CRITICAL MINERAL RESOURCES IN THE MIDWESTERN UNITED STATES

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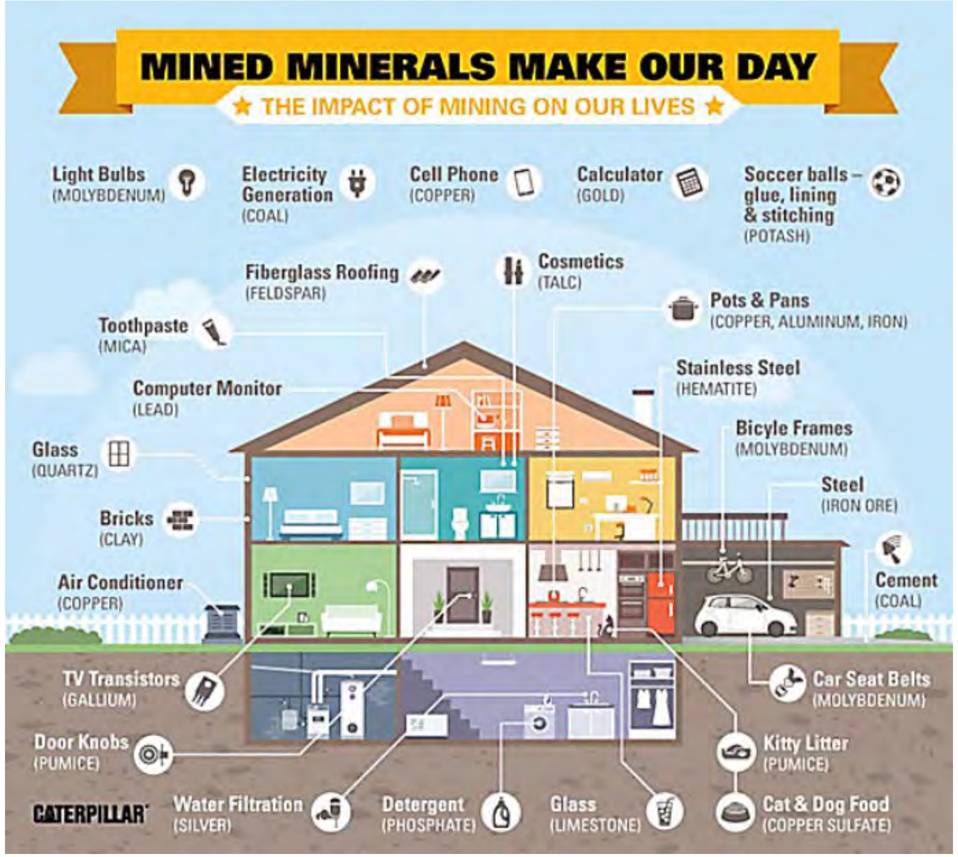
U.S. Department of the Interior
U.S. Geological Survey

USGS photo of silica carbide

Mineral resources are essential parts of our daily lives

Mineral resources provide many of the essential building blocks of modern society and are vital for human health and safety

- Every year, each person in the U.S. requires more than 39,000 pounds of new nonfuel minerals
- Most of the mineral resources we consume are non-renewable
- Global population is projected to exceed 8.5 billion by 2030, mineral consumption is growing faster than population
- In 3 years, China consumed as much concrete (6.6 gigatons) as U.S. did during the 20th century (4.4 gigatons)



Every American born in 2008 is estimated to use the following amounts of nonfuel mineral commodities in their lifetime	
Aluminum (bauxite)	5,677 pounds
Cement	65,480 pounds
Clays	19,245 pounds
Copper	1,309 pounds
Gold	1,567 ounces
Iron ore	29,608 pounds
Lead	928 pounds
Phosphate rock	19,815 pounds
Stone, sand, gravel	1.61 million pounds
Zinc	671 pounds

Source: USGS and US Energy Information Administration

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Mineral resources are essential parts of our daily lives

Mineral resource needs have diversified considerably with advances in modern technology

3 **Li** Lithium | 6 **C** Carbon | 27 **Co** Cobalt | 28 **Ni** Nickel

Electric and hybrid vehicles

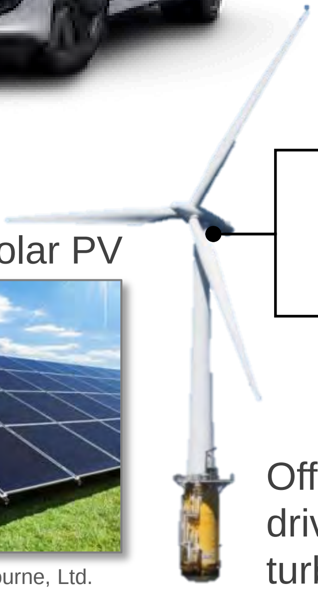
Photo credit: Telsa, Inc.

49 **In** Indium | 31 **Ga** Gallium | 34 **Se** Selenium

Thin-film solar PV

Photo credit: Testbourne, Ltd.

60 **Nd** Neodymium | 66 **Dy** Dysprosium



Offshore direct drive wind turbine

Photo credit: US DOE

An average smartphone may contain up to 62 different types of metals

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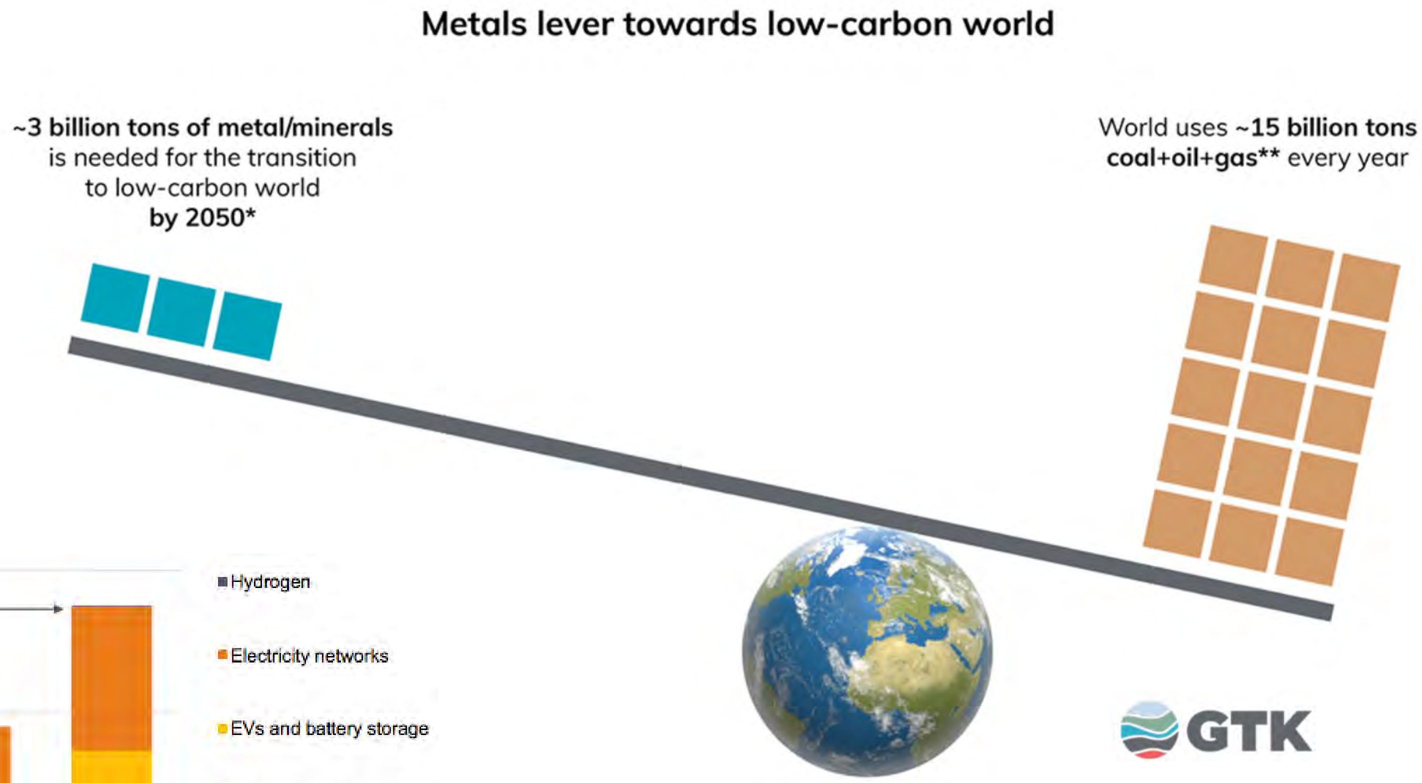
Global demand for mineral resources increases with transition to green energy

Mineral resource demand is increasing globally in the push toward alternative energy and zero-emission goals

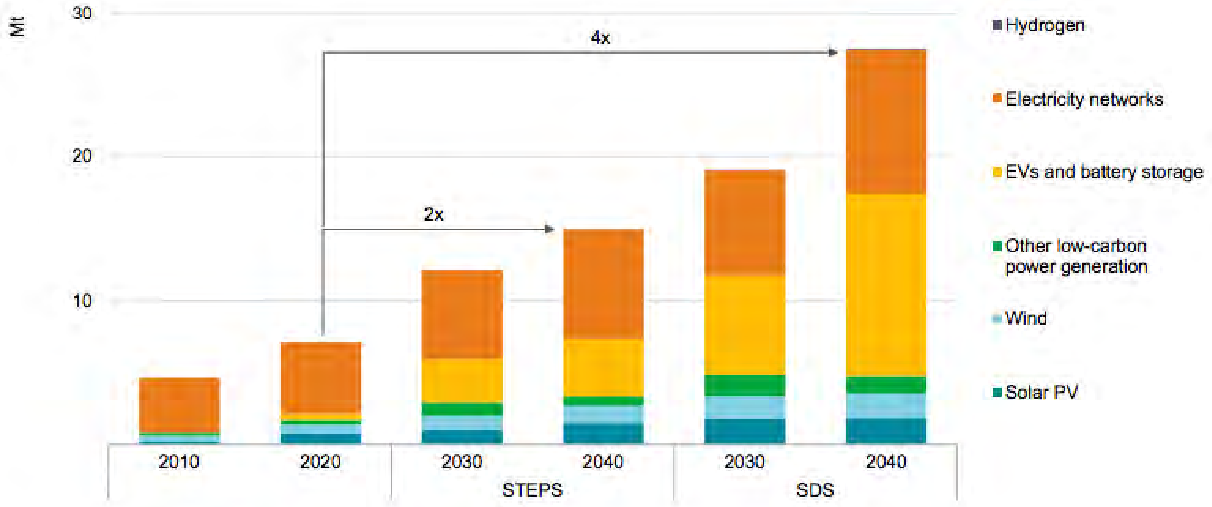
- Some green technologies (EVs, photovoltaics) are more resource intensive than their predecessors
- EVs still require a stable, distributed power grid regardless of power sources
- The path from discovery to production of new mineral resources can take 20-30 years



Source: Geological Survey of Finland

12.4.2022

GTK Research: The Currently Known Global Mineral Reserves Will Not Be Sufficient to Supply Enough Metals to Manufacture the Planned Non-fossil Fuel Industrial Systems



Total mineral demand for clean energy technologies by scenario. Source: IEA.

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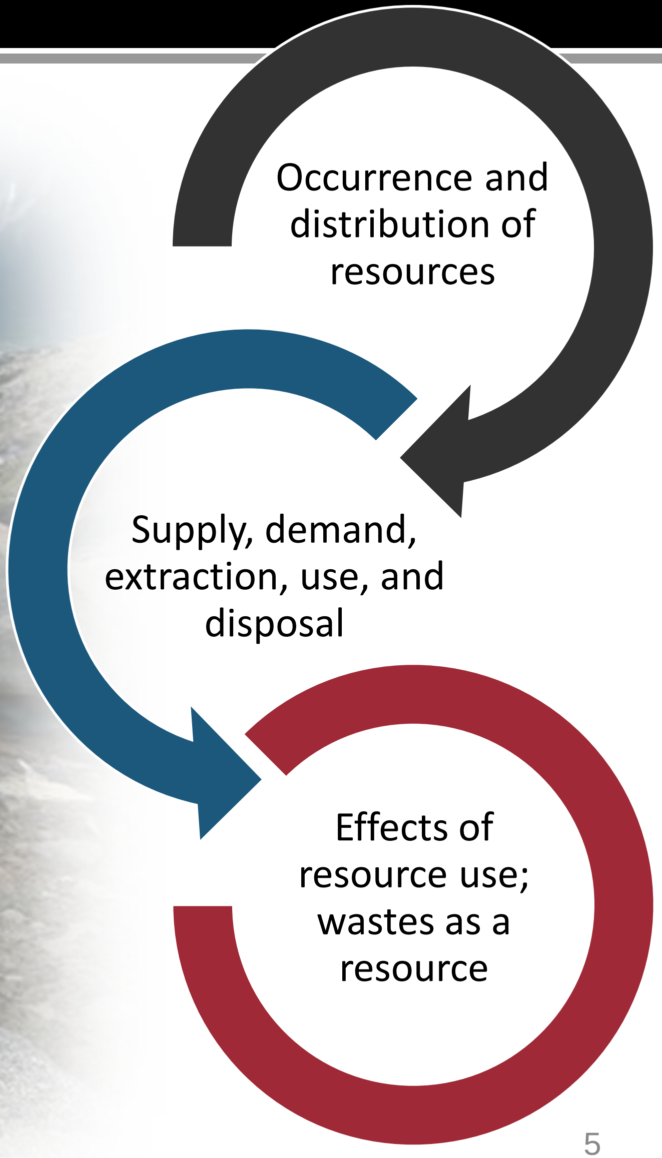
USGS provides unbiased science to support decision-making

The **USGS Energy and Mineral Resources Mission Area** leads research and assessment of natural resources in the U.S.

- Energy Resources Program
- Mineral Resources Program

Organic Act of 1879

> "examine the geological structure, mineral resources, and products within and outside the national domain"



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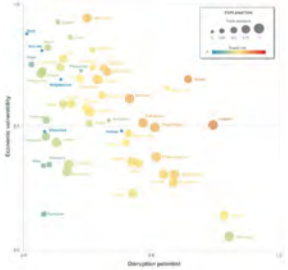
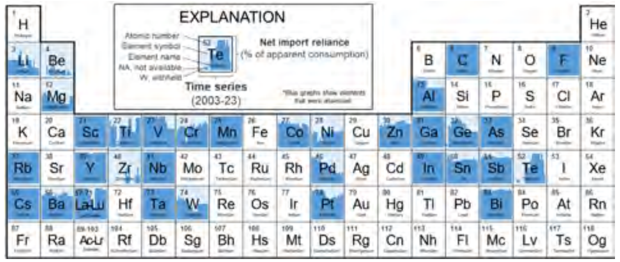
USGS provides unbiased science to support decision-making

The **USGS Mineral Resources Program** conducts research and assessment of the geologic framework and mineral resources of the U.S.

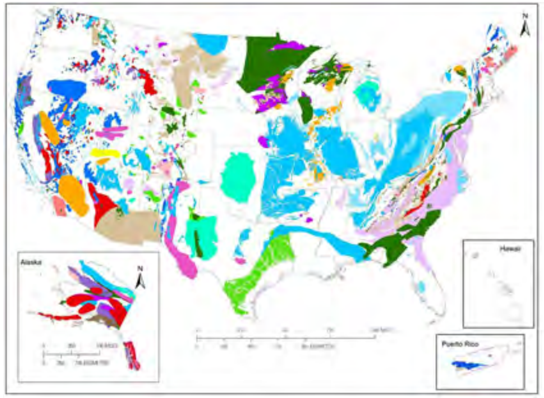




Mineral Information and Intelligence

- Analyze present-day and future supply, demand, and global trade for mineral commodities and evaluate mineral criticality

→ Supply chain analysis and list of critical minerals



Earth Mapping Resources Initiative

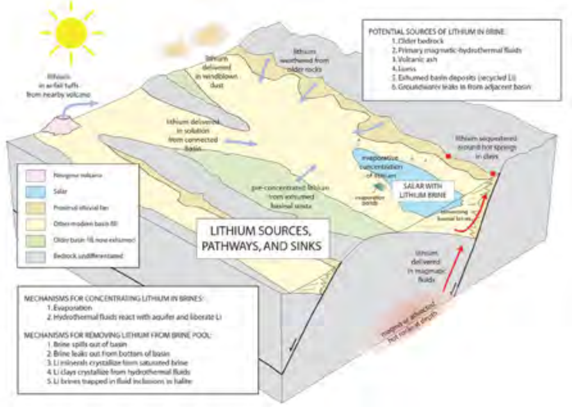
- Domestic data acquisition, mapping, and synthesis to characterize mineral resources still in the ground and above ground in mine wastes

→ Mapping the Nation's geologic framework and mineral resource potential

Research and Assessments

- Understand mineral systems and deposits, as well as the impacts of development, and conduct mineral resource assessments

→ Decision support to land managers and policy makers



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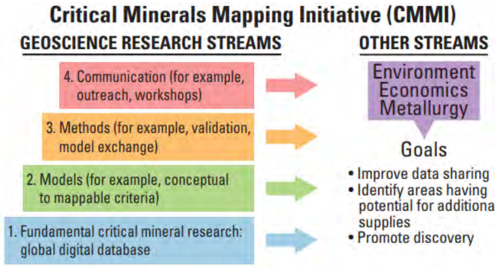
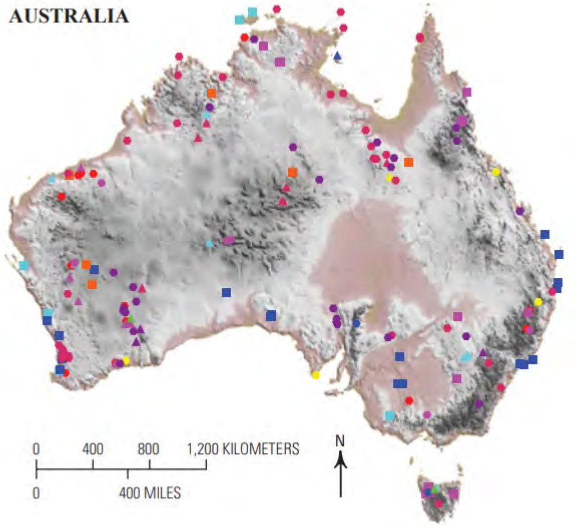
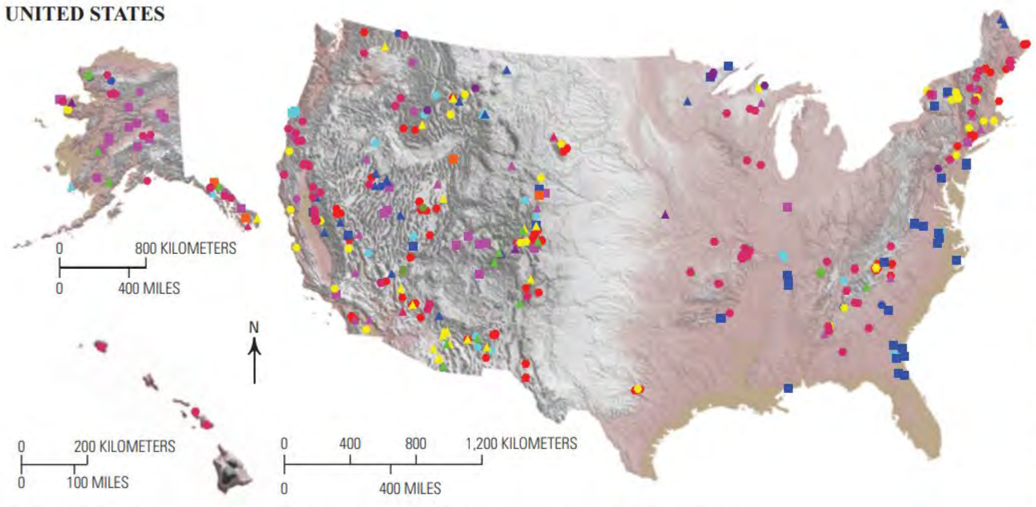
USGS provides unbiased science to support decision-making

The **USGS Mineral Resources Program** engages in international collaboration to improve global understanding and support discovery

The **Critical Minerals Mapping Initiative (CMMI)** is a trilateral partnership between USGS, Geoscience Australia, and the Geological Survey of Canada







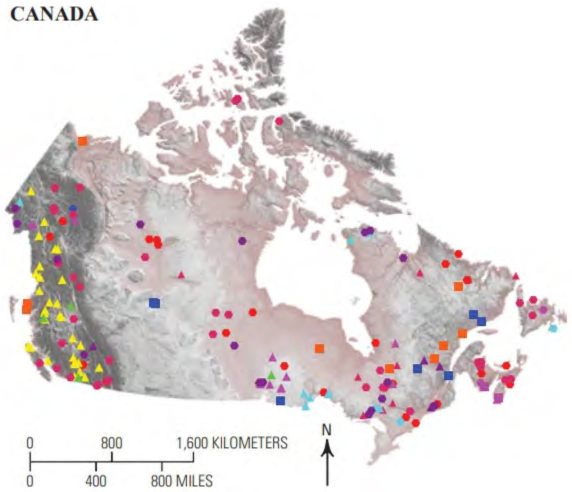
Base from National Oceanic and Atmospheric Administration ETOPO1 1 Arc-Minute Global Relief Model, 2017

EXPLANATION

Critical Minerals

- Antimony
- Barite
- Beryllium
- Cobalt
- Fluorite
- Gallium
- Germanium
- Graphite
- Indium
- Lithium
- Manganese
- Niobium and Tantalum
- Platinum Group Elements
- Rare Earth Elements
- Rhenium
- Tellurium
- Tin
- Titanium
- Vandium
- Zirconium

Figure 1. Critical mineral resources in Australia, Canada, and the United States (Labay and others, 2017). Critical minerals support a broad range of industrial sectors and a diversity of high-tech industries important to global economies (see Primary Uses of Critical Minerals sidebar).



Mineral resource production is fundamental to the U.S. economy

Mineral resources are important to the U.S. economy, but we are not self-sufficient

- 2023 estimated value of total nonfuel mineral production in U.S. was $105 billion, an increase of 4% from $101 billion in 2022
- Estimated value of U.S. metal mine production was $35 billion
- Principally from copper, gold, iron ore, and zinc
- Industries that use nonfuel mineral materials— such as steel, aerospace and electronics—created an estimated $3.84 trillion in value-added products in 2023, a 6% increase from $3.62 trillion in 2022.

Data sources: U.S. Geological Survey and U.S. Department of Commerce

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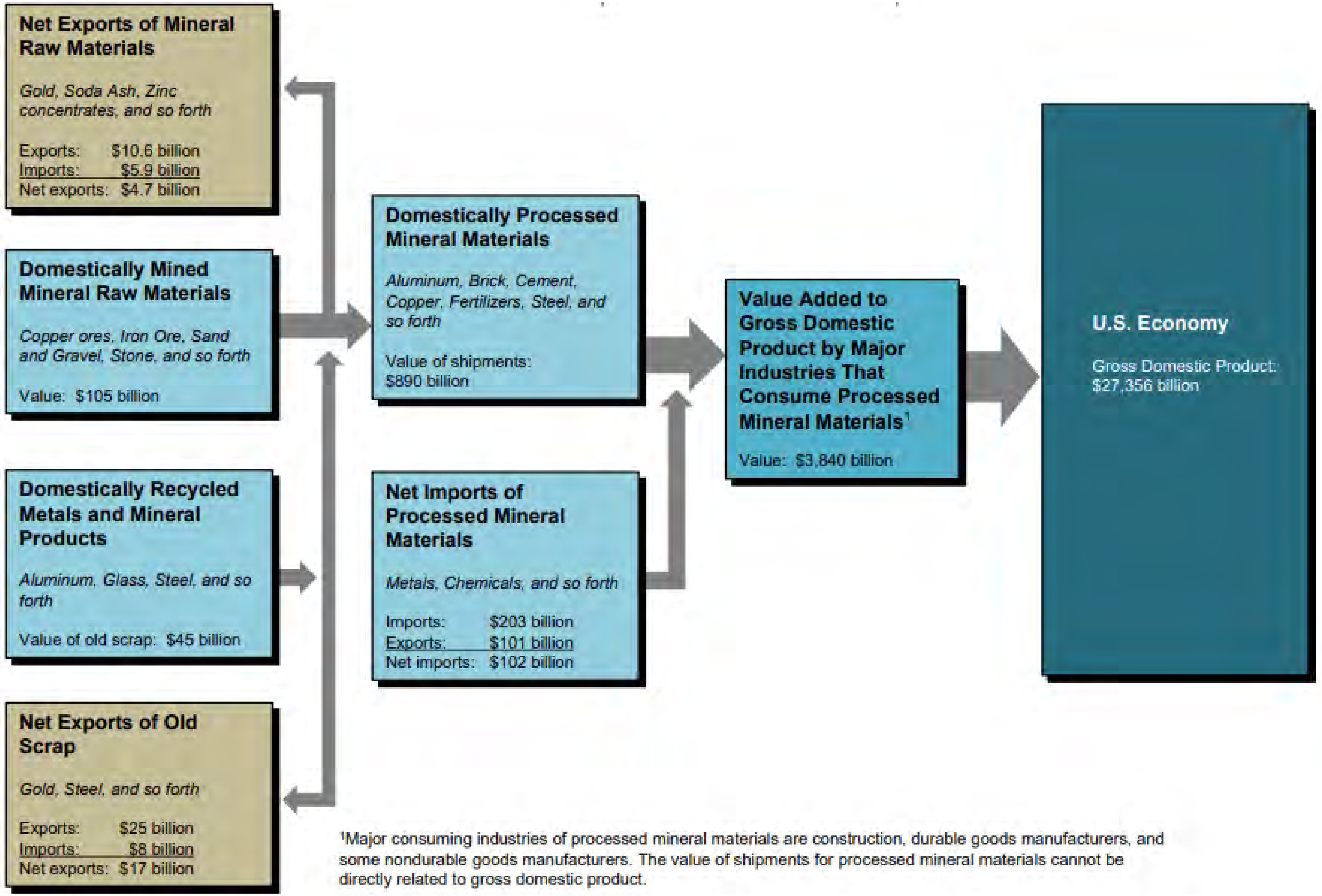
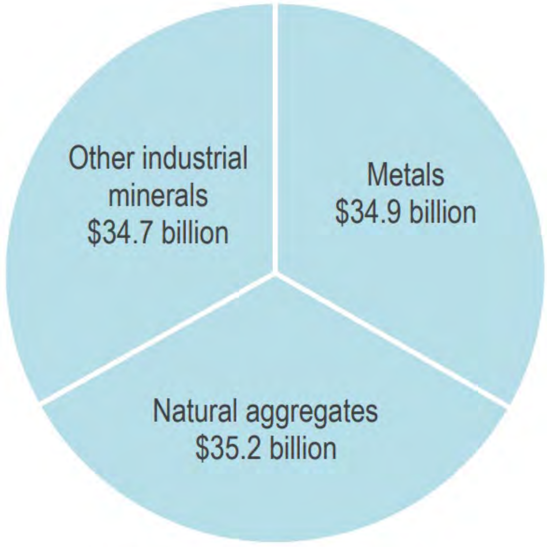
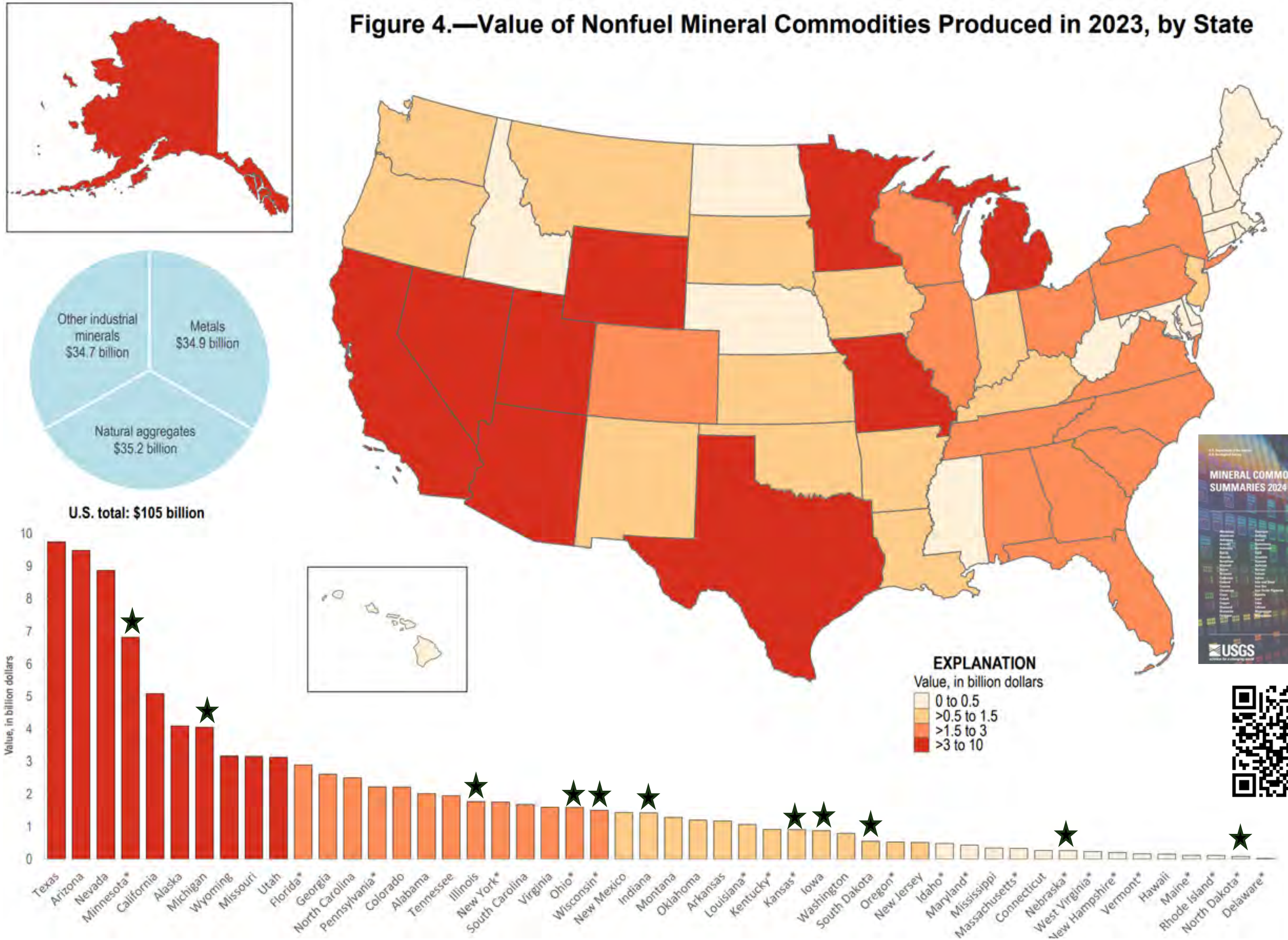


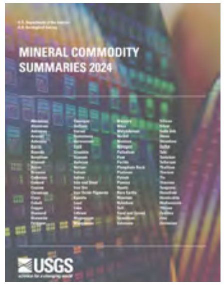
Mineral resource production is fundamental to the U.S. economy

Value of Nonfuel Mineral Commodities Produced in 2023, by State



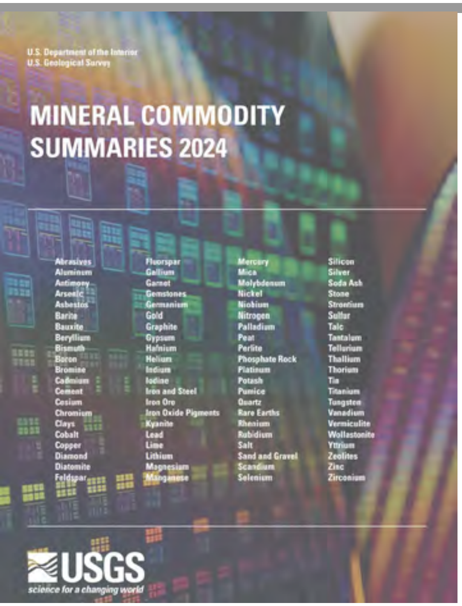
U.S. total: $105 billion





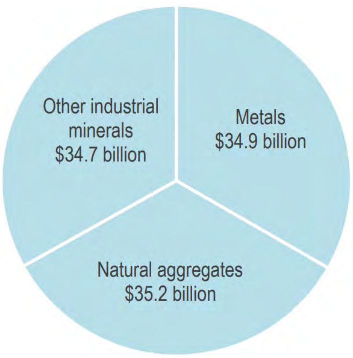
*Partial total; excludes values that must be withheld to avoid disclosing company proprietary data, which are included with "Undistributed" in table 3.

Midwestern U.S. has an active mineral resources sector



Metallic minerals produced include

- Iron (Minnesota, Michigan)
- Gold and silver (Wharf Mine, South Dakota)
- Nickel, copper, cobalt, and gold (Eagle Mine, Michigan)
- Lead, zinc, copper, silver (Missouri)
- Cobalt, copper, nickel (Missouri)



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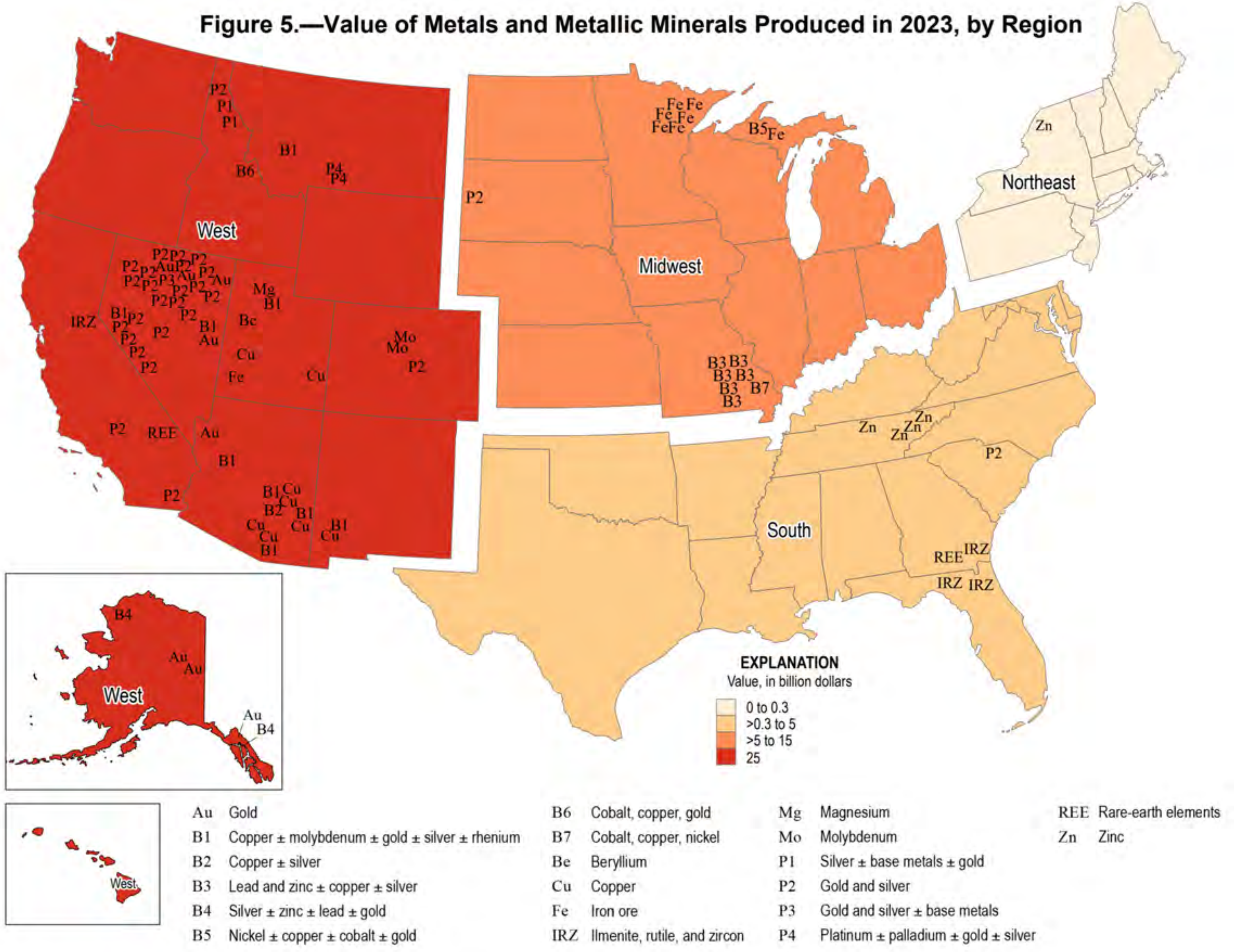
Sulfide ore from Eagle Mine, MI



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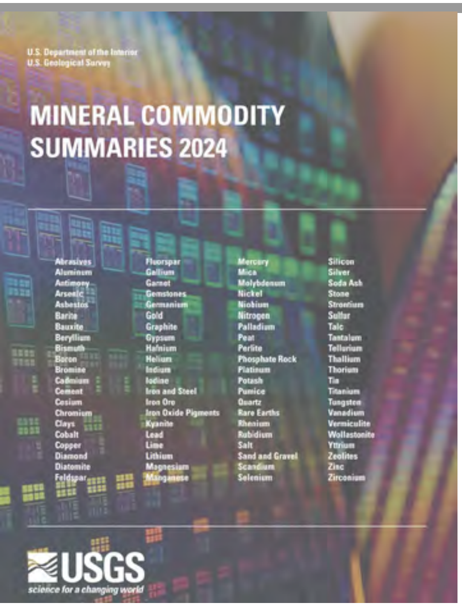
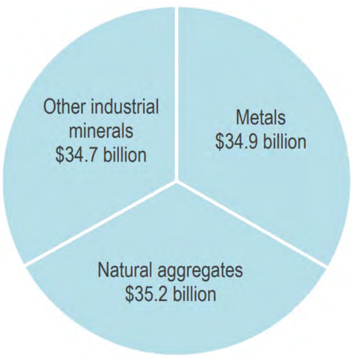


Other industrial minerals produced include

- Clay
- Industrial sand
- Peat
- Gypsum
- Mica
- Feldspar
- Pumice
- Helium
- Fuller's earth
- Dimension stone
- Magnesium
- Salt



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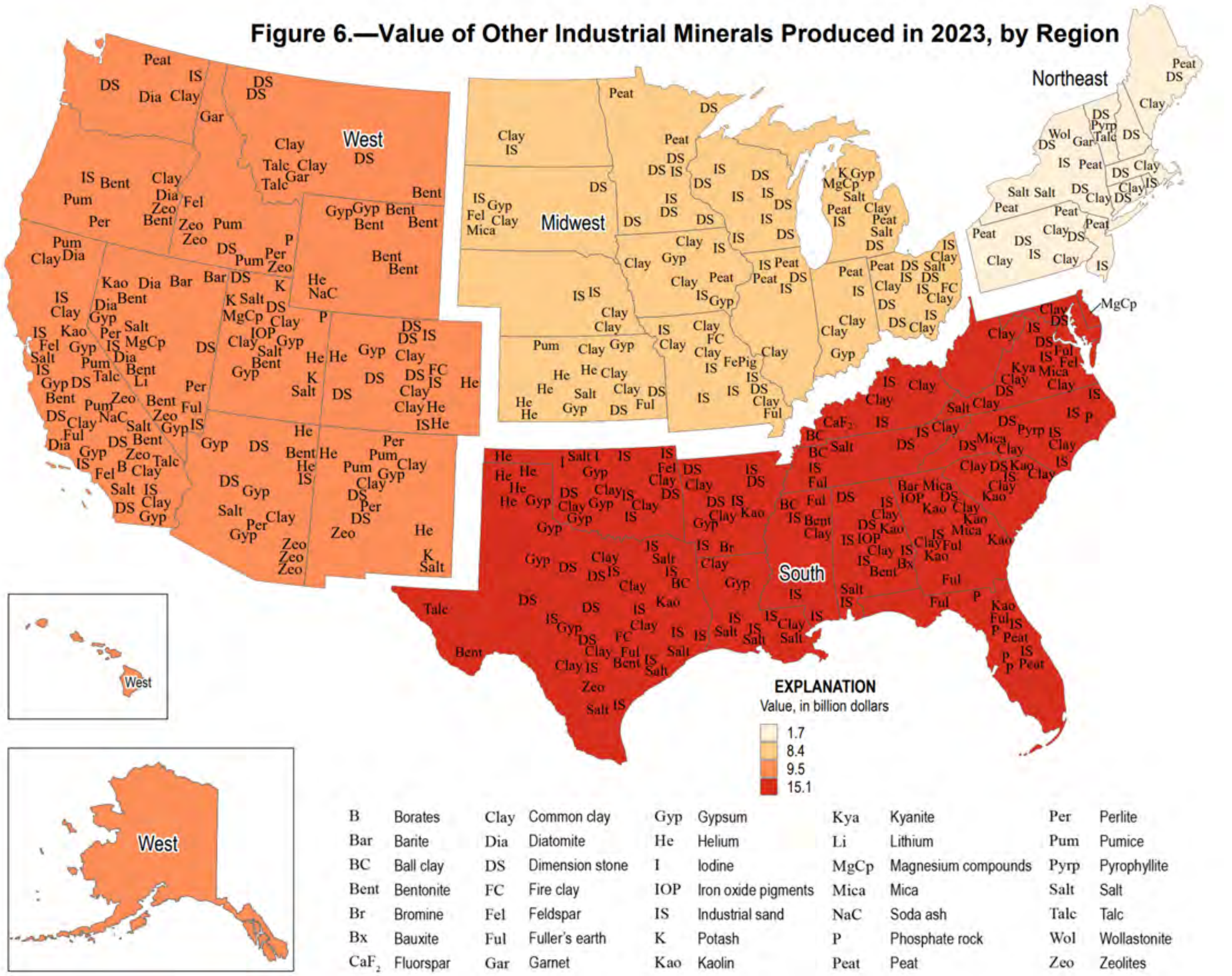

USGS National Minerals Information Center
Mineral Commodities Summaries 2024

The U.S. is not self-sufficient in many key mineral commodities

The U.S. is import reliant on many key mineral commodities

- In 2023, imports made up more than ½ of U.S. apparent consumption for 51 nonfuel mineral commodities, and U.S. was 100% net reliant on 15 of those

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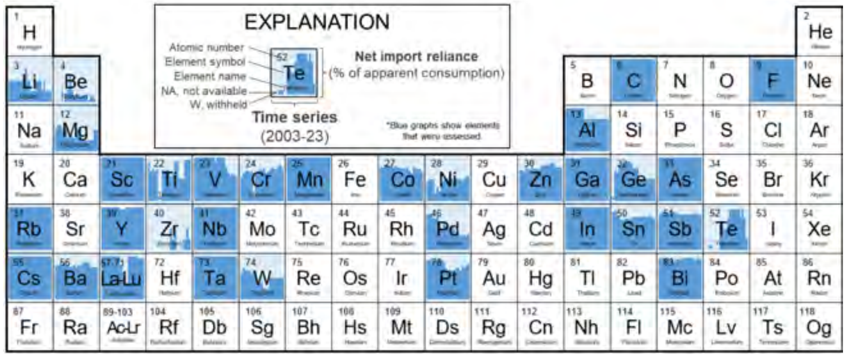
Commodity	Net import reliance as a percentage of apparent consumption in 2023	Leading import sources (2019–22)[2]
ARSENIC, all forms	100	China,[3] Morocco, Malaysia, Belgium
ASBESTOS	100	Brazil, Russia
CESIUM	100	Germany
FLUORSPAR	100	Mexico, Vietnam, China, South Africa
GALLIUM	100	Japan, China, Germany, Canada
GRAPHITE (NATURAL)	100	China,[3] Mexico, Canada, Madagascar
INDIUM	100	Republic of Korea, Canada, Belgium
MANGANESE	100	Gabon, South Africa, Australia, Georgia
MICA (NATURAL), sheet	100	China, Brazil, India, Belgium
NIOBIUM (COLUMBIUM)	100	Brazil, Canada
RUBIDIUM	100	China, Germany, Russia
SCANDIUM	100	Japan, China, Germany, Philippines
STRONTIUM	100	Mexico, Germany, China
TANTALUM	100	China,[3] Germany, Australia, Indonesia
YTTRIUM	100	China,[3] Germany, France, Republic of Korea
GEMSTONES	99	India, Israel, Belgium, South Africa
ABRASIVES, fused aluminum oxide	>95	China,[3] Canada, Brazil, Austria
NEPHELINE SYENITE	>95	Canada
RARE EARTHS,[4] compounds and metals	>95	China,[3] Malaysia, Japan, Estonia
TITANIUM, sponge metal	>95	Japan, Kazakhstan, Saudi Arabia, Ukraine
BISMUTH	94	China,[3] Republic of Korea, Belgium, Mexico
POTASH	91	Canada, Russia, Belarus
STONE (DIMENSION)	87	Brazil, China,[3] Italy, Turkey
DIAMOND (INDUSTRIAL), stones	84	India, South Africa, Russia, Congo (Kinshasa)
PLATINUM	83	South Africa, Switzerland, Germany, Belgium
ANTIMONY, metal and oxide	82	China,[3] Belgium, India, Bolivia
ZINC, refined	77	Canada, Mexico, Peru, Republic of Korea
BARITE	>75	India, China,[3] Morocco, Mexico
BAUXITE	>75	Jamaica, Turkey, Guyana, Australia
IRON OXIDE PIGMENTS, natural and synthetic	75	China,[3] Germany, Brazil, Canada
TITANIUM MINERAL CONCENTRATES	75	South Africa, Madagascar, Australia, Canada
CHROMIUM, all forms	74	South Africa, Kazakhstan, Russia, Canada
PEAT	74	Canada
TIN, refined	74	Peru, Bolivia, Indonesia, Malaysia
ABRASIVES, silicon carbide	73	China,[3] Brazil, Canada, Netherlands
SILVER	69	Mexico, Canada, Poland, Switzerland
COBALT	67	Norway, Canada, Finland, Japan
GARNET (INDUSTRIAL)	67	South Africa, Australia, China,[3] India
RHENIUM	60	Chile, Canada, Germany, Kazakhstan
ALUMINA	59	Brazil, Australia, Jamaica, Canada
VANADIUM	58	Canada, Brazil, Austria, Russia
NICKEL	57	Canada, Norway, Finland, Russia
DIAMOND (INDUSTRIAL), bort, grit, and dust and powder	56	China,[3] Republic of Korea, Ireland, Russia
MAGNESIUM COMPOUNDS	52	China,[3] Israel, Canada, Brazil
GERMANIUM	>50	Belgium, China, Canada
IODINE	>50	Chile, Japan
MAGNESIUM METAL	>50	Canada, China,[3] Israel, Taiwan
SELENIUM	>50	Philippines, Mexico, Germany, Canada
TUNGSTEN	>50	China,[3] Germany, Bolivia, Vietnam

The U.S. has a current focus on "critical" mineral resources

Critical mineral resources are those that are essential to the U.S. economy and national security, have a supply chain that is vulnerable to disruption, and serve an essential function in the manufacturing or a product

- Initiated by Presidential Executive Order 13817 (2018)
- Critical minerals defined by the Energy Act of 2020
- USGS published the first list of 35 critical minerals in 2019 and a revised list in 2021 that contains 50 individual mineral commodities



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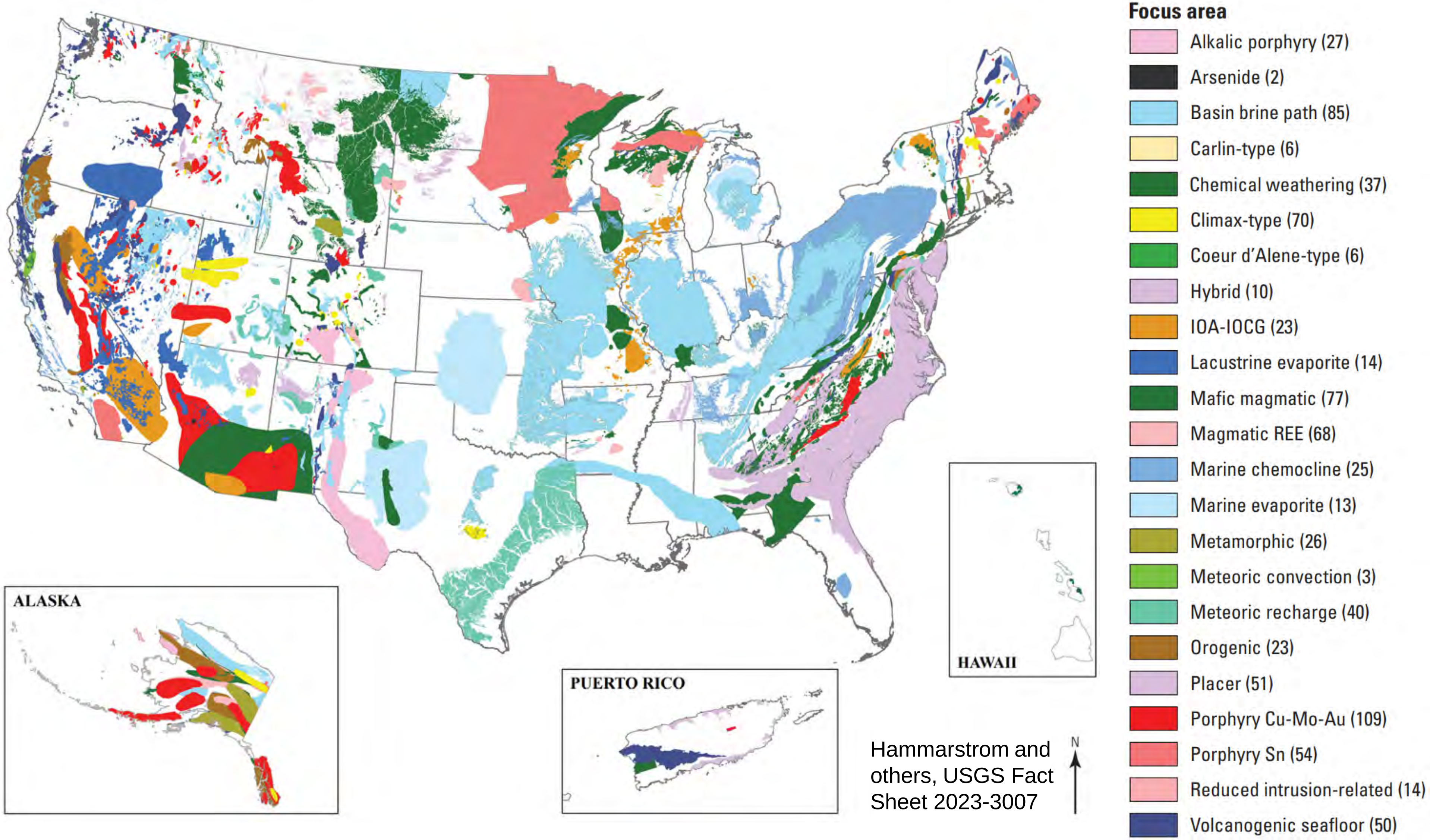
Revised list individually lists the rare-earth elements and platinum-group elements by specific element forms; added Ni and Zn; removed He, potash, Re, Sr, and U

Critical mineral	United States: Primary production	Secondary production	Apparent consumption	Net import reliance as a percentage of apparent consumption	Primary import source (2017–20)	World: Leading producing country	Production in leading country	World production total	Percentage of world total
Aluminum (bauxite)	W	—	[2]3,600,000	>75	Jamaica	Australia	110,000,000	[3]390,000,000	28
Antimony	—	4,100	[4]28,000	84	China	China	60,000	110,000	55
Arsenic	—	—	[5]6,800	100	China	Peru	[6]27,000	[6]59,000	46
Barite	W	—	W	>75	China	China	2,800,000	[3]7,300,000	38
Beryllium	170	NA	200	16	Kazakhstan	United States	170	260	65
Bismuth[7]	—	80	810	90	China	China	16,000	19,000	84
Chromium	—	120,000	590,000	80	South Africa	South Africa	18,000,000	41,000,000	44
Cobalt	700	1,600	6,700	76	Norway	Congo (Kinshasa)	120,000	170,000	71
Fluorspar	NA	—	450,000	100	Mexico	China	5,400,000	8,600,000	63
Gallium	—	—	[2]16	100	China	China	420	430	98
Germanium[7]	—	W	[5]30	>50	China	China	95	[3]140	68
Graphite (natural)	—	—	45,000	100	China	China	820,000	1,000,000	82
Helium[8]	71	NA	40	E	Qatar	United States	71	160	44
Indium[7]	—	NA	[5]170	100	China	China	530	920	58
Lithium	W	W	[5]2,000	>25	Argentina	Australia	55,000	[3]100,000	55
Magnesium[7]	W	98,000	[2]50,000	<50	Canada	China	800,000	[3]950,000	84
Manganese	—	—	640,000	100	Gabon	South Africa	7,400,000	20,000,000	37
Niobium	—	NA	7,000	100	Brazil	Brazil	66,000	75,000	88
Palladium (platinum-group metal)	14	42	90	37	Russia	South Africa	80	200	40
Platinum (platinum-group metal)	4	7	37	70	South Africa	South Africa	130	180	72
Potash	480,000	—	7,400,000	93	Canada	Canada	14,000,000	46,000,000	30
Rare-earth elements[9]	43,000	—	[10]6,100	>90	China	China	168,000	280,000	60
Rhenium	9	NA	32	72	Chile	Chile	29	59	49
Scandium	—	—	NA	100	NA	China	NA	NA	NA
Strontium	—	—	4,800	100	Mexico	Spain	150,000	360,000	42
Tantalum	—	NA	710	100	China	Congo (Kinshasa)	700	2,100	33
Tellurium[7]	W	—	W	>95	Canada	China	340	[3]580	59
Tin	—	10,000	45,000	78	Indonesia	China	91,000	300,000	30
Titanium[7]	W	W	[2]W	>90	Japan	China	120,000	[3]210,000	57
Tungsten	—	W	W	>50	China	China	66,000	79,000	84
Vanadium	—	NA	3,600	100	Canada	China	73,000	110,000	66
Zirconium	[11]20,000	—	[11]30,000	<25	South Africa	Australia	400,000	1,200,000	33

USGS uses a **Mineral Systems framework** to understand and map critical mineral associations

USGS MRP used a mineral systems approach to:

- Identify prospective areas and regions
- Locate key gaps in data coverage
- Guide USGS and State data collection
- Accelerate assessment of critical mineral resources
- Show resource managers and developers where emerging minerals-dependent technologies may create economic opportunities



Hammarstrom and others, USGS Fact Sheet 2023-3007

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Mineral systems are the geo-tectonic environments in which mineral deposits form

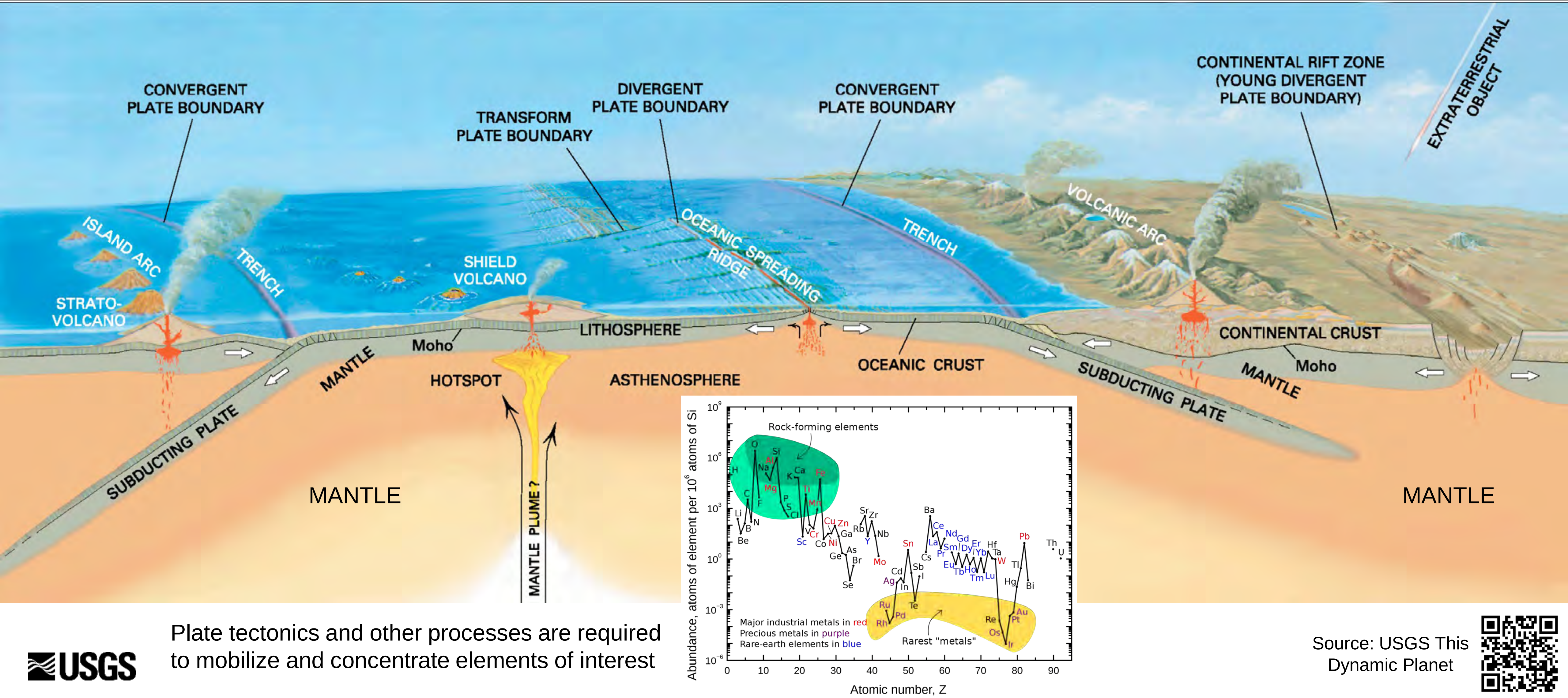

Plate tectonics and other processes are required to mobilize and concentrate elements of interest

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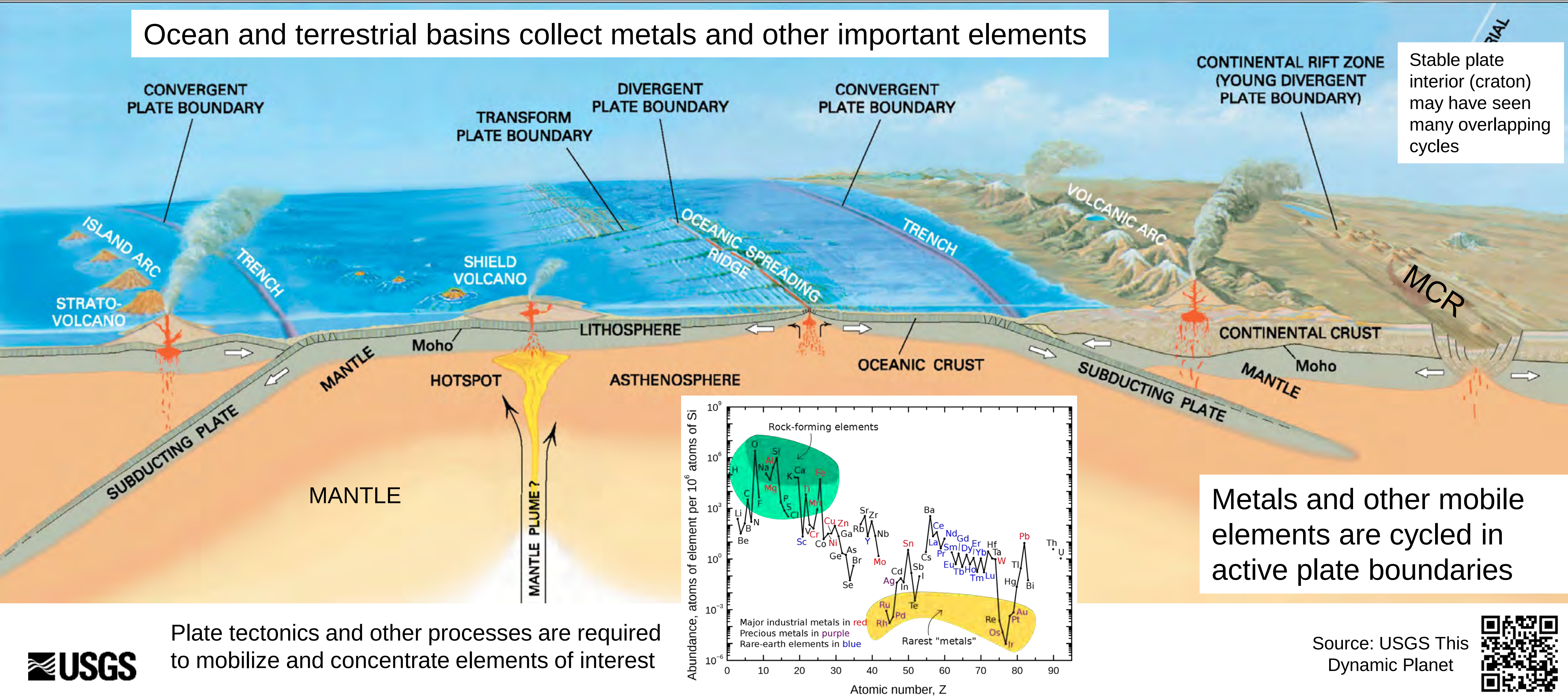
Source: USGS This Dynamic Planet

Mineral systems are the geo-tectonic environments in which mineral deposits form

Ocean and terrestrial basins collect metals and other important elements



Stable plate interior (craton) may have seen many overlapping cycles

Metals and other mobile elements are cycled in active plate boundaries

Plate tectonics and other processes are required to mobilize and concentrate elements of interest

USGS

Source: USGS This Dynamic Planet

Mineral systems in the midwestern U.S. are diverse and span billions of years of Earth history

Only one current critical mineral producer in the Midwest – Eagle Mine, MI

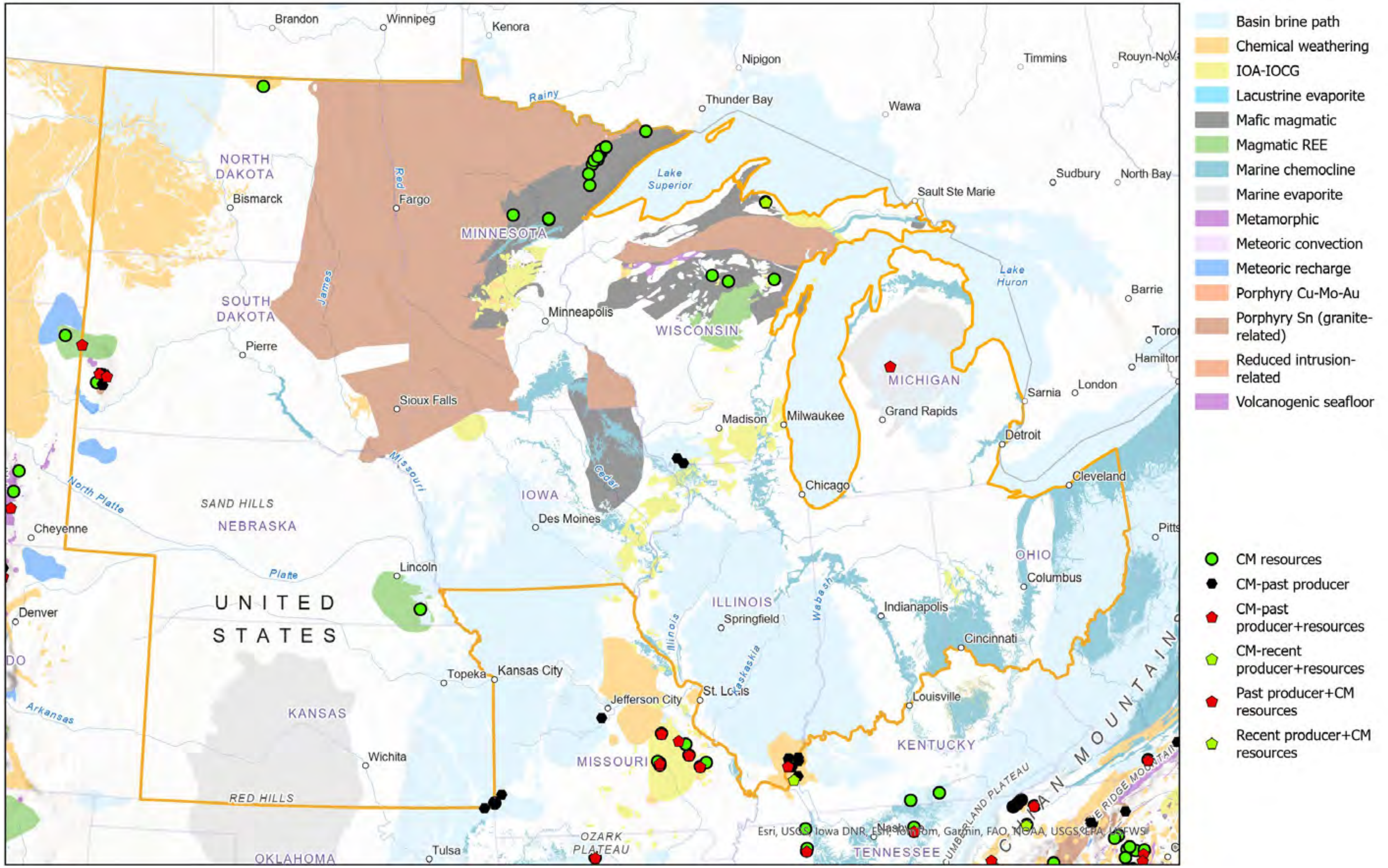
A few past producers:

- fluorspar, barite (IL)
- tin, tantalum, lithium, beryllium, niobium (SD)
- zinc, germanium, barite (WI)

Hammarstrom and others, 2023, Mineral Systems of the U.S., USGS Fact Sheet 2023-3007

Hammarstrom and others, 2023, Critical Mineral Deposits of the U.S., USGS Data Release

USGS

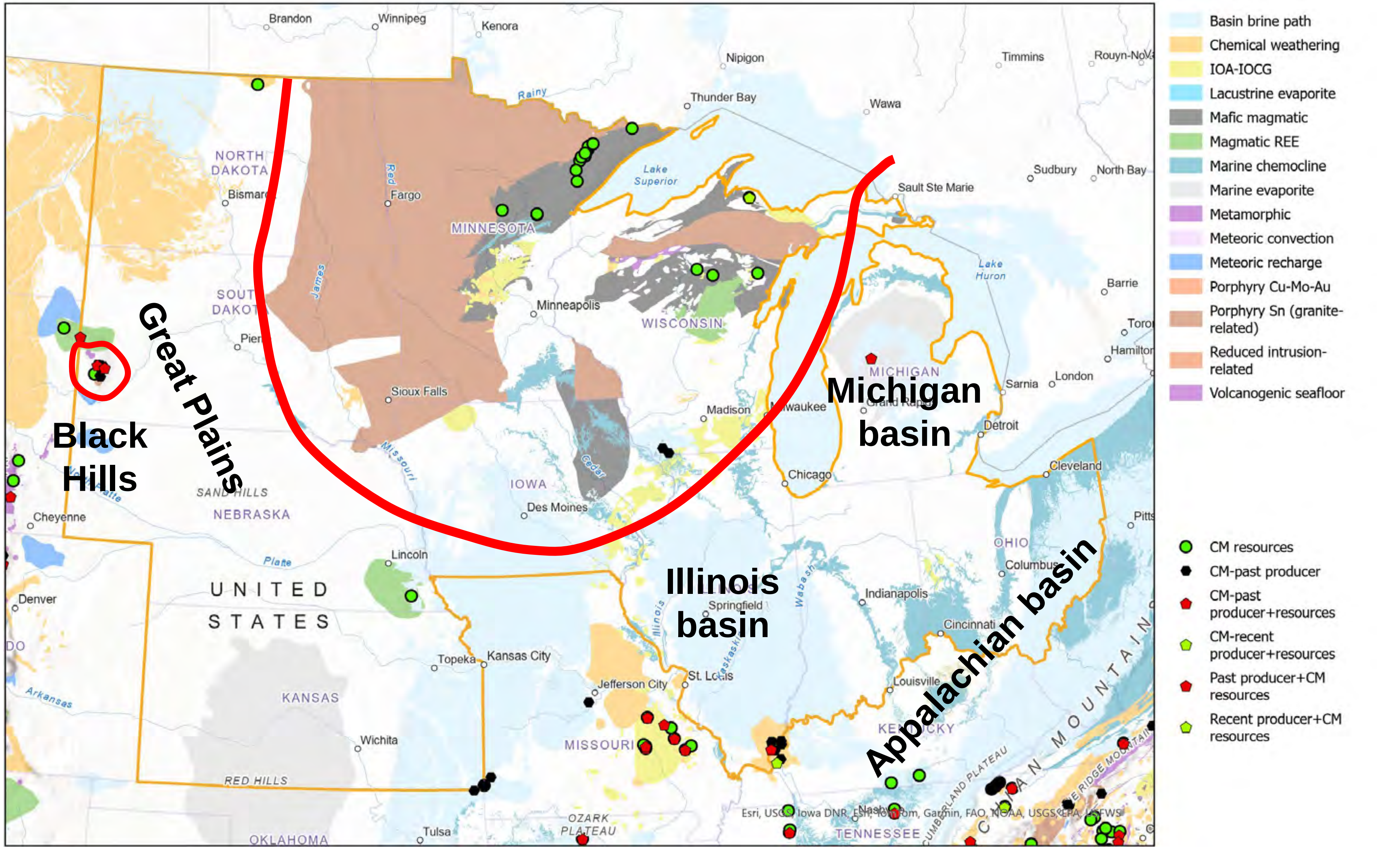


Critical mineral resources reflect the geologic history and tectonic environment(s) of each province or sub-region

Region is cored by the North America craton, a stable region of rocks ranging in age from ca. 3.7 to 1.4 billion years old

Complex, overlapping geo-tectonic systems produced diverse mineral resource potential

Iron ranges (manganese), gold, copper, lead, silver, graphite, zinc, rare earth elements, cobalt, tin, tungsten, lithium,



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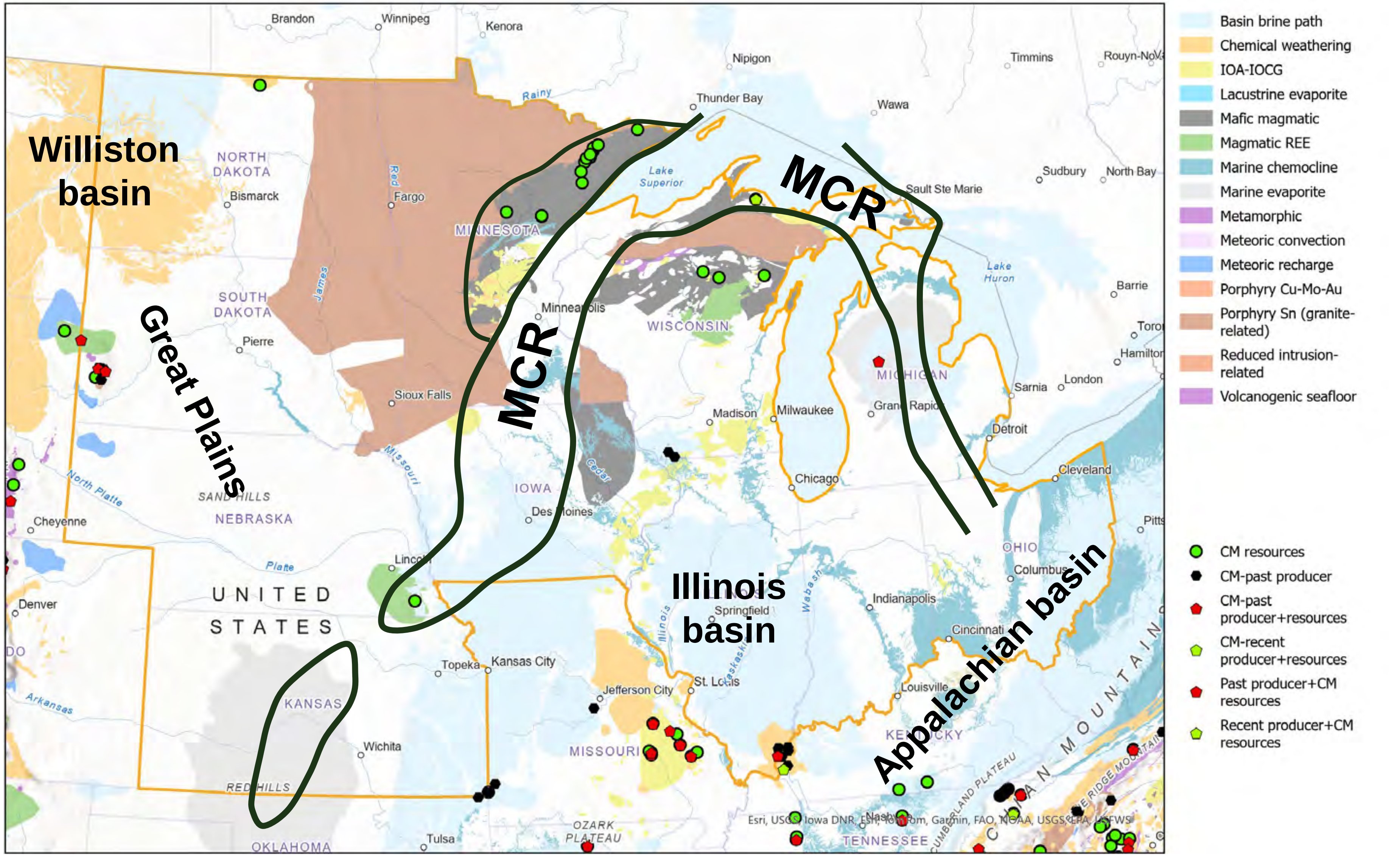
About 1.1 to 1.0 billion years ago, the Midcontinent Rift split apart the continent's interior and produced major igneous successions around Lake Superior

Duluth Complex (nickel, cobalt, platinum group elements), Eagle Mine and Tamarack deposit (copper, nickel, cobalt, platinum group elements)

Geologic hydrogen potential where MCR is buried to the south



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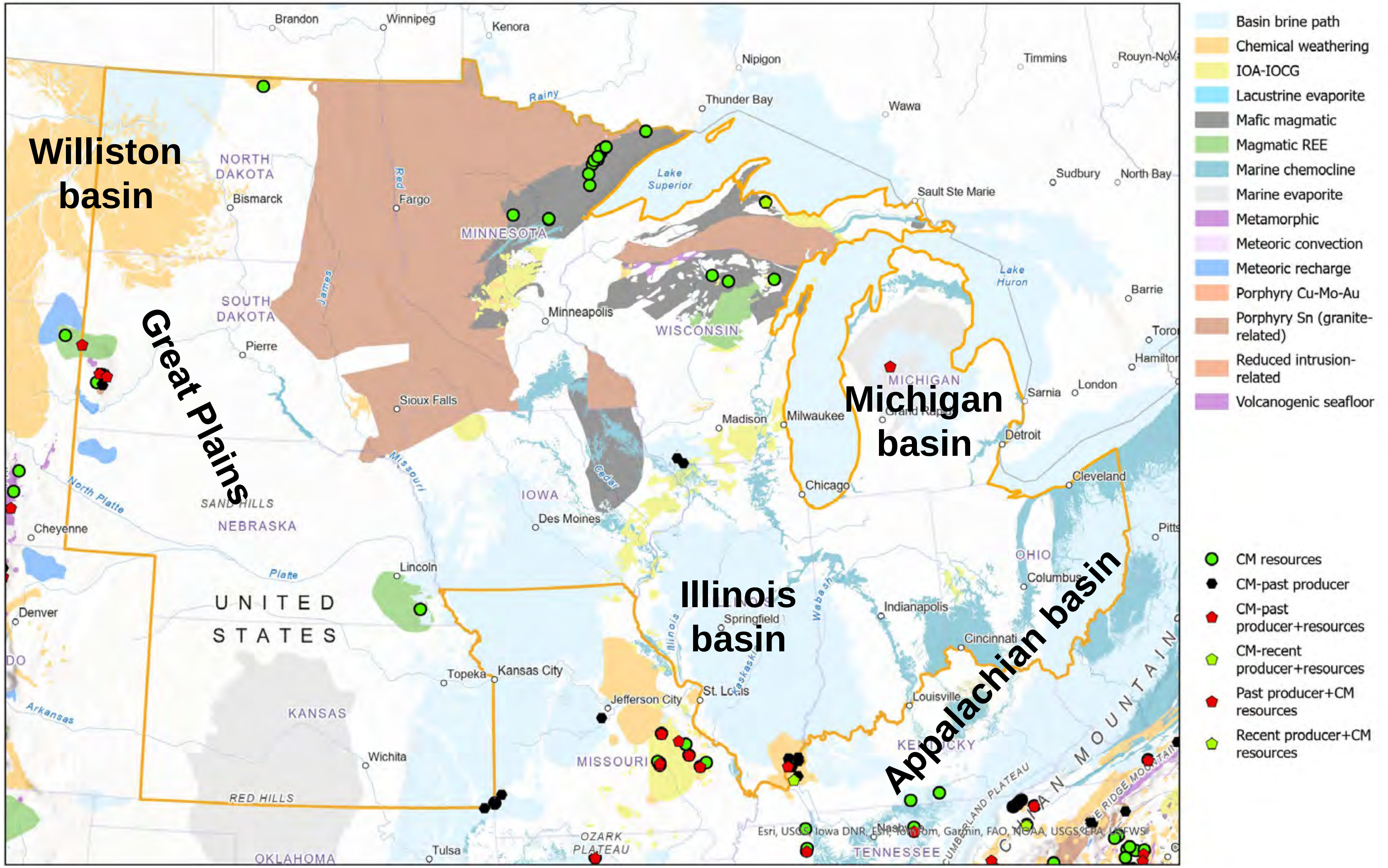
Critical mineral resources reflect the geologic history and tectonic environment(s) of each province or sub-region

Paleozoic Era (~550 to 250 million years ago) involved deposition of mostly marine basinal sedimentary successions

Marine evaporites have potential for potash, salt, possibly rare earth elements

Thick, extensive black shale successions are rich in phosphate and potentially rare earth elements



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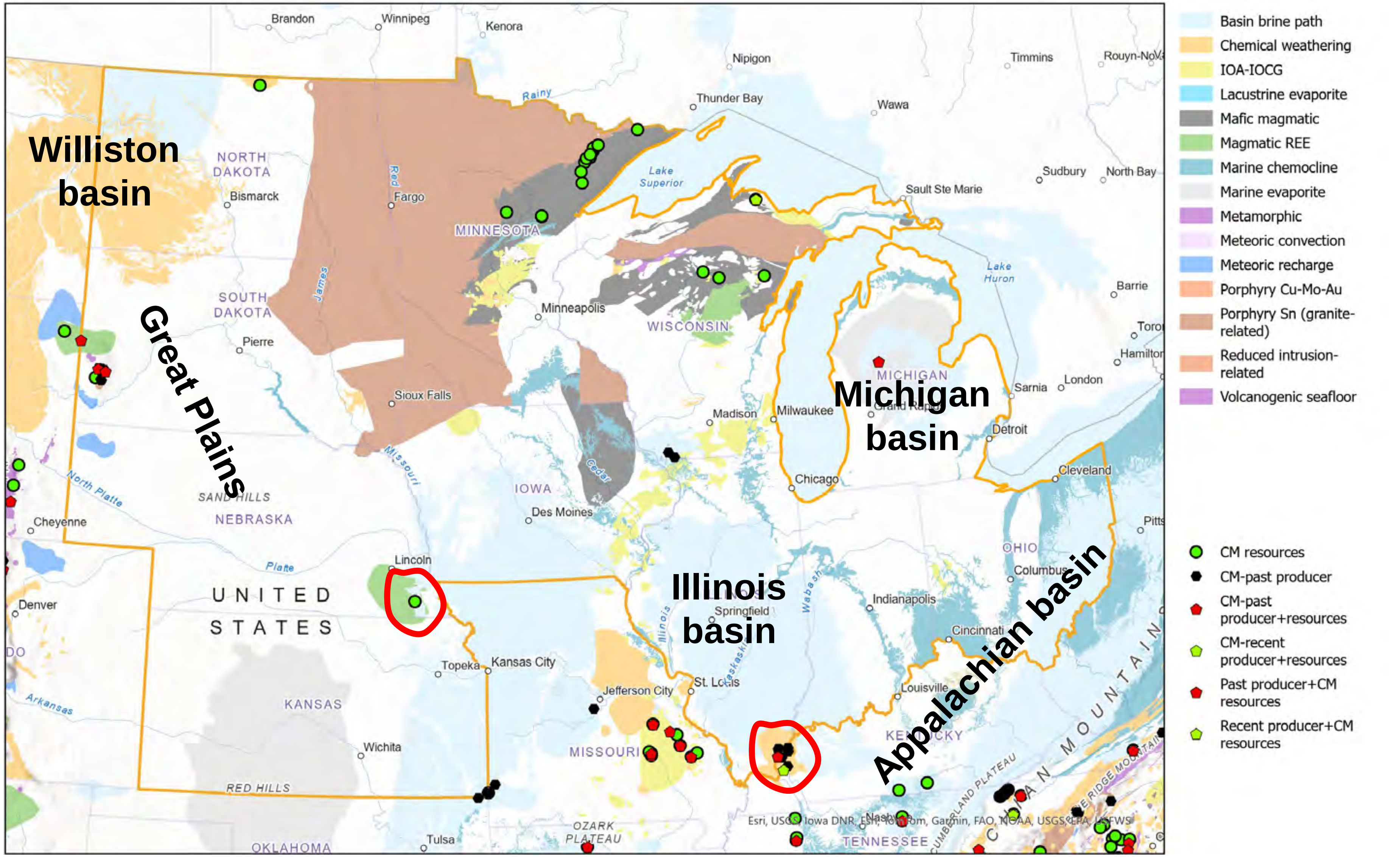
Buried “oddball” intrusions such as Elk Creek carbonatite (NE) host niobium, rare earth elements

Other oddball intrusions include Hicks Dome in southernmost Illinois, also have significant fluorspar potential



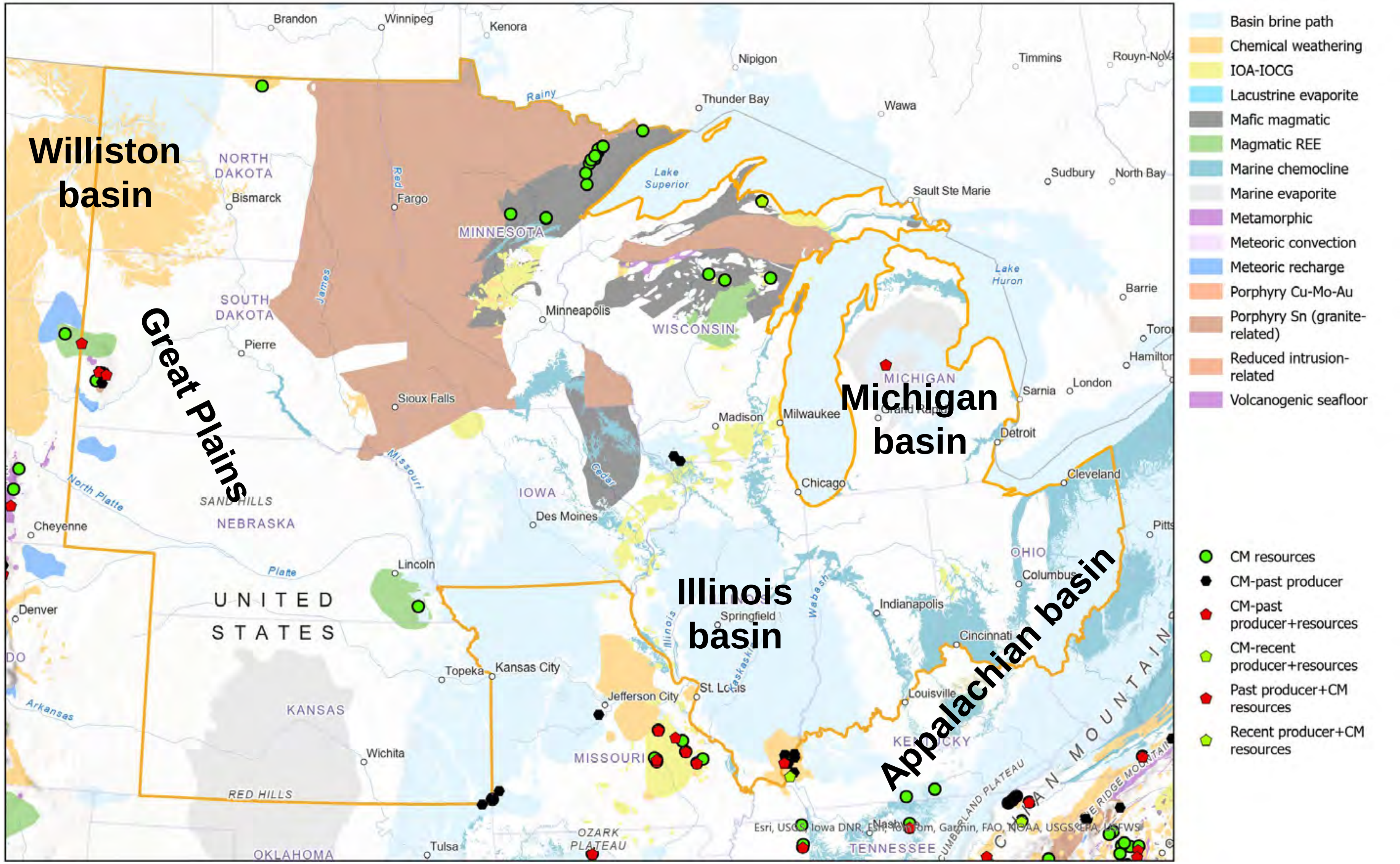
USGS

Critical mineral resources reflect the geologic history and tectonic environment(s) of each province or sub-region

Mesozoic Era (~250 to 65 million years ago) involved deposition of mostly marine basinal sedimentary successions in the western Great Plains and Rocky Mountains

Marine evaporites have potential for potash, salt, possibly rare earth elements

Thick, extensive black shale successions are rich in phosphate and potentially rare earth elements



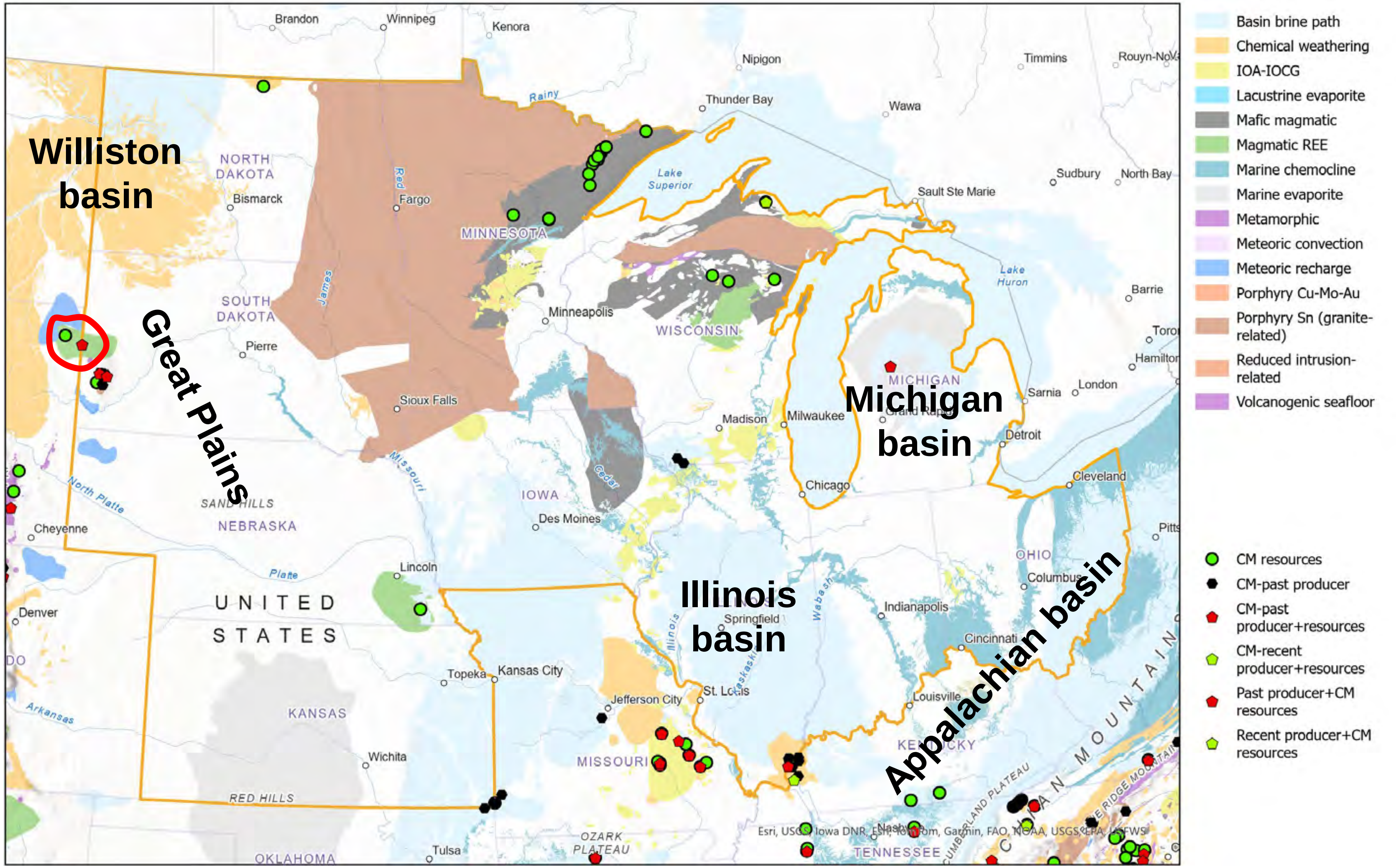
USGS

Critical mineral resources reflect the geologic history and tectonic environment(s) of each province or sub-region

Mesozoic Era (~250 to 65 million years ago) involved deposition of mostly marine basinal sedimentary successions in the western Great Plains and Rocky Mountains

Coal basins have potential for rare earth elements, aluminum (kaolin), gallium, lithium, scandium, vanadium in underclays

Cenozoic Era intrusions in western South Dakota have rare earth element potential



USGS

Critical mineral resources reflect the geologic history and tectonic environment(s) of each province or sub-region

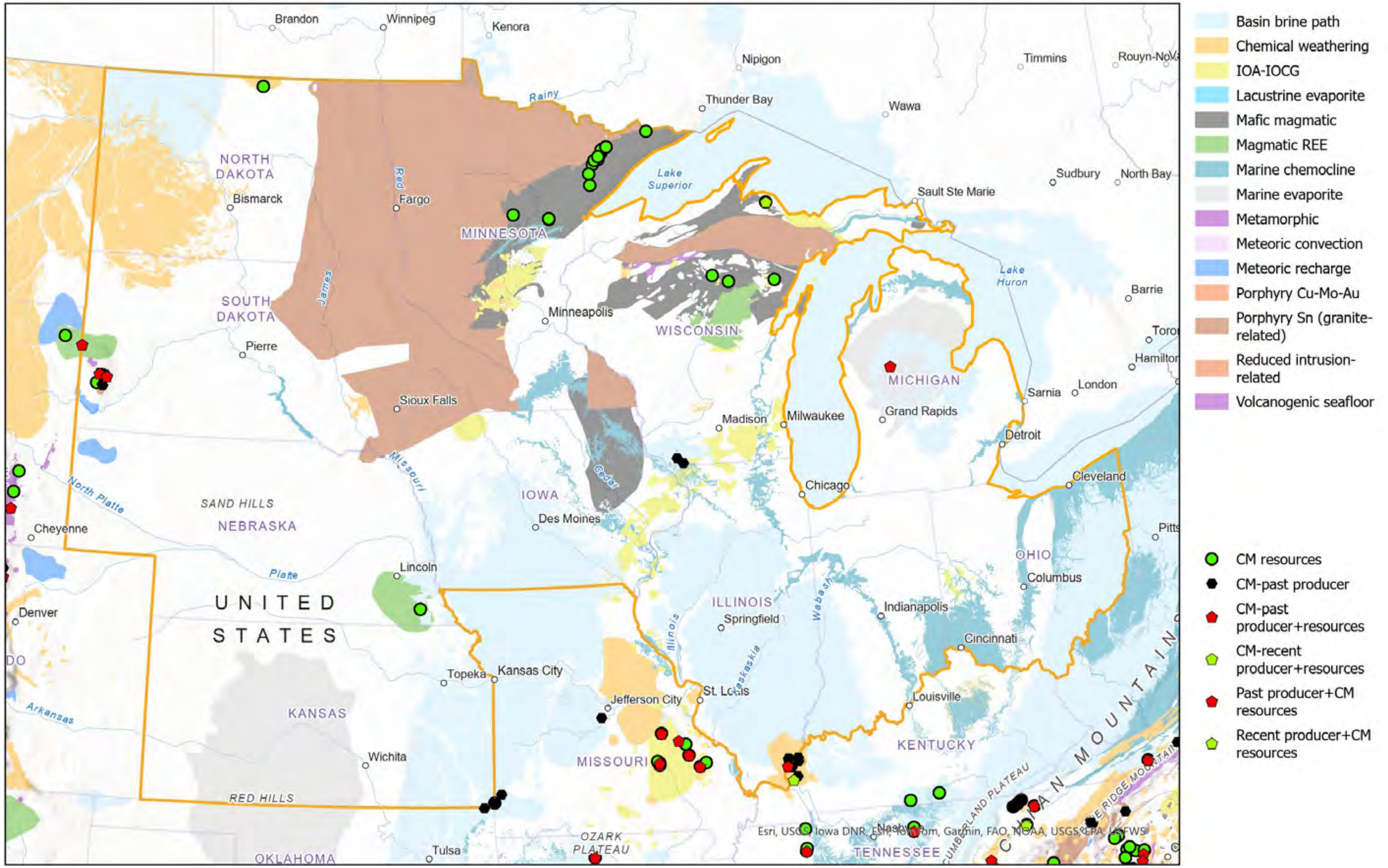
Known critical mineral resources do not necessarily measure critical mineral resources potential

United States is woefully undermapped relative to other countries

Critical elements have not been fully characterized in most mineral systems or known/mined deposits

USGS Earth Mapping Resources Initiative is helping to close data gaps

USGS



The USGS Earth Mapping Resources Initiative (Earth MRI) is modernizing the nation's geoscience data

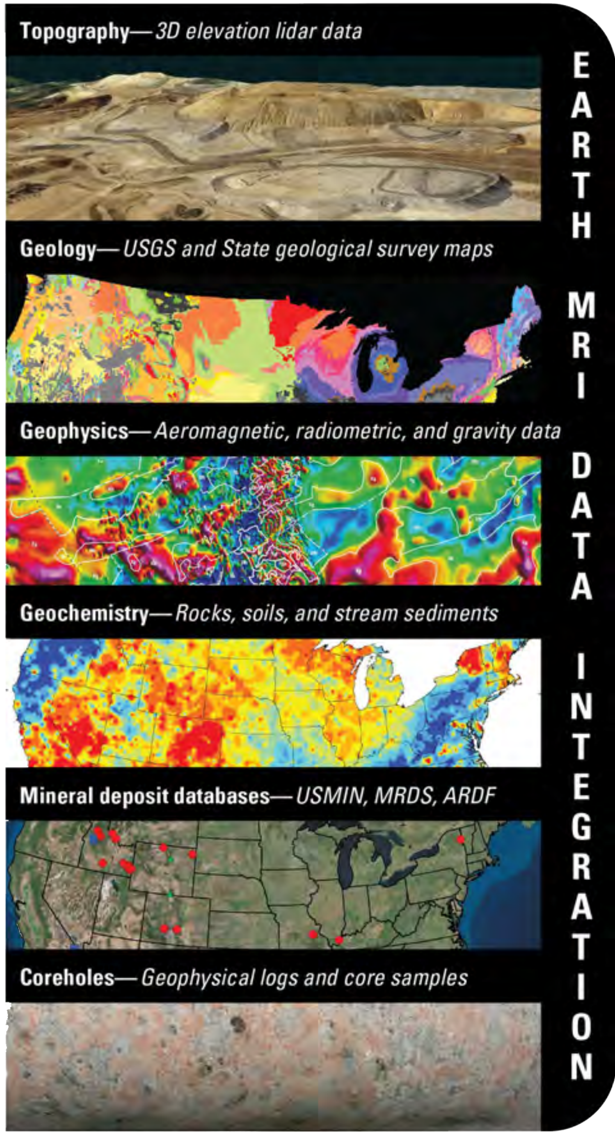
Established in 2019 as a **partnership between the USGS and State geological surveys** to modernize the Nation's mapping related to mineral resources

Collects fundamental geoscience data including:

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

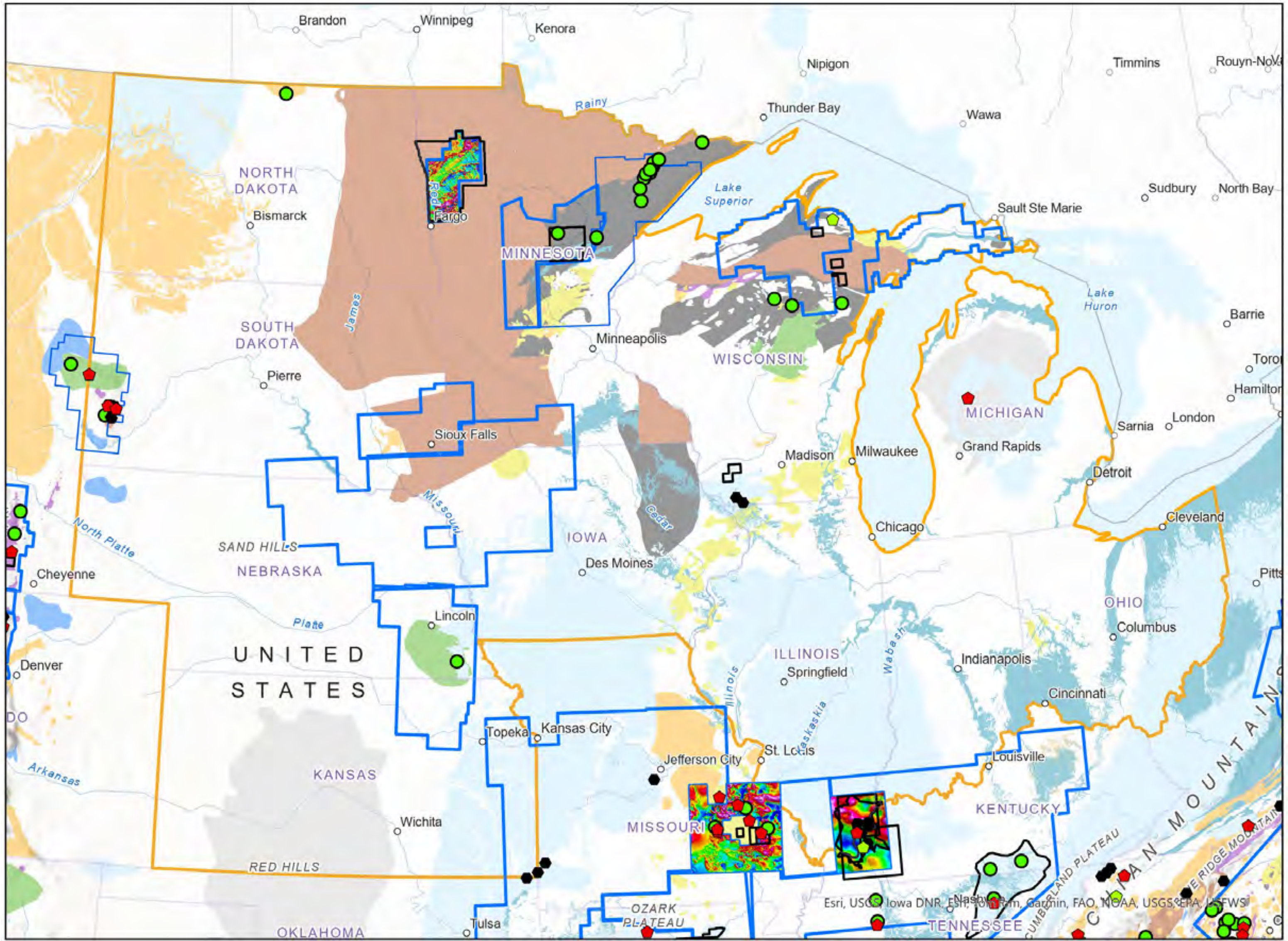
Annual appropriation of **$10.8 million**, an additional **$320 million** over 5 years through the Bipartisan Infrastructure Law

Has since expanded to multiple partners and stakeholders (including DOE, NASA, Tribes, and the private sector) and applications that include mine waste, energy, groundwater, natural hazards, and other vital geoscience issues



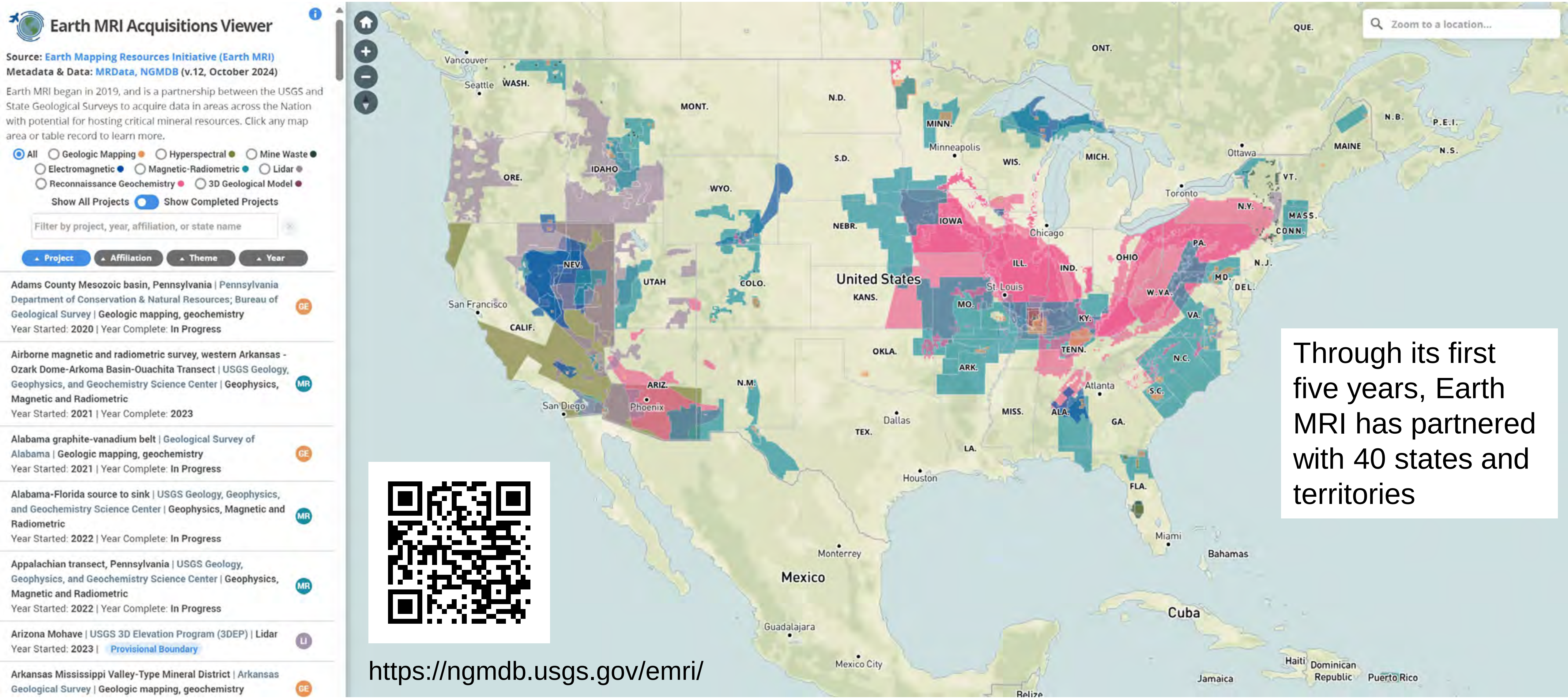
USGS

The USGS Earth Mapping Resources Initiative (Earth MRI) is modernizing the nation's geoscience data



USGS

The USGS Earth Mapping Resources Initiative (Earth MRI) is modernizing the nation’s geoscience data



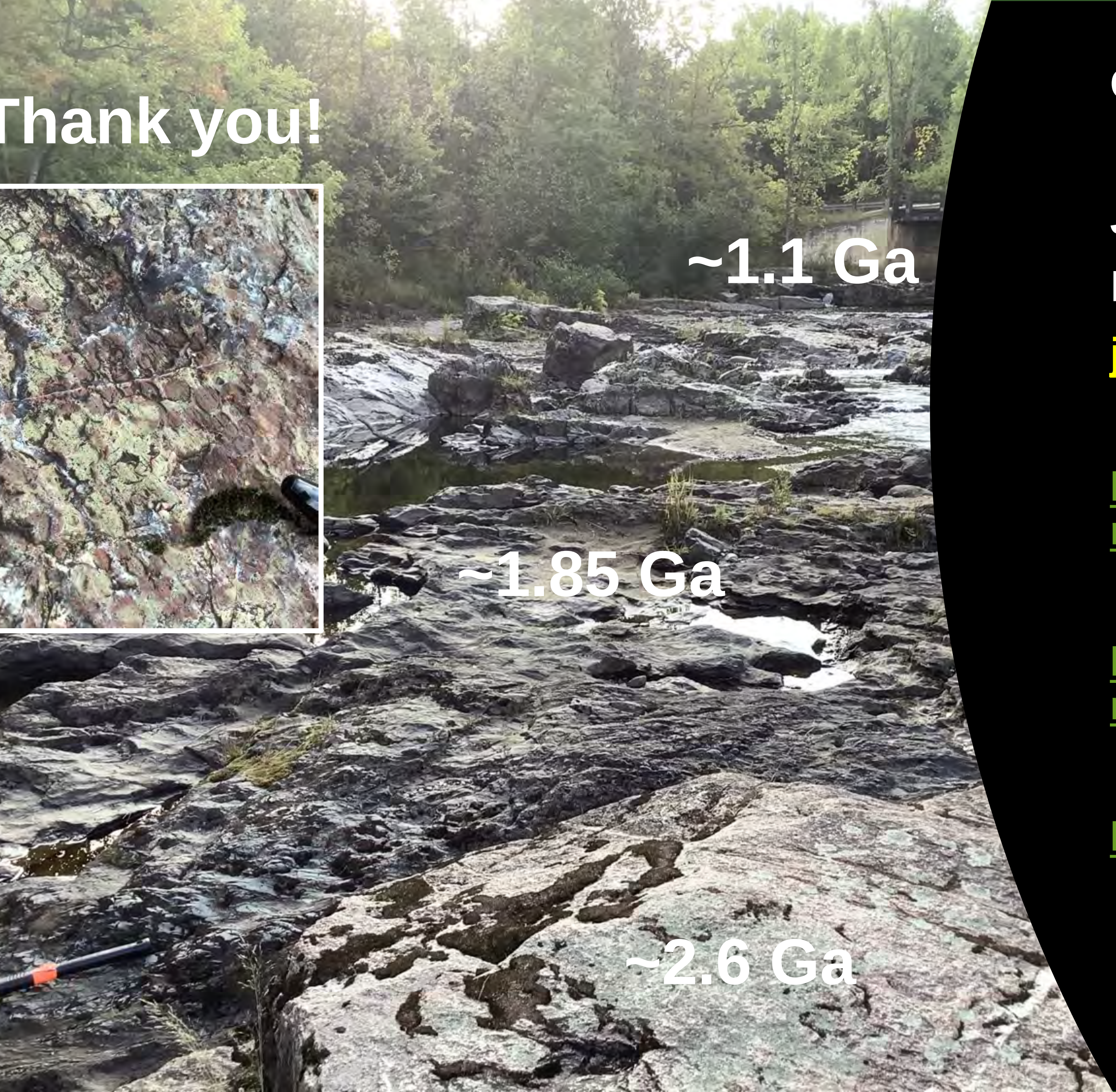
Through its first five years, Earth MRI has partnered with 40 states and territories

https://ngmdb.usgs.gov/emri/

Summary

- National and global initiatives toward sustainable development, green energy, and zero emissions have distinct mineral resource requirements
- Critical mineral resources are those for which supply chain risks are significant and the U.S. is important reliant
- The midwestern U.S. currently produces multiple mineral commodities including some presently considered critical (nickel, cobalt)
- The midwestern U.S. also has known or suspected potential to host many other critical mineral commodities, and the USGS is working to assess domestic resource potential
- A number of challenges limit mineral resource exploration and development in the U.S., including incomplete or imprecise geological and geophysical information
- USGS is working to fill key geoscience gaps with new data collection, mapping, research, and synthesis through the Earth MRI program and international collaboration

Thank you!



Contact information

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https://www.usgs.gov/programs/mineral-resources-program

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

https://ngmdb.usgs.gov/emri/#3/40/-96

Big Erick’s crossing, Huron River, Michigan
Photo credit: Jamey Jones, USGS