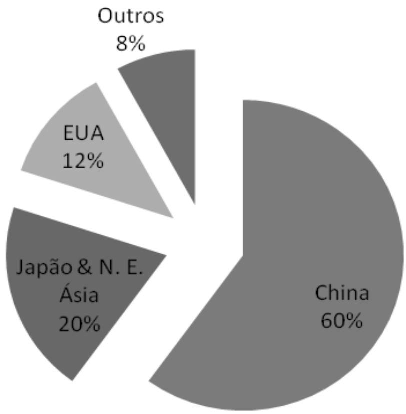
Capítulo III

PERSPECTIVAS DE DESENVOLVIMENTO DA INDÚSTRIA MÍNERO-QUÍMICA DAS TERRAS RARAS NO BRASIL EM FACE DA RETOMADA MUNDIAL DE SUA EXPLORAÇÃO

At the moment, China is the dominant player in the rare-earth space, which is where the operation of Western free-market capitalism, always seeking the lowest price, placed China. This cannot and will not change for two to three years, the least time it will take, if everything goes according to plan, for new or restarted production and refining in significant quantities of rare earths produced outside of China, refined outside of China, and incorporated in end-use products outside of China to come to the world market.
Jack Lifton, January 16, 2011. In: China. News.Analysis. Rare Earths.

6. AS NOVAS CARACTERÍSTICAS DA REGLOBALIZAÇÃO DA INDÚSTRIA DAS TERRAS RARAS

A demanda mundial de terras raras para o ano de 2010 foi estimada em 134.000 toneladas/ano para uma produção mundial de 124.000 toneladas/ano, sendo o maior consumidor a China, que é também de longe o maior produtor, enquanto o Japão e muitos outros países do ocidente estão totalmente dependentes de importações e, até mesmo, de reciclagem, conforme apontou SEAMAN (Figura 23).



Fonte: SEAMAN, 2010

Figura 23 – Consumo mundial estimado de terras raras, por países, em 2010

Existiam previsões de que a demanda atingiria 180.000 toneladas/ano em 2012 e 200.000 toneladas em 2014, sendo pouco provável que a entrada de novas minas em produção pudessem compensar essa diferença, no curto prazo. Como a produção chinesa não deve ultrapassar 160.000 toneladas, no curto prazo, pode-se prever que haverá um déficit anual de 40.000 toneladas/ano, nesse horizonte (HUMPHRIES, 2010).

A situação é preocupante em países altamente industrializados como EUA, Japão, Coréia do Sul, União Europeia, mas também, especialmente, naqueles em desenvolvimento, que não pretendem ser apenas importadores de produtos de tecnologia de ponta.

Existia farto noticiário de que, no caso dos EUA, a demanda por ímãs permanentes deveria crescer em 2012, entre 10 e 16% e que a demanda por aplicações em catálise deveria subir de 6 a 8%. Por outro lado, especialistas norte-americanos apontavam, à mesma época, que: *The lighter elements such as lanthanum, cerium, praseodymium, and neodymium are more abundant and concentrated and usually make up about 80% - 99% of a total deposit. The heavier elements – gadolinium through lutetium and yttrium – are scarcer but very "desirable" according to USGS commodity analysts* (HUMPHRIES, 2010).

No Brasil, embora não exista uma cadeia verticalizada em produtos de terras raras, já está bem conhecido que as terras raras, além de formarem depósitos específicos, ocorrem com outros elementos como o cobre, ouro (a região de Salobo, Carajás apresenta bom potencial), urânio, fosfatos, assim como em minérios de Sn (cassiterita), Nb (pirocloro), Nb-Ta (niobotantalitas), Zr (zircão), F (fluorita).

Corroborando com essa afirmativa, destaque-se a opinião do especialista americano Anthony Mariano, que é conhecedor do potencial geológico do Brasil: *Careful consideration should be given to the feasibility of mining and processing of REEs as a byproduct of phosphorus deposits and from titanium ad niobium mines in Brazil* (MARIANO et al., 2010).

Segundo especialistas do Serviço Geológico Americano (USGS), no longo prazo, as reservas já descobertas e os recursos que estão a ser definidos, principalmente no Canadá, EUA, Groenlândia e Austrália, em três dezenas de projetos, serão suficientes para satisfazer a demanda (HUMPHRIES, 2010).

O mesmo autor, em relatório preparado para os membros de comitês do congresso norte-americano, coloca os seguintes dados:

> *World demand for rare earth elements is estimated at 134,000 tons per year, with global production around 124,000 tons annually. The difference is covered by above-ground stocks or inventories. World demand is projected to rise to 180,000 tons annually by 2012, while it is unlikely that new mine output will close the gap in the short term. By 2014, global demand for rare earth elements may exceed 200,000 tons per year. China's output may reach 160,000 tons per year (up from 130,000 tons in 2008) in 2014. An additional capacity shortfall of 40,000 tons per year may occur. This potential shortfall has raised concerns in the U.S. Congress. New mining projects could easily take 10 years for development. In the long run, however, the USGS expects that reserves and undiscovered resources are large enough to meet demand.*

Em nossa opinião, entretanto, mesmo depois da entrada em operação de novas usinas de processamento, poderá continuar a haver carência dos elementos La, Nd, Eu e das terras raras pesadas, em especial, Tb, Dy, Lu e Y. Daí o interesse demonstrado por empresas internacionais no xenotímio de Pitinga (AM) e em identificar ocorrências ricas nestes elementos.

É fato que nos últimos anos tem-se verificado na China grande aumento do consumo interno dos elementos das terras raras. Associado a esse fato contribuem ainda para o risco da escassez, o fechamento de garimpos e de pequenas minas, por razões ambientais e de extração predatória, o que provocou, entre 2010 e 2011, em consequência, limitações na produção interna e nas suas exportações.

ZHANHENG CHEN (2011), Director of the Academic Department of the Chinese Society of Rare Earths (CSRE), na sua apresentação, em janeiro de 2011, em Vancouver, divulgou os seguintes números, os quais foram também citados por HATCH (2011):

Total supply in 2013 of 87 kt from China, out of a total 134 kt of global supply. He also forecast a total global supply target after 2015, of 278 kt of rare earths, with the target for China's production set at 100 kt of rare earths and 178 kt from other sources. In some quarters, this figure of 278 kt appears to have been misinterpreted as being a demand forecast from Dr. Chen, but this is not the case.

Ainda, na apresentação de Chen foi feita uma referência a um particular projeto da Mitsubishi / Neo Material Technologies, a ser implantado, no futuro próximo, em Pitinga (AM), como: *non-Chinese sources of supply of rare earths preparing to come on-stream.* As previsões de produção futura segundo HATCH, correspondem a: para o período 2011-2013 seria 0,5 ktpa TREO, enquanto a capacidade prevista para 2015 atingirá 1 ktpa TREO (HATCH, 2011).

Esses fatos, que estão associados ao forte aumento na demanda mundial, vêm, entretanto, viabilizando a retomada de projetos em vários países. Segundo HOCQUARD (2010), dez desses projetos estão em fase adiantada, devendo ser salientado que a mina do Pitinga - AM (majoritariamente de elementos das terras raras pesadas) foi incluída nessa lista.

Por outro lado, LIFTON prevê que a China *will be completely self-sufficient in domestic rare-earth production for its supply chain in 2015 as it is today. I also think that higher prices for rare earths are inevitable as China cleans up the environment in general and in mining in particular. The one, the greening of rare earth mining, adds costs to rare-earth mining; the other, the greening of the Chinese economy, adds demand. Both are upward price drivers.* (LIFTON, 2011).

Esse mesmo especialista J. Lifton, que é reconhecido como um profundo conhecedor da problemática das terras raras, apresenta os seguintes comentários sobre o redobrado interesse na definição e explotação de novos depósitos.

The best market plan for non-Chinese miners who plan to produce rare earths is to acquire or JV with existing companies that already have the skill sets needed. These will be Chinese, Japanese, French, British, Indian, or Estonian companies. Some have already done this. Any mining venture *that intends to go head-to-head with a Chinese mining venture, solely on the ability to produce ore concentrates or even separated and purified chemical compounds must, I think, fail. There is also one more thing that all rare-earth end users must do. They must secure their supply of the total of the critical rare earths for their products or processes. This means to me, that they must secure their supplies of one or more of lanthanum, neodymium, samarium, europium, dysprosium, and terbium* (LIFTON, 2011a).

O mesmo autor alerta, ainda, que as indústrias que queiram entrar na produção de ímãs de alto rendimento, como é o caso dos motores de carros híbridos elétricos e de turbinas eólicas, setores em ampla expansão, devem procurar garantir o fornecimento das terras raras para as suas necessidades, preferencialmente, por meio de associações estratégicas com os produtores dos insumos.

Retornando ao contexto nacional, lembra-se que elementos de terras raras pesadas, com significativa presença no xenotímio de Pitinga, como: Nd (69,4%), Pr (23,4%), Dy (5%), Gd (2%) e Tb (0,2%), são usados, entre outras aplicações, para fabricar ímãs permanentes (Nd-Fe-B) de grande eficiência e alta qualidade.

Por exemplo, é reconhecido que o motor híbrido do Toyota Prius necessita de 1kg de Nd, o do Mercedes S-400, 0,5kg e as baterias Ni-M-H (Nickel-Metal Hydrid) do Toyota Prius, de grande durabilidade, requerem 12 a 20kg de La por unidade

Os mais recentes modelos de grandes fabricantes de turbinas eólicas, , por exemplo, Vestas e China's Goldwin, principalmente aquelas de aplicação em centrais *offshore*, também usam ímãs Nd-Fe-B que lhes aumenta a eficiência e reduz, substancialmente, a necessidade de manutenção. Cite-se, ainda, a título de exemplo, as turbinas de 3 MW desenvolvidas pela empresa Siemens, as quais requerem 2 toneladas de ímãs por turbina, correspondendo ao consumo de 600kg de Nd por turbina (HOCQUARD, 2010; SEAMAN, 2010).

A ampla utilização de lâmpadas frias de alta eficiência energética, em substituição às incandescentes, da mesma forma, é responsável por uma parcela significativa do aumento de consumo de elementos de terras raras, nesse caso, especificamente, representados por Y, La, Ce, Eu, Gd, Tb.

Nos EUA, por exemplo, há estudos que mostram que o uso deste tipo de lâmpadas em iluminação pública e em prédios governamentais poderá traduzir-se, em economia de energia, que implica na redução de emissão da GEE (Gases de Efeito Estufa), proporcional a 1/3 do volume total que é emitido pelos veículos que utilizam combustíveis fósseis naquele país (HAXEL, HEDRICK, ORRIS, 2010).

Não se deve esquecer, ainda, que há um desenvolvimento constante de novos materiais para aplicação em novas tecnologias, nos quais a aplicação dos elementos de terras raras é indispensável. Esse é o caso dos supercondutores (ítrio), com aplicação em refrigeração magnética e de novos campos de aplicação, como é o caso da termoeletricidade. Nesse caso específico, descobriu-se que a adição de apenas 1% de um elemento do grupo das terras raras, cério ou itérbio, melhora o desempenho de materiais termoelétricos, conhecidos como TAGS - em até 25% (LEVIN et al., 2011).

Os materiais termoelétricos são capazes de converter diferenças de temperatura diretamente em eletricidade - um fenômeno conhecido como efeito Seebeck – por outro lado, convertem a eletricidade diretamente em diferenciais de temperatura - um fenômeno conhecido como efeito Peltier.

Retornamos, entretanto, a destacar algumas das percepções de Jack Lifton (LIFTON, 2010; LIFTON, 2011), sobre a atual problemática das terras raras.

- *The most critical of the current rare earths are dysprosium and terbium, two of the heavy rare earths, today produced only in China and historically produced only in the former Soviet Union and in China.*
- *There are only a small number of rare-earth projects outside of China capable of producing commercial quantities of dysprosium and terbium.*
- *Some or all of these MUST be brought into production as soon as possible, because it is said by the Chinese themselves, that their heavy-rare-earth production has less than 25 years remaining at present levels, and much less if demand increases.*

- *China, like the rest of the rare-earth-using countries, is therefore also seeking out heavy-rare-earth production.*
- *There will be no non-Chinese, rare-earth-based, mass-produced devices utilizing rare-earth permanent magnets, until a reliable steady supply of dysprosium can be secured.*
- *The lighting industry outside of China will founder, without a secure supply of the heavy rare earth terbium.*
- *Therefore, if there is to be a non-Chinese, rare-earth-utilizing manufacturing industry, one or more of the heavy-rare-earth deposits that are technically feasible, must be brought into production even if it is not economically sensible on a freestanding basis as a business.*
- *The rare earths supply issue is one of contemporary economics not of scarcity. I think we are now beginning to see the issue of absolute scarcy of some of the technology metals, as I call the rare metals that underpin all our of technology and which appear in the chart in the Appendix, almost entirely as metals produced at a rate lower than that of lanthanum (32,000 tonnes in 2009).*
- *If the goal of future society is to live in a world of unlimited consumption then it will fail; it's time to make some very long term plans and make choices about the allocation of human intellectual as well as financial capital to ensure the best life for the most people. The problems are water, energy, and metals* (LIFTON, 2010).

Há que se salientar que enquanto as terras raras leves são produzidas como coprodutos da mineração organizada de minério de ferro, Dy e Tb são produzidos no sul da China em 200 minas artesanais das quais 50% delas são ditas ilegais.

Em Guyun, pequena aldeia do SE da China a extração é feita manualmente, com pás. A laterita mineralizada é colocada em fossas onde é lançado, diretamente, reagentes químicos, que se infiltram no solo, provocando fortes problemas ambientais. Esta produção vinha sendo, geralmente, contrabandeada para exportação (HOCQUARD, 2010), porém as recentes medidas tomadas pelo governo chinês devem reorganizar e melhorar o controle desses atos.

Em função dessa reestruturação, é de se prever que a China poderá, no curto prazo, decidir por uma diminuição de oferta desses elementos pesados para o mercado mundial, coincidindo, ainda, com o aumento do seu consumo interno.

7. RESUMINDO E CONCLUINDO: RUMOS TÉCNICOS PARA O DESENVOLVIMENTO DA INDÚSTRIA MINERAL DAS TERRAS RARAS NO BRASIL

A situação e a problemática das terras raras no Brasil, está inserida no atual contexto mundial, merecendo, mais do que nunca, uma reflexão atenta, que se apoia em alguns fatos.

Parafraseando a conhecida afirmação de Eduardo Portela, pode-se dizer que as terras raras NÃO SÃO raras (várias), ESTÃO raras (algumas como, por exemplo, Dy, Tb, Nd, Eu), e talvez continuem escassas até que novas minas entrem em produção em vários países.

Não há risco de penúria de recursos desses elementos a médio/longo prazo, desde que entrem em produção os depósitos/reservas já conhecidas, ao redor do mundo, havendo assim, disponibilidade imediata de terras raras para a indústria.

Para compensar a rápida redução da produção e das vendas chinesas, há necessidade de colocar em produção, no curto prazo, jazidas conhecidas que ainda não estejam em produção, avaliar ocorrências e desenvolver campanhas de prospecção para localização de novos depósitos de forma a atender ao aumento de consumo e à escassez das reservas atuais de certos elementos, como é o caso das terras raras ítricas.

Neste contexto, deve ser observada, com bastante atenção, no Brasil, a feição polimineralica dos depósitos de baixo teor, para se pesquisar a possibilidade de recuperação das terras raras como subproduto e/ou coproduto das indústrias de nióbio, estanho e fosfatos.

É mandatório que se considerem os mais atuais preceitos de sustentabilidade, os quais devem ser aliados àqueles técnico-econômicos para o desenvolvimento de caminhos inovadores de explotação desses elementos.

O Brasil que já teve posição de destaque, tem enorme potencial para explotar terras raras, porém está perdendo a corrida nos campos da produção e industrialização desses elementos, o que se reflete, da mesma forma, nas ações relacionadas à pesquisa, desenvolvimento e inovação.

O Brasil deveria, portanto, projetar e fomentar a verticalização da indústria das terras raras não se atendo apenas a produzí-las e exportá-las, na condição de *commodities*, tal como acontecia há cerca de 20 anos.

É bastante promissor, portanto, a implantação de uma cadeia produtiva de ímãs permanentes de terras raras, de alto rendimento, no Brasil. Uma vez existente essa cadeia poderá atender, entre outras, às chamadas "indústrias verdes", que fabricam as turbinas eólicas e os carros híbridos elétricos, já que irão requerer grande quantidade de terras raras, principalmente, Nd, Dy, Tb (ímãs - motores), La (baterias), entre outras (GROUPE D'INFORMATION SUR LES ÉOLIENNES, 2011).

VILLAVERDE (2011) cita que o governo planeja dar forte estímulo ao 'carro verde' e, ainda, que segundo um dos principais articuladores do regime automotivo, "nossa chance de liderar o desenvolvimento tecnológico na indústria automobilística, inclusive para construir uma fábrica 100% nacional, focada no carro elétrico, é agora".

É quase consenso, nesse segmento, que as empresas que se lançarem nesses projetos devem ter garantido o abastecimento das terras raras que necessitarão para uso nos seus produtos.

É fato, ainda, no Brasil que se tem verificado, ao longo do tempo, a não viabilização de jazidas e/ou o subaproveitamento de outras, acarretando, inclusive, danos ambientais, por não serem consideradas como jazidas polimineralicas.

Uma das razões talvez seja o fato das grandes empresas mineiras atuarem mais como empresas que comercializam minérios do que como empresas de mineração, no termo mais estrito, tendo como alvo, tão somente, a obtenção do maior lucro possível.

Percebe-se que, via de regra, tem sido feitas lavras predatórias. Há um descaso com o aproveitamento integral de depósitos/jazidas que deveriam incluir subprodutos, rejeitos e resíduos, isto é, verifica-se, via de regra, a inobservância do conceito de sustentabilidade na indústria mineira.

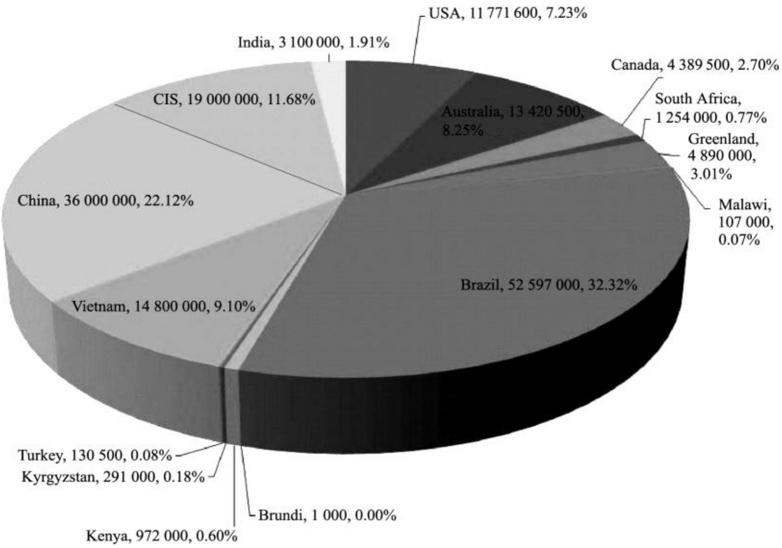
Uma outra percepção que se pode ter é que as empresas brasileiras, talvez por falta de visão técnica ou de espírito inovador e de vontade política, ou por simples omissão, estão a sujeitar o país à carência de elementos estratégicos, não raramente de elevado valor comercial, os quais são importados a altos preços, na forma de produtos transformados.

Há, pois, necessidade de se implantar uma política de estado que possa corrigir os danos que estão sendo causados à economia do país, ao meio ambiente e ao conceito de desenvolvimento sustentável.

É notório que não têm sido realizados estudos detalhados e sistemáticos direcionados à prospecção e definição de ocorrência de terras raras em rochas graníticas. As informações que existem são resultantes, em grande parte, de estudos acadêmicos (teses) e da avaliação de ocorrências de outros bens minerais, principalmente cassiterita, fluorita e criolita, realizados há cerca de 20 anos.

Enquanto essa situação não se resolve, o Brasil está totalmente dependente da importação de terras raras, sendo que em 2008, importou cerca de 378 milhões de dólares, em bens primários, semimanufaturados, manufaturados e, principalmente, compostos químicos (US$ 264 milhões), de produtos à base de terras raras.

Autores estrangeiros, por outro lado, citam que os recursos brasileiros de terras raras, com base em estudos internacionais bem fundamentados (depósitos), são referidos como sendo da ordem de 52,5 milhões de toneladas (CHEN, 2011).



Fonte: CHEN, 2011

Figura 24 – Distribuição de terras raras no mundo

Chama-se mais uma vez a atenção para o fato de, só em Catalão e Araxá, o Brasil, possuir recursos medidos ("reservas contidas"), de terras raras leves, superiores às reservas oficiais da China mas, ainda, sem comprovação de tecnologia viável para justificar uma extração econômica.

Note-se que quando citamos, "ainda sem comprovação de tecnologia de extração econômica", referimo-nos às condições prevalecentes há, pelo menos, 20 anos atrás, quando a China derrubou os preços internacionais das terras raras e inundou os mercados com os seus produtos, a preços baixíssimos, fato que não se verifica nos últimos 10 anos.

Ressalte-se, ainda, o fato da monazita do depósito do Córrego do Garimpo, Catalão I (GO), apresentar baixos teores de Th e de U (NEUMANN, 1999; RIBEIRO, 2008), sendo bastante provável que o mesmo aconteça no depósito vizinho de Lagoa Seca.

É reconhecido que os concentrados de xenotímio, que podem ser obtidos em Pitinga (AM), como subprodutos da cassiterita, têm enorme valor estratégico e comercial, em virtude dos altos teores e do perfil de distribuição dos elementos de terras raras pesadas.

Como já foi referido, o xenotímio de Pitinga (AM) é uma variedade incomum pela sua composição. Apresenta altíssimo valor para o somatório dos teores das terras raras pesadas (98,4%), embora relativamente baixo de ítrio (42,13%). Merecem destaque especial os valores de Yb (20,97%), Er (14,27%) e Dy (10,64%).

Até onde se sabe oficialmente, não foi estabelecido, ainda, o volume total das reservas de xenotímio existente no aluvião e no minério primário de cassiterita da mina do Pitinga.

Por outro lado, está bem definida uma área anômala para terras raras ao norte do corpo de minério primário da mina do Pitinga. Em complemento, é sabido que a produção da liga FeNbTa, por aluminotermia, deixa nas escórias, Y e outros elementos de terras raras, caso não tenham sido separados na etapa de beneficiamento. Outra parcela fica retida nas escórias da metalurgia do estanho.

Há outro aspecto que deve ser visto com particular atenção: as terras raras não devem ser consideradas apenas como produto base ou único, para fins de definição de uma jazidas, mas também e principalmente, como subproduto ou coproduto de depósitos polimineRálicos, isto por razões de sustentabilidade econômica e ambiental.

Além de existirem indústrias já estabelecidas que necessitam de terras raras como, por exemplo, a FCC (Fábrica Carioca de Catalisadores), sabe-se que há propostas para a execução de projetos consorciados, incluindo a iniciativa privada e o setor governamental, representado por universidades e centros de pesquisa, que buscam viabilizar a produção, no Brasil, de ímãs permanentes, de turbinas eólicas, de carros híbridos elétricos (empresa EBX e Renault/Nissan) e de trens de levitação magnética para transporte urbano (Projeto MagLev Cobra – COPPE / UFRJ). Todos eles serão grandes consumidores de terras raras.

Outro aspecto a levar em consideração é o fato da cadeia de abastecimento das terras raras ser complexa, exigindo, pelo menos, cinco etapas até a sua aplicação, quais sejam: lavra, concentração, extração, separação e purificação para a produção de compostos. Os produtos finais são, segundo C. Hocquard (2010), mais de 400 compostos, sob a forma de aproximadamente 1000 especificações diferenciadas, conforme as aplicações.

A explotação mineral das terras-araras pode dar origem, de uma forma mais simples, a uma mistura de 17 elementos que podem formar o chamado *mischmetal*. A separação dos elementos de terras raras, seguindo o caminho da extração por solventes é, entretanto, complexa. No caso do Yb, por exemplo, pode requerer até 1000 estágios para que seja possível a produção do metal de alta pureza, dependendo das etapas iniciais, incluindo a solubilização e os circuitos de separação.

Existe, portanto no Brasil, uma excelente oportunidade para a exploração das terras raras, considerando a grande proporção de ocorrências polimineralícas com enorme potencial, desde que as terras raras sejam consideradas como coproduto ou subproduto.

Há que se reiterar que suas fontes principais, no Brasil, são os granitos alcalinos da região de Pitinga (AM) e os minérios de zircônio e de estanho na Amazônia, neste caso como coproduto da explotação desses bens minerais. É também referida a presença de xenotímio, em pegmatitos, no extremo sul de Minas Gerais, na região do rio Sapucaí.

O xenotímio que é o principal mineral de elementos de terras raras pesadas ocorre em alcaligranitos, associados a depósitos de cassiterita e de niobotantalitas, com ampla distribuição no norte e noroeste do Brasil.

No Brasil os principais minerais de terras raras são a monazita, a bastnaesita (terras raras leves) e o xenotímio (terras raras pesadas). Os únicos depósitos que deram origem à produção industrial de terras raras foram as areias monazíticas do litoral da Bahia e do norte fluminense.

É sobre as terras raras pesadas que, prioritariamente, deverão incidir os programas de prospecção e pesquisa mineral que venham a ser desenvolvidos no Brasil, tanto mais que já são conhecidos depósitos com grandes reservas e teores elevados de elementos terras raras leves no País.

Em capítulo anterior foi demonstrado que são numerosas as ocorrências de terras raras no país. Além dos *placers* de litorais e de rios, conhecidos há muito, existem, no caso das terras raras leves, importantes depósitos com teores e reservas elevados, associados a complexos carbonatíticos, já bem definidos em Catalão (GO) e Araxá (MG). Em associação com outros bens minerais, tais como os de P (apatita), Ti (anatásio), Nb-Ta (niobotantalitas), Zr (zircão), Sn (cassiterita) são conhecidas várias ocorrências de TR – U – Th em diversas regiões do Brasil (LAPIDO-LOUREIRO, 1994). São depósitos com enorme potencial desde que as terras raras sejam consideradas como coproduto ou subproduto. Os minérios de cobre também apresentam bom potencial para elementos de terras raras como subproduto.

Outros minerais contendo terras raras como a apatita, a perovskita e o pirocloro, em matrizes carbonatítico-ultrabásicas, dão origem, por intemperismo, à neoformação de minerais e enriquecimento residual. Formam depósitos com boas reservas e teores elevados de elementos de terras raras leves, mas constituem minérios complexos, ainda carentes de tecnologia para sua extração econômica. Apresentam grande potencial para se transformar em jazidas, principalmente agora com a subida do preço das terras raras, uma consequência da demanda já ultrapassar a oferta.

Antes de finalizar sugere-se alguns pontos que, em nossa opinião, deveriam merecer prioridade e ações competentes do governo e do setor privado, para que o Brasil retome a produção de terras raras, que ocorrem habitualmente em depósitos polimineralícos, como produto principal, coproduto ou subproduto, de outros metais raros de alto valor econômico-estratégico. São sugeridas algumas ações que premiam todas as etapas necessárias para mapear a cadeia produtiva de terras-araras, conforme a seguir:

- Inventariação, caracterização e avaliação das ocorrências e depósitos conhecidos de terras raras, selecionando os mais promissores e estabelecendo prioridades, o que, em grande parte, já foi realizado, não esquecendo que cada minério tem o seu perfil característico de distribuição dos elementos de terras raras.

- Integração do bem mineral terras raras num programa de prospecção de metais raros;
- Caracterização tecnológica, avaliação de teores, reservas e desenvolvimento sistemático de trabalhos de P,D&I para recuperação de terras raras nos depósitos que apresentem teores promissores de recuperação, reservas e mineralogia favorável.
- Pesquisar e definir processos de beneficiamento e de extração hidrometalúrgica das terras raras, no(s) depósito(s) selecionado(s), se necessário seguindo caminhos inovadores.
- Realizar estudos de pré-viabilidade, em escala de bancada e piloto, demonstrativos da viabilidade técnico-econômica de extração das terras raras do(s) minério(s) selecionado(s).
- Estabelecer projeto(s) de lavra que atendam às condicionantes sócio-econômico-ambientais.
- Pesquisar e definir a separação individual das terras raras e de outros metais.
- Implantação do(s) núcleo(s) produtor(es) após aprovação ambiental do projeto de lavra, beneficiamento e produção.
- Estudar a possibilidade de recuperação de terras raras a partir de rejeitos (fosfogesso) e de escórias (por exemplo; da produção da liga de Fe-Nb).
- Incentivar o aproveitamento integral de jazidas poliminerálicas, estabelecer penalidades para as práticas de lavras predatórias que apenas explotam o bem mineral que traz maior e mais fácil retorno comercial.
- Prestar particular atenção ao fato de que, como já foi dito, *the most critical of the current rare earths are dysprosium and terbium, two of the heavy rare earths, today produced only in China /…/ all rare-earth end users must do: they must secure their supply of the total of the critical rare earths for their*

products or processes; this means to me, that they must secure their supplies of one or more of lanthanum, neodymium, samarium, europium, dysprosium, and terbium (LIFTON, 2011; 2011a).

Assim ao finalizar, entende o autor que para que o Brasil retome o lugar de destaque, que já teve, na produção de terras raras não se deve limitar à extração, mas, principalmente, à implantação de um amplo programa de P,D&I que leve ao desenvolvimento, em cadeias produtivas de processos e de produtos de alto valor agregado. É previsível que será necessário encetar ações mútuas e complementares de governo e do setor privado, considerando a relevância estratégica desses elementos e produtos para o País.

Pode-se considerar, ainda, que há nesse momento sinais evidentes de alinhamento entre o setor público e privado no tocante a implantação de uma cadeira produtiva de terras raras no Brasil, tendo em vista as iniciativas efetuadas por ambas as partes nesse sentido. Há que se destacar, ainda, o aumento considerável dos requerimentos de áreas para pesquisa mineral em terras raras, que tem acontecido nos últimos três anos.

Por oportuno, o Apêndice J apresenta a lista atualizada dos projetos mais promissores para explotação de terras raras no mundo, segundo a análise do especialista Garet Hatch. Na visão desse autor, no caso do Brasil, aparece nessa lista o projeto Araxá, mostrando o interesse efetivo do setor privado na exploração de uma das reservas consideradas como das mais promissoras do País.

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APÊNDICES

APÊNDICE A

A questão das terras raras no Senado Americano

Fonte: H.R. 4866 (111th): Rare Earths Supply-Chain Technology and Resources Transformation Act of 2010

Nos EUA, em 28 de outubro de 2009, o Senador Christopher S. Bond enviou uma carta aos Secretários da Defesa e da Energia, alertando e mostrando que:

The United States is currently 100% import dependent upon a group of minerals called Rare Earths. A reliable and steady supply of these elements is essential to national security /.../. Rare Earth elements also hold unique chemical, magnetic, electrical, luminiscence, and radioactive shielding characteristics for environmental and "green technology" applications.

Em março de 2010 o senador Mike Coffman apresentou, no senado americano, uma proposta de lei to adress the looming rare earth crisis". Trata-se da House Resolution 4866, the Rare Earths Supply-Chain Technology and Resources Transformation Act of 2010 (RESTART Act). /.../

The Act would require that the United States develop a policy to: "take any and all actions necessary to ensure the reintroduction of competitive domestic rare earth suply chain, to include the reintruduction of the capacity to conduct mining, refining / processing, allowing and manufacturing operations using domestic suppliers to provide a secure source of rare earth materials as a vital component of national security and economic policy."

Acompanhando a proposta, voltou a acentuar aquilo que é também uma preocupação brasileira:

> *"The U.S. needs to support and encourage the development of a competitive, domestic rare earth supply chain to support American Jobs and manufacturing and ensure our national defense interests. This legislation is critical to creating a competitive, domestic rare earth supply chain in the U.S. over the next 5 years".*

Além do H.R. 4866, a Senadora Lisa Murkowsky introduziu o S.3521: Rare Earths Supply Technology and Resources Transfrmation Act of 2010.

Especificou que "*many modern defense technologies such as radar and sonar systems, precision-guided weapons, cruise missiles, and lasers cannot be built, as designed and specified, without the use of rare earths*."

> *The legislation introduced by Murkowski proposes assembling a task force chaired by the Secretary of Interior and composed of the secretaries of State, Energy, Defense, Commerce and Agriculture.*
>
> *The primary objective of the high-ranking panel would be to "monitor and assist federal agencies in expediting the review and approval of permits or other actions, as necessary, to accelerate the completion of projects that will increase investment in, exploration for, and development of domestic rare earths"*
>
> *Among proposals in Coffman's bill are assessments and implementations of "obtaining loan guarantees to support the re-establishment of mining, refining, alloying and manufacturing operations for (rare earth elements) in the United States."*
>
> *The legislation introduced by Murkowski proposes assembling a task force chaired by the Secretary of Interior and composed of the secretaries of State, Energy, Defense, Commerce and Agriculture.*
>
> *The primary objective of the high-ranking panel would be to "monitor and assist federal agencies in expediting the review and approval of permits or other actions, as necessary, to accelerate the completion of projects that will increase investment in, exploration for, and development of domestic rare earths."*
>
> *"Rather than further restrict mining in this country, the industry could be creating American jobs and producing minerals that are essential to clean energy technologies. Unless action is taken, we will trade our current dependence on foreign oil for an equally unsettling dependence on foreign minerals," the Alaska senator advised her colleagues.*

APÊNDICE B

"Minerals at Risk and for Emerging Technologies"

Fonte: GRAUCH, R.I. et al. (2010)

This program focuses on updating the existing geological information in mineral resources, such as rare earths, that are the subject of increasing demand from industry and elsewhere. /…/

With the growing interest of late in the need to develop rare earth deposits outside China, Wings has been promoting the presence of rare earths on its property in Missouri. The new USGS report, titled "Chemistry of Selected Core Samples, Concentrate, Tailings, and Tailings Pond Waters: Pea Ridge Iron (-Lanthanide-Gold) Deposit, Washington County, Missouri" was the result of a visit to the property in October 2008. It notes that the deposit "contains concentrations of lanthanides that may be economic as a primary product or as a byproduct of iron ore production", while noting that the dataset presented for the deposit is preliminary, has not been verified by the USGS or other entities, and that the inclusion of data from Wings was for comparative purposes only.

According to the report there are four rare-earth-bearing breccia pipes in the deposit, containing a variety of minerals such as monazite and xenotime, with historical claims of 12-13% total rare earth oxide present. There are also significant tailings left over from prior iron ore mining campaigns, that also contain rare earths. The initial sampling work by the USGS produced results that were consistent with the prior data sets produced by prior mine owners, though the USGS was at pains to point out that the results did not confirm the historical numbers.

"The Pea Ridge lanthanide resource is high grade and enriched in heavy REE+Y as compared to world class lanthanide deposits such as Bayan Obo (China), Mountain Pass (California), and the South China Clay Type Lanthanide Deposits (southern China). However, the open-ended, probable REE+Y reserve of Pea Ridge is smaller in comparison to the others".

APÊNDICE C

Uses and Sources of the Rare Earth Elements

Fonte: HURST (2010)

La Lanthanum 57

Uses: Lanthanum is strategically important due to its use as a catalyst to create fuel for vehicles and aircraft. It is also used in alloys needed as part of fuel cells and batteries. Lanthanum is the key to modifying glass crystal structure and the refractive index, which makes it easier for optical lens designers to create their lenses. Lanthanum is used in night vision instruments. Lanthanum is also used as a compound in carbon arc lamps, color television sets, cigarette lighter flints, and optical fibers. Its phosphors are used in X-ray films and certain lasers to help reduce the dose of radiation to patients by up to 75%. There is current interest in hydrogen sponge alloys containing lanthanum. These alloys take up to 400 times their own volume of hydrogen gas, and the process is reversible. Each time they take up gas, heat energy is released. Hence, these alloys have possibilities in an energy conservation system.

Abundance earth's crust: 3.9x101 milligrams per kilogram.

Abundance Ocean: 3.4x10-6 milligrams per liter

Sources: Found in rare-earth minerals such as cerite, monazite, and bastnaesite. Lanthanum and other rare earths have become more available in recent years. The metal can be produced by reducing the anhydrous fluoride with calcium.

Ce Cerium 58

Uses: Cerium has many uses. It is used for catalytic converters in automobiles to reduce emissions. It is used as a catalyst in petroleum refining and in metallurgical and nuclear applications. As an oxide, it is used in glass polishing agents. Along with other rare earths, cerium is used in carbon-arc lighting, especially in the motion picture industry. It is also used in self cleaning ovens. As part of a Mischmetal, it is used to manufacture pyrophoric alloys for cigarette lighters. A cerium based conversion coating is non corrosive and may have significant military applications.

Abundance earth's crust: 6.65x101 milligrams per kilogram

Abundance Ocean: 1.2x10-6 milligrams per liter

Sources: Cerium is the most abundant rare-earth metal. It is found in allanite (aka: orthite), monazite, bastnasite, cerite, and smarskite. Monazite and bastnasite are most predominant. There are large deposits of monazite on the beaches of Travancore, India, and in Brazilian river sands. Alanite can be found in the western United States. Bastnaesite is in Southern California.

Pr Praseodymium 59

Uses: Praseodymium is used as an alloying agent with magnesium to create high-strength metals used in aircraft engines. It is also used in a Misch metal compound (5%) for the flints in lighters. Praseodymium forms the core of carbon arc lighting, used in the motion picture industry. It is added to fiber optic cables 35 as a doping agent where it is used as a signal amplifier. Praseodymium salts give color to glasses and enamels. It is also a component of didymium glass, used to make various types of welder's masks.

Abundance earth's crust: 9.2 milligrams per kilogram

Abundance Ocean: 6.4x10-7 milligrams per liter

Sources: Monazite and bastnaesite are the two primary commercial sources of

Praseodymium.

Nd Neodymium 60

Uses: Modern day technology, such as cell phones, portable CD players, computers and sound systems would be vastly different without the use of strong permanent magnets made from neodymium. The Neodymium-Iron-Boron (NdFeB) permanent magnets are so strong that they are ideal for the miniaturization of a variety of technologies. Neodymium based permanent magnets are also at the heart of anti-lock brakes, air bags, anti-glare automobile light glass and mirrors. Neodymium oxide can be added to CRT glass to enhance picture brightness by absorbing yellow light waves. The oxide also has a sky-blue color and is used to produce various coloring pigments for ceramic tile, artistic glass, and others. Neodymium compounds help stabilize electrical properties in ceramic capacitors. Many solid state lasers use neodymium due to its optimal selection of absorption and emitting wavelengths. Neodymium lasers are used in material processing, drilling spot welding/marking and medicine, where the neodymium light laser is *used for non-evasive surgical procedures. MRIs also use the neodymium magnet. Neodymium is also used in Mischmetal (18%) for the flint in lighters.*

Abundance earth's crust: 4.15x101 milligrams per kilogram

Abundance Ocean: 2.8x10-6 milligrams per liter

Pm Promethium 61

Uses: Promethium is not found naturally on earth. Promethium is used as a beta source for thickness gages and can be absorbed by a phosphor to produce light. It can be used as a nuclear powered battery by capturing light in photocells which convert it into electric current. Such a battery, using 147Pm would have a useful life of about 5 years. Promethium shows promise as a portable X-ray source. It might also be useful as a heat source to provide auxiliary power for space probes and satellites. Promethium can be used to make lasers that can be used to communicate with submerged submarines.

Abundance earth's crust: Not applicable

Abundance Ocean: Not applicable

Sources: It now seems that Pm is missing from the earth's crust.

Sm Samarium 62

Uses: Samarium is combined with cobalt to create a permanent magnet with the highest resistance to demagnetization of any material known. Because of its ability to take continuous temperatures above 250 degrees, it is essential in both aerospace and military applications. Precision guided munitions use samarium-36 cobalt permanent magnet motors to direct the flight control surfaces (fins). Samarium-cobalt can be used as part of stealth technology in helicopters to create white noise to cancel or hide the sound of the rotor blades. These permanent magnets are also used as part of the aircraft electrical systems. They also are used to move the flight control surfaces of aircraft, including flaps, rudder, and ailerons. Samarium is used in both missile and radar systems' traveling wave tube (TWT). Samarium-cobalt magnets are used in defense radar systems as well as in several types of electronic counter measure equipment, such as the Tail Warning Function. Samarium is also used as carbon arc lighting for the motion picture industry. Samarium oxide has been used in optical glass to absorb the infrared. It is used in infrared absorbing glass and as a neutron absorber in nuclear reactors.

Abundance earth's crust: 7.05 milligrams per kilogram

Abundance Ocean: 4.5x10-7 milligrams per liter

Sources: Found in minerals such as monazite (2.8%) and bastnaesite, which are commercial sources.

Eu Europium 63

Uses: There are no commercial uses for europium metal. However, europium has been used to dope some types of plastics to make lasers. Europium is the most reactive of the rare earth elements. It is being studied for possible use in nuclear reactors. Europium oxide is widely used as a red phosphor in television sets and as an activator for yttrium-based phosphors. Europium-doped plastic has been used as a laser material.

Abundance earth's crust: 2.0 milligrams per kilogram

Abundance Ocean: 1.3x10-7 milligrams per liter

Sources: Identified spectroscopically in the sun and certain stars. 17 isotopes are now recognized.

Gd Gadolinium 64

Uses: Gadolinium has unique magnetic behavior, which allows it to form the heart of magneto-optic recording technology used for handling computer data. Magnetic resonance imaging (MRI) systems use materials that contain Gadolinium to enhance the images created. Gadolinium is also the most efficient element used to detect power plant radiation leaks. Gadolinium is used with yttrium to form garnets that have microwave applications. Gadolinium can be alloyed with certain metals, such as iron and chromium, to improve their workability and resistance to high temperatures and oxidation. Gadolinium compounds are also used to make phosphors for color televisions.

Abundance earth's crust: 6.2 milligrams per kilogram

Abundance Ocean: 7x10-7 milligrams per liter

Sources: Found in several other minerals such as monazite and bastnaesite, both of which are commercially important.

Er Terbium 65

Uses: Terbium with zirconium dioxide can be used as a crystal stabilizer in fuel cells that operate at high temperatures. It is used in energy efficient fluorescent lamps and metal alloys that provide suitable metallic films for magneto-optic recording of data.

Abundance earth's crust: 1.2 milligrams per kilogram

Abundance Ocean: 1.4x10-7 milligrams per liter

Sources: Found in cerite, gadolinite and other minerals along with other rare earths.

Dy Dysprosium 66

Uses: Dysprosium, which is critical to improve the coercive force of high efficiency, high performance motors used in next-generation vehicles, energyconserving home electronics, and wind power generation, it is difficult to find a substitute. The metal, which has natural high oxidizing properties, is also difficult to store. Dysprosium is essential for Japanese technology, making electronic components smaller and faster. At this point, Japan is wholly dependent on China for a stable supply of this REE. *It can be an additive to enhance the coercivity in neodymium-iron-boron magnets. It has been used to make laser materials.*

Abundance earth's crust: 5.2 milligrams per kilogram

Abundance Ocean: 9.1x10-7 milligrams per liter

Sources: Dy occurs with other rare-earth elements in a variety of minerals such as xenotime, fergusonite, gadolinite, euxenite, polycrase, and blomstrandine. Monazite and bastnasite are the most important sources though.

Ho Holmium 67

Uses: Holmium is one of the least abundant rare earth elements. It has no commercial uses. However, it possesses unusual magnetic properties that could be exploited in the future.

Abundance earth's crust: 1.3 milligrams per kilogram

Abundance Ocean:2.2x10-7 milligrams per liter

Er Erbium 68

Uses: Erbium is used as an amplifier for fiber optic data transmission. Erbium has also been introduced in lasers for medical and dental uses because they are suited to energy delivery without thermal build up in human tissue. Erbium is used to color glass. It is the only pink colorant truly stable in glass melts. It is used in sunglasses and decorative crystal glassware. Erbium has also been finding uses in nuclear and metallurgy. For example, adding erbium to vanadium lowers the hardness and improves workability.

Abundance earth's crust: 3.5 milligrams per kilogram

Abundance Ocean: 8.7x10-7 milligrams per liter

Sources: Found in the same metals mentioned under Dy.

Tm Thulium 69

Uses: Thulium is the rarest of the rare earths. Its chemistry is similar to yttrium. It can be used in sensitive X-ray phosphors to reduce X-ray exposure. However, it is very expensive and therefore has few practical applications.

Abundance earth's crust: 5.2x10-1 milligrams per kilogram

Abundance Ocean: 1.7x10-7 milligrams per liter

Sources: Tm occurs in small quantities along with other rare earths in a number of minerals. It is obtained commercially from monazite, which contains about 0.007% of the element. Tm is the least abundant of the REEs. New sources, however, have been discovered and now it is considered as rare as silver, gold or cadmium.

Yb Ytterbium 70

Uses: When subject to very high stresses, ytterbium increases its electrical resistance by an order of magnitude and is used in stress gauges to monitor ground deformations caused, for example, by nuclear explosions. Ytterbium might have some use in improving the grain refinement, strength, and other mechanical properties of stainless steel.

Abundance earth's crust: 3.2 milligrams per kilogram

Abundance Ocean: 8.2x10-7 milligrams per liter

Sources: Occurs with other rare earths in a number of rare minerals.

Commercially recovered mostly from monazite sand (0.03%). Handling: Has a low-acute toxic rating.

Lu Lutetium 71

Uses: Stable lutetium nuclides emit pure beta radiation after thermal neutron activation. Therefore, it can be used as catalysts in cracking, alkylation, hydrogenation, and polymerization. Cerium-doped lutetium oxyorthosilicate (LSO) is currently used in detectors in positron emission tomography (PET).

Abundance earth's crust: 8x10-1 milligrams per kilogram

Abundance Ocean: 1.5x10-7 milligrams per liter

Sources: Lu occurs in very small amounts in nearly all minerals that contain yttrium. In Monazite, it is present about 0.003% of the time (commercial source). The pure metal has been isolated only in recent years. It is one of the most difficult to prepare.

Handling: Lu is radioactive.

Y Yttrium 39

Uses: Yttrium oxide is the most frequently used oxide. Every vehicle uses yttrium based materials to help improve the efficiency of fuels and eliminate pollution.

Yttrium is also used in microwave communication devices for the defense and satellite industries. Yttrium iron garnets are used as resonators for use in frequency meters, magnetic field measurement devices, tunable transistor s and Gunn oscillators. Yttrium with garnets are used in cellular communications devices. Yttrium and other lanthanides have many high-tech and defense uses, such as stabilizers for exotic light-weight jet engine turbines and other parts and 39 as a stabilizer material in rocket nose cones. They can also be formed into laser crystals specific to spectral characteristics for military communications. Yttrium ceramics can be used as crucibles for melting reactive metals and as nozzles for jet casting molten alloys. Cars contain oxygen sensors composed of yttrium based ceramic materials. Yttrium is also widely used to give the red color in color television tubes.

Abundance earth's crust: 3.3x101 milligrams per kilogram

Abundance Ocean: 1.3x10-5 milligrams per liter

Sources: Y occurs in nearly all of the rare-earth minerals. There has been found high Y content on lunar rocks. Y is recovered commercially from monazite sand (3%) and from bastnaesite (0.2%).

Sc Scandium 21

Uses: There are two primary uses for scandium. First, due to its luminescence and electrical conductivity properties, scandium is used in lighting, lasers and consumer electronics. Second, it is used as an alloy in aluminum to produce high-performance materials in the aerospace and sporting goods industries. There are currently no substitutes for scandium in its applications to lasers and the illumination industry. However, titanium/aluminum alloys and carbon fiber can be used to replace scandium/aluminum alloys in some cases, especially in the sports equipment industry.

Abundance earth's crust: 2.2x101 milligrams per kilogram

Abundance Ocean: 6x10-7 milligrams per liter Handling: Little is known about toxicity.

Sources: More abundant in the sun and certain stars than on earth. It is widely distributed on earth. It occurs in very minute quantities in over 800 mineral species. Found in Scandinavia and Malagasy. Most Sc today is recovered from thortveitite or is extracted as a by-product from uranium mill tailings.

APÊNDICE D

Uses of REE

Fonte: HURST (2010)

Catalysts

- *Petroleum refining*
- *Chemical processing*
- *Catalytic converter*
- *Diesel additives*
- *Industrial pollution scrubberElectronics*
- *Display phosphors*

  -- *CRT*

  -- *PDP*

  -- *LCD*
- *Medical imaging phosphors*
- *Lasers*
- *Fiber optics*
- *Optical temperature sensors*

Glass

- *Polishing compounds*
- *Optical glass*
- *UV resistant glass*
- *X-ray imaging*
- *Thermal control mirrors*

- *Colorizers/Decolorizers Ceramics*
- *Capacitors*
- *Sensors*
- *Colorants*
- *Scintillators*

Metal Alloys

- *Hydrogen storage*

-- *NiMH batteries*

-- *Fuel cells*

- *Steel*
- *Lighter flints*
- *Aluminum/Magnesium*
- *Cast iron*
- *Superalloys*

Other

- *Water treatment*
- *Nuclear control rods*
- *Pigments*
- *Fertilizer*
- *Medical tracers*
- *Coatings Magnets*
- *Motors*
- *Disc drives & disk drive agnés*
- *Power generation*
- *Actuators*
- *Microphones & speakers*

- *MRI*
- *Anti-lock brake system*
- *Automotive parts*
- *Communication systems*
- *Electric drive & propulsion*
- *Frictionless bearings*
- *Magnetic storage disk*
- *Microwave agné tubes*
- *Magnetic refrigeration*
- *Magnetostrictive alloys*

APÊNDICE E

China's programs 863 and 973

Fonte: HURST (2010)

There is [in China] a great amount of interest in both the industry and the academics of rare earths elements. In fact, nearly 50 percent of the graduate students who come to study at the U.S. Department of Energy's Ames National Laboratory are from China and each time a visiting student returns to China, he or she is replaced by another Chinese visiting student.

China has long lagged behind the U.S. technologically. However, as of the early 1990s, China's vast rare earth resources have propelled the country into the number one position in the industry. Hence, it is only fitting that Chinese student interest follow suit. The study of rare earth elements in China is still new and exciting. Additionally, China has set out on an expansive effort to increase its overall technological innovation, effort which includes the use of rare earth elements. China's academic focus on rare earth elements could one day give the country a decisive advantage over technological innovation.

China first began its push for domestic innovation during the 1980's. Two programs came about as a result of China's desire to become a world leader in high-tech innovation. In March 1986, three Chinese scientists jointly proposed a plan that would accelerate the country's high-tech development. Deng Xiaoping, China's leader at the time, approved the National High Technology Research and Development Program, namely Program 863. According to China's Ministry of Science and Technology, the objective of the program is to "gain a foothold in the world arena; to strive to achieve breakthroughs in key technical fields that concern the national economic lifeline and national security; and to achieve 'leapfrog' development in key high-tech fields in which China enjoys relative advantages or should take strategic positions in order to provide high-tech support to fulfill strategic objectives in the implementation of the third step of China's modernization process5". Rare earth elements are an important strategic resource in which China has a considerable advantage due to the massive reserves in the country. Therefore, a great deal of money has gone toward researching rare earths. Program 863 is mainly meant to narrow the gap in technology between the developed world and China, which still lags behind in technological innovation, although progress is being made.

Program 863 focuses on biotechnology, space, information, laser, automation, energy, and new materials. It covers both military and civilian projects, with priority going to projects that may be used for both civilian and military purposes. 6. The use of rare earth elements can be found in each one of the areas in which Program 863 focuses.

Eleven years later, in March 1997, China's Ministry of Science and Technology announced Program 973. It is the largest basic research program in China.

5 Ministry of Science & Technology of the PRC, available from Internet;

http://www.most.gov.cn/eng, accessed 4 November 2009.

Research projects supported by Program 973 can last five years and receive tens of millions of RMB (10 million RMB = $1.46 million). Program 973 is specialized to meet the needs of the country. An example of a research project that would fall under Program 973, and which involves the study of rare earth elements, would be more efficient oil refining processes.

There are other programs as well, such as the Nature Science Foundation of China (NFSC), which generally lasts three years. However, no other program is as significant to China's technological innovation, including the research and development of rare earth elements, as Programs 863 and 973.

One cannot discuss the academics of rare earth elements in China without talking about Professor Xu Guangxian, who, in 2009, at the age of 89, won the 5 million yuan ($730,000) State Supreme Science and Technology prize, China's equivalent to a Nobel Prize. Xu was the second chemist ever to receive the prize.

Xu, considered the father of Chinese rare earth chemistry, persisted in his academic research despite numerous political setbacks and frustrations. China credits Xu with paving the way for the country to become the world's primary exporter of rare earth elements. Xu attended Columbia University, in the U.S., from 1946 to 1951, where he received a Ph.D. in chemistry. After the Korean War broke out, Xu returned to China, and was hired as an associate professor at Peking University. At first, he researched coordination chemistry, focusing on metal extraction. In 1956, he is said to have switched his focus to radiation chemistry, supporting China's efforts to develop atomic bombs. His work focused mostly on the extraction of nuclear fuels. After the Cultural Revolution began in 1966 1966, Xu's department stopped its atomic research and he turned his focus to theoretical research. Three years later, however, he, and his wife Gao Xiaoxia were *accused of being spies for the former Kuomintang government. Xu and Gao were held in a labor camp until 1972, after which time Xu returned to Peking University. Xu then began to study the extraction of praseodymium from rare earth ores as laser material.8 It was during this time that Xu made his greatest breakthrough. He applied his previous research in extracting isotopes of uranium to rare earth extraction and succeeded.*

/…/

There are two basic types of research – applied and fundamental. Prior to the 1990's, China focused on the separation of rare earths, which falls under applied research. Gschneidner, who is also a senior scientist at the Ames Laboratory, stated that 20 years ago, China focused too heavily on applied research. Applied research is the scientific study and research directed toward trying to solve practical problems.11 China has since recognized this "weakness" and there is a bigger effort to conduct more fundamental research as well.

There are two state key laboratories in China, both established by Xu, that focus on rare earths. The State Key Laboratory of Rare Earth Materials Chemistry and Applications is affiliated with Peking University in Beijing. The State Key Laboratory of Rare Earth Resource Utilization is affiliated with the Changchun Institute of Applied Chemistry, under the Chinese Academy of Sciences and is located in Changchun.

The "Open Laboratory of Rare Earth Chemistry and Physics" was established in August 1987, at the Changchun Institute of Applied Chemistry with the approval of the Chinese Academy of Science (CAS). In 2002, it changed its name to the "CAS Key Laboratory of Rare Earth Chemistry and Physics." Then, in 2007, it became the "State Key Laboratory of Rare Earth Resource Utilization," falling under the Ministry of Science and Technology. There are currently 40 faculty members in the lab, including two CAS academicians and 20 professors.

/…/

The state key laboratory of Rare Earth Materials Chemistry and Applications made significant progress in the 1980s in the separation of rare earth elements. There are approximately 29 faculty members in the lab, including three CAS members, 13 professors, three senior engineers, and one administrative assistant.13 Currently there are 55 Ph.D. graduate students, four masters graduate students, *and 17 postdoctoral research fellows working in the lab. 14 The lab focuses on rare earth separation techniques, the exploration of new rare earth functional materials, and optical, electrical, and magnetic properties and materials of rare earth elements.*

There are two other laboratories in China dedicated to rare earth elements. The Baotou Research Institute of Rare Earths was established in 1963. This organization has become the largest rare earth research and development institution in the world. 15.It focuses on the comprehensive exploitation and utilization of rare earth elements and on the research of rare earth metallurgy, environmental protection, new rare earth functional materials, and rare earth applications in traditional industry. The General Research Institute for Nonferrous Metals (GRINM) was established in 1952. This is the largest research and development institution in the field of nonferrous metals in China. The institute does not focus exclusively on rare earths, but also on many of the metals of the periodic table, other than iron.

While each of the four laboratories and institutes mentioned above complement each other, they each have different keystone research efforts. The State Key Laboratory of Rare Earth Resource Utilization focuses on applied research. The State Key Laboratory of Rare Earth Materials Chemistry and Applications focuses on basic research. Baotou Research Institute of Rare Earths and GRINM both focus on industrial applied research of rare earth elements.

14 Peking University, College of Chemistry and Molecular Engineering: The State Key Laboratory of Rare Earth Materials Chemistry and Applications: History and Development, available from http://www.chem.pku.edu.cn/page/relab/english/history.htm; Internet; accessed October 28, 2009.

15 According to Karl Gschneidner, Baotou Research Institute of Rare Earths has been the world's largest research organization of its kind for the past 30 years.

In addition to having state run laboratories dedicated to researching and developing rare earth elements, China also has two publications dedicated to the topic. They are the Journal of Rare Earth and the China Rare Earth Information (CREI) journal, both put out by the Chinese Society of Rare Earths.

These are the only two publications, globally, that focus almost exclusively on rare earth elements and they are both Chinese run.

APÊNDICE F

6th International Conference on Rare Earth Development and Application

Fonte: www.csre.org.cn/cres

Rare-earth industry is at a turning point. In order to promote the development of rare earth science & technology and industry, China Rare Earth Summit will be held by the Chinese Society of Rare Earths on Aug 2-6, 2010, Beijing of China, during the 6th International Conference on Rare Earth Development and Application. Its theme is "China rare earth industry policy and worldwide rare earth economy". The event aims at building a platform for enterprises on rare earths to understand the rare earth industry policy of China, to discuss and exchange issues on world rare earth resources, production, environment & protection, application, market and trade so as to promote the health development of rare earth industry worldwide.

The forum will focus on the impact of China rare earth industry policy on rare earth related industry, overview of the world rare earth resources, the relation between new energy industry and the rare earth industry, the status and the trends of rare earth new materials, the influence of rare earth industry on the environment, etc. Leaders from the relevant government, entrepreneurs of rare earth production, application, trading, and information, well-known experts and scholars will be invited to give wonderful speeches in the summit. For information in detail, please visit the conference website at http://www.cs-re.org.cn/cres/.

APÊNDICE G

Is America About to Become Even More Dependent on China?

Fonte: National Center for Public Policy Research – May 2010

The Case for Domestic Rare Earth Elements (REEs) Exploration and Excavation by Caroline May

REE minerals are essential to the function of such common devices as the catalytic converter, MRI machines, X-ray machines, iPods, cell phones and color televisions.3 Perhaps more critically, REEs are integral to America's defense systems, as they are used in night vision goggles, precision-guided munitions, cruise missiles and the like.

REEs also are critical if "green" energy is to replace today's carbon-based fuels, as most "green" technologies require vast amounts of these metals. For example, the permanent magnets used to manufacture one wind turbine use two tons of REEs and electric cars such as the Prius use up to 25 pounds of REEs.6 Furthermore, without REEs, there would be no such thing as a compact fluorescent light bulb.

In the last ten years two game-changing developments have made legislation hindering domestic mining more damaging to American interests. First, worldwide demand for REEs has tripled from an annual demand of 40,000 tons to 120,000 tons in the past decade.8 Second, the United States has moved from being completely self-sufficient to being 100% reliant on foreign nations for its REEs. Between 2005 and 2008, the United States imported 91% of its REEs from China and most of the rest from Russia, Japan and France.

Controlling 97% of global supply, China is a veritable REE powerhouse and is wielding its authority accordingly by severely restricting export of the precious resource. In the past seven years alone, China has reduced its exports of REEs by 40% the amount available for export. The Independent newspaper in Britain reports that by 2012 China could halt exports entirely, producing only enough to satisfy its own domestic need.

Jack Lifton, an independent consultant and leading commentator on nonferrous strategic metals, explains what such a halt means: "A real crunch is coming. In America, Britain and elsewhere we have not yet woken up to the fact that there is an urgent need to secure the supply of rare earths from sources outside China. China has gone from exporting 75% of the raw ore it produces to shipping just 25%… There has been an effort in the West to set up new mines but these are 5 to 10 years away from significant production".

APÊNDICE H

Fonte: China: Research Center for Rare Earth Materials - CREM

CREM is mainly engaged in the research and development of rare earth ore decomposition and purification, high purity rare earth compounds, rare earth metals and alloys, rare earth luminescent materials, rare earth magnetic materials, rare earth materials for agriculture development and other functional materials. Two special labs were set up: the lab of high purity rare earth compounds and the lab of rare earth metals and functional materials. Five production lines with certified ISO9001 Quality System Assessment were built up: rare earth metals and alloys, rare earth magnetic materials, rare earth luminescent materials, rare earth compounds and rare earth materials for agriculture development. Most of the products are exported to Japan, Europe and America.

The mission of CREM is to conduct scientific research, technical development, hi-tech production and consulting service for strengthening the competitive position of China's rare earth materials.

CREM hopes to cooperate with different institutes and companies related with rare earth in various ways, to form a world famous research and production foundation of rare earth materials, to fulfill the changing of rare earth productions to hi-tech advance materials, to obtain economic advantage from the resource advantage.

/.../

CREM has courageously been taking up the historic mission to transfer the primary products to those with high additive values. CREM has made great efforts to develop advanced RE materials, and to improve the progress of the RE applications. Five production lines has already been built up: RE metals and alloys, RE magnetic materials, RE luminescent materials, RE fine chemical materials and RE materials for agriculture development. PDP-used phosphors, giant magneto-strictive materials, magneto-optical materials, catalytic and environmental materials, long afterglow materials, biological materials and other advanced RE function materials are being developed. Through technical innovation, system innovation and management innovation, and with the help of the social resources such as the capital market etc, jumping development is hoped to *be fulfilled, and the hi-tech enterprise with quite international influence is hoped to be established.*

/…/

The history of CREM is splendent. The future of CREM is waiting for our creation.

Rare Earth is not rare. Rare earth materials have lots to be done.

APÊNDICE I

Hybrid Cars and Wind Turbines

Fonte: Editing by Alan Elsner and Mary Milliken (2012)

That makes market gasoline-electric hybrid car and other similar vehicles vulnerable to a supply crunch predicted by experts as China, the world's dominant rare earths producer, limits exports while global demand swells.

Worldwide demand for rare earths, covering 15 entries on the periodic table of elements, is expected to exceed supply by some 40,000 tonnes annually in several years unless major new production sources are developed. One promising U.S. source is a rare earths mine slated to reopen in California by 2012.

Among the rare earths that would be most affected in a shortage is neodymium, the key component of an alloy used to make the high-power, lightweight magnets for electric motors of hybrid cars, such as the Prius, Honda Insight and Ford Focus, as well as in generators for wind turbines.

Close cousins terbium and dysprosium are added in smaller amounts to the alloy to preserve neodymium's magnetic properties at high temperatures. Yet another rare earth metal, lanthanum, is a major ingredient for hybrid car batteries.

Production of both hybrids cars and wind turbines is expected to climb sharply amid the clamor for cleaner transportation and energy alternatives that reduce dependence on fossil fuels blamed for global climate change.

APÊNDICE J
TMR Advanced Rare-Earth Projects Index

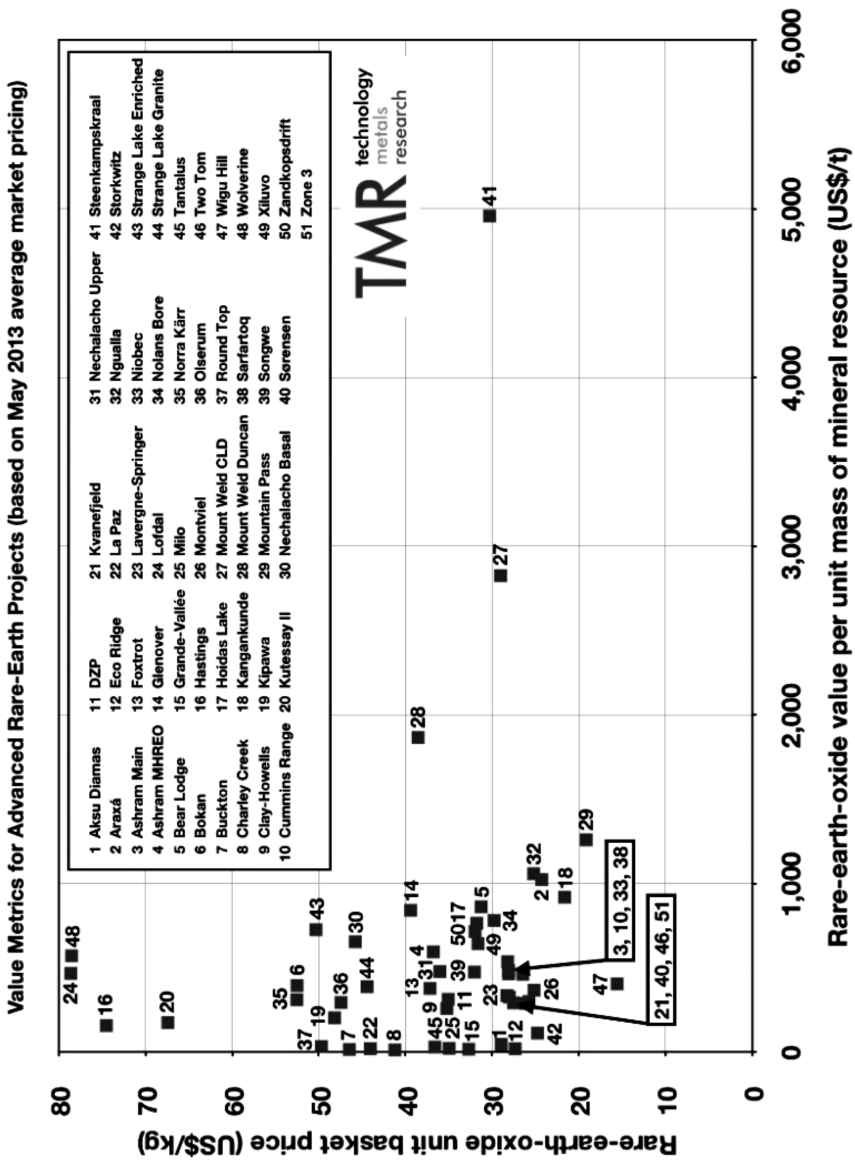
Project	Country	Owner	Ticket Symbol(s)	MR (Mt)	TREO (wt%)	TREO (Mt)	In-Situ TREO ($/t(MR))	Basket Price ($/kg)
Aksu Diamas	TUR	AMR Mineral Metal Inc.	N/A	494.00	0.07	0.345	19	27
Araxá	BRA	MBAC Fertilizer Corp.	TSX:MBC, OTCQX:MBCFF	28.29	4.21	1.190	1,022	24
Ashram Main	CAN	Commerce Resources Corp.	TSX.V:CCE, OTCQX:CMRZF, F:D7H	239.71	1.90	4.549	535	28
Ashram MHREO	CAN	Commerce Resources Corp.	TSX.V:CCE, OTCQX:CMRZF, F:D7H	9.35	1.61	0.151	594	37
Bear Lodge	USA	Rare Element Resources Ltd.	TSX.V:RES, MKT:REE	51.71	2.75	1.423	861	31
Bokan	USA	Ucore Rare Metals Inc.	TSX.V:UCU, OTCQX:UURAF	3.67	0.75	0.028	394	53
Buckton	CAN	DNI Metals Inc.	TSX.V:DNI, F:DG7	250.09	0.03	0.080	15	46
Charley Creek (JV)	AUS	Crossland Strategic Metals Ltd.	ASX:CUX	805.30	0.03	0.235	12	41
Charley Creek (JV)	AUS	Pancontinental Uranium Corporation	TSX.V:PUC	805.30	0.03	0.235	12	41
Clay-Howells	CAN	Canada Rare Earth Corp.	TSX.V:LL	8.48	0.73	0.062	258	35
Cummins Range	AUS	Navigator Resources Limited	ASX:NAV	4.90	1.74	0.085	460	26
DZP	AUS	Alkane Resources Ltd.	ASX:ALK, OTCQX:ANLKY	73.20	0.89	0.651	312	35
Eco Ridge	CAN	Pele Mountain Resources Inc.	TSX.V:GEM, OTCQX:GOLDF	59.30	0.16	0.093	45	29

Fonte: http://www.techmetalsresearch.com/metrics-indices/tmr-advanced-rare-earth-projects-index/ (20 Junho 2013)

Foxtrot	CAN	Search Minerals Inc.	TSX.V:SMY	14.39	1.01	0.146	377	37
Glenover (JV)	ZAF	Galileo Resources PLC	AIM:GLR	10.37	2.13	0.221	840	39
Glenover (JV)	ZAF	Fer-Min-Ore (Pty) Ltd.	N/A	10.37	2.13	0.221	840	39
Grande-Vallée	CAN	Orbite Aluminae Inc.	TSX:ORT, OTCQX:EORBF	1209.64	0.05	0.606	16	33
Hastings	AUS	Hastings Rare Metals Limited	ASX:HAS	36.20	0.21	0.076	156	75
Hoidas Lake	CAN	Great Western Minerals Group Ltd.	TSX.V:GWG, OTCQX:GWMGF	2.85	2.40	0.068	763	32
Kangankunde	MWI	Lynas Corporation Ltd.	ASX:LYC, OTCQX:LYSDY	2.53	4.24	0.107	918	22
Kipawa (JV)	CAN	Matamec Explorations Inc.	TSX.V:MAT, OTCQX:MHREF	24.45	0.42	0.103	203	48
Kipawa (JV)	CAN	Toyotsu Rare Earth Canada, Inc.	N/A	24.45	0.42	0.103	203	48
Kutessay II	KGZ	Stans Energy Corp.	TSX.V:HRE, OTCQX:HREEF	18.01	0.26	0.047	174	67
Kvanefjeld	GRL	Greenland Minerals and Energy Ltd.	ASX:GGG, PK:GDLNF	619.00	1.06	6.547	291	28
La Paz	USA	AusAmerican Mining Corp. Ltd.	ASX:AIW	128.20	0.04	0.056	19	44
Lavergne-Springer	CAN	Canada Rare Earth Corp.	TSX.V:LL	16.90	1.16	0.196	326	28
Lofdal	NAM	Namibia Rare Earths Inc.	TSX:NRE	1.65	0.59	0.010	466	79

Milo	AUS	GBM Resources Ltd.	ASX:GBZ	187.00	0.06	0.114	21	35
Montviel	CAN	Geomega Resources Inc.	TSX.V:GMA	250.60	1.45	3.646	366	25
Mount Weld CLD	AUS	Lynas Corporation Ltd.	ASX:LYC, OTCQX:LYSDY	14.95	9.73	1.454	2,824	29
Mount Weld Duncan	AUS	Lynas Corporation Ltd.	ASX:LYC, OTCQX:LYSDY	8.99	4.84	0.435	1,865	39
Mountain Pass	USA	Molycorp Inc.	NYSE:MCP	31.55	6.57	2.072	1,258	19
Nechalacho Basal	CAN	Avalon Rare Metals Inc.	TSX:AVL, MKT:AVL	125.72	1.43	1.795	654	46
Nechalacho Upper	CAN	Avalon Rare Metals Inc.	TSX:AVL, MKT:AVL	177.73	1.32	2.353	477	36
Ngualla	TZA	Peak Resources Ltd.	ASX:PEK	41.70	4.19	1.748	1,057	25
Niobec	CAN	IAMGOLD Corporation	TSX:IMG, NYSE:IAG	466.80	1.65	7.702	464	28
Nolans Bore	AUS	Arafura Resources Ltd.	ASX:ARU, PK:ARAFF	47.16	2.62	1.235	780	30
Norra Kärr	SWE	Tasman Metals Ltd.	TSX.V:TSM, MKT:TAS, F:T61	58.10	0.59	0.343	310	53
Olserum	SWE	Tasman Metals Ltd.	TSX.V:TSM, MKT:TAS, F:T61	7.80	0.62	0.048	293	47
Round Top	USA	Texas Rare Earth Resources Corp.	OTCQX:TRER	1033.83	0.06	0.662	32	50
Sarfartoq	GRL	Hudson Resources Inc.	TSX.V:HUD, OTCQX:HUDRF	8.34	1.72	0.143	482	28
Songwe	MWI	Mkango Resources Ltd.	TSX.V:MKA	31.75	1.48	0.469	474	32

Sørensen	GRL	Greenland Minerals and Energy Ltd.	ASX:GGG, PK:GDLNF	242.00	1.10	2.662	288	26
Steenkampskraal	ZAF	Great Western Minerals Group Ltd.	TSX.V:GWG, OTCQX:GWMGF	0.45	16.36	0.074	4,956	30
Storkwitz	GER	Seltenerden Storkwitz AG	N/A	4.46	0.45	0.020	112	25
Strange Lake Enriched	CAN	Quest Rare Minerals Ltd.	TSX:QRM, MKT:QRM	20.02	1.44	0.288	725	50
Strange Lake Granite	CAN	Quest Rare Minerals Ltd.	TSX:QRM, MKT:QRM	472.46	0.87	4.119	387	44
Tantalus	MDG	Tantalus Rare Earths AG	F:TAE:GR	435.00	0.08	0.348	29	37
Two Tom	CAN	Canada Rare Earth Corp.	TSX.V:LL	40.64	1.18	0.480	335	28
Wigu Hill	TZA	Montero Mining and Exploration Ltd.	TSX.V:MON	3.30	2.59	0.085	404	16
Wolverine	AUS	Northern Minerals Limited	ASX:NTU	1.44	0.73	0.010	570	79
Xiluvo (JV)	MOZ	Galileo Resources PLC	AIM:GLR	1.11	2.03	0.023	642	32
Xiluvo (JV)	MOZ	Rare Earth International Ltd.	N/A	1.11	2.03	0.023	642	32
Zandkopsdrift (JV)	ZAF	Frontier Rare Earths Ltd.	TSX:FRO, PK:FREFF	42.48	2.23	0.948	714	32
Zandkopsdrift (JV)	ZAF	Korea Resources Corp.	N/A	42.48	2.23	0.948	714	32
Zone 3	GRL	Greenland Minerals and Energy Ltd.	ASX:GGG, PK:GDLNF	95.30	1.16	1.106	299	26


Value Metrics for Advanced Rare-Earth Projects (based on May 2013 average market pricing)
Rare-earth-oxide unit basket price (US$/kg)
Rare-earth-oxide value per unit mass of mineral resource (US$/t)
1 Aksu Diamas
2 Araxá
3 Ashram Main
4 Ashram MHREO
5 Bear Lodge
6 Bokan
7 Buckton
8 Charley Creek
9 Clay-Howells
10 Cummins Range
11 DZP
12 Eco Ridge
13 Foxtrot
14 Glenover
15 Grande-Vallée
16 Hastings
17 Hoidas Lake
18 Kangankunde
19 Kipawa
20 Kutessay II
21 Kvanefjeld
22 La Paz
23 Lavergne-Springer
24 Lofdal
25 Milo
26 Montviel
27 Mount Weld CLD
28 Mount Weld Duncan
29 Mountain Pass
30 Nechalacho Basal
31 Nechalacho Upper
32 Ngualla
33 Niobec
34 Nolans Bore
35 Norra Kärr
36 Olserum
37 Round Top
38 Sarfartoq
39 Songwe
40 Sørensen
41 Steenkampskraal
42 Storkwitz
43 Strange Lake Enriched
44 Strange Lake Granite
45 Tantalus
46 Two Tom
47 Wigu Hill
48 Wolverine
49 Xiluvo
50 Zandkopsdrift
51 Zone 3
3, 10, 33, 38
21, 40, 46, 51
TMR technology metals research