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MBMG
Montana Bureau of Mines and Geology

Critical Mineral: Thulium

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Overview

Thulium (Tm) is a chemical element included on the United States Geological Survey's 2022 Critical Minerals list. Tm is a lanthanide. It is the third heaviest of the rare earth elements (REEs) and universally low in abundance. The soft, silvery gray metal is used in fluorophores (e.g., anti-counterfeiting measures), superconductors, lasers, and radiology (as a portable radiation source).

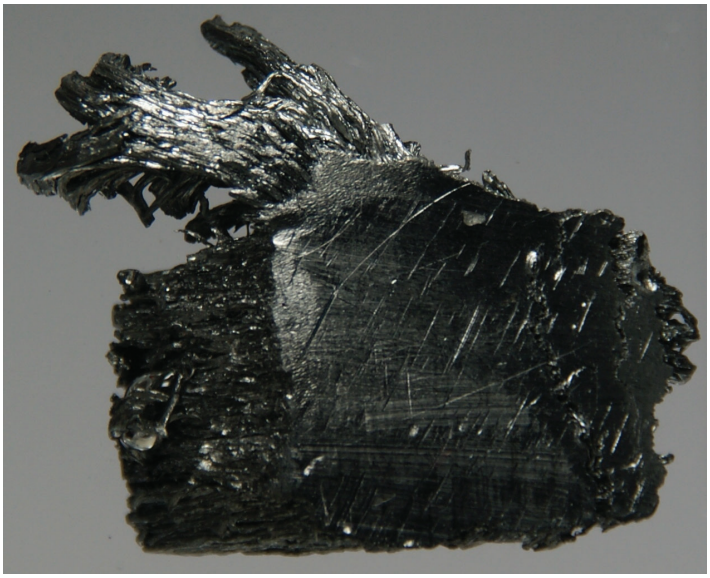

Figure 1. A 22.3-gram sample of refined Tm metal. Photo by Hi-Res Images of Chemical Elements (CC BY 3.0)

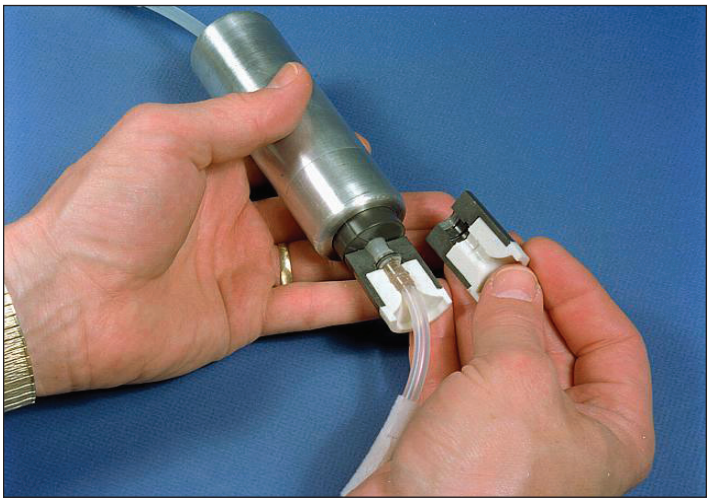

Figure 2. A portable blood irradiator that provides mobile, extra-corporeal irradiation of blood in vivo. The blood irradiator uses thulium and vitreous carbon to destroy circulating lymphocytes, nearly colorless cells that function in the development of immunity. Photo courtesy of Pacific Northwest National Laboratory.

Supply

Tm 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 more-abundant yttrium (Y), terbium (Tb), dysprosium (Dy), and holmium (Ho). The U.S. imports all of its Tm from China, the major miner and refiner. Other countries that refine Tm for export are Germany, Korea, and Japan. The U.S. produces a near-negligible amount of Tm from the one American REE mine at Mountain Pass in California. The only other non-Chinese REE mine of note is Mt. Weld in Australia.

Given its extreme rarity and niche uses, there are no comprehensive data on pricing or consumption of Tm. Tm is derived from any deposit where other REEs are also present in economic quantities. Most of the world's Tm is mined from clay deposits in southern China under environmentally damaging conditions. Grades of Tm in REE deposits range from 0.0001 (Montviel, Quebec) to 0.006 (Browns Range, Australia) wt.%. The proportion of Tm in the total REE grade is a function of the deposit type.

Mineralogy

REEs, including Tm, 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.

Tm 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 potential REE deposits is phosphorite, a sedimentary rock. These are typically mined for

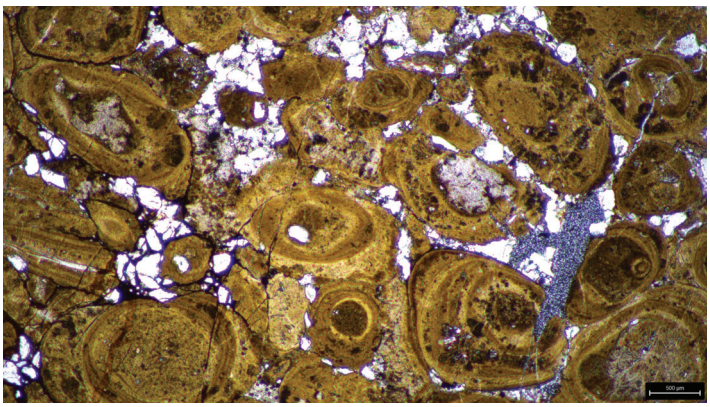

Figure 3. Photomicrograph (in transmitted plane-polarized light at 25x magnification) of REE-bearing (~0.0007% Tm) phosphorite from the Phosphoria Formation by Elliston (Powell Co.), Montana. The ovoid nodules are called ooids and are made of primarily calcium–phosphate with REEs. The angular white grains are quartz sand with cementing calcite. Photo by Adrian Van Rythoven.

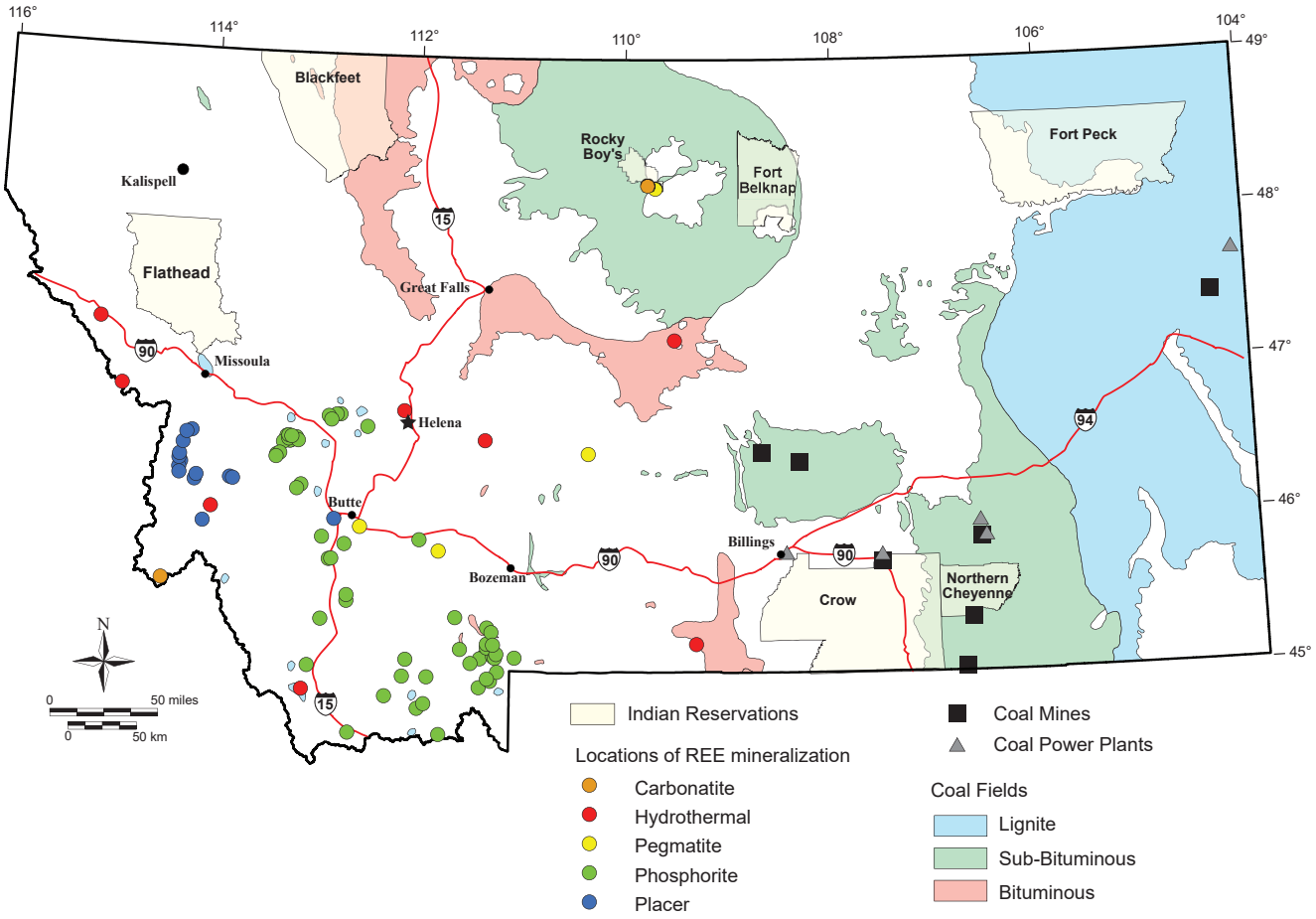

Figure 4. A map of Montana displaying known Tm occurrences, coalbeds, coal mines, and coal power plants (both active and inactive, as proxies for coal ash repositories).

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 Tm 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 have also dissolved REEs. The water in the Berkeley Pit in Butte (Silver Bow Co.) may represent an unconventional Tm resource.

Outlook in Montana

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