Current and Emerging Research in Critical Minerals and Rare Earth Elements

Minerals, Modernization, Minimal Footprint

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Montana Bureau of Mines and Geology

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CENTER FOR ADVANCED MATERIALS PROCESSING
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Critical Minerals & Rare Earth Elements

Image Courtesy of Craig Bleile

Drivers

- **Material intensification for 2050 Clean Energy Forecasts**
- **National Security Imperative for Domestic Supply Chain**
- **Vulnerability in electronics and economic development**

Concerns

- **NIMBY!**
- **Environmental Footprint of a transfer from a 'fossil-based' to a 'materials-based' economy**
- **Loss of critical workforce in extractive/geological fields**

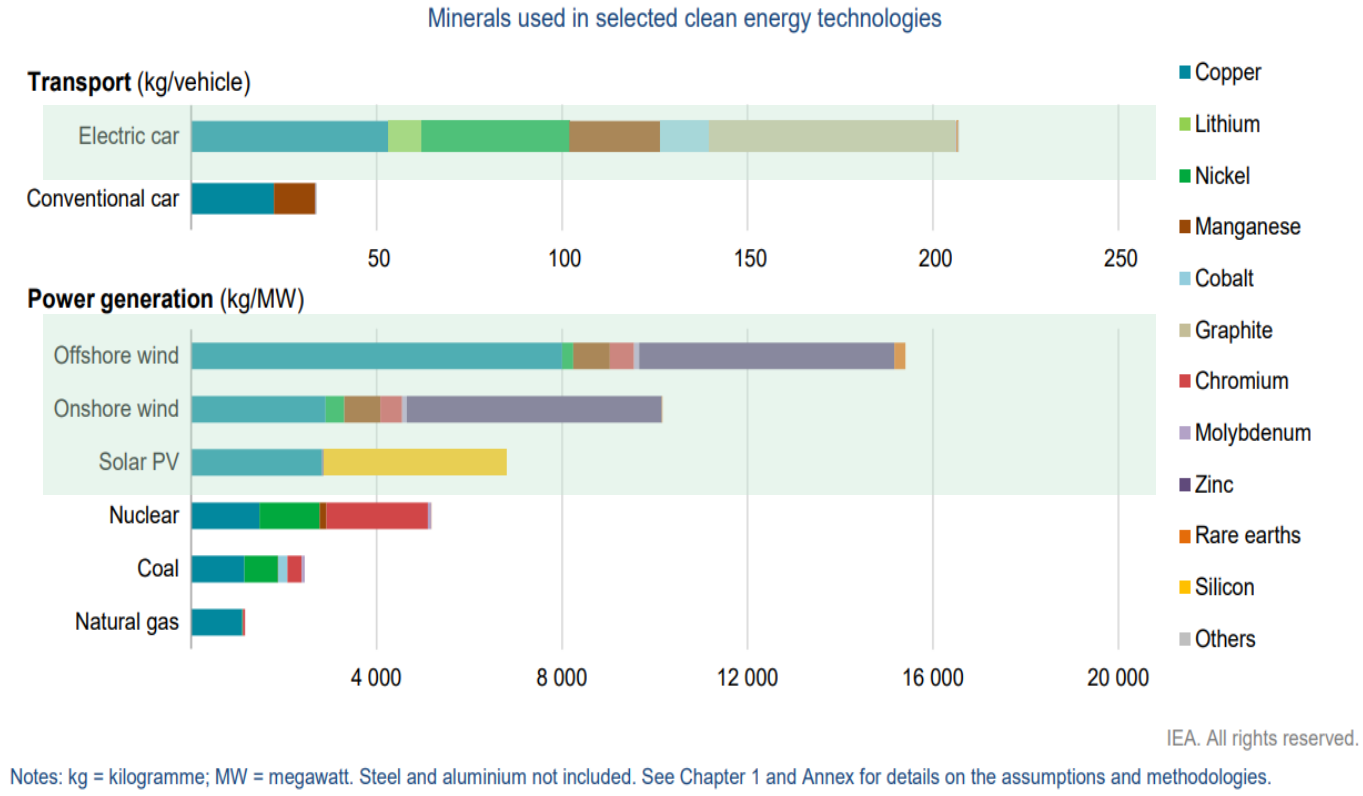
Material intensification for 2050 Clean Energy Forecasts

Lithium needs:

- 1.4 billion cubic meters of rock
- 900 holes Melbourne Cricket Ground Stadium (largest stadium in the Southern Hemisphere)

Copper, Iron, Aluminum, Nickel needs

- A hole the size of Delaware to 9.5 feet, or 6000-12000 Melbourne Cricket Ground Stadium



Original calculations from Prof. M. Moats, Missouri S&T; Analysis for U.S. State Department; May 2021

Slide from IEA, The Role of Critical Minerals in Clean Energy Transitions (windows.net)

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Material intensification for 2050 Clean Energy Forecasts

Lithium needs:

- 1.4 billion cubic meters of rock
- 900 holes Melbourne Cricket Ground Stadium (largest stadium in the Southern Hemisphere)
- **~ 0.75 Berkeley Pits**

Copper, Iron, Aluminum, Nickel needs

- A hole the size of Delaware to 9.5 feet, or 6000-12000 Melbourne Cricket Ground Stadium
- **5-10 Berkeley Pits**

Original calculations from Prof. M. Moats, Missouri S&T; Analysis for U.S. State Department; May 2021

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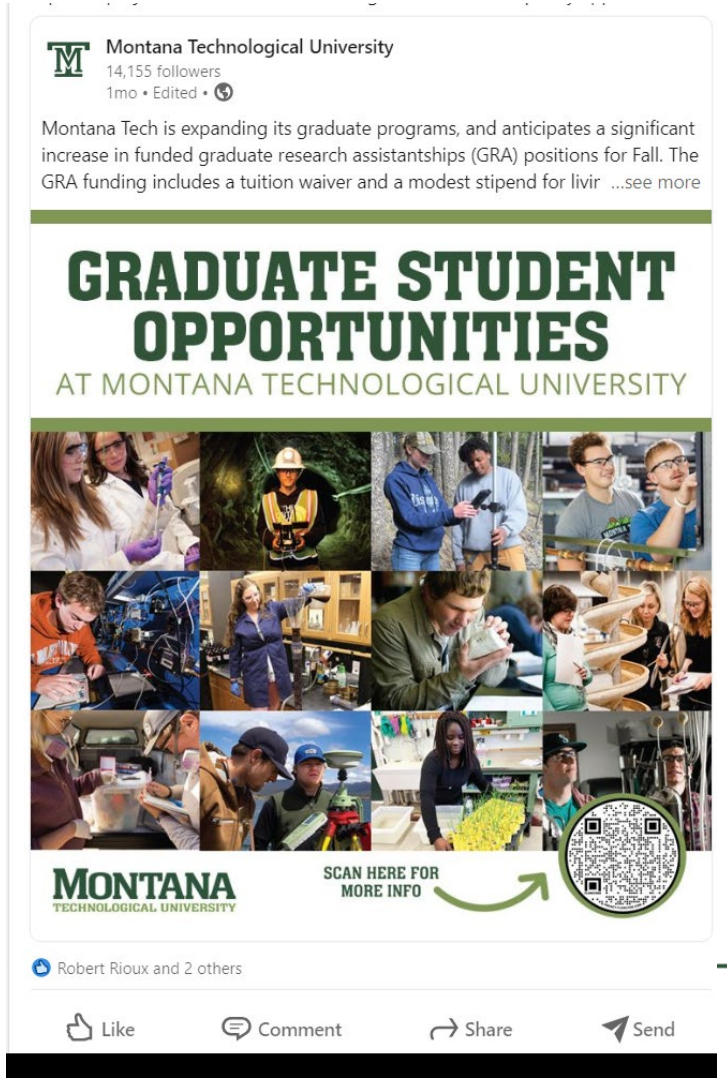
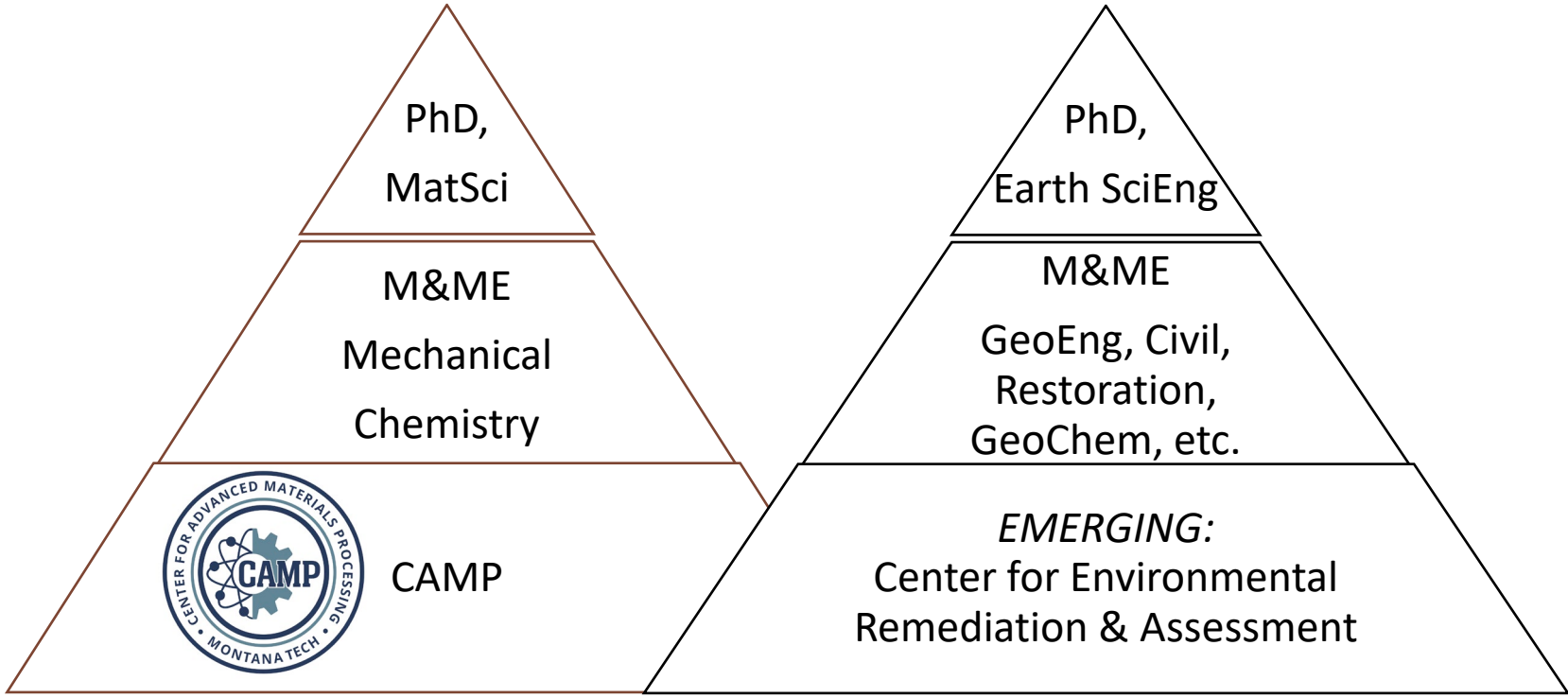
MTECH VISION: COUPLING RESEARCH WITH EDUCATION

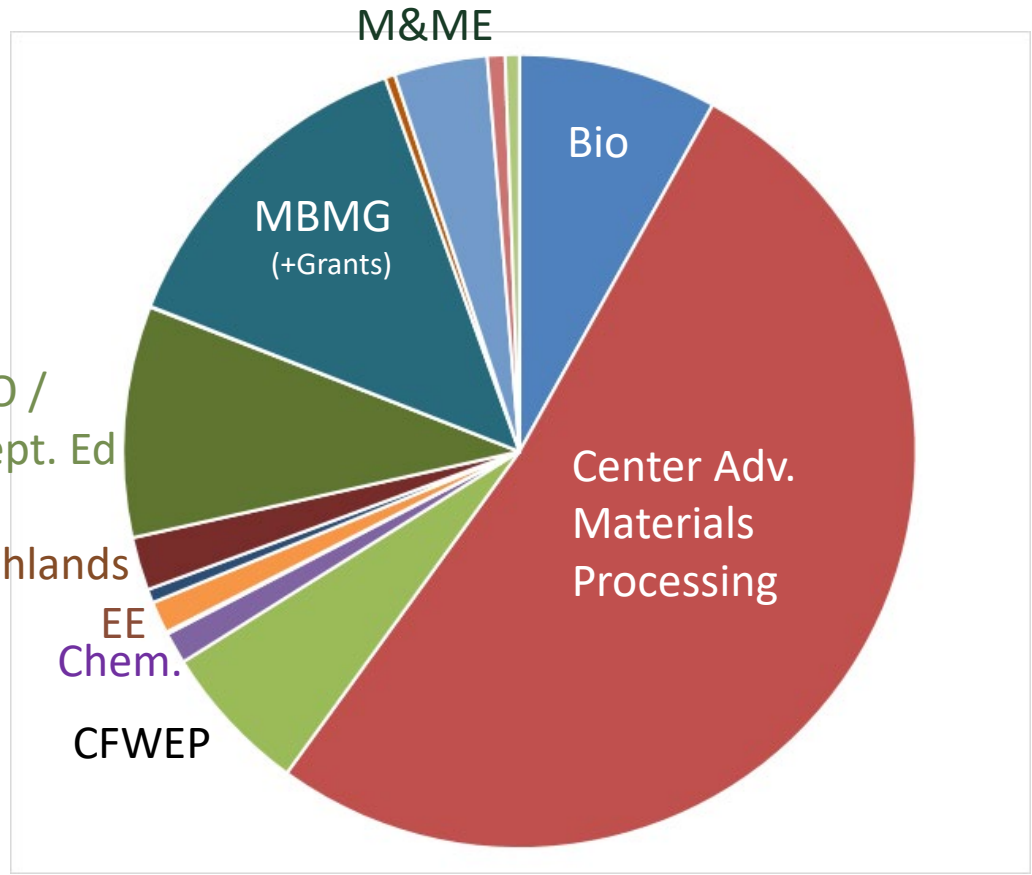




MTECH RESEARCH: Quantifying Direct Impacts

- Campus-wide Impact
  - Significant involvement of 30 faculty, 195 staff [current on ARL]
  - $535K supplemental salaries (faculty and staff, FY23*)
- Student Impact
  - $126K tuition (FY23*) ~ 20% grad tuition revenue
  - $325K student wages (FY23*)
  - 76 grads, 100 undergraduates
- Budget Impact
  - $1.3M equipment (FY23*) ~ 74% campus
  - ~20% of external graduate tuition revenue
  - $1.4M IDC revenue (FY22)
    - Graduate School Staff, Student Programs, Development
    - Research Office Staff
    - EHS Staff & Hazardous Waste Disposal
    - New Investments: CERA, Seed Funds, Start-up
    - Research Awards
    - Partial Library
    - Partial Equipment O&M
- New external partnerships

FY23 Snapshot:
External Research Awards



*FY23 is through February 2023

Source: Internal Award Data (Updated Dec 2022)

Montana Tech, MBMG, and the Army Research Laboratory

Mechanism

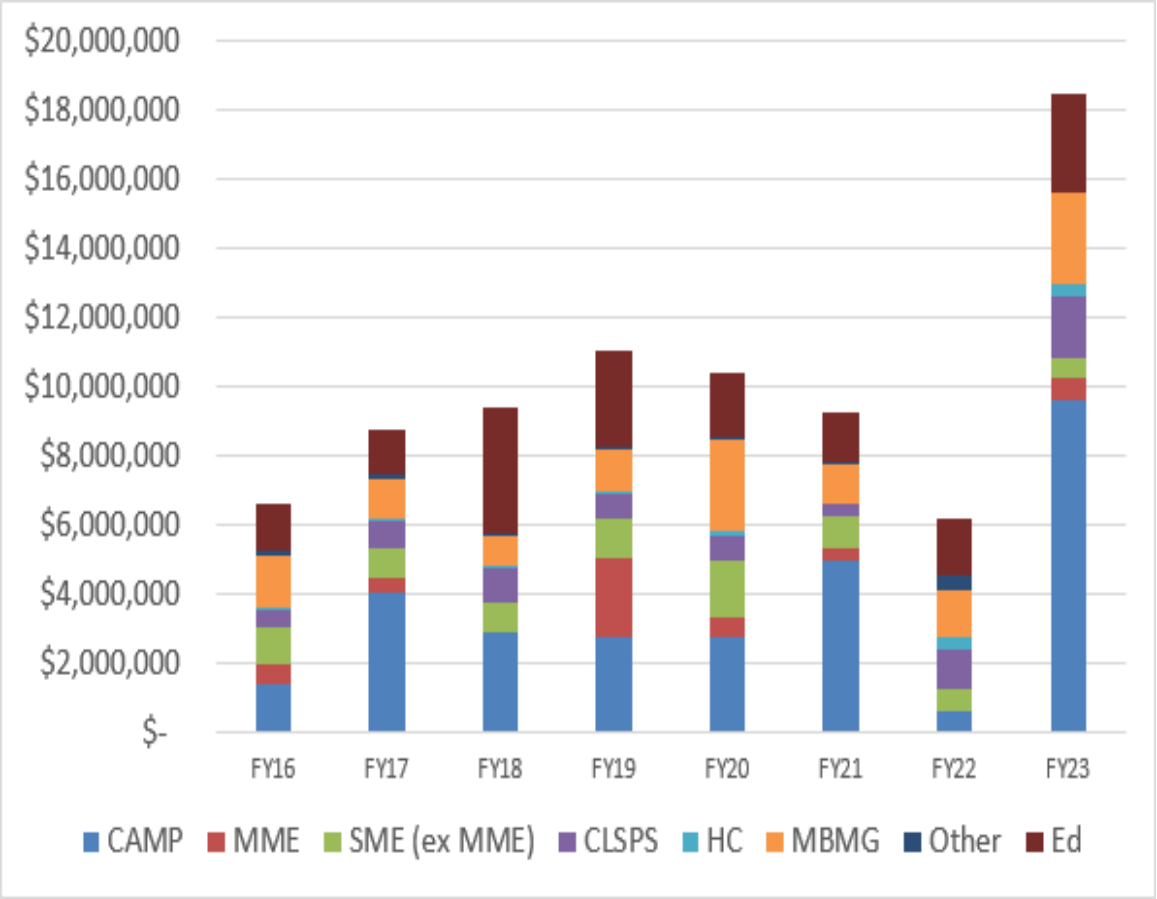
10 years of collaboration and joint effort

Materials Technology Science and Engineering Research for the Army (MT-SERA), 2015-2021

Materials Technology Research for Army Modernization and Readiness (MT-RAMR), 2020-present

Materials Technology for Rare Earth Elements Processing (MT-REEP), January 2022 - Present

Additional Growth Anticipated for FY24!



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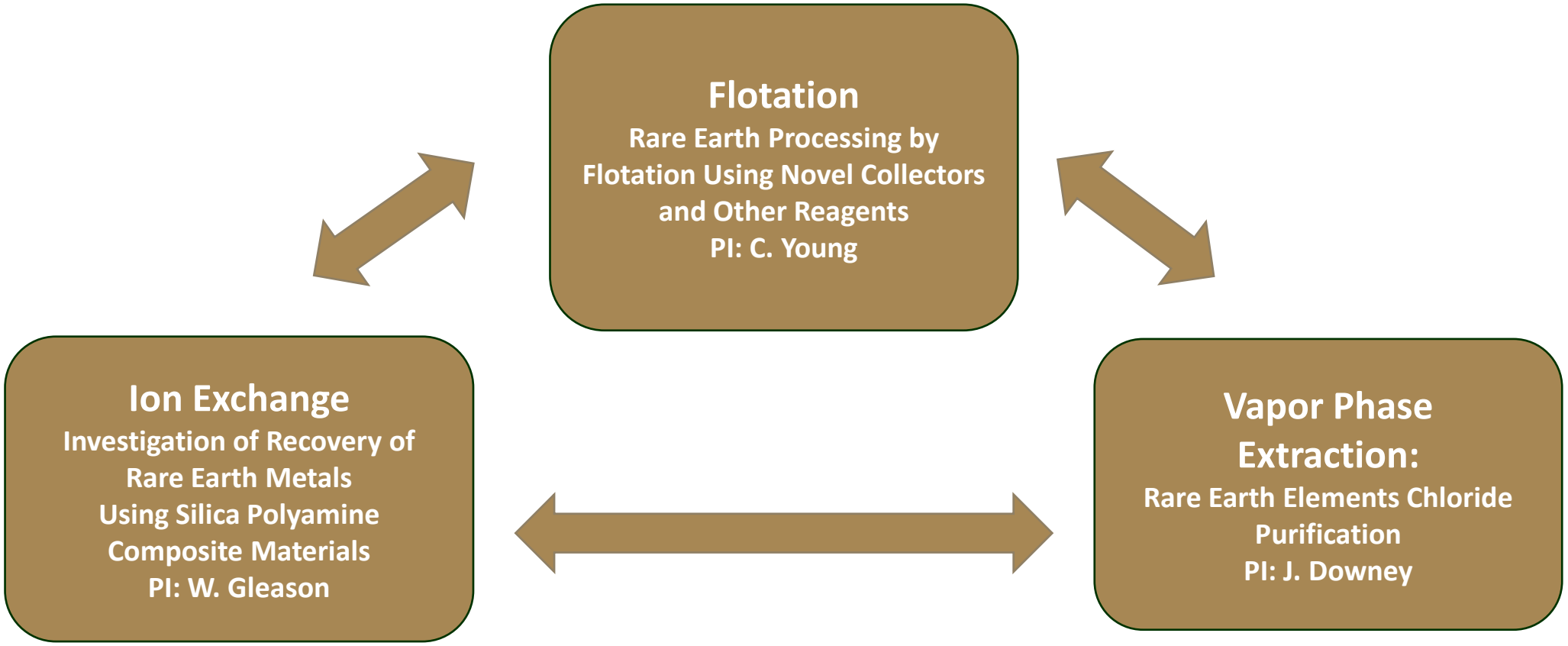
Early Adopters (2014)



Montana Tech, MBMG, and the Army Research Laboratory

VISION 2023

Utilize the State of Montana as a MODEL to develop environmentally acceptable sources and processing methods for discovering, extracting, separating, and recycling REEs, thereby laying the technological groundwork for a viable, readily implementable domestic REE supply chain.

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Montana Tech, MBMG, and the Army Research Laboratory Current Work (January 2022 – present)

Exploration

- Geological and Geochemical Exploration in the Montana-Idaho Alkalic Belt
- Exploration using combined geophysical and remote sensing technologies
- Assessment in the Phosphoria Formation
- Identification in Large-Scale Mine Waste
- Assessment in Abandoned Mine Lands
- Economic Evaluation of Previously Mined Orebodies
- Coalbeds, sediments and coal waste

Other (non-ARL projects)

- Critical commodities in coal (DOE; with WY, ND)
- Mapping of abandoned mines and ore bodies (USGS)

Processing

- Advanced Processing of Coal Ash
- Integrated Pyrometallurgical Processing
- Advanced Processing by Flotation
- Metal Recovery from Aqueous System, using Continuous Flow
- Novel "Swing" Separation Mechanisms
- Advanced Recycling of Magnets and Batteries
- Bio- and Enviro-compatible Nanomaterials for Selective REE Extraction

Emerging

- Full-Scale Concentration and Refinement from Acid-Mine Drainage

*Tech Projects; MBMG Projects; Center for Environmental Remediation Proposal

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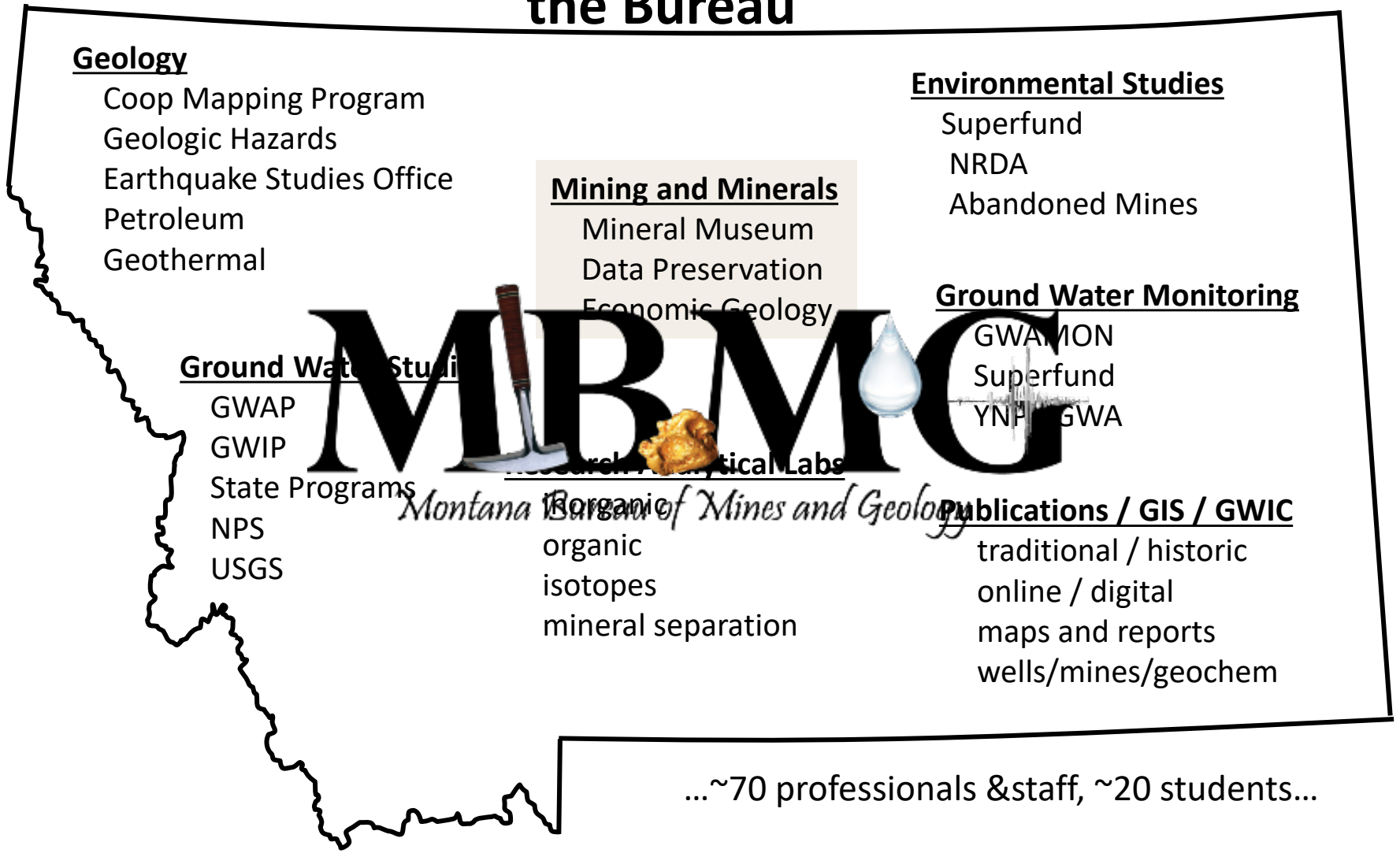
"the Bureau"



Geology
- Coop Mapping Program
- Geologic Hazards
- Earthquake Studies Office
- Petroleum
- Geothermal

Mining and Minerals
- Mineral Museum
- Data Preservation
- Economic Geology

Environmental Studies
- Superfund
- NRDA
- Abandoned Mines

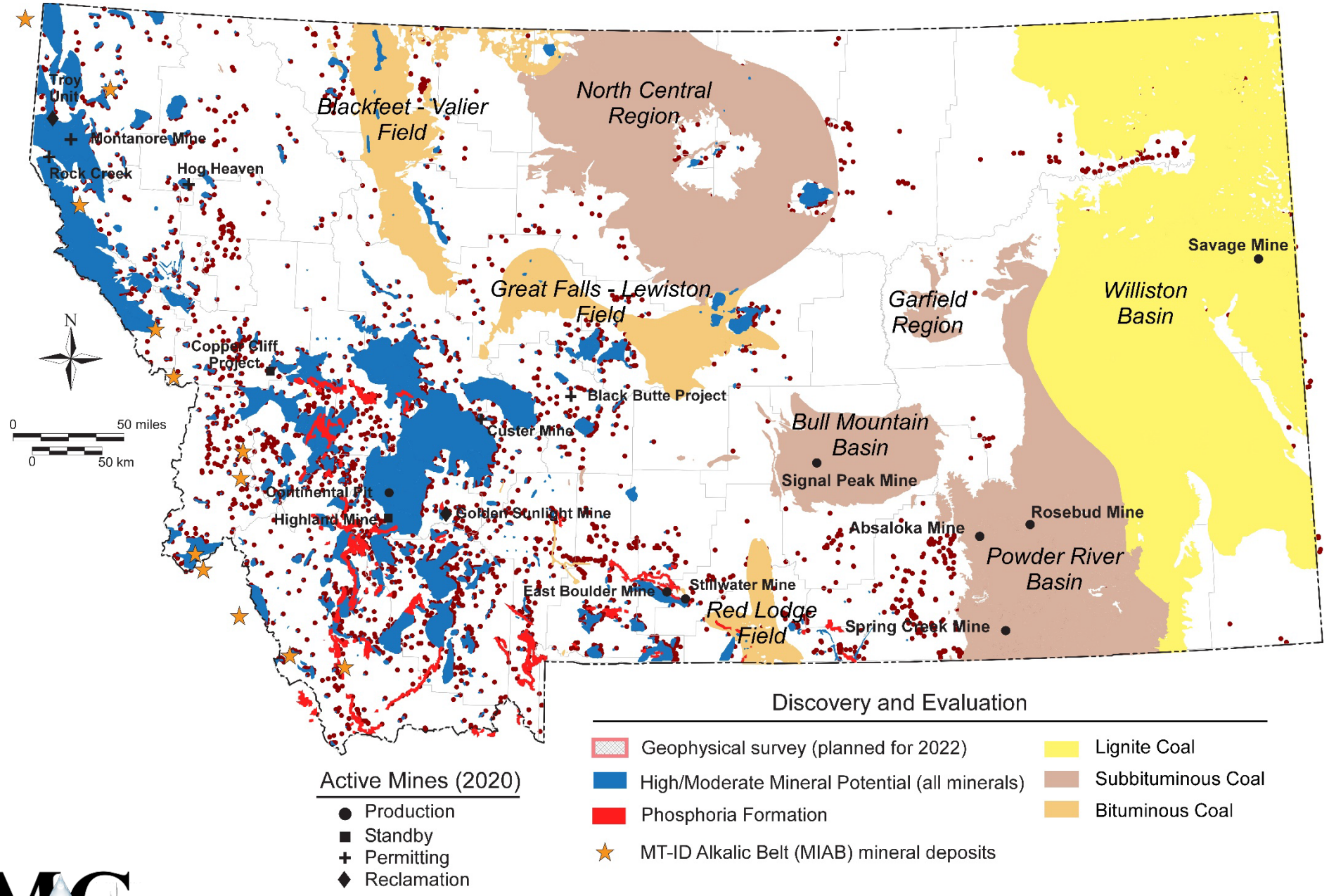
Ground Water Monitoring
- GWAMON
- Superfund
- YNP GWA

Ground Wat Studi
- GWAP
- GWIP
- State Programs
- NPS
- USGS

Research Analytical Labs
- Inorganic
- organic
- isotopes
- mineral separation

Publications / GIS / GWIC
- traditional / historic
- online / digital
- maps and reports
- wells/mines/geochem

…~70 professionals &staff, ~20 students…



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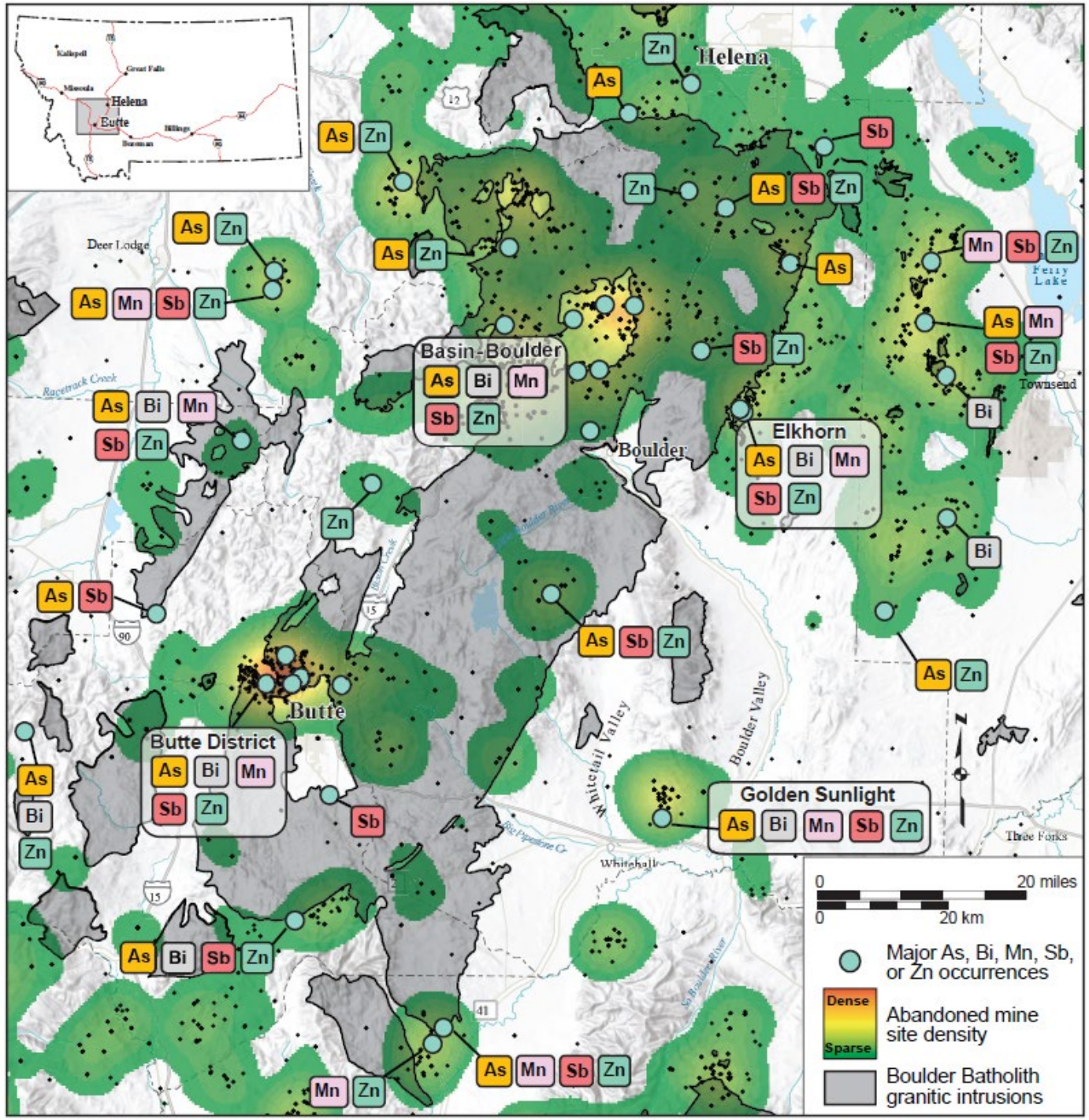

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Questions and Discussion