Advancing Critical Minerals Exploration through MBMG's Data Preservation and Economic Geology Programs

Chelsea Pincock and Kyle Eastman

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Introduction

Modern critical minerals exploration increasingly depends on integrating newly collected data with historic geologic information. Many of Montana's most valuable geologic observations and samples cannot be replaced because mine workings have been reclaimed, flooded, or otherwise become inaccessible. The Data Preservation Program at the Montana Bureau of Mines and Geology (MBMG) preserves these irreplaceable collections, making them available to the MBMG's Economic Geology Program, where they support modern geologic mapping, geochemical and mineralogical characterization, and critical minerals research. Together, these programs demonstrate that historic collections are more than archival resources—they are essential scientific assets that directly support modern critical minerals exploration.

Collaborative Support for Earth MRI and NGGDPP

The U.S. Geological Survey's (USGS) National Geological and Geophysical Data Preservation Program (NGGDPP) and the Earth Mapping Resource Initiative (Earth MRI) provide complementary support for the MBMG's critical minerals research by preserving historic mining and geological information while generating new geological data. The Earth MRI program funds geologic mapping, geophysical surveys, geochemical sampling, and mine waste characterization. The NGGDPP supports the systematic digitization of maps and documents while facilitating the geochemical analysis of historic sample materials. By leveraging these Federal programs alongside State matching funds, the MBMG has transformed static archives into accessible digital resources that support modern critical minerals exploration while making geologic information broadly accessible to researchers, industry, and the public.

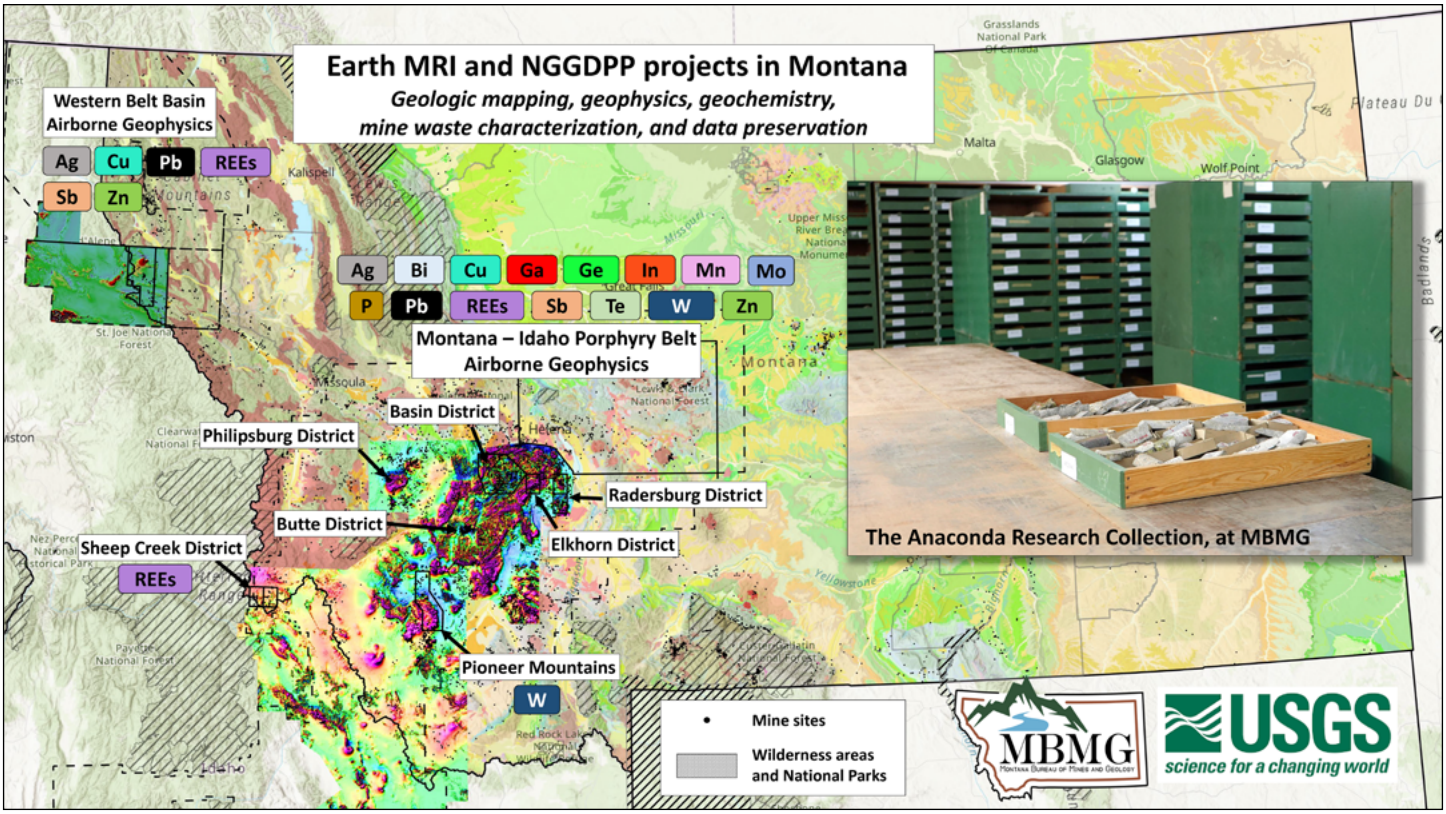

Figure 1. Map of Montana showing Earth MRI project areas that have benefited from NGGDPP geochemical samples and data; inset photo shows the Anaconda Research Collection.

Focus Area: The Philipsburg District

The Philipsburg District in southwest Montana (fig. 1) was an important historic producer of silver, zinc, lead, copper, gold, and manganese. From 1865 until the 1980s, it ranked second among polymetallic producers in Montana, just behind the Butte District. Montana Tech Professor Celine Beaucamp revisited this area to assess its critical minerals potential as part of her PhD project. With support from the NGG-DPP, sample splits were sent to the USGS laboratory for whole-rock geochemistry. The results identified UV-fluorescent sphalerite (ZnS) as a major host of critical and other commodities in the Philipsburg District, including W, Cu, Ga, Ag, In, As, Sb, Bi, and Ge (Beaucamp and others, 2024). New geochemical data generated as part of this project confirmed these sphalerite-hosted commodities, and identified elevated critical minerals content in both mine waste and primary ore samples at mines in the Philipsburg District, including Mn (to >10 wt.%), Zn (to >1 wt.%), As (to >1 wt.%), Ba (to >1 wt.%), W (to 600 ppm), Sb (to 8,000 ppm), Ge (to 200 ppm), Ga (to 500 ppm), In (to 400 ppm), and Te (to 1,000 ppm).

Focus Area: The Boulder Batholith

The Late Cretaceous (~85–70 Ma) Boulder Batholith is one of Montana's most well-mineralized provinces and includes the Butte, Basin, Radersburg, and Elkhorn mining districts (fig. 1). Historically, it hosted a wide variety of ore deposits, many of which are now recognized as potential sources of critical minerals. Since 2022, USGS airborne geophysical surveys have provided high-resolution magnetic and radiometric imagery of the region. The MBMG is partnering with USGS researchers to investigate the ore-forming magmatic processes of the batholith by utilizing our historic sample collections to complement these modern geophysical data.

Critical Minerals in Butte

One of the MBMG's most notable collections, the Anaconda Research Collection (ARC), was recently recognized by the International Union of Geological Sciences (IUGS) as an official Geo-Collection. The ARC includes ~14,000 individual samples, with >8,000 samples from mines in the Butte District. Many

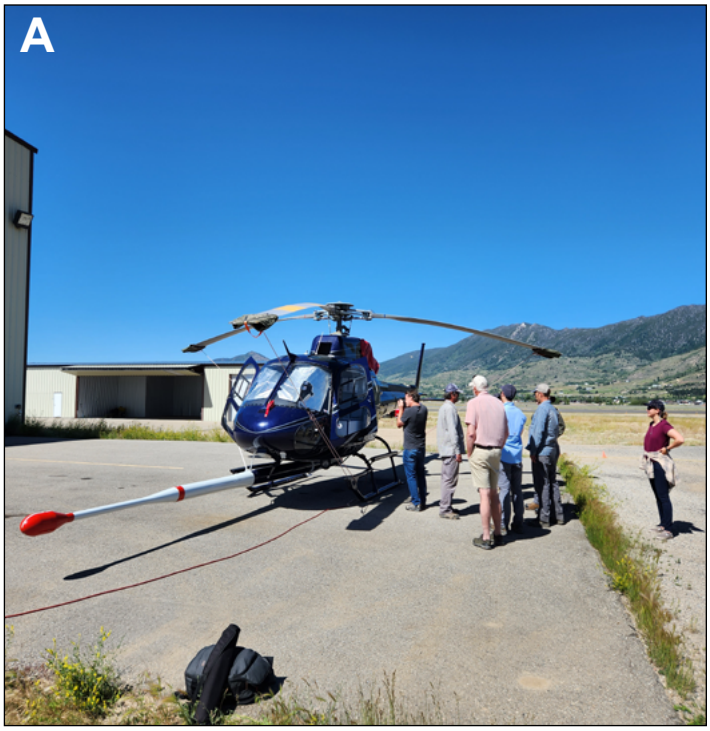

Figure 2. Earth MRI airborne geophysical surveys and field validation. (A) Helicopter used by the USGS to acquire high-resolution airborne magnetic and radiometric data as part of the Earth MRI program. (B) USGS, MBMG, and Montana Tech geologists in the field ground-truthing geophysical anomalies and interpreting the geology.

Figure 3. UV-fluorescent sphalerite from the Anaconda Research Collection. Fluorescence of sphalerite is related to trace element content and can indicate important byproduct critical commodities. (A) UV-fluorescent sphalerite from the Leonard Mine, Butte District. (B) UV-fluorescent sphalerite from the Badger Mine, Butte District.

of these samples were collected from mine workings that have been flooded or reclaimed, making them impossible to replace. Recently, these samples provided a key dataset for NSF-funded critical minerals research at Montana Tech and MBMG by Dr. Chris Gammons, Dr. Celine Beaucamp, and Kyle Eastman. This work identified high concentrations of critical elements—including Ga, Ge, In, and W—within UV-fluorescent sphalerite. Recent collaborative work using high-energy X-rays at the Stanford Synchrotron Radiation Lightsource has further investigated the atomic structure of this sphalerite. These analyses were made possible because the MBMG had preserved the historic samples needed for modern synchrotron-based research.

Historic Document Preservation and Delivery

The MBMG Data Preservation Program preserves and delivers historic maps and geologic information through systematic scanning, metadata creation, and web-based delivery. To maximize the utility of these collections, Data Preservation is developing an interactive geospatial tool using ArcGIS and the CollectionBuilder platform. This interface allows users to search the collections geographically. By interacting with defined polygons (e.g., mining districts or counties), users can access pop-up panels containing associated historic content with metadata, preview images, and download relevant data.

This digital delivery streamlines Earth MRI research by supporting project area investigations. All digital resources are curated in alignment with FAIR (Findable, Accessible, Interoperable, and Reusable) principles (Wilkinson and others, 2016), ensuring that this geologic information remains a lasting, accessible asset for the professional community and the public. As of this publication, Data Preservation has 3,474 digitized maps and 3,223 mining-related documents being prepared for website delivery. An estimated 10,000 maps and 30,000 mining-related documents are planned for website delivery.

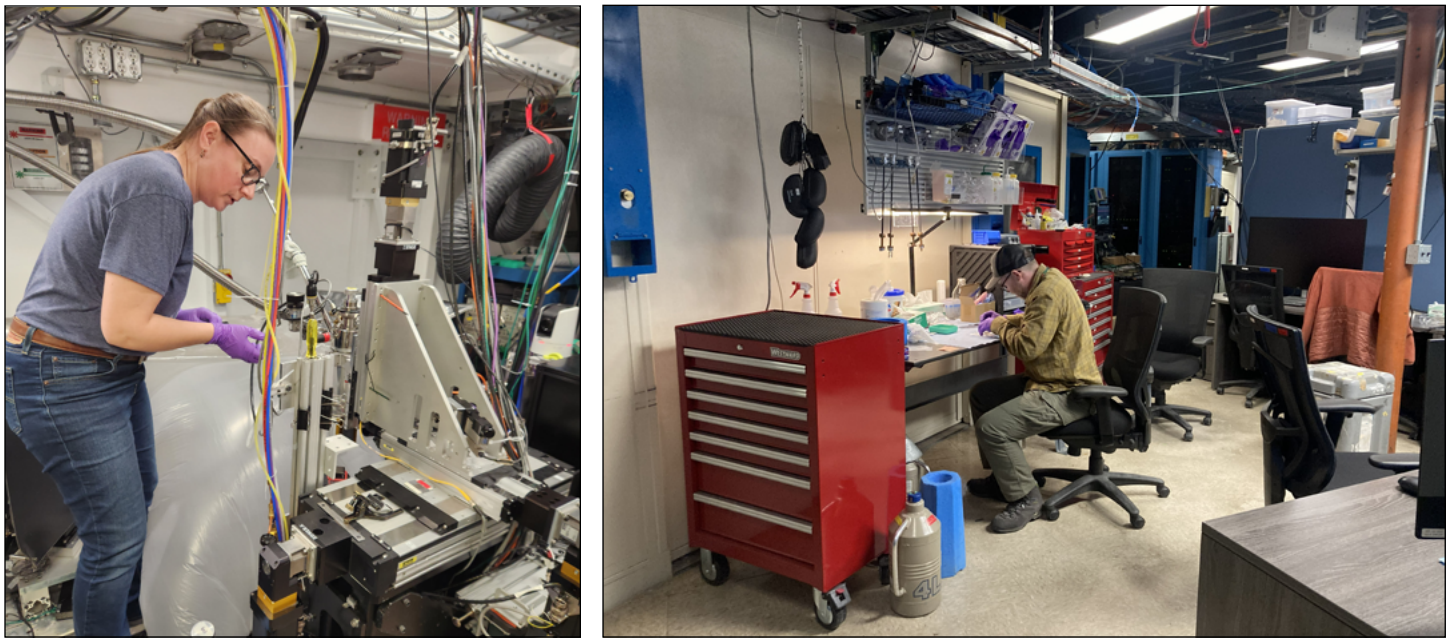

Figure 4. Celine Beaucamp (left) and Kyle Eastman (right) work with Anaconda Research Collection samples at the Stanford Synchrotron Radiation Lightsource. This work helps understand how critical elements are incorporated into the atomic structure of the mineral sphalerite.

Summary and Future Plans

The MBMG's Data Preservation and Economic Geology programs will continue to align their efforts to preserve, integrate, and apply both historic and newly acquired geologic data in support of critical minerals research. By integrating these datasets, the MBMG provides the essential baseline data required to advance our understanding of Montana's critical minerals potential. Future priorities include reducing scanning and metadata backlogs, finalizing the interactive geospatial discovery tool, and expanding our digital archive to include records and physical objects that support Earth MRI research. Continued institutional support and funding will be essential to sustain and grow these collections for future research. Ultimately, these projects demonstrate that archival preservation is an investment in future critical minerals exploration.

References

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MBMG—Data Preservation

mbmg.mtech.edu

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.