GEONOTE 44

Rare Earth Elements and Other Critical Metals in Idaho

Because of recent international trade issues, as well as their incorporation into a wide variety of critical modern technologies, the rare earths have made it out of the geological and technical journals and into the popular media (internet and printed newspapers such as the *New York Times*) and halls of Congress. Prices for rare earth metals have risen dramatically. Mining companies and the federal government are renewing the search for domestic sources of rare earth elements necessary in the manufacture of important consumer and national defense-related products. In reality, rare earth elements (REE) are not any rarer than many other elements, but they are so regarded owing to the difficulty in separating and isolating the pure element, usually derived from the rare earth oxide (REO). Because REEs share similar chemical properties, REE-bearing minerals commonly contain multiple REEs bound together in the crystal lattice, which makes the processing and separation of individual REOs expensive. Yet, whatever the cost, individual REEs are critical components in numerous U.S. military applications as well as such high-tech yet common items like smart

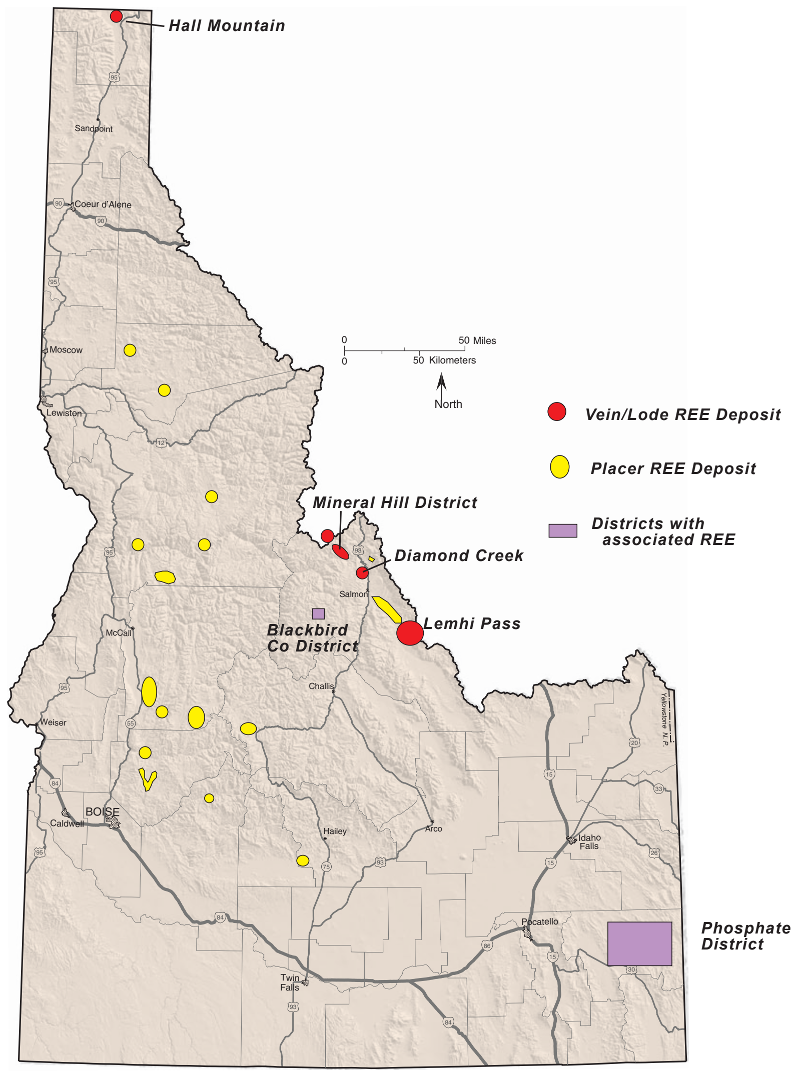

Figure 1: Map of rare earth deposits in Idaho.

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phones, fluorescent lighting, NiMH rechargeable batteries in hybrid vehicles, powerful Nd-bearing permanent magnets used in wind turbines and electric and hybrid vehicles, Eu-rich red phosphors in television sets, and computer hard drives (Hedrick, 2010; Cordier and Hedrick, 2010; U.S. DOE, 2010).

Few people realize how many minerals the United States imports to supply companies and manufacturing plants. In 1996, the U.S. relied 100% on imports for nine non-fuel mineral materials; by 2006, the number had grown to 17; and in 2009, the country was 100% dependent on imports for 19 mineral materials (USGS Mineral Commodity Summaries 2010, p. 6). Of those 19 commodities, Idaho hosts significant resources or is a past producer of at least eight (arsenic, fluorspar, mica, niobium, rare earths, tantalum, thorium, and vanadium). Mining of rare earths in the U.S. ended in 1998 when the Mountain Pass mine in California closed. Since the mid-1980s, China has increased production from its large REE reserves, and today dominates rare earth mining and processing. In 2010, China supplied over 95% of the global production of rare earth elements. However, recent announcements of higher export tariffs and lower export quotas for Chinese rare earth exports have worried consumers, governments, and trade organizations. Federal agencies have been tasked by Congress with reporting on REE supply for needs in the defense and energy industry. In the private sector, the prospect of possible future supply limits and rising commodity prices have prompted resurgent exploration worldwide for new rare earth deposits.

What are these esoteric substances that have garnered headlines in the business news? Rare earths, also called the lanthanides, are little known elements that chemists did not fully isolate until the 19th Century (Castor and Hedrick, 2006). On the periodic table of the elements, they start with lanthanum (atomic number 57) and end with lutetium (no. 71). Yttrium (no. 39) and scandium (no. 21) are commonly included as well, for a total of seventeen elements. The lower atomic weight elements, lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), and europium (Eu) are classified as light rare earths (LREE); the others—gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), and lutetium (Lu)—are the heavy rare earths (HREE). A third, middle rare earth group (MREE) is sometimes delineated as well. A new Department of Energy report particularly noted five rare earths (Dy, Nd, Tb, Eu, and Y), plus indium, as being the most critical in the short term for the nation's clean energy economy (U.S. DOE, 2010).

Rare earth mineral deposits are found in several geologic settings. Perhaps the most famous type of REE deposit, and one of considerable economic importance, is a carbonatite, an unusual igneous rock which is composed of carbonate minerals. At both the Mountain Pass mine in California and the renowned Bayan Obo deposit in China, rare earth minerals are found in carbonatites, though the exact genesis of the Bayan Obo is complex and still controversial. The major economic mineral, bastnasite, is a REE-bearing carbonate. The rare earths contained in carbonate minerals are typically the easiest to process. Rare earths are also enriched in pegmatites, where they were first mined, but these were eclipsed in commercial importance by mining from placer deposits of the mineral monazite, a REE-bearing phosphate (Ce, La, Nd, Th) PO_4, in the second half of the 20th Century. Beach placers were mined in the southeastern United States, Australia, and elsewhere, and river placers were mined in Idaho (Castor and Hedrick, 2006). Other types of REE deposits include hydrothermal veins, lateritic clays, and alkaline intrusive complexes. Rare earths are also enriched – though not to commercial amounts – in phosphorites, which are mined in southeastern Idaho.

Idaho is an obvious target for new exploration because it has several known rare earth deposits, and its geologic make-up holds the promise of additional discoveries (Anderson and Savage, 1964; Figure 1). Rare earths and thorium (Th), a common associate, are typically found in geologic terrains underlain by old continental crust, which includes much of Idaho. Black sand placer deposits of central Idaho were mined in the late 1940s and 1950s for thorium, uranium, and rare earths, principally contained in the mineral monazite (Savage, 1961; Breckenridge, and others, 1980). Like uranium, thorium is naturally radioactive. The monazite is a primary accessory mineral of the granitic rocks and pegmatites in the Idaho batholith and other intrusions. Weathering of the granites contributed monazite and other minerals to river sands which were deposited and preserved in Idaho's central drainage basins. This is similar to processes that formed the gold-bearing placer deposits. Dredges operated in the Bear Valley region, Cascade-Long Valley, and other areas (Mackin and Schmidt, 1957; Staley, 1948).

In 1949, prospectors looking for uranium discovered thorium in the Lemhi Pass area of Idaho and Montana. Subsequent study and exploration revealed numerous thorium- and rare earth-bearing veins (Anderson, 1958; Staatz, 1979a; Gillerman and others, 2003, 2008; Gillerman, 2008) in the Beaverhead Range of Lemhi County, Idaho, and adjoining areas in Montana. Early studies by the U.S. Geological Survey concluded that this district had the largest thorium resource in the nation and also hosted an equal amount of rare earths (Staatz, 1979a,b). These enigmatic deposits, hosted in Precambrian quartzites and siltites, have been explored at the surface by government and industry. A modest reserve of Th plus REE was delineated from underground work by IERCO on the near-surface portions of the Last Chance vein in Montana in the early 1980s, before the companies lost interest owing to low thorium prices. Since then, no underground exploration or drilling has been done, and there is little subsurface information for the district. On average, the veins contain about as much thorium, bound up in thorite ($ThSiO_4$), as total rare earths. District-wide grades of the veins are approximately 0.4% to 0.5% total rare earth oxides, but individual veins vary significantly (Staatz, 1972, 1979a; Gillerman, 2008; Reed and Gillerman, 2008). The major REE host mineral is monazite. The Lemhi Pass ores are unusual in that they consistently show a strong enrichment in the middle rare earths, especially neodymium. Electron microprobe analyses of monazite reveal as much as 35 weight percent Nd oxide (Gillerman, 2008; Gillerman and others, 2009), which is possibly the highest content known in the world. Most of the deposits are quartz veins with associated hematite, apatite, feldspar, thorite, and sparse monazite. A few deposits in more argillaceous and sheared rocks have biotite, abundant specular hematite, thorite, apatite, and Nd-monazite. The geology is complex, and the origin of the deposits is a topic of ongoing IGS research. Age dating of the monazite and other evidence suggests that the veins formed during the late Paleozoic times, subsequent to Early Paleozoic alkaline intrusives and base metal mineralization (Gillerman and others, 2010; Gillerman, 2008).

Lemhi County has at least two other REE districts (Anderson, 1958). Veins in the Diamond Creek area, northwest of the town of Salmon, are similar to those at Lemhi Pass and most likely formed by the same mineralizing process. In the northern part of the county, a wide mineralized zone, referred to as the "monazite-rutile belt" or Mineral Hill district, cuts northwestward across rugged terrain for nearly twenty miles, west of North Fork, from the Salmon River north into Montana. Monazite and some rare earth carbonates are found in thin calcite-bearing horizons or veins within metamorphic rocks. The mineralogy and rocks show a clear affinity to carbonatites (Anderson, 1958, 1960), though the structure and textures suggest that the rocks were metamorphosed, most likely during the Cretaceous. The mineralized horizons exhibit the LREE enrichment typical of carbonatites worldwide, with some unusual minerals such as niobium-rich ilmenorutile and actinolitic amphibole. These carbonatite "veins" in the monazite-rutile belt were explored for rutile and monazite in the 1950s by several operators, but the deposits were found to be uneconomic at the time (Anderson, 1958). The Mineral Hill district is structurally complex and remains poorly understood geologically.

A large "source" for the Lemhi County rare earth mineralization, such as a carbonatite or alkalic pluton, has yet to be found, though it certainly could be buried under gravels or hidden by later structures. Regional airborne geophysical surveys are expensive, but combined with new mapping such studies could help develop new ideas and targets. Other areas in Idaho with potential to host REE deposits include the thorite deposits at Hall Mountain in Boundary County, the central Idaho placers, and a variety of small pegmatites throughout the state. Given Idaho's geology, future exploration may discover entirely new geologic types and locations of rare earth deposits.

Other critical metals for green technology and energy and modern defense applications include As, Li, Co, Ni, Ga, Ge, Nb, In, Sb, Ta, Re, Pt, Pd, and Te (Watanabe and Hitzman, 2010; National Research Council, 2008a,b). The Idaho Cobalt Project, a newly permitted mine in the Blackbird District of Lemhi County, should soon be the country's only source of high purity cobalt metal (Gillerman and Bennett, 2010; Gillerman, 2010). Cobalt is essential for superalloys used in aircraft engines and specialty steels. In addition, rare earth elements are locally enriched in the copper-cobalt-gold ores (Slack, 2006; Gillerman, 2008). Studies are underway to better determine distribution of the rare earth concentrations in the Idaho Cobalt Project deposit and the potential for rare earth byproduct production from the future mine. Occurrences of Te (used in solar panels), Nb and Ta (mined in Brazil), and of course Sb (used in flame retardants and batteries), are noted in several Idaho deposits, and Re is a potential byproduct of molybdenum deposits in Idaho, such as the giant Cumo deposit being explored today in Boise County.

Discovery of a "mineral resource" requires significant exploration work, but it is only the first step. A resource is speculative; a "reserve" is a measured amount of ore (rock enriched in a commodity which can be extracted economically with current technology and at current prices). To mine and produce a commodity in the modern world, both a reserve and environmental permits are required. With the lead times needed for exploration, mine and plant permitting, and mine financing and construction, it is typically a decade or more after discovery before a new metallic mineral source is available (Gillerman, 2010).

The National Research Council (2008b) described the five dimensions of mineral availability for critical minerals as: geologic, technical, environmental and social, political, and economic. Geologic availability is determined by the geologic history of a region and the mineral associations found. As noted, Idaho is favorable terrain for molybdenum, cobalt, rare earths, and other commodities; hence, Idaho is a good starting place for new exploration, particularly if modern methods, such as airborne geophysics, structural mapping, and development of new geologic models can be funded and utilized. Successful exploration and commercial mineral development involves sifting through 100 or 1000 small prospects or "footprints" to find the extremely rare large and economic deposit that can compete in the global marketplace. Information on Idaho's many mineral resources and historical mining can be found on the website and in publications of the Idaho Geological Survey (www.idahogeology.org).

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