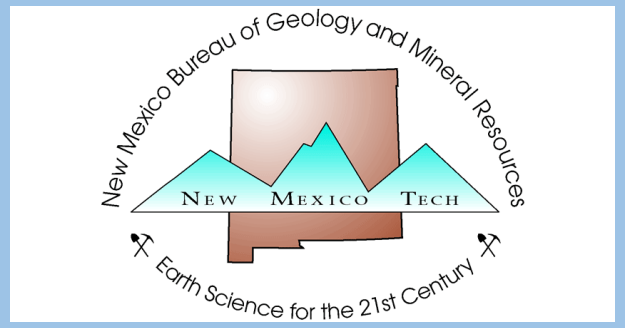
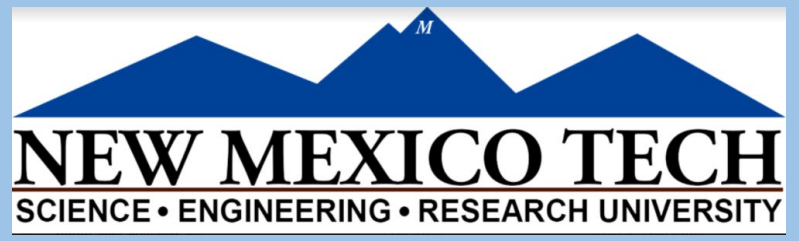
CRITICAL MINERALS IN PREVENTING HAZARDS

Virginia T. McLemore

New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM



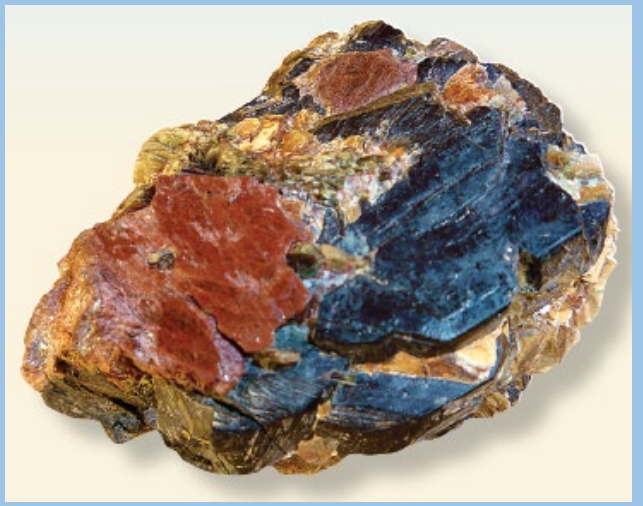


What is a mineral?

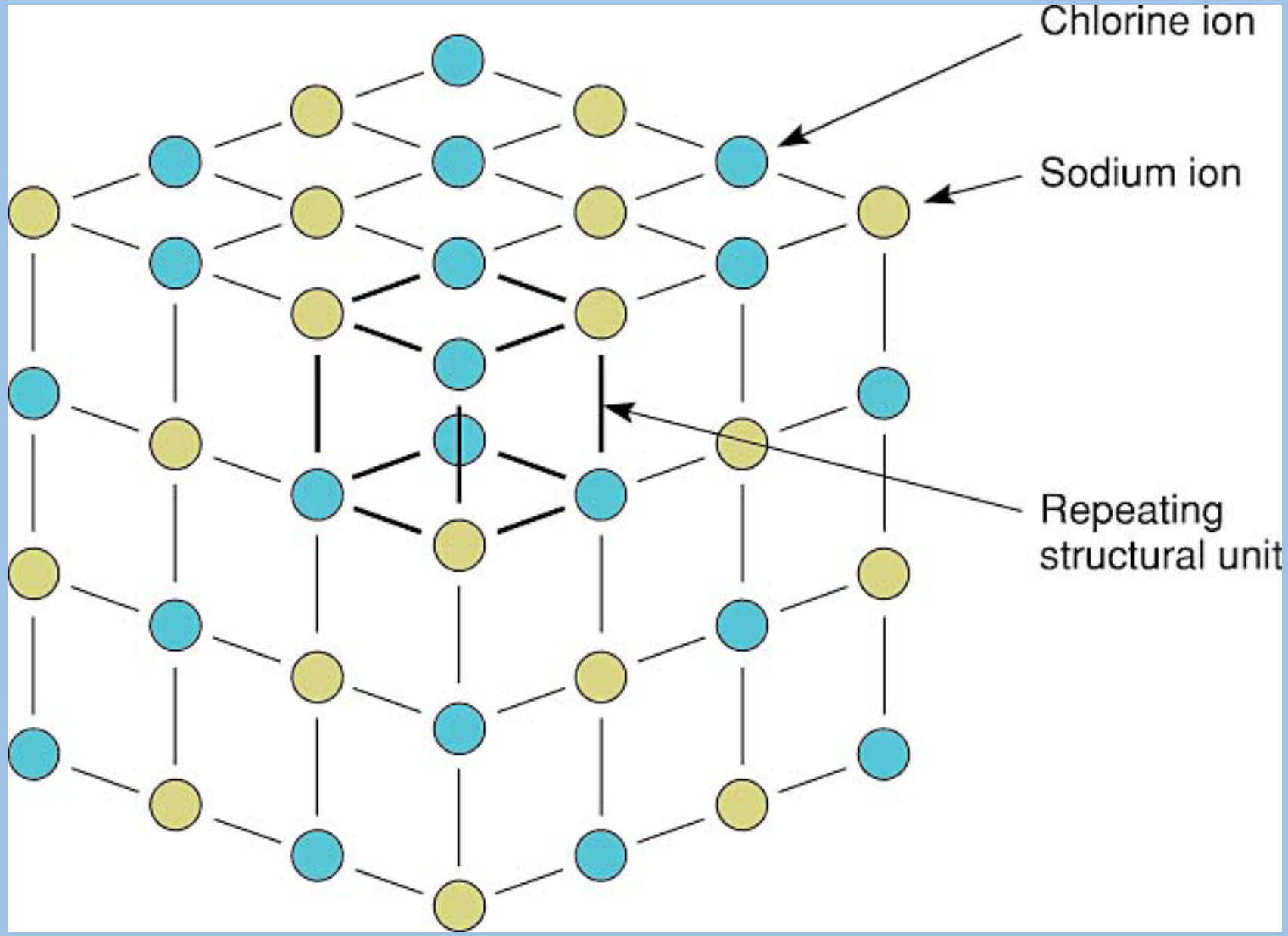
What is a mineral?

- Naturally occurring
- Inorganic
- Solid
- Homogeneous
- Crystalline material
- With a unique chemical element or compound with a set chemical formula
- Usually obtained from the ground

Uranophane, episyenite, Caballo Mountains, Sierra County



Monazite, Petaca pegmatite, Rio Arriba County



A crystal is composed of a structural unit that is repeated in three dimensions. This is the basic structural unit of a crystal of sodium chloride, the mineral halite.

Another definition

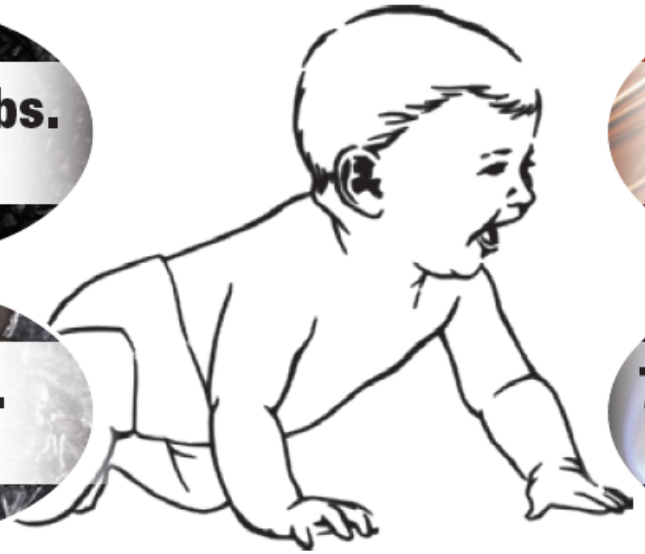
Definition of Minerals

In industry, *minerals* refer to any rock, mineral, or other naturally occurring material of economic value, including metals, industrial minerals, energy minerals, gemstones, aggregates, and synthetic materials sold as *commodities.*

Every American Born Will Need...

3.19 MILLION POUNDS

of minerals, metals, and fuels in their lifetime



- 2,692 lbs. BAUXITE (ALUMINUM)
- 53,847 lbs. CEMENT
- 11,614 lbs. CLAYS
- 282,444 lbs. COAL
- 950 lbs. COPPER
- 1.54 Troy oz. GOLD
- 21,645 lbs. IRON ORE
- 871 lbs. LEAD
- 7.97 million cu.ft. NATURAL GAS
- 75,114 gallons PETROLEUM
- 13,231 lbs. PHOSPHATE ROCK
- 30,091 lbs. SALT
- 1.42M lbs. STONE, SAND & GRAVEL
- 502 lbs. ZINC
- +58,767 lbs. OTHER MINERALS/ METALS

Learn more at **www.MineralsEducationCoalition.org**

https://mineralseducationcoalition.org/mining-mineral-statistics/

What are critical minerals?

Presidential Executive Order No. 13817 define critical minerals as

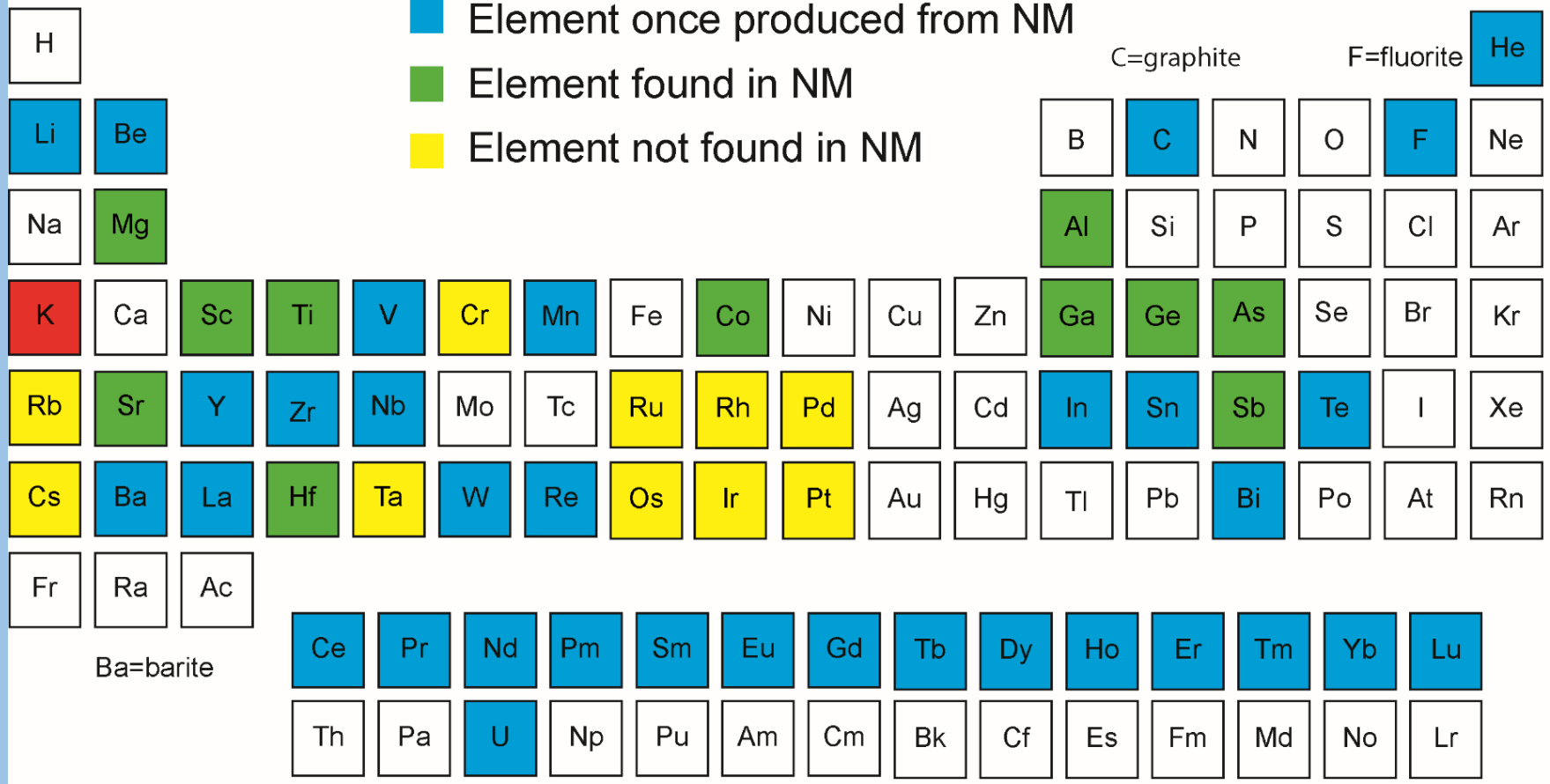
"*a mineral (1) identified to be a nonfuel mineral or mineral material essential to the economic and national security of the United States, (2) from a supply chain that is vulnerable to disruption, and (3) that serves an essential function in the manufacturing of a product, the absence of which would have substantial consequences for the U.S. economy or national security*"

Critical Minerals

- Minerals needed for military, industrial or commercial purposes that are essential to renewable energy, national defense equipment, medical devices, electronics, agricultural production and common household items
- Minerals that are essential for use but subject to potential supply disruptions
- Minerals that perform an essential function for which few or no satisfactory substitutes exist
- The absence of which would cause economic, national security, or social consequences
- 33-50% minerals are classified as such

Critical Minerals in New Mexico

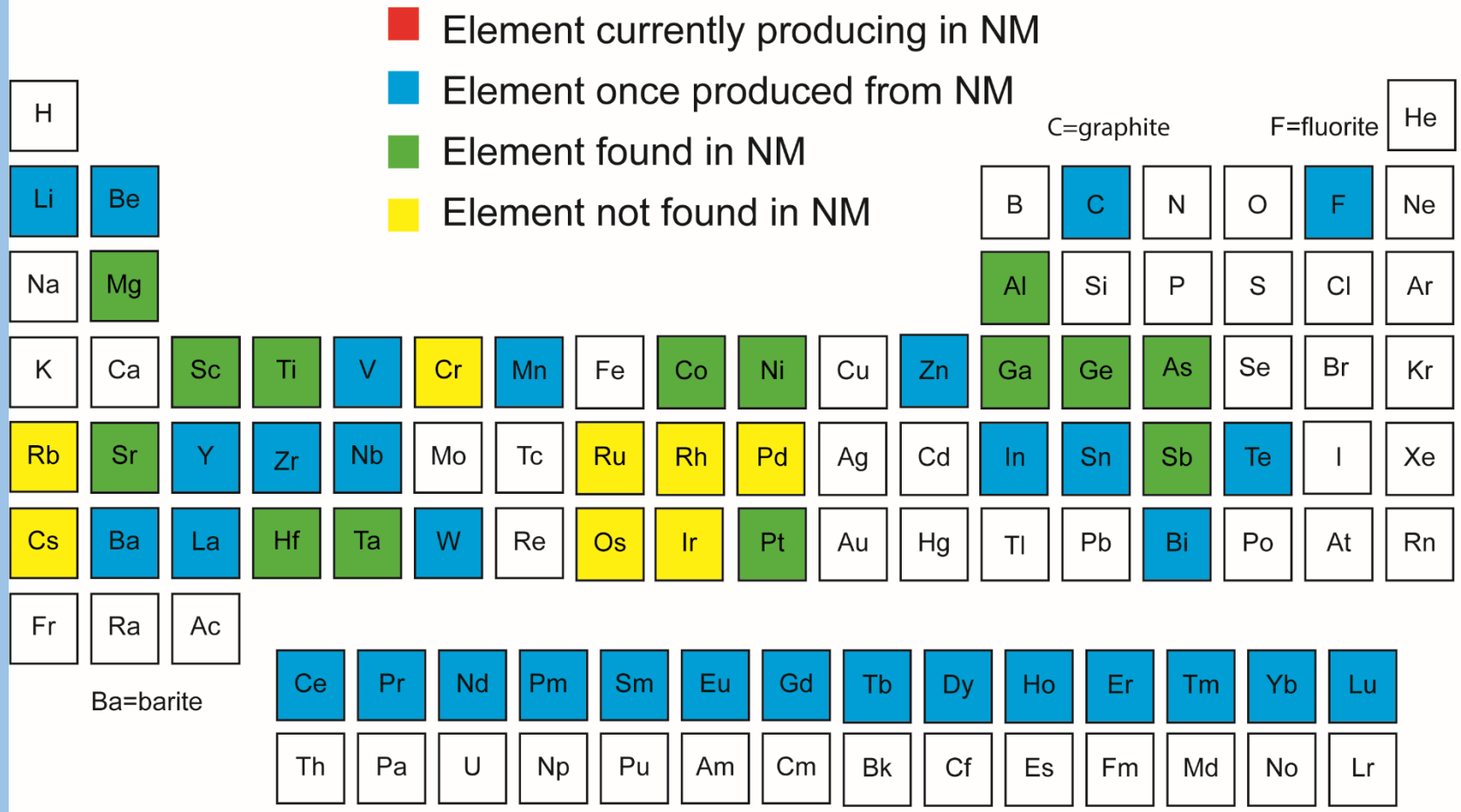
2020



Note that any element or commodity can be considered critical in the future depending upon use and availability. Coal contains several of these critical elements.

Critical Minerals in New Mexico

2022



Note that any element or commodity can be considered critical in the future depending upon use and availability. Coal contains several of these critical elements.

U, Re, He, and K (potash) were removed from the critical minerals list in 2022 and Zn and Ni were added.

Coal and copper deposits are important because the volume of material mined for the primary commodity is so large that the concentrations of recoverable the REE and critical minerals can be much lower than conventional mines

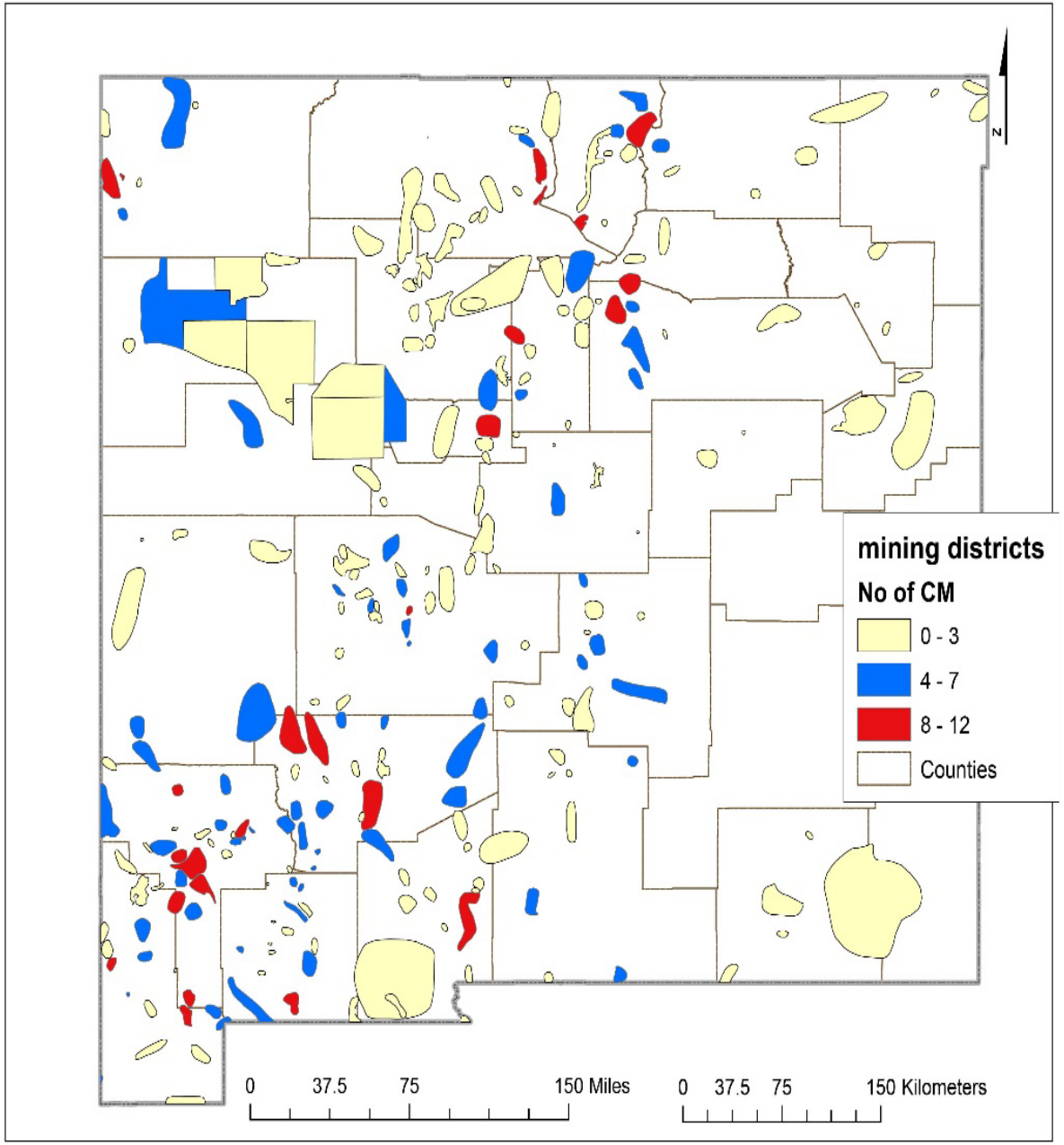
Figure 2.—2021 U.S. Net Import Reliance[1]

Commodity	Net import reliance as a percentage of apparent consumption	Major import sources (2017–20)[2]
ARSENIC, all forms	100	China, Morocco, Belgium
ASBESTOS	100	Brazil, Russia
CESIUM	100	Germany, China
FLUORSPAR	100	Mexico, Vietnam, South Africa, Canada
GALLIUM	100	China, United Kingdom, Germany, Ukraine
GRAPHITE (NATURAL)	100	China, Mexico, Canada, India
INDIUM	100	China, Canada, Republic of Korea, France
MANGANESE	100	Gabon, South Africa, Australia, Georgia
MICA (NATURAL), sheet	100	China, Brazil, Belgium, India
NEPHELINE SYENITE	100	Canada
NIOBIUM (COLUMBIUM)	100	Brazil, Canada
RUBIDIUM	100	Germany
SCANDIUM	100	Europe, China, Japan, Russia
STRONTIUM	100	Mexico, Germany, China
TANTALUM	100	China, Germany, Australia, Indonesia
VANADIUM	100	Canada, China, Brazil, South Africa
YTTRIUM	100	China, Republic of Korea, Japan
GEMSTONES	99	India, Israel, Belgium, South Africa
TELLURIUM	>95	Canada, Germany, China, Philippines
POTASH	93	Canada, Russia, Belarus
IRON OXIDE PIGMENTS, natural and synthetic	91	China, Germany, Brazil
RARE EARTHS,[3] compounds and metals	>90	China, Estonia, Malaysia, Japan
TITANIUM, sponge	>90	Japan, Kazakhstan, Ukraine
BISMUTH	90	China, Republic of Korea, Mexico, Belgium
TITANIUM MINERAL CONCENTRATES	90	South Africa, Australia, Madagascar, Mozambique
ANTIMONY, metal and oxide	84	China, Belgium, India
STONE (DIMENSION)	84	China, Brazil, Italy, India
CHROMIUM	80	South Africa, Kazakhstan, Russia, Mexico
PEAT	80	Canada
SILVER	79	Mexico, Canada, Chile, Poland
TIN, refined	78	Indonesia, Peru, Malaysia, Bolivia
COBALT	76	Norway, Canada, Japan, Finland
DIAMOND (INDUSTRIAL), stones	76	South Africa, India, Congo (Kinshasa), Botswana
ZINC, refined	76	Canada, Mexico, Peru, Spain
ABRASIVES, crude fused aluminum oxide	>75	China, France, Bahrain, Russia
BARITE	>75	China, India, Morocco, Mexico
BAUXITE	>75	Jamaica, Brazil, Guyana, Australia
SELENIUM	>75	Philippines, China, Mexico, Germany
RHENIUM	72	Chile, Canada, Kazakhstan, Japan
PLATINUM	70	South Africa, Germany, Switzerland, Italy
ALUMINA	58	Brazil, Australia, Jamaica, Canada
GARNET (INDUSTRIAL)	56	South Africa, China, India, Australia
MAGNESIUM COMPOUNDS	55	China, Brazil, Israel, Canada
ABRASIVES, crude silicon carbide	>50	China, Netherlands, South Africa
GERMANIUM	>50	China, Belgium, Germany, Russia
IODINE	>50	Chile, Japan
TUNGSTEN	>50	China, Bolivia, Germany, Canada
CADMIUM	<50	Australia, China, Germany, Peru
MAGNESIUM METAL	<50	Canada, Israel, Mexico
NICKEL	48	Canada, Norway, Finland, Australia

https://www.usgs.gov/centers/nmic/mineral-commodity-summaries

Critical Minerals

- Over 50 critical minerals are identified
- New Mexico has many of these critical minerals
  - Copper deposits in Grant County contain rhenium, indium, gallium, germanium, and zinc
  - Uranium deposits in the Grants district contain selenium, REE, vanadium, molybdenum
  - Exploration for other critical minerals include REE, tellurium, lithium, beryllium, cobalt
  - Other critical minerals were once produced from New Mexico (tin, vanadium, manganese, fluorspar, barite, graphite, zinc)



Critical minerals change with time and country

- Salt was once a critical mineral, but is now abundant with low supply disruptions
- Copper is considered critical mineral by Japan

minerals

MDPI

Article

Environmental Implications of Resource Security Strategies for Critical Minerals: A Case Study of Copper in Japan

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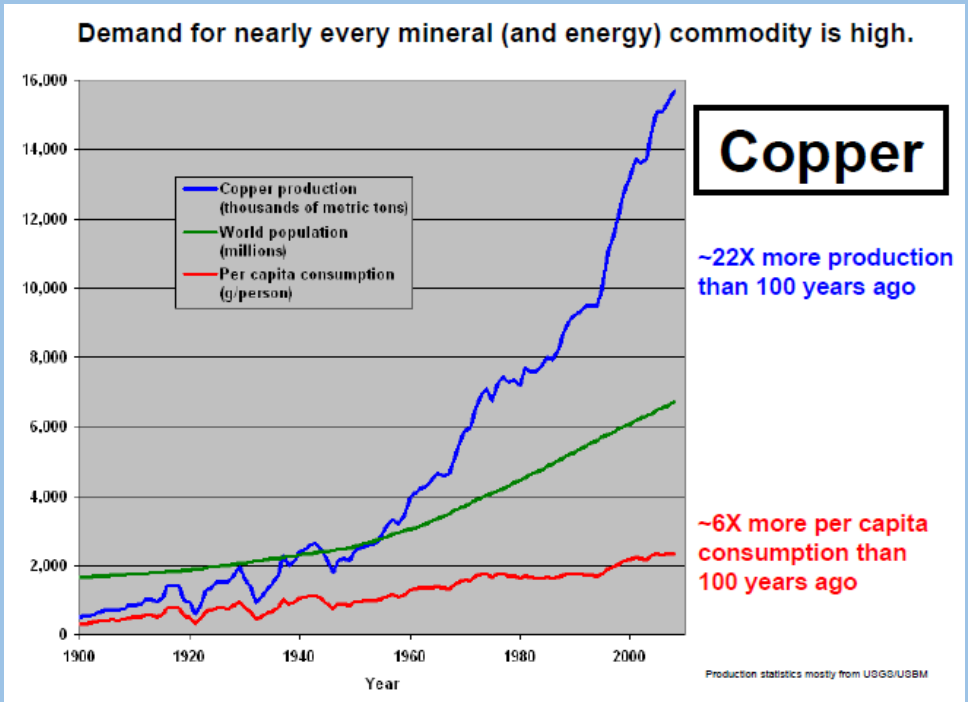
check for updates

Abstract: In the assessment of critical minerals, environmental impacts have been a focus of a number of methodologies. In the case of resource security for critical minerals, there are a variety of potential strategies that might be used to reduce criticality from the supply risk perspective, but

Why isn't copper a critical mineral in the U.S.?



World Mine and Refinery Production and Reserves: Reserves for multiple countries were revised based on company and (or) Government information.

	Mine production		Refinery production		Reserves[6]
	2020	2021[e]	2020	2021[e]	
United States	1,200	1,200	918	1,000	48,000
Australia	885	900	427	450	[7]93,000
Canada	585	590	[e]290	300	9,800
Chile	5,730	5,600	2,330	2,200	200,000
China	1,720	1,800	10,000	10,000	26,000
Congo (Kinshasa)	1,600	1,800	1,350	1,500	31,000
Germany	—	—	643	630	—
Indonesia	505	810	269	270	24,000
Japan	—	—	1,580	1,500	—
Kazakhstan	552	520	515	470	20,000
Korea, Republic of	—	—	671	650	—
Mexico	733	720	492	470	53,000
Peru	2,150	2,200	324	350	77,000
Poland	393	390	560	590	31,000
Russia	[e]810	820	1,040	920	62,000
Zambia	853	830	378	350	21,000
Other countries	2,840	2,800	3,450	4,300	180,000
World total (rounded)	20,600	21,000	25,300	26,000	880,000

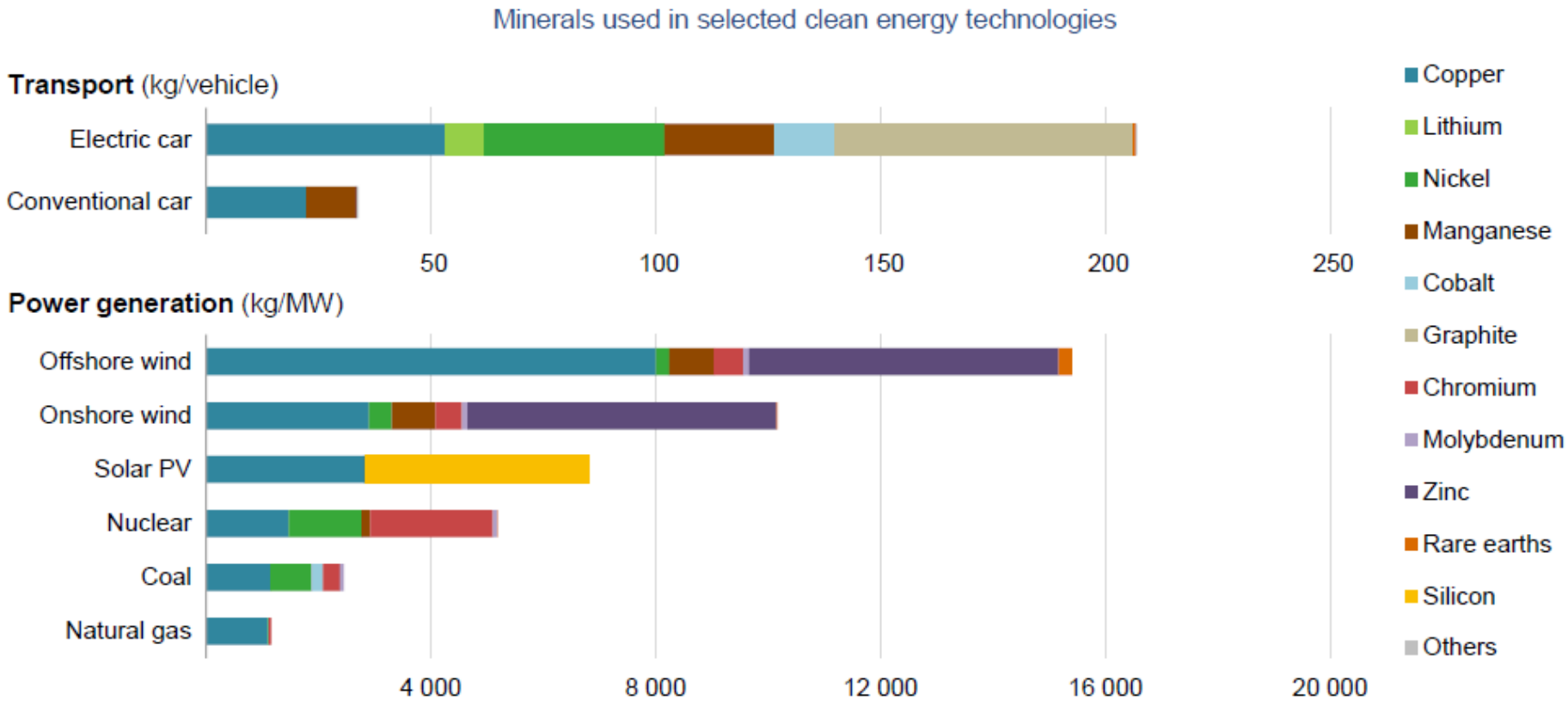
World Resources:[6] A U.S. Geological Survey study of global copper deposits indicated that, as of 2015, identified resources contained 2.1 billion tons of copper, and undiscovered resources contained an estimated 3.5 billion tons.[8]

thousand metric tons of contained copper

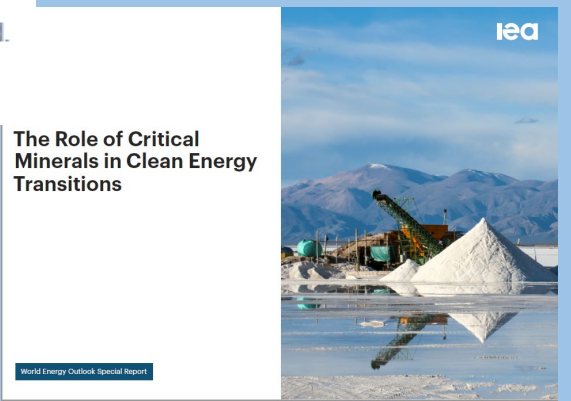
- Copper production is abundant in U.S.
- Import only 45% of our consumption
- Abundant reserves

Why are critical minerals so important?

The rapid deployment of clean energy technologies as part of energy transitions implies a significant increase in demand for minerals



Notes: kg = kilogramme; MW = megawatt. Steel and aluminium not included. See Chapter 1 and Annex for details on the assumptions and methodologies.



Mineral needs vary widely across clean energy technologies

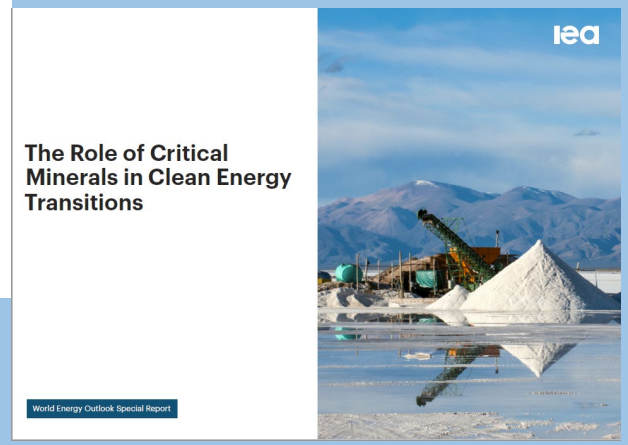
Critical mineral needs for clean energy technologies

	Copper	Cobalt	Nickel	Lithium	REEs	Chromium	Zinc	PGMs	Aluminium*
Solar PV	●	○	○	○	○	○	○	○	●
Wind	●	○	◉	○	●	◉	●	○	◉
Hydro	◉	○	○	○	○	◉	◉	○	◉
CSP	◉	○	◉	○	○	●	◉	○	●
Bioenergy	●	○	○	○	○	○	◉	○	◉
Geothermal	○	○	●	○	○	●	○	○	○
Nuclear	◉	○	◉	○	○	◉	○	○	○
Electricity networks	●	○	○	○	○	○	○	○	●
EVs and battery storage	●	●	●	●	●	○	○	○	●
Hydrogen	○	○	●	○	◉	○	○	●	◉

Notes: Shading indicates the relative importance of minerals for a particular clean energy technology (● = high; ◉ = moderate; ○ = low), which are discussed in their respective sections in this chapter. CSP = concentrating solar power; PGM = platinum group metals.

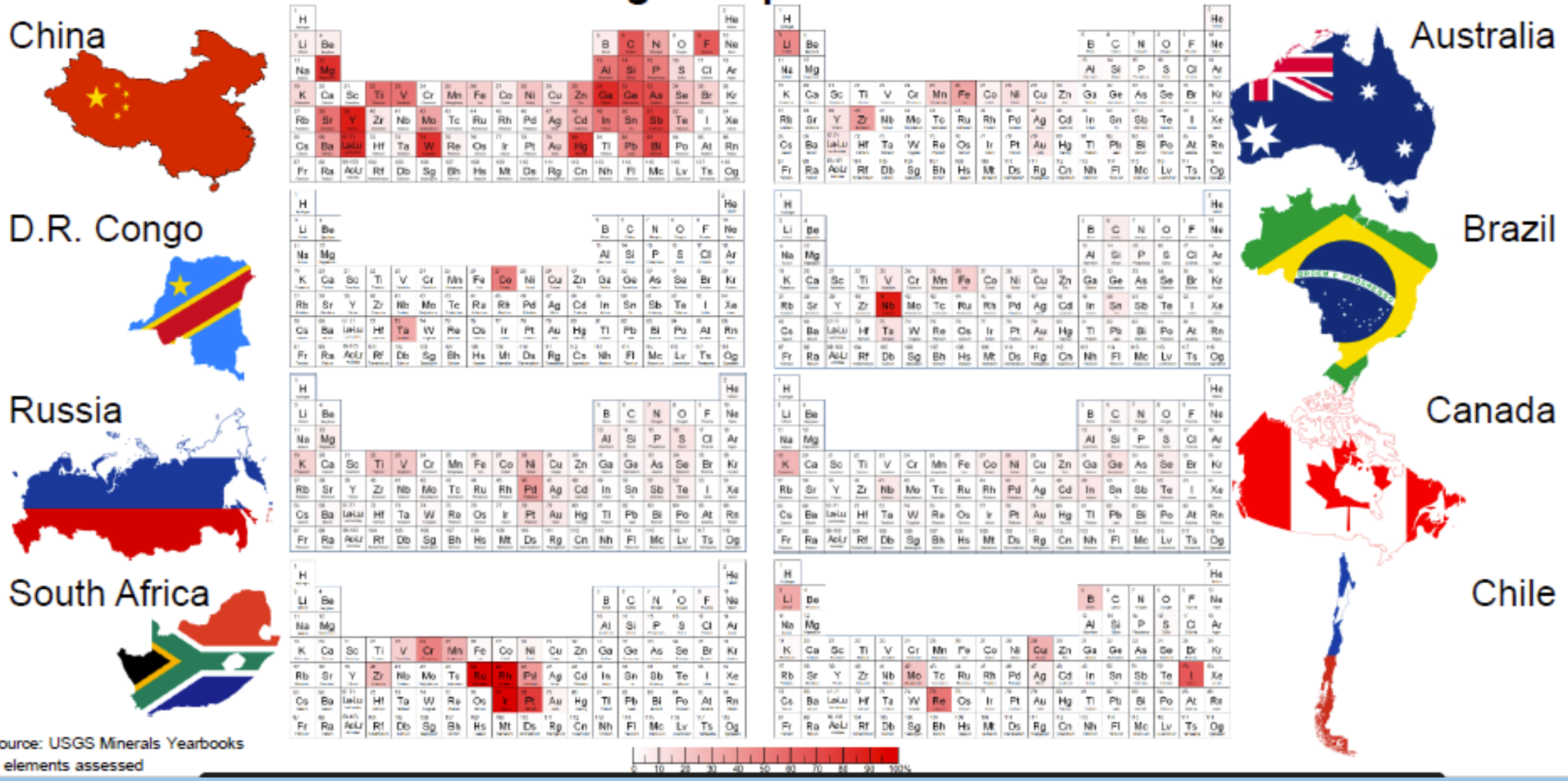
* In this report, aluminium demand is assessed for electricity networks only and is not included in the aggregate demand projections.

IEA



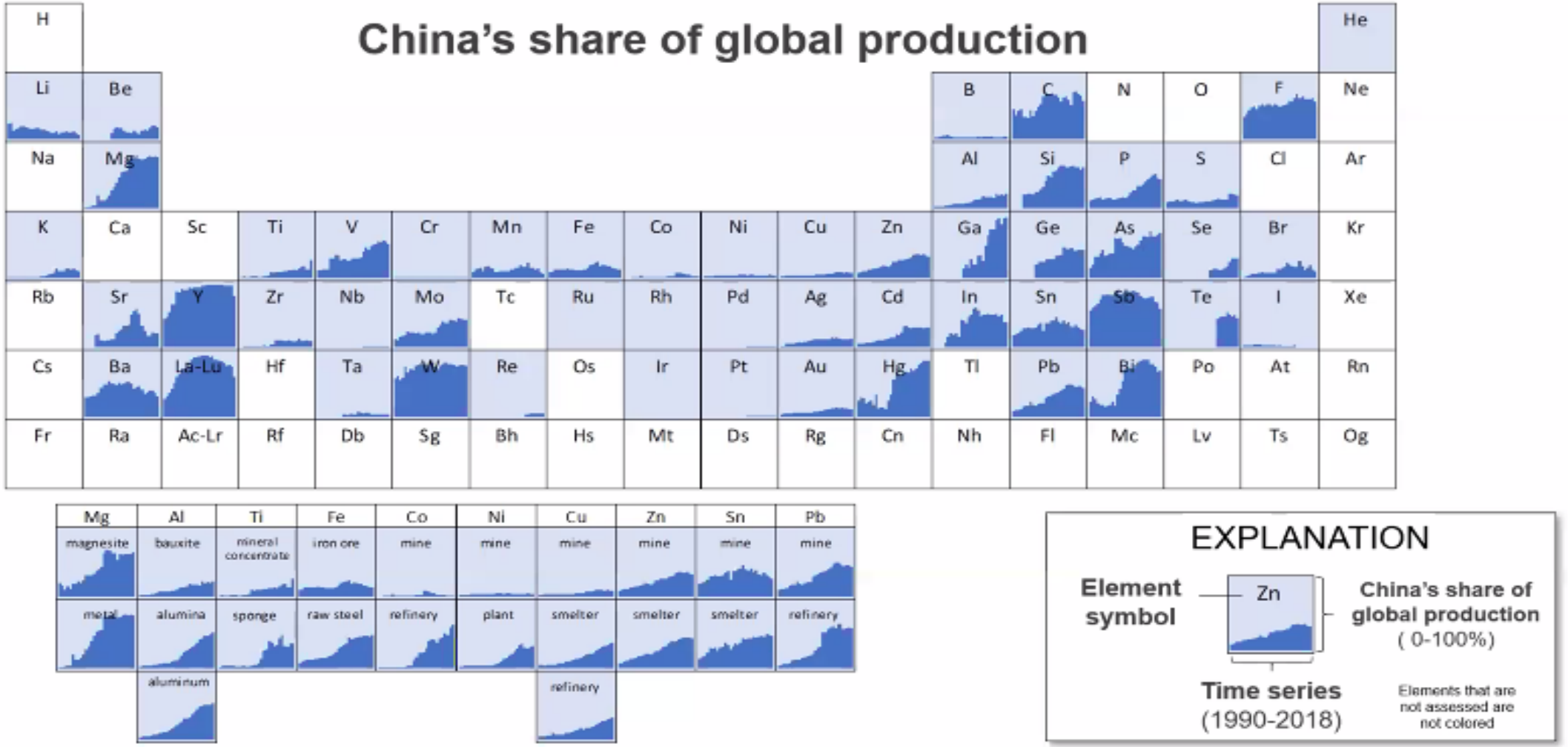
Production of many mineral commodities is highly concentrated in a few countries.

Share of each element's global production from various countries



Data source: USGS Minerals Yearbooks
Not all elements assessed

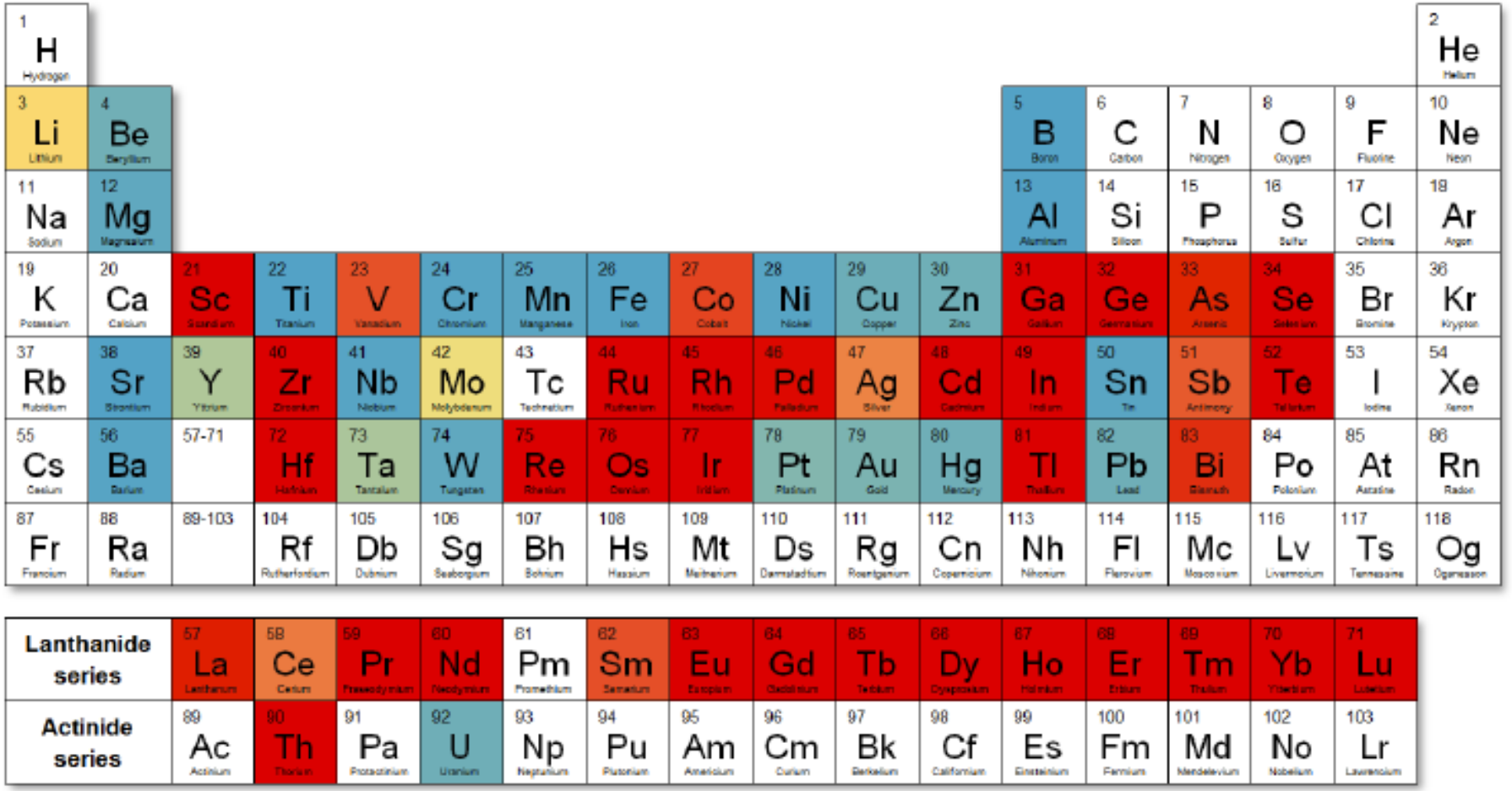
China's share of global production has increased markedly over the past three decades for many mineral commodities.



Nassar, N.T., Alonso, E., and Brainard, J.L., 2020, Investigation of U.S. Foreign Reliance on Critical Minerals—U.S. Geological Survey Technical Input Document in Response to Executive Order No. 13953 Signed September 30, 2020 (Ver. 1.1, December 7, 2020): U.S. Geological Survey Open-File Report 2020–1127, 37 p., https://doi.org/10.3133/ofr20201127.

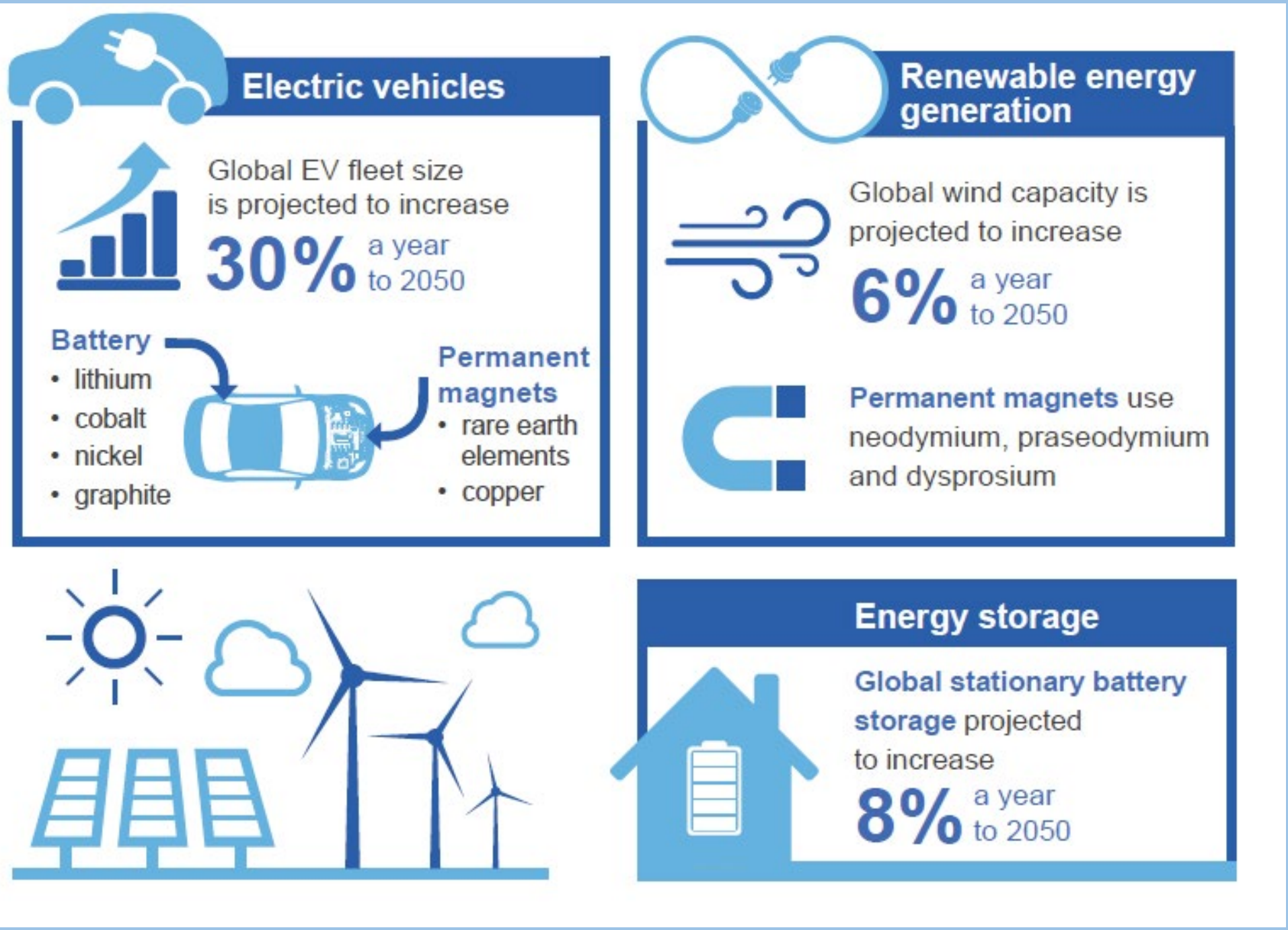
Many of the mineral commodities required for advanced technologies are recovered only as byproducts during the processing of other minerals.

Share of element's primary production obtained as a byproduct



N. T. Nassar, T. E. Graedel, E. M. Harper, By-product metals are technologically essential but have problematic supply. *Science Advances* **1**, e1400180 (2015).

Uses of critical minerals



Cell phone

[A World of Minerals in Your Mobile Device (usgs.gov)]

A BREAKDOWN OF THE CRITICAL

METALS IN A SMARTPHONE

Some vital metals used to build these devices are considered at risk due to geological scarcity, geopolitical issues or trade policy.

This infographic details the critical metals that you carry in your pocket.

ALKALI METAL | ALKALINE EARTH | TRANSITION METAL | BASIC METAL | LANTHANOID

TOUCH SCREEN

It contains a thin layer of **indium** tin oxide, highly conductive and transparent, allowing the screen to function as a touch screen.

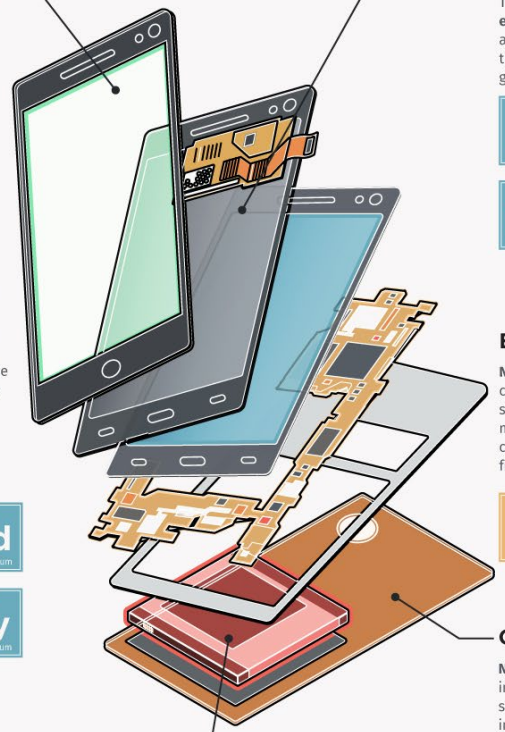
49 In Indium

MICROPHONE, SPEAKERS, VIBRATION UNIT

Nickel is used in the microphone diaphragm (that vibrates in response to sound waves). Alloys containing **neodymium, praseodymium and gadolinium** are used in the magnets contained in the speaker and microphone. **Neodymium, terbium and dysprosium** are used in the vibration unit.

28 Ni Nickel | 59 Pr Praseodymium | 60 Nd Neodymium

64 Gd Gadolinium | 65 Tb Terbium | 66 Dy Dysprosium



DISPLAY

The display contains several **rare earth elements**. Small quantities are used to produce the colors on the liquid crystal display. Some give the screen its glow.

57 La Lanthanum | 59 Pr Praseodymium | 63 Eu Europium

64 Gd Gadolinium | 65 Tb Terbium | 66 Dy Dysprosium

ELECTRONICS

Nickel is used in electrical connections. **Gallium** is used in semiconductors. **Tantalum** is the major component of micro capacitors, used for filtering and frequency tuning.

28 Ni Nickel | 31 Ga Gallium | 73 Ta Tantalum

CASING

Nickel reduces electromagnetic interference. **Magnesium** alloys are superior at electromagnetic interference (EMI) shielding.

12 Mg Magnesium | 28 Ni Nickel

BATTERY

The majority of smartphones use **lithium**-ion batteries.

3 Li Lithium | 27 Co Cobalt | 28 Ni Nickel

Source: University of Birmingham

ELEMENTS

elements.visualcapitalist.com

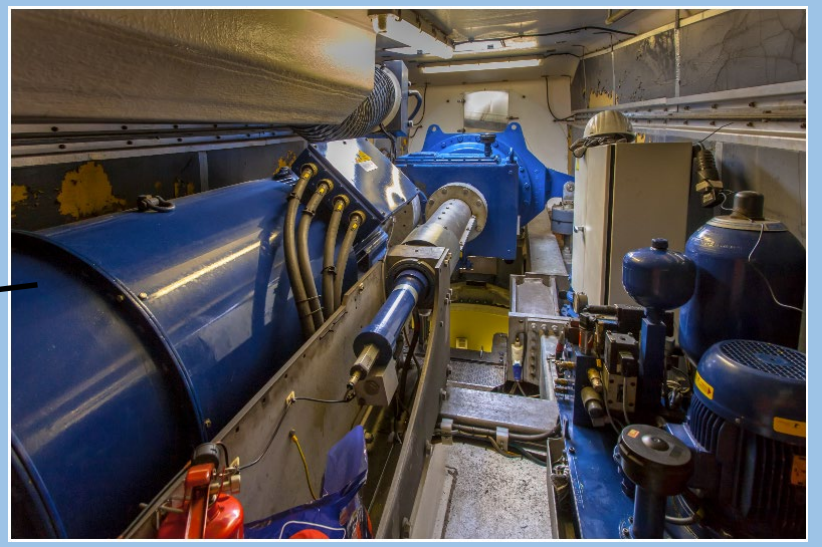
The Earth's natural resources power our everyday lives. VC Elements breaks down the building blocks of the universe.

We live in a **material world.**

https://www.mining.com/web/a-breakdown-of-the-critical-metals-in-a-smartphone/

Wind turbines

Blades made of composite materials: fiber glass, mineral fibers, wood, **aluminum** and cemented together with epoxy or resin.



Nacelle houses the inner machinery including the generator, which converts the mechanical energy to electrical energy.

- permanent magnet generator (PMG) use **REE**, copper, boron, insulation
- superconducting wires contain **gadolinium**, **barium**, and the cryogenics (liquid helium)
- rotor hub, main shaft, gearbox, bedplate are produced from different types of low-alloy steels and cast irons, including **zinc**

Tower is made of tubular steel or steel lattice and concrete. **Zinc** is used to prevent corrosion. **Titanium** in paint provides the color white.

Foundations contain thousands of tons of concrete and rebar

How to make bridges earthquake-proof

- Bridges are made of concrete, rebar and pre-stressed concrete beams to hold up the road deck
- But the joints must be flexible
  - By reinforcing bars with a metal alloy made from a mix of **nickel** and **titanium** (critical minerals), they will flex and snap back into their original shape when the earthquake is over
  - The concrete is made with small polyvinyl fibers that are coated to bind with the concrete and limit cracking.

Tappan Zee Bridge,
New York

The new Tappan Zee Bridge is a precast concrete, steel girder structure that spans 3 miles across the Hudson River. The 584 EPS Triple Pendulum isolators reduce the seismic forces transferred to the substructure so that it will remain essentially elastic during the design earthquake.

https://materialdistrict.com/article/earthquake-resistant-bridge-flexible-materials/

Fire proofing your house

- Clay tiles—fireproof, prevent heat from escaping the property, which helps put out the flame faster
- Metal roofs—**zinc**, copper, steel, galvanized steel, **aluminum, tin**
- Slate, concrete
- Composite fiberglass asphalt shingles
- Perlite ceiling tiles
- Gypsum wallboard

Frank Lloyd Wright's "A Fireproof House for $5,000" inspired the design of many Prairie Style homes, including the Stockman House in in Mason City, Iowa.
Pamela V White / Wikimedia Commons / CCA 2.0 Generic license

Supply chains

What are supply chains?

What are supply chains?

- network between a company and its suppliers to produce and distribute a specific product to the final buyer
- includes different activities, people, entities, information, and resources
- represents the steps it takes to get the product or service from its original state to the customer

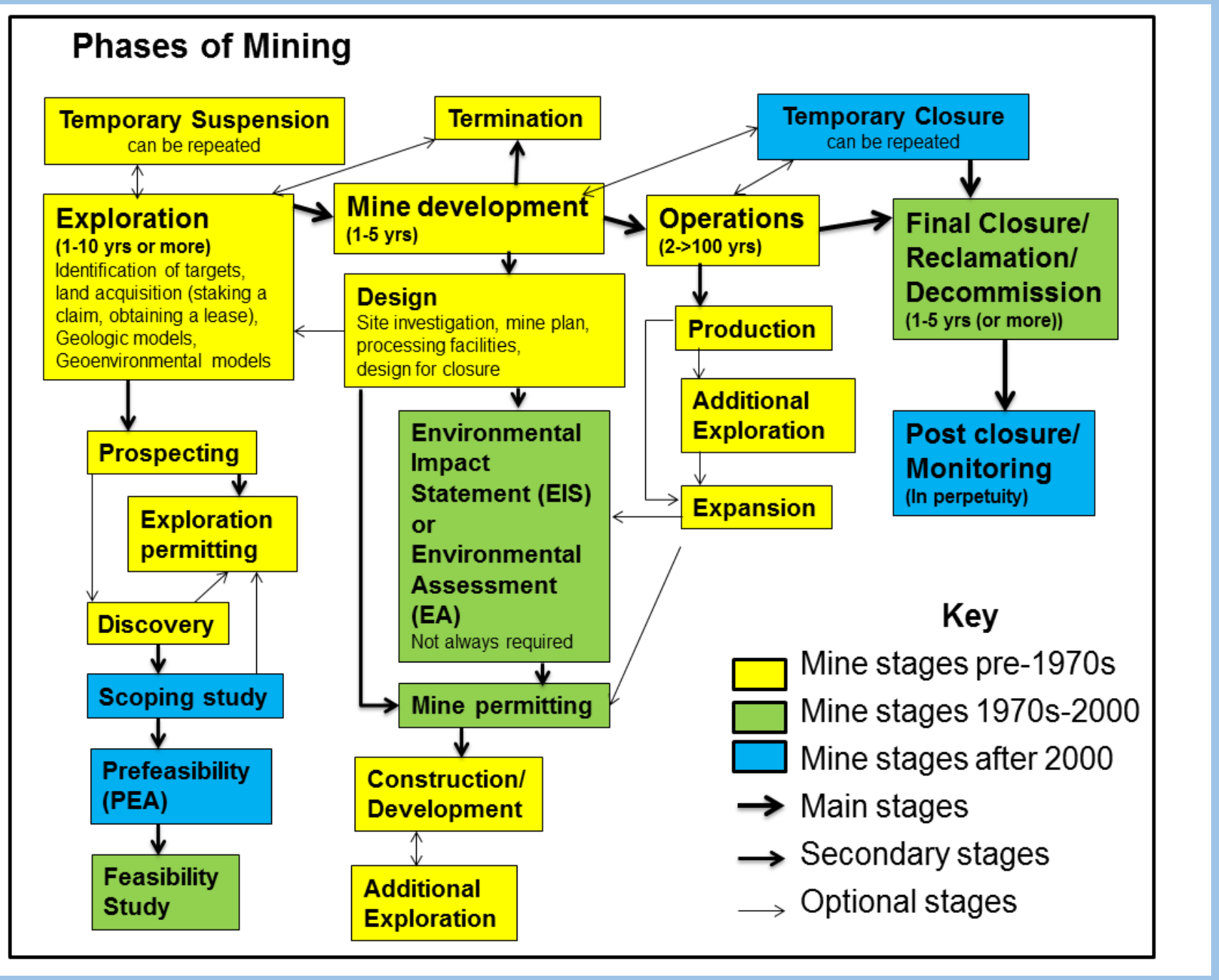
What is a mineral supply chain?

What is a mineral supply chain?

- The mining, transport, and trade of mineral resources that promote growth and employment, generate income, and promote local development
- Mining ⟶ Processing ⟶ Refining ⟶ Manufacture products

Life cycle of a mine

- Exploration takes years
- Permitting takes >10 yrs
- Operators are not going to jeopardize their primary commodity for a potential risky by-product



REE

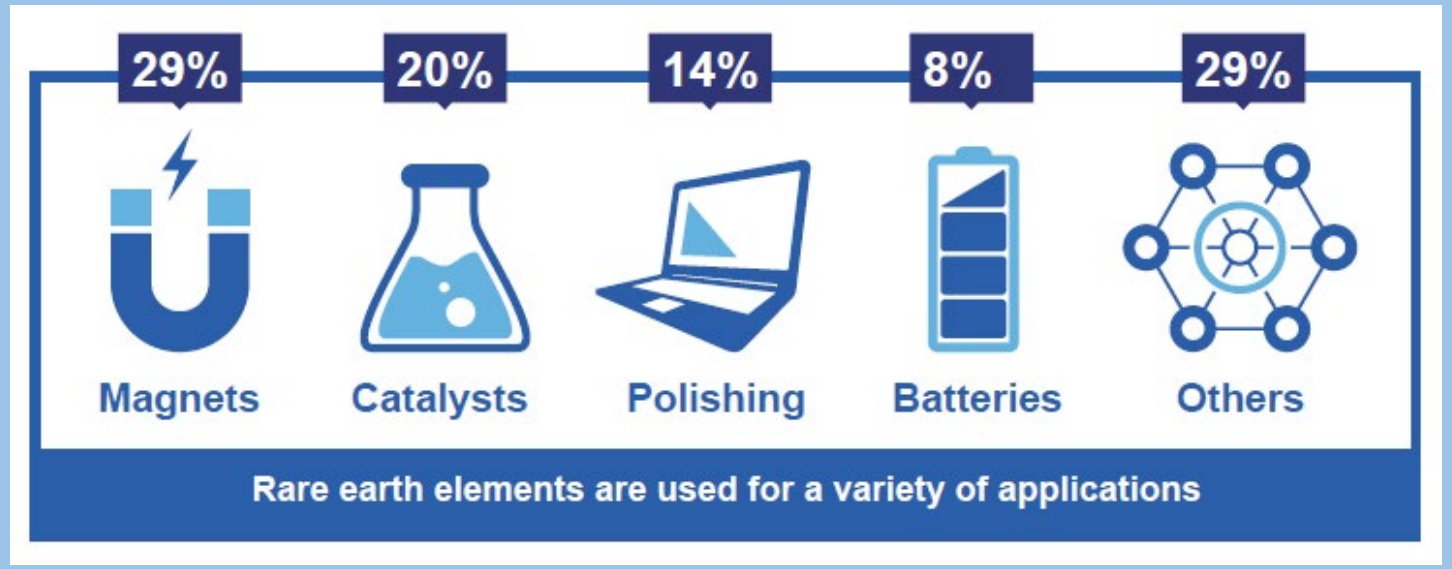
57	58	59	60	62	63	64	65	66	67	68	69	70	71	39
La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Y
138.91	140.12	140.91	144.24	150.36	151.96	157.25	158.93	162.5	164.93	167.26	168.93	173.04	174.97	88.906

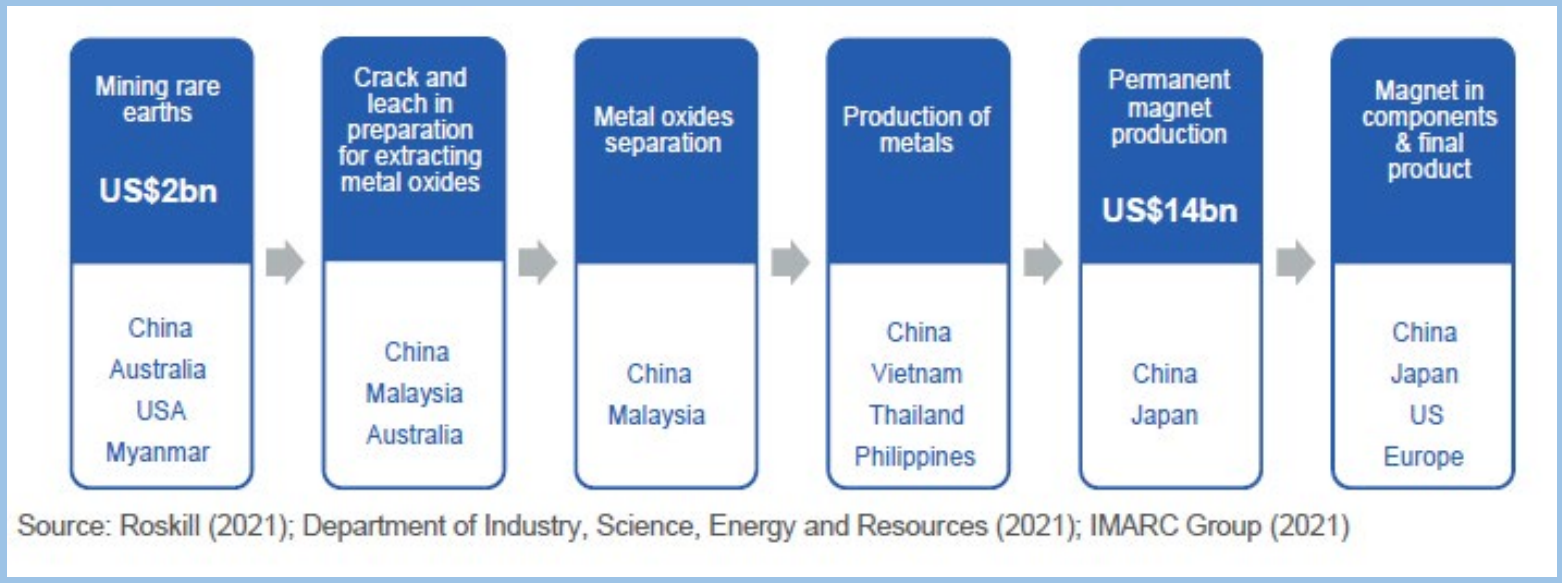
Light rare earths | **Heavy rare earths**

La - Lanthanum
Ce - Cerium
Pr - Praseodymium
Nd - Neodymium
Sm - Samarium

Eu - Europium
Gd - Gadolinium
Tb - Terbium
Dy - Dysprosium
Ho - Holmium

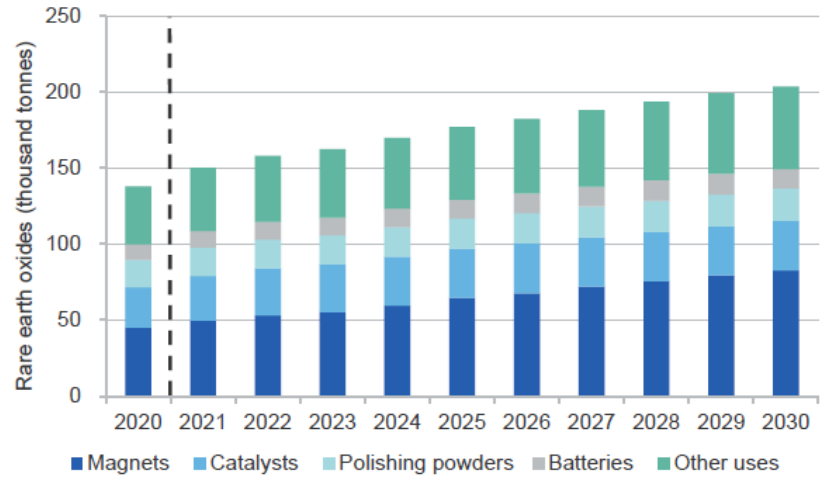
Er - Erbium
Tm - Thulium
Yb - Ytterbium
Lu - Lutetium
Y - Yttrium





Source: Roskill (2021); Department of Industry, Science, Energy and Resources (2021); IMARC Group (2021)

Figure 2.5: Projected rare earths consumption by end use



Source: Roskill (2021); Department of Industry, Science, Energy and Resources (2021)

Cobalt

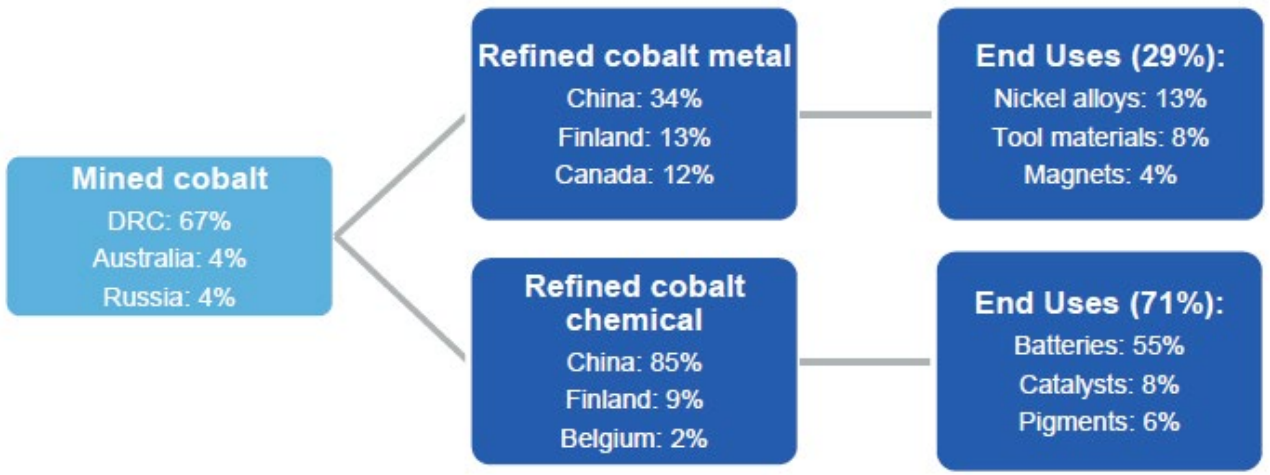
Uses

59% of cobalt is used in batteries

Laptops
5-15 grams cobalt

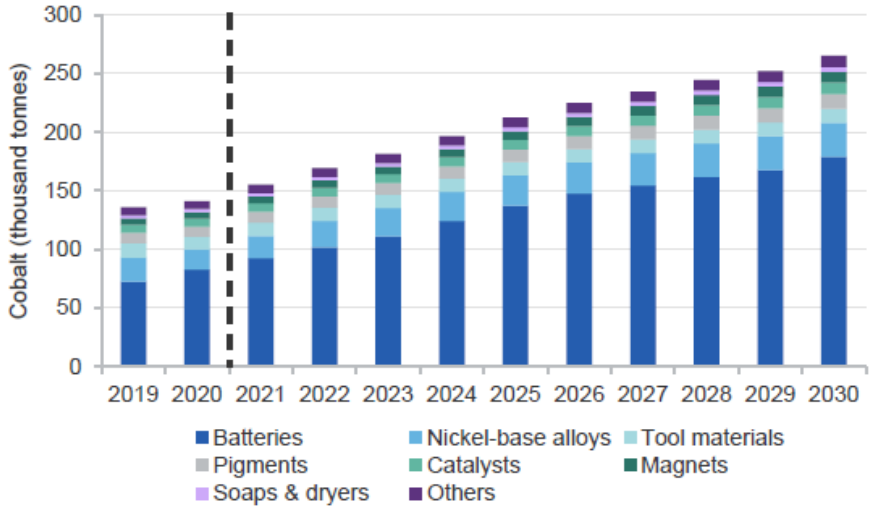
Mobile phones
5-10 grams cobalt

Electric cars
10-20 kilograms cobalt



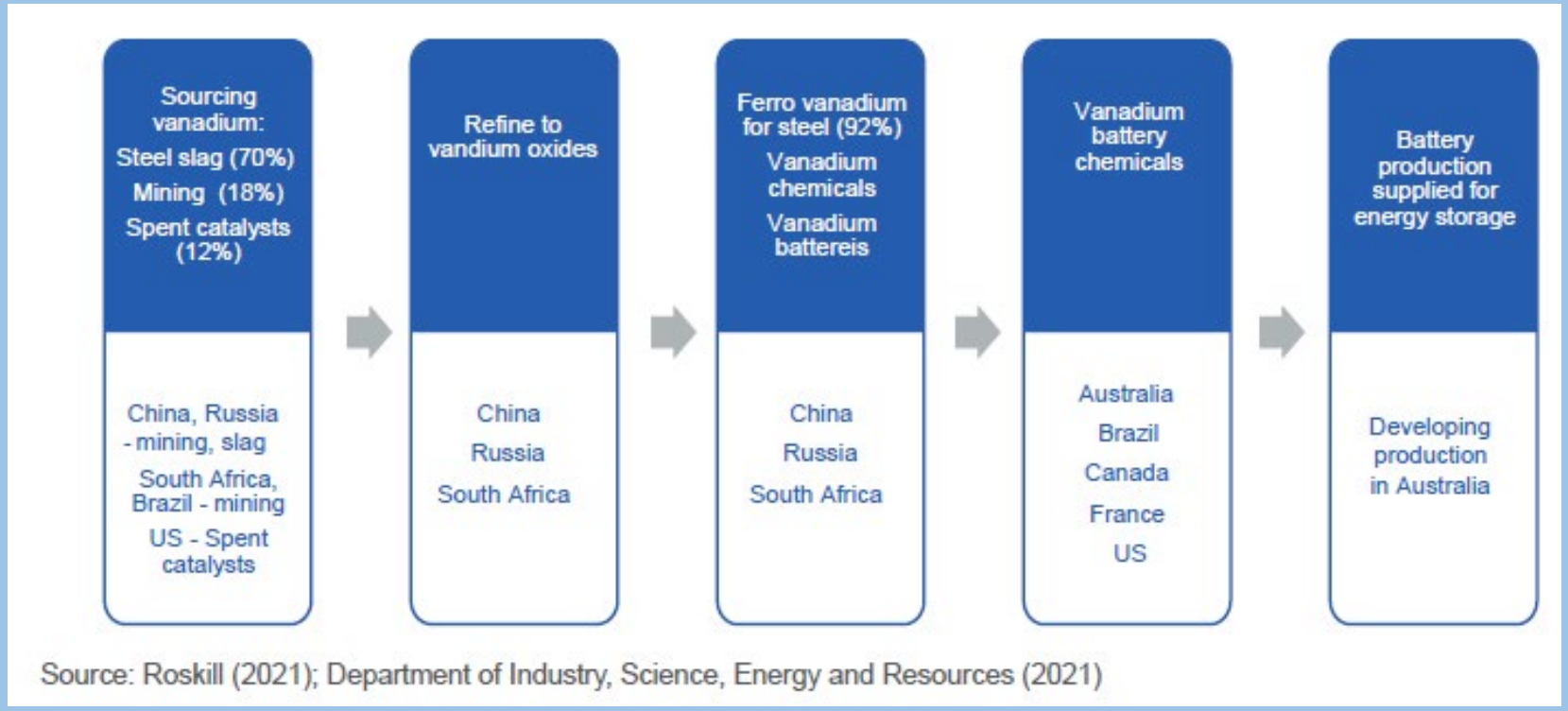
Source: Roskill (2021); Department of Industry, Science, Energy and Resources (2021)

Figure 3.4: Projected cobalt consumption by end-use



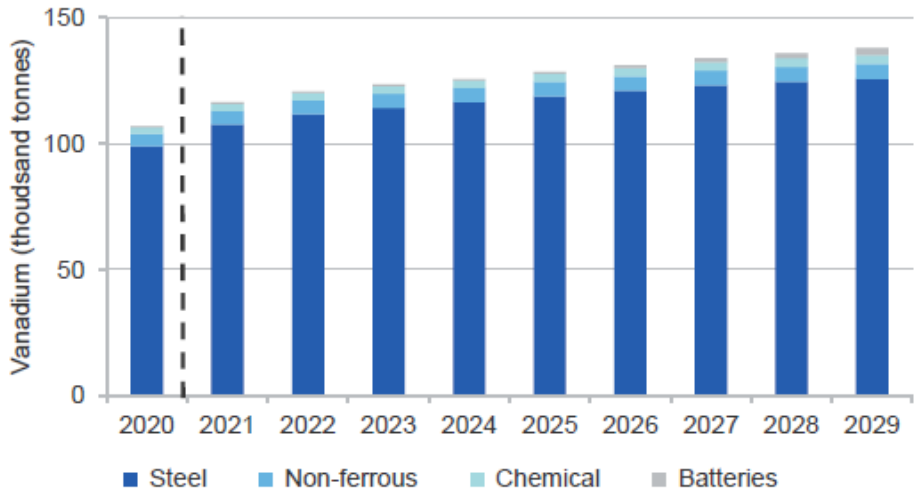
Source: Roskill (2021); Department of Industry, Science, Energy and Resources (2021)

Vanadium in batteries



Source: Roskill (2021); Department of Industry, Science, Energy and Resources (2021)

Figure 5.4: Projected vanadium consumption by end-use – including steel



Source: Roskill (2020); Department of Industry, Science, Energy and Resources (2021)

Why are supply chains important in understanding critical minerals?


How much raw material does a 30GWh NCM Li-ion Megafactory consume?
Graphite anode
33,000 tonnes
Cobalt
6,000 tonnes
Nickel
19,000
tonnes
Lithium
25,000
tonnes
© Benchmark Mineral Intelligence 2021

Some of the challenges in producing critical minerals

5 Dimensions of Mineral Availability

WHAT Questions Must We Ask?

1. **Geologic** Availability  ✓Does the mineral resource exist?

2. **Technical** Availability  ✓Can we extract and process it?

3. **Environmental & Social** Availability  ✓Can we produce it in environmentally and socially responsible and acceptable ways?

4. **Political** Availability  ✓How do governments influence availability through their policy and actions?

5. **Economic** Availability  ✓Can we produce it at a cost users are willing and able to pay?

Challenges

- How much of the minerals do we need?
- Are there enough materials in the pipeline to meet the demand for these technologies and other uses?
- Can any of these be recycled?
- Are there substitutions that can be used?
- Are these minerals environmental friendly—what are the reclamation challenges?
  - REE and Be are nearly always associated with U and Th and the wastes from mining REE and Be will have to accommodate radioactivity and radon

Challenges

- The small volumes of strategic/critical minerals utilized makes them price sensitive
- New producers need a reliable, long-term buyer
- Long-term buyers require a fixed price, but operating costs are variable
- Monopolies/oligopolies can drive out marginal producers by over-supplying the market until the competition is eliminated
- Are any of these minerals “conflict minerals”, i.e. minerals that fall under the Conflict Minerals Trade Act (H.R. 4128)
  - Minerals that provide major revenue to armed fractions for violence, such as that occurring in the Democratic Republic of Congo (GSA, Nov. 2010)

What are some of the programs being developed to address availability of critical minerals?

USGS Earth Mapping Resources Initiative (Earth MRI)

USGS's Response to EO 13817 and SO 3359:

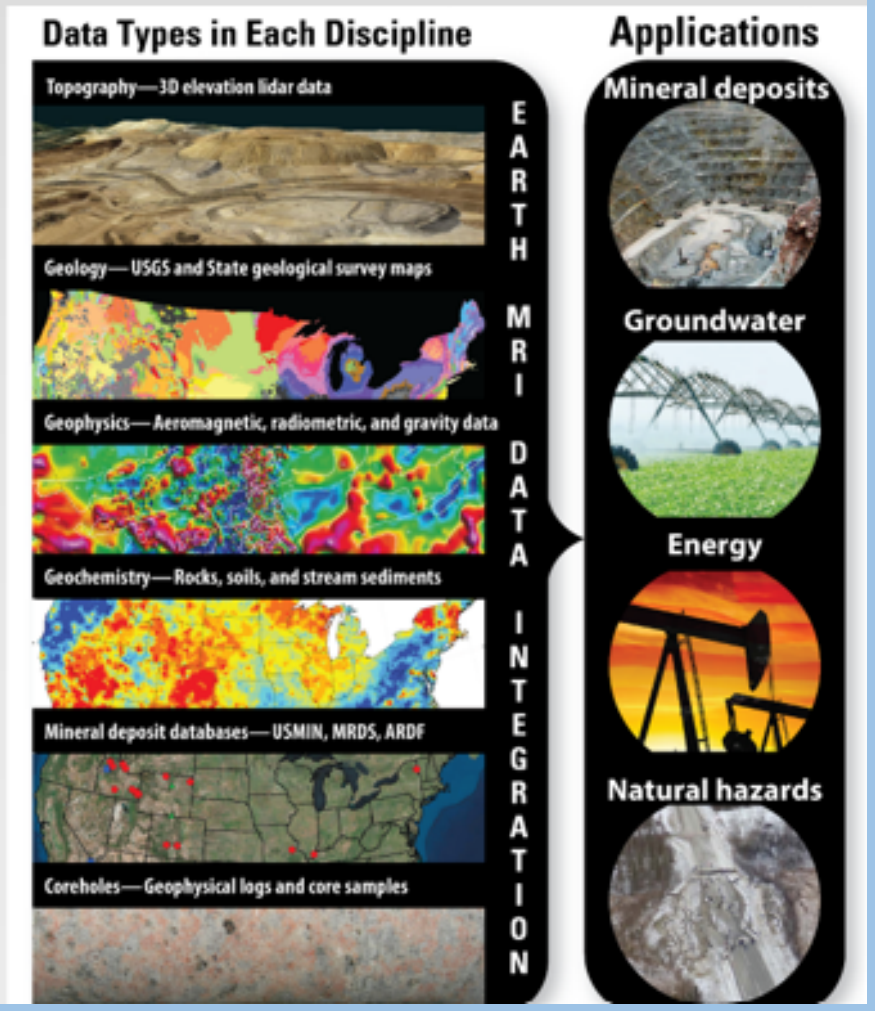
Earth MRI: Partnership between USGS and State Geological Surveys to generate state-of-the-art geologic mapping, geophysical surveys, and lidar data for the Nation in areas with critical mineral potential.

Earth MRI Budget

- **FY 2019**: $9.598M
- **FY 2019 State Matching Funds:** ~$2.9M from 29 States
- **FY 2020:** $10.598M
- **FY 2020 State Matching Funds:** ~$2.2M from 27 States
- Seeking Other Agency Partnerships to leverage funds

Activities

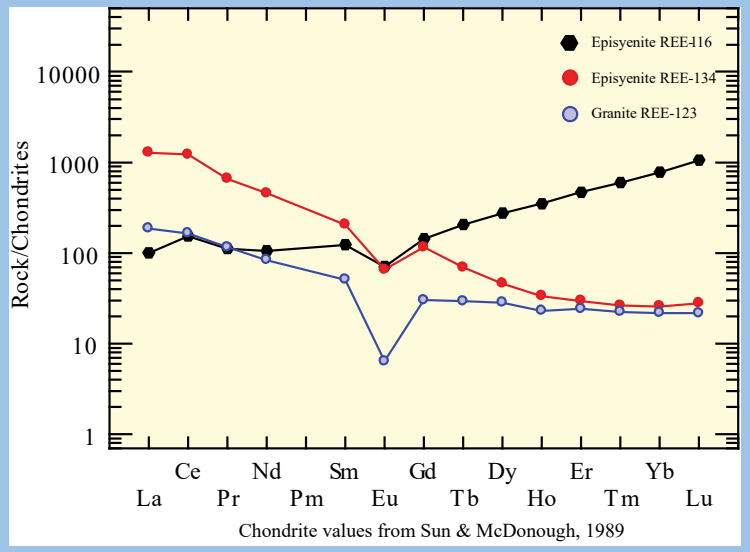
- **FY 2019:** Focused on rare earth elements
- **FY 2020:** Focused on rare earth elements and 10 more commodities: Al, Co, graphite, Li, Nb, PGEs, Ta, Sn, Ti, and W

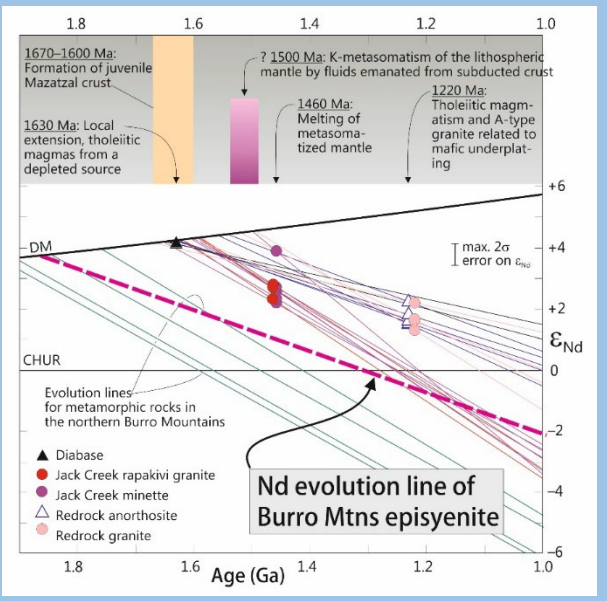


USGS MRERP
Mapping and origin of REE in Cambrian-Ordovician Episyenites in the Caballo and Burro Mountains, southern NM (2012-2022)

Annelise Riggins
Nelia Dunbar,
Virginia McLemore
Matthew Heizler
William McIntosh
Kwame Frempong
Adam Smith
Tapani Ramo (Univ Helsinki)

- Brick-red episyenites are metasomatic in origin, possibly related to alkaline or carbonatite intrusions at depth
- REE minerals are associated with altered amphiboles, magnetite, secondary chlorite, hematite, zircon, and fluorite
- Samples have low-moderate TREE, Th, and U; but some samples have relatively high HREE





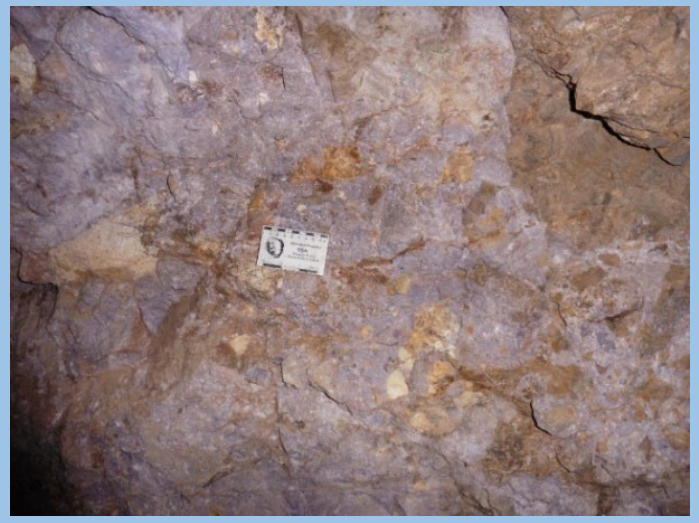
Epsilon Nd versus age diagram showing evolution line of episyenite compared to Redrock gr, Jack Creek gr and metamorphics. The line is between the time-intergrated evolution of the granites and metamorphics, suggesting that the episyenite may comprise a magmatic source and a fluid component from the upper crust Matzazal metamorphics.

USGS Earth MRI Project Mapping REE in Gallinas Mountains, Lincoln County, NM (2019-2021)

Virginia McLemore, Shari Kelley, Matt Zimmerer, Alex Gysi and many students

$^{40}Ar/^{39}Ar$ Geochronology Results

- Early magmatic activity (38.5-29.3 Ma)
- Alkaline intrusive flare-up (28.8-28.0 Ma)
- Alteration and younger intrusions (25.8-24.4 Ma)

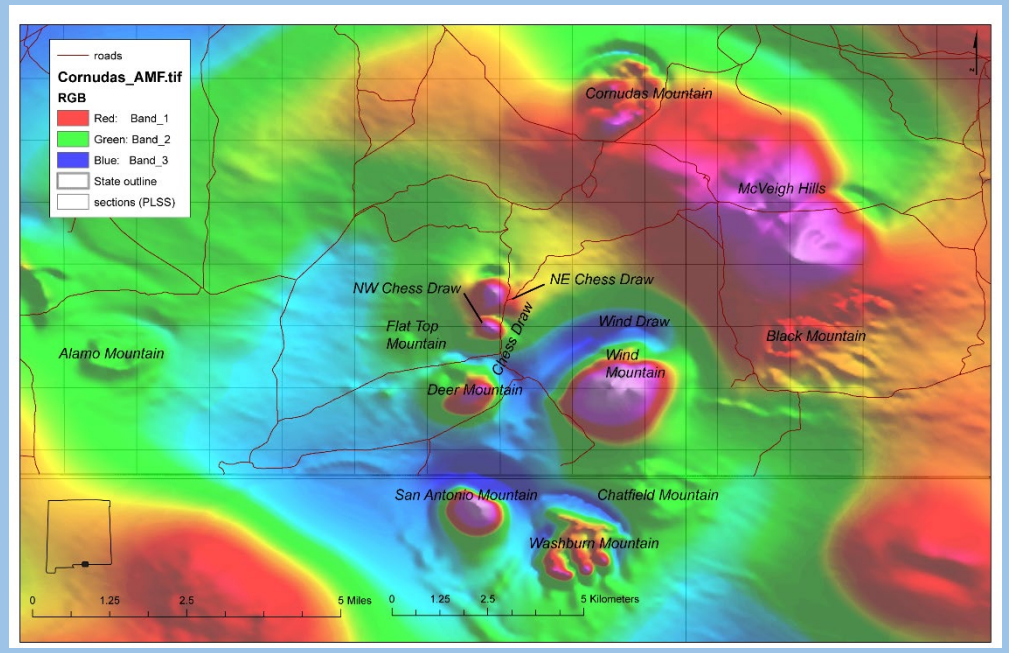


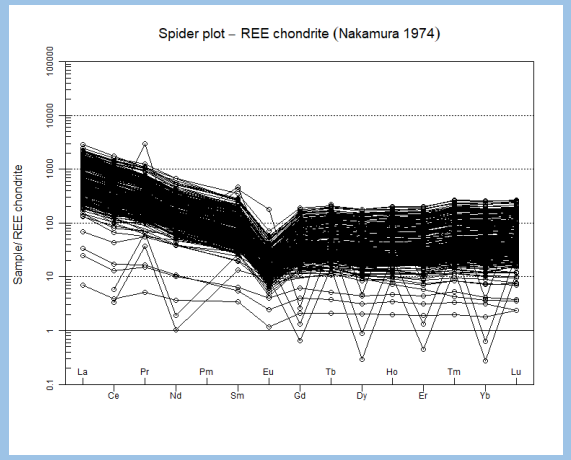
Yellow bastnäsite [(Ce,La)(CO_3)F] in purple fluorite breccia from the Red Cloud mine (length is ~8 mm). Bastnaesite is the most common REE mineral mined in the world today.

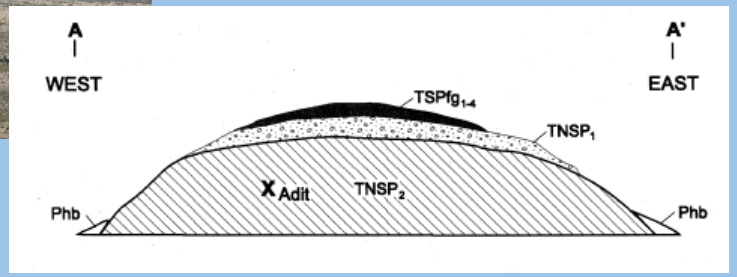
USGS Earth MRI Project
Mapping REE in Cornudas Mountains, Otero County, NM (2020-2022)

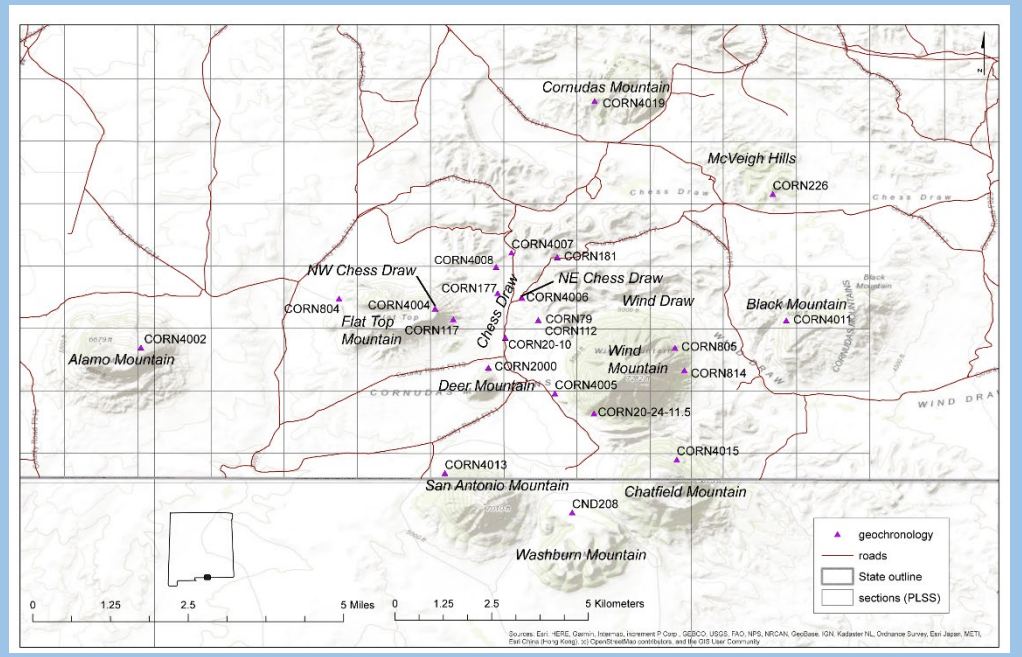
Drs. Virginia McLemore, Nels Iverson, Snir Attia, and students

- Differential cooling of the magma resulted in the textural variations at Wind Mountain
  - 36.32±0.15 Ma
- Eudialyte is primary REE mineral
- Chemical analyses—3790 ppm total REE, 2332 ppm Nb, 92 ppm Be, and 3137 ppm F
- Additional mineralogy, mapping, and dating underway



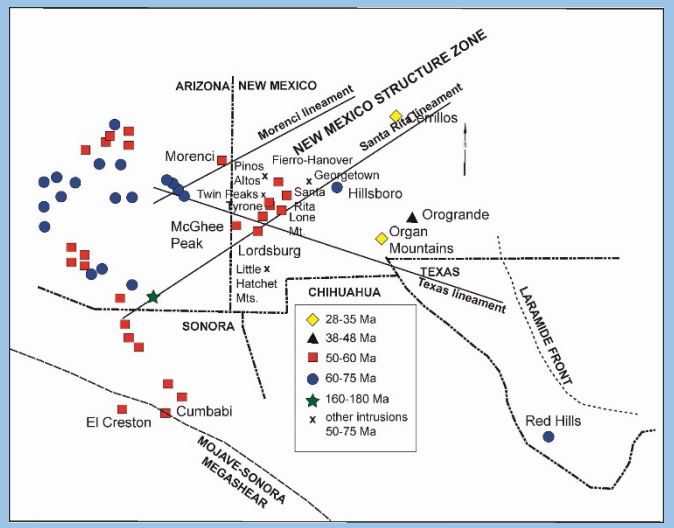




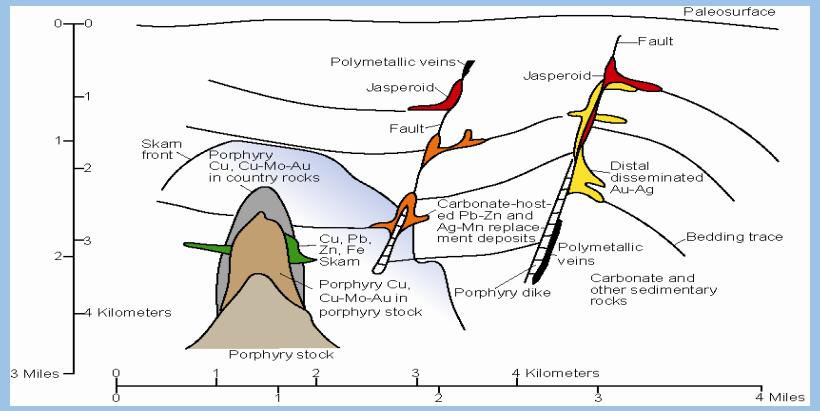


USGS Earth MRI Project
Critical minerals in Laramide porphyry copper deposits (Aug 2022—July 2025

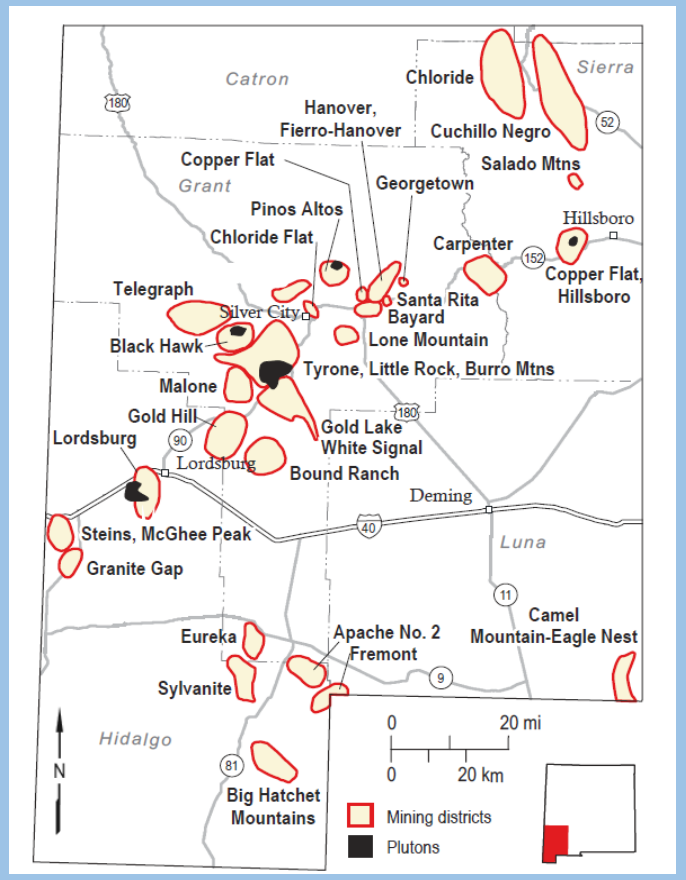
Critical minerals found in porphyry copper deposits: Rhenium, PGEs, Tellurium, Indium, Germanium, Gallium, Aluminum (alunite, kaolinite)



Laramide porphyry copper deposits in southwestern United States and northern Mexico.

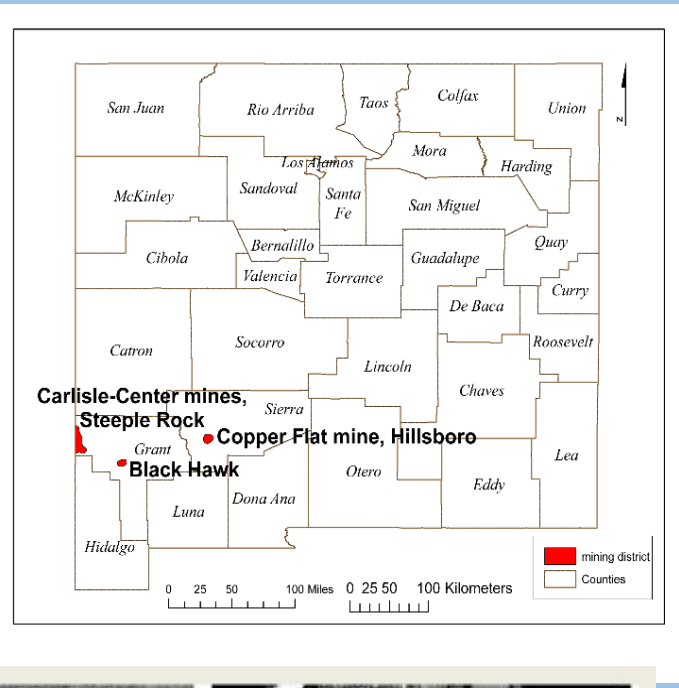


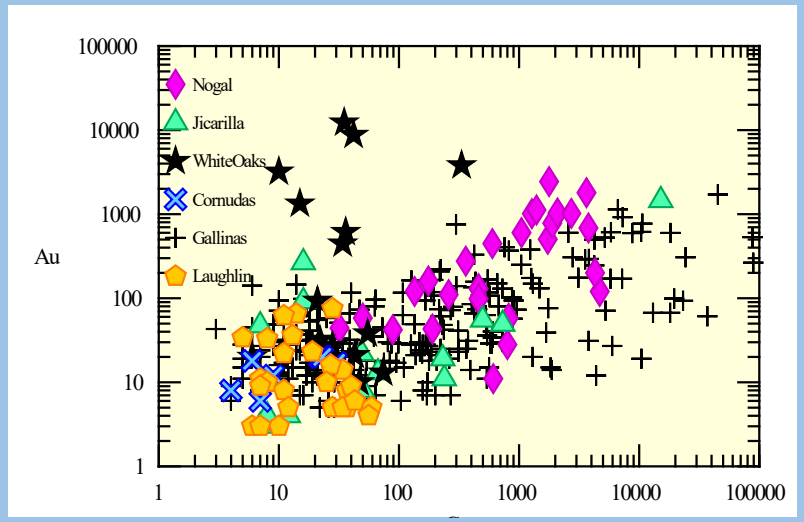
Simplified settings of porphyry copper and associated deposit types (John, 2010).



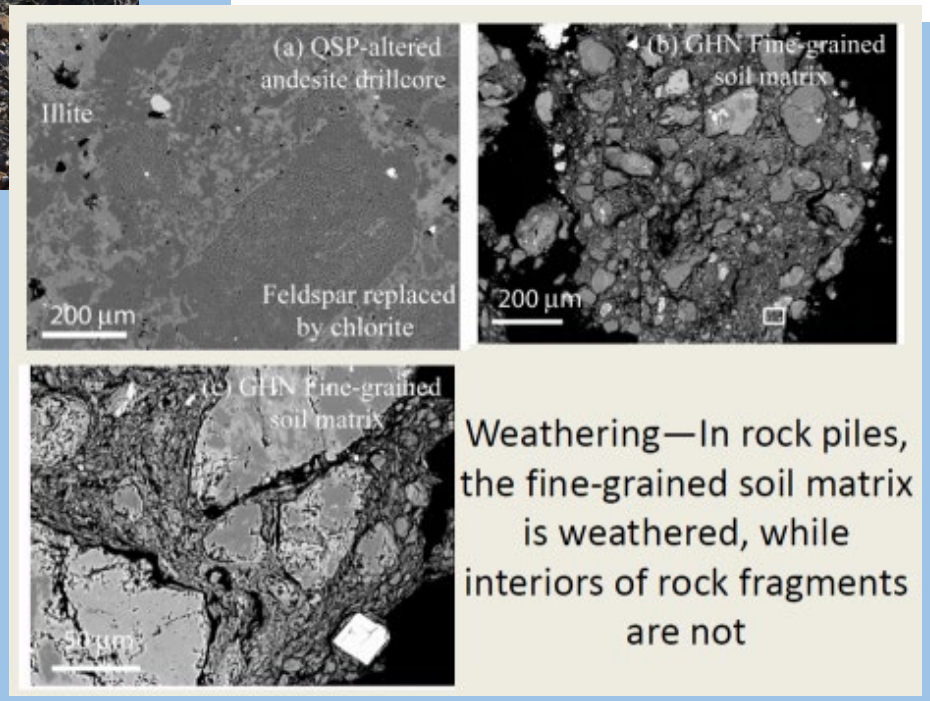
Districts with Laramide deposits and plutons (black) in southwestern New Mexico

USGS Earth MRI Project
Critical minerals from mine wastes (August 2022-July 2024)



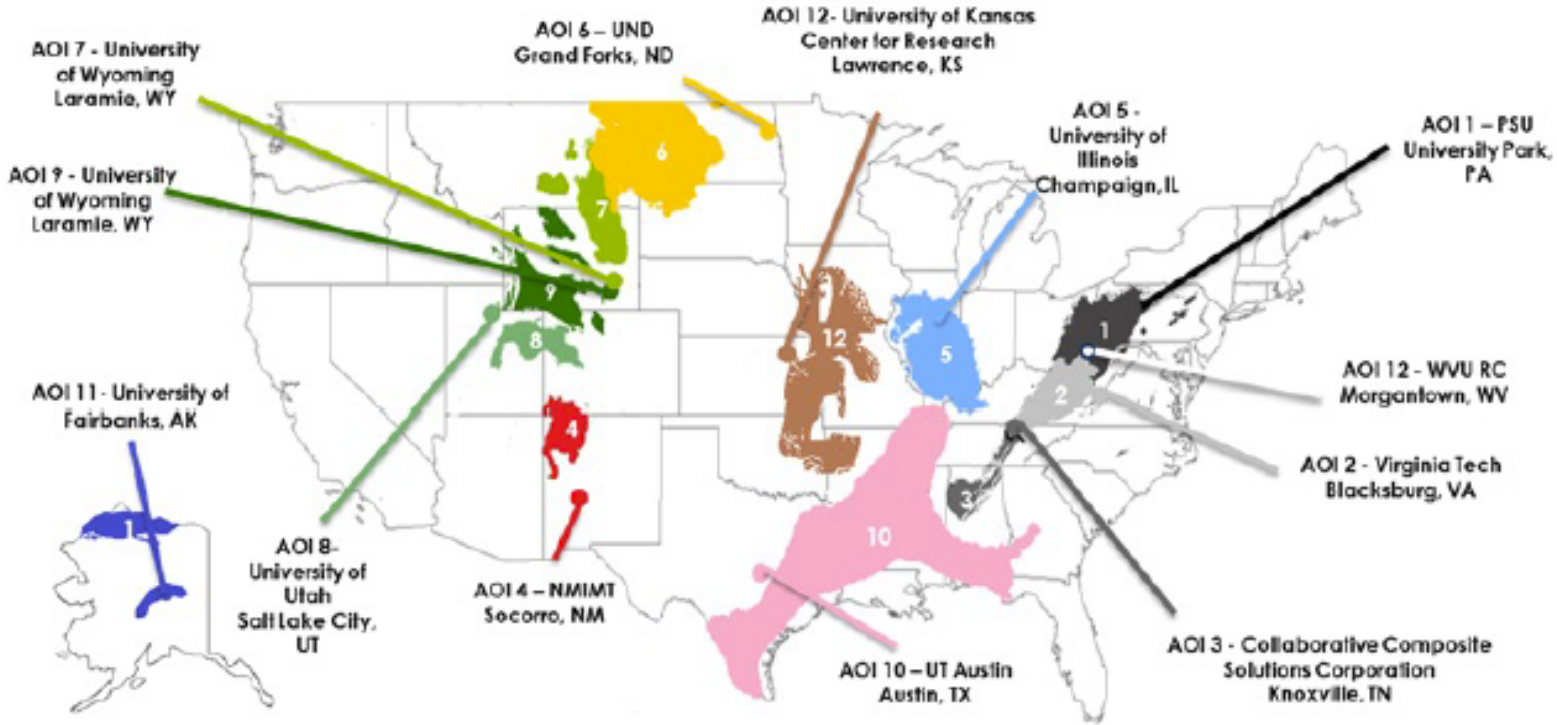


Gold vs copper, alkaline-related deposits, New Mexico



CORE-CM Regional Challenges

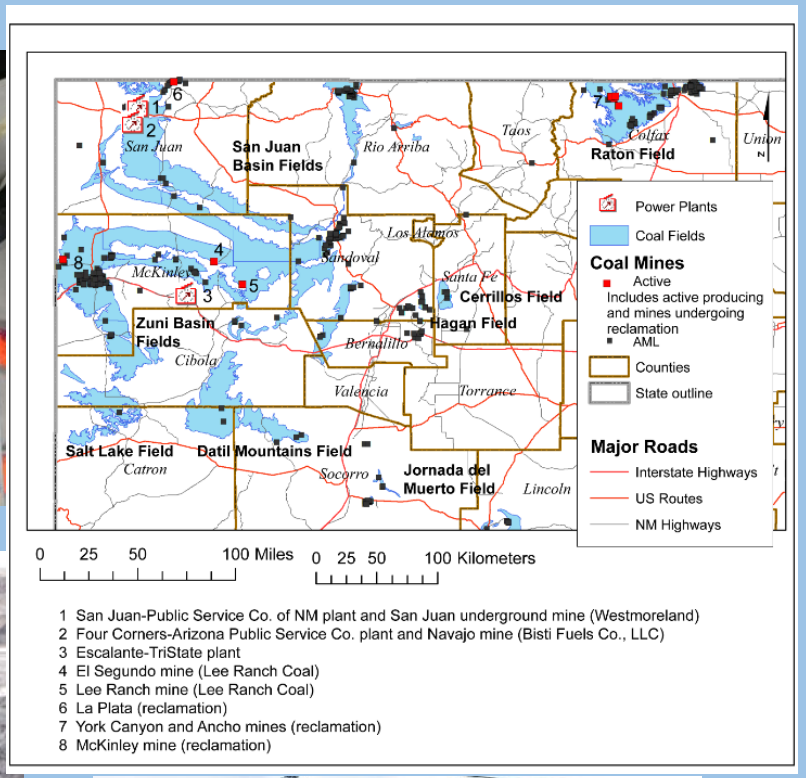
Building coalitions to develop and implement strategies that accelerate and realize the full economic potential of carbon ore and critical minerals across the U.S.



- Address the upstream and midstream CM supply chain and downstream manufacturing of high-value, nonfuel, carbon-based products, ores and critical minerals
- Co-located with economically stressed communities in need of clean energy jobs and will provide the foundation for educating next generation technicians, skilled workers, and STEM professionals.

DOE CORE-CM project—San Juan River-Raton Basin, New Mexico DOE contract (Oct 2021-Sept 2023)

- CORE-CM=Carbon Ore, Rare Earth and Critical Minerals
- Identify and quantify the distribution of REE and CM in coal beds and related stratigraphic units in the San Juan and Raton basins
- Identify, sample, and characterize coal waste stream products
- Sandia: Microscale characterization techniques to identify where REEs and critical metals are hosted
- LANL: Field-portable, in situ LIBS/RAMAN analysis



SAN JUAN COLLEGE

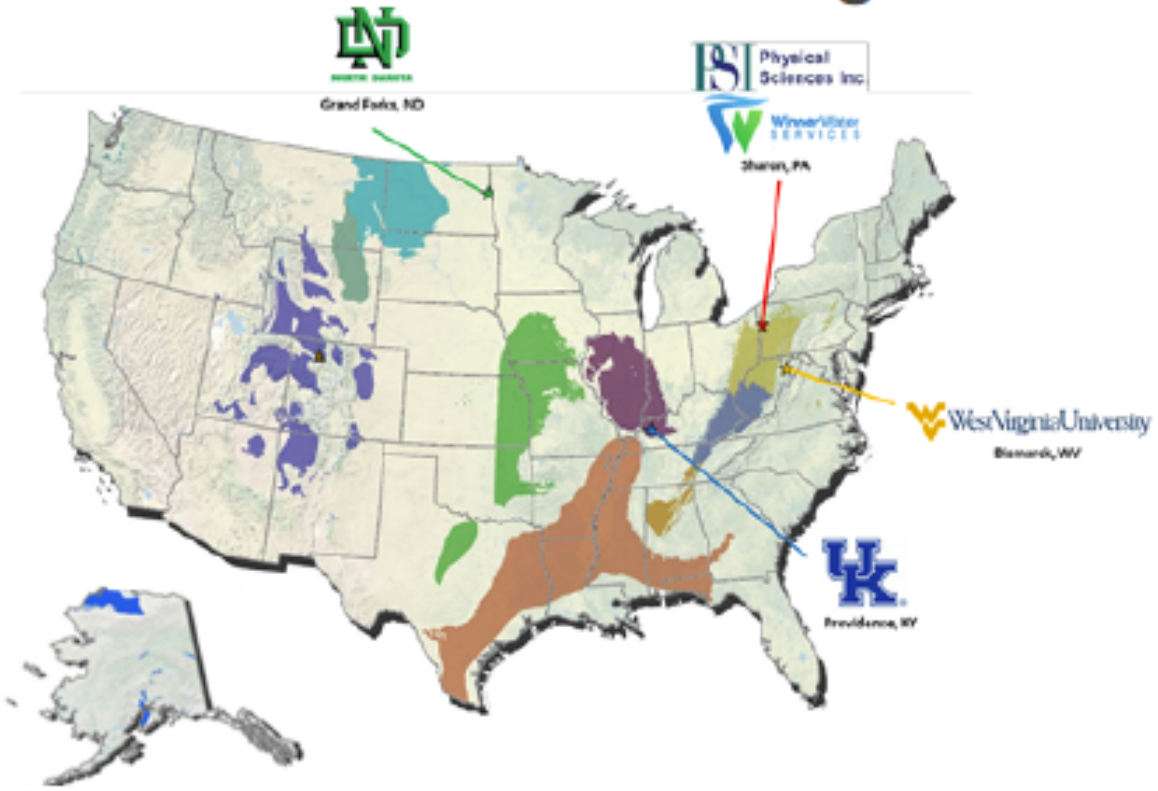
New Mexico Tech

Los Alamos NATIONAL LABORATORY EST. 1943

Sandia National Laboratories

SonoAsh

Small Scale Pilots: Proving Technical Feasibility



Quantity MREO Produced Annually				
	2018	2019	2020	2021
UKY (Refuse)	0.6 kg	1.5 kg	0.5 kg	Processing Begins in Fall
	80% purity	>90% purity	~98% purity	
WVU (AMD)	44 g		Field Pilot Construction (Facility Start Up January 2022	
	95 – 99% purity			
PSI (ASH)	0.01 kg MRES	0.149 kg MRES	1.06 kg MRES	1.76 kg MRES
	≤10% purity	≤14% purity	≤67% purity	≤91% purity
	0.004 kg MREO equivalent	0.057 kg MREO equivalent	0.41 kg MREO equivalent	0.67 kg MREO equivalent
UND (Lignite)	5-10 g	500 g	Pilot Construction (Facility Start – Up October 2021)	
		30 -85% purity		
	5 – 15% purity	4000 g		
		4 – 9 % purity		

Projects increased purity of MREOs being produced up to 99%

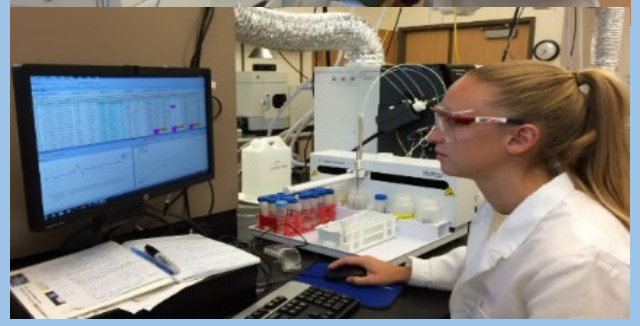
What types of careers are needed?

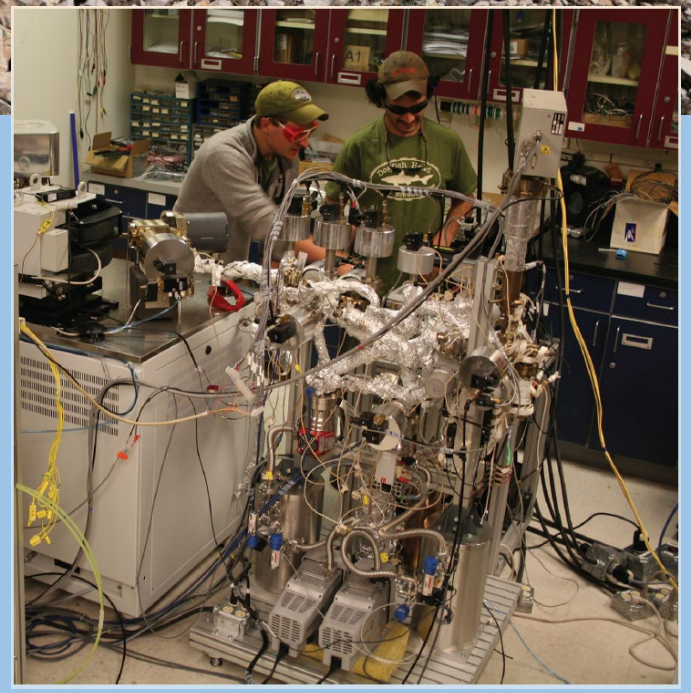
- Geologists, engineers, mineralogists, hydrologists
- Drillers for exploration
- Mechanics to keep equipment running
- Business men and women to finance these ventures
- Inventors to improve the technology of exploration (drones)
- Inventors to find new uses of commodities to make our life better
- Reclamation specialists to reclaim the mine sites when mining is completed
- Government regulators

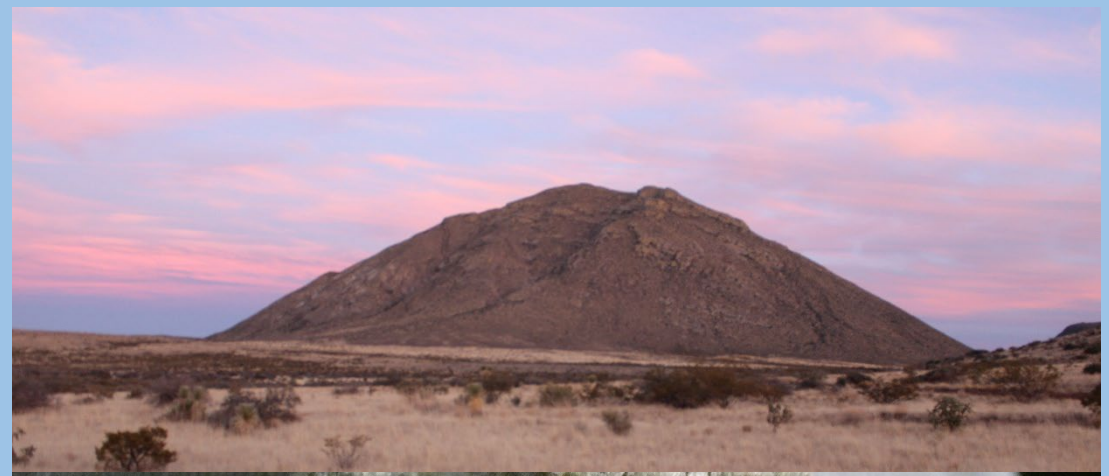
Summary

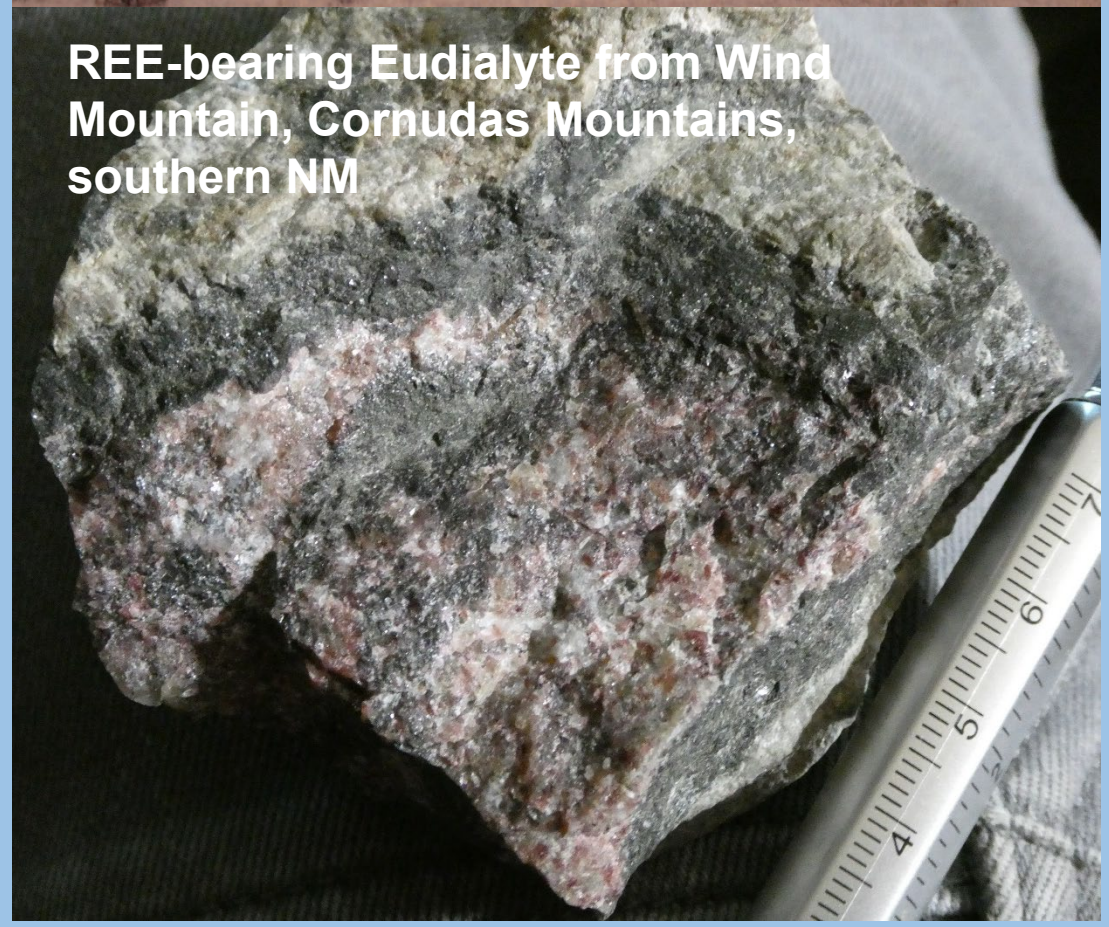
- Critical minerals are nonfuel minerals that are essential to the economy and defense of the U.S. that are subject to potential supply disruptions
- Both administrations (U.S.) have tasked the DOI (USGS), DOE, and DOD with critical minerals research
- Critical minerals are stand alone deposits, by-products or co-products, or trace amounts in known deposits
- Critical minerals are needed in order to move to a “green” CO2-free economy
- Solving the shortage of critical minerals will involve more than exploration, mining, and processing (including recycling); but also changes in permitting but still protecting the affected environment and communities as well as the business models for financing some of these commodities

Research









REE-bearing Eudialyte from Wind Mountain, Cornudas Mountains, southern NM

Bastnäsite [(Ce,La)(CO_3)F] in purple fluorite breccia from the Red Cloud mine, Gallinas Mountains, central NM

Activities

- **Critical minerals in preventing hazards—activities**
  - In notebook
- Television minerals—see activity in your notebook
  - Addition—what critical minerals are needed to manufacture televisions?
- Soccer—see activity in your notebook
  - Addition—what critical minerals are needed to play soccer?

Other resources

- My web page https://geoinfo.nmt.edu/staff/mclemore/home.html
  - Other activities (including this powerpoint)
- Video of Socorro Perlite mine https://geoinfo.nmt.edu/staff/mclemore/DicaPerl17minmovie.mp4
- Video of gold panning https://geoinfo.nmt.edu/staff/mclemore/GoldPanningVideo7.8.2020.mp4


QUESTIONS?