 Mt of indicated resources grading 0.1157% total rare earth oxides and 37.8 Mt of inferred resources grading 0.1100% total rare earth oxides using a cut-off grade of 0.028% U_3O_8.

Eco Ridge anticipates mine construction to begin in 2016 and, apart from the annual production of uranium, may potentially produce 5000 t/y of REE over a 14-year span. Eco Ridge contains roughly a 10% concentration of HREE in its total rare earth resource. Further information on the Eco Ridge project can be viewed on Pele's web site at www.pelemountain.com.

Quest Rare Minerals Ltd. - Strange Lake "B" Zone Project

Quest Rare Minerals Ltd. is a Canadian-based exploration company focused on the identification and discovery of new world-class rare earth deposit opportunities. Quest is currently advancing several high-potential rare earth projects, including in the Strange Lake and Misery Lake areas of northeastern Quebec and the Plaster Rock area of northwestern New Brunswick. The Strange Lake project is the most advanced of Quest's portfolio and is located 220 km northeast of Schefferville, Quebec, covering an area of 54 000 ha. During the summer of 2010, a drilling program included the expansion of several 2009 drill holes coupled with an additional 78 new drillings totaling 14 267 metres (m). By the end of 2010, the drill hole database consisted of 91 drill holes for a total of 17 474 m.

The mineral resource estimates for the Strange Lake "B" Zone deposit at a 0.50% total rare earth oxides cut-off grade were indicated resources of 278.1 Mt grading 0.933% total rare earth oxides plus yttrium and an inferred resource of 214.4 Mt grading 0.85% total rare earth oxides plus yttrium. The "B" Zone mineral resource estimate indicates a concentration of roughly 38% HREE contained in the total rare earth deposit. Recoverable by-product minerals include zirconium, niobium, and hafnium. Annual production of 10 000-12 000 t is expected to commence in 2017/18. Further information on the Strange Lake project can be found on Quest's web site at www.questrareminerals.com.

Rare Earth Metals Inc.

Rare Earth Metals Inc. is a Canadian exploration company based in Thunder Bay, Ontario, that is presently developing several rare earth properties in Ontario and Newfoundland and Labrador that exhibit multi-element potential (REE, niobium, beryllium, zirconium, and iron ore) and that are in proximity to available infrastructure.

Clay-Howells Project

Rare Earth Metals Inc.'s Clay-Howells deposit is located in northern Ontario roughly 50 km north-northeast of Kapuskasing. REE-bearing minerals within the Clay-Howells deposit are complex, but primarily consist of a cerium-lanthanum-calcium (Ce-La-Ca) silicate and monazite (or phosphate phases similar in composition to monazite). A high iron-REE mineral (fergusonite) and allanite are also observed in trace amounts. Monazite, apatite, and a Ce-La-Ca silicate are the three main mineral groups hosting the REE. The REE-bearing minerals are typically very coarse grained with approximately 50% of the distribution occurring as grains greater than 100 microns wide. The mineral resource estimate for the deposit, at a 0.6% total rare earth oxides cut-off grade, is an inferred resource of 8.5 Mt at 44.15% iron oxide (Fe_2O_3) and 0.73% total rare earth oxides. The project contains an estimated 9% concentration of HREE. The company has drilled 18 diamond drill holes in the main carbonatite/magnetite zone and an additional 8 diamond drill holes in surrounding magnetic anomalies of the Clay-Howells project. Further information can be obtained from the company's web site at www.rareearthmetals.ca.

Lavergne-Springer Project

Rare Earth Metals Inc.'s Lavergne-Springer project is located in Springer Township, immediately north of the town of Sturgeon Falls and 80 km east of Sudbury, Ontario. In 2012, the company announced its initial NI 43-101 compliant resource estimate in respect of the Lavergne-Springer project indicating 4.2 Mt of an indicated resource grading 1.14% total rare earth oxides with an approximate 6% concentration of HREE at a cut-off grade of 0.9% and 12.7 Mt of inferred resources grading 1.17% total rare earth oxides with an approximate 4% concentration of HREE at a 0.9% cut-off grade. Additional information can be found on the company's web site at www.rareearthmetals.ca.

Two Tom Project

A 2012 NI 43-101 technical report was produced on Rare Earth Metals Inc.'s Two Tom deposit in the Red Wine Complex in central Newfoundland, Canada. The deposit is situated approximately 140 km northeast of Churchill Falls and 160 km northwest of Happy Valley-Goose Bay, Newfoundland and Labrador. The Red Wine Complex consists of 46 claims covering an area of 11.5 km^2. The Two Tom deposit is situated within the eastern end of the Complex. The deposit's mineral resource is classified as having inferred resources of 41 Mt at 1.18% total rare earth oxides with a 0.6% cut-off grade and containing roughly a 6% HREE content. The resource further identifies 0.26% niobium pentoxide and 0.18% beryllium oxide. Additional information can be found on the company's web site at www.rareearthmetals.ca.

Search Minerals Inc. - Foxtrot Project

Search Minerals Inc. is a Canadian-based exploration company that is developing the Foxtrot project located in the Port Hope Simpson district in southeastern Labrador. The company has a number of other mineral prospects in its portfolio located in Newfoundland and Labrador, including claims in the Strange Lake Complex in northern Labrador and at the Red Wine Complex in western Labrador. A 2012 NI 43-101 compliant mineral resource estimate identified 3.41 Mt of indicated resources grading 1.09% total rare earth oxides and containing 0.21% HREE (20%) and 5.85 Mt of inferred resources grading 0.96% total rare earth oxides and containing 0.21% HREE. Further information on this project can be found on the company's web site at www.searchminerals.ca.

CONCLUSIONS

The use of rare earths is critical to a wide variety of industries and the world will continue to rely upon China as a sole source for heavy rare earths until new production can be brought to the marketplace. A quick review of the advanced rare earth exploration projects globally indicates that China's dominance as a global supplier of HREE is likely to persist until 2016 -18. Throughout this period, industries that require access to HREE will be obliged to obtain supplies via exports from China or to sub-contract component parts production to China.

China’s recent domestic measures to consolidate control over its REE mining and processing industries have seen a significant reduction in the number of companies permitted to mine and process REE, and an equivalent increase in the control of domestic mining and processing in the hands of state-owned enterprises. This corporate consolidation may allow China to exert more direct control on production, trade, and pricing of these resource materials.

Much of China’s policy direction related to the use of rare earths and, for that matter, the use of many raw materials, may not be consistent with traditional commercial market-based objectives. Rather, China’s policy objectives appear to favour state influence over entire value chains through to the production of final consumer and industrial products. Full employment, and potentially other strategic considerations, would appear to be some of the policy drivers which, if correct, could override considerations of financial profitability directed towards increasing shareholders’ wealth.

In relation to Canada’s role as a potential future producer of REE, a review of the Canadian advanced exploration projects reveals that many contain elevated concentrations of HREE. It is possible that Canada could, over the next 10 years, become a major global supplier of HREE. Consideration should be given to providing support for exploration companies seeking to advance their REE mine projects and potentially provide a valued resource to the global community.

SOURCE NOTES

[1] International Union of Pure and Applied Chemistry.

[2] Source: Industrial Minerals Company of Australia (IMCOA).

[3] IMCOA 2012; Roskill Information Services Ltd.; Technology Metals Research (TMR); U.S. Department of Energy.

[4] IMCOA.

[5] IMCOA, *The Global Rare Earths Industry: Poised for Growth*, November 2012.

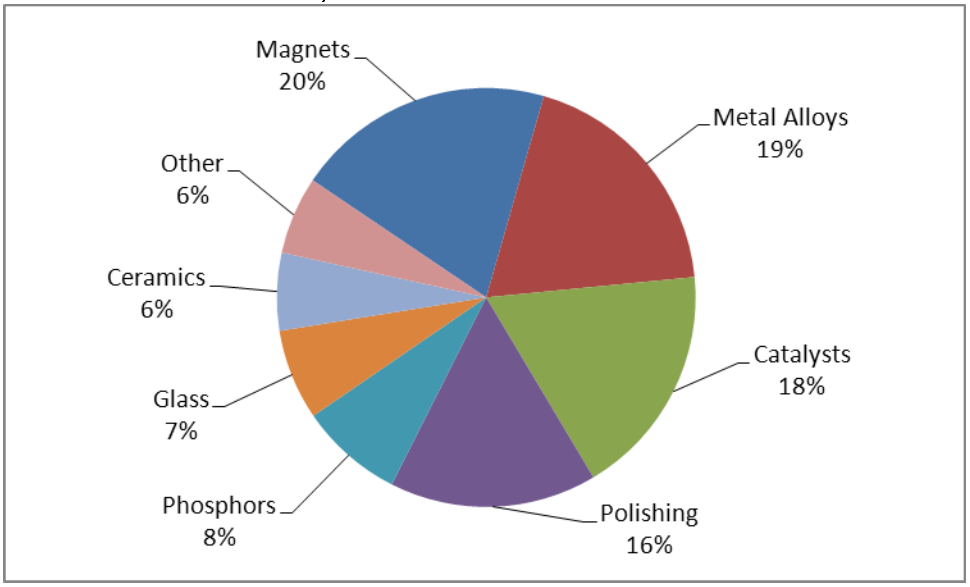
[6] Congressional Research Service, September 5, 2012.

[7] Congressional Research Service, September 6, 2011, p. 17; *Financial Post*; Interview with Constantine Karayannopoulos, Chief Executive Officer, NEO Material Technologies Inc., November 20, 2010.

[8] American Resources Policy Network Report.

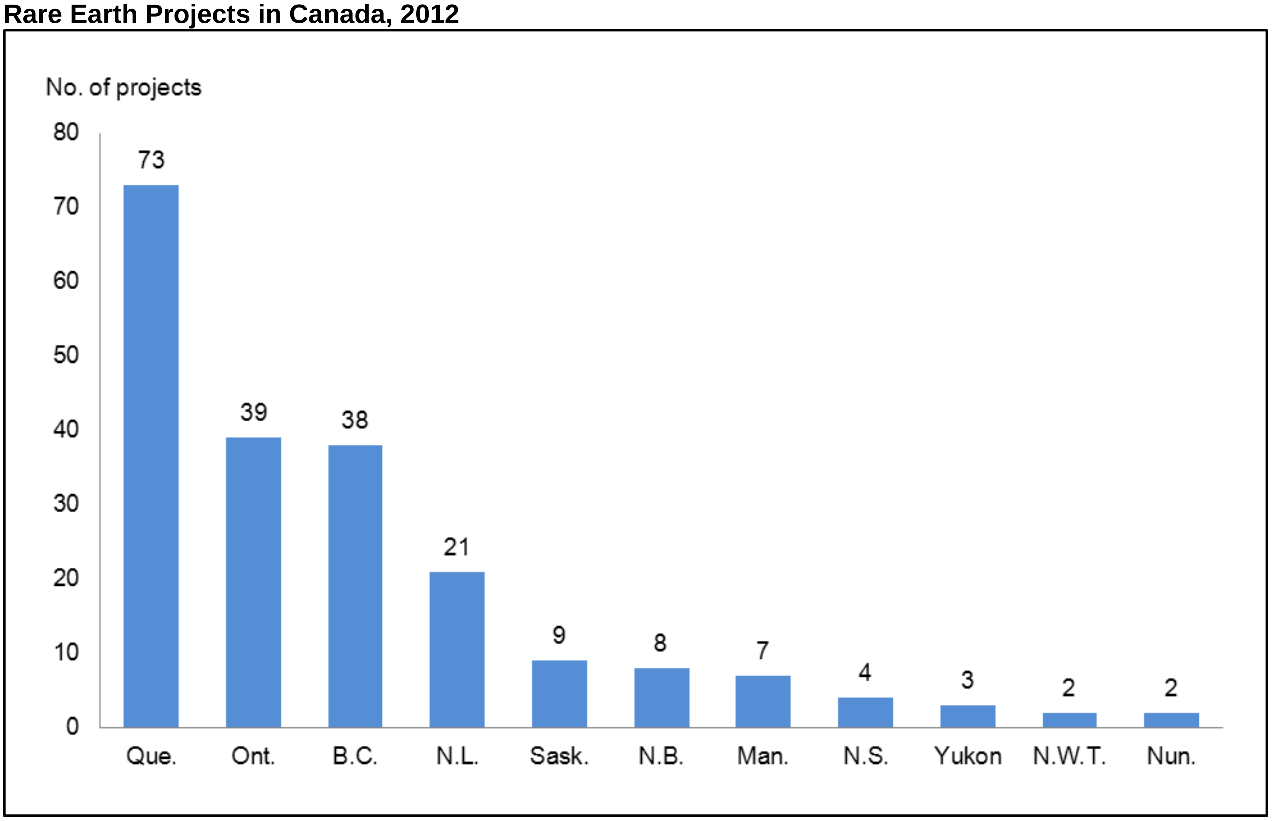
Note: Information in this article was current as of June 2012.

Figure 1
Rare Earth Elements Use, 2012



Source: Industrial Minerals Company of Australia.

Figure 2
Rare Earth Projects in Canada, 2012



Source: Natural Resources Canada.

TABLE 1. CHEMICAL INFORMATION

Chemical Element	Atomic Number	Atomic Weight	Melting Point (degrees Celcius)
Lanthanum (La)	57	138.9	920
Cerium (Ce)	58	140.1	795
Praseodymium (Pr)	59	140.9	935
Neodymium (Nd)	60	144.2	1 024
Promethium (Pm)	61	146.0	1 042
Samarium (Sm)	62	150.4	1 072
Europium (Eu)	63	152.0	826
Gadolinium (Gd)	64	157.2	1 312
Terbium (Tb)	65	158.9	1 356
Dysprosium (Dy)	66	162.4	1 407
Holmium (Ho)	67	164.9	1 461
Erbium (Er)	68	167.2	1 529
Thulium (Tm)	69	169.9	1 545
Ytterbium (Yb)	70	173.0	824
Lutetium (Lu)	71	174.9	1 652

Source: International Union of Pure and Applied Chemistry.

TABLE 2. FORECAST RARE EARTH OXIDES SUPPLY AND DEMAND, 2012 AND 2016

Rare Earth Oxide	Production (tonnes)		Demand (tonnes)	
	World	ROW	World	ROW
2012				
Light Rare Earths (La, Ce, Pr, Nd)	95 000	10 000	100 000	30 000
Medium Rare Earths (Sm, Eu, Gd)	4 000	250	2 500	750
Heavy Rare Earths (Tb, Dy, Er, Y)	7 000	75	10 000	3 000
2016				
Light Rare Earths (La, Ce, Pr, Nd)	165 000	60 000	145 000	50 000
Medium Rare Earths (Sm, Eu, Gd)	6 000	1 350	4 250	1 500
Heavy Rare Earths (Tb, Dy, Er, Y)	7 000	750	14 500	5 000

Source: The Industrial Minerals Company of Australia.

ROW Rest of world (world minus China).

TABLE 3. CANADA, DISTRIBUTION OF RARE EARTH PROJECTS BY STATUS FOR ALL JURISDICTIONS, 2012

Status	Alta.	B.C.	Man.	N.B.	N.L.	N.S.	N.W.T.	Nun.	Ont.	P.E.I.	Que.	Sask.	Yukon	Canada
Operating	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Building	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Feasibility	–	–	–	–	–	–	–	–	3	–	1	–	–	**4**
Pre-feasibility, scoping	–	–	–	–	–	–	1	–	1	–	2	1	–	**5**
Advanced exploration	–	3	–	–	–	–	–	–	4	–	2	1	–	**10**
Exploration	–	3	2	4	5	1	–	1	13	–	17	2	–	**48**
Grassroots	–	29	5	4	16	3	1	1	16	–	50	5	3	**133**
Closed	–	–	–	–	–	–	–	–	2	–	–	–	–	**2**
Unknown	–	3	–	–	–	–	–	–	–	–	1	–	–	**4**
Total	–	**38**	**7**	**8**	**21**	**4**	**2**	**2**	**39**	–	**73**	**9**	**3**	**206**

Source: Natural Resources Canada.