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Critical Minerals in South Dakota

On December 20th, 2017 the White House issued Executive Order 13817, entitled "A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals," citing the reliance of the United States on imports for certain mineral commodities vital to economic and national security interests. The order states that increased domestic exploration, production, recycling, and processing will reduce reliance on imports.

A critical mineral is defined as (i) a non-fuel mineral or mineral material essential to the economic and national security of the United States, (ii) the supply chain of which is vulnerable to disruption, and (iii) that serves an essential function in the manufacturing of a product, the absence of which would have significant consequences for our economy or our national security. The United States is 100-percent dependent on imports for 21 critical minerals and is at least 50-percent dependent on imports for another 28 critical minerals.

The concept of critical minerals is not new in the United States. In 1922, after World War I, the Joint Army and Navy Munitions Board was established by the War Department to plan for obtaining raw materials required by the military. Two separate Strategic and Critical Minerals Stockpiling Acts were passed in 1939 and 1946 to establish reserves of commodities required for national defense. The stockpiles increased through the early 1960s but then were partially or completely sold when the materials were no longer needed.

The U.S. Department of Defense, Department of the Interior, and Department of Energy established a list of critical minerals in 2019 and revised that list in 2022. Table 1 contains a list of all 50 critical minerals and their primary application as of 2022.

Most of the "minerals" on the list are chemical elements. Minerals are composed of specific chemical elements or compounds arranged in a specific way. The element or the mineral itself may be considered critical. Currently, there are only three minerals on the list: barite, fluorspar, and graphite. Barite and fluorspar are considered critical because they are the predominant source of the elements barium and fluorine, respectively. Graphite is a soft, crystalline form of the element carbon and is considered critical. Other forms of carbon, for example coal, are not considered critical and therefore graphite rather than carbon is on the list. Some versions of the list may include the mineral bauxite because it is the predominant source for the chemical element aluminum. The rest of the list is chemical elements and sixteen are from the rare earth elements (REEs) group on the periodic table (Figure 1).

Table 1. List of critical minerals and their primary applications as of 2022

Critical Mineral	Primary Application	Critical Mineral	Primary Application
Aluminum	Powerlines, construction, electronics - used in almost every sector of the economy	Magnesium	Alloy and for reducing metals
Antimony	Lead-acid batteries and flame retardants	Manganese	Steelmaking and batteries
Arsenic	Semi-conductors	Neodymium	Magnets, rubber catalysts, and in medical and industrial lasers
Barite	Hydrocarbon production	Nickel	Stainless steel, superalloys, and rechargeable batteries
Beryllium	Alloying agent in aerospace and defense industries	Niobium	Steel and superalloys
Bismuth	Medical and atomic research	Palladium	Catalytic converters and as a catalyst agent
Cerium	Catalytic converters, ceramics, glass, metallurgy, and polishing compounds	Platinum	Catalytic converters
Cesium	Research and development	Praseodymium	Magnets, batteries, aerospace alloys, ceramics, and colorants
Chromium	Stainless steel and other alloys	Rhodium	Catalytic converters, electrical components, and as a catalyst
Cobalt	Rechargeable batteries and superalloys	Rubidium	Research and development in electronics
Dysprosium	Permanent magnets, data storage devices, and lasers	Ruthenium	Catalysts, electrical contacts and chip resistors in computers
Erbium	Fiber optics, optical amplifiers, lasers, and glass colorants	Samarium	Magnets, absorber in nuclear reactors, and in cancer treatments
Europium	Phosphors and nuclear control rods	Scandium	Alloys, ceramics, and fuel cells
Fluorspar	Manufacturing of aluminum, cement, steel, gasoline, and fluorine chemicals	Tantalum	Electronic components, mostly capacitors and in superalloys
Gadolinium	Medical imaging, permanent magnets, and steelmaking	Tellurium	Solar cells, thermoelectric devices, and as alloying additive
Gallium	Integrated circuits and optical devices like LEDs	Terbium	Permanent magnets, fiber optics, lasers, and solid-state devices
Germanium	Fiber optics and night vision applications	Thulium	Various metal alloys and in lasers
Graphite	Lubricants, batteries, and fuel cells	Tin	Protective coatings and alloys for steel
Hafnium	Nuclear control rods, alloys, and high-temperature ceramics	Titanium	White pigment or metal alloys
Holmium	Permanent magnets, nuclear control rods, and lasers	Tungsten	Wear-resistant metals
Indium	Liquid crystal display screens	Vanadium	Alloying agent for iron and steel
Iridium	Coating of anodes for electrochemical processes and as a chemical catalyst	Ytterbium	Catalysts, scintillometers, lasers, and metallurgy
Lanthanum	Produce catalysts, ceramics, glass, polishing compounds, metallurgy, and batteries	Yttrium	Ceramic, catalysts, lasers, metallurgy, and phosphors
Lithium	Rechargeable batteries	Zinc	Galvanized steel
Lutetium	Scintillators for medical imaging, electronics, and cancer therapies	Zirconium	High-temperature ceramics and corrosion-resistant alloys

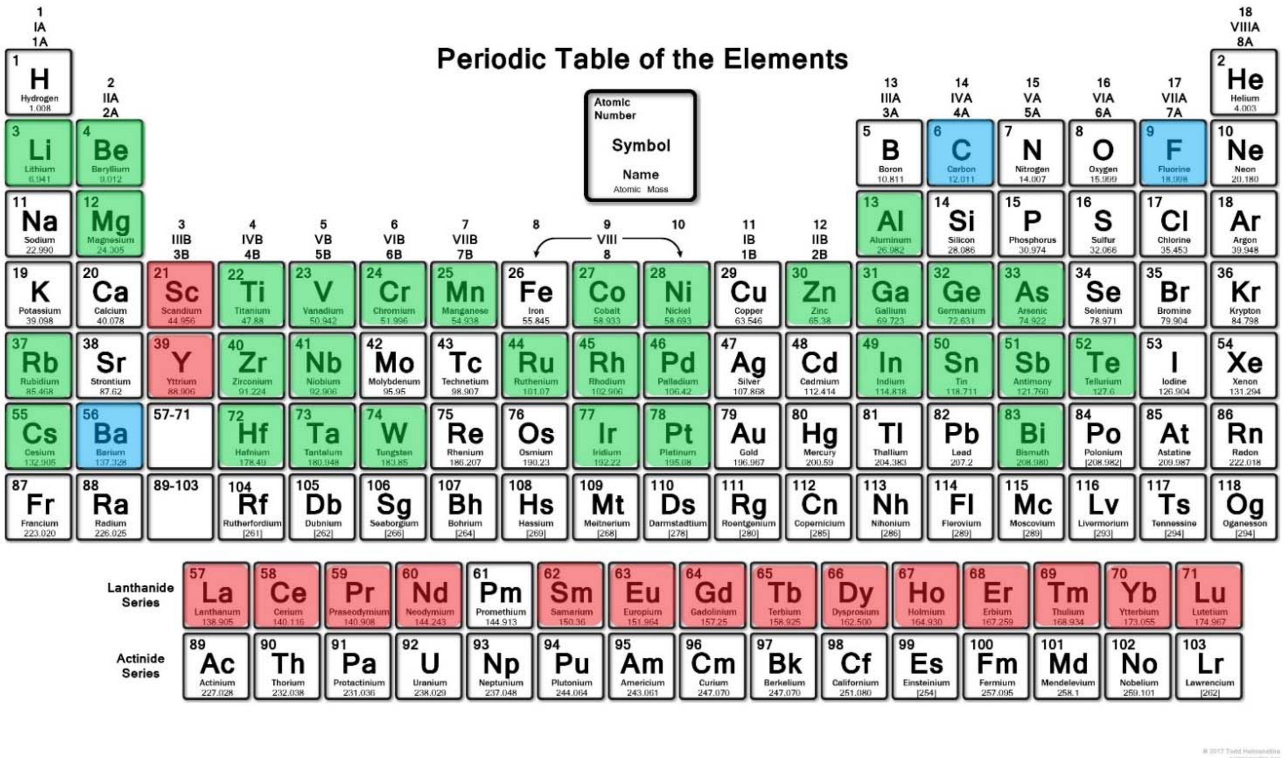

Figure 1. Periodic table of elements showing current list of critical "minerals". Green = chemical element, red = chemical element of the REE group, blue = chemical element represented by a mineral on critical mineral list – barium (barite), carbon (graphite), and fluorine (fluorspar).

Critical minerals are essential in the manufacturing of products required for our lifestyle, economy, and national security. Critical minerals are used in cell phones, televisions, computer chips, solar panels, wind turbines, batteries, electric cars, desalination plants, carbon sequestration facilities, military equipment, and more. For example, it takes nine different REEs to make an iPhone. Modern automobiles are made of over 70 different chemical elements and more than half of these are considered critical. Each electric car currently requires about 20 lbs. of lithium, 29 lbs. of cobalt, 54 lbs. of manganese, 88 lbs. of nickel, and 146 lbs. of graphite.

Many critical minerals do not exist as economically viable, stand-alone mineral deposits but rather as co-minerals or by-products of other mineable deposits. These primary mineral deposits are called gateway minerals—the principal mineral deposits recovered from mining provide additional critical minerals which add value to the deposit. For example, copper deposits can be a gateway mineral for cobalt, gallium, tellurium, indium, and REEs. Gold deposits can be the gateway mineral for antimony, tellurium, and arsenic. Lead and zinc are the gateway minerals for indium, gallium, germanium, antimony, bismuth, and tellurium. Uranium is the gateway mineral for vanadium, and potentially REEs. Coal deposits could become economic for REEs, cobalt, germanium, and gallium.

Critical minerals are known to occur in South Dakota; however, none are currently produced primarily because they cannot be mined economically. For example, a relatively large manganese deposit is known to occur in the central and south-central part of the state, but due to the low grade and the deposit being spread over a wide range, it cannot be mined economically. Rare earth elements are known to exist within the northern Black Hills but are widely disseminated within their host rocks making them uneconomical to mine. During the 1920's the Etta mine in the southern Black Hills was the principal producer of lithium in the United States. The mine shut down in 1959 because it became unprofitable. With renewed interest in lithium several companies have recently staked lithium claims in the south-central portion of the Black Hills. Current mineral production in South Dakota is limited to gold, silver, mica, feldspar, gypsum, gemstones, clay/shale and lime. Recent mining of these resources has not produced critical minerals in any significant quantities.

Undiscovered deposits of critical minerals certainly exist in the United States, but mineral exploration by the private sector is hampered by the lack of modern geological, geophysical, and topographic data. These types of data are needed by geologists to find mineral resources but can be expensive and time consuming to acquire. Geophysical data in particular is extremely expensive to acquire but instrumental in defining areas that may contain mineral resources beneath the ground surface. In response to the 2017 Executive Order, several federal agencies implemented programs to provide funding to states to acquire the necessary data needed to aid in mineral exploration.

The United States Geological Survey (USGS) developed the Earth Mapping Resource Initiative (Earth MRI) to identify areas with potential for undiscovered critical mineral deposits. Earth MRI is a collaborative effort between the USGS and State geological surveys to identify, prioritize, and acquire new geoscience data for areas that have potential to host critical mineral resources. In 2021 and 2022, the South Dakota Geological Survey (SDGS) worked with geologists from the USGS and surrounding states to finalize a proposal for an airborne magnetic and radiometric geophysical survey to be flown in southeastern South Dakota, southwestern Minnesota, northwestern Iowa, and northeastern Nebraska. These types of data have been acquired previously in this region, but the existing data is considered inadequate. This proposal, known as the Western Spirit Lake Tectonic Zone survey (Figure 2), was chosen to be funded by Earth MRI. The survey began in May of 2023 and was completed in August of 2024.

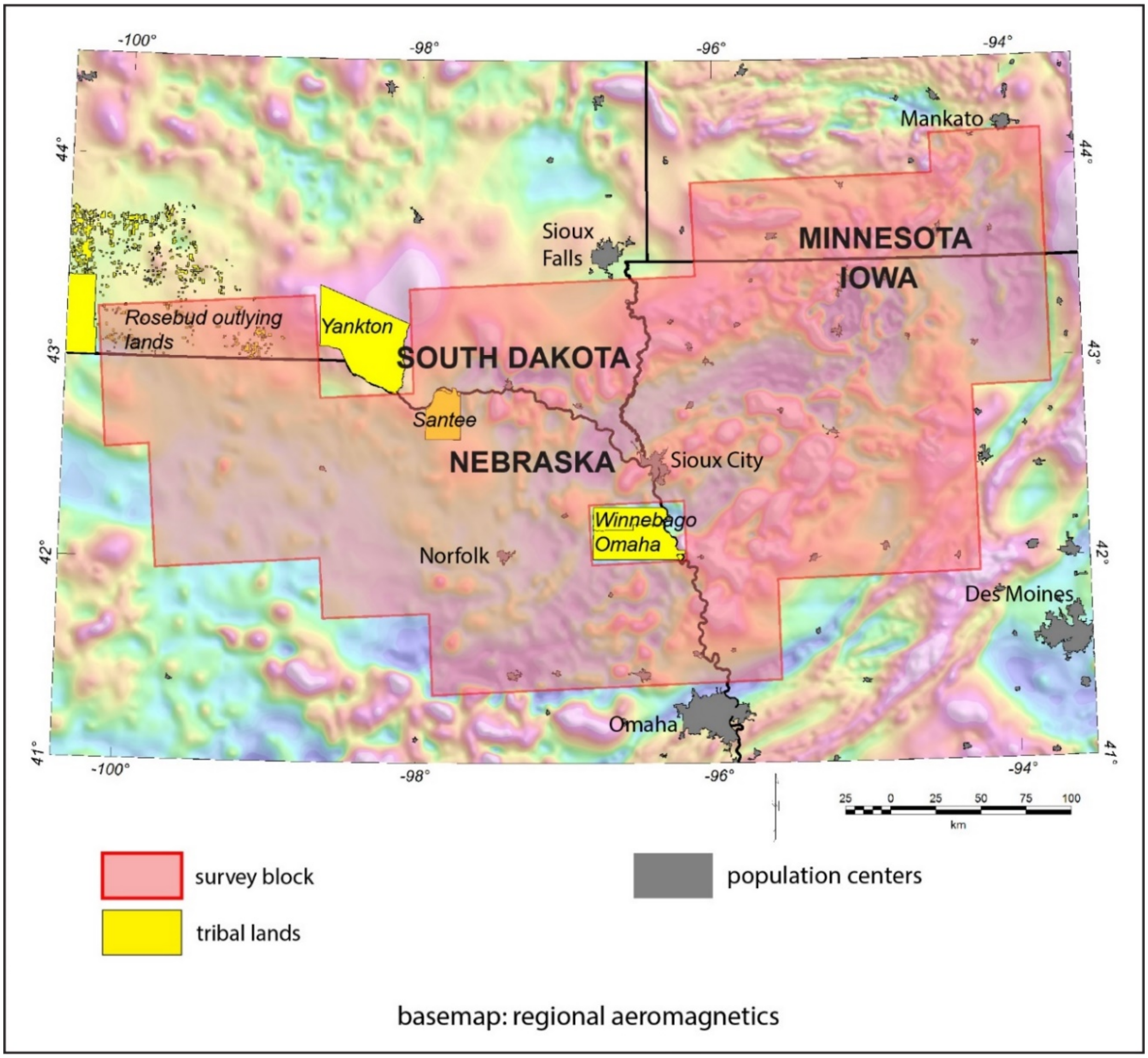

Figure 2. Map showing the Western Spirit Lake Tectonic Zone geophysical survey area (pink). Multicolored base map is older magnetic geophysical data for the region showing magnetic differences in rocks beneath the ground surface.

In February of 2024 Earth MRI program choose to fund another airborne magnetic and radiometric survey over the Sioux Falls region (Figure 3). This survey area is a relatively small area directly north of the Western Spirit Lake Tectonic Zone survey. The survey began in September of 2024 and it is anticipated that it will be completed sometime during the 2025 flight season.

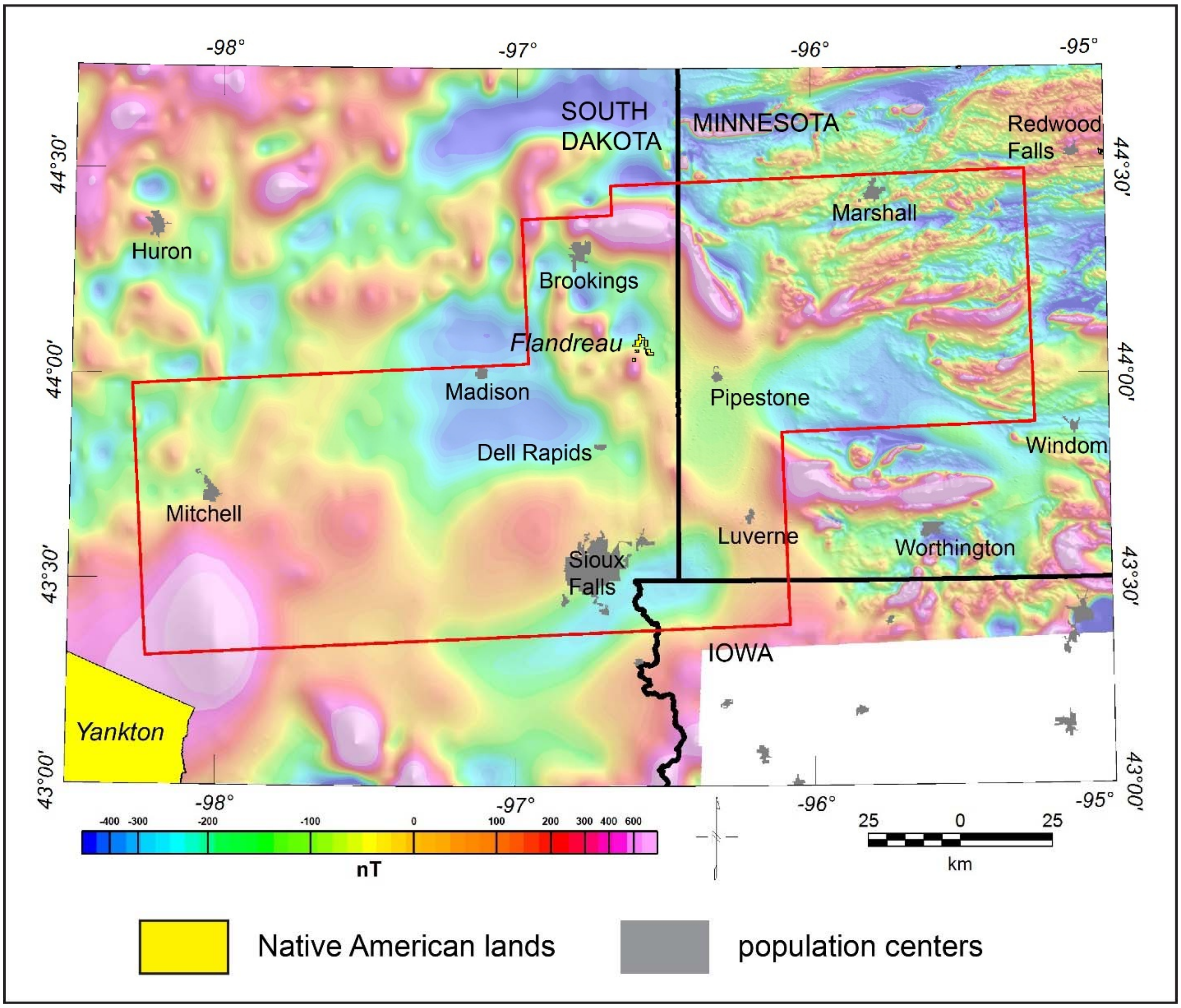

Figure 3. Map showing the Sioux Falls geophysical survey area (red line). Multicolored base map is older magnetic geophysical data for the region showing magnetic differences in rocks beneath the ground surface.

Two other proposals for geophysical surveys in South Dakota have been completed. The SDGS worked with the Wyoming Geological Survey and USGS to write the Cheyenne Belt to Black Hills Airborne Electromagnetic Survey proposal. This survey was chosen to be funded by the Earth MRI program and will acquire electromagnetic data over parts of southeastern Wyoming and the Black Hills of Wyoming and South Dakota. This survey will be a helicopter-based survey and is anticipated to begin in Wyoming in 2025 with the South Dakota portion to be flown in 2026.

The second proposal written in conjunction with the Wyoming Geological Survey and the USGS is an airborne magnetic and radiometric geophysical survey to be flown over the Black Hills of Wyoming and South Dakota. This survey was chosen to be funded by Earth MRI in December of 2024 and likely won't begin until sometime in 2026.

In 2020 the Department of Energy (DOE) developed the Carbon Ore Rare Earth – Critical Minerals (CORE-CM) program. This program is specifically looking at coal beds within 13 geologic basins around the United States. One of the projects that was selected by the DOE was the Williston Basin project. The University of North Dakota's Energy & Environmental

Research Center (EERC) is heading up the Williston Basin portion of the CORE-CM project. In the spring of 2022, the EERC petitioned the SDGS to help identify areas in northwestern South Dakota where samples of lignite (coal) could be acquired and subsequently analyzed for REEs. In October of 2022, the SDGS collected 14 lignite samples in the Cave Hills area in Harding County (Figure 3). Lab analyses indicate that REEs exist in the lignite beds, but at concentrations that would likely make them uneconomical to mine.

Figure 3. South Dakota Geological Survey personnel preparing to sample a lignite bed in the Cave Hills area of Harding County.

The current list of critical minerals is not a permanent list but will be updated periodically to reflect current data on supply, demand, and concentration of production, as well as current policy priorities. The critical minerals list is reviewed by the federal government every 2 to 3 years. Demand for critical minerals is expected to continue to grow and thus the search for critical mineral deposits within the United States will likely continue for years to come.