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Montana Bureau of Mines and Geology

Critical Mineral: Dysprosium

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Overview

Dysprosium (Dy) is a chemical element included on the United States Geological Survey's 2022 Critical Minerals list. Dy is a lanthanide. It is the most abundant of the heavy rare earth elements (REEs), excluding yttrium (Y).

The silvery metal is used in magnets, alloys, and nuclear control rods. It is the heaviest REE that is commonly considered a "magnet metal" along with neodymium (Nd), praseodymium (Pr), samarium (Sm), and terbium (Tb).

Figure 1. Refined Dy metal. Photo by W. Oelen (CC BY 3.0).

Supply

Dy is sourced from REE mining. It occurs in ore minerals along with the other REEs. It is most concentrated in heavy REE deposits that are also rich in Y and Tb. The U.S. imports almost all of its Dy from China, the major miner and refiner. Other countries that refine Dy for export are Germany, Korea, and Japan. The U.S. produces a near-negligible amount of Dy from the one American REE mine at Mountain Pass in California. The only other operating non-Chinese REE mine of note is Mount Weld in Australia.

Given its relative scarcity and specialty uses, there are few data on national Dy reserves. Dy is derived from any deposit where other REEs are also present in economic quantities. Much of the world's Dy is mined from clay deposits in southern China under environmentally damaging conditions. Grades of Dy in REE deposits range from 0.0015 (Eco Ridge, Ontario) to 0.129 (Steenkampskraal, South Africa) wt.%. The proportion of Dy in the total REE grade is a function of the deposit type. Average pricing for Dy in 2023 was \$323/kg Dy_2O_3, down from a high of \$410/kg in 2021.

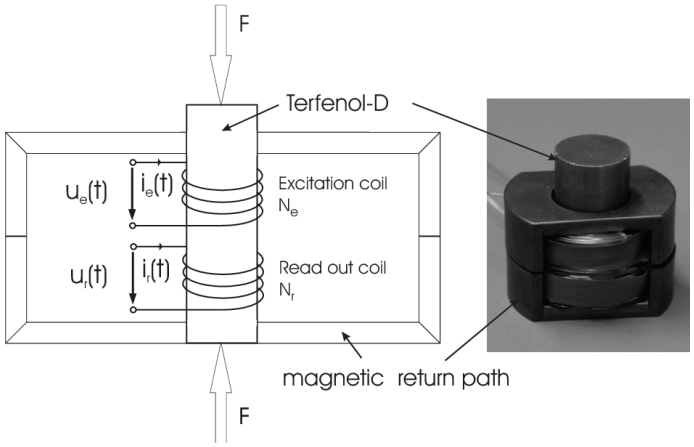

Figure 2. A pressure sensor (right) and schematic of the same (left) that incorporates the magnetostrictive alloy Terfenol-D. This iron (Fe), Tb, and Dy alloy can change shape in response to an applied magnetic field. Photo from Oppermann, K., and Zagar, B.G., 2009, A8.3—A Novel Magneto–Elastic Force Sensor Design Based on Terfenol–D: Proceedings SENSOR 2009, v. II, p. 77–82. https://doi.org/10.5162/sensor09/v2/a8.3

Mineralogy

All REEs, including Dy, co-crystallize in the same minerals due to their geochemical similarities. Ore minerals are typically phosphate or carbonates such as xenotime or parisite, respectively. These occur in exotic intrusive rocks such as carbonatites, peralkaline granitoids, and some types of pegmatites. Other critical minerals that can occur in these rare rock types are fluorspar (CaF_2), barite ($BaSO_4$), niobium (Nb), tantalum (Ta), scandium (Sc), titanium (Ti), and zirconium (Zr). Heavy REE minerals, specifically xenotime and fergusonite, can resist weathering and become concentrated in placer (mineral sands) deposits along with the other REEs, Zr, Ti, Nb, and Ta.

Dy has been recovered from unconventional deposits. In southern China, the aforementioned clay deposits formed from tropical weathering and hold low-grade, but easily extracted, amounts of REEs. Another type of uncon-

Figure 3. A sample of REE mineralization taken from weathered outcrop in Beaverhead County that has 0.016 wt.% Dy. Photo by Adrian Van Rythoven.

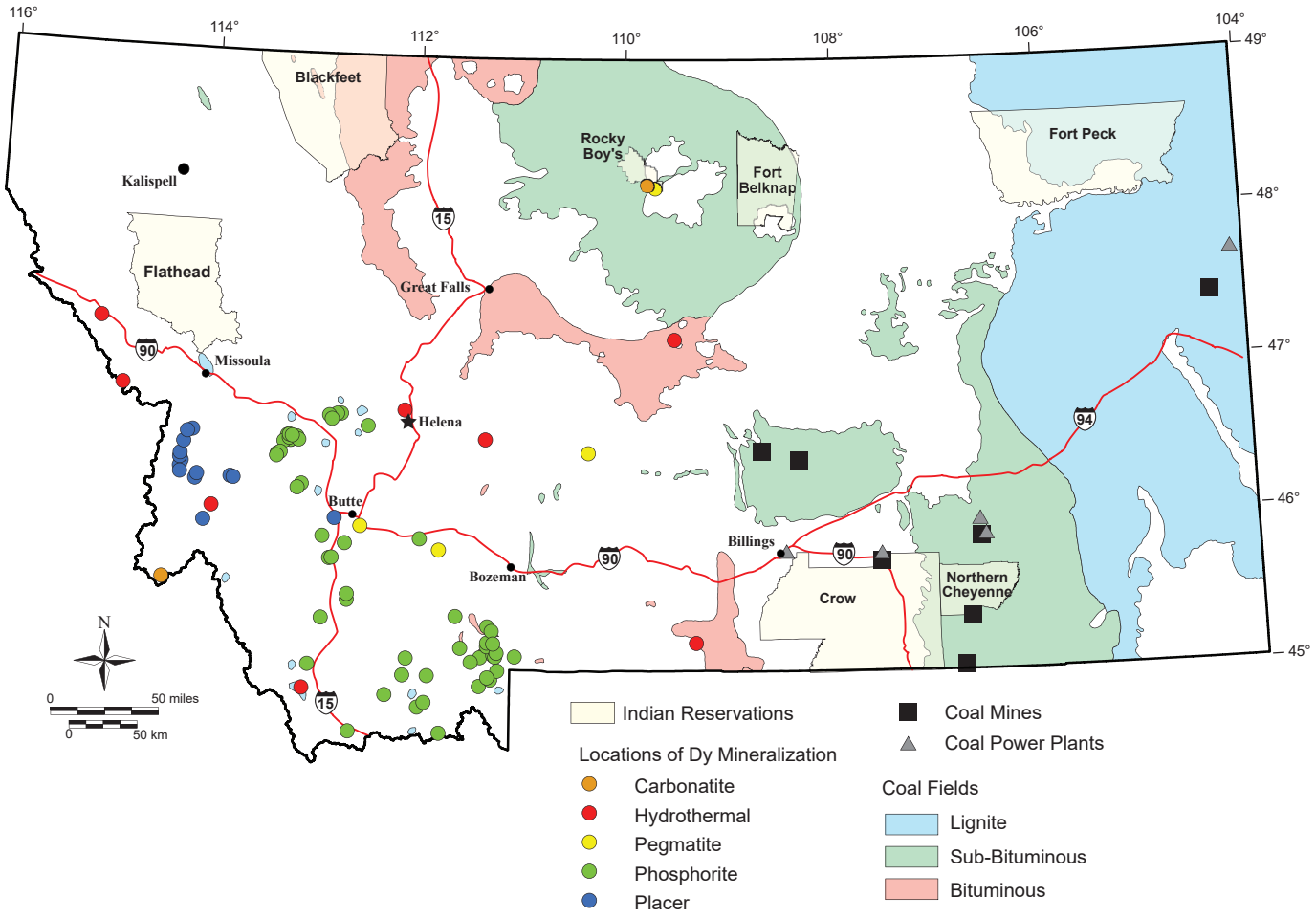

Figure 4. A map of Montana displaying known Dy occurrences, coalbeds, coal mines, and coal power plants (both active and inactive, as proxies for coal ash repositories).

ventional REE deposit is phosphorite, a sedimentary rock. These are typically mined for phosphorous (P), but can also contain high levels of REEs. Other critical minerals that can occur in phosphorite are CaF_2, vanadium (V), chromium (Cr), nickel (Ni), and zinc (Zn). Coal can contain elevated levels of REEs that are then concentrated in coal ash after combustion. Coal, and particularly coal waste, may also be a potential resource for REEs, along with other critical minerals such as germanium (Ge).

Deposits in Montana

Conventional "hard rock" deposits of Dy in Montana are best shown by the Sheep Creek carbonatite complex in the far southwest of the State (Ravalli County), and the Rocky Boy carbonatite and pegmatite intrusions in the center of the State (Hill and Chouteau Counties). There are a few scattered pegmatite, hydrothermal, and placer deposits in the southwestern quadrant of the State. The most notable of these is the Snowbird deposit on the Idaho border (Mineral Co.), a hydrothermal fluorite–parisite deposit containing abundant REEs. In addition to the other REE deposit types, phosphorite deposits are also scattered throughout this quadrant (Powell, Granite, Beaverhead, Silver Bow, Madison, and Jefferson Counties).

Eastern Montana has vast coal fields, with five current and former coal power plants that represent significant coal ash repositories on or near site. Finally, the more well-known metal sulfide mines throughout the State have a legacy of acid mine drainage that may also have dissolved REEs. The water in the Berkeley Pit in Butte (Silver Bow County) may represent an unconventional Dy resource.

Outlook in Montana

Active REE exploration is largely restricted to the Sheep Creek carbonatite. Academic research is focused on Dy potential in unconventional deposits such as phosphorite, coal, coal ash, and mine waste. This research could support exploration and development on such deposits.

About the MBMG

Established in 1919, the Montana Bureau of Mines and Geology (MBMG) continues to fulfill its mandate to collect and publish information on Montana's geology to promote orderly and responsible development of the energy, groundwater, and mineral resources of the State. A non-regulatory state agency, the MBMG provides extensive advisory, technical, and informational services on the State's geologic, mineral, energy, and water resources. The MBMG is increasingly involved in studies of the environmental impacts to land and water caused either by past practices in hard-rock mining or by current activities in agriculture and industry. The Montana Bureau of Mines and Geology is the principal source of Earth science information for the citizens of Montana. More information is available at mbmg.mtech.edu.