Technical Overview of the U.S. Geological Survey Earth Mapping Resources Initiative (Earth MRI)

The Earth Mapping Resources Initiative (Earth MRI) was developed by the U.S. Geological Survey (USGS) in response to a Federal directive calling on various Federal agencies to address potential vulnerabilities in the Nation's supply of critical mineral resources. The primary purpose of this initiative is to identify potentially mineralized areas containing critical minerals by gathering new basic geologic data about the United States and its territories and to make these data publicly available through the Earth MRI web portal (https://usgs.gov/earthmri). The gathering of data is accomplished through geophysical surveys, geologic mapping, and the collection of topographical (light detection and ranging, or lidar) data. In addition to identifying areas permissive for hosting critical minerals, the new data collected are likely to be helpful in addressing other societal needs as well, such as by helping to locate groundwater resources, providing information needed to mitigate effects of natural hazards, and identifying locations of the mineral resources useful for restoring and rebuilding aging infrastructure in the United States.

Background

On December 20, 2017, the President of the United States issued Executive Order 13817, which directed several Federal agencies, including the USGS, to develop "a Federal strategy to ensure secure and reliable supplies of critical minerals" (Trump, 2017). On December 21, 2017, this executive order was followed up by the U.S. Department of the Interior's Secretarial Order 3359 directing the USGS to develop a plan "to improve the topographic, geological, and geophysical mapping of the United States and make the resulting data and metadata electronically accessible to support private-sector mineral exploration of critical minerals" (Secretary of the Interior, 2017). A list of critical minerals as defined by Executive Order 13817 was prepared by the USGS in conjunction with several other Federal agencies and published in the Federal Register on May 18, 2018. As stated in the Federal Register notice, "this list of critical minerals, while "final," is not a permanent list, but will be dynamic and updated periodically to reflect current data on supply, demand, and concentration of production, as well as current policy priorities. This final list will serve as the Department of Commerce's initial focus as it develops its report to comply with Section 4 of Executive Order 13817" (Secretary of the Interior, 2018). Earth MRI is an outgrowth of Secretarial Order 3359 and of a larger Department of Commerce report titled "A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals" that was released on June 4, 2019 (U.S. Department of Commerce, 2019).

What Is Earth MRI?

The Earth MRI is a national mapping and data collection effort being conducted across all 50 States and U.S. territories. The USGS is working in partnership with the State Geological Surveys to improve knowledge of the geologic framework of the United States and identify areas that may have the potential to contain undiscovered critical mineral resources. The USGS is supporting geophysical surveys, geologic mapping, and high-quality lidar data acquisitions in regions across the Nation that have the potential for hosting critical mineral resources. An overview of the Earth MRI effort can be found at https://usgs.gov/earthmri.

Enhancement of the U.S. domestic mineral supply will decrease U.S. reliance on foreign sources of minerals, especially those that are fundamental to the security and economy of the United States. Locating domestic supplies of these minerals will make the U.S. economy less vulnerable to supply disruptions.

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."—Executive Order 13817

In addition, the new knowledge gained about the fundamental geologic underpinnings of the United States can be applied towards solving other problems. For instance, the new mapping of geologic bedrock provides an essential tool for understanding the local geologic setting, which can provide information on groundwater, geothermal, and petroleum resources, and will help mitigate effects of natural hazards, such as landslides and flooding. Better and expanded geologic maps will also identify areas with potential for containing materials, such as sand and gravel, that are needed for repairing deteriorating infrastructure.

What Data Does Earth MRI Collect?

Earth MRI collects data through three main methods: airborne geophysical surveys (fig. 1), geologic mapping, and the collection of topographic (lidar) data. Figures 2, 3, and 4 illustrate the extent of the data that are currently available publicly and at an appropriate scale and sufficient quality to support identification of areas of possible mineral potential.

Figure 1. Photographs of typical survey aircraft. *A*, A helicopter with a mounted magnetometer is used to survey areas of rugged terrain. In this case, the "stinger," which holds the magnetometer, is mounted in the front of the helicopter. Photograph by Benjamin Drenth, U.S. Geological Survey. *B*, A small airplane is used to survey areas of relatively flat terrain. Here, the stinger containing the magnetometer is mounted on the tail of the airplane. Photograph courtesy of EON Geosciences Inc.; used with permission.

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Geophysical Surveys

The new geophysical data are being acquired primarily through airborne magnetic ("aeromagnetic") surveys as well as airborne radiometric surveys, where appropriate. These geophysical methods have been routinely used worldwide for many decades as cost-effective tools to aid in mapping geologic units and structures (such as geologic faults). To collect these geophysical data, the USGS contracts with professional services, operating small aircraft from local municipal airports, that are experienced in flying these kinds of surveys.

Aeromagnetic Surveys

The effectiveness of aeromagnetic surveys is based upon natural variations of the magnetic properties of earth materials. The surveys are conducted by helicopter over rugged terrain, whereas airplanes are used when the terrain is relatively flat (fig. 1). A sensor on the aircraft detects slight disturbances (or anomalies) in the intensity of Earth's natural magnetic field caused by the variable magnetic properties of nearby soil and rocks, as well as of deeper materials. With modern magnetometers, the anomalies can be measured from the ground or the air, normally at altitudes of approximately 300 to 500 feet (90 to 150 meters). Earth MRI is using aeromagnetic surveys because they are much more cost-effective than ground magnetic surveys in that they cover larger areas, are less obtrusive, and allow for uniform coverage.

Data from aeromagnetic surveys are normally presented on a map that shows the spatial variations of the Earth's magnetic field intensity. Geophysicists who specialize in magnetic interpretation use a series of tools to convert these maps into geologic models that are constructed using the available knowledge of the local geology and the magnetic data as guides. The models can be either two-dimensional or three-dimensional and presented as cross sections or as full three-dimensional representations of the buried rocks.

The magnetic method is entirely passive; that is, no energy is transmitted by the sensors. Only the intensity of the Earth's natural magnetic field is being measured.

Airborne Radiometric Surveys

Airborne radiometric surveys detect and map natural radioactive emanations (gamma rays) from rocks and soils. The gamma radiation is generated by the natural decay of radioactive elements, including the most common ones—potassium, thorium, and uranium. Radiometric surveys are tuned to detect the radiation at the sensor in the air from these three naturally occurring elements present at the ground surface. Airborne radiometric data are used to help identify mineral types at the surface that include these elements in their structures.

For instance, potassium feldspar is a common mineral that occurs in granites and rhyolites yet is very uncommon in rocks like basalt. Knowing that an area is relatively enriched in potassium (based on the results of the radiometric survey) and that the local geology includes known granite outcroppings containing potassium feldspar allows a mapping geologist to infer the granitic rock boundary in areas of poor outcrop or obscured by vegetative cover.

A second example might involve finding potassium in a different way. Potassium is commonly enriched in areas that have been altered by hydrothermal (hot water) solutions producing desirable mineral deposits. Knowing that an area has been altered hydrothermally (based on the presence of high levels of potassium as measured by the radiometric survey) and knowledge of the local geology allows a geologist to map areas possibly associated with mineral deposits.

Earth MRI airborne surveys often include radiometric surveys. These surveys help better define the regional geology, including outlining potential faults that may not be detected with ground-based geologic mapping.

Radiometric surveys are entirely passive; that is, no radiation is generated by the survey. Only naturally occurring radiation from the earth is being measured. The data are collected from the aircraft flying at about 300 to 500 feet (90 to 150 meters) or higher above the ground surface. Radiometric data are typically collected simultaneously with aeromagnetic data.

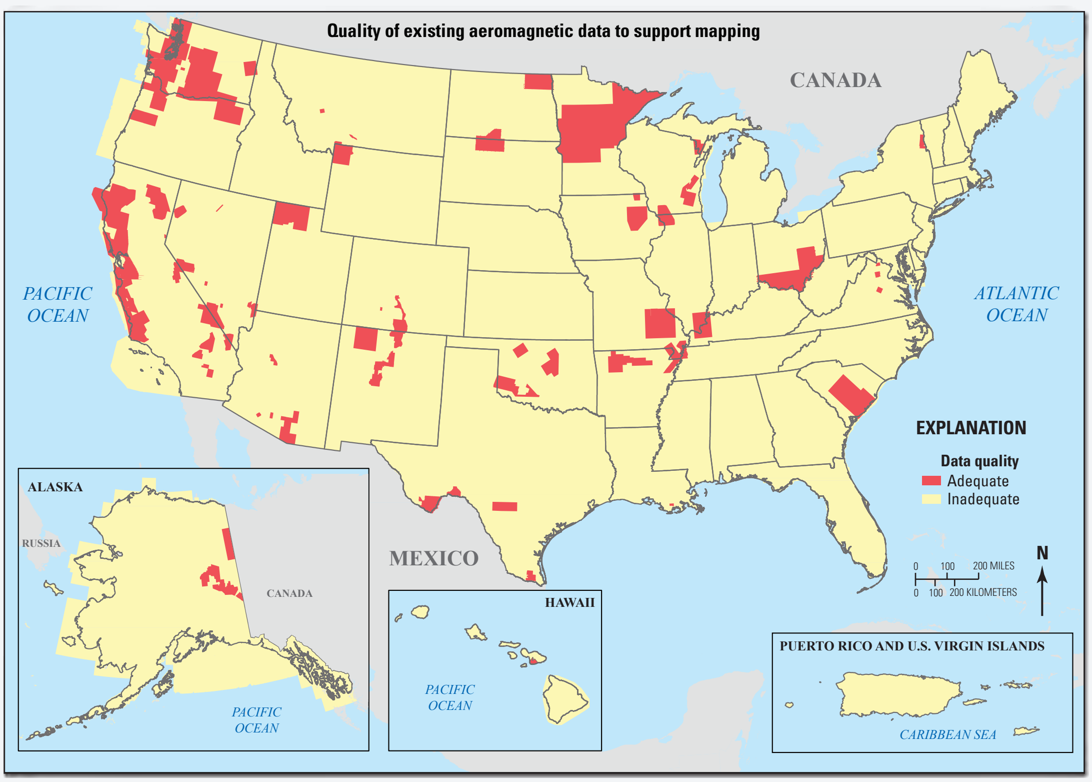

Figure 2. Illustration showing the quality of available aeromagnetic mapping data of the United States as of April 2020. The entire country has some level of aeromagnetic coverage; however, most of the surveys have older data of poor quality or the surveys were not designed adequately for use in determining the local geologic setting or addressing other societal needs, such as groundwater modeling. Only the areas shown in red have public data at resolutions sufficiently detailed to support subsurface mapping and three-dimensional geologic mapping. The data for this map are available from the National Geologic Map Database at https://ngmdb.usgs.gov/ and from https://cse.umn.edu/mgs (for Minnesota data) and https://dggs.alaska.gov/ (for Alaska data).

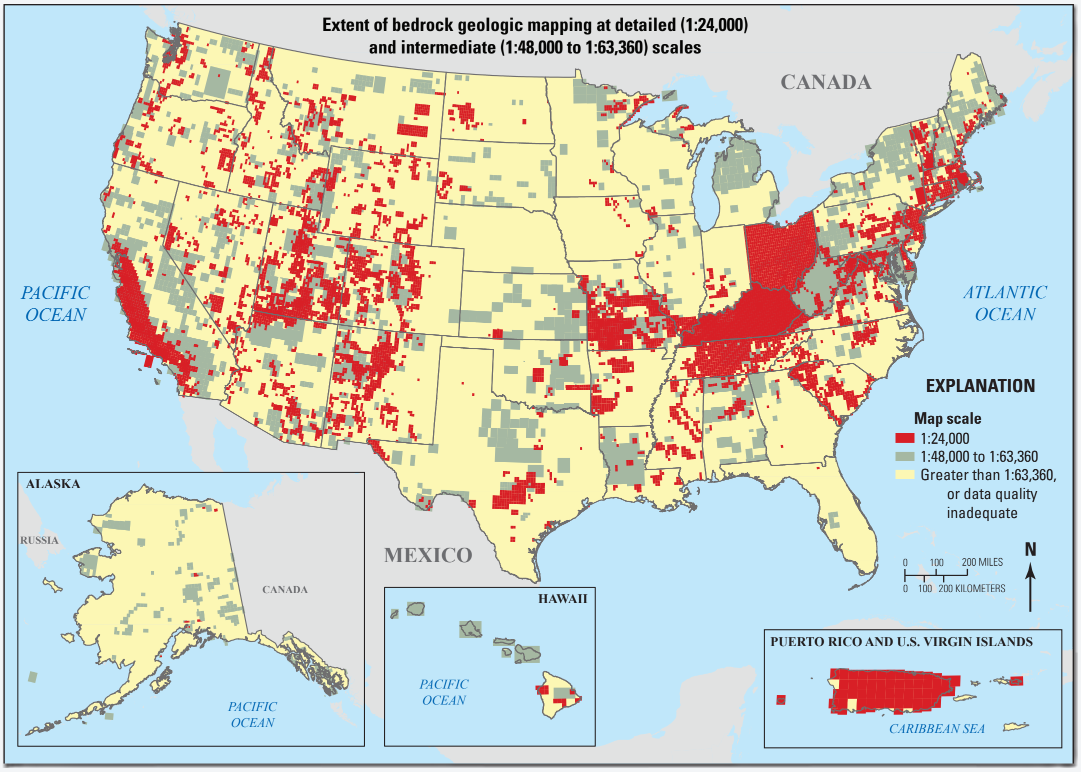

Figure 3. Map showing the current extent of bedrock geologic mapping in the United States at both detailed (1:24,000) and intermediate (from 1:48,000 to 1:63,360) scales that are useful for defining the local geologic setting to assess critical mineral potential. Data are current as of February 2020. Nearly all the mapping was conducted by the U.S. Geological Survey and the State Geological Surveys. Areas shown in yellow have geologic mapping that are at scales insufficient to support detailed assessments for critical mineral potential. The data for this map are available from the National Geologic Map Database at https://ngmdb.usgs.gov. (Source: U.S. Geological Survey National Cooperative Geologic Mapping Program)

Geologic Mapping

The new surficial and bedrock geologic mapping funded by the USGS is carried out largely by State Geological Surveys and (or) academic institutions. Geologic mapping requires fieldwork, including examining outcrops; identifying structural features, such as faults and folds; and collecting rock samples for chemical analysis and age dating. These data are integrated into a two-dimensional geologic map or three-dimensional block diagram that identifies rock units and characterizes the nature of the bedrock and surficial materials.

As part of characterizing the geologic rock units, the USGS is providing geochemical analyses of rock samples using USGS and commercial laboratories. In addition, the USGS is developing a database of drill-hole information in collaboration with the State Geological Surveys. The drill-hole information is typically housed with State agencies. The USGS's goal is to help the States better archive their information and eventually make it publicly available through the Earth MRI website.

Surface Elevation Data

The collection of elevation data in the form of lidar data is being done through the 3D Elevation Program (3DEP). This program aims to complete the acquisition of nationwide lidar data (or interferometric synthetic aperture radar [IfSAR] data in Alaska) by 2023. In doing so, it will provide the first-ever national baseline of consistent high-resolution elevation data, providing both "bare earth" and three-dimensional point cloud data. 3DEP works in partnership with Federal, State, and Tribal agencies and other partners to collect elevation data systematically over the conterminous United States, Alaska, Hawaii, and the U.S. territories. The data collection is conducted by contractors in the private sector. Earth MRI is providing supplemental funding to 3DEP to acquire lidar data for specific priority areas where such data do not already exist.

Lidar data for the 3DEP are collected at high altitude from a fixed-wing aircraft using an instrument that sends a pulsed beam of light toward the ground. Reflections of this light beam from ground surfaces, vegetation, buildings, and other reflective surfaces are detected and collected by a sensor, forming a point cloud that is used to develop precise three-dimensional maps of the Earth's surface as well as digital elevation models (DEMs) of the bare earth surface. These data offer a precise depiction of the Earth's surface, unobscured by vegetation, but cannot detect any information below the ground surface. Lidar data are critical for—

- Mapping young deposits and landforms, which are those most essential to understanding Earth resources.
- Underpinning the geologic mapping that guides the assessments and development of natural solid-earth resources—including mineral, energy, and groundwater resources.
- Supporting site-specific engineering studies by the geotechnical industry.
- Improving the efficiency of geologic mapping, dramatically improving the spatial precision of geologic maps, and increasing the number of geologic units that can be mapped (in some cases doubling them).

Data collected through 3DEP are publicly available, free of charge, and without use restrictions. The USGS makes these data available through The National Map website at https://nationalmap.gov.

How Are the Data and Information Products Made Available?

The fundamental data collected through Earth MRI can be accessed through a dedicated Earth MRI website (https://usgs.gov/earthmri). These data include aeromagnetic data as well as interpretative maps, new surficial and bedrock geologic maps, and lidar data. Interpretative products will be published by the States and the USGS and linked through the Earth MRI website. The Earth MRI website also provides ready access to historical geologic data currently maintained by the USGS. All the data collected through Earth MRI are made publicly available, free of charge, and without use restrictions.

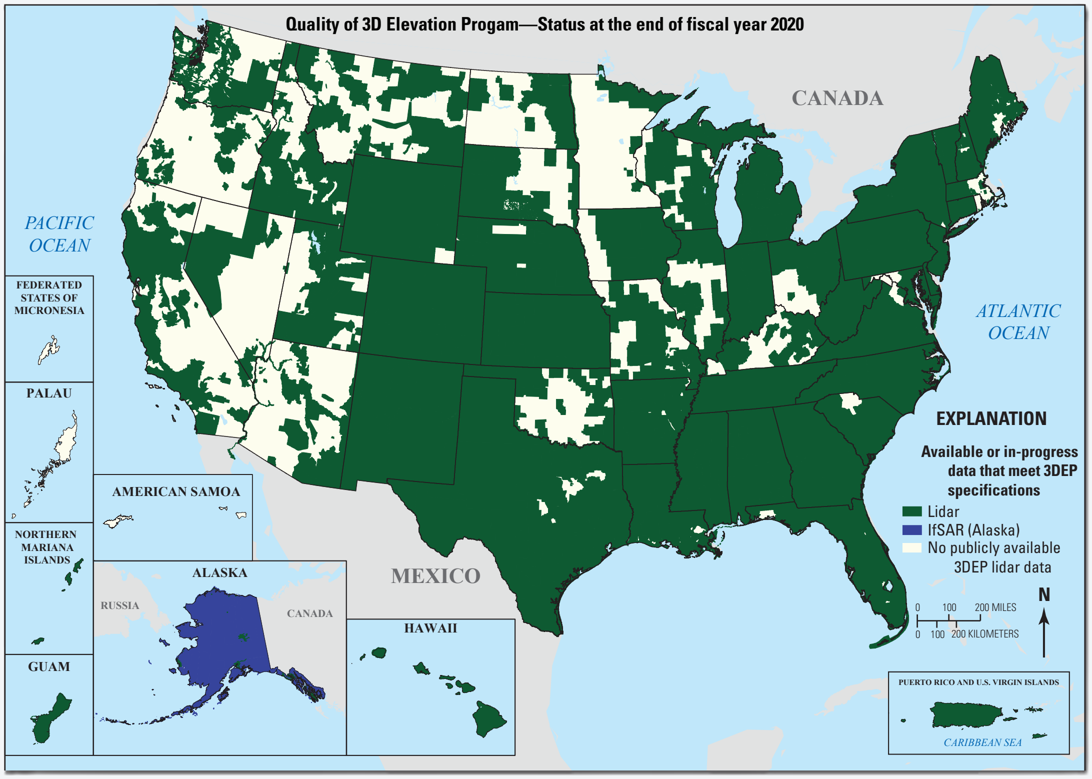

Figure 4. Map showing the extent of planned, in progress, and publicly available topographic (or lidar; ifSAR in Alaska) mapping in the United States at the resolution of the 3D Elevation Program (3DEP) as of September 2020. Areas shaded dark green have sufficiently detailed topographic mapping to support geologic mapping of potential mineral resources and other societal needs, such as groundwater modeling. (Source: U.S. Geological Survey 3D Elevation Program) ifSAR, interferometric synthetic aperture radar; lidar, light detection and ranging

How Will the Data Be Used?

The fundamental data collected through Earth MRI will be used to study the geologic structure and framework of the Nation, to understand the conditions under which critical minerals may be concentrated into deposits, and to develop more detailed elevation models. Because these are fundamental data, they can also be used to characterize groundwater resources; to recognize and mitigate potential natural hazards, such as landslides, flooding, and earthquakes; and to identify materials needed for improvement and restoration of infrastructure, such as roads, bridges, and rail lines. For example, a new aeromagnetic survey being flown over the Charleston, South Carolina, area to better understand the regional geology and mineral potential is also helping to define earthquake-generating faults that are buried beneath a cover of sedimentary rocks and soils. Additionally, some data can be used to identify and describe manmade changes, including archaeological and cultural sites. The Earth MRI data are likely to be used by a wide variety of groups, including Federal, State, and Tribal governments, private industry, academia, and the public at large.

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Useful Links

Earth Mapping Resources Initiative
https://usgs.gov/earthmri

The National Map
https://nationalmap.gov

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Caption for banner, top of page 1: View looking south at the Alaska Range, east-central Alaska. Photograph by W. Day, U.S. Geological Survey.

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