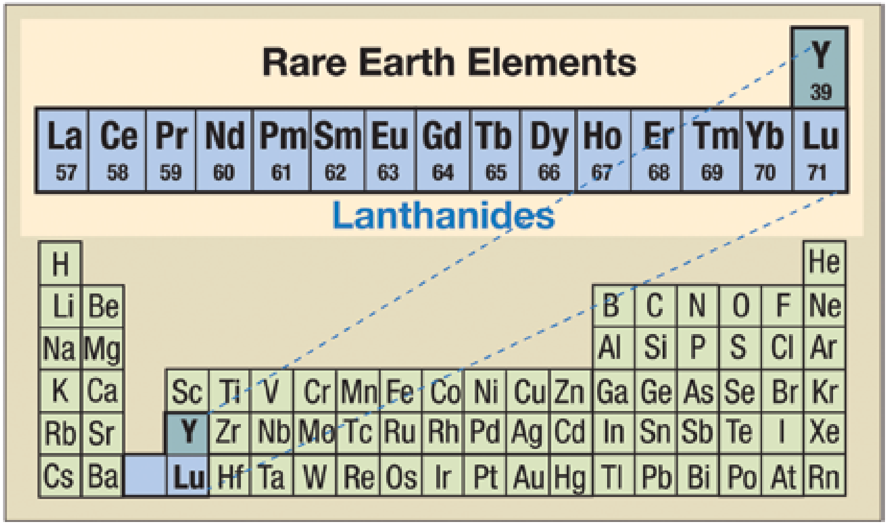
Rare Earths RESTRICTED

(Credit: Ames Laboratory)

by Wendy Hankle

If you head south on the periodic table of elements, names like lanthanum, cerium, neodymium and dysprosium pop into view. For those who aren't well versed in the ways of rare earth elements, these terms might not mean much. But for those who understand the importance of REEs to industry, especially green industry, well, they might as well be looking at the words "hybrid car battery" and "ceramic oxide superconductor."

Seventeen elements make up REEs: 15 in the lanthanide series, and scandium and yttrium. And, when you consider the range of places REEs can be found, they seem anything but rare.



But industry, researchers, and even some members of Congress have started to make noise lately about what appears to be a Chinese corner on the market – raising fears that dwindling suppliers could mean less REEs available for advanced applications, research and even national security.

Rare elements? Or rare competition?

Today, China produces the lion's share of REEs, 95–98 percent, for the world. The list of uses of REEs is dizzying: cerium, lanthanum, neodymium, europium, all used in glass additives; europium and yttrium, used in fiber optics and energy-efficient light bulbs; neodymium, praseodymium, terbium and dysprosium, used in computer hard drives, mobile phones, camera, and hybrid electric motors and batteries.

Makers of hybrid and electric cars are large consumers. Typical is Toyota's Prius, which requires 1 kilogram of neodymium overall and 10 kilograms of lanthanum for the battery, itself.

The problem with the supply isn't how much there is – it's how to get your hands on it. Mining the ore is only the first step. Once the mineral deposit is mined, the ore then has to be separated into individual rare earth oxides, which are then refined into metals. Metals are formed into alloys, and, finally, the alloys are manufactured into components.

It's a painstaking process – and one not undertaken currently in the United States. In fact, a summary by the U.S. Geological Survey looking at where the U.S. gets its REEs was released in January, using data up to 2008. The report found that the U.S. has a full dependency on imports. From 2005 to 2008, 91 percent of its consumption came from China, 3 percent from France, 3 percent from Japan, 1 percent from Russia and 2 percent from other sources.

Unfortunately, since 2008, the potential problems and risks with such a dependency on China are looming even larger. Recently, the Chinese government has adopted domestic production quotas and decreased export quotas for REE products. This, along with increasing export taxes on all REEs to a range of 15 to 25 percent, is sending U.S. government and industry scrambling for strategies.

But it wasn't always this way. In the mid-20th century, most of the world's REEs were mined in India, Brazil and South Africa. The U.S. had its own supply, the prolific Mountain Pass rare earth mine in California. Mountain Pass served as the primary source of REEs from mid-century to the mid-1980s.

But the trouble started in the late 1990s and continued into the new millenium. In 1998, the Mountain Pass separation plant closed after regulatory and environmental problems with the main wastewater pipeline. *Altantic* magazine reported that chemical processing at the mine was stopped after a series of wastewater leaks in which hundreds of thousands of gallons of water carrying radioactive waste spilled into and around Ivanpah Dry Lake. In 2002, the mine fully suspended operations.

According to USGS data, the mid-2000s in the U.S. also saw a departure of permanent-magnet production sites that used REEs: Magnequench moved to China in 2003; the Elizabethtown, Ky., operations of Germany's Vacuumschmelze closed, also in 2003; and


(Credit: Molycorp Minerals.)

Molycorp Minerals' Mountain Pass mine in California served as the primary source of rare earth elements from mid-century to the mid-1980s.

(Credit: Wikipedia Commons.)

China's internal demand of rare earth elements is increasing dramatically because of the robust growth they've been experiencing in the manufacturing sector. They are consuming more and more of their own rare earth elements.

Hitachi Magnetic Corp. shuttered its Edmore, Mich., production facility in 2005.

Alarm bells

The issue of REE shortages recently caught the eye of Congress. In March 2010, the Subcommittee on Investigations and Oversight of the House Committee on Science and Technology held a conference to elicit testimony from key industry and academic experts regarding the global supply of REEs. The conference, titled "Rare Earth Minerals and 21st Century Industry," included speakers representing General Electric Global Research, DOE's Ames National Laboratory and Molycorp Minerals LLC, a REE mining company and current owner of the Mountain Pass mine. The speakers used the platform to detail how the lack of a domestic supply of REE would negatively affect the U.S.'s ability to manufacture cutting-edge technological products.

The federal government also addressed this issue with a Government Accountability Office report on rare earth materials in the defense supply chain to the Committees on Armed Services of the Senate and House of Representatives, delivered in April. The GAO report spelled out how the U.S. defense industry uses REEs – in precision-guided munitions, lasers, communications and radar systems, avionics, night-vision equipment and satellites. The Army's M1A2 Abrams tank, for instance, has a reference and navigation system that uses samarium cobalt permanent magnets. Now, the magnets come from China. The Navy's DDG-51 Hybrid Electric Drive uses permanent magnet motors. These magnets, too, come from China.

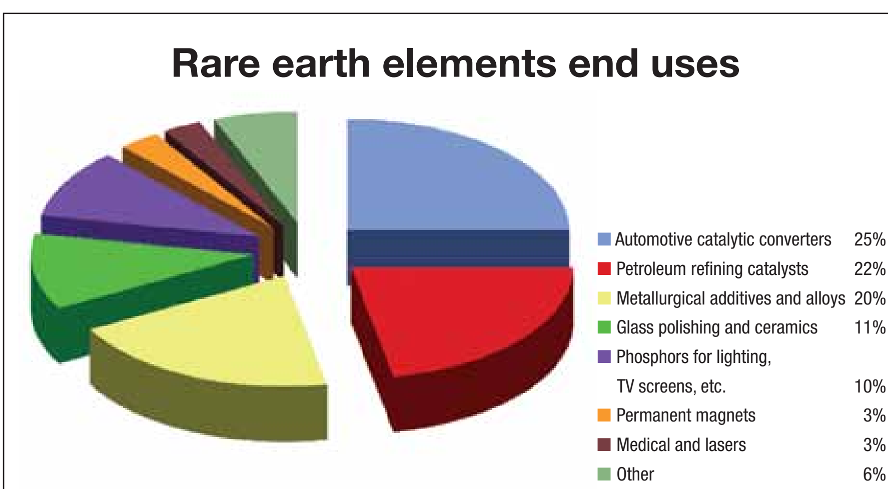
"It becomes more and more clear that in the last 20 years, we've started, in terms of technical applications, to use up a lot of new metals that we've never used before in the consumption of goods like cell phones, computers and other lifestyle things," says Armin Reller, chair and professor of research strategy, Institute of Physics, Augsburg University (Germany). "We cannot fulfill our dreams of technological progress all the time. We have to combine this resource issue with lifestyle research, to some extent."

Criticality and environmental concerns

Reller's research with mineral resources looks for answers using a different tack to investigate REE shortages – that of interdisciplinary study. His team is comprised of individuals with backgrounds in education, geography, physics, chemistry and politics. According to Reller, this multidisciplinary approach is necessary to solve problems like the use of increasingly rare of materials.

"We need to think about the essential technologies we really need for the future: energy, water, mobility and communications," Reller says. "Then, we have to go to the research level and see what happens. What would be the materials that are efficient and available for the future?"

Reller says he works with a concept called "criticality," measuring these needs not only quantitatively, but also qualitatively. "This means the dynamics play an important role," Reller says. "Not only do we estimate how much we need and how much is available, but where it's coming from. Conflict situations must be considered,. Then, of course, we certainly have to try to become much more resource efficient.



(Credit: Avalon Rare Metals.)

Don Bubar, president of Avalon Rare Metals, visits the site of Avalon's Nechalacho rare earth deposit at Thor Lake in Canada.

And, this is a major task for the product designers."

Other than the concentration of supply, China's position raises other questions: Illegal rare earth mines are not uncommon in the rural countryside, and unregulated mining has catastrophic potential for the pollution of water supplies and the surrounding environment. The irony, of course, being that – despite the promise of REE-enabled devices to improve society, improve communications and renewable energy production, etc. – the production of REEs also has the potential to destroy the environment.

"It's a real concern," Reller says of the potential for negative environmental effects. "On the one hand, we need to change our technologies to become more sufficient and more sustainable, and, for these technologies, we need these metals, which are not readily available." Another frustration for the green-minded is the inability or lack of will to recycle and reuse REEs once they've been used in a product. "The energy we put into refining these metals and just losing it by dissipation is really a nuisance," Reller adds.

Even so, some nations, such as Japan, have launched aggressive "urban mining" programs to recycle REEs and other valuable materials from cell phones, appliances and other electronics. Government officials have cooperated with large-scale retailers of these products and have implemented a program to give shopping coupons or cash-back points to users of the cell-phone recycling system.

Looking closer to home

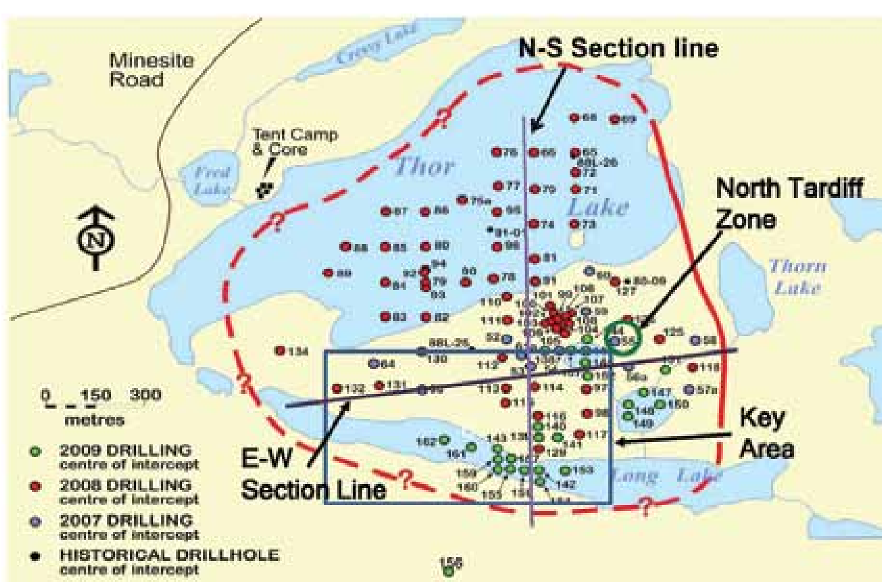
Three North American companies are stepping into the fray, hoping to swing the production pendulum away from China: Molycorp Minerals, headquartered in Greenwood Village, Colo.; Avalon Rare Metals, located in Toronto, Ontario; and Rare Element Resources in Vancouver.

Molycorp Minerals purchased California's Mountain Pass mine from Chevron in 2008. Jim Sims, director of public affairs for Molycorp, says under Molycorp's tenure, the mine is due for an overhaul – as he puts it, a "dramatic and systemic rebuilding, and modernization of the processing facilities." With an investment of nearly $500 million, Sims says the new technologies the mine plans to utilize will result in an excess of a 90 percent recovery rate of REEs. In turn, Sims says the company hopes to reduce its environmental footprint by mining less ore. He thinks Molycorp can deliver approximately the same amount of product using only about half the ore required in the past. Ground is set to be broken to kick off the facility improvements in January 2011, and, in July, did an IPO to raise funds for the project.

Sims gives his projections for the mine's production. "Our goal is to ramp up to full production of 20,000 [metric] tons per year by 2012," he says. "And, we have the capability of increasing that production from 20,000 to 40,000 tons per year. Of course, that rate of production will depend upon the market."

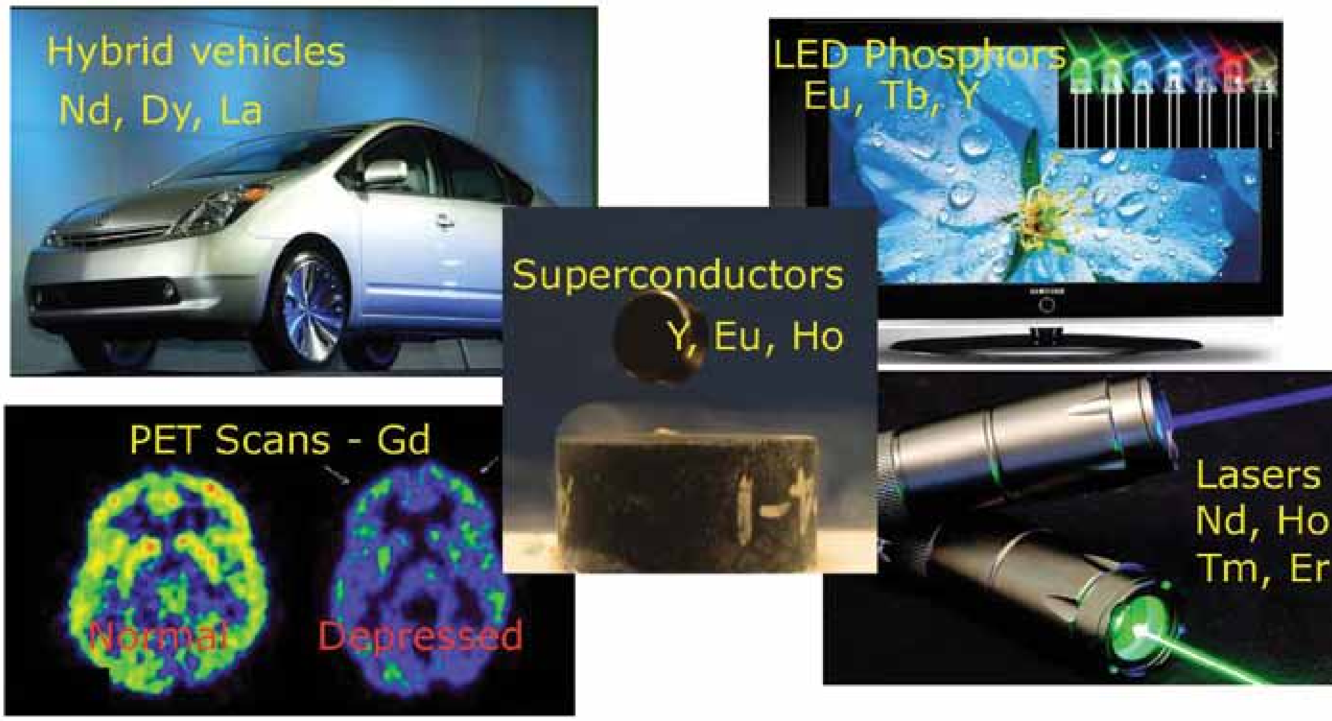
Avalon's primary asset is the Nechalacho Rare Earth Element Deposit, located at Thor Lake in Canada's Northwest Territories. The company believes this play is one of the highest quality undeveloped REE deposits in the world, especially when it comes to heavy rare earths. President and CEO Don Bubar says Avalon is in the feasibility stage of the project at Thor Lake and adds it will take a few years before it will be in production. He calls early estimates on what the mine will produce – a projected 12 million tons of REE over an 18-year timeframe starting in 2014 – a "moving target."

"We've done a lot more drilling since that number was generated. [It's] not a matter of finding enough tons of material to mine," Bubar says. "It's more a question of finding enough at a high enough grade in terms of quality and concentration."



(Credit: Avalon Rare Metals.)

Avalon Rare Metals asserts that the Thor Lake mine is one of the highest quality, under-developed REE mines in the world. The company projects mining 12 million tons of REE over 18 years.



(Credit: Avalon Rare Metals.)

With the range of places that rare earth elements can be found, they seem anything by rare.

Given the current shortage, Bubar and Sims say that government and industry officials should be worried. "Suffice it to say that almost all the experts believe that we are already in a situation where there's too much demand chasing supply," Sims says. "This underscores the near-term and dramatic need to get alternative sources of supply online." Bubar concurs. "The shortages are starting to emerge. I don't think they're in extremely short supply right now, but it's pretty clear that without new sources to supply the market, there will be a deficit in the market."

Rare Element Resources is attempting to develop REE mines in northeast Wyoming and recently became a publicly traded company on the New York Stock Exchange.

But Reller remains unconvinced that production from North American mines will solve all the problems. "If these mines produce metals, the Chinese people will lower their prices," he says. "It's an economic issue, it's a geopolitical issue and it's an environmental issue. These mines are quite difficult to handle, have radioactive materials and there are labor-safety issues."

Sims and Bubar point to their company's efforts to reduce the environmental footprint of the ore mining. This year, Avalon received the Prospectors and Developers Association of Canada 2010 Environmental and Social Responsibility Award, in recognition of the company's community engagement efforts during the exploration of the Thor Lake deposit. "The more you do to minimize your environmental impacts, the more costly it is to produce REEs," Bubar says. "The gap (between Chinese and Western considerations of environmental protection) is starting to close now. As the middle class grows in China, there is more of an environmental consciousness developing there."

Molycorp's retooling of the Mountain Pass mine also has green sensibilities. "In the early 2000s, most of the intellectual capital related to rare earth processing had left the country or retired," Sims says. So the company hired relatively young chemists and Ph.D.s in the hopes of generating breakthroughs to overhaul the REE process. "That's what allowed us to come up with the plan for the new facility," Sims adds. Among the new processes are a move toward becoming a near-zero water discharge facility – it would be the only REE-processing facility in the world that would be able to do that, Sims points out – and Molycorp also is reexamining supply chains to cut back on greenhouse gas emissions and waste products.

But, environmental efforts or not, Reller would like to see more restraint and forethought given to how the materials are used.

Therein lies the key to battling shortages and breaking potential strangleholds on supply. "I think one has to be discerning," he says. "In many applications, metals or metal alloys can be used. In other applications, metal oxides. One has to discern the function these materials have."

"For new technologies," he continues, "if one is calculating how much of one material versus another one might use, it becomes important to answer questions about how much energy is required to be produced by a particular green technology, for instance, how much electricity must be produced from wind-energy turbines. From there, one can determine the total quantity of REEs that might be needed to produce the equipment to meet the energy-production requirements of the technology." Although that seems logical, Reller says that, surprisingly, it isn't been done much by planners and policy makers.

Moving forward

The shortage of REEs points to a bigger picture about social and technological advancement, and for consumer appetites for the bigger, the better and the faster.

"[China's] internal demand for REEs is increasing dramatically because of the relatively robust growth they've been experiencing in their manufacturing sector," Sims says. "They are consuming more and more of their own REEs."

And, Sims opines, cutting back on exports is the Chinese government's way to fuel value-added manufacturing and create jobs. "Their need to create an ever-growing number of jobs each year just to keep their employment static requires more consumption of rare earths. All these things are internal to China's economy."

But Reller would like to see more awareness of resource use and, perhaps, a decrease in consumption, not an increase. "One of the most important things is that the consumer in general does not know how his life is performing in terms of resource use," Reller says. "If you ask somebody on the street whether he knows how his cell phone is constructed, he'd have no idea: No idea where it comes from, no idea about the supply chain and no awareness of the social or environmental issues behind it."

World geopolitical forces may force this awareness upon them. After export cuts earlier in 2010, China announced in July that it is cutting REE export quotas by 72 percent (compared with 2009) for the second half of 2010. In light of what happened already in 2009, this is a huge reduction. According to *BusinessWeek*, China's Ministry of Commerce put the limit at 7,976 metric tons, down from 28,417 tons for the same period a year ago.

According to Chinese officials, undercompensation has a lot to do with these changes. Liu Aisheng, director of the Chinese Society of Rare Earth, was quoted by *BusinessWeek* as saying, "The rare earths industry officials have realized that, after many years of continued growth in exports, the industry didn't receive due profit returns. They adjusted the policy to ensure that the resources are optimally utilized."

Will domestic and neighboring suppliers come to the rescue? Higher prices for REEs are sure to help spur the reopening of old mines and new explorations, but the rarity of awareness of the problem among scientists, government officials and the captains of industry may be the biggest factor influencing how soon the U.S. and other REE-scarce nations make headway. ■