Rare Earths: US gets ready to cooperate

Several American junior mining companies are preparing to tap the country's rich resources of these critical minerals. *Antonio Torrisi,* Reporter, discovers how the US is looking to compete with a 14-year long Chinese monopoly in the rare earths market.

When the US stopped the production of rare earths elements (REE) at Mountain Pass, California, in 2002, the country did not foresee the consequences for the US economy of complete reliance on China for the supply of these strategic minerals.

Since 2000, China has become the largest REE producer in the world, controlling 95% to 97% of the global supply due to concentrated resources, ease of extraction, easily obtainable mining licences and cheap methods of production.

This monopoly has left many international markets vulnerable, due to the fact that REE has applications in many high-technological and strategic end markets; catalysts for the automotive industry, light bulbs and LEDs, electronics, imaging medical devices and permanent magnets in wind turbines and defence systems.

On the back of increasing global REE demand, amounting to 130,000 tonnes in 2012, demand in the US has steadily increased since 2000, with imports in 2012 amounting to 5,630 tonnes, of which 1,200 tonnes were cerium compounds and 2,700 tonnes were rare earths oxides (REO) and compounds, according to the US Geological Survey (USGS).

Marc Humphries, a specialist in energy policy at the US Congress Research Service (CRS), says that the demand for REE-based products in the US is projected to increase in the coming years, with permanent magnets up by 10%-16% pa and REE demand for auto catalysts and petrol cracking expected to grow annually by 6%-8%. Demand is also set to increase in the manufacture of flat panel displays, hybrid vehicle engines, defence, and medical applications.

China's decision to halt REE exports to Japan in September 2010, owing to a dispute over island territories in the East China Sea, threatened the international supply of REE,

and has equally led to an increasing number of complaints and concerns from the US, Europe, Japan and other economies to the World Trade Organisation (WTO).

"Right now, there are 25 recent federal studies by six different federal agencies having to do with critical minerals in general and most of those studies covered REEs. Each one concluded that we have a crisis, we have an emergency and we have to address it," George Byers, vice-president government and community relations at the US junior REE mining company, Rare Element Resources, told **IM**.

"We are becoming more dependent in the US on foreign sources for raw materials and this is especially true for REEs. This became evident in September-October 2011, when the Chinese, who control over 90% of the supply, dramatically reduced REE exports," Byers said.

Colorado-headquartered miner, Molycorp Inc., acquired the Mountain Pass mine in 2008 and re-started operations in 2012, with the production of 9,000 tonnes of REE-rich bastnasite mineral.

However, Mountain Pass alone cannot guarantee REE supply for the entire US high-tech, military, automotive and other end-markets. Moreover, Mountain Pass' REE resources consist principally of light REE (LREE), which are lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu) and gadolinium (Gd), the majority of which are not used in strategic applications such as permanent magnets.

Heavy REE (HREE), include yttrium (Y), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb) and luthetium (Lu). They are critical for several end-users, and strategic for the development of military equipment for the Department of Defence (DoD), which is ultimately relying on China's supply for these elements.

Rare Earths projects and deposits in the US

Source: USGS 2010

The US has vast REE resources, hosting some of the biggest deposits of bastnasite minerals in the world, accounting for the largest REE concentrations and monazite deposits, as well as the second largest concentrations of REEs rich in critical HREE.

US REE deposits are present in several states including Montana, Colorado, Idaho, Missouri, Nebraska, New Mexico, Arizona, Alaska and Wyoming.

Following the rising number of REE projects in Canada, Australia and Africa, a number of exploratory and re-development projects have started in the US, focusing on HREE production.

The Bear Lodge project in Wyoming and Bokan Mountain project in Alaska, are two of the most advanced developments of critical HREE deposits, and could be in full production within the next three years.

other projects currently under development are Pea Ridge deposit in Missouri, Iron Hill and Wet Mountain carbonatite complexes in Colorado, with high content of HREEs, thorium oxide and niobium oxide, Rount Top Mountain HREE-rich rhyolite deposit in Texas, critical REE-rich Lehmi Pass deposit in Idaho and Montana, Elk Creek deposit in Nebraska and La Paz reserve in Arizona.

Chinese monopoly and Molycorp's lesson

The real challenge is how new US projects will be able to market their REE products

REO relative distribution (% in weight)

	La_2O_3	Ce_2O_3	Pr_2O_3	Nd_2O_3	Sm_2O_3	Eu_2O_3	Gd_2O_3	Tb_2O_3	Dy_2O_3	Ho_2O_3	Er_2O_3	Tm_2O_3	Yb_2O_3	Lu_2O_3	Y_2O_3	TREO (tonnes)
Mountain Pass	33.20	49.10	4.30	12.00	0.80	0.10	0.20	0.06	0.05	0.02	0.02	0.02	0.02	0.01	0.01	2,581,490
Bear Lodge	26.22	43.63	5.00	17.96	2.90	0.64	1.55	0.13	0.43	0.05	0.09	0.01	0.05	0.01	1.33	384,000
Bokan Mountain	11.45	27.81	3.27	13.81	3.60	0.33	3.76	0.65	4.25	0.92	2.32	0.33	1.57	0.16	25.77	164,000
Round Top	3.72	15.48	2.02	5.28	1.86	0.03	1.86	0.62	5.58	1.40	5.86	1.24	9.93	1.55	43.56	500,000*
Lehmi Pass	7.27	18.06	3.08	27.97	19.16	5.95	12.33	0.66	1.76	0.66	0.44	0.66	0.66	0.66	3.30	370,000
Iron Hill	21.58	42.55	5.17	19.76	3.34	0.61	2.43	0.24	0.88	0.09	0.24	0.02	0.15	0.02	3.04	9,696,000
La Paz	17.20	38.32	4.38	16.44	3.12	0.78	2.72	0.40	2.08	0.42	1.13	0.15	0.88	0.12	11.88	47,470**
Pea Ridge	27.09	47.93	3.19	10.59	2.21	0.18	0.91		1.02	0.16	0.49		0.76	0.07	5.40	72,000

* estimated from the publication *Journal of Rare Earths*

** estimated from NI 43-101

Source: Technology Metals Research and USGS

competitively with Chinese products being produced in large amounts, at low costs and with very few environmental restrictions.

Jim Kennedy, president of ThREE consultancy group, told **IM** that the Chinese government has a precise political plan in its control of 95% of REE projects and production, within a vertically integrated scheme. China can set the price of REEs at whatever level they choose and at any time, and in so doing determine the survival or failure of any independent project outside of China.

"The true goal is to force all global REE based technology inside China. A few highly vulnerable REE projects outside China will not stem the current flow of technology companies going into China," Kennedy said.

Molycorp's Mountain Pass project has been deeply affected by the high costs to develop processing facilities in respect of the environmental regulations set on water treatment and tailings disposal as well as Chinese market strategies which determined REE prices, which were extremely volatile during 2011 and 2012.

The company recently completed commissioning of a multi-stage cracking plant, which started operations in January this year. The plant is set to improve REE recover rates up to 90%. The company is also set to increase its annual production rate, from 10,600 tonnes in Q3 2013 to 15,000 tonnes in Q2 2014, with production capacity projected to reach 23,000 tpa in Q4 2014.

However, Molycorp is still struggling to increase its profits, though it expects cash flow to be in a more positive state by the end of 2014 or, at the very least, by the start of 2015, through long term contracts.

The company is still not able to refine the REE content in a final value added-product and has to ship the product to China for further refinement.

Another major problem for Molycorp is its large production of cerium, which is currently stockpiled owing to low demand. A partial solution could be offered by the newly designed water-purifying compound, SorbX, which is more effective than iron and aluminium-based products for water purification, but demand for this product is expected to increase in the long term only.

Kennedy told **IM** that current policies adopted by Australia's Lynas Corp. and Molycorp have no way of withstanding China's monopoly for setting pricing and, alone, cannot recover the high costs of a fully developed REE value chain.

"The development of a fully integrated value chain is the only way the 'west' can protect and insure their domestic industries, technology and jobs from migrating to China," Kennedy said.

Bear Lodge Project – Rare Element Resources

Location and Resources

The project develops REE-thorium deposits and nearby gold mineralisation of the southern Bear Lodge Mountains, Wyoming. The REE bearing minerals are carbonatite, monazite, thorite and brockite.

"We have done 10 years of work on the Bear Lodge Project, and during the last three years we have spent $10s of millions in new drilling. This work has expanded the resource, also increasing the heavy rare earths (HREE) resource," Rare Element Resources CEO, Randy Scott, told **IM**.

Recently, resources were increased by almost 75%, anticipating a mine life in excess of 40 years. Rare Element already completed a NI 43-101 technical report.

The project consists of two deposits:

- Bull Hill, with high-grade zone containing about 4.9m tonnes grading 4.8% total rare earth oxides (TREO) with a 3.1% cutoff grade.
- Whitetail Ridge, with HREE content amounting to 3.8m tonnes at an average grade of 2.5% TREO, using a 1.5% cutoff grade, corresponding to 95,000 tonnes of TREO.

The total estimated resources amount to 15.2m tonnes, of which 473,000 tonnes of TREO, with total europium (Eu), terbium (Tb), dysprosium (Dy) and yttrium (Y) content being 0.29%, of which 0.101% in Bull Hill and 0.19% in Whitetail.

Project plans

The project area is restricted to 200 acres (0.8km^2) of an open pit mine. A physical upgrade (PUG) plant is to be located near the mine for the pre-stage processing of the ore, to remove barren ore and increase REE concentration, through crushing, washing, screening and magnetic separation.

The pre-concentrate product from the PUG plant will be delivered to the hydrometallurgical plant in the city of Upton, Wyoming, approximately 40 miles from the mine site, where leaching operations with hydrochloric acid (HCl) and the removal of impurities through additional chemicals are expected to produce a 97% REE bulk concentrate.

The plant will also recycle HCl and dispose of tailings, such as leach residue and solid produced from acid regeneration.

The company has already patented a process for the safe extraction of thorium (Th) from REE compounds. Thorium product will be isolated and shipped to an off-site licensed disposal facility.

Jaye Pickarts, Rare Element Resources COO, told **IM** that the plant is expected to produce between 5,000 and 10,000 tpa of high purity REE concentrate. Further refining will be done according to the needs of end-users, with the possibility of separating from five to nine different REE products which are currently being evaluated.

However, the company told **IM** that it does not see itself moving towards vertical integration in the near future.

The company is also continuing drilling explorations in the targeted area called Carbon and Taylor, respectively located in north-west and west of Whitetail Ridge.

The company has started the preparation of the environmental impact statement (EIS) in February this year under the National Environment Policy Act (NEPA). A public scoping meeting is expected to identify environmental issues related to the project.

"In the last three years, we have collected a great amount of environmental data on the project," Pickarts told **IM**. He added that completion of the Environmental Impact Statement (EIS) is an essential step in obtaining mining permits from the Wyoming Department of Environmental Quality (WDEQ), which the company expects to obtain in the next two years.

Paul Zink, Rare Element Resources CFO, told **IM** that some of the product from pilot plant testing will help the company assess future demand and identify potential joint ventures with end-using companies.

Notes

Scott told **IM** that at least three main features make Bear Lodge an outstanding REE project worldwide:

First, the project contains critical and strategic HREEs and is considered to be one of the non-Chinese world-class deposits in the world.

Secondly, the project is located in Wyoming, a mining friendly state with a tradition of mining industry and a well-developed infrastructure and strong support from local communities.

Thirdly, the location, and the limited size of the project, allows its development with low capital costs, which will total between $300m and $600m, well below the costs of other projects worldwide that range between $1.5bn and $3bn. This will allow the company to accomplish the development within the time-schedule.

Rare Element expects to start the construction of the hydrometallurgical plant in 2016 and to start production towards the end 2016 or the beginning of 2017.

Other US rare earths projects

Project	Location	Company	Minerals	Resources	Notes
Diamond Creek	Idaho	US Rare Earths Inc.	iron oxide minerals; goethite; limonite	Historical data from USGS estimate mineral resources containing 0.59% to 5.51% TREO and 0.04% to 1.71% thorium oxide (ThO_2). Estimated resources amount to 68,500 tonnes of TREO at an average grade 1.2% REO. Preliminary estimates of REE in the deposit are 22,400 tonnes of CeO_2, 17,125 tonnes of Nd_2O_3 8,220 tonnes of La_2O_3, 5,480 tonnes of Sm_2O_3, 4,795 tonnes of Y_2O_3, 3,425 tonnes of Pr_6O_{11}, 3,425 tonnes of Gd_2O_3, 1,370 tonnes of Dy_2O_3 and Eu_2O_3 each, and 685 tonnes of remaining HREE at average grade of 0.005% or less each.	Early stage exploration. Recent analyses indicate an enrichment in Nd, Sm, Eu, Gd, Y and an overall TREE/Th ratio of about 6/1. Total REE concentrations were measured as high as 4.7% in a sample from one of the newly discovered veins. One of the largest veins contains about 3% TREO and a TREE/Th ratio of about 10/1.
El Creek	Nebraska	Niocorp Developments Ltd	carbonatite	It is the only primary niobium (Nb) deposit in the US. The deposit also contains high-grade REE 2.5km distant from the Nb deposit. Historical data indicate resources of 19.3m tonnes of mineral at 0.67% Nb_2O_5 and inferred resources of 538,000 tonnes of Nb_2O_5.	Preliminary exploration of the open pit deposit. Drilling operations in summer 2011 on three holes reported Nb mineralisation at 0.58%Nb_2O_5 , 0.73%Nb_2O_5 and 0.87% Nb_2O_5. The drilling operations intersected mineralisation greater than 1.0% REO at depeths greater than 20 feet (6.1 metres).
Iron Hill	Colorado	US Rare Earths Inc.	carbonatite; pyroxenite	Historical data from 1979 indicate resources for 2.4bn tonnes, containing 9.7m tonnes of TREO at 0.4% cutoff grade. Explorations in 2007 indicate that the carbonite mineral might host up to 2.6m tonnes of REO, 28,600 tonnes of thorium oxide and 373,700 tonnes of niobium oxide (Nb_2O_5).	Preliminary exploration. The company acquired the property in 2010 and extended it of 4,000 acres (100km^2). Total rare earth element (TREE) concentrations of about 0.07% to 2.2 % have recently been measured in grab samples from the South Powderhorn in the Rudolph Hills area. TREE concentrations of about 0.02% to 1.2 % have recently been measured in samples from the North Powderhorn area. REE mineralisation in the deposits is relatively rich in neodymium (Nd) and samarium (Sm).
La Paz	Arizona	AusAmerican Mining Corp.	allanite	Total indicated mineral resources amount to 16.2m tonnes, containing 54,000 tonnes of TREO with grade above 0.037% cutoff. Inferred resources amount to 112m tonnes, containing 375,000 tonnes of TREO with grade above 0.037% cutoff.	Preliminary exploration of the open pit mine. The company completed NI 43-101 technical report in December 2011. Total budget for phase I exploration was $1.3m; total budget for phase II exploration is $1m. The studies show high percentage of HREO. Low content of thorium and uranium (below 10 ppm).
Lemhi Pass	Idaho; Montana	US Rare Earths Inc.	monazite; bastnasite; xenotime	Historical data in 1972 show Th/REE ratio of 1/1. Resources amount to 176,000 tonnes of ThO_2 and probable additional 2,000 tonnes. REE resources contain 77,345 tonnes of Y_2O_3, 25,780 tonnes of La_2O_3, 69,980 tonnes of CeO_2, 11,000 tonnes of Pr_6O_{11}, 66,296 tonnes of Nd_2O_3, 40,150 tonnes of Sm_2O_3, 14,735 tonnes of Eu_2O_3, 40,515 tonnes of Gd_2O_3, 1,840 tonnes of Tb_4O_7, 14,730 tonnes of Dy_2O_3, 1,840 tonnes each of Yb_2O_3 and Ho_2O_3 and less than 930 tonnes of remaining HREE.	Initial exploration programme in 2008 confirmed historical data with indicated and inferred resources for 248,000 tonnes of thorium dioxide at an average concentration of 0.4%. Indicated and inferred resources of 322,000 tonnes of REO at an average concentration of 0.52% were also reported in Lehmi Pass. The company also reported an average 14,900 tonnes of ore in the Last Chance vein, containing 174 tonnes of ThO_2 and 138 tonnes of REO.
North Fork	Idaho	US Rare Earths Inc.	aueralite; apatite; allanite; monazite; pyrite	The carbonate veins may also be relatively enriched in the REE, Er-Lu in addition to LREE in similar amount to those of Bayan Obo, China and Mountain Pass, California, US.	Drilling programme in 2013 reported grades 10.3% of TREO and grades of critical REO (CREO) between 1.4% and 1.2% in the North Fork deposit, an area of approximately 181km^2. CREO include Dy, Tb, Eu, Nd and Y oxides. The company extended the drilling programme to phase II, and will complete the North Fork explorations thorought 2014. In January 2014, preliminary leaching tests recovered 79% of CREE. The company and is planning to build a complete HREE and CREE separation facility.

Other US rare earths projects (*Continued*)

Project	Location	Company	Minerals	Resources	Notes
Pea Ridge	Missouri	MFC Industrials Ltd Alberici Group Inc.	magnetite; hematite; xenotime; monazite	Historical data from 1990 report resources for 660,000 tonnes of REE, with average grade of 12% of REO. Data from 2008 report additional resources of 250,000 tonnes of mineralised rock at 13% REE. The deposit contain mainly La, but also HREE, including Dy, Ho, Er, Yb, Lu, Y.	Planned exploration of the underground mine. Pea ridge is an underground mine which was in operation between 1963 and 2001. A pre-feasibility report was prepared by Behre Dolbear Group, in 2008. US-based MFC Industrial Ltd and Alberici Group Inc. bought the mine in a 50%-50% partnership in 2012. The companies are working toward the completion of a NI 43-101 feasibility study of the re-development project, which includes re-opening the mine, exploiting tailings accumulations and continuing with REE explorations.
Round Top	Texas	Texas Rare Earths Resources	bastnasite; Y-fluorite; xenotime; cerianite; zircon	The mountain is a rhyolite rock of about 1.6bn tonnes, 375 m tall and 2km in diameter. Measured, indicated and inferred resources could exceed 500,000 tonnes of REE, of which 72% being Y and HREE. The lifetime of the mine is estimated at 20 years, with mining rate at 20,000 tpa. indicates measured and indicated resources of 77,919 tonnes of TREO and inferred resources of 17,172 tonnes of TREO. The content is particularly rich in strategic and critical REE such as Y, Dy, Er and Yb. The deposit has a small amount of uranium. Mineralisation is dilute, with TREE grade just over 500 ppm and diffuse, with no concentrated zones.	Advanced exploration of the mine at 130km southeast from El Paso, Texas. The company, which owns mining licences for exploration of 950 acres (3.8km^2), completed a NI 43-101 report in December 2013. Preliminary tests of direct heap leaching with sulphuric acid at room temperature demonstrated that Y-rich fluorite is easily dissolved, with up to 91% Y and 87% Dy recovery and average recovery of 71% TREE. The planned processing consists of rocks crushing, piling and a sprinkler system to spread leaching acid on rock beds. A ground liner system will protect the ground from acid filtration. In the preliminary economic assessmet study, the company has estimated a capital cost of $292.7m for the construction of an on-site separation plant and an additional contingency provision of $58.5m.
Wet Mountains	Colorado	US Rare Earths Inc.	carbonatite; pyroxenite	Historical data from 1979 indicate mineral resources for 2.4bn tonnes, containing 9.7m tonnes of TREO at 0.4% cutoff grade. This deposit consists of 145,600 tonnes of ThO_2, 66,500 tonnes of LREE and 44,300 tonnes of HREE. Reports from 1988 indicate mineralisation of 0.46% ThO_2, 0.21% LREE and 0.14% HREE, with Th/TREE ratio between 0.8 and 1;	Very little exploration and development work has been done. Most of the work has been limited to a few shallow exploration shafts and adits less then 100 feet (30 metres) in extent, outcrop surface trenching, grab sampling, and elemental analysis. TREE concentrations are about 0.06% to 1.3% and TREE/Th ratios are 5/1 to 20/1 respectively.

Molycorp is set to become vertically integrated through a series of acquisitions, including its Japanese subsidiary Santoku America in Arizona, which was renamed Molycorp Metals and Alloys (MMA) for the production of neodymium-iron-boron (NdFeB) and samarium-cobalt (SmCo) permanent magnets.

MMA is studying a way to recycle metal using hot-pressed technology to manufacture NdFeB magnets, requiring 2%-6% less dysprosium at certain temperatures, avoiding the fluctuating availability and price volatility of this strategic element.

The company also acquired Toronto-based Neo Materials Technology Inc., with REE processing and permanent magnet powder facilities in China, as well as entering in a joint venture (JV) with Japan-based Daido Steel and Mitsubishi Corp. to manufacture NdFeB permanent magnets in Japan and sell them worldwide.

Additionally, Molycorp has also entered in a cooperative research and development agreement with US Department of Energy's Ames Laboratory to study new methods to market commercial-grade permanent magnets for industrial applications.

Mark MacDonald, vice president of business development at junior REE mining company, Ucore Rare Metals Inc., said "Ucore is interested in Molycorp's 'mines to magnets' strategy. Ucore is taking the appropriate steps to deliver REE for magnet applications."

"We are located in a supportive jurisdiction that has expressed interest in developing downstream value added products from these primary resources," he added.

Environmental issues and mining permits

While projects in Australia and Canada can benefit from relatively simple mining permits and clear legislation, the projects in the US presently face a long-term and complicated procedure for obtaining mining permits.

The US is "one of the least desirable countries in which to begin a new mining project," according to Tom Tanton, policy researcher at the National Centre for Policy Analysis (NCPA) in the US.

Behre Dolbear Group, an international mining and mineral advisory group, notes that "obtaining mining permits takes an average of seven to ten years, among the longest waiting times in the world."

"Time, not the severity of regulations, is the greatest problem with the permitting process," Tanton says in NCPA's 2013 report.

There are eight US regulatory agencies overseeing mining operations, including the Environmental Protection Agency (EPA) and the Mine Safety and Health Administration, which has already set laws to safely regulate mining and milling.

According to Tanton, the US should model Australia's and Canada's successful regulations and dramatically shorten domestic permitting time, based on some general principles:

- A concurrent non-sequential approach to analyse permitting issues and address concerns.
- A combination of all permitting into a single "one stop" authority in place of multiple agencies.
- A rapid dispensing of non-critical issues giving priority to financial burdens.

Four new bills have been recently discussed by the US government to boost new REE project developments in critical and strategic minerals: the National Strategic and Critical Minerals Production Act (HR761), the Critical Minerals Act (S1600), the National Rare Earth Cooperative Act (NRECA) 2014 and Motor System Market Awareness Act 2014.

The bills consider different aspects to boost exploration, exploitation and market consumption of new critical mineral resources in the US.

The HR761 bill focuses on speeding up the process to obtain mining permits, setting the total review process for permitting at 30 months.

The Critical Mineral Act (S1600) does not change the time-schedule of the mining permits but directs the governmental agencies, including the Department of Interior and Agriculture and the Department of Energy (DoE), to assess the critical mineral resources in the US and ensure that permitting and review processes inform decision makers and local communities about the positive and negative impacts of any new project.

"The House Bill is directed at speeding the process of permitting. The Senate Bill does not go quite in that direction. If the Senate Bill is passed, it will have to be merged with the House Bill in a compatible way," Byers told **IM**.

Cooperative approach vs free market

Other industries and resource experts believe the problem goes beyond the environmental and mining permitting legislations and extends to the current market model.

There is a growing view in the US that a free market will not be able to help the new mining companies cope with the Chinese monopoly.

China has two cities dedicated to the development and production of value added rare earth products and research and development.

"To put this in perspective, the direct manpower dedicated to this is at least 10 times greater that the US commitment to developing the atomic bomb under the Manhattan project," Kennedy told **IM**.

Kennedy said that the present problem is that China can lower prices indiscriminately and whenever they want, letting current companies and mining developers fail.

Bokan Mountain project – Ucore Rare Metals Inc.

Location and Resources

The Bokan Mountain Project is located at the southern part of the Alaskan panhandle, on the southern end of Prince of Wales Island, Alaska, covering an area of about 30km^2. The project is 100% owned by Ucore.

Pegmatites are found throughout the Bokan peralkaline granite complex, containing a range of minerals including albite, aegirine, and zircon, with variable amounts of allanite, ilmenite, riebeckite, arsenopyrite and yttrium-rich fluorite.

Both Bokan-Dotson Ridge and Ray Mountain projects have well known mineralisation including xenotime and monazite.

The project is rich in HREE, but has very low thorium (Th) and uranium (U) content. HREE content includes dysprosium (Dy), terbium (Tb) and yttrium (Y). Mineralisation also contains rare metals such as zirconium (Zr) and niobium (Nb).

Bokan Mountain mostly focuses on HREO content, which amounts to 39% of TREO, compared with 4% at the Bear Lodge and 1% at the Mountain Pass, according to Ucore's estimates.

The total number of resources indicated in October 2013 amounted to about 9.6m tonnes, of which 3.3m tonnes of mineral with 0.58% total TREO at 0.3% cutoff, 2.9m tonnes of 0.61% TREO at 0.4% cutoff, 2.1m tonnes of 0.68% TREO at 0.5% cutoff and about 1.3m tonnes with 0.77% TREO at 0.6% cutoff.

The total number of inferred resources amounted to about 6.5m tonnes, of which 2.2m tonnes of mineral with 0.58% total TREO at 0.3% cutoff, 2.0 tonnes of 0.6% TREO at 0.4% cutoff, 1.5m tonnes of 0.66% TREO at 0.5% cutoff and about 830,000 tonnes with 0.75% TREO at 0.6% cutoff.

Project plans

Following a 37 drilling holes exploration programme in 2008, the company is currently developing a Bankable Feasibility Study for the Bokan-Dotson Ridge project.

Explorations are still underway at Ray Mountain and the ore samples are currently undergoing detailed metallurgical analysis.

"Ucore's focus is to put a mine into operation at Bokan-Dotson Ridge. We contemplate refining our ore to pure REOs to capture the revenue uplift available from this process," MacDonald told **IM**.

Ore sorting technology will allow the company to eject over 50% of ore while retaining almost 95% recovery of REE mineralisation before further processing with grinding circuit.

The secondary processing will use a recycling circuit saving up to 85% of the nitric acid leach media. This is much more environmentally friendly and reduces capex costs dramatically. The company aims to save 78.9 tpd of CO_2 and 284,000 tonnes of CO_2 during the mine's lifetime.

"Preliminary Economic Assessment indicates that total annual production will be up to 2,400 tpa of REOs including 471.6 tpa of yttrium oxide (Y_2O_3), 92.6 tpa of dysprosium oxide (Dy_2O_3), 14.3 tpa of terbium oxide (Tb_2O_3) and 8.6 tpa of europium oxide (Eu_2O_3)," MacDonald told **IM**.

MacDonald added that the Ray Mountain project is highly prospective for REEs, though it is too early to speculate on production.

"Ucore has already entered the permitting process: the United States Forest Service (USFS) has approved permitting for Ucore's upcoming field program at the Company's Bokan," MacDonald said.

The permitting process is expected to start in Q2 2014 and a feasibility study to be completed within Q3 2014. Ucore expects to receive the mining permits by Q3 2015 with a construction programme starting immediately after receiving the permits.

The calculated pre-production capital expenditure is about $221m and net present value (NPV) of $577m with an expected payback period of just over 2 years.

Construction of the plant is expected to take place over a one and a half year period with production expected to start in the second half of 2017.

Notes

"100% of the uranium, thorium and iron will be removed as contaminants at the mine site and put into the paste backfill used in the underground stopes as part of our mine plan. All of these contaminants will end up underground where they came from," MacDonald told **IM**.

"We are under contract with the Department of Defence (DoD) currently to collaborate on separation technology research," MacDonald added.

The CRS said that processing companies will need to secure a large amount of capital to begin operations, but investors are concerned about the possibility of China undercutting US prices, and so negatively affecting their return on investments.

This would have a very negative effect on future developers, which would be discouraged by the example of financial challenges or economic failures. With the prospect of struggling or failing enterprises, no "smart money" is likely to be forthcoming.

"Their monopoly position in the global marketplace increases China's ability to interrupt supply and influence prices, actions which dissuade other potential mine developers," Tanton says in the NCPA's 2013 report.

This is even more significant when the high costs for the development of new REE projects are considered. According to mineral resource analyst, Keith Long, from the US Western Mineral and Environmental Resource Science Centre, estimated costs vary from $500m, for the Nolans Bore project in Australia, to $2.3bn, for the Kvanfjeld project in Greenland. The Mountain Pass (US) and Mount Weld (Australia) developments reached costs between $1.5bn and $3bn.

"Currently, policies adopted by Lynas and Molycorp in developing their production using a free market model have put these companies at risk," Kennedy said, calling for a cooperative approach which will allow a distribution of risk among the different developers and end-producers joining the cooperative.

"Historically, cooperatives have been used to overcome market failures when pricing and capital risks are too large for the individual," Kennedy said.

Due to the cost, complexity, interdependency and ongoing rate of necessary innovation within the rare earth value chain, the cooperative needs to be multinational in scope.

"Sponsorship needs to start at the national level with the US Department of Defence (DoD) and Department of energy (DoE), Japan Oil Gas and Metals National Corporation (JOGMEC), Korea Resources Corporation (KORES), NATO and the EU, with broad ownership at the multinational corporate level, including companies like General Electric, Hitachi, Siemens, Samsung and possibly defence and auto industry consortia," Kennedy told **IM**.

In October last year, Canada created a joint industry and Canadian federal government partnership, the Canadian Rear Earth Elements Network (CREEN), with the scope to control 20% of REE world production by 2020.

"This is recognised as a possible system that the US can follow to boost the mining industry in the country," Byers told **IM**.

However, the director of investor relations at Rare Elements, Robbin Lee, told **IM** that in Canada there is greater government-industry co-development which may not be a model that would work in the US, nor one that private industry necessarily wants to push.

The Bull Hill complex in Wyoming, US, where the Bear Lodge project is located

"Although CREEN could be a good organisation, we do not necessarily want to replicate it here in the US, as it would mean too many federal agencies involved in the REE business," Lee said.

Another important initiative focuses on the exploration of other minerals containing REE such as monazite, apatite, phosphates, iron ore and titanium. In particular, efforts are being directed to exploit monazite, which was the original primary ore for rare earths worldwide.

"In the early 1980s the US government, and International Atomic Energy Agency (IAEA), changed the definition and interpretation of regulations regarding nuclear materials which adversely affected the production and flow of monazites into the REE industry," Kennedy told **IM**.

"Current available rare earth resources from monazite and other thorium, bearing phosphate based rare earths could easily exceed 50,000 tpa. Unlike bastnasite, monazite and the other phosphate mineralization's contain heavy rare earths, in recoverable quantities," Kennedy said.

According to Kennedy, the creation of a thorium bank would offer the possibility of creating industrial commercial products, which would have the certification of safety assurance materials.

Thorium stockpiling could also generate positive long-term benefits in future applications for energy.

A new Senate bill, the National Rare Earth Cooperative Act (NRECA) 2014, was released in February this year, which favours the creation of a cooperative market model for strategic minerals.

The bill grants private REE suppliers and end-users the setting up of a REE refining cooperative in the US as well as supporting a private corporation to take possession of thorium by-products and market them for commercial use.

The bill, introduced by US Senator Roy Blunt, and Senator Joe Manchin, also gives high relevance to the REE recycling operations, allowing end-users to invest in their own sources of rare earths.

"In addition to the rare earth cooperative, the legislation establishes a federally chartered thorium storage facility to insure proper storage of these materials and to develop markets and uses for thorium, including energy," Kennedy told **IM**.

Industries can only do competitive processing of rare earths with a thorium repository. This has made mining companies often deposit high quality rare earths into tailings piles to avoid both the thorium liability and the inevitable financial losses accompanied by going up against China's monopoly and pricing pressure.

The REE market in the US includes important strategic elements such as dysprosium and yttrium, which are used in military applications.

In January this year, it was revealed that the Pentagon waived laws restricting REE imports from China, and allowed the import of Chinese magnets in order to maintain the time-schedule of the $392bn F-35 fighter jet programme.

This supply emergency has motivated the National Defence Authorisation Act, scheduled for 2014, to allow the Department of Defence (DoD) to stockpile dysprosium and yttrium.

Recently, US Senators Mike Enzi and Mark Pryor introduced the Motor System Market Awareness Act 2014, which encourages industries to use REE to achieve greater

efficiencies in several technologies, in particular catalytic convertors in the automotive industry.

Refining and recycling

While new legislations will continue to promote the exploration and development of new REE resources within the US, the REE industry has started focusing on recycling REE elements, both from refining operations and end-products.

The initial step in processing rare earths oxides (REO) is the separation and concentration from the raw mineral. This is done using acidic or alkaline solutions. REO are separated using solvent extraction or ion exchange methods.

A second stage called leaching is needed to further process the REE product and extract high-purity concentrates, using hydrochloric, sulphuric and nitric acid with high-yield recoveries of yttrium, lanthanum and cerium, between 80% and 97%.

However, process optimisations vary depending on the different elements, and the separation and recovery of HREEs, such as dysprosium, samarium, gadolinium and terbium, require a more delicate process which has its own issues, due to their low concentrations and similar chemical properties.

Researchers from the University of Leuven in Belgium have studied the possibility of separating neodymium and samarium from metals such as iron, manganese and cobalt by using ionic liquids.

According to Koen Binnemans, professor at the University of Leuven, recycling is only a partial solution to the risk of supply shortage and it cannot replace primary mining. However, although currently less than 1% of REE is recovered by recycling, this technique could account for the 20% of supply in the future.

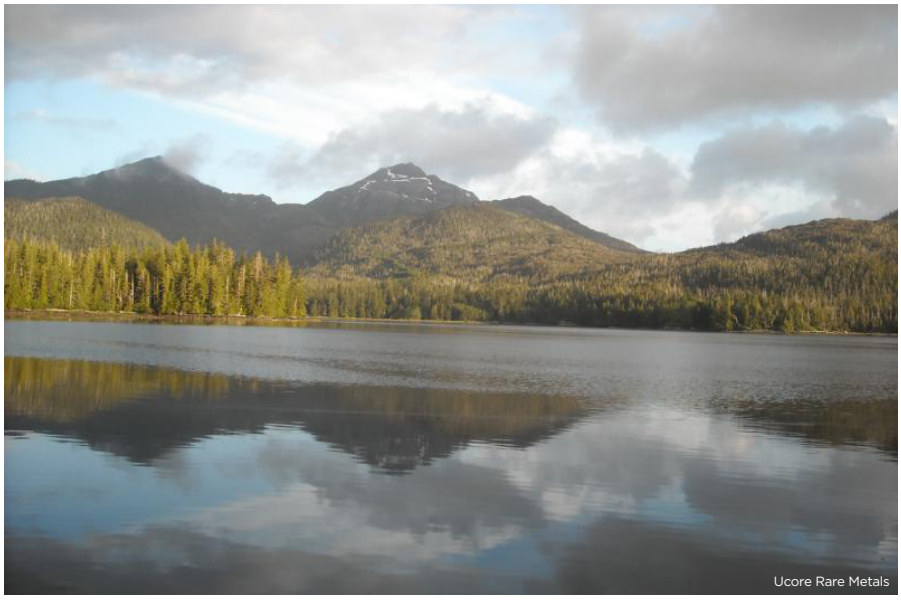
Several end-users are also studying how to recycle REE from end-products, such as batteries, light bulbs and electronics, as well as developing products with less REE content.

US-based Veolia ES Technical Solutions, a company specialising in hazardous material disposal, is developing processes to recover REE from phosphor powder.

General Motors, the car manufacturer, has found a method of lowering dysprosium content in its motors for hybrid vehicles, while the Japanese car manufacturer, Honda, has developed a process that allows 80% recovery of REEs from nickel metal hydride batteries using molten salts.

Hitachi, the Japanese electronics manufacturer, has developed processes to recover REEs from the voice coil motors used in hard disk drives and from air compressors.

In 2012, Belgian chemicals producer, Solvay Group, announced the opening of two plants for the recycling of REEs in France, operating through a process that allows the recovery of REEs, including neodymium and samarium, from light bulbs, batteries and magnets using a liquid extraction method.



Lake of the Bokan Mountain, in the Prince of Wales Island, Alaska, US

A group of researchers from the Ames Laboratory, affiliated to the DoE, developed a method to recycle REEs from magnets using molten magnesium.

The process consists of breaking the magnets into long pieces, adding them to solid magnesium and liquefying the magnesium through a radio frequency furnace. The REEs diffuse into the molten metal leaving behind impurities. The REEs are then recovered by boiling off the magnesium after casting.

The DoE will fund a new research centre, the Critical Materials Institute, in Ames, Iowa, to develop new methods for rare earth recycling and production, with an initial budget of $120m.

Molycorp, and other US REE producers, began studying processes to recycle REEs from REE-based materials.

Achim Steiner, executive director at the United Nations Environmental Programme, stresses that REE recycling should be already considered in the development of end-products, and product designers should ensure a simple recovery of REE from REE-containing materials at the end of their life cycle.

Getting ready

Although Chris Berry, founder of the consultancy company House Mountain Partners, says that nothing has changed in the REE market, with China still controlling 97% of the supply and setting prices, many investors, industries and governmental agencies believe that new producers will have a role to play as REE demand will continue to increase on the back of the demand for high-tech consumer products.

"We think that the demand for REEs will continue to grow. As dependable supplies from sources other than China come on stream, new applications will be developed," MacDonald, told **IM**.

In 2012 Chinese domestic consumption outstripped their domestic production of HREEs. "Resource nationalism dictates that this will be an issue for manufacturers outside China in the very near future," MacDonald said.

"There is a realistic possibility, around 2015-2016, of sufficient REE capacity to meet demand under conditions of healthy price competition," according to the USGS.

The current development of REE mining projects in the US, and worldwide, might come at the right time, as the US economy is getting ready to guarantee new sources of long-term critical REE.

Berry also believes that, "For the first time in many months, consideration should be given to those REE players that have the optimal mix of balance sheet strength, good metallurgical results, geopolitical certainty, and luck."

But before luck, a key factor to untie the global REE supply from China's monopoly might be the new US legislation on critical minerals, aiming to promote the domestic REE supply chain and to reduce the risk of failure for individual companies through a cooperative market.

Based on the policy developments already in process in the US, something might have started to change in the long-term future of the REE market worldwide.