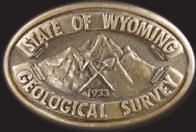


Critical Minerals in Wyoming

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Summary Report



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Other sources of critical
minerals information:

[Wyoming State Geological Survey](#)

[USGS Methodology for Reviewing the 2021 Critical Minerals List](#)

[USGS Mineral Resources Program](#)

[USGS Mineral Deposits Database](#)

[USGS Earth MRI](#)

[UW PRB CORE-CM Project](#)

[UW GGRB CORE-CM Project](#)

[DOE-NETL Critical Minerals Sustainability](#)

[Draft List of Critical Minerals, November 2021](#)



Critical minerals play an important and often overlooked role in society. These minerals and elements are key components in consumer electronics, renewable energy production, medical research, the defense industry, and many more technologies. Many critical minerals are known to occur throughout Wyoming. Some were mined historically, others are currently being produced, and still others are in various phases of exploration. As the U.S. works to establish a domestic supply chain for these minerals, knowledge of their location, extent, and character is essential.

Historical Critical Mineral Production

Mineral exploration and mining shaped much of Wyoming's history as a territory and as a state. Beginning in the mid-1800s, a wide range of ores, including gold, copper, iron, and minerals now classified as critical like platinum, palladium, graphite, and zinc, were discovered statewide.

One of the most extensive periods of exploration occurred in response to World War II. Shortages of raw materials led to exploration of vanadium deposits in the Salt River Range, tungsten mining in the Laramie and Owl Creek mountains, and mining of aluminum-rich rocks in the Laramie Mountains. In many cases, data from this period continue to guide current research efforts on mineral commodities.

What are critical minerals?

Critical minerals are minerals, elements, or materials—excluding energy minerals—that are essential to economic and national security. These minerals are necessary in the manufacturing of crucial products and have supply chains that are vulnerable to disruptions. In 2018, the U.S. Department of the Interior identified 35 minerals and elements that fit the definition of a critical mineral. In November 2021, a revised draft list of critical minerals was added to the federal register for public comment. An updated list, which proposes adding nickel and zinc but removing uranium, helium, potash, rhenium, and strontium, is expected to be available in 2022. This list will be revisited and updated every three years.

Current Critical Mineral Production and Exploration

A handful of operations in Wyoming are responsible for modern production of critical minerals, while several more are in exploration and development phases. The continuation of these operations will lead the way in providing materials essential for current and future technologies. These industries also have the potential to help drive the Wyoming economy forward by providing employment opportunities and generating state revenue.

Uranium

Wyoming hosts the largest-known uranium ore reserves and is the leading producer of uranium in the United States. Since the 1950s, more than 200 Wyoming mines have collectively produced nearly 240 million pounds of yellowcake, or uranium oxide (U_3O_8). The U.S. Energy Information Administration estimates that more than 200 million pounds of uranium ore remain economically recoverable from sandstones throughout the state.

Over the past decade, national uranium production has dropped dramatically as a result of international market conditions that have depressed prices. In 2017, more than 1 million pounds of yellowcake was produced by six active operations in Wyoming, yet in 2019 four active in-situ mining recovery operations produced only 100,000 pounds of yellowcake. Active production at these four operations was suspended in 2020. However, recent market developments have forecasters expecting production to resume in the next several years if prices remain above the break-even point for operators. In fact, uranium market prices recently reached levels not seen since 2012, driven by a reduction of available uranium on the market, private firm investments, and plans for the creation of a \$75 million federal uranium reserve.

The revised federal draft list of critical minerals released in November 2021 does not include uranium. Under the current legal definition, uranium is an energy mineral and therefore cannot also be considered a critical mineral. This denotation does not imply that uranium is not of strategic importance to the nation.

Helium

The United States is the leading global producer of helium and is a net exporter. With over a dozen plants capable of producing crude and grade-A helium, the domestic supply chain does not have a single point of failure. Due to these factors, helium was also proposed to be removed from the critical minerals list in 2021.

Wyoming is home to the largest helium reserves in the country. Helium is recovered from deep wells in association with natural gas and carbon dioxide and processed into grade-A (99.997 percent pure) helium at the LaBarge-Shute Creek treating facility in Lincoln County. Estimates from the U.S. Geological Survey suggest there are 148 billion cubic

feet of recoverable helium from known natural gas reservoirs in the Rocky Mountain region, and much of this is from Wyoming.

Rare earth elements

Rare earth elements (REEs) are a group of 17 metallic elements that, among many other commercial and industrial applications, are essential to manufacturing magnets and batteries. Legislation was recently introduced in the U.S. House of Representatives which would provide a tax credit to U.S. magnet manufacturers for purchasing domestically produced REEs. If passed, H.R. 5033 “Rare Earth Magnet Manufacturing Production Tax Credit Act of 2021” has the potential to incentivize the establishment of a domestic supply chain for REE magnets.

Wyoming hosts several promising deposits that contain elevated amounts of REEs and could be potential sources of REEs in the near future.

The Bear Lodge deposit, located in northeast Wyoming near the Black Hills, is one of the most promising REE deposits in the country. Rare Element Resources Ltd. is seeking to develop an onsite preliminary processing facility to separate REE ore from the surrounding rock. The company recently secured \$47 million in federal and private funding to build an initial separation and processing demonstration plant in Upton, where existing REE ore would be processed into highly refined REE extracts.

American Rare Earths Ltd. is currently exploring a REE deposit in the Laramie Mountains as part of their Halleck Creek project. During the last two years the company collected and assayed surface samples, studied the extent of mineralization, and staked claims. Next steps for the company include exploratory drilling across the claim area.

Promising Critical Mineral Deposits

While technological advancements continue to increase demand for many critical minerals, the access to and supply of these minerals is threatened by an ever-changing geopolitical landscape. In the U.S., there is significant potential for expanding domestic supply chains for critical minerals, which could spur economic growth across the country and in Wyoming. Ongoing work by both public and private entities is laying the foundation by increasing the understanding of these geologic deposits.

Heavy-mineral sandstones

Worldwide, titanium, zirconium, and hafnium are primarily produced from heavy-mineral sand deposits, which can also contain elevated amounts of REEs, niobium, and vanadium. The U.S. imports nearly all of its sources of these elements, which are essential to the aerospace industry and



Photo of a heavy mineral sandstone deposit in the Rock Springs Formation, Sweetwater County, WY.

for numerous manufacturing applications. In Wyoming, heavy-mineral sandstones likely contain these same critical minerals. A preliminary Wyoming State Geological Survey (WSGS) investigation of a small heavy-mineral sandstone deposit in southwestern Wyoming showed the presence of abundant titanium, zirconium, and REEs.

Coal deposits

Elevated levels of uranium and critical minerals such as REEs and germanium have been measured in coal seams, bounding beds, and coal byproducts worldwide. However, many of Wyoming's coal deposits lack the data needed to characterize their full critical mineral potential.

The University of Wyoming's School of Energy Resources (SER) and the Wyoming State Geological Survey are working to address this. The WSGS recently released a report on critical mineral concentrations in select coals and associated rocks from the Kemmerer area. SER has received funding from the Department of Energy for two multi-year projects to assess carbon ore, REEs, and other critical mineral resources within the Powder River, Greater Green River, and Wind River basins. These projects will investigate new technologies and applications for additional development of critical minerals from coal deposits, associated byproducts, and waste streams.

Mine waste

Waste rock and tailings, left over after extraction of primary commodities, can often be enriched in other elements, including those defined as critical. These elements may not have been extracted initially due to limited technology, uneconomical methods, or a lack of demand. Supply-chain constraints and growing momentum towards more environmentally friendly energy and industrial practices has led to a reevaluation of these potential resources. Large mining companies are expanding their ability to recover additional byproducts and critical minerals from their waste streams. Nationally, the U.S. Geological Survey and Department of Energy are studying critical mineral distribution and availability within mine waste, byproducts, and tailings piles.

Looking Ahead

Federal designation of certain minerals as critical was the first step to establishing secure and reliable domestic sources of these materials. The development of critical mineral supply chains is dependent on identifying and

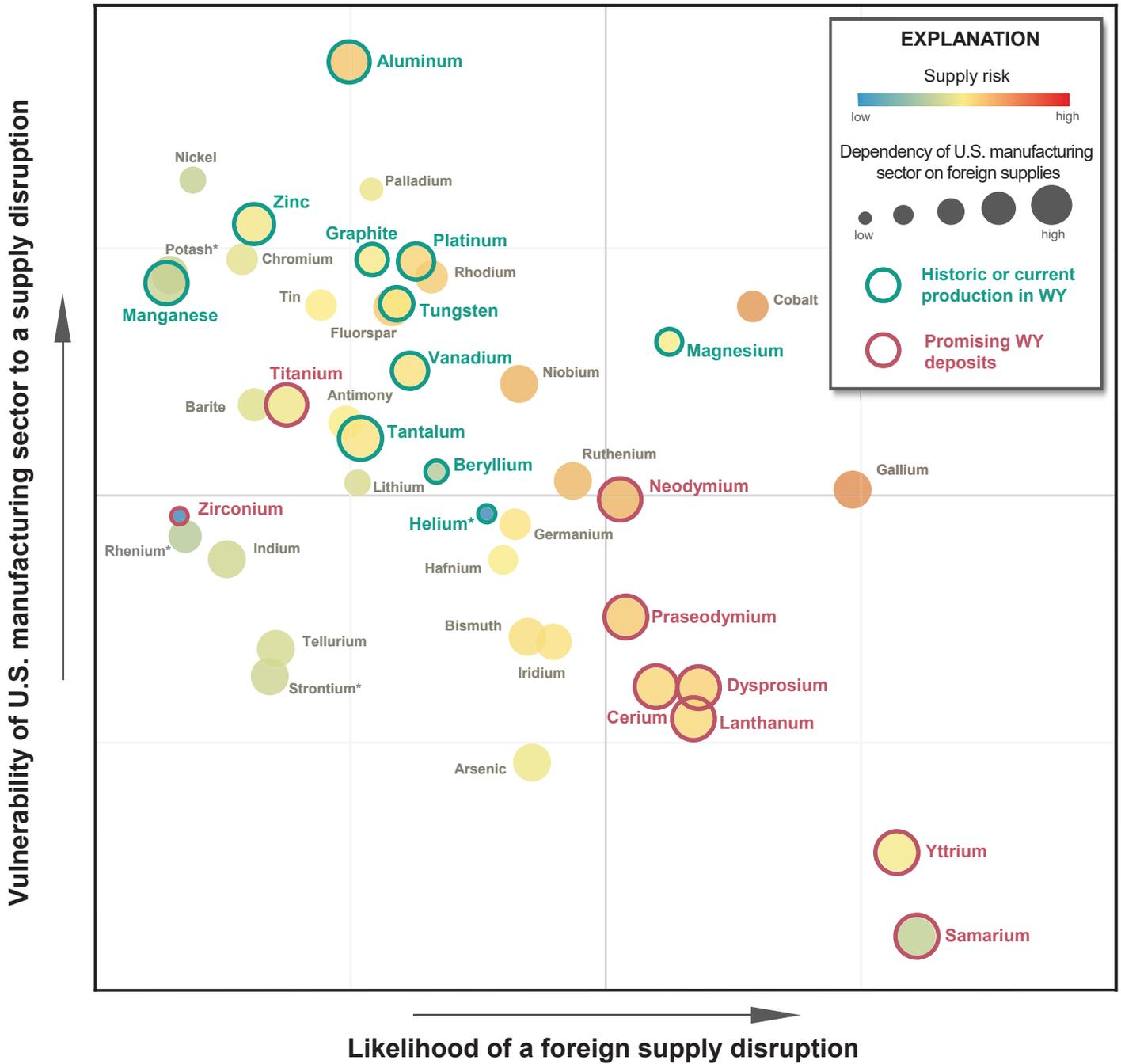
describing potential critical mineral resources throughout the United States—a difficult task made more challenging by the lack of high-quality public data. This highlights the need, and presents an opportunity, for expanded data collection and research in order to improve our understanding of the geologic systems that create critical mineral deposits in the United States.

Research on critical minerals in Wyoming has leveraged federal funding from the U.S. Geological Survey's Earth Mapping Resources Initiative (Earth MRI) and mapping programs (STATEMAP and EDMAP), the National Science Foundation, and the Department of Energy's Carbon Ore, Rare Earth and Critical Minerals (CORE-CM) program. Ongoing WSGS projects include research on critical minerals in the Laramie Mountains and an upcoming airborne geophysical survey of the complicated subsurface geology in the Medicine Bow and eastern Sierra Madre mountains. This geophysical survey was funded in part by Wyoming House Bill HB001 from the 2020 legislative session, which directed the WSGS to investigate critical mineral and other commodities across the state. Other projects that have come from HB001 include the WSGS's recent study of the Kemmerer coal field and ongoing projects on helium and heavy-mineral sandstones.

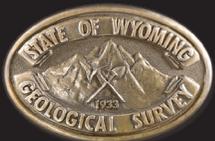
As technology advances and the demand for critical minerals grows, a comprehensive understanding of their occurrences and distribution is necessary. In addition to coal and trona, economic mineral commodities such as gold and copper, and strategic mineral commodities such as uranium and helium, Wyoming hosts significant deposits of REEs and other critical minerals. When coupled with historical data and a proven history of mineral extraction, Wyoming is in a unique position to become a national leader in the development of domestic critical mineral production.



Photo of the historic Iron Mountain Mine, located in the Laramie Mountains. The Iron Mountain Mine targeted a very large titaniferous magnetite deposit, which is rich in the critical minerals titanium and vanadium, with trace amounts of nickel and chromium. However, titanium production from oxide deposits such as this is considered subeconomic. At this deposit, the ore was mined not as a source of titanium, but rather for use as heavy ballast for ships and oil rigs and as loose aggregate in concrete.



Plot of the supply risk of each critical mineral, which takes into account three aspects of its supply chain: the vulnerability of the U.S. manufacturing sector to a supply disruption, the likelihood of a foreign supply disruption, and how dependent the U.S. manufacturing sector is on foreign suppliers. Critical minerals that have been historically or are currently produced in Wyoming are circled in green, and critical minerals that occur in promising deposits in Wyoming are circled in red. Elements marked with an asterisk have been proposed for removal from the critical minerals list. Chart is modified from U.S. Geological Survey Open-File Report 2021-1045.



Interpreting the past, providing for the future

