



Critical Mineral: Samarium

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Overview

Samarium (Sm) is a chemical element included on the United States Geological Survey's 2022 Final List of Critical Minerals. Sm is a lanthanide. It is a light rare earth element (REE). It is also considered a magnet REE.

The silvery and moderately hard metal is best known for its use in alloys with fellow critical mineral cobalt (Co) to make Sm-Co magnets. This was the first type of rare earth magnet developed. It has since been surpassed by stronger and less brittle neodymium (Nd) magnets. However, Sm-Co magnets have the rare ability to maintain their magnetism under high temperature conditions, and do not corrode as readily as Nd magnets. Other uses of Sm are in X-ray lasers, ceramics, and as catalysts.

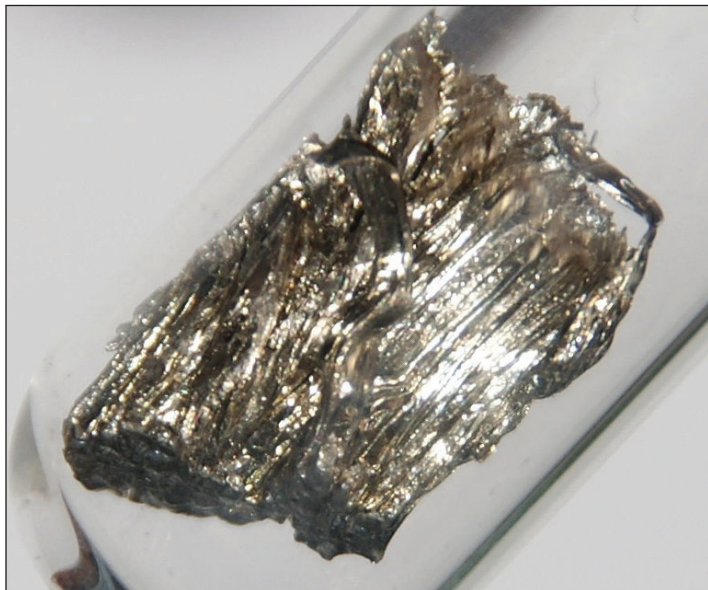


Figure 1. Two grams of refined Sm metal. Photo by images-of-elements.com (CC-BY-SA-3.0).

Supply

Sm is sourced from REE mining. It occurs in ore minerals along with other REEs. The U.S. imports much of its Sm from China, the world's major REE miner and refiner. Other entities that refine Sm for export are the European Union, Korea, and Japan. The U.S. produces a modest amount of Sm 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 limited production, there are few data on domestic Sm reserves. Sm is derived from any deposit where other REEs are also present in economic quantities. Much of the world's Sm is mined from carbonatite deposits in China. Average grades of Sm in REE resources range from 0.0001 (Round Top, Texas) to 0.372 (Steenkampskraal, South Africa) wt.%. The proportion of Sm in the total REE grade is a function of the deposit type. Sm content is typically moderate in all REE deposits



Figure 2. A cylindrical (1" x 0.25") Sm-Co magnet demonstrating its strength holding a small (~6 lbs) sledgehammer to a metal doorframe. A conventional (non-REE) ceramic magnet of the same size would not be able to hold this weight. Photo by Adrian Van Rythoven (MBMG).

except for those hosted in carbonatite, where it is higher. Recent pricing for Sm in 2024 was ~\$2.14/kg Sm₂O₃.

Mineralogy

All REEs, including Sm, co-crystallize in the same minerals due to their geochemical similarities. Ore minerals are typically phosphates or carbonates, such as monazite or bastnaesite, respectively. These occur in exotic intrusive rocks such as carbonatite, peralkaline granitoids, and some types of pegmatite. Sm grades are typically higher in carbonatite. Other critical minerals that can occur in these rare rock types are fluor spar (CaF₂), barite (BaSO₄), niobium (Nb), tantalum (Ta), scandium (Sc), titanium (Ti), and



Figure 3. A sample of weathered REE-mineralized carbonatite with 0.073 wt.% Sm from Beaverhead County, Montana. Photo by Adrian Van Rythoven (MBMG).

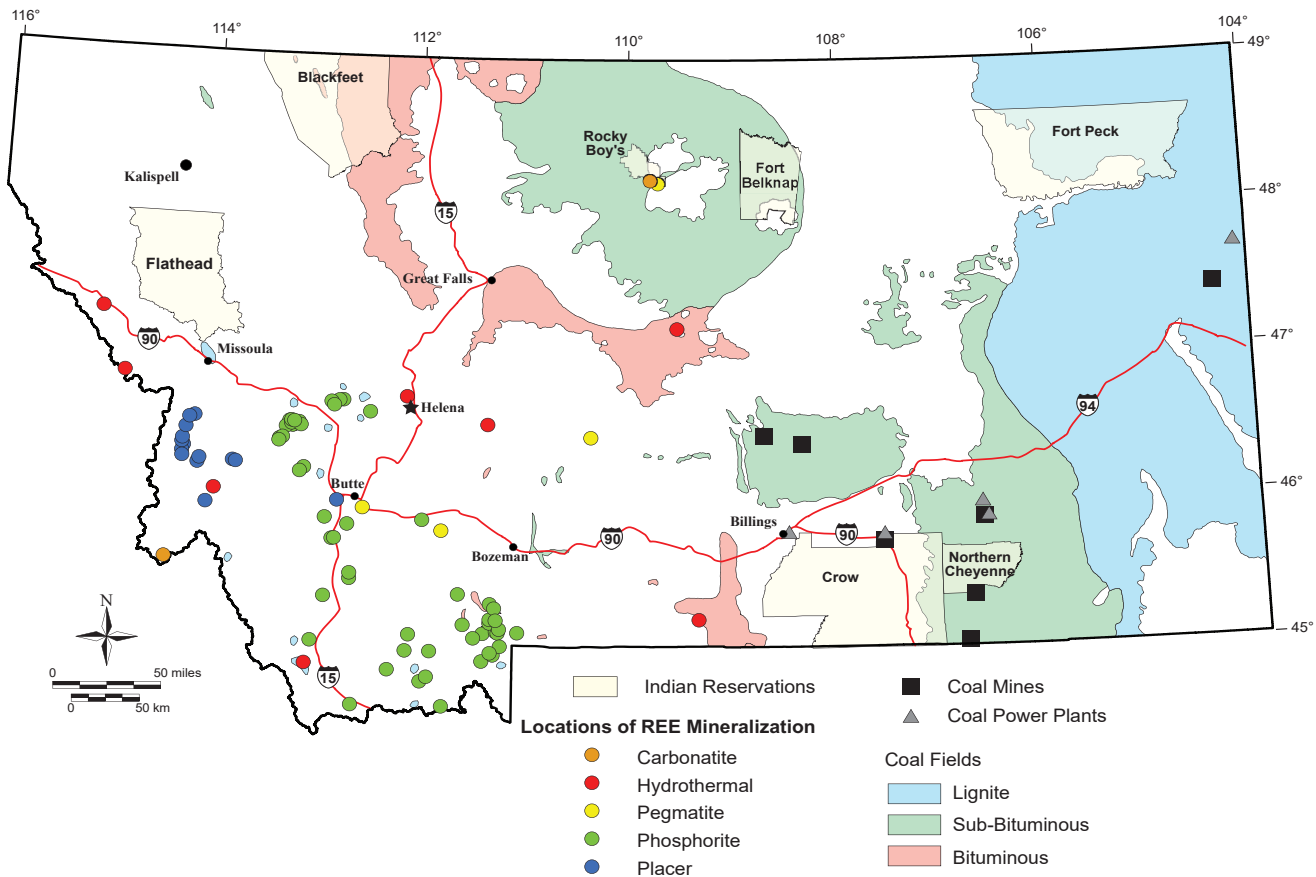


Figure 4. A map of Montana displaying known Sm occurrences, coalbeds, coal mines, and coal power plants (both active and inactive, as proxies for coal ash repositories).

zirconium (Zr). Certain dense REE minerals, specifically xenotime, monazite, and fergusonite, can resist weathering and become concentrated in placer (mineral sands) deposits along with the other REEs, Zr, Ti, Nb, and Ta.

Sm has been recovered from unconventional deposits. In southern China, clay deposits formed from tropical weathering hold low-grade, but easily extracted, amounts of REEs. Another type of unconventional 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 CaF₂, 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, particularly coal waste, may also be a potential resource for REEs and other critical minerals such as germanium (Ge).

Deposits in Montana

Conventional “hard rock” deposits of Sm 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, mostly along the Idaho border. The most notable of these is the Snowbird Deposit (Mineral County), 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, Deer Lodge, Silver Bow, Madison, and Jefferson Counties).

Eastern Montana has vast coal fields, with five current or 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 have also dissolved REEs. The water in the Berkeley Pit in Butte (Silver Bow County) may represent an unconventional Sm resource.

Outlook in Montana

Active REE exploration is largely restricted to the Sheep Creek Carbonatite. Academic and MBMG research is focused on Sm 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.