

The background of the slide is a collage of five images showing various USGS research activities. From left to right: 1) A person in a blue shirt operating a camera on a tripod. 2) A person in a pink vest kneeling by a stream. 3) A person in a yellow shirt and blue cap working in a field. 4) A person in a white lab coat and safety goggles working in a laboratory. 5) A person in a blue shirt working on a piece of equipment. A vertical rainbow light effect is visible in the center of the collage.

Overview of the USGS Earth Mapping Resources Initiative *Geoscience Data for the Upstream Critical Minerals Supply Chain*

**National Academy of Sciences Electric Vehicle Workshop
October 25-28, 2021**

Warren Day, USGS Earth MRI Science Coordinator, Mineral Resources Program, Golden, CO

Critical minerals support the global economy

Future technologies require increased supply

Energy generation

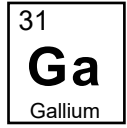
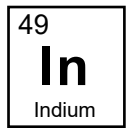
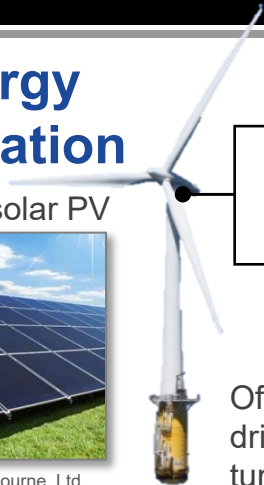
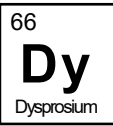
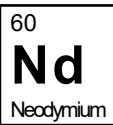


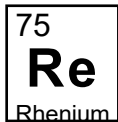
Photo credit: Testbourne, Ltd.



Offshore direct
drive wind
turbine

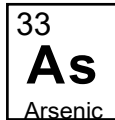
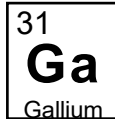
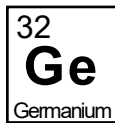
Photo credit: US DOE

Defense and national security



U.S. Air Force F-35A
Lightning II Joint Strike
Fighter

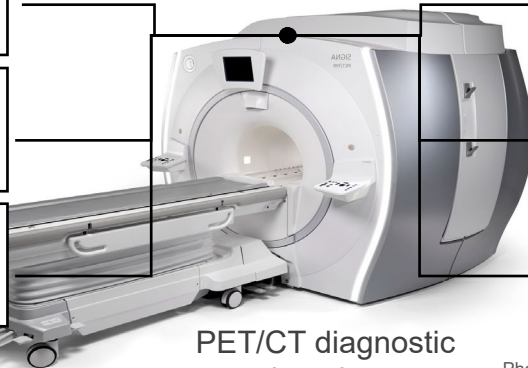
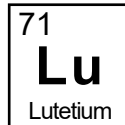
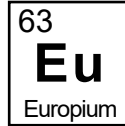
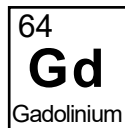
Photo credit: Master Sgt. John R. Nimmo, Sr.



Gen. III Ground Panoramic
Night Vision Goggles

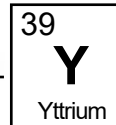
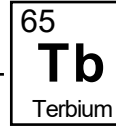
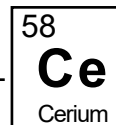
Photo credit: L3 Technologies, Inc.

Healthcare



PET/CT diagnostic
imaging

Photo credit: GE Healthcare



Transportation

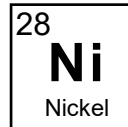
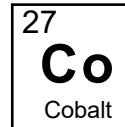
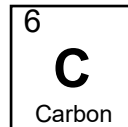
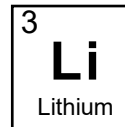
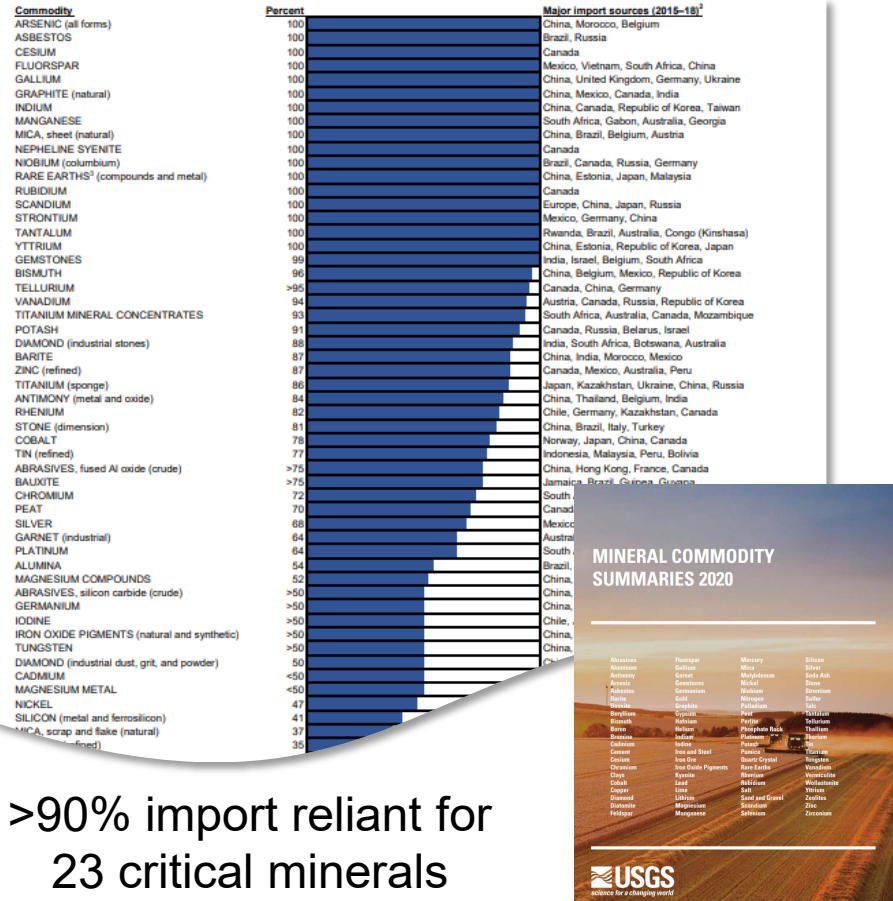


Photo credit: Tesla, Inc.

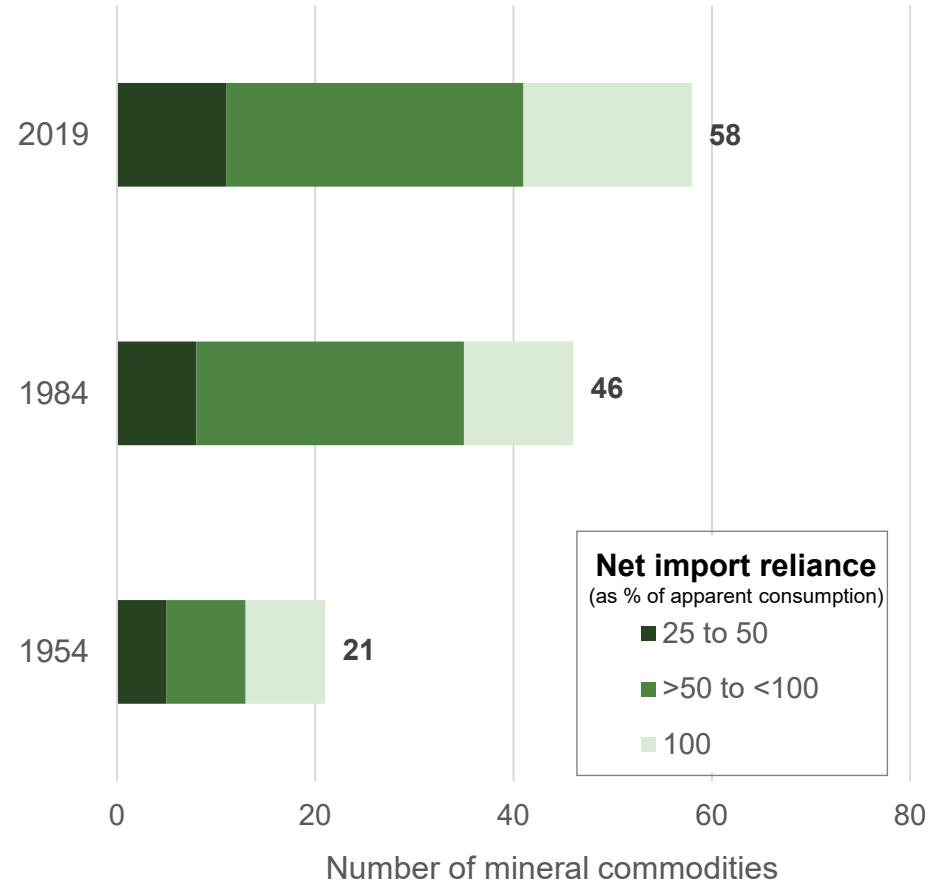
Electric and hybrid vehicles

Like many developed countries, the United States is highly import reliant for a large and growing number of mineral commodities

2019 U.S. net import reliance



Growing U.S. net import reliance



USGS Earth Mapping Resources Initiative (Earth MRI)

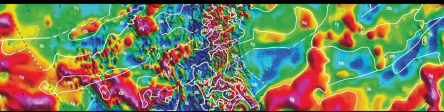
Topography—3D elevation lidar data



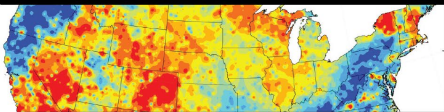
Geology—USGS and State geological survey maps



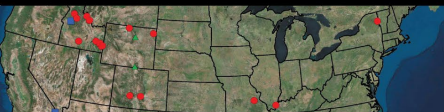
Geophysics—Aeromagnetic, radiometric, and gravity data



Geochemistry—Rocks, soils, and stream sediments



Mineral deposit databases—USMIN, MRDS, ARDF



Coreholes—Geophysical logs and core samples



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Mineral deposits



Groundwater resources



Energy

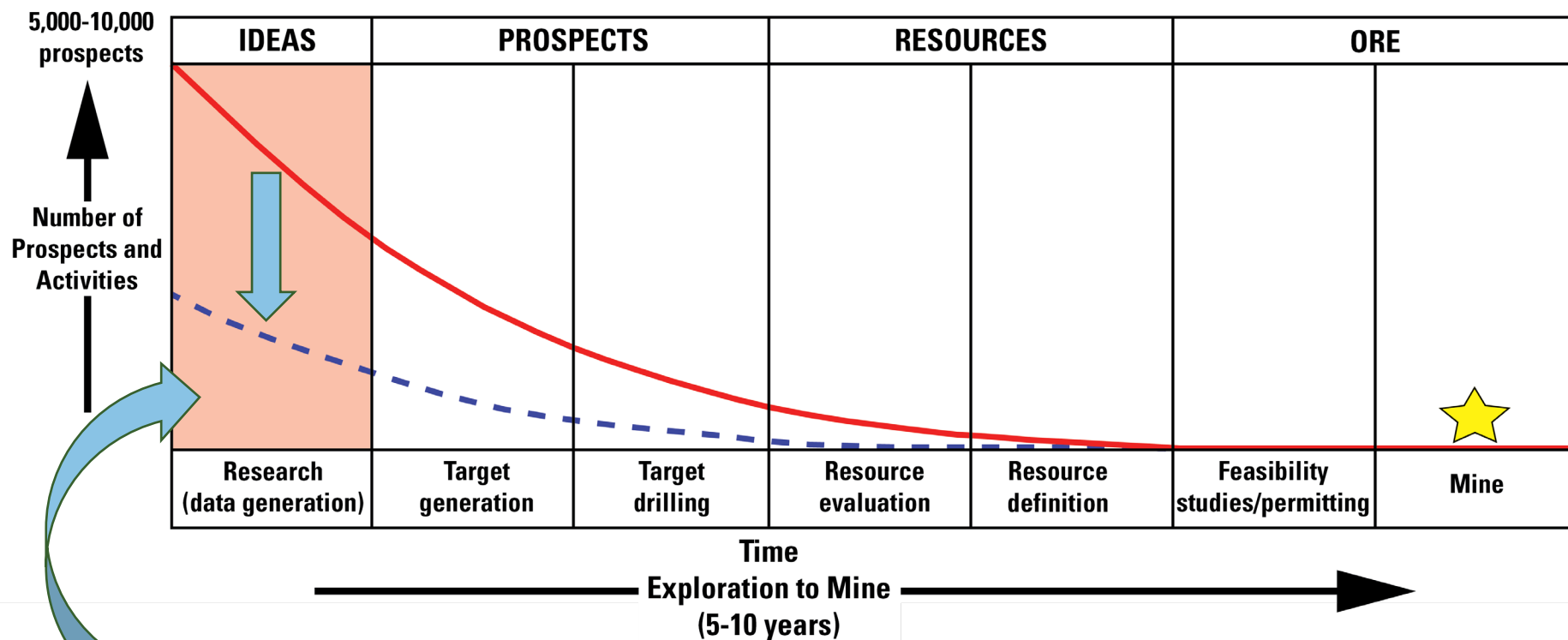


Natural hazards



- Established in 2019 under Executive Order 13817 and Secretarial Order 3359 to address the shortfall in the critical minerals supply needed for National defense and economic security.
- Goal: Improve our knowledge of the geologic framework of the United States in areas permissive for hosting undiscovered critical mineral resources.
- Partnership between the USGS, State Geological Surveys, and the private sector to generate state-of-the-art surface geologic maps, geophysical surveys, and elevation (lidar) data in areas with critical mineral potential.
- Multiple stakeholders and applications that include energy, groundwater, natural hazards, and other vital geoscience issues.

Role of Geoscience Data in Upstream Part of Critical Mineral Supply Chain



Earth MRI geoscience data role in the upstream critical minerals supply chain:
Flatten the time curve from ideas to new commodities for the economy

Project Phase by Critical Mineral

List of 35 Critical Minerals Currently Drives the Process

Need national-scale maps showing where critical minerals may occur to drive funding decisions.

- **Phase 1:** Rare earth elements.
- **Phase 2:** Primary and co-product critical mineral commodities for which new geologic information will impact discovery and production.
- **Phase 3:** Co-products and by-product commodities for which new geologic information will impact discovery and production.
- **Remaining mineral** commodities are primarily by-products from mining of other commodities. Their recovery is largely dependent on the economics of recovery and market forces.

Phase 1

Rare earth element group

Phase 2

Aluminum

Cobalt

Graphite (natural)

Lithium

Niobium

Platinum group elements

Rare earth element group

Tantalum

Tin

Titanium

Tungsten

Phase 3

Antimony

Barite

Beryllium

Chromium

Fluorspar

Hafnium

Helium

Magnesium

Manganese

Potash

Uranium

Vanadium

Zirconium

Phase 4

Arsenic

Bismuth

Cesium

Gallium

Germanium

Indium

Rhenium

Rubidium

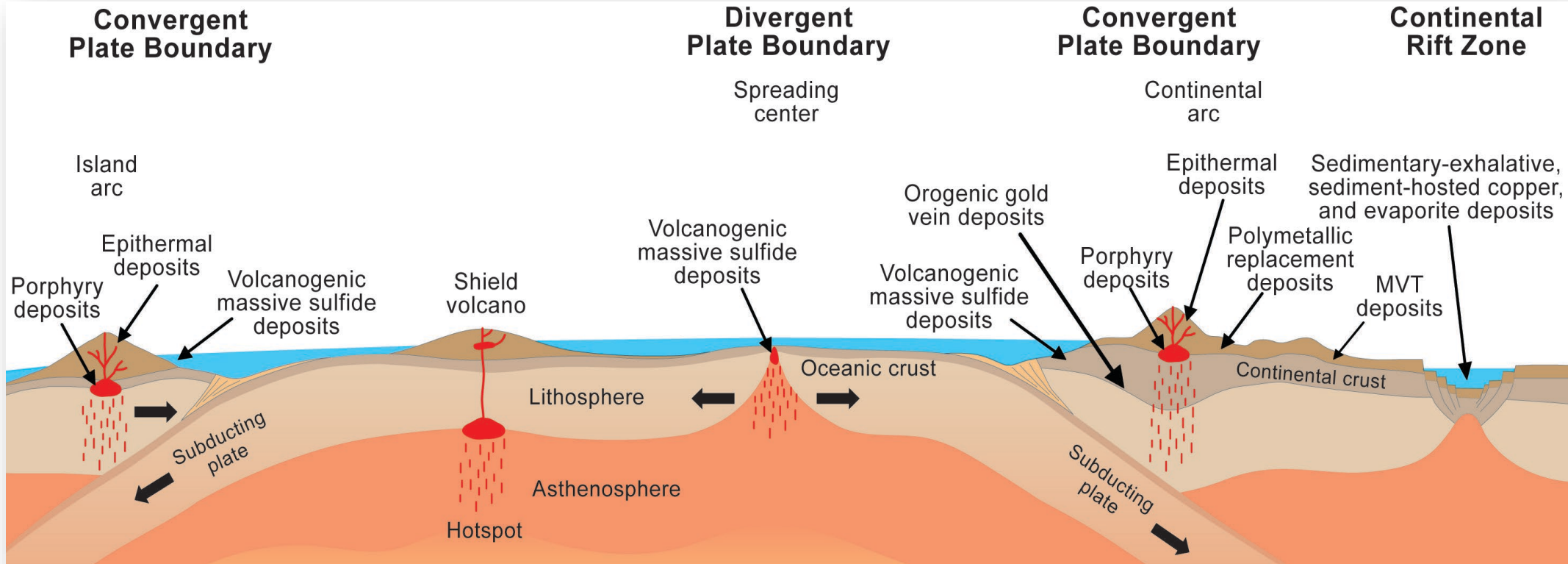
Scandium

Strontium

Tellurium

Mineral Systems Framework

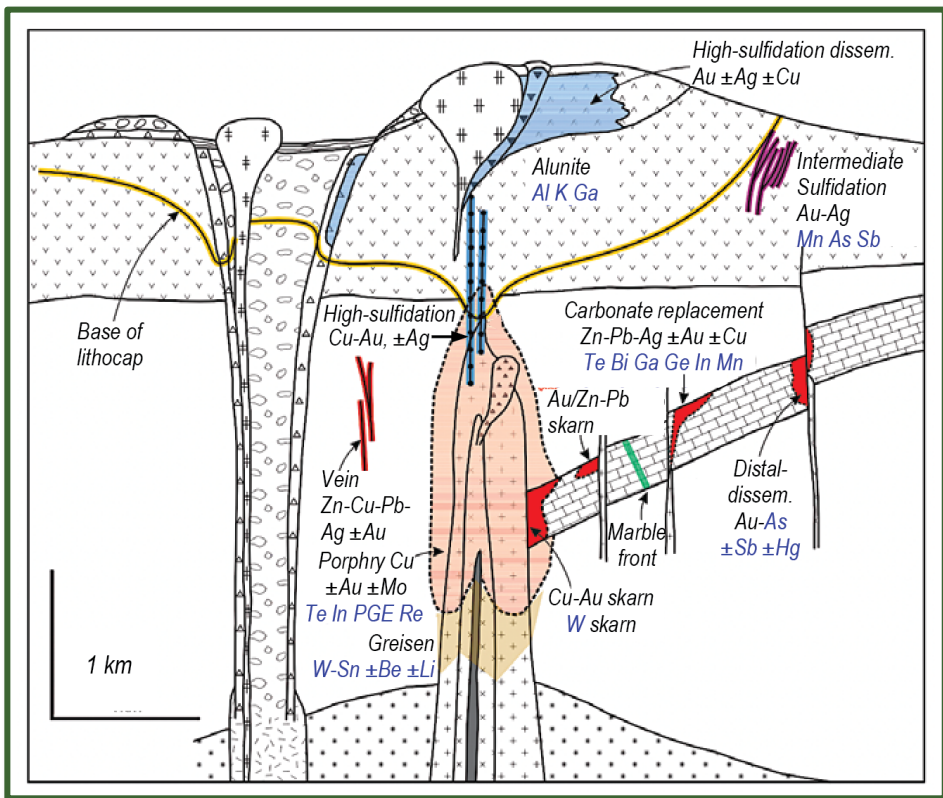
Mineral system: family of ore deposit types genetically linked in time, space, and shared tectonic processes



Mineral Systems Approach

Example: Porphyry Copper-Molybdenum-Gold System

Mineral system: family of ore deposit types genetically linked in time, space, and shared tectonic processes



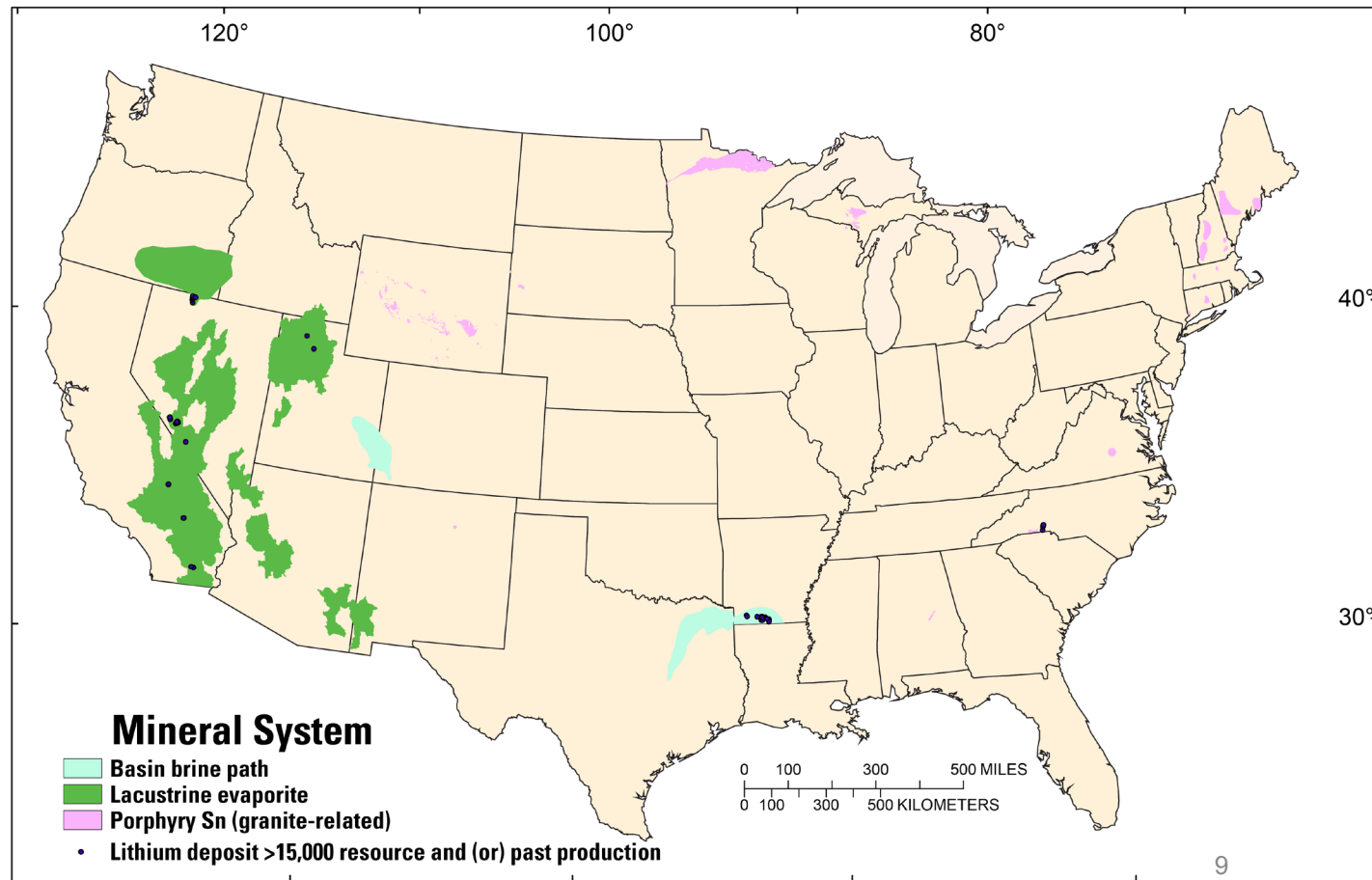
System Name	Deposit type	Principal commodities	Critical commodities
Porphyry Cu-Mo-Au	Greisen	Mo, W, Sn	W, Sn
	S-R-V tungsten	W	W, Bi, Mn, Sc
	Porphyry/skarn molybdenum	Mo, W, Sn	W, Re, Bi
	Porphyry/skarn copper	Cu, Au, Ag, Mo	PGE, Te, Re, U, Sc, Co, Bi
	Skarn iron	Fe, Cu	Ge
	Skarn magnesite	Mg	Mg
	R-V manganese	Mn	Mn, Co
	Polymetallic sulfide S-R-V-IS	Cu, Zn, Cd, Pb, Ag, Au	Mn, Ge, Ga, In, Bi, Sb, As, W, Te
	Distal disseminated silver-gold	Ag, Au	Sb, As
	High sulfidation gold-silver	Cu, Ag, Au	As, Sb, Te, Bi, Sn, Ga
	Intermediate sulfidation antimony	Sb, Hg	Sb, As
	Lithocap alunite	Al, K ₂ SO ₄ (potash)	Al, K ₂ SO ₄ , Ga
	Lithocap kaolinite	Kaolin	Ga

Example: Significant Lithium Deposits in the Conterminous US

Important Mineral Systems for Lithium

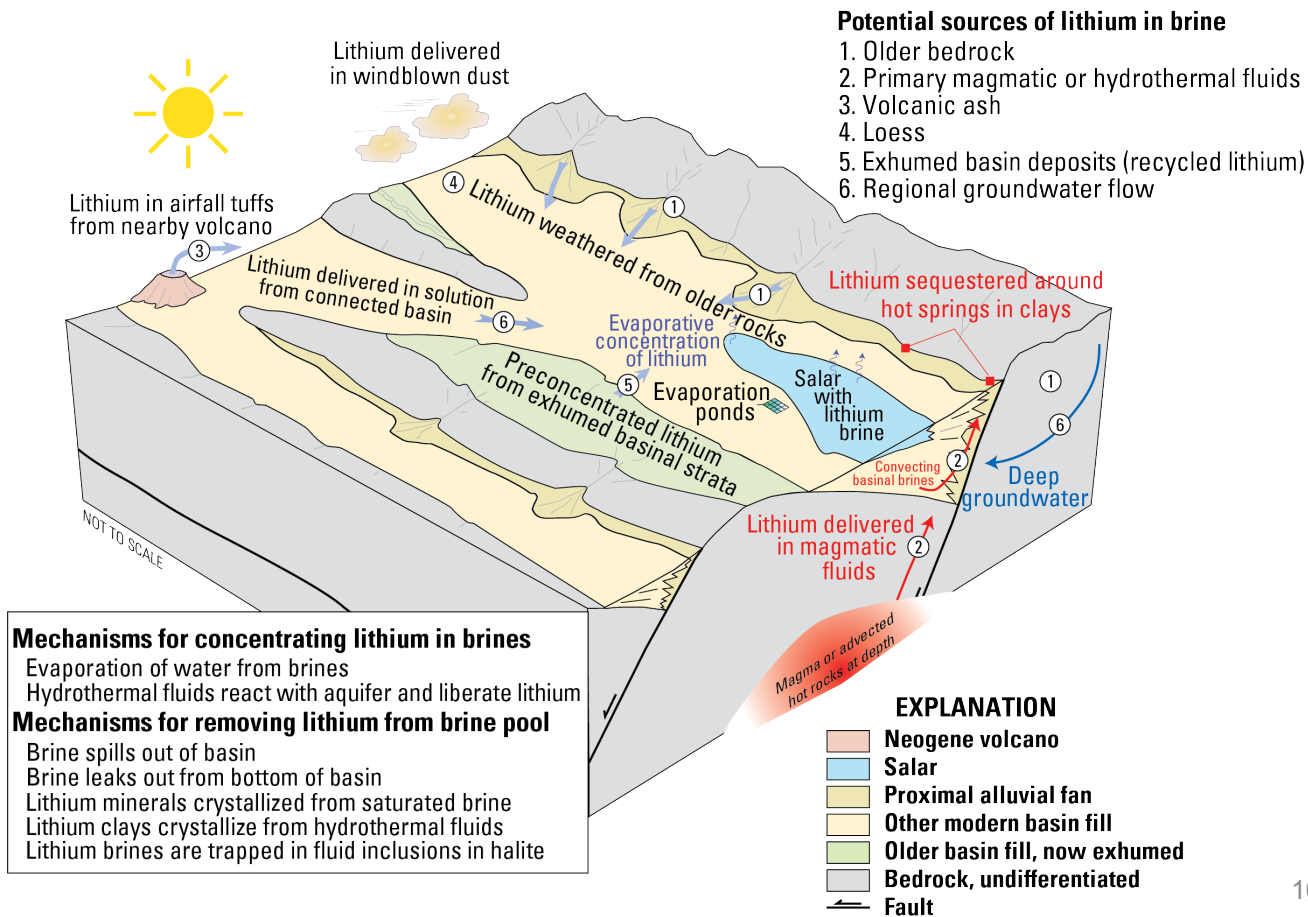
- Basin brine pathway
- Lacustrine evaporite
- Porphyry Tin (granite-related): includes lithium-bearing pegmatite deposits

Source: Dicken and Hammarstrom, 2020, USGS data release,
<https://doi.org/10.5066/P95CO8LR>



Deposit Model for Lacustrine Evaporite Lithium Deposits

Modified from Bradley and others,
2017: U.S. Geological Survey
Professional Paper 1802, p. K1–K21,
<https://doi.org/10.3133/pp1802K>



Example: Geoscience Data Acquisition for Western Nevada (GeoDAWN)

Background

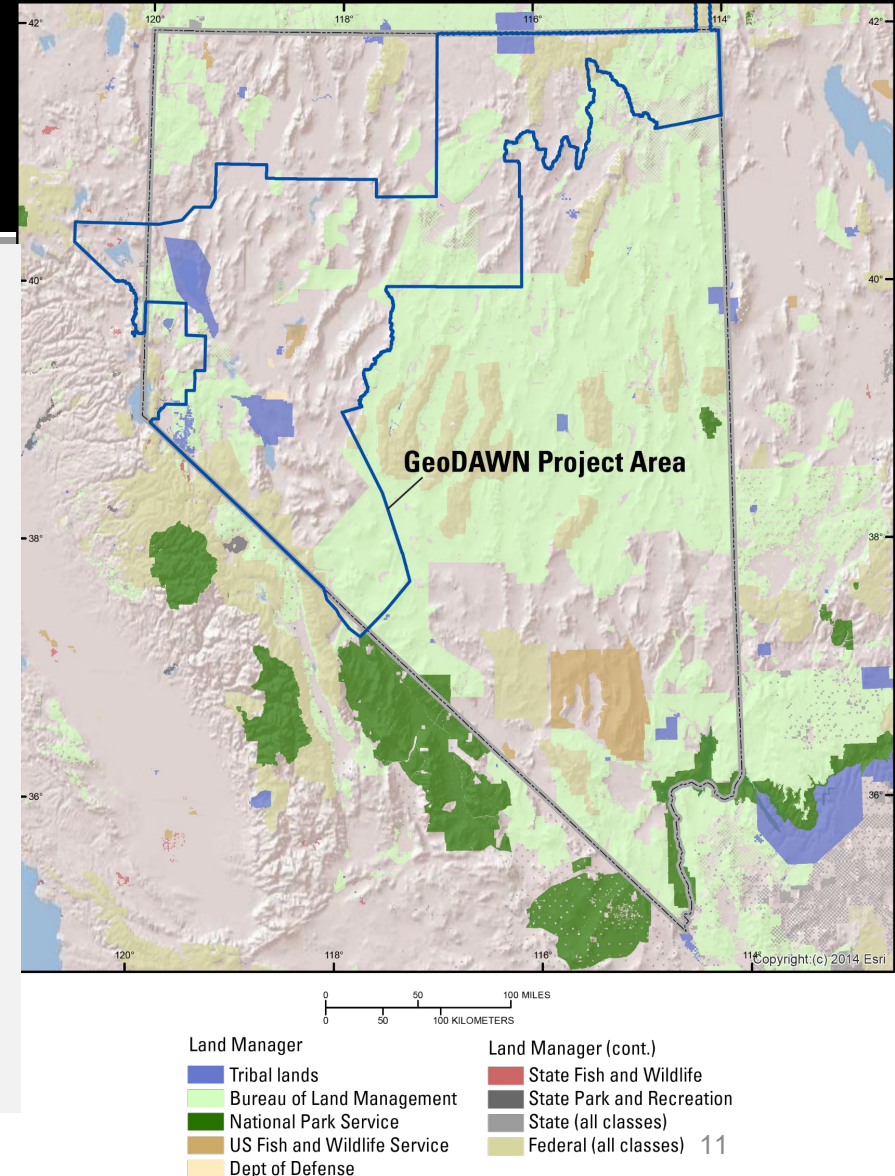
- Region is known to host gold, copper, and many critical mineral resources. Lithium mining is ongoing in project area.
- DOE Geothermal Technologies Office play-fairways-analysis identified region as having potential for geothermal energy resources

Goal

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

Details

- Multi-agency partnership includes: USGS, DOE GTO, BLM, NRCS, FEMA, and Nevada Bureau of Mines and Geology
- Lidar data collection complete. Target October 2022 release
- Flying of geophysical survey to beginning Fall 2021



Example: Geoscience Data Acquisition for Western Nevada (GeoDAWN)

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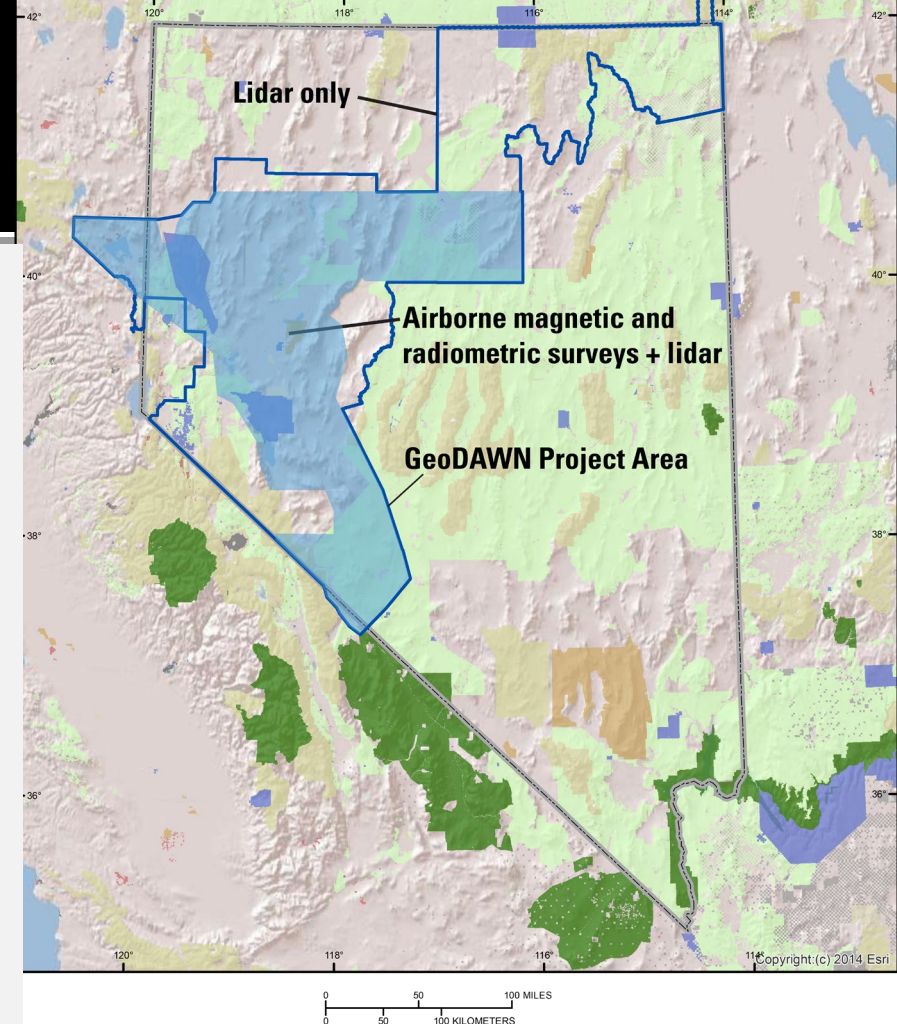
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Land Manager

- Tribal lands
- Bureau of Land Management
- National Park Service
- US Fish and Wildlife Service
- Dept of Defense

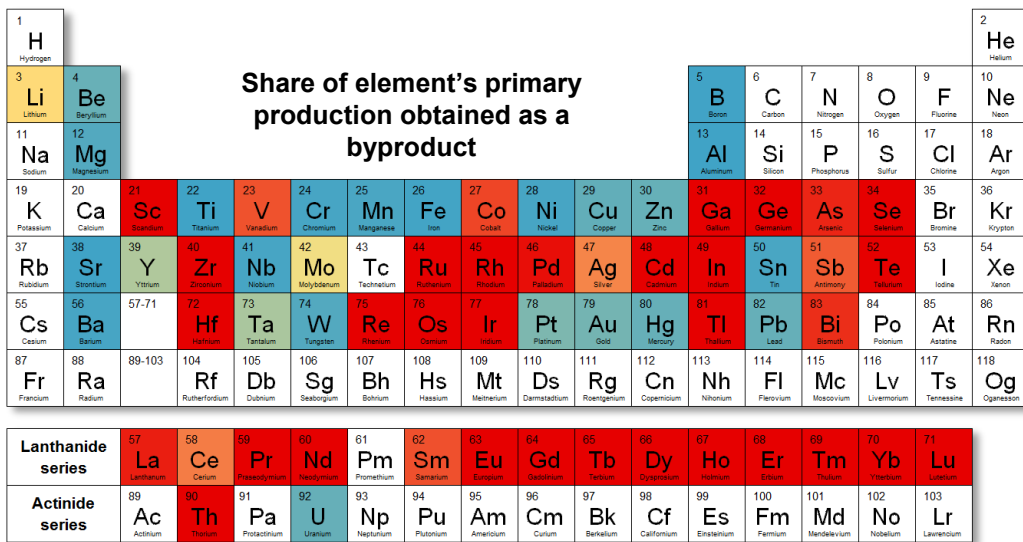
Land Manager (cont.)

- State Fish and Wildlife
- State Park and Recreation
- State (all classes)
- Federal (all classes)

Unconventional Mineral Resources: Mine Wastes

Reclaiming mine sites offers co-benefits for remediation and critical mineral recovery.

USGS and partners are planning a national mine waste inventory



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

% of metal's global primary production obtained as companion
0 10 20 30 40 50 60 70 80 90 100



New USMIN geospatial database of current and historical mining locations. Yellow dots are mine features captured from historical USGS topographic maps. (A collaboration with BLM and State geological surveys)

Horton, J.D., and San Juan, C.A., 2021, Prospect- and Mine-Related Features from U.S. Geological Survey 7.5- and 15-Minute Topographic Quadrangle Maps of the United States (ver. 6.0, April 2021): U.S. Geological Survey data release, <https://doi.org/10.5066/F78W3CHG>.

All Earth MRI data at <https://usgs.gov/earthmri>

Earth MRI Acquisitions Viewer

Source: [Earth Mapping Resources Initiative \(Earth MRI\)](#)
Metadata & Data Services: [MRData](#), [NGMDB](#)

Earth MRI began in 2019 and is a partnership between the USGS and State Geological Surveys to acquire new geologic maps, geophysical surveys, and lidar data to better understand the fundamental geologic framework of areas across the Nation with potential for hosting critical mineral resources. Click any map area or table record to learn more.

☒ All ☐ Geology ☐ Geophysics ☐ Lidar ☐ Geochemistry

Showing 73 projects on screen.

Filter by project, year, affiliation, or state name

Project Affiliation Theme Year

Adams County Mesozoic Basin, Pennsylvania |
Pennsylvania Department of Conservation & Natural
Resources, Bureau of Geological Survey | Geologic
mapping GE
Year Started: 2020 | Year Complete: In Progress

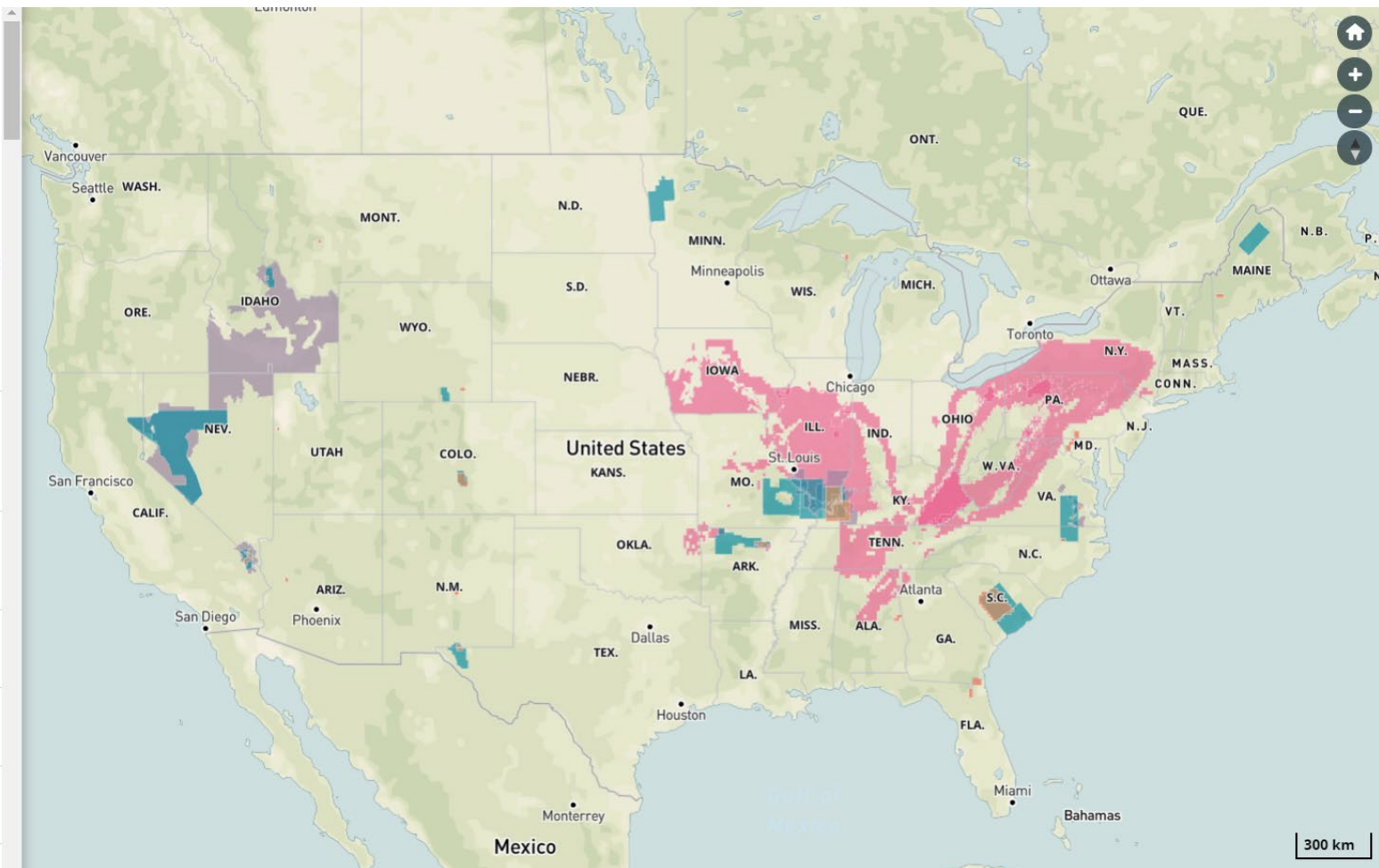
Adams County Mesozoic Basin, Pennsylvania |
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Big Sandy Valley, Arizona | Arizona Geological Survey |
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Geochemistry GC
Year Started: 2020 | Year Complete: In Progress

Blue Ridge area, Maryland | Maryland Geological Survey
| Geologic mapping GE
Year Started: 2019 | Year Complete: In Progress

Blue Ridge area, Maryland | Maryland Geological Survey





Questions?