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Optimizing the USGS Mineral Resources Program Science Portfolio Consensus Study Kick-off

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Colin Williams, Darcy McPhee, Tanya Gallegos, and Moji KunleDare
USGS Mineral Resources Program

U.S. Department of the Interior
U.S. Geological Survey

27 March 2024, National Academies of Science, Engineering, and Medicine

Who We Are

Sarah Ryker, USGS Associate Director for Energy and Mineral Resources

Colin Williams, USGS Mineral Resources Program Coordinator

Darcy McPhee, USGS Earth MRI Program Manager

Tanya Gallegos, USGS Mineral Resources Associate Program Coordinator

Moji KunleDare, USGS Mineral Resources Associate Program Coordinator

Outline

- Mineral Resources Program: Accomplishments and Opportunities
- Statement of task and Motivation for the Study
- Brief introduction to the USGS, the Energy and Mineral Resources Mission Area, and the Mineral Resources Program
- Our role in the Department of the Interior and the broader Federal minerals enterprise
- Budget, portfolio, and how things work
- Questions and discussion

-- Break –

- Mineral information, supply chain studies, and mineral criticality
- Mineral system and deposit research
- Mineral resource assessments
- Mine waste studies
- Earth Mapping Resources Initiative
- Questions and discussion

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The USGS Mineral Resources Program: Accomplishments and Opportunities

Sarah Ryker

U.S. Department of the Interior
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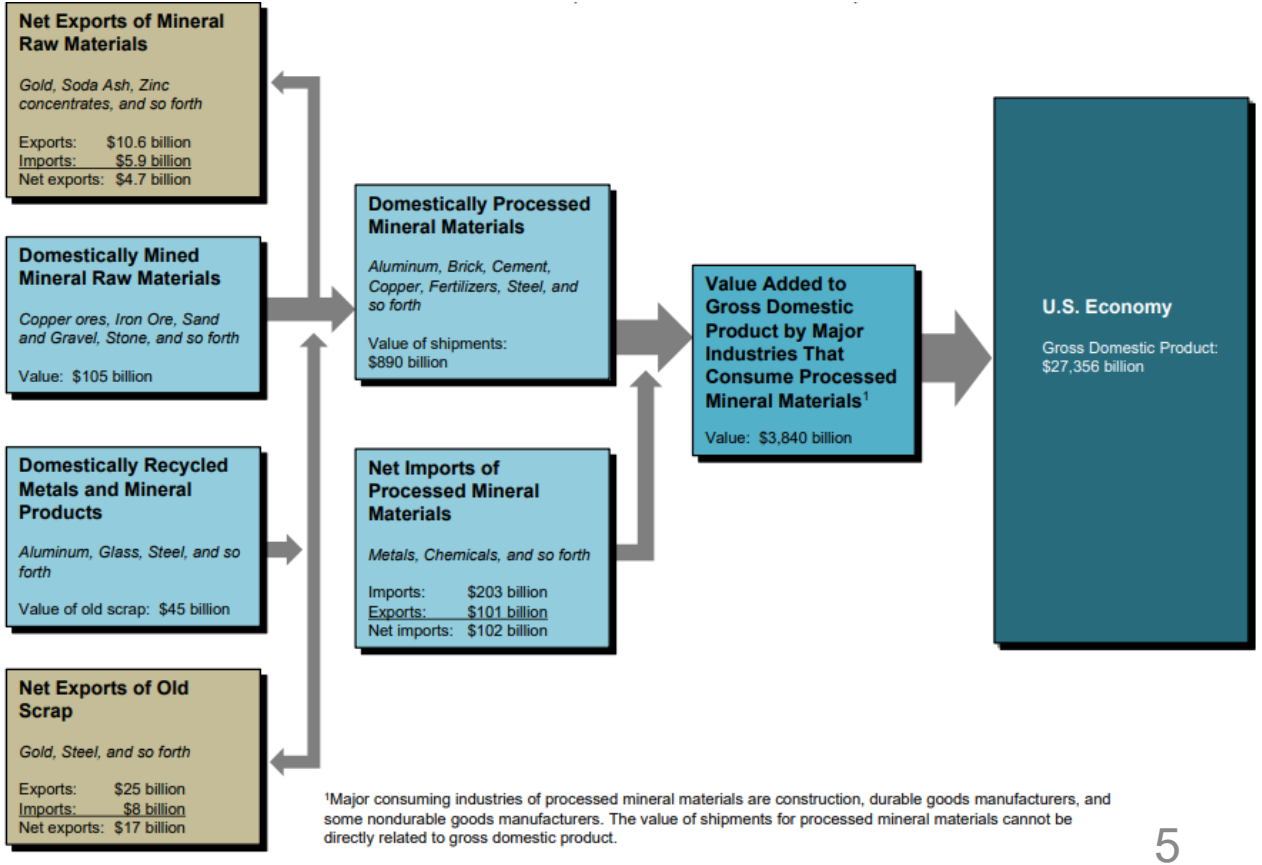
Non-Fuel Mineral Commodities in the U.S. Economy
(ESTIMATED VALUES IN 2023)

- U.S. mineral production contributed more than $105B to the U.S. economy in 2023, a $4B increase over 2022.
- Industries that use nonfuel mineral materials—such as steel, aerospace and electronics—contributed $3.84T to the U.S. economy in 2023, a 6% increase from $3.62T in 2022.

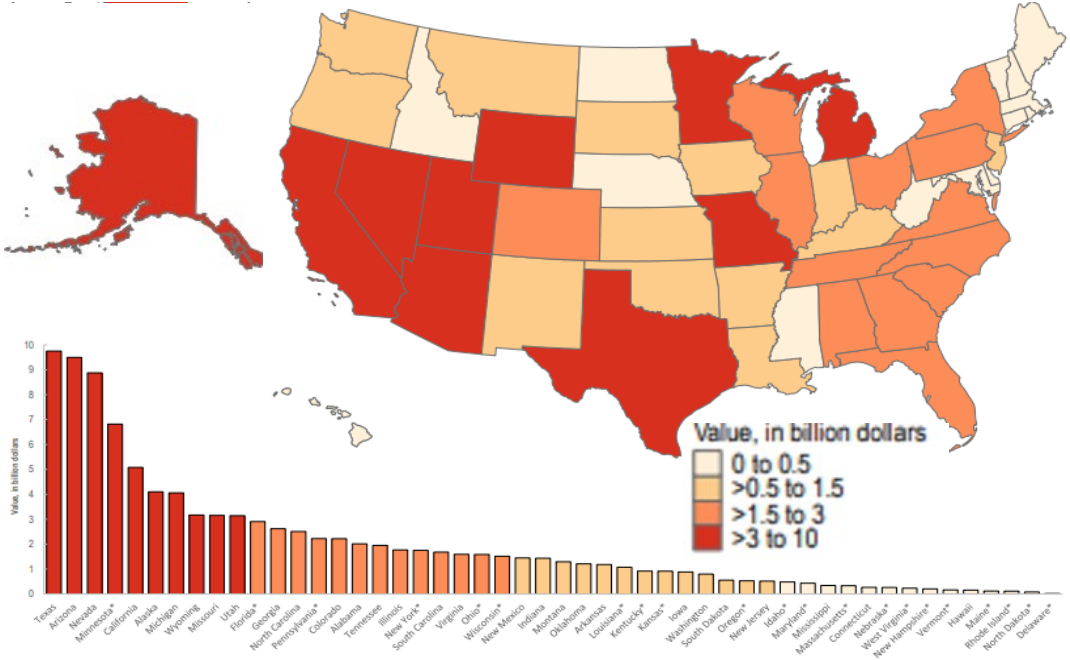


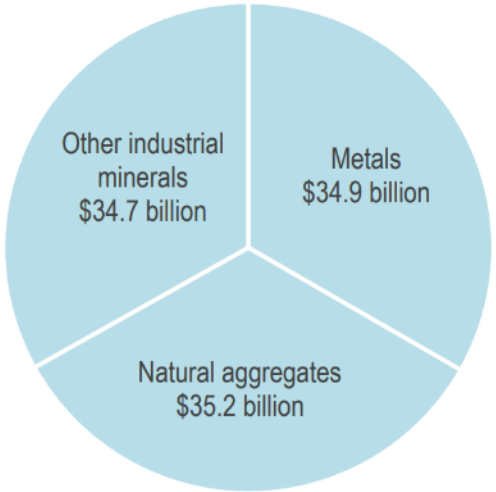
[1]Major consuming industries of processed mineral materials are construction, durable goods manufacturers, and some nondurable goods manufacturers. The value of shipments for processed mineral materials cannot be directly related to gross domestic product.

U.S. Geological Survey, 2024, Mineral commodity summaries 2024: U.S. Geological Survey, 212 p., https://doi.org/10.3133/mcs2024

State Mineral Economies
(Production only)

Value of Nonfuel Mineral Commodities Produced in 2023, by State



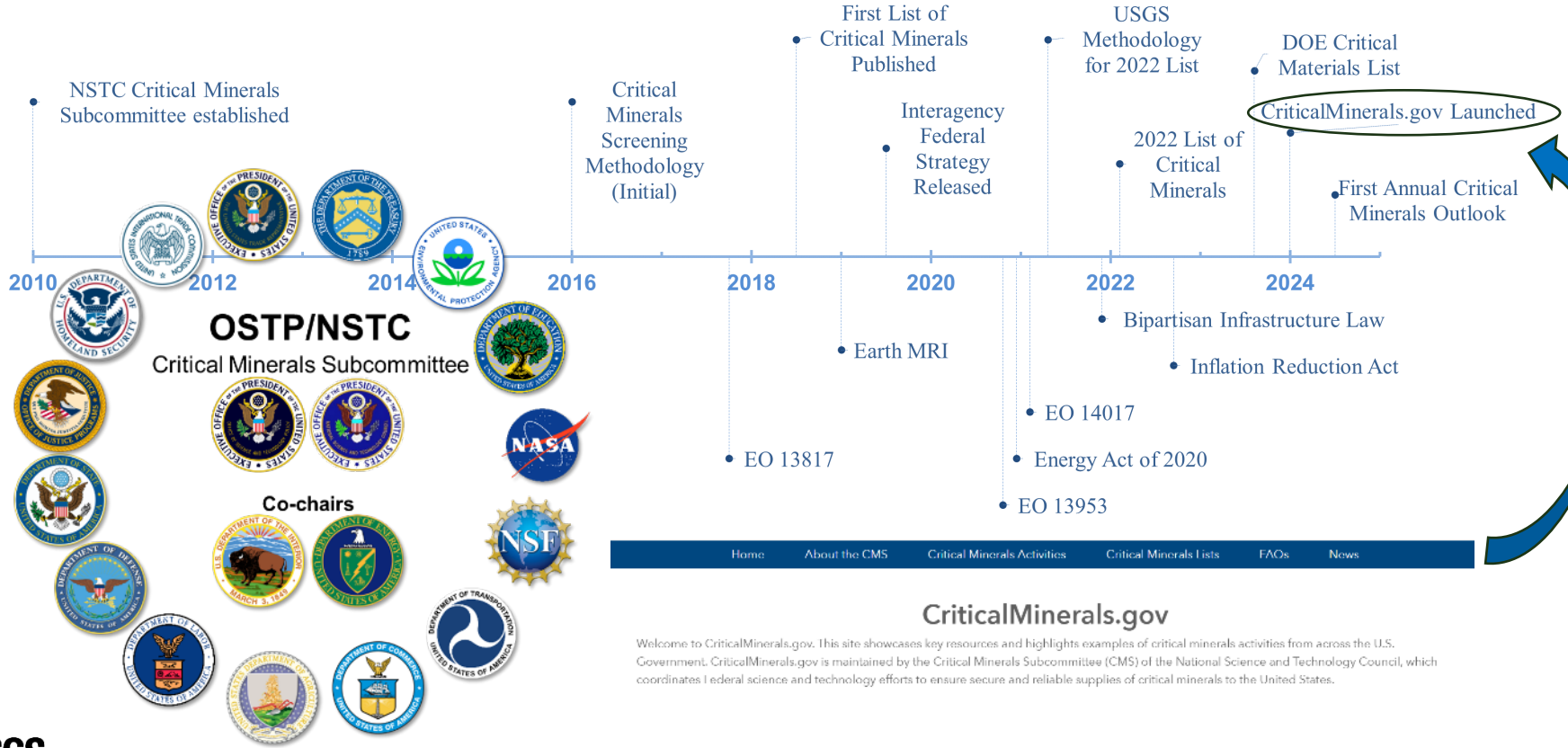


U.S. total: $105 billion

U.S. Geological Survey, 2024, Mineral commodity summaries 2024: U.S. Geological Survey, 212 p., https://doi.org/10.3133/mcs2024

A Leadership Role for the Federal Government on Critical Minerals - History and Timing

List of Critical Minerals



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Earth MRI: State Geological Survey & Bipartisan Infrastructure Law Success Stories

Regional effects

- Support to State Surveys: Funding
  - Federal & state
- Support to State Surveys: Data
- Rebuilding regional geoscience communities
  - Within states & across state lines
- Nucleating larger research, funding, and partnerships for an issue/region

Strengthening geoscience

- Strengthening STEM pipelines
- Reconnecting disciplines
- Transferring knowledge across generations of geoscientists
  - Data rescue, workshops, synthesis

Transforming the nation's evidence base for resource management

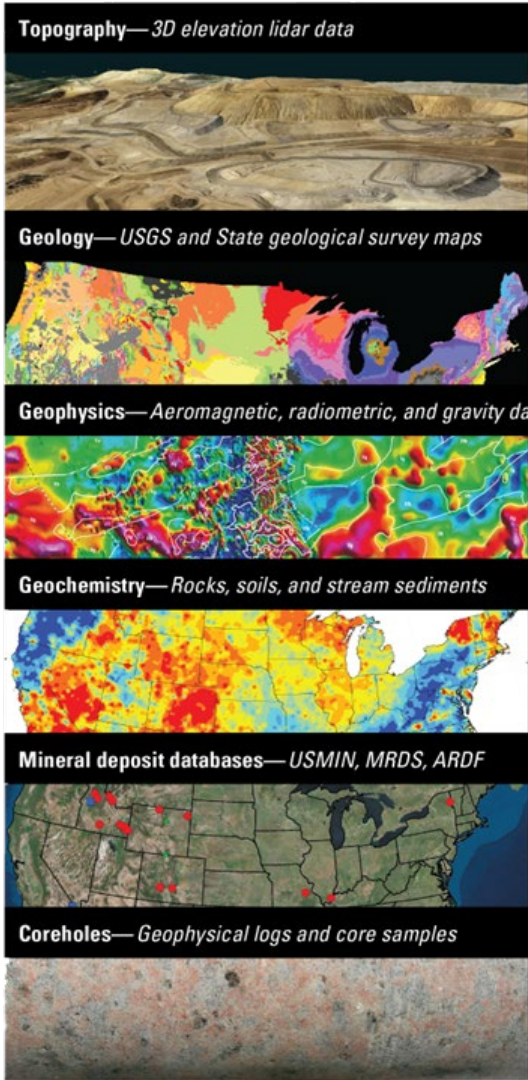
- Products for decision-makers: Inventory (e.g. where is all the mine waste?), assessment, mapping, sustainability/suitability/mitigability questions
- "Total resource" approach (above and below ground)

Strengthening diminished American industries

- Geophysical surveying
- Mining
- Waste management

Economic futures

- Inform federal & private-sector supply chain planning
- Inform state economic futures



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Roles for the USGS Mineral Resources Program

- Decision Support
- Innovation
- Sustainability
- Flagship Products and Data

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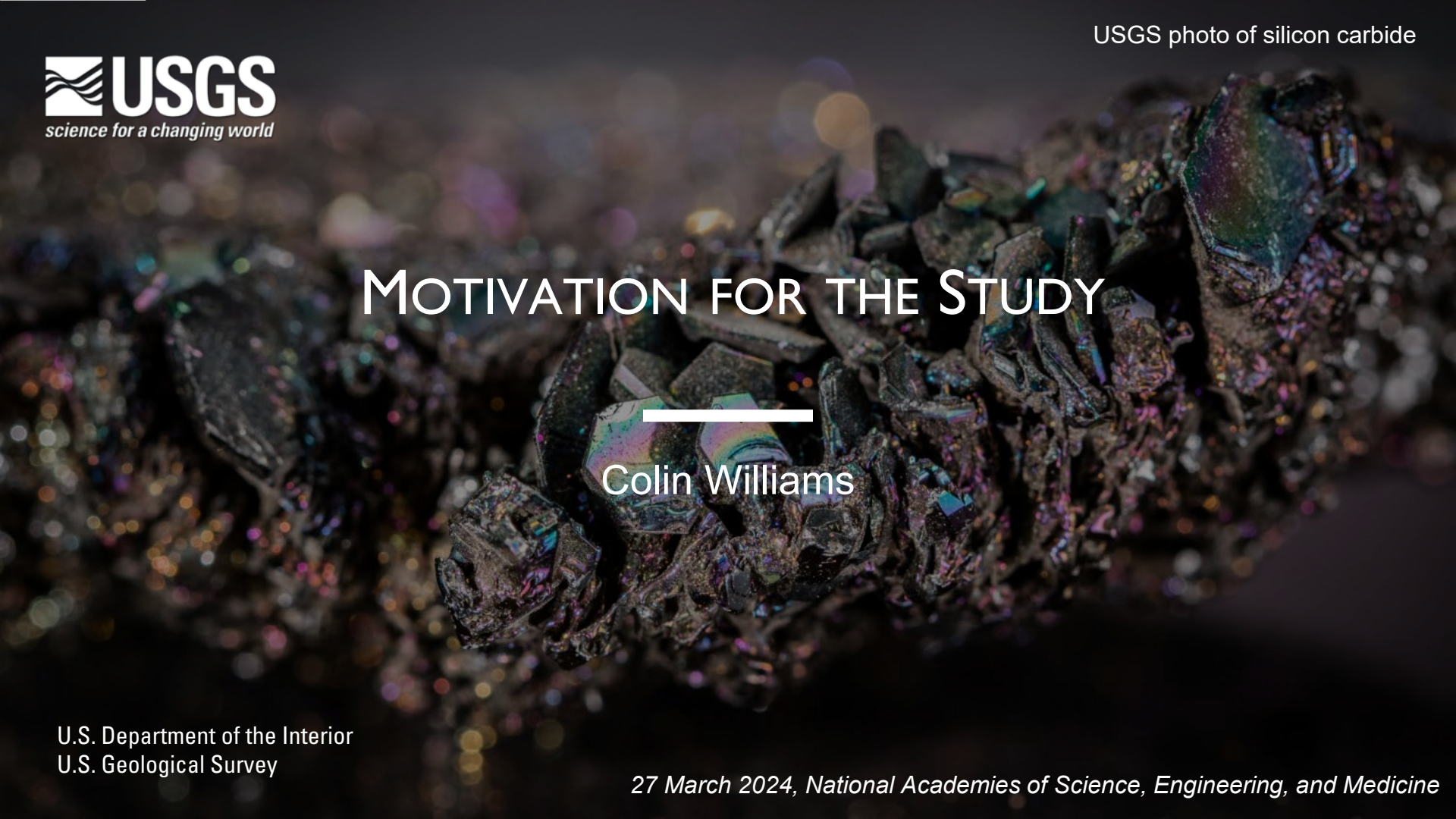

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Motivation for the Study

Colin Williams

U.S. Department of the Interior
U.S. Geological Survey

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Statement of Task

The National Academies of Sciences, Engineering, and Medicine will convene an ad hoc committee of experts to consider the USGS Mineral Resources Program (MRP) science portfolio (including mineral resource life cycle and supply chain research, data collection through its Earth Mapping Resources Initiative, and products) and how well it meets current and future U.S. mineral resources needs. The committee will:

- Assess the alignment of MRP's research and products with current needs of federal and non-federal MRP partners and stakeholders, including other USGS mission areas, federal agencies, tribes, and domestic and international partners;
- **Identify gaps** in the science portfolio that may preclude meeting those partner and stakeholder needs at present and in the future;
- Summarize the greatest **challenges to meeting U.S. mineral resource needs** over the next decade and recommend:
    - **Ways that MRP's science portfolio, expertise, and role should evolve** to address those challenges and the needs of its present and future partners and stakeholders, and
    - How MRP can **leverage its partners and stakeholders** to better inform decisions related to mineral resource challenges expected in the next decade.

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Motivation for the Study

Why are we asking for this study?

In the past decade the MRP portfolio has evolved dramatically, reflecting the rapid and profound changes in the global and domestic mineral resource community, from science and technology to markets and geopolitics. Our partners at all levels of government, in academia, within NGOs, and in the private sector are engaging with the same changes and associated challenges.

In addition to transforming and advancing its portfolio, MRP has been developing plans for both the near- and longer-term. We believe this planning and prioritization work will benefit from a knowledgeable external perspective. Previous NASEM reviews, in 1996 and 2003, had a significant impact on MRP, but these are out of date.

We believe the perspective of this panel will help us prioritize and optimize the MRP portfolio so MRP can best fulfill its mission and lead the Nation in addressing the mineral resource challenges of today and tomorrow.

1996 and 2003 National Academies Reviews

Mineral Resources and Society: A Review of the U.S. Geological Survey's Mineral Resource Surveys Program Plan (1996)

- Review conducted at the time of the dissolution of the Bureau of Mines with the transfer of the minerals information function to USGS and significant budget cuts and an associated Reduction in Force in the USGS Geologic Division.
- Recommendations on:
  1. the program's vision, mission, and objectives;
  2. increased collaboration with users, balanced with independent research;
  3. maintaining and increasing core competence; and
  4. planning, prioritization, and performance.

Future Challenges for the U.S. Geological Survey's Mineral Resources Program (2003):

1. assess the USGS's response to the 1996 review of the MRSP plan;
2. evaluate the contributions of the minerals information functions in meeting the goals of the USGS and its partner agencies
3. characterize how the customer base for the program has changed since the 1996 review; and
4. examine how the program's vision and activities should evolve to meet the nation's future needs over the next decade.

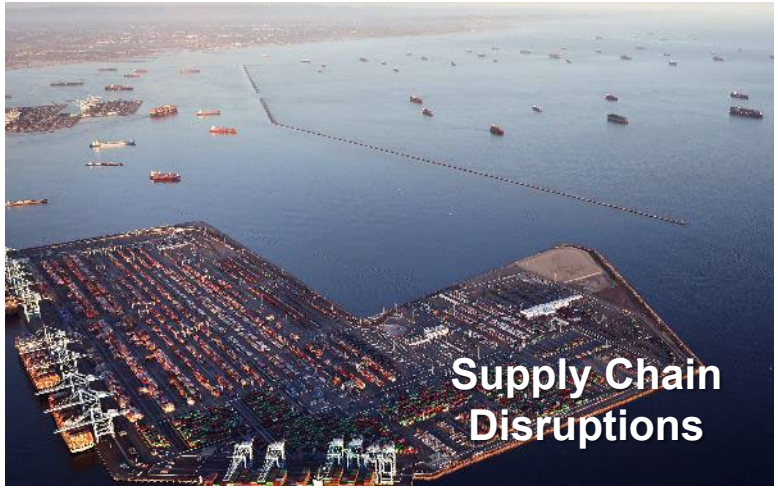
1996 and 2003 National Academies Reviews

But things have changed.

From the 2003 review: "There are no shortages of imported minerals available at prices at or below historical averages. There does not seem to be the level of concern about the acquisition of strategic materials as there was in the past, such as during World War II."

Geopolitical Challenges

Pressing Mineral Resource Issues



Energy Generation

49 In Indium

31 Ga Gallium

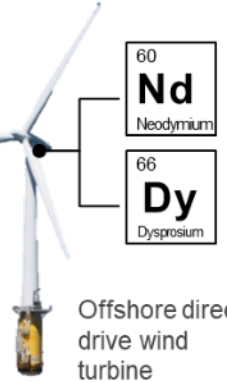
34 Se Seleniu m

Thin-film solar PV

Photo credit: Testbourne, Ltd.

60 Nd Neodymium

66 Dy Dysprosium



Offshore direct drive wind turbine

Photo credit: US DOE

Transportation

Electric and hybrid vehicles

3 Li Lithium

6 C Carbon

27 Co Cobalt

28 Ni Nickel

Photo credit: Telsa, Inc.

Non-Fuel Mineral Commodities in the U.S. Economy (estimated values in 2023)

- U.S. mineral production contributed more than $105B to the U.S. economy in 2023, a $4B increase over 2022.
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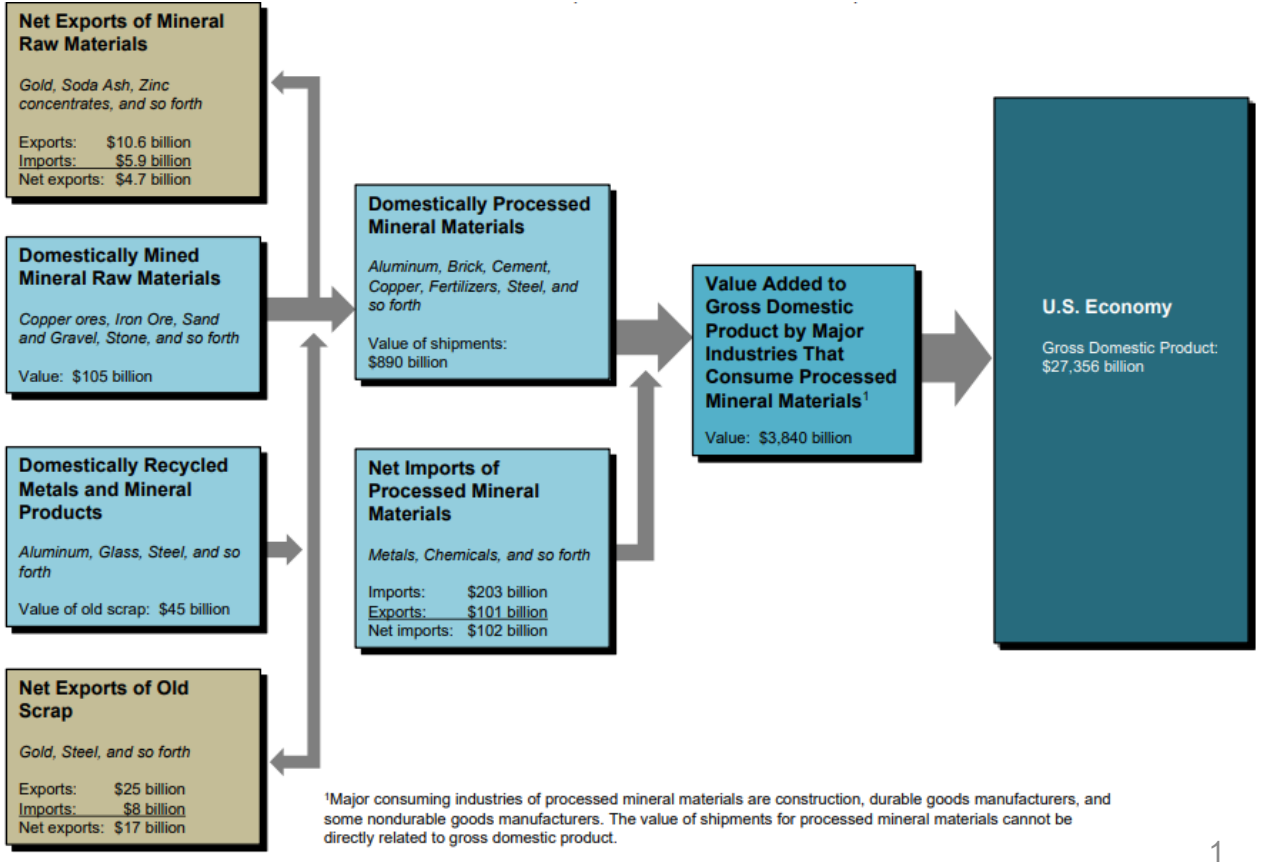

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State Mineral Economies
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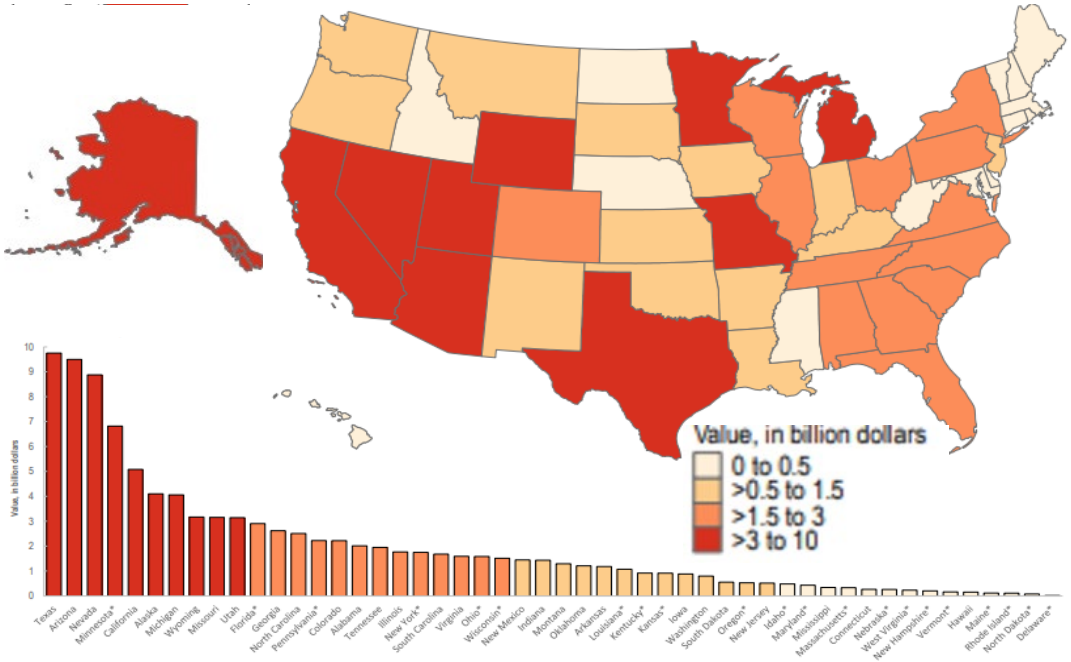

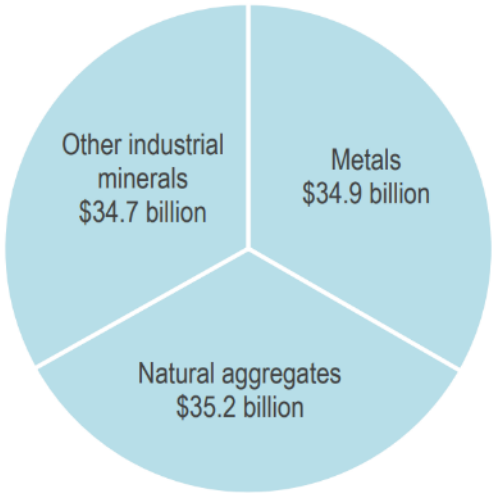

U.S. total: $105 billion

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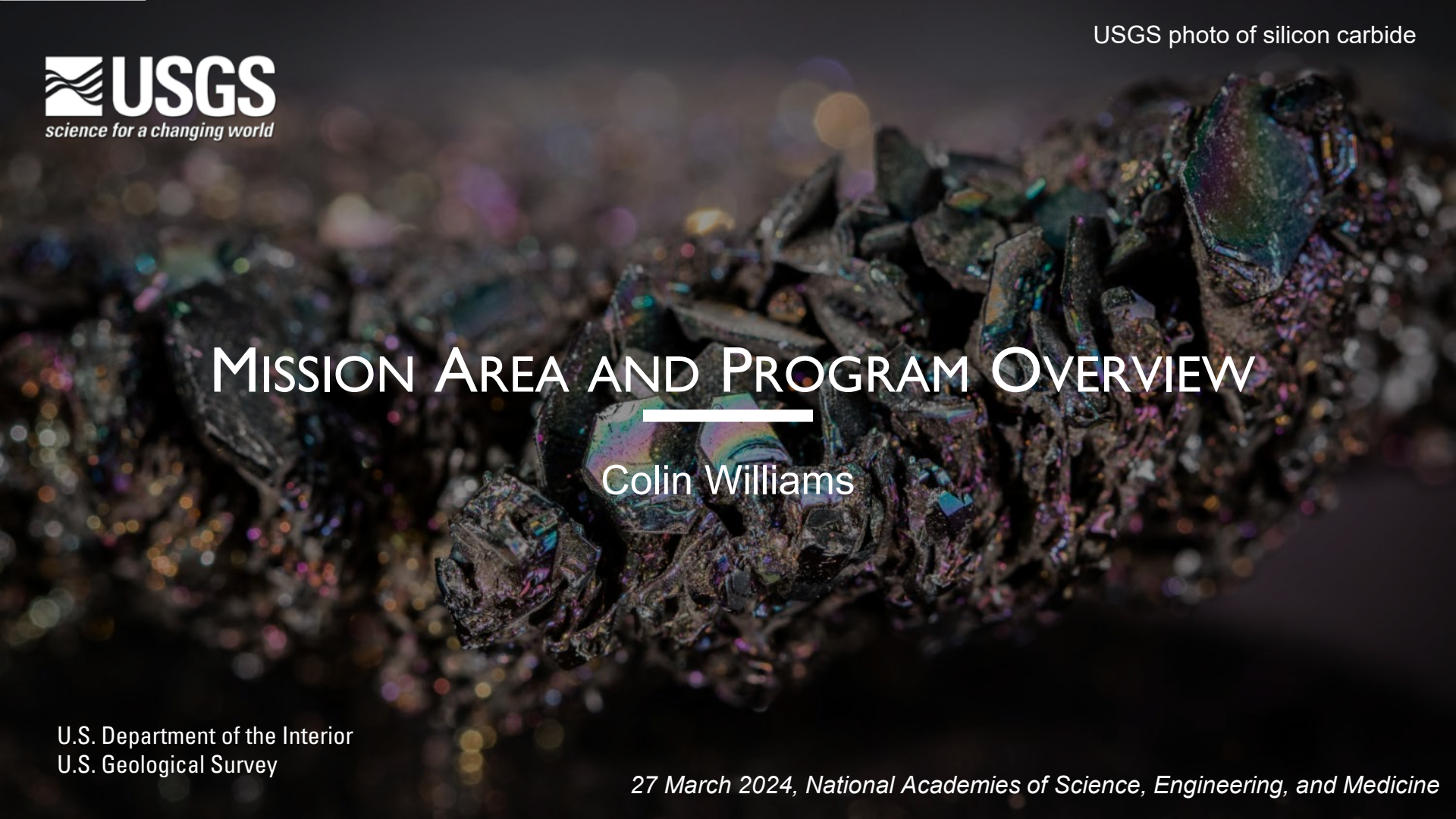
Looking Forward

This moment in time poses daunting challenges and extraordinary opportunities. How do we structure our portfolio to seize these opportunities and also structure a sustainable Program for long-term mineral resource needs?



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Mission Area and Program Overview

Colin Williams

U.S. Department of the Interior
U.S. Geological Survey

27 March 2024, National Academies of Science, Engineering, and Medicine

U.S. Department of the Interior

- Manages one-fifth of U.S. lands
- Provides water and electricity in the western U.S.
- Determines which species are endangered
- Manages vegetation (habitat, grazing rights, wildfire response)
- Provides access to outdoor recreation
- Protects and manages cultural heritage
- Has special responsibilities to Indigenous peoples

BOEM
Bureau of Ocean Energy Management

BSEE

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U.S. Geological Survey

The **USGS mission** is to monitor, analyze and predict current and evolving dynamics of complex human and natural Earth system interactions and to deliver actionable information at scales and timeframes relevant to decision makers.

Vision Statement: Lead the Nation in 21st-century integrated research, assessments, and prediction of natural resources and processes to meet society's needs.

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Energy and Mineral Resources Mission Area

- Energy Resources Program
- Mineral Resources Program

The USGS Energy and Mineral Resources Mission Area provides impartial science, supply chain analysis, and decision support informing

- Billions of dollars in investments by the private sector and federal government
- Resource management decisions by both federal and state land managers.

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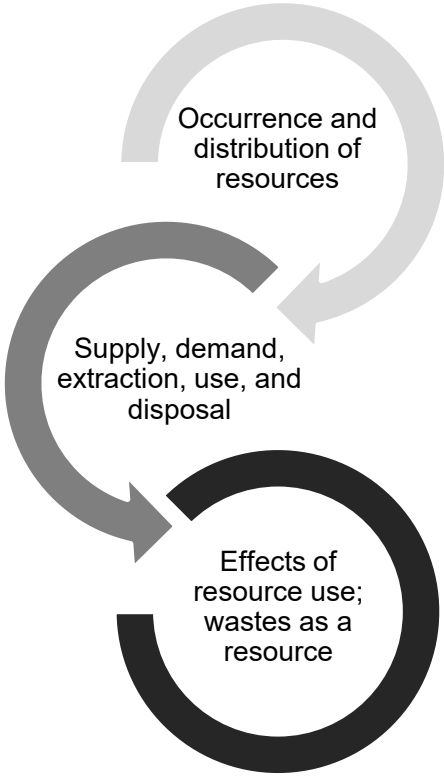
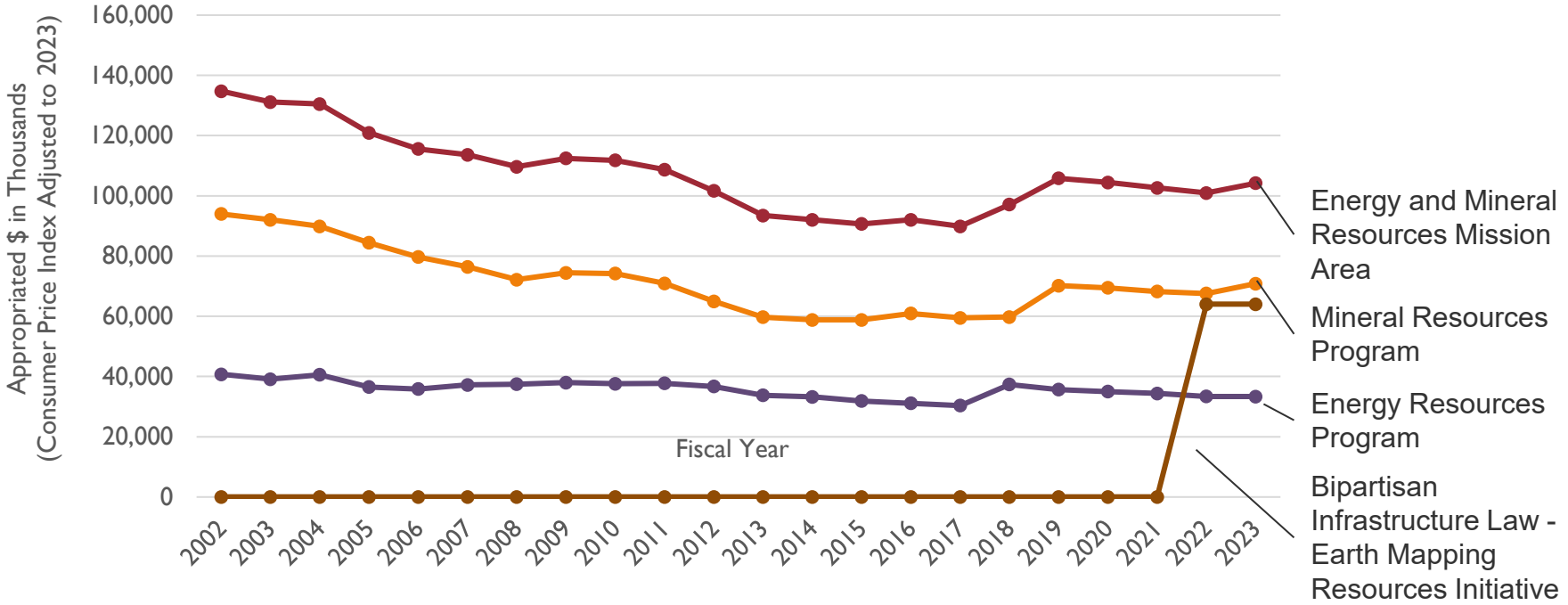
The Full Life Cycle of Resources



Energy Resources	Mineral Resources
Petroleum/hydrocarbons • Oil • Natural Gas • Gas Hydrates • Produced Waters • Coal Uranium Geothermal Energy gases • Carbon • Helium • Hydrogen Wind Solar	Major metals • Copper, zinc, molybdenum, gold, silver, and others Industrial minerals • Phosphate, sand, gravel, aggregate, and others Specialty minerals • Low-volume but highly specialized uses, e.g. the rare earth elements

Energy and Mineral Resources Appropriations History



On the Landscape: Centers and Laboratories

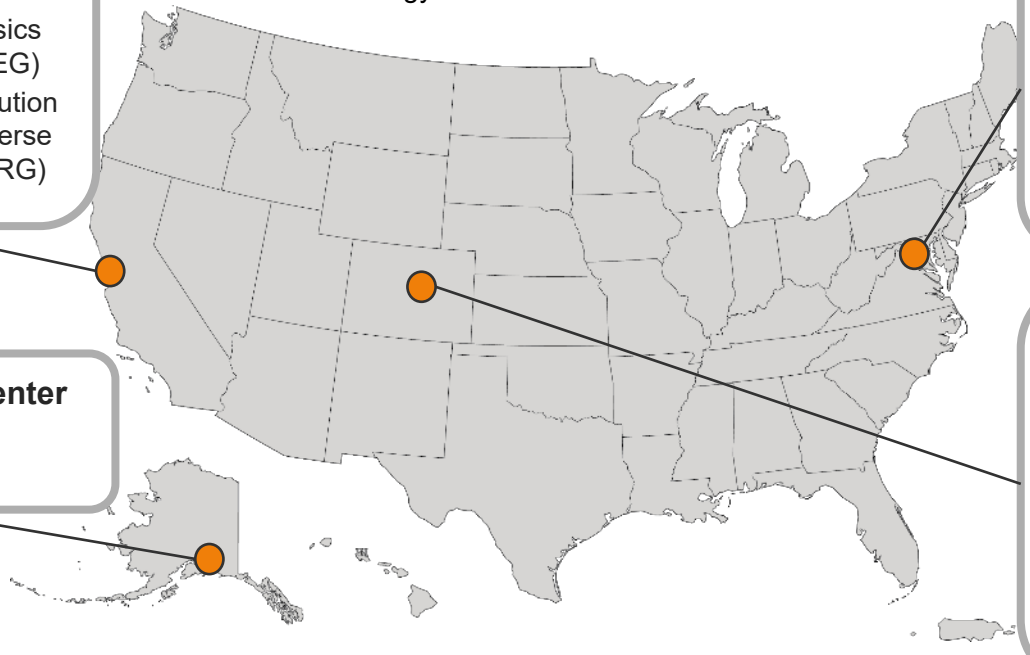
Moffett Field – Tucson – Reno - Spokane

- Geology, Minerals, Energy, and Geophysics Science Center (GMEG)
- Sensitive High-Resolution Ion Microprobe - Reverse Geometry (SHRIMP-RG) Lab at Stanford

Alaska Science Center

- Energy
- Minerals

Total Funded FTE (FY 2023)
Energy – 130 • Minerals - 300



Reston

- Geology, Energy, and Minerals Science Center (GEMSC)
- National Minerals Information Center (NMIC)
- Science and Decisions Center (SDC)

Denver

- Central Energy Research Science Center (CERSC) **(Will move to Energy and Minerals Research Facility)**
- Geology, Geophysics, and Geochemistry Science Center (GGGSC) **(Will move to Energy and Minerals Research Facility)**
- TRIGA Reactor

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Strengthening and Growing Partnerships

Primary Stakeholders & Partners

Federal

- DOI (BLM, BOEM, Office of Environmental Policy and Compliance, International Technical Assistance Program)
- Other agencies (Department of Energy, Department of Defense, Environmental Protection Agency, Department of Commerce, Intelligence Community, Department of State, USAID)

Interagency

- Cabinet-level Council on Supply Chain Resilience
- Interagency Policy Committee (IPC) on E.O. 14017 America's Supply Chains (National Economic Council-led)
- Interagency Policy Committee (IPC) on the Arctic Strategy (National Security Council-led)
- National Science and Technology Council (Office of Science and Technology Policy-led)
  - Critical Minerals Subcommittee
  - Materials Genome Initiative
- Federal Consortium for Advanced Batteries

State

- State Geological Surveys/Association of American State Geologists
- State Departments of Transportation

International

- Other Federal geological surveys (Canada, Australia, others)
- Federal trade agencies and statistical agencies, through:
  - U.S.-Canada Critical Minerals Work Group
  - U.S.-Australia Critical Minerals Work Group
  - Quadrilateral Security Dialogue (U.S., India, Japan, Australia)

Private Industry

- Data sharing
- Mine waste research
- Metrics of sustainability in electronics

Academia

- Research and education
- Wide ranging collaborations across the portfolio

A Growing Partnership: Bipartisan Infrastructure Law-Funded USGS Energy and Minerals Research Facility at the Colorado School of Mines

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Strengthening the Geologic Resource Community

Education and Workforce directions

Interns sampling mine waste
Photo credit: Kathryn Watts, USGS

Education & Workforce Investments

Energy Act §7002(k)(2-3)

"the USGS shall enter into an arrangement with the National Academy of Sciences and the National Academy of Engineering… to design an interdisciplinary program on critical minerals… and ***address undergraduate and graduate education especially to assist in the development of graduate level programs of research and instruction*** *that lead to advanced degrees with an emphasis on the critical mineral supply chain or other positions that will increase domestic, critical mineral exploration, development, production, manufacturing, research, including fundamental research into alternatives, and recycling."*

In partnership with BESR:

- MRP-sponsored 2024 BESR workshop: Building Capacity to Meet Current and Future Challenges and Needs Facing the U.S. Mineral Resources Workforce

Earth MRI investments in State Geological Surveys:

- Strengthening STEM pipelines
- Reconnecting disciplines
- Transferring knowledge across generations of geoscientists
  - Data rescue, workshops, synthesis

Within the Federal government:

- Mendenhall postdoctoral fellows
- USGS Mineral Resource Assessment Training
- Training U.S. Forest Service and Bureau of Land Management certified mineral examiners in mineral fundamentals, including field trips to industry sites that develop critical mineral resources and recover minerals from wastes.

MINERAL RESOURCES PROGRAM

The Mineral Resources Program (MRP) is the Federal government's provider of scientific information and research on mineral potential, production, consumption, and interaction with the environment.

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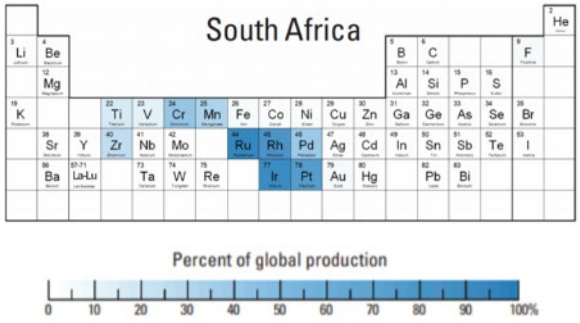

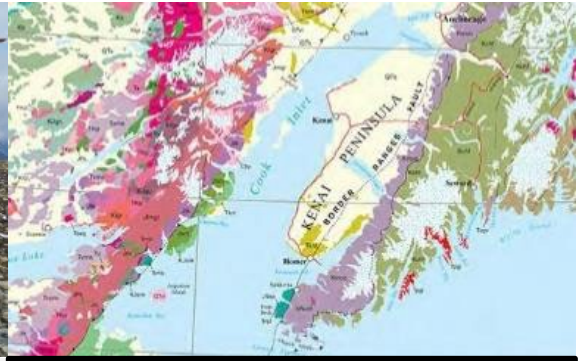

Mineral Information and Supply Chain Analysis

- Analyze global supply, demand, and trade of mineral commodities.
- Forecast supply chain disruptions.
- Develop and update the Nation's critical minerals list.
- Under E.O. 14017, lead a whole-of-government strategy to ensure sustainable and secure mineral supplies.

Research and Assessments

- Understand mineral systems and deposits.
- Understand impacts of mineral development.
- Quantify mineral resources across the resource life cycle and produce mineral resource assessments for Federal, State and international partners

Earth Mapping Resources Initiative (Earth MRI)

- Data collection, mapping, and synthesis for understanding the Nation's geologic framework and mineral resources, including
  - Mineral resources still in the ground.
  - Above-ground resources in mine wastes and other waste streams.

MINERAL RESOURCES PROGRAM SUPPORT FOR RECENT EXECUTIVE ORDERS AND LEGISLATION

Energy Act of 2020	Executive Order 14008 – Tackling the Climate Crisis at Home and Abroad	Executive Order 14017 – America's Supply Chains	Bipartisan Infrastructure Law of 2021
Collect and disseminate mineral information	Quantify potential resources in mine wastes and their risks to ecosystems	Collect and disseminate mineral information	Earth Mapping Resources Initiative (Earth MRI)
Forecast critical mineral supply chains	Evaluate large legacy mine sites for reprocessing and reclamation potential	Forecast critical mineral supply chains	10-year initial mapping products for the Nation
Develops the Nation's list of critical minerals and updates on a 3-year cycle		Identify sites where critical minerals may be sustainably produced	Energy and minerals research facility
Critical mineral resource assessments		Develop a national strategy to reclaim materials from mine wastes	
		Develop national strategy to strengthen supply chains	

Foundational to these efforts: Collecting, preserving and disseminating geological, geochemical, and geophysical data and conducting resource assessments.

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Legal Authorities for Program Activities

43 U.S.C. 31 | The Organic Act of March 3, 1879

50 U.S.C. 98 | Strategic and Critical Materials Stock Piling Act of 1946 as amended by the Revision Act of 1979.

42 U.S.C. 4321 et seq. | National Environmental Policy Act of 1969, as amended.

30 U.S.C. 21(a) | Mining and Minerals Policy Act of 1970.

30 U.S.C 1601 et seq. | National Materials and Minerals Policy, Research and Development Act of 1980.

16 U.S.C. 1604. | Forest and Rangeland Renewable Resources Planning Act of 1974, as amended by the National Forest Management Act of 1976.

Energy Act of 2020 (P.L. 116-260, enacted 12/27/2020)

Section 7002, Mineral Security, of the Energy Act of 2020 defined "critical mineral", and directed the Secretary of the Interior acting through the Director of the USGS to publish the list of critical minerals and provide updates no less than every 3 years, it requires the MRP to conduct a national assessment of every critical mineral resource, and it requires MRP to publish the Annual Critical Minerals Outlook. The Act also directs MRP to work with the National Academies of Science, Engineering, and Medicine and the National Science Foundation to design an extramural granting program for research and education.

Bipartisan Infrastructure Law (P.L. 117-58, enacted 11/15/2021) Sec. 40201. Earth Mapping Resources Initiative.

This section of the Bipartisan Infrastructure Law codifies the Earth Mapping Resources Initiative to accelerate mapping efforts at the USGS and authorizes $320,000,000 for the period of FY22-26 to complete an initial comprehensive national modern surface and subsurface mapping and data integration effort to better understand our domestic mineral resources.

Recent Requests of the Program (I)

Congressional and Administration decision support

- COVID-19 effects on commodity supply chains
- Inflation Reduction Act investments/incentives
- Russia/Ukraine and other regional conflicts
- China's export controls on gallium, germanium, and graphite
- Cabinet-level Council on Supply Chain Resilience – Supply Chain Data & Analytics workstream
- National Science and Technology Council – Critical Minerals Subcommittee; provides multi-sectoral data and analysis to integrate sector-specific perspectives of other agencies

Federal agencies decision support

- Department of Defense – National Defense Stockpile and Defense Production Act investments
- Department of Energy – energy technology loan programs
- Treasury Department – implementation of Inflation Reduction Act tax incentives supporting domestic critical mineral processing; U.S. Mint supply chain verification
- Foreign investment and credit agencies (U.S. International Development Finance Corporation and Export-Import Bank); trade negotiators (U.S. Trade Representative, State Dept, International Trade Administration)

State agencies, private sector minerals and manufacturing decision-makers, Wall Street market analysts, and foreign trade partners similarly rely on USGS data and analysis.

Recent Requests of the Program (II)

Congressional and Administration decision support

- White House Council on Environmental Quality and Federal Permitting Improvement Steering Council
- Resource maps developed for Congressional use
- Mineral resource and supply chain information for Mineral Security Partnerships, regional international mineral collaborations under activities such as the Indo-Pacific Economic Forum and the North American Leaders Summit, and country-specific capacity building for USAID and other organizations

Land management decision support

- Resource assessments, inventories, and other information to support regional and state-level resource management plans
- Reviews of existing information on mineral resource potential to inform proposed land status changes
- Subject matter expertise for the Interagency Working Group on mining reform
- Training to BLM and USFS mineral examiners

USGS photo of silicon carbide

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BREAK!

USGS Mineral Resources Program

U.S. Department of the Interior
U.S. Geological Survey

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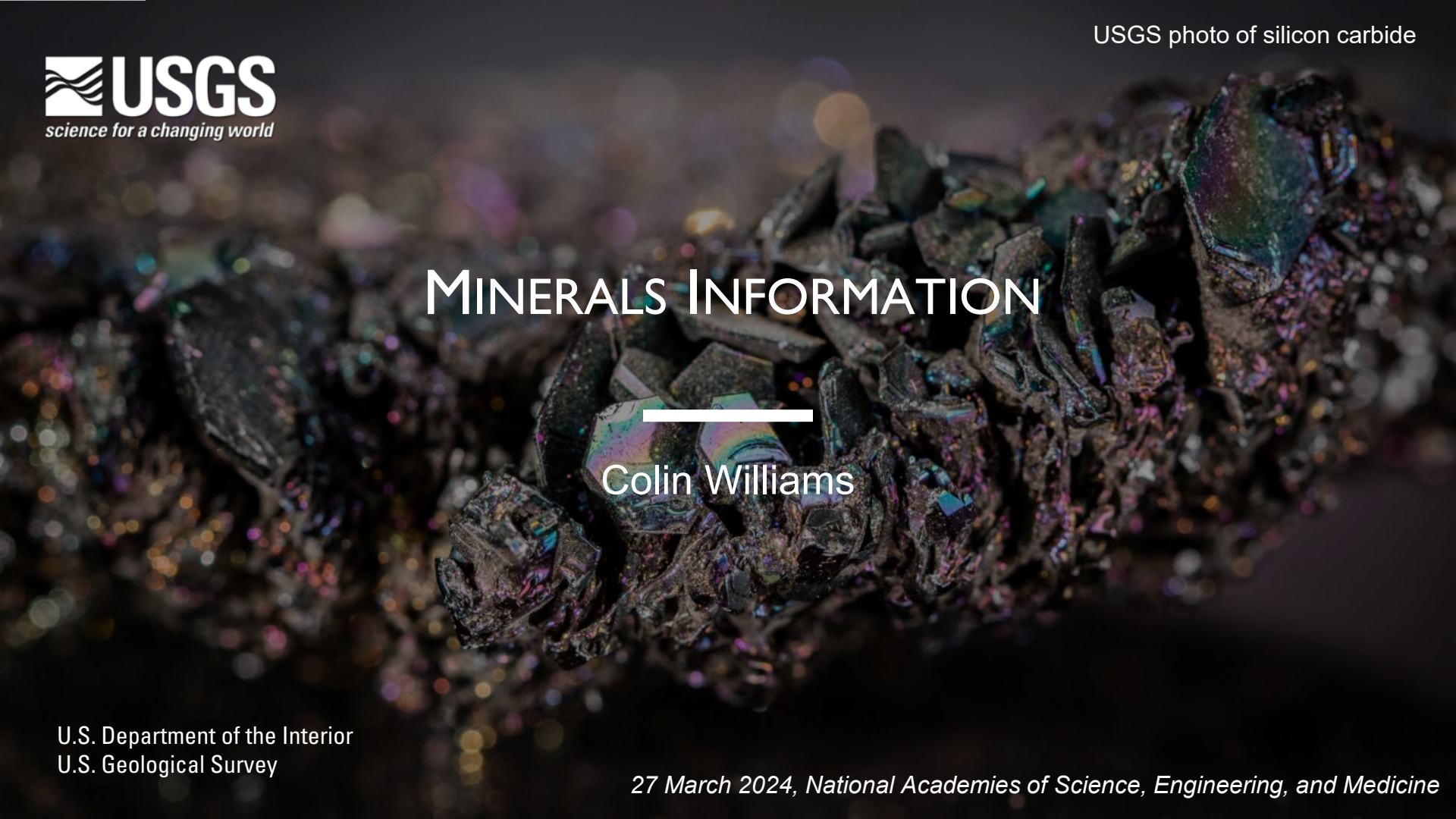

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Minerals Information

Colin Williams

U.S. Department of the Interior
U.S. Geological Survey

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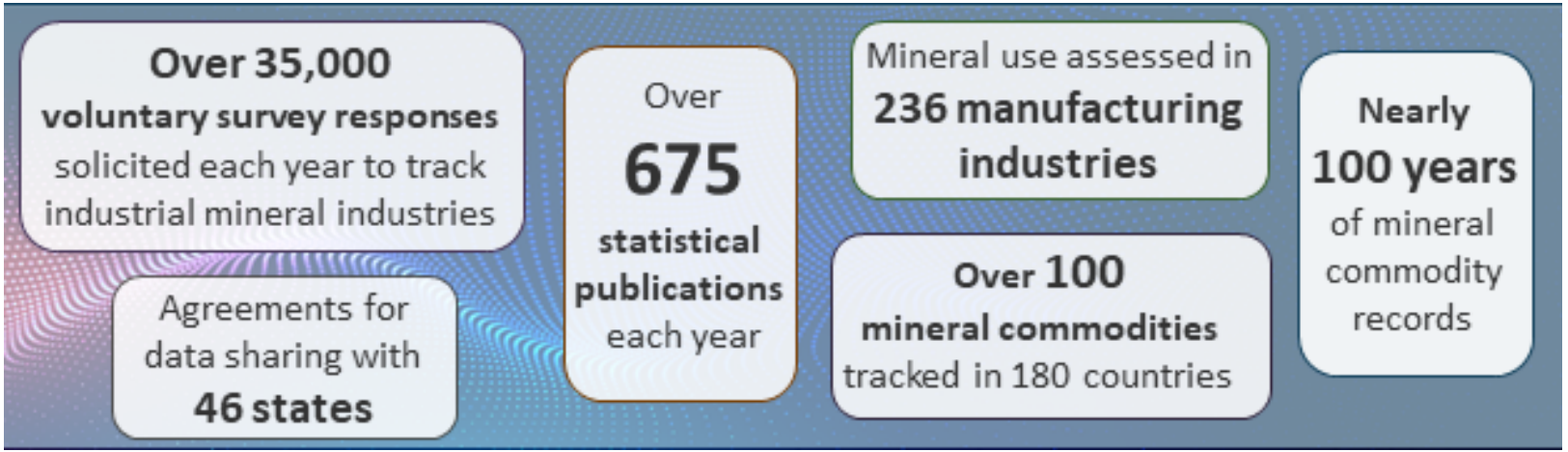
Roles for the USGS Mineral Resources Program

- Decision Support
- Innovation
- Sustainability
- Flagship Products and Data

USGS

National Minerals Information Center (NMIC)

Collects, analyzes, and disseminates information on the domestic and international supply of and demand for minerals and materials essential to the U.S. economy and national security



NMIC: Major Functions

Flagship Products and Data Decision support

Data and Statistical Responsibilities

- The U.S. government source of mineral data and statistics
- Legal authority to collect mineral information
- Over a century of data collection
- All NMIC mineral information products are published
- Long-established procedures for managing sensitive commercial (proprietary) mineral data
- Supports the National Science and Technology Council's Critical Minerals Subcommittee; provides multi-sectoral data and analysis to integrate across the sector-specific perspectives of Depts. of Energy, Defense, Commerce, and other agencies

Data and Decision Support

- Department of Defense – National Defense Stockpile and Defense Production Act authorities
- Department of Energy – energy technology loan programs
- Treasury Department – implementation of Inflation Reduction Act tax incentives supporting domestic critical mineral processing
- Foreign investment and credit agencies (U.S. International Development Finance Corporation and Export-Import Bank); trade negotiators (U.S. Trade Representative, State Dept, International Trade Administration)

State agencies, private sector minerals and manufacturing decision-makers, Wall Street market analysts, and foreign trade partners similarly rely on USGS data and analysis.

Mineral Information Collection

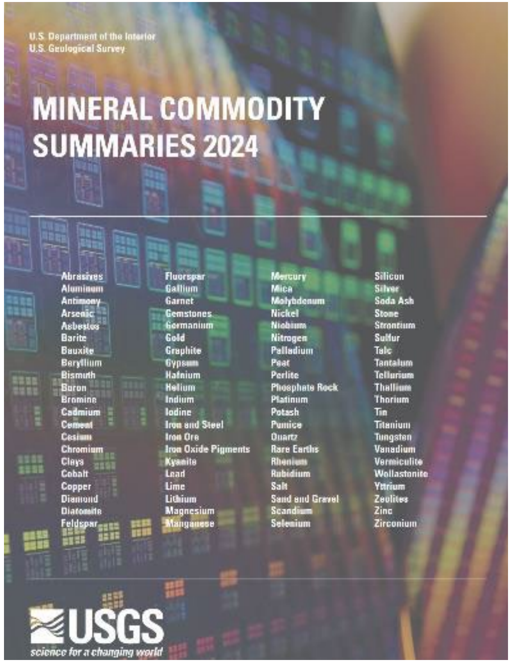
- More than 140 years of mineral information experience
  - U.S. Geological Survey: 1882-1924
  - U.S. Bureau of Mines: 1925-1995
  - U.S. Geological Survey: 1996 – present
- Domestic mineral information collected on a monthly, quarterly, and annual basis
  - 18,000 mineral related production and consumption establishments
  - 40,000 (voluntary) survey forms completed annually
- Continuous record of mineral commodity supply, consumption, imports, exports, recycling, world production: Data Series-140
- Global mineral information collection
  - Mineral questionnaires to ~145 countries
  - Site visits
  - Membership on domestic and international mineral related committees
  - Coordination with organizations from other governments and trade associations
  - Reports from economic officers at U.S. embassies
  - Mineral industry reports
  - Company reports

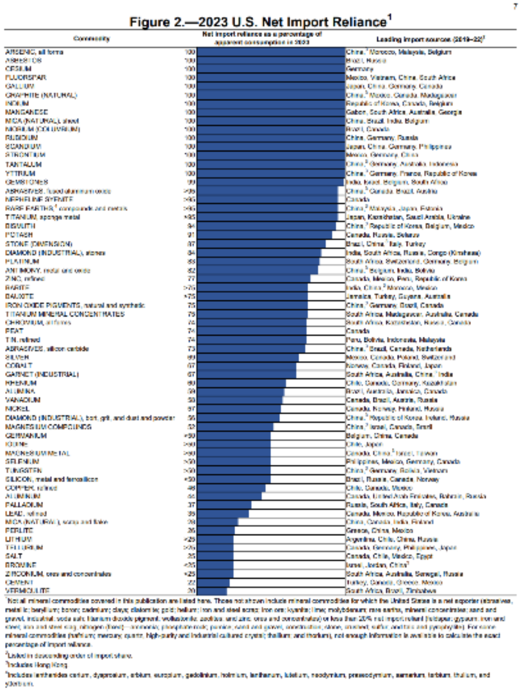
Mineral Information Collection

Mineral Commodity Summaries

Earliest comprehensive source of domestic and international mineral production data for the prior year.

- Issued annually at the end of January.
- More than 90 individual minerals and materials are covered by 2-page synopses.
- Information on events, trends, and issues for each mineral commodity.
- Production, consumption, and trade data and analysis.
- U.S. Net Import Reliance.
- ***Drives decision making and investing by government and private industry.***





U.S. Geological Survey, 2024, Mineral commodity summaries 2024: U.S. Geological Survey, 212 p., https://doi.org/10.3133/mcs2024.

NMIC's Major Product Types

- HOME
- COMMODITIES
- COUNTRIES
- MATERIALS FLOW
- US STATES
- NMIC SEMINARS
- DATA
- MULTIMEDIA
- PUBLICATIONS
- NEWS
- CONNECT
- ABOUT

National Minerals Information Center

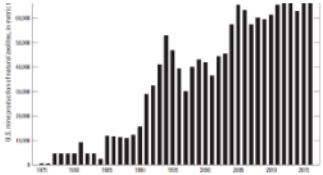
Statistics and information on the worldwide supply of, demand for, and flow of minerals and materials essential to the U.S. economy, the national security, and protection of the environment.

Statistical Periodicals

On-line statistical and economic publications designed to provide timely statistical data on production, distribution, stocks, and consumption of significant mineral commodities.

Periodic Pubications

Materials Flow



Understanding the whole system of materials flow, from source to ultimate disposition, can help us better manage the use of natural resources and protect the environment, and ensure a supply of critical minerals.

Special Publications

Quick Links

Contributions of data by mineral industry companies through canvass forms completed annually, monthly, or quarterly are the basis of U.S. mineral industry publications. Information can be accessed through the following major categories.

- Commodity
- Country
- State
- Materials Flow
- RSS feed - recent periodicals
- List services - publication notifications

Flagship products and data

NMIC Products Leverage the USGS Open Science Infrastructure

USGS open data and publication platforms include the Publications Warehouse and the ScienceBase Trusted Digital Repository

Example from: https://doi.org/10.5066/P9I9KJ9J

ScienceBase Catalog → National Minerals Informatio... → Trade Codes Related to the ...

Trade Codes Related to the Lithium-Ion Battery Supply Chain for the United States, the European Union, and the People's Republic of China

View

Dates

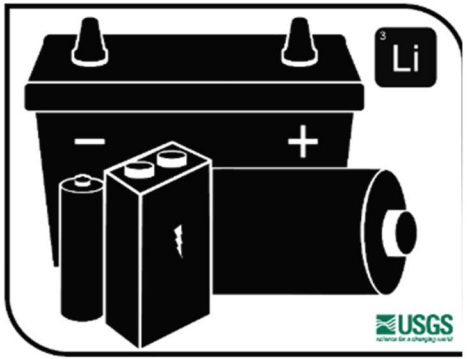
Publication Date : 2022-02-18
Time Period : 2021

Citation

McMahon, K.S., 2022, Trade Codes Related to the Lithium-Ion Battery Supply Chain for the United States, the European Union, and the People's Republic of China: U.S. Geological Survey data release, https://doi.org/10.5066/P9I9KJ9J.

Summary

This dataset presents information concerning 8- and 10-digit trade codes related to the rechargeable lithium-ion battery (LIB) supply chain for the People's Republic of China (PRC) and the European Union, and the United States as classified by Customs and Border Protection (CBP) rulings. Note that this dataset is not intended to be a complete or comprehensive list of trade codes for the LIB supply chain; rather, it presents trade codes from the PRC and the EU that more granularly classify products related to LIB supply chain in comparison to the Harmonized Tariff Schedule of the United States (HTSUS). CBP rulings are included to indicate existing classification decisions for relevant products related to the LIB supply chain. Disaggregated trade codes offer more detailed insight into trade flows, supply chains, and the state of domestic and international industries. The dataset covers raw materials, refined and processed materials, battery materials, cell components, batteries and battery components, end-of-life batteries, and machinery. Tariff line information was assembled through conversations with experts and reviews of supply chain process flows in concert with an examination of trade databases, domestic trade documentation, and primary international customs import and export tariff documents.



Communities

- National Minerals Information Center
- USGS Data Release Products

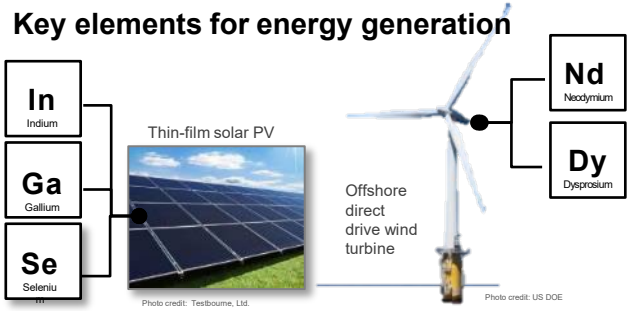
Tags

Categories : Data
Harvest Set : USGS Science Data Catalog (SDC)
Theme : anodes, battery, business and economics, cathodes, chemicals, cobalt, critical minerals,

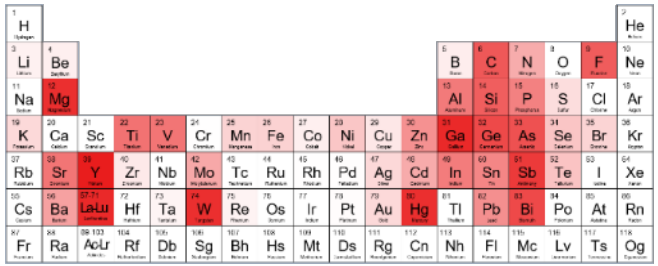
USGS science for a changing world

MINERAL INTELLIGENCE

Tracking Supply Chains and Identifying Critical Mineral Commodities: Supply, Demand & Trade Data



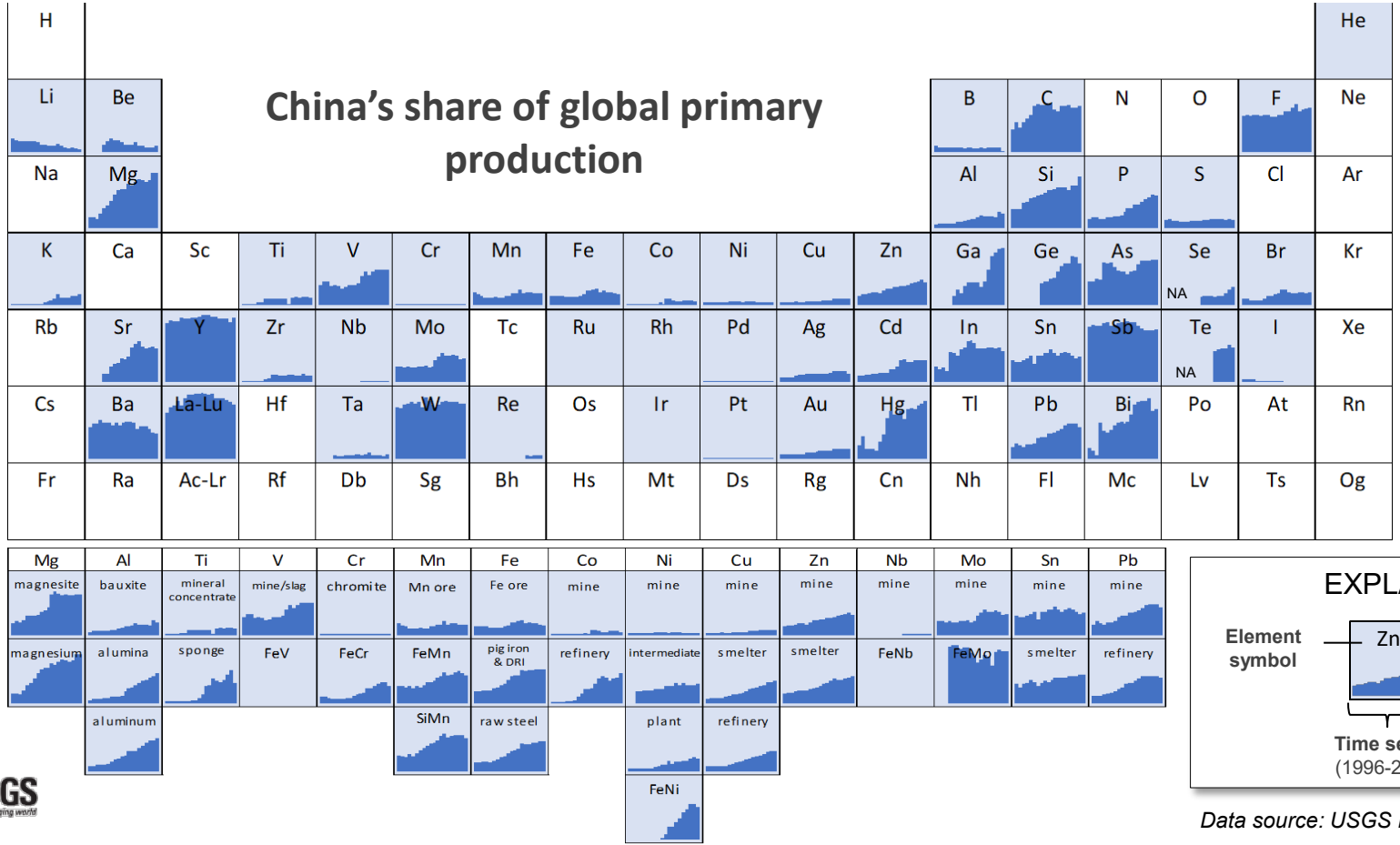
Share of each element's global production from China:



- Monitor net import reliance by commodity, trade partner, technology, and manufacturing sector.
- Analyze supply chain dependencies for emerging technology sectors including:
  - Defense
  - Advanced manufacturing
  - Consumer technologies
  - Renewable energy generation and storage
- ***Advise the State Dept., Dept. of Commerce, U.S. International Development Finance Corp., and U.S. Trade Representative on strategic investments and trade partnerships for mineral commodities, processing, and related manufacturing.***
- ***Provide subject matter expertise to:***
  - ***DOD Defense Production Act Title III programs***
  - ***DOE Loan Program***
  - ***U.S. Intelligence Community***

USGS science for a changing world

Global Production Trends Over 20 Years

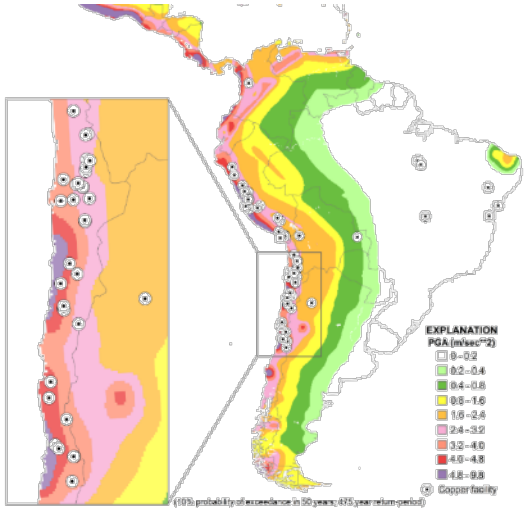


Data source: USGS Minerals Yearbooks

Critical Mineral Supply Risk Depends on Three Factors

Disruption Potential

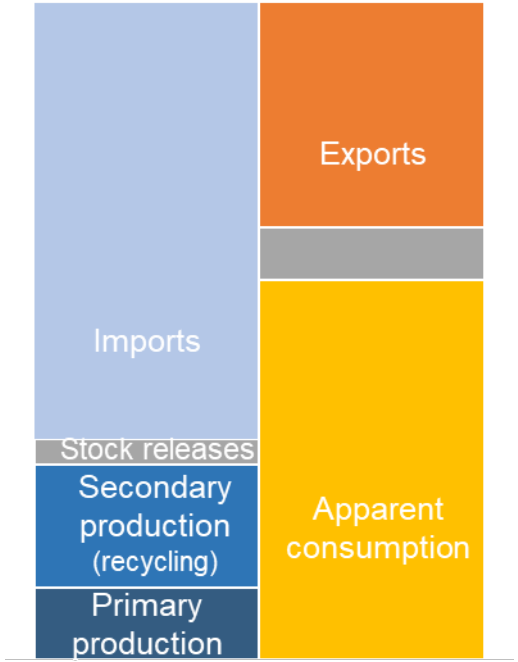
Likelihood of a foreign or domestic supply disruption



Schnebele, E.; Jaiswal, K.; Luco, N.; Nassar, N. T. Natural Hazards and Mineral Commodity Supply: Quantifying Risk of Earthquake Disruption to South American Copper Supply. *Resources Policy* 2019, *63*, 101430.

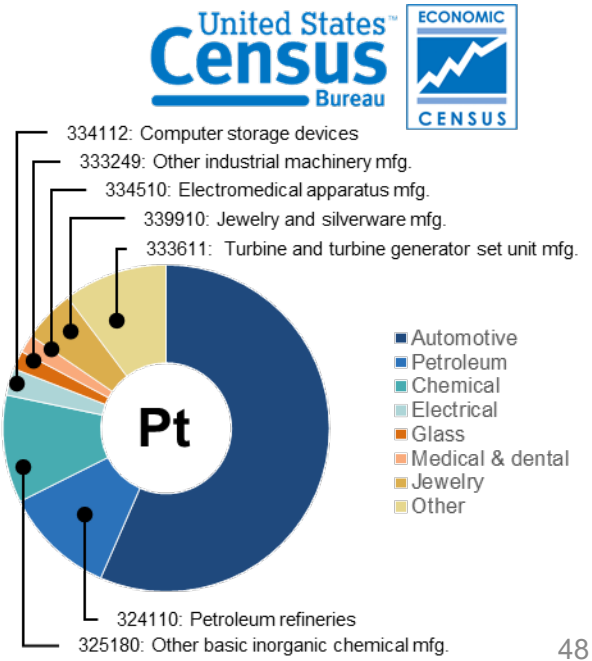
Trade Exposure

Degree of exposure to a supply disruption



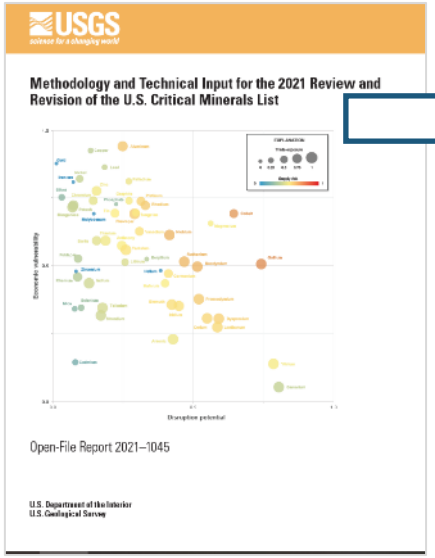
Economic Vulnerability

Ability to withstand the effects of a supply disruption



List of Critical Minerals

Under the Energy Act of 2020, the USGS develops and maintains the whole-of-government list of critical minerals



https://doi.org/ 10.3133/ofr20211045*

* Peer reviewed per USGS Fundamental Science Practices

Decision support

Methodology Development and Input
- NMIC's data and analysis support recommendations to a USGS-led working group under NSTC CMS

Interagency Consultation
- NSTC Critical Minerals Subcommittee review / recommendations
- USGS publishes methodology

Federal Register Notice
- Draft list of critical minerals
- Draft byproduct list of critical minerals

Public Comment
- DOI review and consideration of public comments

Federal Register Notice
- Final, revised list of critical minerals
- Final byproduct list of critical minerals

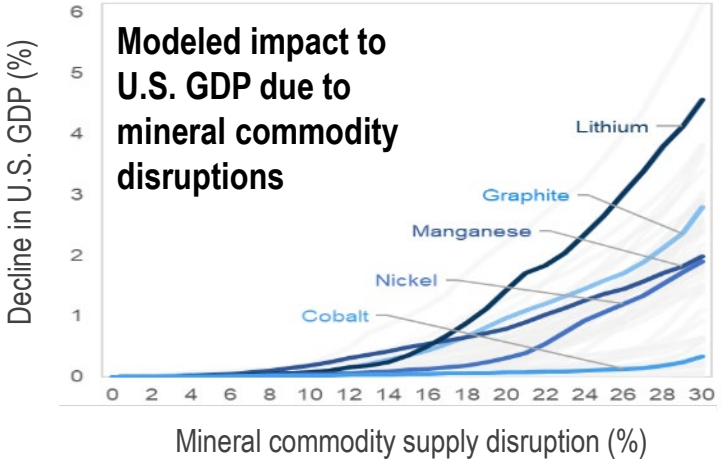
USGS

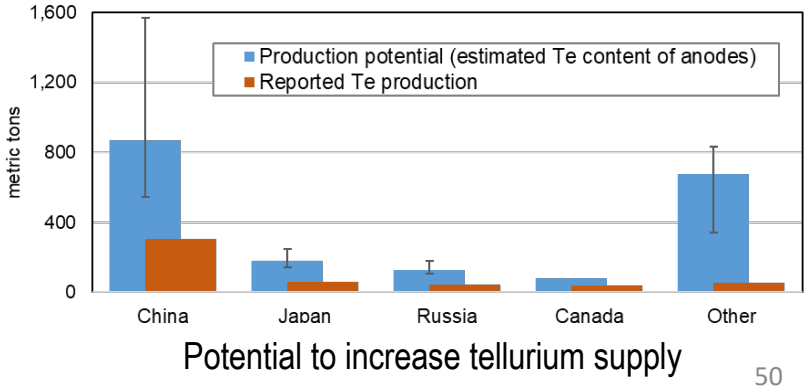
Supply Chain Forecasts and Scenarios

Innovation portfolio
Decision support

The Energy Act of 2020 directed the USGS to expand our supply chain and scenario analyses. Current efforts include:

- ***Developing supply chain disruptions scenarios and assessing their potential impacts to the U.S. economy***
  - Example: assessing impact of China's export controls on gallium, germanium, and graphite
- ***Developing supply and demand scenarios including technology development and policy changes***
  - Example: assessing potential to increase supply of tellurium from copper anode slimes for solar photovoltaics





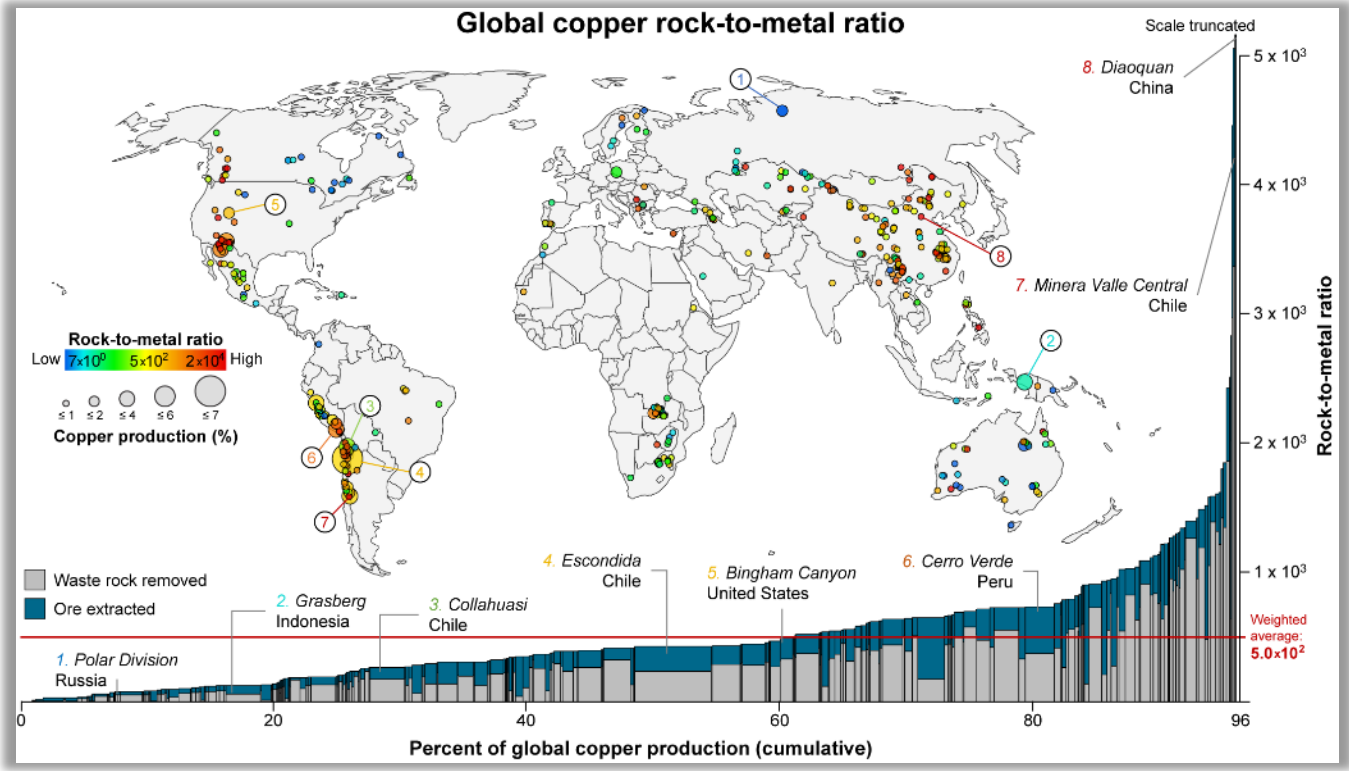
Manley, R.L., Alonso, E., and Nassar, N.T., 2022, A model to assess industry vulnerability to disruptions in mineral commodity supplies: Resources Policy, v. 78, p. 102889.

Nassar, N.T., Kim, H., Frenzel, M., Moats, M.S., and Hayes, S.M., 2022, Global tellurium supply potential from electrolytic copper refining: Resources, Conservation and Recycling, v. 184, p. 106434.

USGS science for a changing world

Rock to Metal Ratio

- Through a cooperative agreement with Apple, developed a new metric, Rock-to-Metal ratio, to quantify the waste produced by mining.
- Global Rock-to-Metal Ratio Varies Significantly
- This metric is vital to understanding mine wastes and potential environmental impacts from mining.



Nassar et al., 2022, Rock-to-Metal Ratio: A Foundational Metric for Understanding Mine Wastes: Environmental Science & Technology, v. 56, no. 10, p. 6710–6721.

USGS

Designating NMIC a Statistical Unit

- DOI/USGS have requested that OMB designate NMIC a **Principal Statistical Unit of the Federal government.**

- NMIC collects the Nation's data on the global supply of minerals.
  - These data are economically impactful and require high trust in data quality and timeliness.
  - Public- and private-sector decisions about billions of dollars are informed by these data.
  - NMIC has significant responsibilities for both open data and protection of proprietary information. As a statistical unit, NMIC's proprietary data would be further protected by the Confidential Information Protection and Statistical Efficiency Act.

- USGS supply chain analysis based on these data informs decision-makers of:
  - Trends in demand for critical minerals associated with the adoption of a wide range of technologies including low-carbon energy generation and storage.
  - The economic impacts of supply chain disruption events ranging from trade sanctions and overseas conflicts to pandemics and natural disasters.

DARPA Partnership: Open Price Exploration for National security (OPEN)

OPEN goal: Increase the transparency of price, supply, and demand predictions and forecasts in critical materials markets

Challenge: Commodity purchases are negotiated using opaque and flawed pricing data from futures or spot transactions

USGS role: Subject matter expertise/Deputy Program Manager for DARPA's effort

USGS interest: We receive frequent inquiries from Congress, the Administration, and industry (manufacturing, healthcare, biomedical research, aerospace) about commodities for which supply risk and pricing shocks are intertwined factors in commodity availability.

Increasing Transparency in Critical Materials Price, Supply, and Demand Forecasts (darpa.mil)

USGS photo of silicon carbide

USGS
science for a changing world

Mineral Resources Research and Assessments

Colin Williams

U.S. Department of the Interior
U.S. Geological Survey

27 March 2024, National Academies of Science, Engineering, and Medicine

A Rich Research Portfolio

Resources Policy
Volume 78, September 2022, 102889

A model to assess industry vulnerability to disruptions in mineral commodity supplies

Ross L. Manley, Elisa Alonso, Nedal T. Nassar

Critical Minerals in Subduction-related Magmatic-Hydrothermal Systems of the United States

By Peter Vikre, David John, Niki E. Wintzer, Fleetwood Koutz, Frederick Graybeal, Chris Dail, and David C. Annis

Scientific Investigations Report 2023–5082

Geochemistry, Geophysics, Geosystems

Research Article | Open Access

Mafic Alkaline Magmatism and Rare Earth Element Mineralization in the Mojave Desert, California: The Bobcat Hills Connection to Mountain Pass

K. E. Watts, D. M. Miller, D. A. Ponce

First published: 09 January 2024 | https://doi.org/10.1029/2023GC011253

Applied Geochemistry
Volume 143, August 2022, 105341

Germanium redistribution during weathering of Zn mine wastes: Implications for environmental mobility and recovery of a critical mineral

Sarah Jane O. White [a, b], Nadine M. Piatak [a], Ryan J. McAleer [a], Sarah M. Hayes [a], Robert R. Seal II [a], Laurel A. Schaider [b, c], James P. Shine [b]

Ore Geology Reviews
Volume 152, January 2023, 105223

Geophysical data provide three dimensional insights into porphyry copper systems in the Silverton caldera, Colorado, USA

Eric D. Anderson, Douglas B. Yager, Maryla Deszcz-Pan, Bennett E. Hoogenboom, Brian D. Rodriguez, Bruce D. Smith

Mineralium Deposita (2023) 58:939–962
https://doi.org/10.1007/s00126-023-01161-3

ARTICLE

Insights into the metamorphic history and origin of flake graphite mineralization at the Graphite Creek graphite deposit, Seward Peninsula, Alaska, USA

George N. D. Case[1] · Susan M. Karl[1] · Sean P. Regan[2] · Craig A. Johnson[3] · Eric T. Ellison[4] · Jonathan Saul Caine[3] · Christopher S. Holm-Denoma[3] · Laura S. Pianowski[3] · Jeffrey H. Marsh[5]

Economic Geology

BULLETIN OF THE SOCIETY OF ECONOMIC GEOLOGISTS

VOL. 118 | January | No. 1

EXPRESS LETTER

A RECENTLY DISCOVERED TRACHYTE-HOSTED RARE EARTH ELEMENT-NIOBIUM-ZIRCONIUM OCCURRENCE IN NORTHERN MAINE, USA

Chunzeng Wang,[1] John F. Slack,[2,3,†] Anjana K. Shah,[4] Martin G. Yates,[5] David R. Lentz,[6] Amber T.H. Whittaker,[7] and Robert G. Marvinney[2,*]

frontiers | Frontiers in Earth Science

A novel non-destructive workflow for examining germanium and co-substituents in ZnS

Sarah M. Hayes[1]*, Ryan J. McAleer[2], Nadine M. Piatak[1], Sarah Jane O. White[1] and Robert R. Seal II[1]

[1]United States Geological Survey, Geology, Energy and Minerals Science Center, Reston, VA, United States, [2]United States Geological Survey, Florence Bascom Geoscience Center, Reston, VA, United States

CRITICAL MINERAL RESOURCES RESEARCH AND ASSESSMENTS

Undiscovered resource assessments:

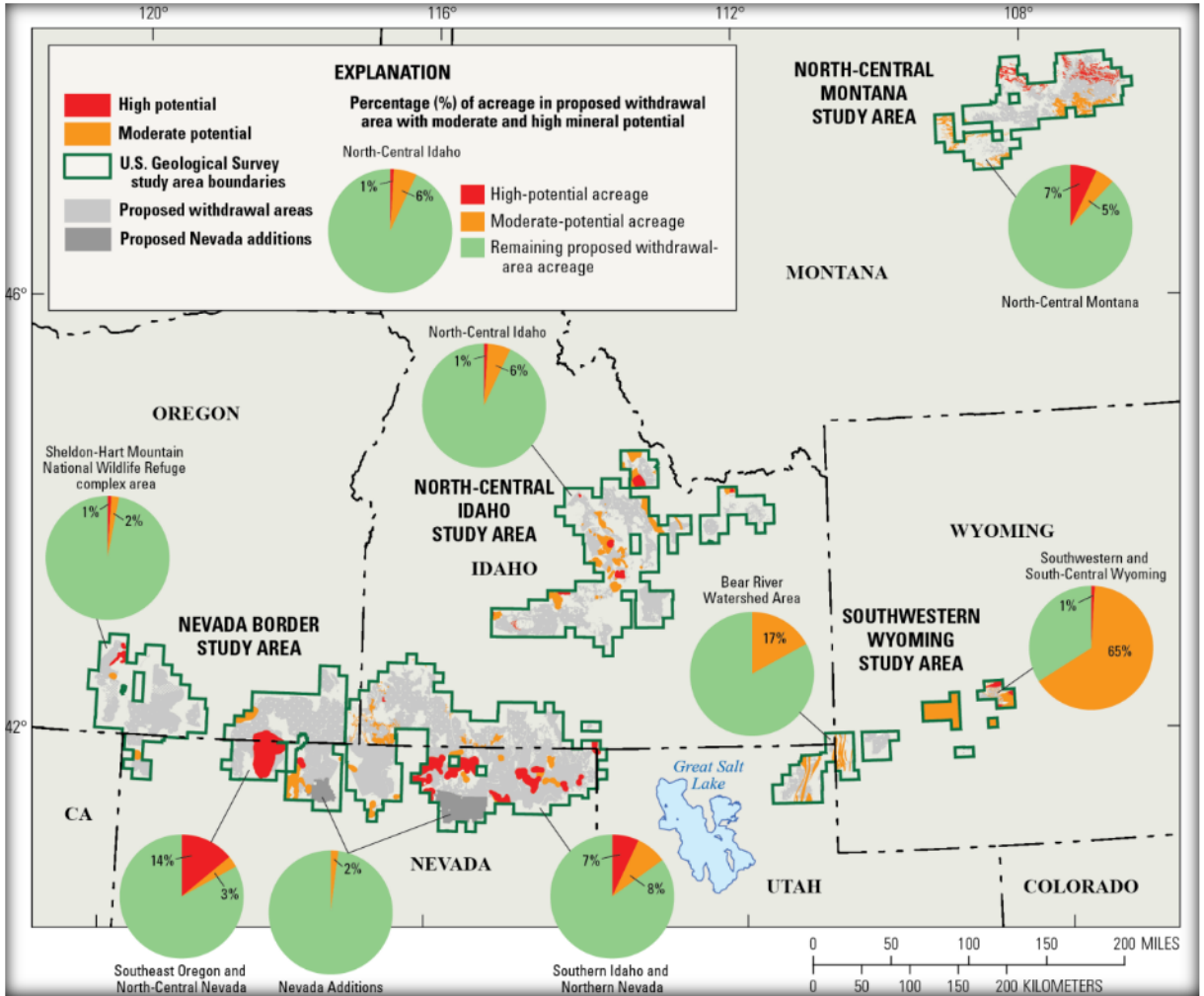
- Provide a method for comparing different types of resources across regions.
- Combine geologic maps, geochemical analysis, geophysics, and additional geoscience analyses.
- Provide land managers information on:
  - Resource potential
  - Potential impacts of development on waste disposal/management, water supply, water quality, land disturbance and ecosystem changes
- Different approaches to addressing – What, How Much, and Where

Current assessment priorities:

- The USGS is focusing its next series of resource assessments on critical minerals needed for the energy sector, ranging from electric vehicle batteries to grid-energy storage applications. Those minerals include:
  - **Graphite**
  - **Lithium**
  - **Cobalt**
  - **Nickel**
  - Vanadium
  - Manganese.

RESOURCE ASSESSMENTS FOR LAND MANAGEMENT - SAMIRA (2017)

- Focal Areas contain areas of known mineral resources
- Provided BLM with information on areas with high- to medium-potential for undiscovered mineral resources
- Incorporation of mineral resource information into subsequent planning efforts assures informed land management decisions



Frank, D.G., Frost, T.P., Day, W.C., and the USGS SaMiRA team, 2016, U.S. Geological Survey Fact Sheet 2016–3074, 4 p., http://dx.doi.org/10.3133/fs20163074.

USGS

Construction Resources & other Industrial Minerals

- Rebuilding following natural disasters requires a reliable, affordable, and nearby supply of industrial minerals such as aggregate, sand and gravel, limestone, shale or clay, and cement.
- In 2022, Hurricanes Fiona and Ian damaged and destroyed infrastructure across Puerto Rico and Florida. Under the Disaster Supplemental Appropriations Act of 2023, MRP is mapping industrial minerals in partnership with:
  - Puerto Rico: University of Puerto Rico and the Territorial Government
  - Florida: Florida Geological Survey, Florida Department of Transportation, and U.S. Army Corps of Engineers
- Other recent Congressional directives:
  - Design a construction resources effort within MRP
    - House Report 117-400 accompanying 2023 appropriations
  - Map pyrrhotite in construction resources
    - House Report 116-9 accompanying 2019 appropriations

USGS

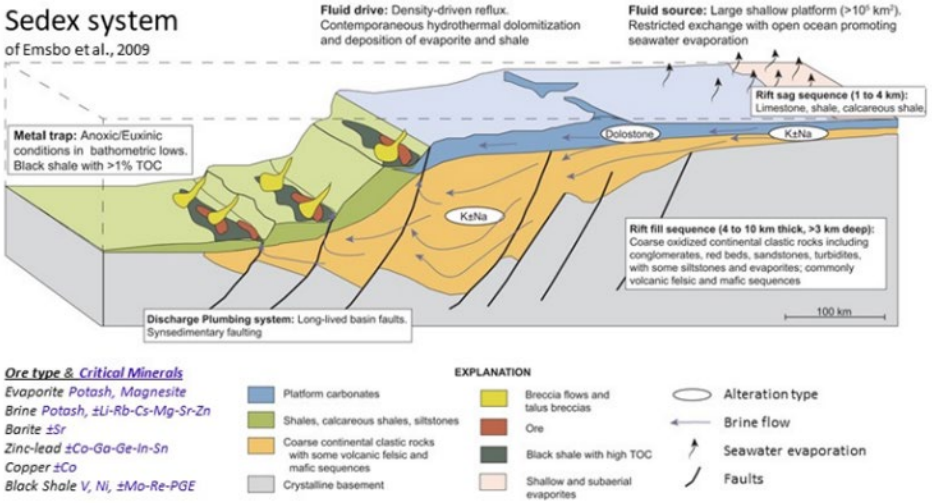
Relating Critical, Base, and Precious Metals through a Mineral Systems Approach

- A mineral system is a framework that relates all geologic processes that control the formation and preservation of mineral deposits
- An episode in a geotectonic setting that generates coeval and cogenetic deposits, often located within the same district
- Mineral systems have larger footprints (including subtle distal expressions) than ore deposits
- Mineral systems may generate one or multiple deposit types containing industrial minerals, base metals, precious metals and critical minerals (typically as by-products)
- Classification is tricky – depends on unifying characteristic

Mineral system slides content mostly courtesy of Doug Kreiner, USGS

Mineral System Concepts and Terminology

1. **Trigger**
   - Short-lived, generally an episode in a larger geotectonic setting – determines spatial extent and temporal window of system
2. **Energy drive**
   - Topography, magma, geothermal gradient that drive movement of fluids
3. **Transport media**
   - Melts, aqueous fluids, petroleum
4. **Source of components**
   - Ligands: required to complex metals in solution
   - Metals: availability and solubility of metals determined by source rock mineralogy and P-T-X of fluids
5. **Transport pathways**
   - Processes that create and enhance permeability at multiple scales
   - Includes “throttles,” or focused areas of high permeability
6. **Traps**
   - May be physical (decompression, density separation) or chemical (mixing of fluids, fluid-rock interaction, magma mixing, fractional crystallization)
   - Site of deposition / concentration of metals of interest
7. **Post-depositional processes**
   - Exhumation or burial preserving and(or) exposing deposit
   - Upgrading of deposits post-mineral



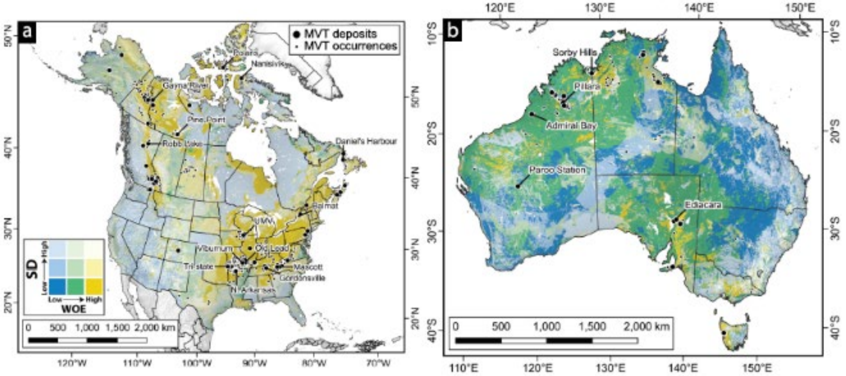
Putting the Mineral Systems Framework to Use

Expert knowledge and data informed prospectivity analyses focused on mineral systems framework show potential for critical minerals through our Critical Minerals Mapping Initiative work with Canada and Australia

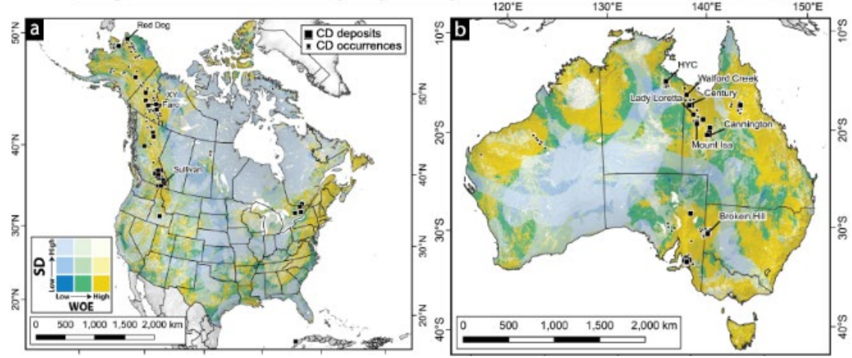
Table 1
Mineral system table for Mississippi Valley–type and Clastic-dominated (CD) Zn–Pb deposits with datasets and sources.

Mineral system component	Theoretical Criteria	Mappable Criteria	Dataset	Dataset source[1]
Sources	Oxidized, basinal fluids	Rocks younger than the great oxidation event at 2.4 Ga	Maximum geological ages	This study[1]
	Source(s) of metals	Immature and oxidized sedimentary, volcanic, and/or basement rocks	Geological maps	This study[1]
	Source(s) of brines	Low-to mid-latitude evaporites and carbonate-platforms at surface	Minimum geological ages; Paleo-geographic reconstructions	This study[1]; Scotese (2021)
Pathways	Orogenic setting	Cratonic edges and steps in crustal thickness	Lithosphere-asthenosphere boundary; Depth to Moho	This study[1]; Hoggard et al. (2020);Kennett et al. (2011);Laske et al. (2013); Priestley et al. (2018);Reguzzoni and Sampietro (2015);Schetselaar and Snyder (2017);Shen and Ritzwoller (2016);Szwillus et al. (2019);Zhang et al. (2019)
	Crustal boundaries	Regional density contrasts associated with the crustal root of orogenic belts	Satellite gravity and derivative products	Ebbing et al. (2018)
	Weak lithosphere	Lithospheric pathways for melts and fluids	Seismic velocities	Debayle et al. (2020)
	Basin-bounding structures	Terrane boundaries; passive margins; surface heat flow; curie point	Global terrane database	Eglington et al., (2013); Li et al. (2017) ;Lucazeau et al. (2019)
	Mid- to upper-crustal pathways	Regional gravity and magnetic anomalies	National gravity anomaly databases	This study[1]
Traps	Fluid focusing and mixing during deposition	Proximity to intra-basinal faults	Fault databases	This study[1]; Styron and Pagani (2020); Raymond et al. (2012);Chorlton (2007); Reed et al. (2005)
	Fluid reduction, triggering sulphide deposition	Proximity to carbonaceous sedimentary rocks	Global shale database	This study[1]; Granitto et al. (2017)
Preservation	Overprinting metamorphism	Metamorphic grade	Geological map databases	This study[1]
Direct detection	Deposits	Active mines, past-producing mines, and advanced exploration projects	Deposit databases	This study[1]; Hoggard et al. (2020)
	Mineral occurrences	Prospects, showings, and drill intercepts	Mineral occurrence databases	This study[1]

Weights-of-evidence (WOE) prospectivity results: Mississippi Valley-type (Zn, Pb)



Weights-of-evidence (WOE) prospectivity results: Clastic-dominated (Zn, Pb)

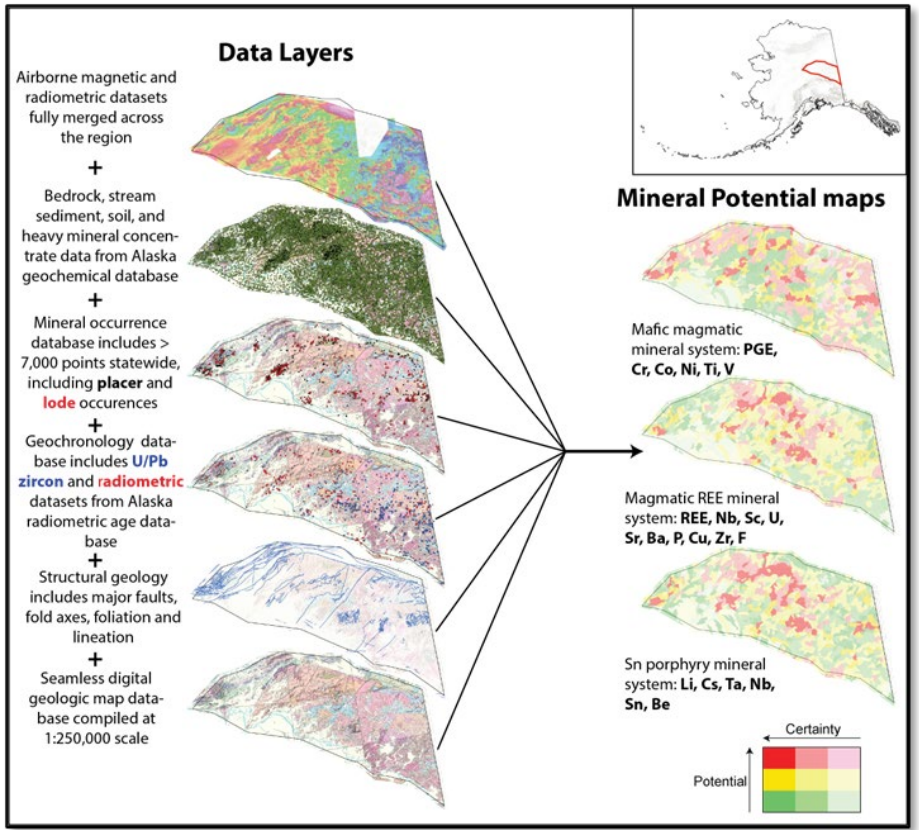


Lawley et al., 2022

Innovation
Decision Support

Future Directions and Challenges for Mineral Systems Research and Resource Assessments

- Focused studies on system components {(1) driver, (2) source of metals, (3) transport medium and pathway, (4) traps} to characterize critical minerals in the systems
- Knowledge of the anatomy of mineral systems to predict what deposits may be present below the surface or in neighboring areas under cover.
- Continued inventory of critical minerals in mineral systems
- Develop mappable criteria for all mineral systems to allow for prospectivity and mineral commodity, including critical mineral potential across the US
- New and legacy **DATA** in machine-readable formats that can be easily used for diverse applications
- Techniques to accelerate assessments and prospectivity mapping



Kreiner et al., 2024

DARPA Partnership: Critical Mineral Assessments with AI Support (CriticalMAAS)

- The Energy Act of 2020 and the Bipartisan Infrastructure Law direct the USGS to accelerate mapping and assessment of the Nation's critical minerals both above and below ground

- The goal of CriticalMAAS is to accelerate USGS mineral resource assessment workflows using artificial intelligence and machine learning to automate parts of the process. The desired outcome is a set of tools and data transformations that make assessment workflows more efficient.

- Success of depends on the involvement of domain experts in geology, geophysics, geochemistry, remote sensing, GIS, and other disciplines at key stages of the assessment workflow, from input data selection, training set curation, and evaluation of outputs. In addition to providing publicly available data, the USGS is contributing the people and expertise needed to develop "human-in-the-loop" solutions.

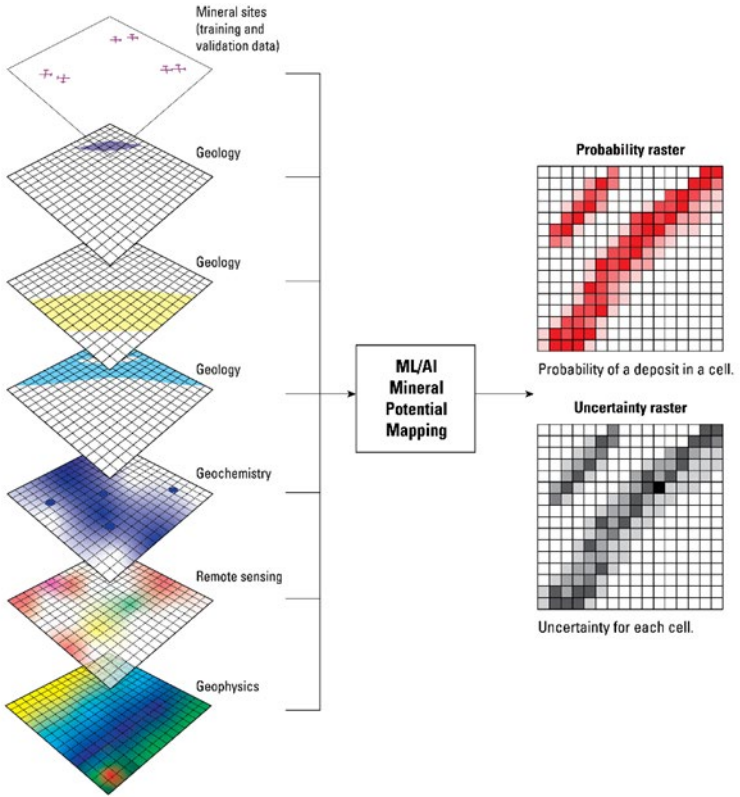
CriticalMAAS slides courtesy of Graham Lederer, USGS

Critical Mineral Assessments with AI Support (CriticalMAAS)

CRITICALMAAS

Four Technical Areas (TAs)

- TA1 – Extracting geospatial data from maps and documents.
- TA2 – Model extraction from knowledge.
- TA3 – Mineral potential mapping exploiting multi-modal fusion.
- TA4 – Human-in-the-loop learning (HITL) and mixed-initiative modeling



USGS photo of silicon carbide

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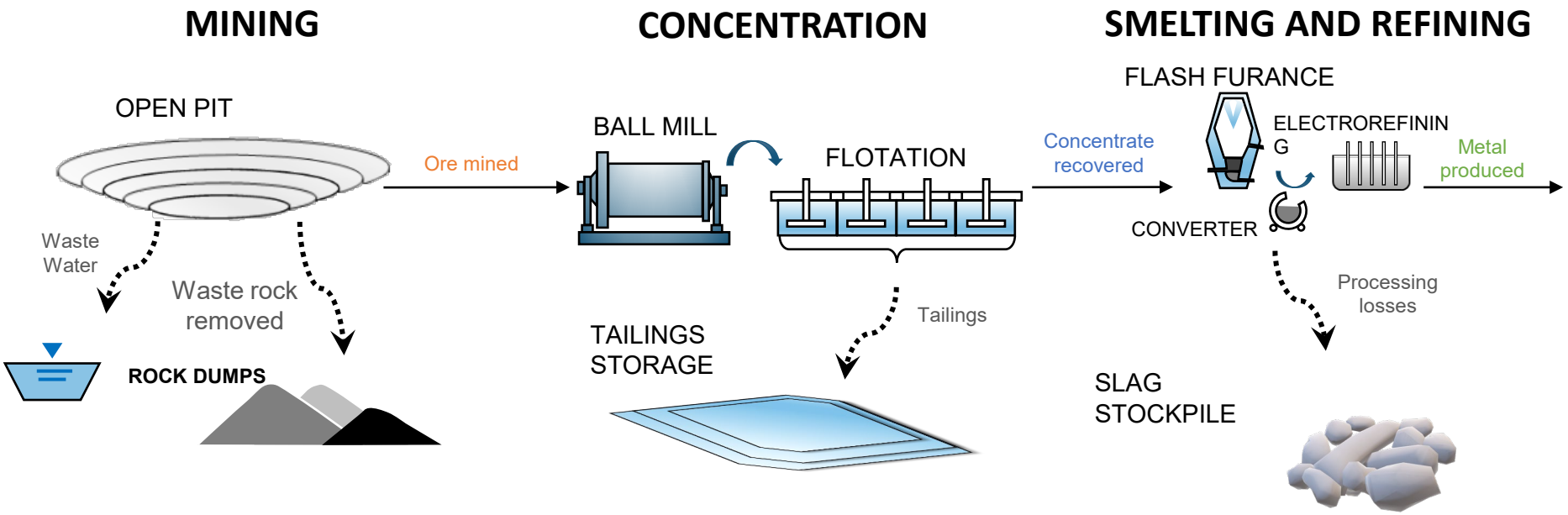
Mine Waste and Environmental Studies

Tanya Gallegos

U.S. Department of the Interior
U.S. Geological Survey

27 March 2024, National Academies of Science, Engineering, and Medicine

Broadly Defined "Mine Waste"



Modified from: Nedal T. Nassar, Graham W. Lederer, Jamie L. Brainard, Abraham J. Padilla, and Joseph D. Lessard, 2022, Rock-to-Metal Ratio: A Foundational Metric for Understanding Mine Wastes, Environmental Science & Technology Article ASAP, DOI: 10.1021/acs.est.1c07875.

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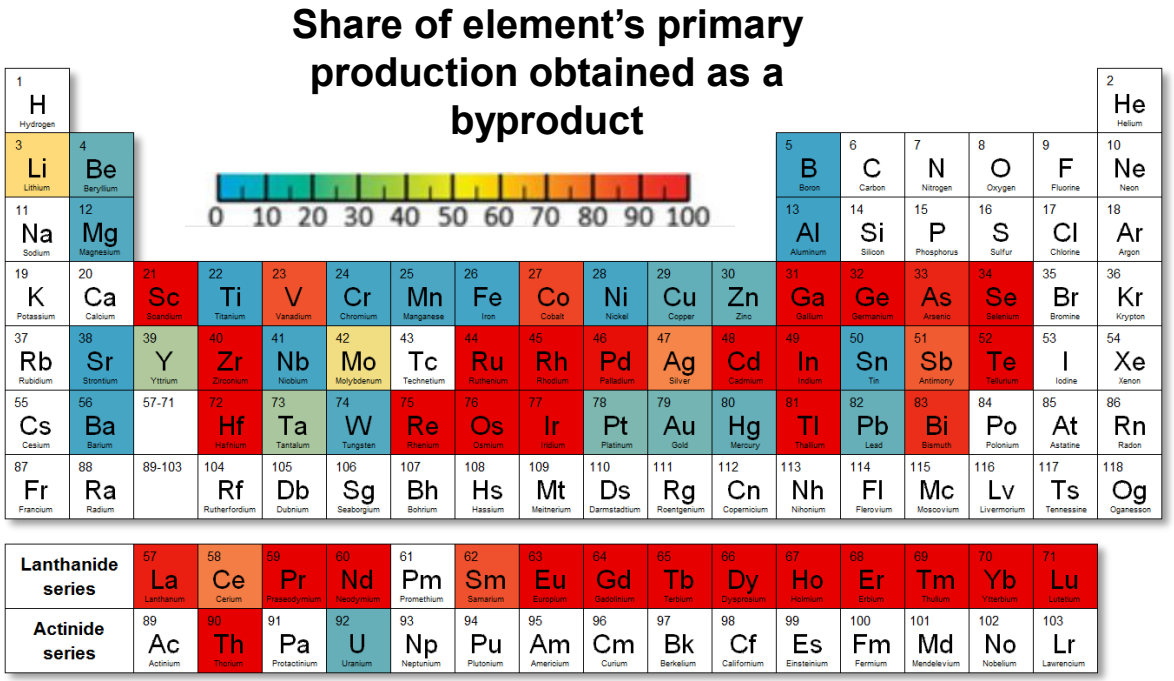
Secondary Sources of Critical Minerals: Mine Waste

- **Byproducts**. Critical minerals often occur as byproducts in lesser amounts relative to the target mineral.
- **Current and future mining.** Prompt industry to add circuits to their operations to capture critical minerals and lessen waste footprint.
- **Legacy Mine Waste.** Minerals not historically economic to mine were considered waste and sources of contaminants decades ago are now considered critical minerals.

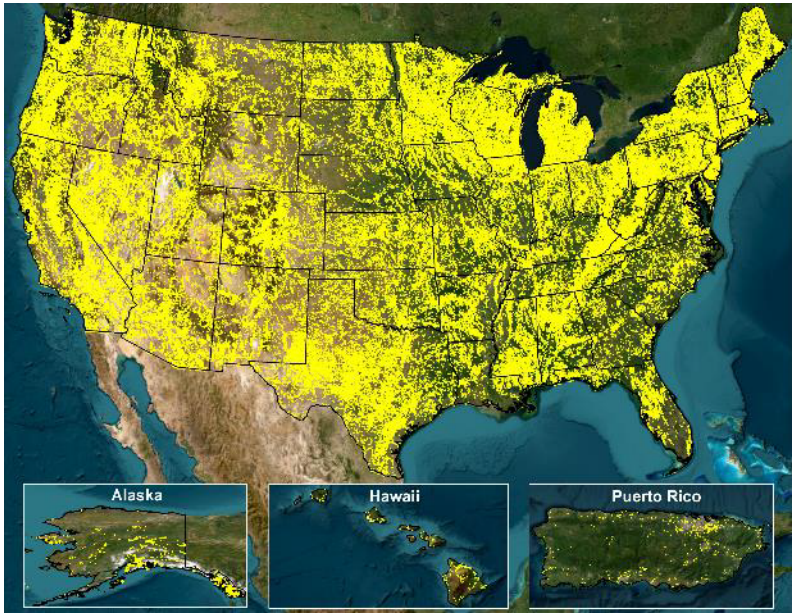


Nassar et al., 2015, By-product metals are technologically essential but have problematic supply, Science Advances 1 (3), e1400180

USGS

Why Study Mine Waste? Resource Recovery *and* Remediation

- **Mine waste is in every state**
  - There is no single authoritative database of all mine locations
- **Many legacy mine sites pose environmental and physical hazards**
  - There is no single authoritative database of legacy mine status
- **Reclaiming mine sites offers co-benefits for remediation and critical mineral recovery**
  - Lack of sampling and characterization
  - Lack of methodology for assessing mineral resources in mine waste
  - Lack of definition of sustainability metrics for future mining and mine waste generation and management



New USMIN geospatial database of current and historical mining locations. Yellow dots are mine features captured from historical USGS topographic maps.

Horton, J.D., and San Juan, C.A., 2016, Prospect- and mine-related features from U.S. Geological Survey 7.5- and 15-minute topographic quadrangle maps of the United States (ver. 10.0, May 2023): U.S. Geological Survey data release, https://doi.org/10.5066/F78W3CHG.

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USGS Mineral Resources Program Mine Waste Studies

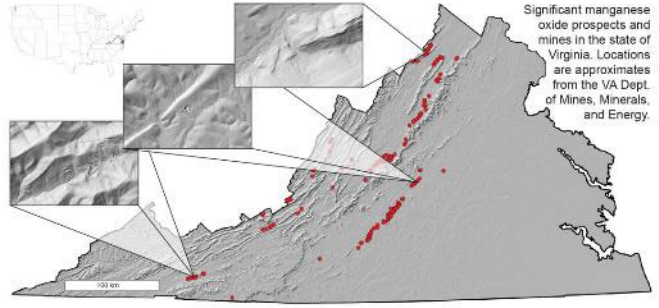
Goals

- Identification and characterization of **additional domestic sources of critical minerals** to mitigate supply chain challenges,
- Evaluation of the **environmental costs and benefits of extracting resources from mine waste**, and
- Development of **tools to support land-management decisions**, including reclamation of legacy mine sites, at federal and state levels.

The National Mine Waste Inventory

USGS, in partnership with other Federal agencies, the States, and private industry, is creating a ***mine waste inventory*** *that will document the amounts of recoverable critical minerals, focused on* ***location, composition, geochemistry, and status of the mine wastes.***

- USMIN Project
- Mine Waste Inventory
- Abandoned Mines Database (DOI)
- Appalachian Manganese Oxide Research Effort



R. McAleer inspects a large excavation of manganese oxide at the Capola Mountain Mine near Zepp, Virginia.

Sandstone breccia cemented by cryptomelane-hollandite (KMn_8O_{16}-$BaMn_8O_{16}$) matrix at Gap Mountain, located approximately nine kilometers NW of Blacksburg, VA.

Manganese-coated faults near Sparta, North Carolina, which was struck by a Mw 5.1 earthquake in 2020.

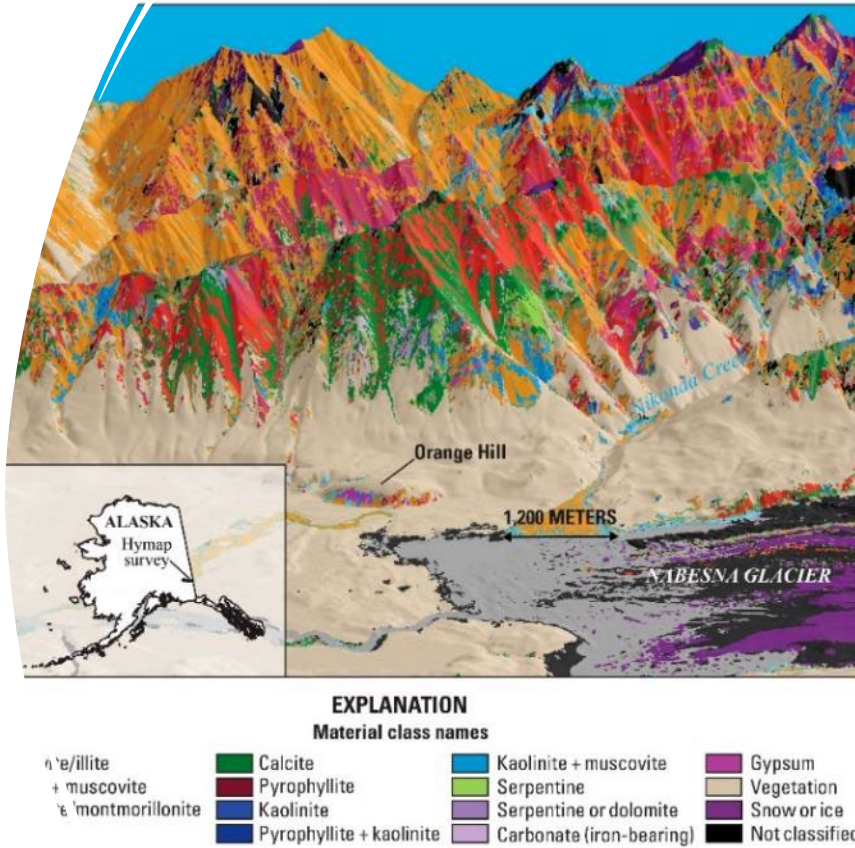
Images Courtesy of Dan Doctor, USGS

USGS

Airborne and Field-based Data Collection and Mapping (Earth MRI)

*Investments in the collection of airborne **geophysical, radiometric, hyperspectral and elevation** data combined with **geologic mapping and sampling** at mine waste sites underpin mine waste research.*

- Airborne radiometric data can help identify REE that might co-occur with U or Th
- Hyperspectral drone-based data can be collected at the mine-scale to help evaluate the mine waste extents



USGS

In-depth Site-Specific Integrated Studies to Characterize Processes at *Legacy* Mine Sites

Biogeochemical and mineralogical analyses and laboratory experiments *on solid mine wastes, affected water and biota provide the foundation for interpretation in both* ***active and legacy mine/mineral processing sites****. Studies ranging from* ***atomic to regional and national scales*** *are critical for predicting the potential recoverability, mobility, bioavailability, and toxicity of elements in mine waste and will aid reclamation and mineral recovery.*

- A post-fire study in Idaho is focusing on the remobilization of mercury associated with historical placer mining
- Sulfur cycle influence on release of sulfide-hosted critical minerals and environmental effects associated with abandoned and future mines
- Ultramafic lands: Sustainability Challenges and Resource Opportunities

Image Courtesy of Phil Verplanck, USGS

In-depth Site-Specific Integrated Studies to Characterize Mine Wastes

Mineralogical investigations of mine waste inform ***critical mineral content, recovery potential, environmental impacts.***

- Critical minerals, toxic elements, and **changes due to weathering and reprocessing are being examined** in mine waste at a **Superfund mine waste** site in Oklahoma.

- Evaluating the potential for **tellurium recovery from mine wastes** to inform the health risks associated with tellurium-enriched historical tailings

USGS

Images Courtesy of Sarah Hayes and Sarah Jane White, USGS

Source: USGS

Data Analysis, Synthesis, and Interpretation to Inform Models and Improve Understanding

*Interpretation and synthesis of new and existing data leads to the development of a variety of **models** that can generalize results determined under specific conditions at specific sites. These models can provide **a general understanding and prediction** of mine waste and its behavior in varying geologic, hydrologic, climatic settings and for different mine, mineral and deposit types.*

- Using hyperspectral data to identify and locate abandoned mine features remotely
- Mineral Mining Waste as a Resource

Image Courtesy of Ryan Taylor, USGS

USGS

Assess Potential Resources, Risks, and Recovery Economics

Any evaluation of the feasibility of recovering mineral resources from mine waste requires an ***assessment of the costs and benefits of mineral resource recovery,*** *including mineral endowment, hazards and risks associated with extraction and the derived products, valuation and use of commodities and restored ecosystem services and potential economic benefits.*

- Primary, coproduct, and byproduct Critical Mineral commodities in placer deposits in Alaska
- Mine waste - A multi-resource integrated approach to critical minerals prospectivity and environmental characterization of mine waste for Alaska

Image Courtesy of Sue Karl, USGS

Action: Decision Support
Example - the Federal Mining Dialogue Mine Waste Demonstrations

- Interested in exploring the extraction of critical minerals from mine waste

Land Management

Research and Development

Regulatory

Statutory

Federal Mining Dialogue Mine Waste Demonstrations: Addressing E.O. 14017 100-day Supply Chain Report Recommendations

Image Courtesy of Ryan Taylor, USGS

The Mineral Resources Program is leading a federal effort to evaluate mine waste as a resource for critical minerals and s*upport demonstration projects to* ***reprocess***, ***reclaim***, ***remediate*** ***and*** ***restore*** *abandoned mine wastes*

The White House, BUILDING RESILIENT SUPPLY CHAINS, REVITALIZING AMERICAN MANUFACTURING, AND FOSTERING BROAD-BASED GROWTH: 100-Day Reviews under Executive Order 14017 June 2021, p. 197

Expected Outcomes

These studies will inform land use decisions and regulatory decisions.

Quantifying the potential for critical mineral resources in mine waste will inform waste managers' reprocessing strategies, environmental management, and reclamation.

The National Mine Waste Inventory will guide investments by other agencies – for example, prioritizing the Department of Energy's BIL-funded investments in technologies to reprocess mine waste.

Ultimately, future re-mining of mine wastes will directly benefit state economies and support potential clean-up efforts.

USGS photo of silicon carbide

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EARTH MAPPING RESOURCES INITIATIVE (EARTH MRI)

Darcy McPhee

U.S. Department of the Interior
U.S. Geological Survey

27 March 2024, National Academies of Science, Engineering, and Medicine

Earth MRI: Mapping the Nation's Geologic Framework and Mineral Resources

Current focus

- Critical mineral resources (in deposits and mine wastes)
- Industrial minerals

Additional applications

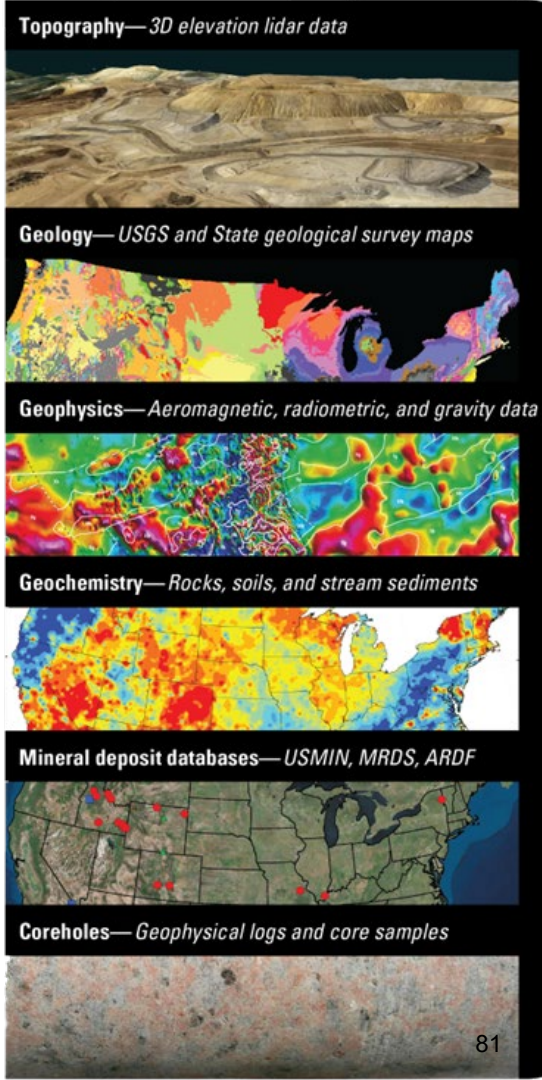
- Energy resources
- Natural hazards
- Water resources
- Land use planning
- Infrastructure

Partners

- State geological surveys
- Federal agencies
- Tribes
- Industry
- NGOs
- Academia
- International

Funding

- $10.8M in annual appropriations
- $64M/yr for 5 yrs in BIL funding
- $5M in disaster supplemental funds



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https://www.usgs.gov/special-topics/earth-mri

Earth MRI Data and Interpretations

Collecting fundamental geoscience data including:

- Airborne geophysical surveys (magnetic, radiometric, electromagnetic)
- Hyperspectral surveys
- High-resolution elevation (lidar) surveys
- Geochemical surveys
- Detailed geologic mapping by State geological surveys
- Preservation of minerals data
- Mine waste inventory and characterization with State partners

https://www.usgs.gov/special-topics/earth-mri

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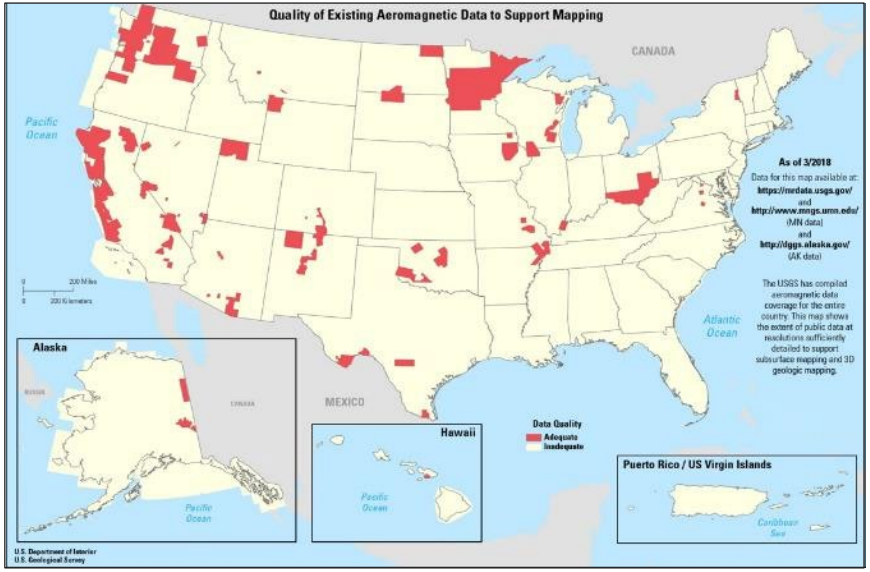
EARTH MAPPING RESOURCES INITIATIVE (EARTH MRI)
LAUNCHED IN 2019 BECAUSE THE NATION IS UNDER-MAPPED

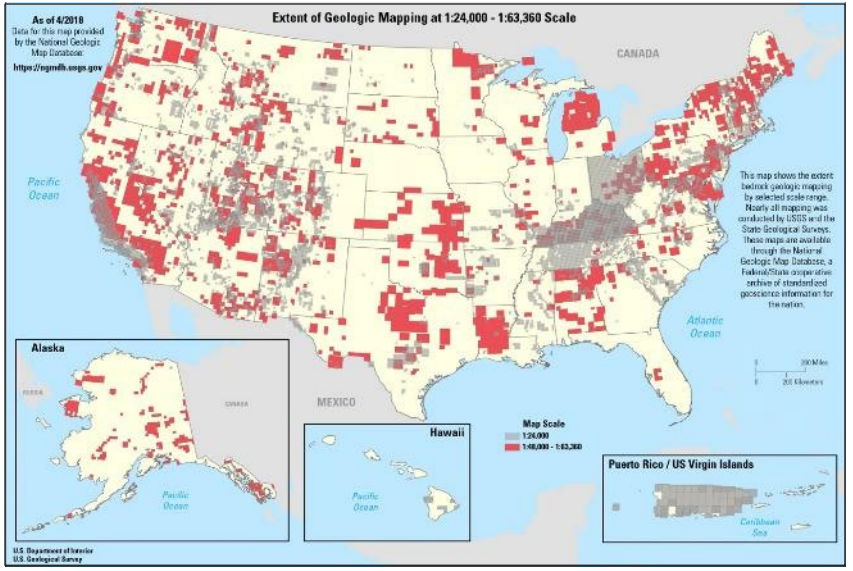
Pre-existing Subsurface Geophysics (2019)



mrdata.usgs.gov,
www.mngs.umn.edu,
dggs.alaska.gov

Usable quality
(<300m line spacing)

Pre-existing Geologic Mapping (2019)



ngmdb.usgs.gov

Moderate (1:40,000-1:63,360)
Fine-scale (1:24,000)

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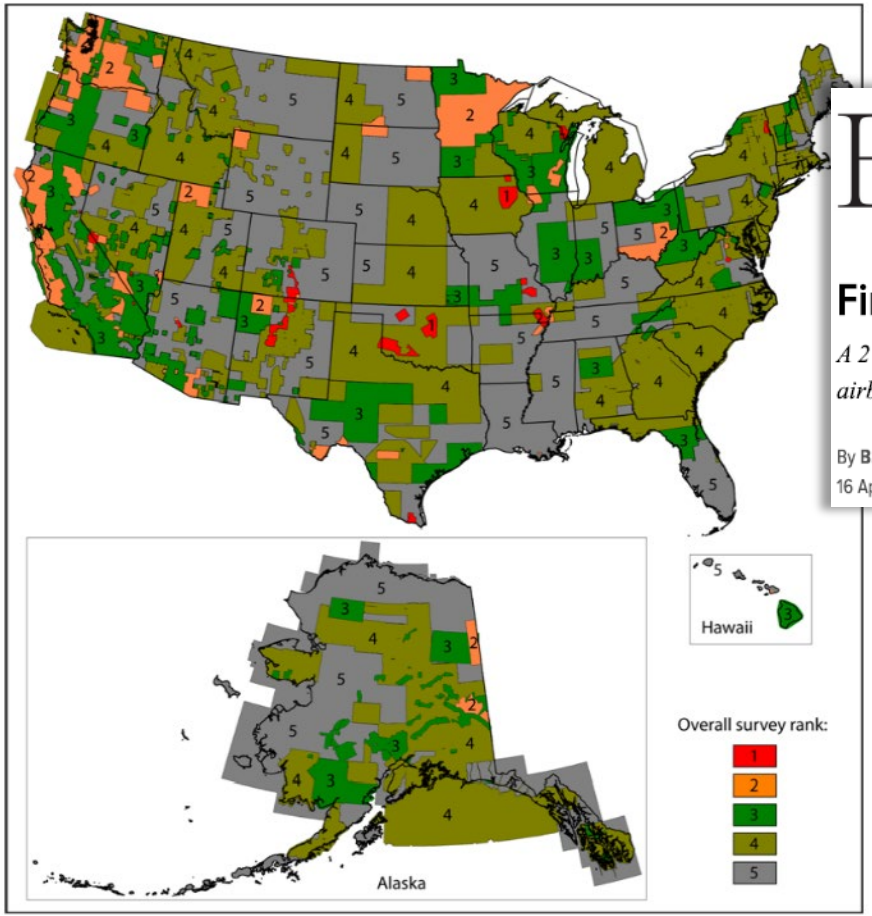
EARTH MRI LAUNCHED IN 2019 BECAUSE THE NATION IS UNDER-MAPPED



Eos

Finding the Gaps in America's Magnetic Maps

A 2017 executive order mandated a plan to evaluate U.S. access to critical mineral resources, but the airborne magnetic survey maps that support this effort are sadly out of date.

By B. J. Drenth and V. J. S. Grauch
16 April 2019

"Assessment of the quality of existing aeromagnetic surveys for the United States, with rank 1 indicating the best quality and rank 5 indicating the worst. The map results from the ranking scheme applied to each public aeromagnetic survey by ***Eric Anderson, Ben Drenth, V.J.S. Grauch, Anne McCafferty, Anji Shah, and Dan Schierer*** *of the USGS"*

Rank 1 data coverage of CONUS has increased 10-fold since 2019

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EARTH MRI: WORKING ACROSS USGS

Within the USGS:

Mineral Resources Program (MRP) provides…

- Program management
- Funding (appropriated and BIL)
- Prioritization of mapping and data collection
- Geophysical and hyperspectral surveys

Partner programs provide…

National Cooperative Geologic Mapping Program (NCGMP)

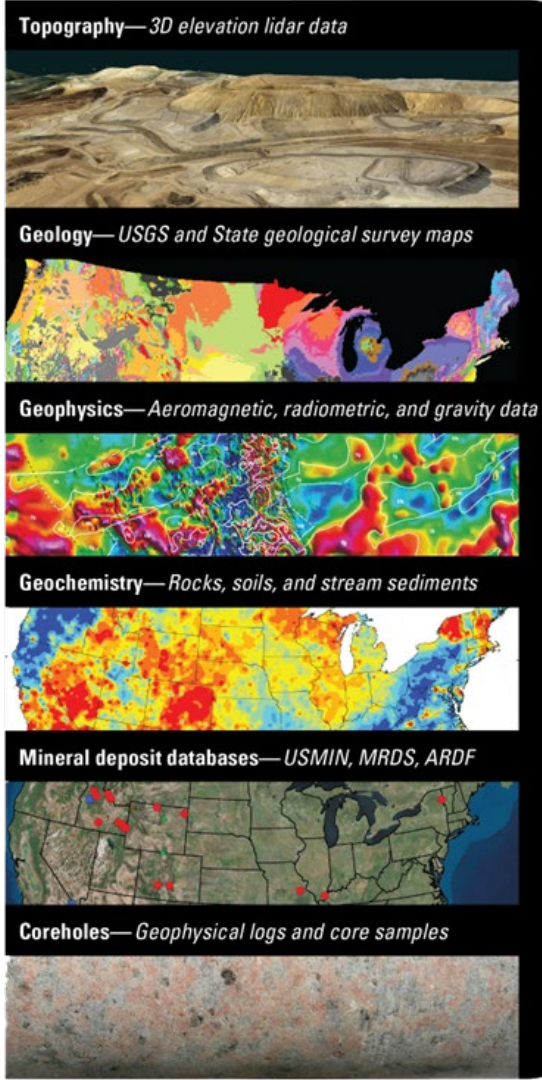
- Geologic mapping with state surveys
- Geochemical samples for analysis by MRP

National Geospatial Program (NGP)

- Lidar surveys (3DEP)

National Geological and Geophysical Data Preservation Program (NGGDPP)

- Data preservation and workshop support



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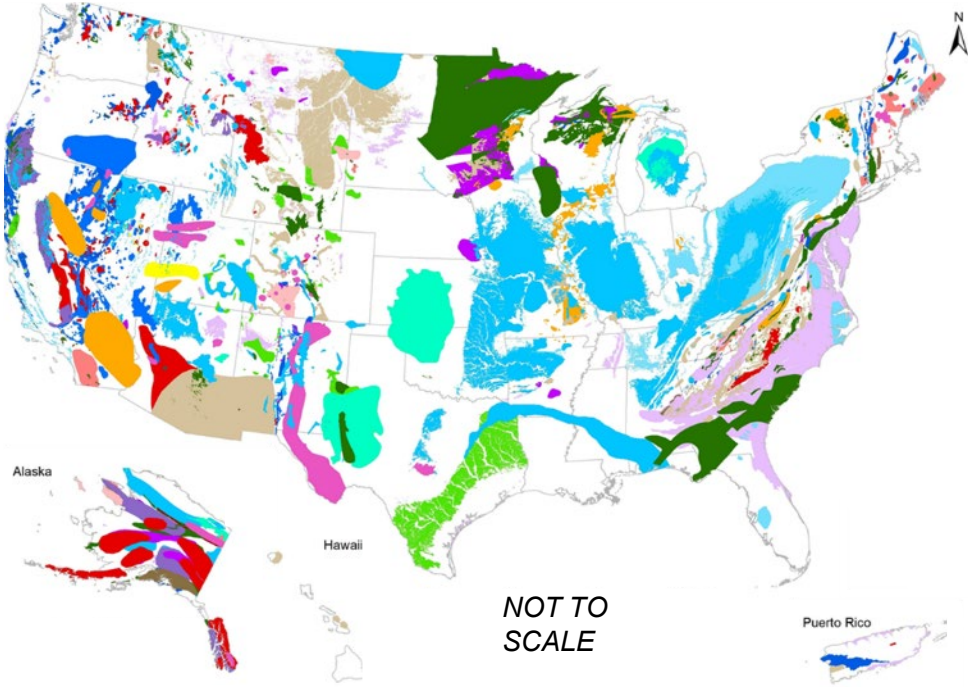
Innovation

Areas with Potential for Critical Mineral Deposits and Mine Waste Critical Mineral Resources

USGS is using a mineral systems approach to:

- Guide Earth MRI data collection
- Accelerate assessing critical mineral resources
- Will lead to products showing resource managers and developers where emerging minerals-dependent technologies may create economic opportunities and community concerns



Mineral System	Critical Mineral Commodities
Alkalic porphyry	Al, As, Bi, fluorspar, Ga, Ge, In, Mn, PGE, Sb, Sc, V, W, Zn
Arsenide	As, Bi, Co, Ni, Sb
Basin brine path	barite, Co, Cs, Ga, Ge, In, Li, Mg, PGE, REE, Sc, Sn, Zn
Carlin-type	As, Sb
Chemical weathering	Al, Bi, Co, Ga, Ge, In, Li, Mn, Nb, Ni, PGE, REE, Sc, Zn
Climax-type	Al, As, Be, Bi, fluorspar, Ga, Ge, In, Li, Mn, Nb, REE, Sb, Sc, Sn, W, Zn
Coeur d'Alene-type	Co, Ga, Ge, In, Sb, Zn
Hybrid magmatic REE / basin brine path	barite, Be, fluorspar, Nb, REE, Ti
IOA-IOCG	As, Bi, Co, Ga, Ge, In, Mn, Ni, REE, Sb, Zn
Lacustrine evaporite	Cs, Li, Mg, Mn, Rb, W, Zn
Mafic magmatic	Co, Cr, Ni, PGE, REE, Te, Ti, V
Magmatic REE	barite, Be, fluorspar, Hf, Nb, REE, Sc, Sr, Ta, Te, Ti, V, Zr
Marine chemocline	Co, Cr, F, Mn, Ni, PGE, REE, V
Marine evaporite	Mg
Metamorphic	Graphite, Mg, REE
Meteoric convection	Sb, Te
Meteoric recharge	Co, Mg, Mn, PGE, REE, Sc, Sr, V
Orogenic	As, graphite, Sb, Te, W
Placer	Barite, fluorspar, Hf, Nb, Mn, PGE, REE, Sc, Sn, Ta, Ti, W, Zr
Porphyry Cu-Mo-Au	Al, As, Bi, Co, Ga, Ge, In, Mg, Mn, PGE, Sb, Sc, Sn, Te, W, Zn
Porphyry Sn (granite-related)	Al, As, Be, Bi, Cs, Ga, Ge, In, Li, Mn, Nb, Sb, Sc, Sn, Ta, Te, W, Zn
Reduced intrusion-related	As, Be, Bi, Cs, Ga, Ge, graphite, In, Li, Mn, Nb, Sb, Sc, Sn, Ta, Te, W, Zn
Volcanogenic seafloor	As, barite, Bi, Co, Ga, Ge, In, Mn, Ni, REE, Sb, Sc, Sn, Te, Zn

***Dicken, C.L, Woodruff, L.G., Hammarstrom, J.M., and Crocker, K.E., 2022**, GIS, supplemental data table, and references for focus areas of potential domestic resources of critical minerals and related commodities in the United States and Puerto Rico: U.S. Geological Survey data release, https://doi.org/10.5066/P9DIZ9N8.*

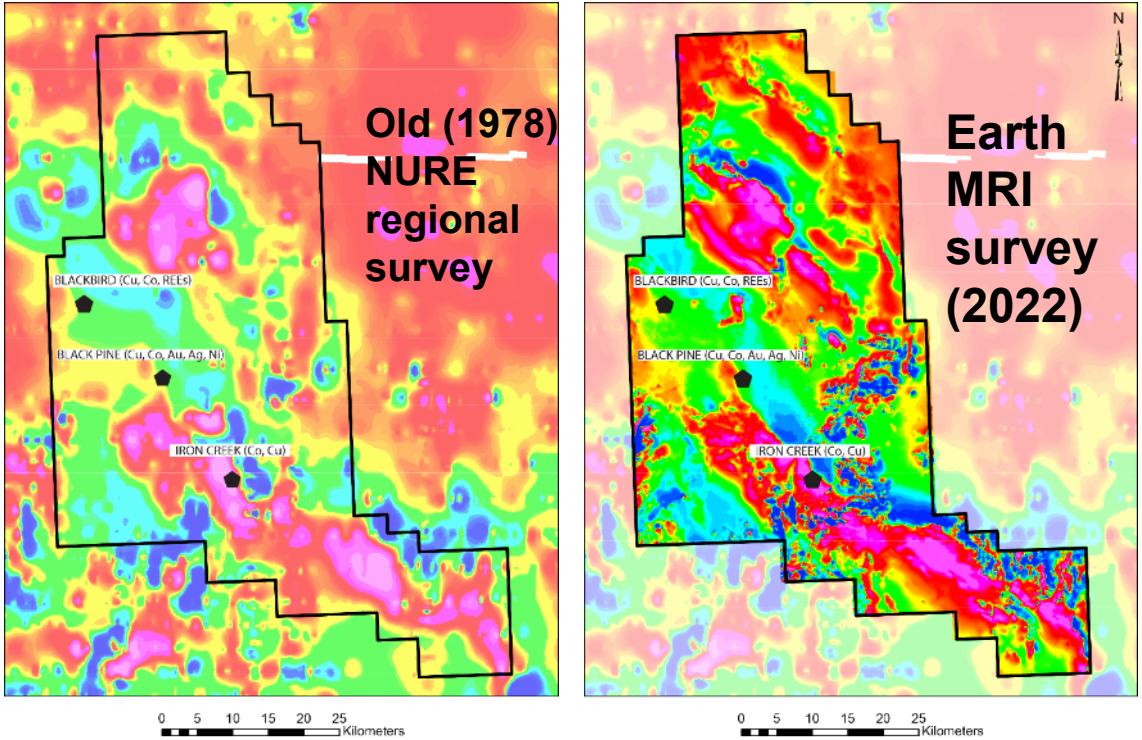
Earth MRI: Nucleating Intergovernmental, Interdisciplinary Partnerships

Partnership: Airborne Magnetic/ Radiometric Survey for Idaho Cobalt Belt, contributing to a consortium studying the geology and mineral resources of the district and developing new technologies for mineralogical and geophysical research.

Idaho Cobalt Belt is an active region for exploration and mining for cobalt, copper, and rare earth element resources.

Collaborators:

- Idaho Geological Survey
- Colorado School of Mines
- North Dakota College
- Virginia Tech
- Mining companies:
  - Electra Battery Materials
  - Idaho Strategic Resources
  - Revival Gold
- Analytical companies:
  - Minalyze AB
  - Norsk Electro Optikk AS
  - Hitachi High-Tech
  - National Center for Autonomous Technologies



Source: Phelps, G., 2022, https://doi.org/10.5066/P9TLBM4U

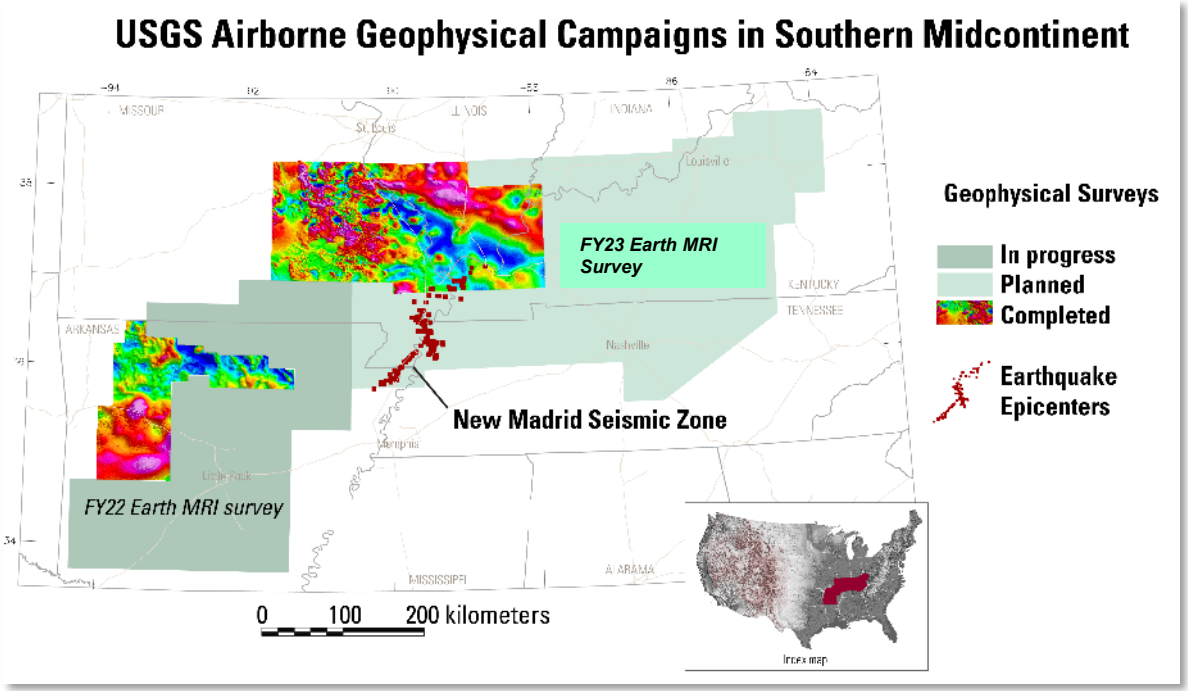
EARTH MRI: ESSENTIAL DATA FOR MULTIPLE DISCIPLINES

Geophysical Survey Campaign for Southern Midcontinent Region

- 2023 Earth MRI high-resolution airborne magnetic and radiometric survey coverage for central and western Kentucky

Science goals:

- Map the magnetic basement to understand controls on ore-forming systems in southern Midcontinent, including REE-bearing mafic intrusions in western Kentucky and the critical mineral-bearing Central Tennessee Mississippi Valley-type zinc district
- 2023 geophysical survey covers the New Madrid seismic zone. Data will help map concealed seismogenic faults
- Surveys cover southern Illinois Basin to help understand potential for carbon sequestration



Slide courtesy of Anne McCafferty (USGS)

Earth MRI: Nucleating Intergovernmental, Interdisciplinary Partnerships

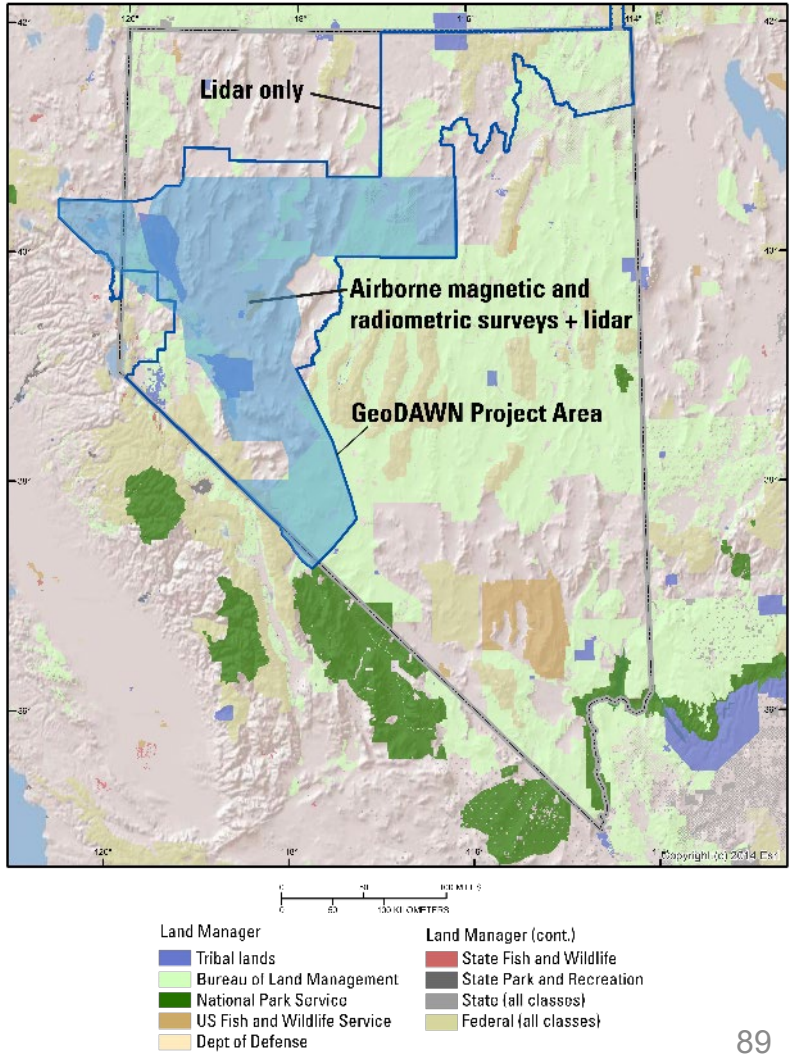
USGS- and DOE-led partnership: Geoscience Data Acquisition for Western Nevada (GeoDAWN)

Data collection:

- Collect high resolution airborne magnetic and radiometric data and lidar data to inform understanding of regional geology, natural resources, and geologic hazards

Partnership:

- USGS, DOE Geothermal Technologies Office, DOI BLM, USDA NRCS, DHS FEMA, Nevada Bureau of Mines and Geology
- Pooled funding: $10M



USGS science for a changing world

Flagship products and data

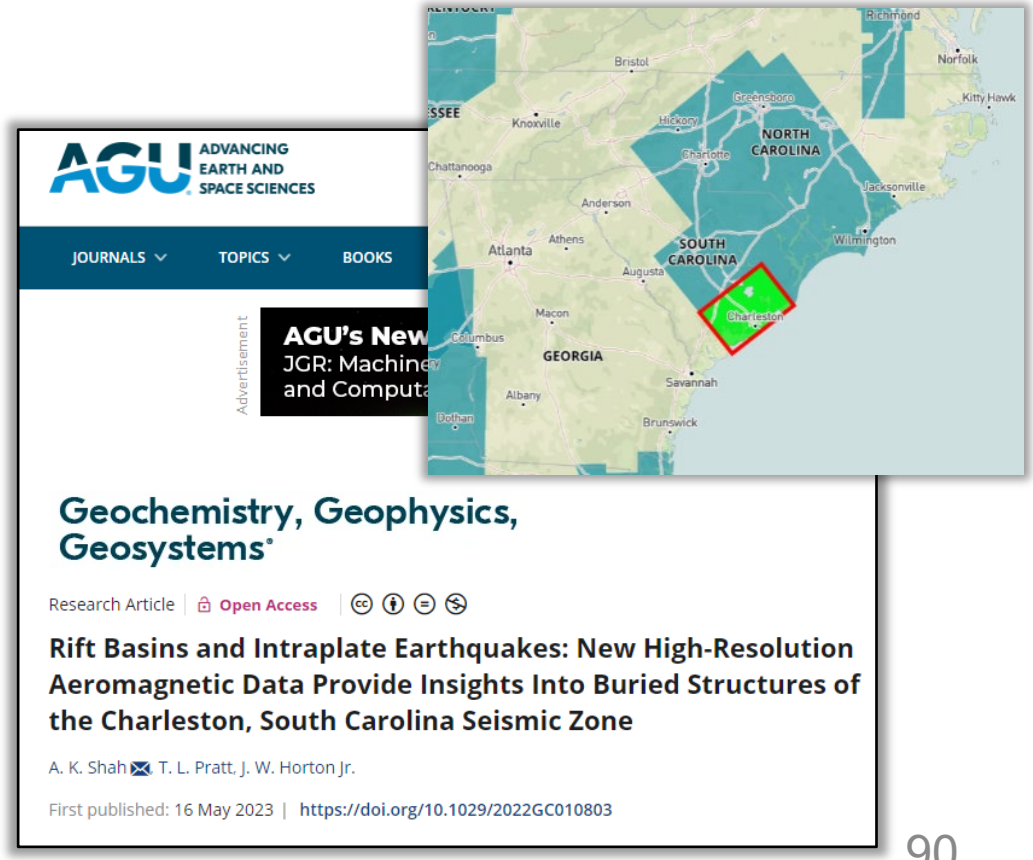
Earth MRI: Essential Data for Multiple Disciplines

Cross-USGS partnership: the Charleston Seismic Zone

Data collection:
- Aeromagnetic and radiometric survey, previous borehole sample information, and reprocessed seismic reflection profiles

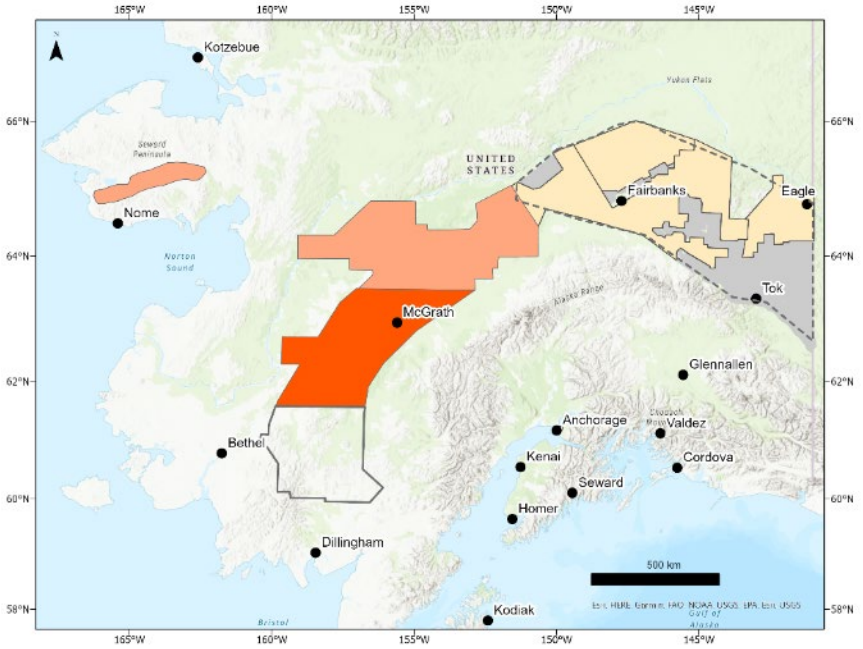
USGS partnership:
- MRP
- Earthquake Hazards Program
- NCGMP

Science goals:
- Map heavy mineral sands
- Delineate faults in intraplate seismic zones
- Map features associated with failed rift basins
- Image subsurface structures & evaluate recent fault activity within the Charleston seismic zone & the associated Mesozoic South Georgia rift basin.



Earth MRI Geophysics in Alaska in collaboration with Alaska DGGS

- Provide modern geophysical maps to better understand the geologic framework of Alaska
- Geophysical maps are crucial for mapping the concealed bedrock geology
- Current magnetic and radiometric surveys focus is the Yukon-Tanana Uplift and Kuskokwim River Region
- Airborne electromagnetic survey in Seward Peninsula over graphite-rich region
- Alaska data also served online with map service for analysis at: https://dggs.alaska.gov



Year	Area (km^2)	Status
2019-2021	56,000	complete
2022	45,000	data collection summer 2023
2023	40,000	data collection 2024

Earth MRI Airborne Electromagnetic Surveys

- Airborne electromagnetic (AEM) surveys image conductivity in the subsurface
- Aid in assessing US graphite resources
- Earth MRI is currently using AEM to:
  - Alabama: Map the Alabama graphite-vanadiaum belt and refine structural understanding of the complex orogenic history of the southern Appalachians
  - Alaska: Target graphite mineral systems in the Seward Peninsula
  - Basin and Range: Investigate basin brine and lacustrine evaporite mineral systems prospective for lithium resources

STATE NEWS RELEASE

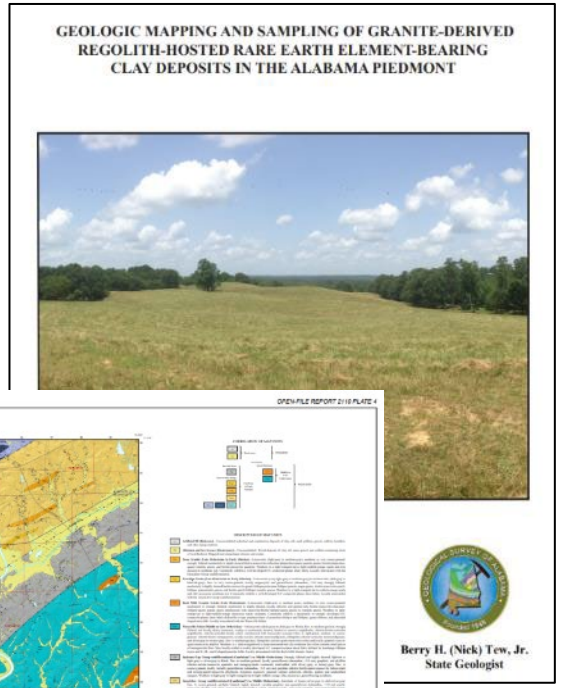
Bipartisan Infrastructure Law helps map critical mineral resources in Alabama

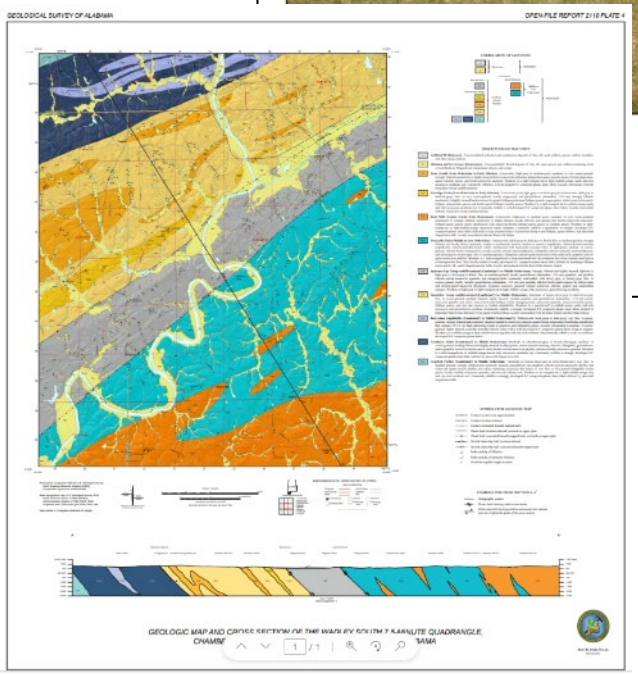
Research across the Piedmont of Alabama will provide data to improve knowledge of mineral resources vital to a range of industries and the Nation's economy

USGS science for a changing world

Earth MRI Geologic & Geochemical Mapping

- Total of 25 State geological surveys supported in 2023
- 16 geologic and/or geochemical mapping projects by State geological surveys funded in 2023
- 2 from states not previously involved in Earth MRI
- 5 reconnaissance geochemical mapping projects involving 9 additional State geological surveys





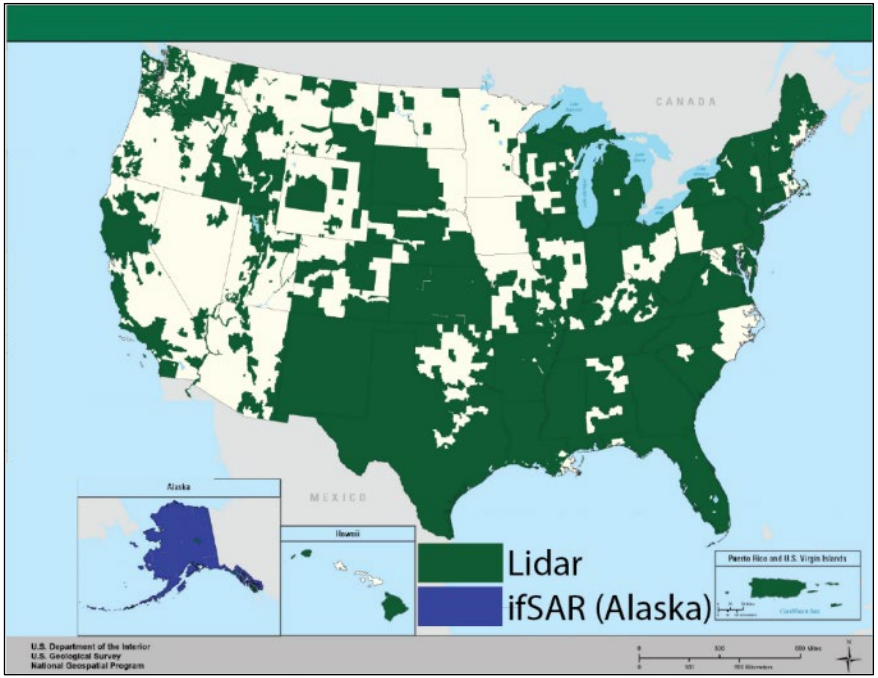
Geologic Mapping of Regolith-Hosted REE Deposits in the Alabama Piedmont, Earth MRI 2019

USGS science for a changing world

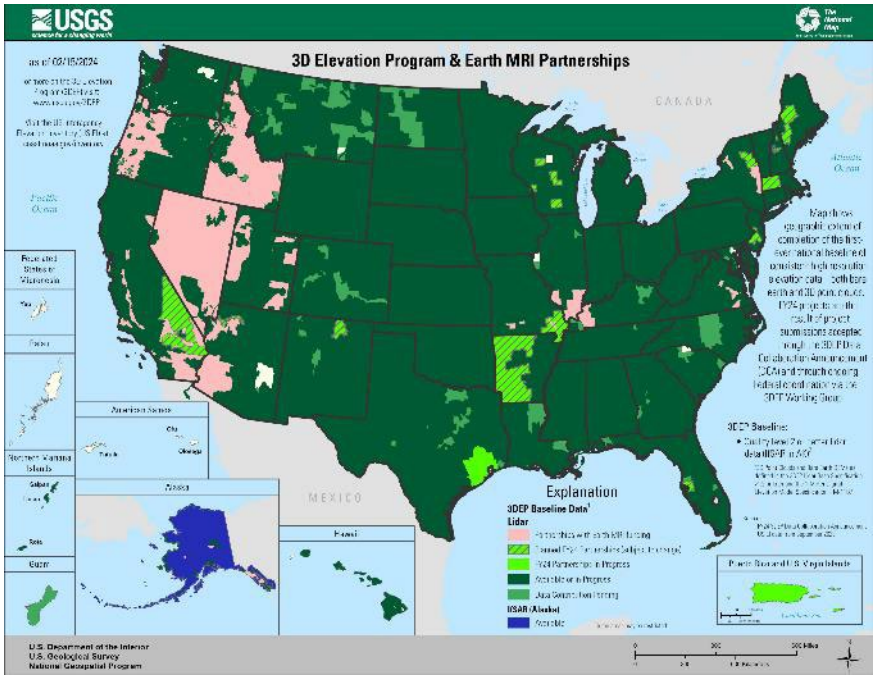
Flagship products and data

Earth MRI Contributions to National Lidar Coverage

Pre-Earth MRI Status of Lidar Coverage
Data available or planned that meet 3DEP specifications



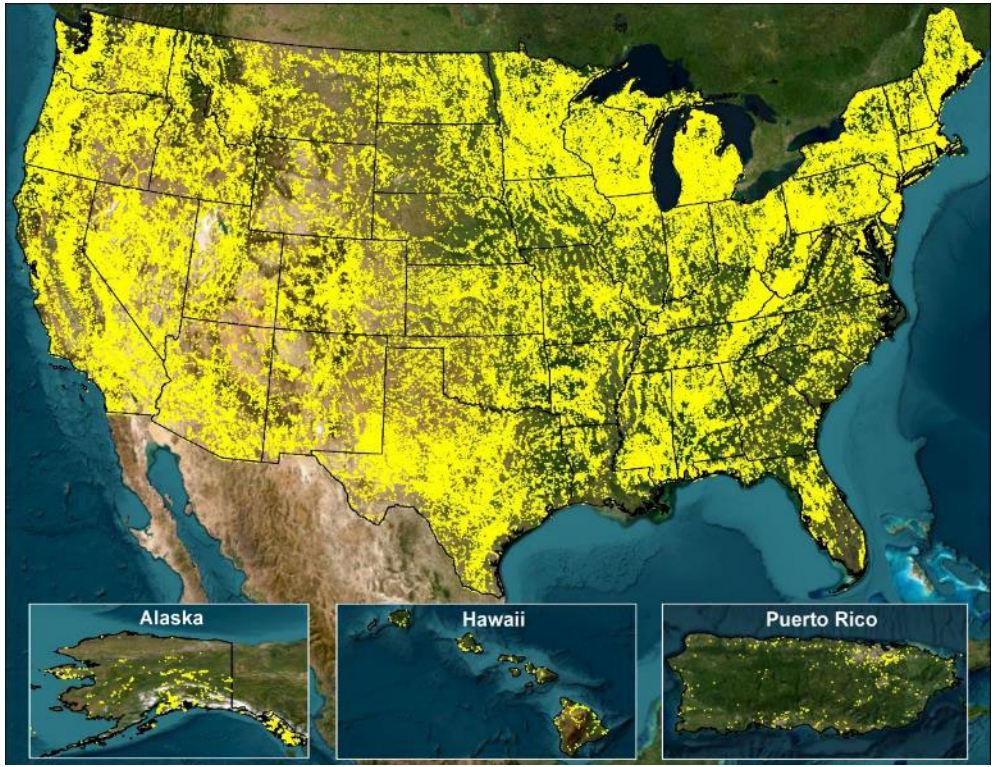
Status as of Feb 2024: Earth MRI-funded additions to Lidar Coverage
Data available or planned that meet 3DEP specifications



Earth MRI Mine Waste Efforts

Earth MRI works with the State Geological Surveys to contribute to MRP mapping and sampling of mine waste across the country to evaluate the potential for critical mineral recovery in association with remediation. Key elements of this include

- **National mine waste inventory** geospatial database of current and historical mine waste
- **Mine waste characterization** projects to help inform the potential critical mineral endowments of nonfuel hard-rock mine waste materials and reclamation decisions



USMIN geospatial database of current and historical mining locations. Yellow dots are mine features captured from historical USGS topographic maps.

Horton, J.D., and San Juan, C.A., 2016, Prospect- and mine-related features from U.S. Geological Survey 7.5- and 15-minute topographic quadrangle maps of the United States (ver. 10.0, May 2023): U.S. Geological Survey data release, https://doi.org/10.5066/F78W3CHG.

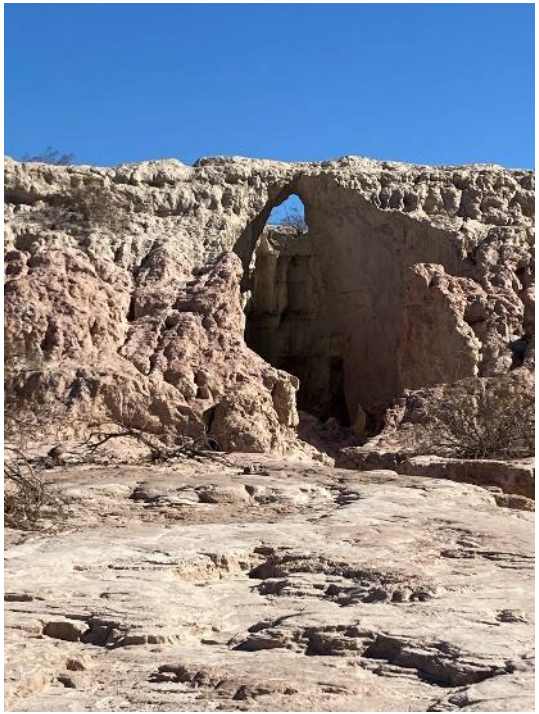
USGS science for a changing world

BIL-Funded Earth MRI/State Mine Waste Projects

- 2023-2026 collaboration with State geological surveys
- Builds on 2022 pilot projects with CO, FL, and NM
- Funds 2-year projects focusing on providing existing data (inventory) or collecting new data (characterization)
- The USGS/MRP developed mine waste site characterization and sampling protocols to guide this effort
- Training and geochemical analyses provided by USGS
- State geological surveys encouraged to work with other State agencies with mine waste management responsibilities

Earth MRI state mine waste projects

CO	Characterization
FL	Characterization
AZ	Inventory
IA	Characterization
KY	Inventory
MT	Inventory, Characterization
NC	Inventory, Characterization
NV	Inventory
OK	Inventory
WA	Inventory, Characterization
IL	Inventory, Characterization
MI	Inventory
MO	Inventory, Characterization
NM	Inventory, Characterization
NY	Inventory, Characterization
VA	Inventory



Mill Tailings Deposits at the Katherine Mine; photo courtesy of Bob Seal, USGS

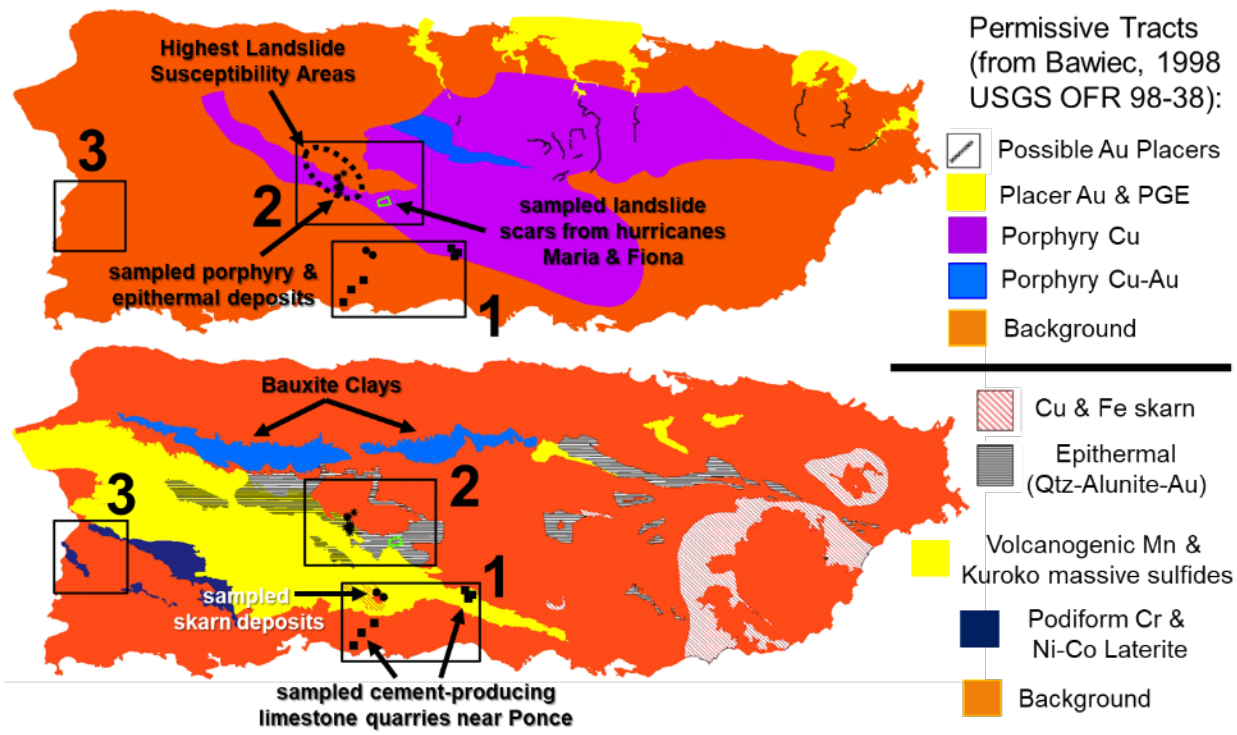
Earth MRI: Essential Data for Multiple Disciplines

2023 Earth MRI Hyperspectral Data Acquisition for the semi-arid Western US.

USGS-NASA partnership: Hyperspectral Survey of the Southwestern U.S.

- Hyperspectral data helps identify minerals at the surface, such as in mine waste. These data are also useful for understanding **geological acid mine drainage, debris flows, agriculture, wildfires, biodiversity, and many other fields**.
- USGS Earth MRI funding is supporting NASA's airborne hyperspectral data collection.
- **Cross-disciplinary innovation investment:** The bare earth/solid earth remote sensing science community is small; MRP Spectral Library and large-area coverage are essential to grow the community.
- 2023 data collection covered more than **172,500 sq. km**. 2024 data collection to start in April 2024.

Earth MRI District Scale Hyperspectral Surveys in Puerto Rico- Disaster Resilience



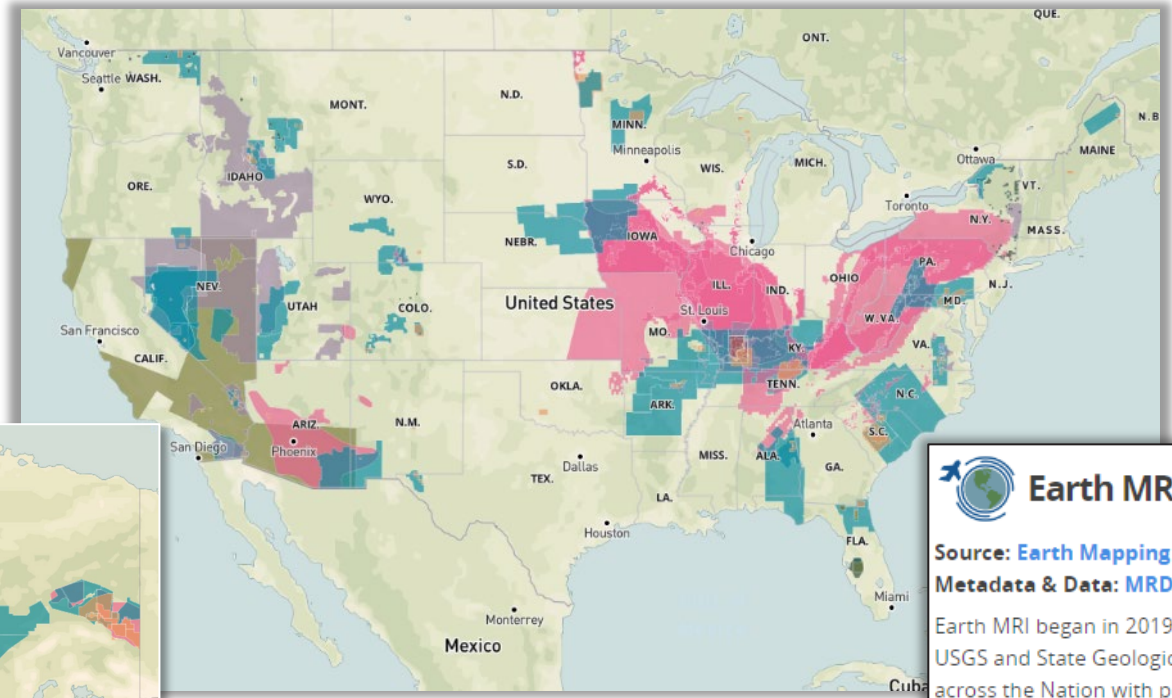
from Bernard Hubbard, USGS

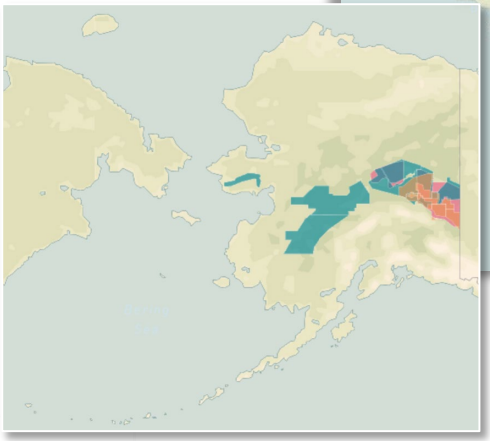
- Funded through the 2023 Disaster Relief Supplemental Approps Act
- Map the geologic landscape to understand natural hazards and identify surface materials that could be used to build and enhance hazard-resilient infrastructure
- Surveys flown in February 2024

USGS science for a changing world

Flagship products and data

EARTH MRI DATA AND REPORTS AT WWW.USGS.GOV/EARTHMRI





Earth MRI Acquisitions Viewer

Source: Earth Mapping Resources Initiative (Earth MRI)
Metadata & Data: MRData, NGMDB (v.10, January, 2024)

Earth MRI began in 2019, and is a partnership between the USGS and State Geological Surveys to acquire data in areas across the Nation with potential for hosting critical mineral resources. Click any map area or table record to learn more.

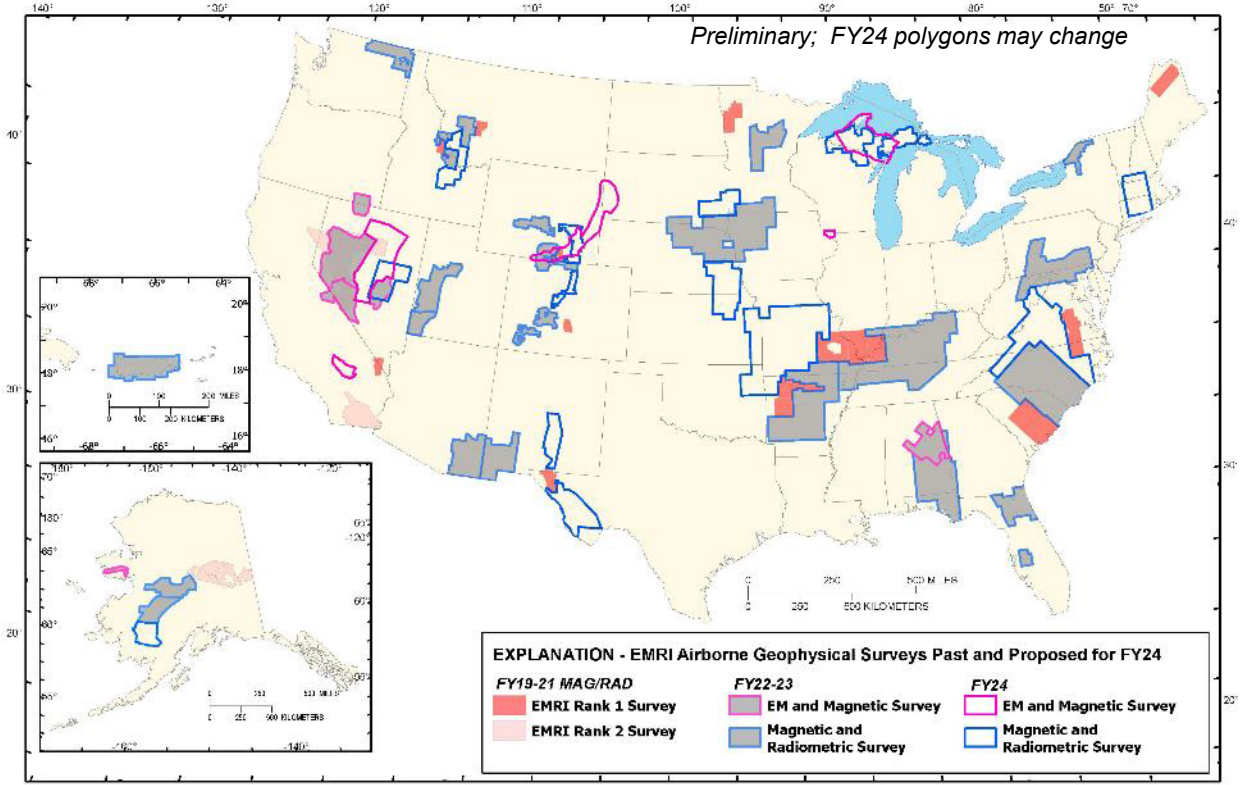
All | Geologic Mapping | Geophysics | Lidar | Reconnaissance Geochemistry | 3D Geological Model | Hyperspectral | Mine Waste

Show All Projects | Show Completed Projects

USGS science for a changing world

https://www.usgs.gov/special-topics/earth-mri

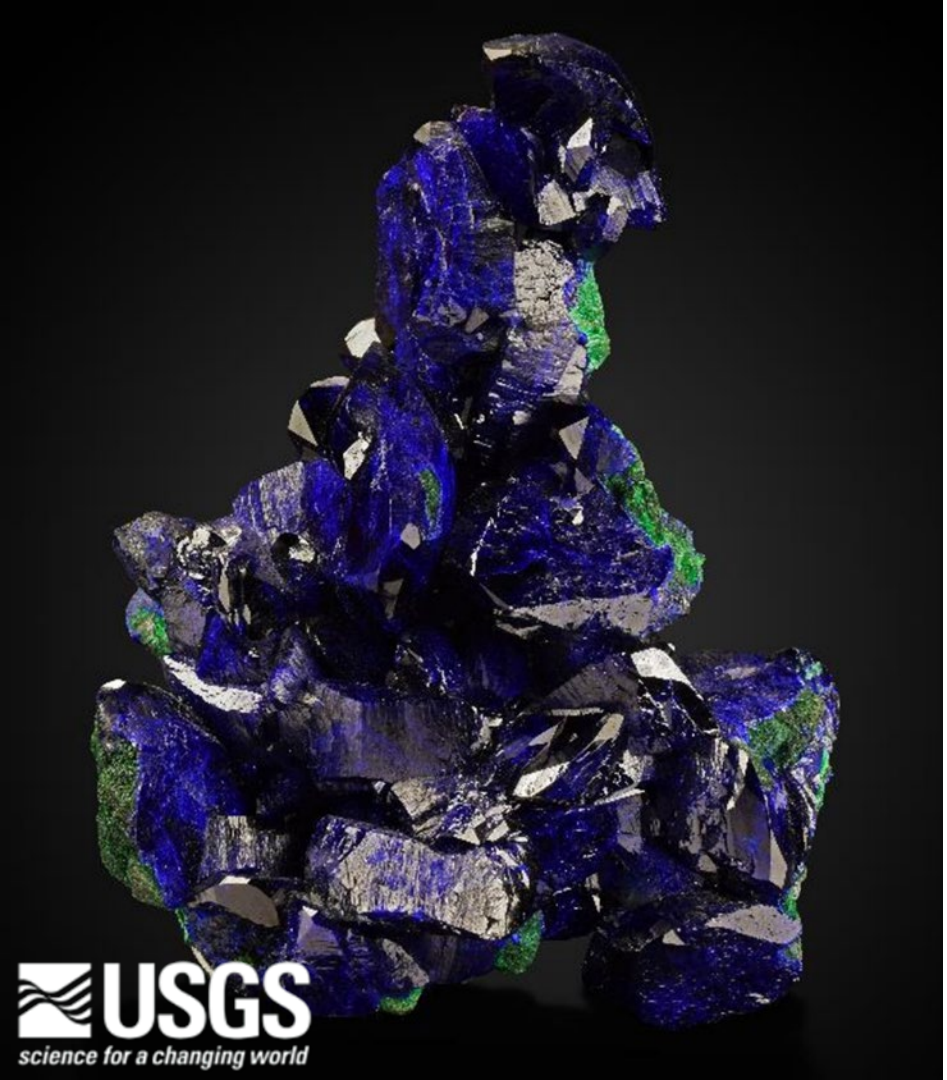
2024 Earth MRI Projects



- Contracting for 17 new geophysical surveys (5 AEM, 12 mag/rad)
- 22 new geological/ geochemical mapping projects with State geological surveys
- FY24 AVIRIS Hyperspectral Spring campaign
- Lidar TBD
- Supporting 15 new data preservation projects with State surveys
- 2024 Mine Waste Funding Opportunity for State surveys (funding decisions in June)
- Disaster Supplemental: Geologic mapping project with Florida Geological Survey; Hyperspectral surveys in Puerto Rico

Annual Earth MRI Workshop: Building the Community's Joint Priorities

- Next annual workshop:
  - USGS and AASG 6th Annual Earth MRI Workshop
  - October 22-24, hybrid/in-person at USGS headquarters, Reston, VA
- Major topics:
  - Review status and discuss future directions of Earth MRI
  - Presentations of Earth MRI projects by USGS and State Geological Survey scientists
  - Jointly plan airborne geophysical surveys, interstate geochemical mapping, cross border mapping/stratigraphy projects, hyperspectral surveys, etc.
  - Regional breakout sessions
  - Review implementation processes and discuss improvements
- Poster Session
- VIP speakers



THANK YOU

1996 and 2003 National Academies Reviews

Mineral Resources and Society: A Review of the U.S. Geological Survey's Mineral Resource Surveys Program Plan (1996)

- Review conducted at the time of the dissolution of the Bureau of Mines with the transfer of the minerals information function to USGS and significant budget cuts and an associated Reduction in Force in the USGS Geologic Division, including MRP.
- General Recommendations on:
  1. the program's vision, mission, and objectives;
  2. increased collaboration with users, balanced with independent research;
  3. maintaining and increasing core competence; and
  4. planning, prioritization, and performance.

1996 and 2003 National Academies Reviews

Future Challenges for the U.S. Geological Survey's Mineral Resources Program (2003):

1. assess the USGS's response to the 1996 review of the MRSP plan;
2. evaluate the contributions of the minerals information functions in meeting the goals of the USGS and its partner agencies
3. characterize how the customer base for the program has changed since the 1996 review; and
4. examine how the program's vision and activities should evolve to meet the nation's future needs over the next decade.

1996 and 2003 National Academies Reviews

Future Challenges for the U.S. Geological Survey's Mineral Resources Program (2003) recommendations (subset):

- comprehensive, mineral-related data and research continue to be published in the USGS's traditional modes of data dissemination
- external review panel be inaugurated to gauge methods and results
- simple, clear mission and vision statements, goals, and objectives that will serve as the guiding principles
- self-assessment to identify and define its core competence… evaluate actions needed to maintain such competence…relate those findings to its staffing and staff development plans
- management review of proposals to align the work with strategic objectives
- an expanded vision that embraces a broad definition of mineral resources, including a focus on life cycle and sustainable development; a strong international role; and a balance between basic and applied research.

Energy Act of 2020	Bipartisan Infrastructure Law	Inflation Reduction Act	Appropriations Report Language
Forecast critical mineral supply chains Update the Nation's list of critical minerals on a 3-year cycle Assess domestic critical mineral resources Co-benefits/co-production/waste as a resource (geothermal, minerals, …) §7002(k)(2-3) Design an extramural grant program addressing gaps in universities' geoscience education & research	§40201 Earth MRI to include "above ground" resources (mine waste and more) Assess the domestic resource base (above and below ground) §40415 Energy Information Administration to collaborate with USGS mineral supply chain forecasting §11526 Federal Highway Administration to collaborate with USGS on covered resources	Creates new uses for the list of critical minerals; MRP's work now guides as much as $9 billion in federal BIL and IRA investments. CEQ and the Federal Permitting Improvement Steering Council's FAST41 permitting process now applies to qualifying critical mineral development projects.	Design a construction resources effort • House Report 117-400 accompanying 2023 appropriations Lithium • … Pyrrhotite in construction resources • House Report 116-9 accompanying 2019 appropriations

Executive Order 13817 (2017) – A Federal Strategy To Ensure Secure and Reliable Supplies of Critical Minerals	Executive Order 13953 (2020) – Addressing the Threat to the Domestic Supply Chain	Executive Order 14017 (2021) – America's Supply Chains
Develop the first whole-of-government list of critical minerals Develop a strategy to reduce the Nation's reliance on critical minerals		Collect and disseminate mineral information Forecast critical mineral supply chains and their disruptions Identify sites where critical minerals may be sustainably produced Develop a national strategy to reclaim materials from mine wastes Develop a national strategy to strengthen supply chains

NMIC: Longest-standing Mineral Information Collection Authorities

- Organic Act of 1910, P.L. 61-179; Mining and Mineral Policy Act of 1970, P.L. 91-631; National Materials and Minerals Policy, Research, and Development Act of 1980, P.L. 96-479
- These require or authorize:
  - The Secretary of the Interior to "collect, evaluate, and analyze information concerning mineral occurrence, production, and use from industry, academia, and Federal and State agencies"
  - Providing guidance to the minerals industry to ensure continuity of production
  - Providing data on national defense industrial base capacity and expansion capabilities
  - Advising on acquisitions and disposals of mineral materials from the National Defense Stockpile.

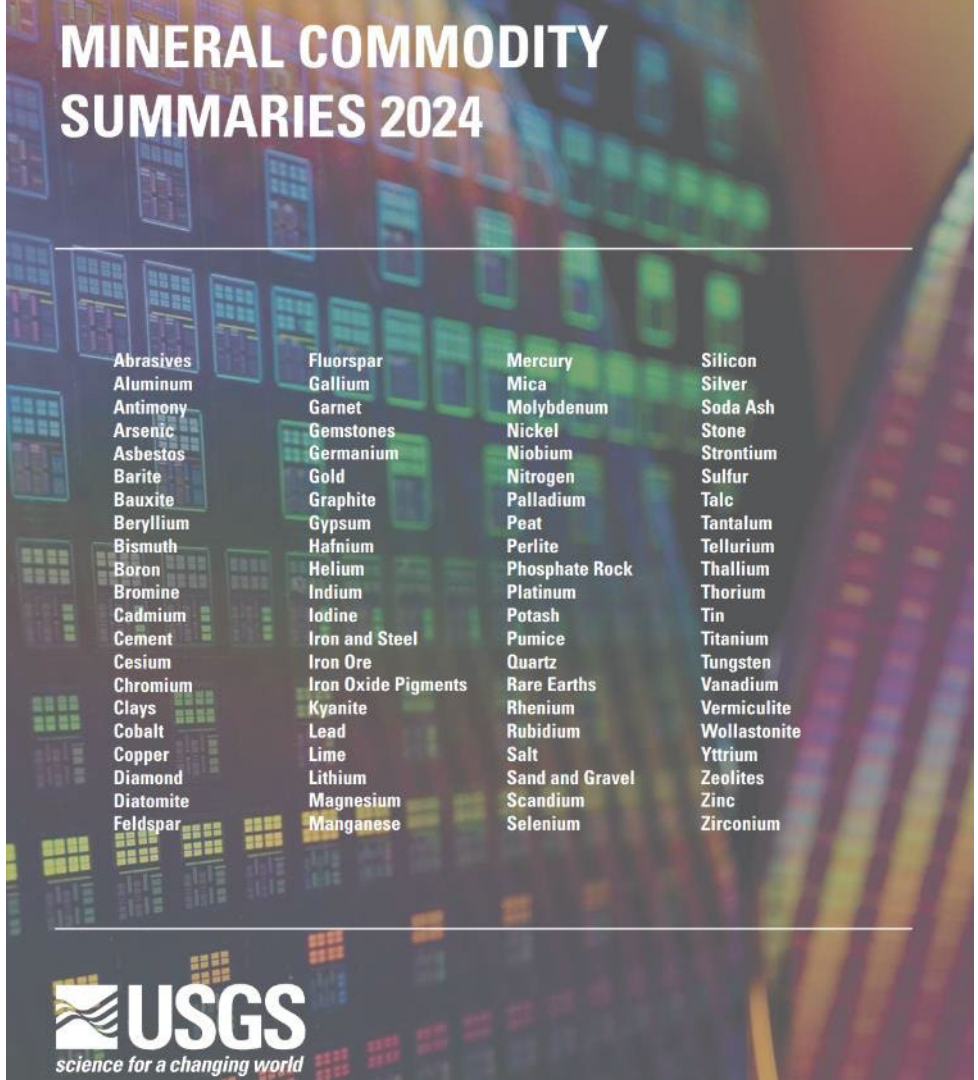
NMIC: Recent Legislation and Executive Orders

Executive Order 13817 (2017) – A Federal Strategy To Ensure Secure and Reliable Supplies of Critical Minerals	Energy Act of 2020	Executive Order 14017 (2021) – America's Supply Chains	Bipartisan Infrastructure Law, Inflation Reduction Act
Develop the first whole-of-government list of critical minerals Develop a strategy to reduce the Nation's reliance on critical minerals	Collect and disseminate mineral information Forecast critical mineral supply chains Update the Nation's list of critical minerals on a 3-year cycle Assess the Nation's critical mineral resources	Collect and disseminate mineral information Forecast critical mineral supply chains and their disruptions Identify sites where critical minerals may be sustainably produced Develop a national strategy to reclaim materials from mine wastes Develop a national strategy to strengthen supply chains	NMIC's identification of which minerals are critical guides as much as $9 billion in federal BIL and IRA investments. CEQ and the Federal Permitting Improvement Steering Council's FAST41 permitting process now applies to qualifying critical mineral development projects.

Mineral Resources Program Science and Decision Support is in Demand

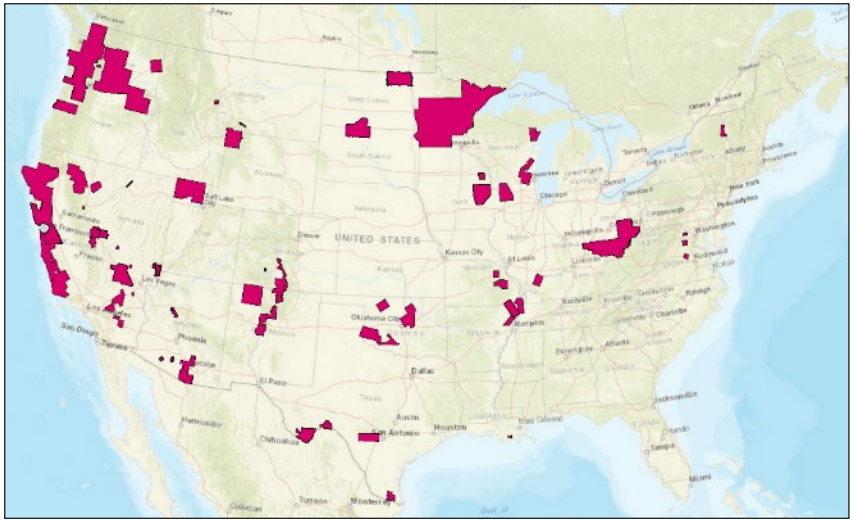
Recent direction:

- Energy Act of 2020 §7002
- Executive Order 13817
- Executive Order 13953
- Executive Order 14017
- Bipartisan Infrastructure Law §40201

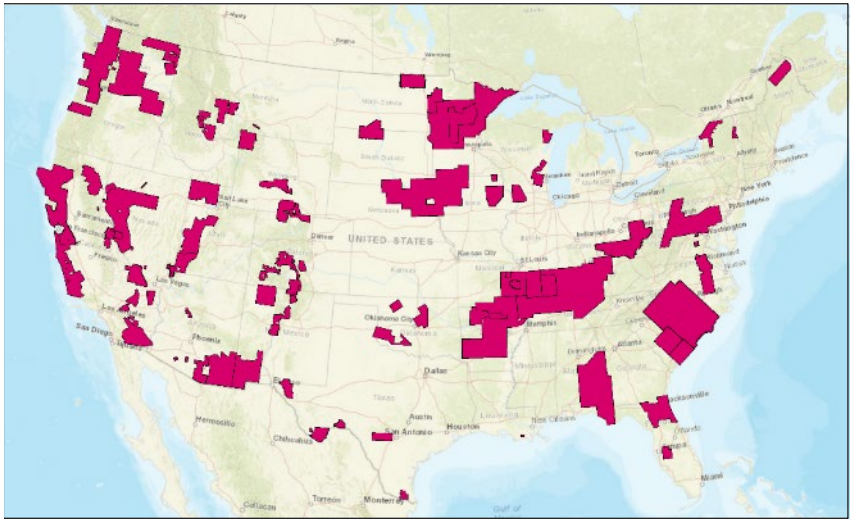


Earth MRI Geophysical Mapping Progress

Pre-Earth MRI Airborne Geophysics (2019)



Current Earth MRI Airborne Geophysics (2023)



Geophysical surveys are distributed across the entire Nation and cover areas with potential for mineral resources both below ground and in mine waste

Progress from 2019 to 2022

- Contracted airborne magnetic and radiometric surveys covering an area the size of Texas

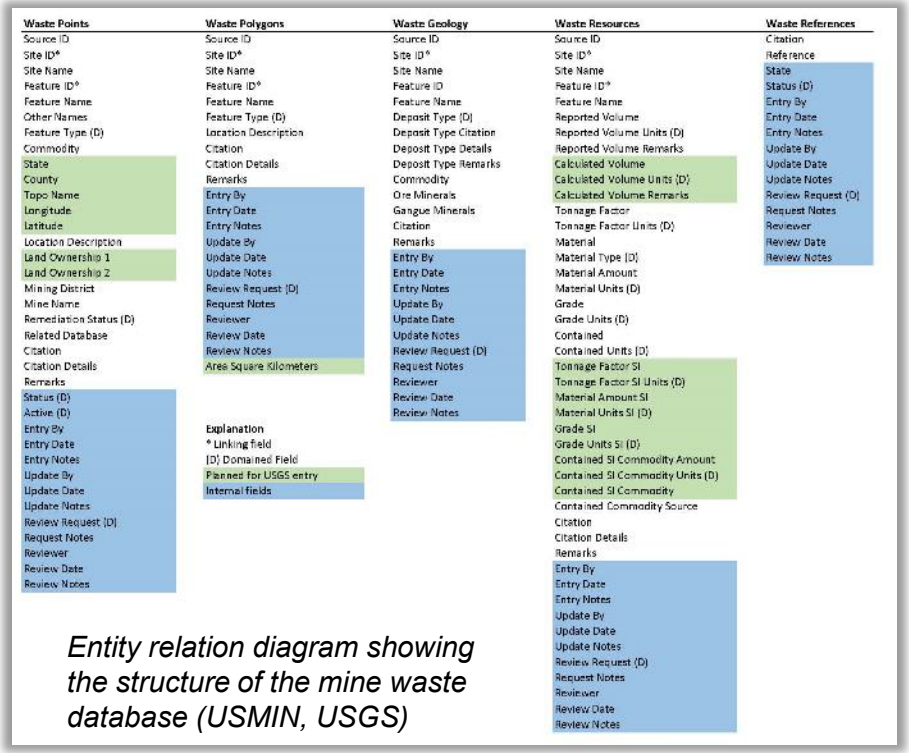
Progress in 2023

- Contracted for magnetic and radiometric surveys over an area approximately the size of Montana

National Mine Waste Inventory

Compilation of mine waste information into a geospatial database that helps address the following outstanding questions:

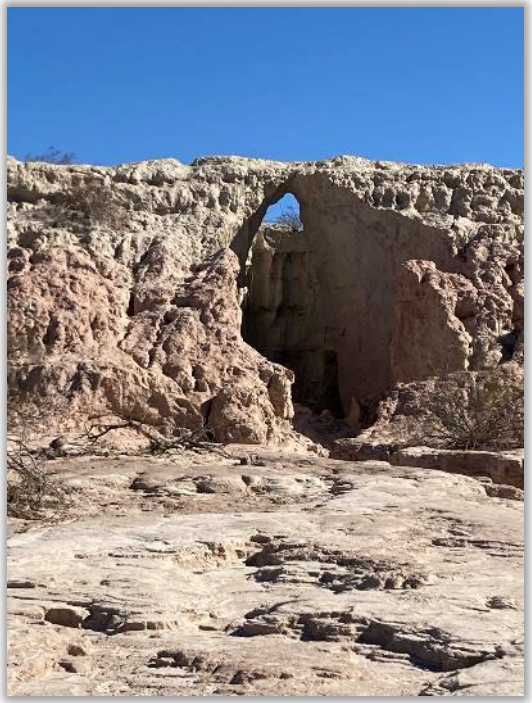
- *How many mine waste piles are there in the U.S., and where are they located?*
- *How much material is available that may contain mineral resources, and what is the tonnage and grade of that material?*
- *What are the characteristics of that material (geological, geochemical, mineralogical) that may influence recovery of the commodities of interest?*
- *How do land ownership and other factors influence access to sites for research and (or) reprocessing of mine waste?*



Entity relation diagram showing the structure of the mine waste database (USMIN, USGS)

Mine Waste Characterization

- Estimate the critical mineral endowment of mine waste
- Identify potential mineral hosts of critical minerals
- Conduct cursory assessment of the environmental characteristics of the mine waste to inform potential reprocessing strategies, environmental management, reclamation, and other attendant costs
- States can help develop a comprehensive and internally consistent database of mine waste locations, masses, geochemical composition, bulk mineralogical composition, and contained commodities
- **The USGS/MRP developed mine waste site characterization and sampling protocols to guide this effort**

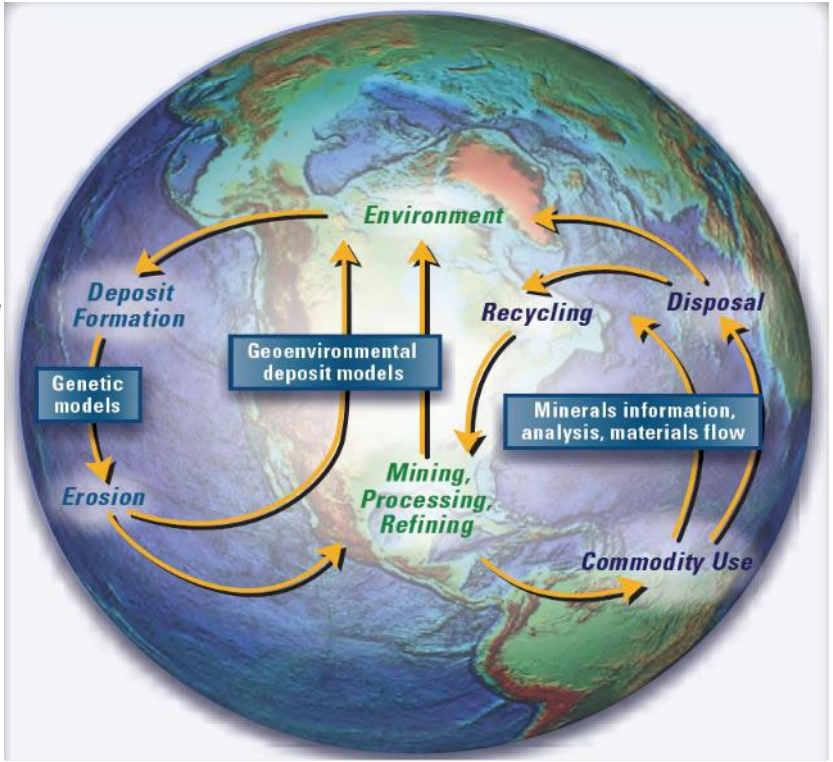


Mill Tailings Deposits at the Katherine Mine; photo courtesy of Bob Seal, USGS

The Mineral Resource Life Cycle

*"*We can take a multidisciplinary approach to understand the **life cycle** of energy and mineral resources—"

-USGS Science Strategy, 2007



Research at mine sites provides information on:

- *long-term biogeochemical processes influencing **environmental signatures…**insights into the naturally occurring or anthropogenic **interactions with air, land, and water** resources…complex natural **exposure routes** to surrounding ecosystems and humans and …information needed for **mitigation and remediation.***

- ***alternative sources** of (mineral and other) resources through **reprocessing** of mine **waste** or **beneficial reuse***

USGS

-USGS energy and minerals science strategy, 2013