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Ancient subtropical soils may hold the key to critical mineral enrichment in the Williston Basin of North Dakota.

BISMARCK, ND - Lynn Helms, Director of the North Dakota Department of Mineral Resources, and Ed Murphy, North Dakota State Geologist, announced that the North Dakota Geological Survey has developed a comprehensive exploration model for lignite coals and organic-rich mudstones enriched in critical minerals. This model is based on the recent discovery of a thirty-foot-thick interval of rocks containing elevated concentrations of many critical minerals, some of which can be significantly enriched. This brightly colored rock unit is called the Bear Den Member of the Golden Valley Formation which is typically present in upland areas covering 340 square miles spread across west-central North Dakota. This important discovery is documented in a just-released 90-page report: ND Geological Survey Report of Investigation no. 133, available for free download on the DMR – Geological Survey website.

Critical minerals are commodities defined by the U.S. Government as essential to the economic or national security of the United States. They are increasingly vital components of modern technologies, especially the electronic components needed for an electrified energy infrastructure and advanced defense applications. There is little or no production of critical minerals in the United States, and domestic manufacturers depend on steady supplies from foreign countries, many of them adversarial to U.S. national interests. Some coal seams are known to contain elevated concentrations of valuable elements and have been proposed as a possible alternative source of critical minerals in the U.S. These deposits are thought to be relatively uncommon but have been poorly researched. Questions remain about the exact geologic processes that enrich coal, as a result, it has been difficult to develop reliable exploration models for economic deposits. Hydrothermal activity or volcanic eruptions have been identified as mechanisms that can transport critical minerals into coal in other basins, but evidence for neither pathway currently exists in North Dakota. However, sampling by the ND Geological Survey since 2015 has identified elevated critical mineral concentrations scattered throughout the Williston Basin. This sampling project has produced one of the most detailed datasets of coal enrichment in North America through the analysis of over 1,700 samples from

more than 300 sites across western and south-central North Dakota. Although these samples represent only a tiny fraction of the state's estimated 25 billion tons of lignite reserves, the geochemical results from them have already offered new insights into the occurrence and origins of promising critical minerals, especially the rare earth elements.

Contrary to what their name implies, rare earths are present in many types of rocks and sediments, but these metallic elements rarely concentrate into ores that can be economically mined. The U.S. has historically only developed one such deposit, the Mountain Pass mine in California, but it won't be able to meet future domestic demand for rare earths. Igneous ores at Mountain Pass and other major mines are mostly enriched in the "light" rare earths, like cerium and lanthanum, resulting in overproduction and low prices for some elements and ongoing global supply shortages for others. These hard rock sources can also harbor large amounts of the radioactive contaminant thorium, making the ores expensive to refine. Coal and coal ash generally contain much lower overall concentrations of rare earths, but with comparatively cheap mining costs, low amounts of thorium, and a higher proportion of the more valuable heavy rare earth elements, the U.S. Department of Energy has estimated that a coal-related feedstock could be an economic source of rare earths in concentrations as low as 300 parts per million. Lignite, a low-rank coal, may be an especially promising source because of its ability to easily uptake and release rare earths, potentially making extraction comparatively low-cost and environmentally friendly.

Most of the global supply of the more valuable, heavy rare earths currently comes from South China, where elements are naturally leached from igneous rocks and concentrated in thick soil horizons. The wet, humid climate is prone to acidic soils that break down granite into the clay mineral kaolinite, which absorbs rare earth elements from groundwater as it carries them through the soil profile. Water moves elements through rocks and sediments in North Dakota in similar ways, but because the climate is comparatively cool and dry, the weathering intensity is much lower. Conditions were much different, however, in North Dakota's past. The coal-bearing strata of the state were deposited in subtropical rivers, lakes, and swamps, and even preserve the record of one of the warmest and wettest climate events in Earth's history, the Paleocene-Eocene thermal maximum. Intense weathering during this event, dated at 56 million years ago, left behind a thick sequence of kaolinite in the Bear Den Member of the Golden Valley Formation, which is traceable across portions of seven counties in west-central North Dakota. Recent sampling by the ND Geological Survey shows rare earth elements and other critical minerals can become significantly enriched, especially when coal is present in the lower portion of this ancient soil profile.

Samples of thin lignite coals and organic-rich mudstones from the lower Bear Den Member contain up to 2,570 parts per million rare earth elements, believed to be the highest spot

concentration yet reported from a North American coal and far exceeding the threshold of 300 parts per million considered potentially economic. Concentrations of many additional critical minerals were enriched in the same samples, including cobalt, gallium, germanium, and lithium. Although the enriched lignite beds were too thin to be economically mined at the first few sites investigated in this report, lignite beds can thicken laterally over short distances and the potential exists for several feet of coal to be enriched at other sites. The identification of widespread enrichment below a prominent weathering zone, linked to a well-studied global warming event, also has important implications for coal-hosted critical mineral exploration in other rocks in North Dakota, and in other U.S. basins. Enrichment may now be better explained in the context of sometimes subtle and localized evidence of ancient soil development rather than looking for influence from volcanic ash or groundwater flowing from distant sources.

The ND Geological Survey has already identified a handful of other weathering zones in the Williston Basin which will be the subject of future reports. One of those, located 1,000 feet stratigraphically below the Bear Den Member, also contains elevated concentrations of critical minerals and has been used to supply enriched lignite to the University of North Dakota's Institute for Energy Studies for research on critical mineral extraction technologies. The discovery and description of these deposits are important steps in the development of a comprehensive exploration model for the coal and mineral industry, with the potential to one day reduce the necessity of critical mineral imports, a strategic vulnerability of the United States.
