Critical Mineral: Cerium

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Overview

Cerium (Ce) is a chemical element included on the U.S. Geological Survey's 2022 Final List of Critical Minerals. Ce is a lanthanide and a light rare earth element (REE). It is the most abundant, and typically the least valuable, of the REEs.

The soft, silvery metal oxidizes more readily than the rest of the REEs. This property allows for relatively easy separation of Ce from other lanthanides. Ce compounds are used as phosphors and in a variety of chemical applications.

Figure 1. A sample of Ce (IV) hydroxide powder. This compound is used in the production for automobile catalysts and as a stabilizer for PVC plastics. Photo by Leiem (CC-BY-SA-2.0).

Supply

Ce is sourced from REE mining. It occurs in ore minerals along with the other REEs. The U.S. imports much of its Ce from China, the world's major REE miner and refiner. Other entities that refine Ce for export are the European Union, Korea, and Japan. The U.S. produces a large amount of Ce 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. Lesser U.S. Ce production is from heavy mineral sands byproduct in the southeast and smaller pilot-plant-scale operations.

Given its relative scarcity and limited production, there are few data on domestic Ce reserves. Ce is derived from any deposit where other, primarily light, REEs are also present in economic quantities. Most of the world's Ce is mined from carbonatite deposits in China. The Mountain Pass Mine has an indicated resource of ~73 million kg of Ce_2O_3. Average grades of Ce in REE resources range from 0.008 (Round Top, Texas) to 5.5 (Steenkampskraal, South Africa) wt.%. The proportion of Ce in the total REE grade is a function of the deposit type. Ce content is typically moderate to low in all REE deposits except for those hosted in carbonatite, where it is very high. Oxidized, sedimentary, or lateritic REE deposits can have much higher or lower Ce content compared to other REEs. Recent pricing for Ce is ~$1/kg Ce_2O_3.

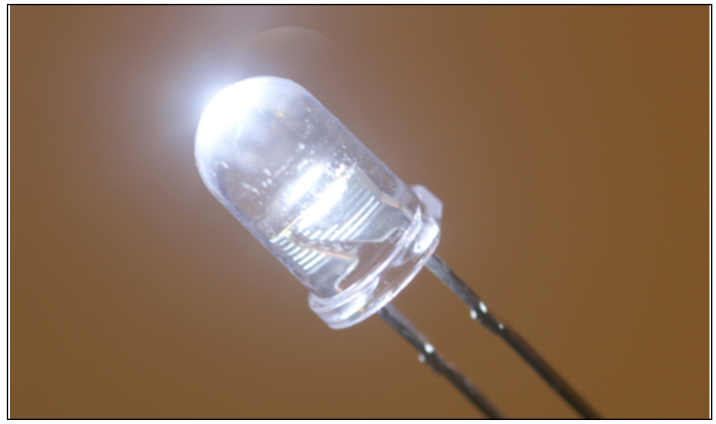

Figure 2. A 5 mm "white" LED. The diode produces monochromatic blue light, but the Ce-phosphor tint converts some of it into yellow light; the combination is perceived as white by the human eye. Photo by oomlout (CC-BY-SA-2.0).

Mineralogy

All REEs, including Ce, co-crystallize in the same minerals due to their geochemical similarities. However, Ce is an exceptional REE as it can oxidize and fractionate from the other REEs. 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. Ce grades are typically higher in carbonatite. The oxide cerianite can also be a major source of Ce in weathered carbonatite. 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). Certain dense Ce minerals, specifically monazite, can resist weathering and become concentrated in placer (mineral sands) deposits along with the other REEs, Zr, Ti, Nb, and Ta.

Figure 3. A sample of REE-mineralized carbonatite with 0.624 wt.% Ce, from Sheep Creek, Ravalli County, Montana. Photo by Adrian Van Rythoven (MBMG).

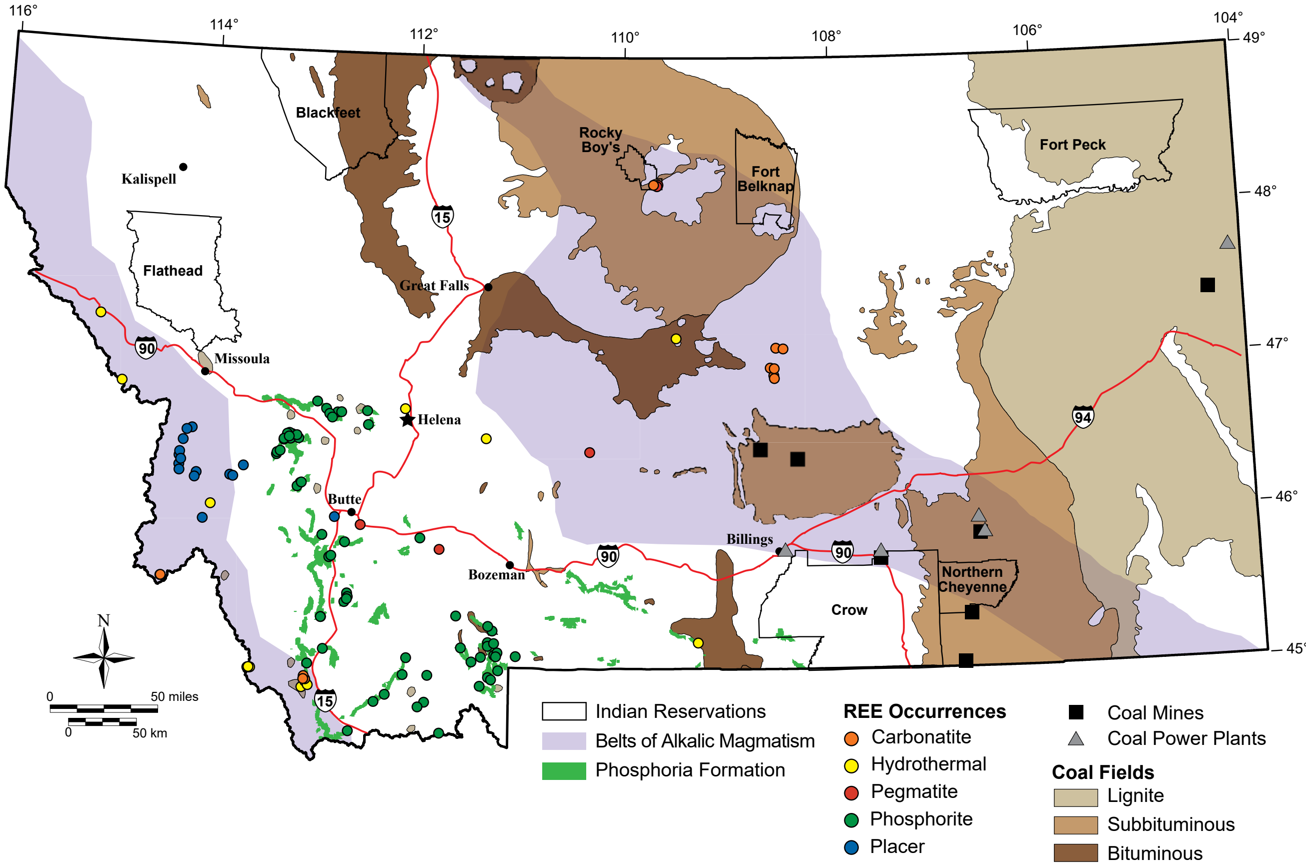

Figure 4. A map of Montana displaying known REE (Ce) occurrences, coalbeds, former and operating coal mines, and coal power plants (both active and inactive, as proxies for coal ash repositories).

A 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 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 Ce in Montana are most common as carbonatite or hydrothermal occurrences in two belts of alkalic magmatism: (1) the Montana–Idaho Alkalic Belt and (2) the Central Montana Alkalic Belt. Both of these regions have multiple occurrences of carbonatite, pegmatite, and hydrothermal REE mineralization. In addition to the other REE deposit types, phosphorite deposits are also scattered throughout this quadrant within the Phosphoria Formation (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 Ce resource. Slag from platinum group metals refining can also be very high in Ce.

Outlook in Montana

Active prospecting for REE mineralization is largely restricted to carbonatite and hydrothermal occurrences in the two alkalic belts.

Researchers at the MBMG are sampling legacy mine sites across the State in order to assess their economic potential for critical minerals, including REEs. Government efforts to document the critical mineral content of mine waste, especially older (legacy) waste, is a recent initiative. The appeal of this initiative is fourfold: (1) secure domestic supply chains for critical minerals, (2) lower mining impacts on the landscape as the material is already fragmented and at surface, (3) increase employment for legacy mining communities, and (4) rehabilitate legacy mine sites that cause pollution.

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.