CRITICAL MINERALS IN PREVENTING HAZARDS

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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

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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
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.
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

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Net import reliance as a percentage of apparent consumption</th>
<th>Major import sources (2017–20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARSENC, all forms</td>
<td>100</td>
<td>China, Morocco, Belgium</td>
</tr>
<tr>
<td>ASBESTOS</td>
<td>100</td>
<td>Brazil, Russia</td>
</tr>
<tr>
<td>Cesium</td>
<td>100</td>
<td>Germany, China</td>
</tr>
<tr>
<td>FLUORSPAR</td>
<td>100</td>
<td>Mexico, Vedanta, South Africa, Canada</td>
</tr>
<tr>
<td>Gallium</td>
<td>100</td>
<td>China, United Kingdom, Germany, Ukraine</td>
</tr>
<tr>
<td>Graphite (natural)</td>
<td>100</td>
<td>China, Mexico, Canada, India</td>
</tr>
<tr>
<td>Indium</td>
<td>100</td>
<td>China, Canada, Republic of Korea, France</td>
</tr>
<tr>
<td>Manganese</td>
<td>100</td>
<td>Gabon, South Africa, Australia, Georgia</td>
</tr>
<tr>
<td>Mica (natural) sheet</td>
<td>100</td>
<td>China, Brazil, Belgium, India</td>
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<tr>
<td>Nepheline Syenite</td>
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<td>Brazil, Canada</td>
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<tr>
<td>Niobium (columbium)</td>
<td>100</td>
<td>Germany</td>
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<tr>
<td>Scandium</td>
<td>100</td>
<td>Europe, China, Japan, Russia</td>
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<tr>
<td>Strontium</td>
<td>100</td>
<td>Mexico, Germany, China</td>
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<tr>
<td>Tantalum</td>
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<td>China, Germany, Australia, Indonesia</td>
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<td>Vanadium</td>
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<td>Yttrium</td>
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<td>Gemstones</td>
<td>96</td>
<td>India, Israel, Belgium, South Africa</td>
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<tr>
<td>Tellurium</td>
<td>63</td>
<td>Canada, Germany, China, Philippines</td>
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<tr>
<td>Potassium</td>
<td>51</td>
<td>China, Germany, Brazil</td>
</tr>
<tr>
<td>Iron oxide pigments, natural and synthetic</td>
<td>98</td>
<td>China, Germany, Brazil, China</td>
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<tr>
<td>Rare earths, compounds and metals</td>
<td>&gt;60</td>
<td>China, Estonia, Malaysia, Japan</td>
</tr>
<tr>
<td>Titanium, sponge</td>
<td>64</td>
<td>Japan, Kazakhstan, Ukraine</td>
</tr>
<tr>
<td>Bismuth</td>
<td>50</td>
<td>China, Republic of Korea, Mexico, Belgium</td>
</tr>
<tr>
<td>Titanium mineral concentrates</td>
<td>90</td>
<td>South Africa, Australia, Madagascar, Mozambique</td>
</tr>
<tr>
<td>Antimony, metal and oxide</td>
<td>90</td>
<td>China, Belgium, India</td>
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<td>Stone (dimension)</td>
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<td>Chromium</td>
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<td>PEAT</td>
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<td>Canada</td>
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<tr>
<td>Silver</td>
<td>79</td>
<td>Mexico, Canada, Chile, Poland</td>
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<tr>
<td>Tin, refined</td>
<td>76</td>
<td>Indonesia, Peru, Malaysia, Bolivia</td>
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<tr>
<td>Cobalt</td>
<td>76</td>
<td>Norway, Canada, Japan, Finland</td>
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<tr>
<td>Diamond (industrial), stones</td>
<td>76</td>
<td>South Africa, India, Congo (Kinshasa), Botswana</td>
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<tr>
<td>Zinc, refined</td>
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<td>Canada, Mexico, Peru, Spain</td>
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<tr>
<td>Abrasives, crude fused aluminum oxide</td>
<td>&gt;75</td>
<td>China, France, Belgium, Russia</td>
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<tr>
<td>Barite</td>
<td>&gt;75</td>
<td>China, India, Morocco, Mexico</td>
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<td>Bauxite</td>
<td>&gt;75</td>
<td>Jamaica, Brazil, Guyana, Australia</td>
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<td>Selenium</td>
<td>&gt;75</td>
<td>Philippines, China, Mexico, Germany</td>
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<td>Rhenium</td>
<td>56</td>
<td>Chile, Canada, Kazakhstan, Japan</td>
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<tr>
<td>Platinum</td>
<td>56</td>
<td>South Africa, Germany, Switzerland, Italy</td>
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<tr>
<td>Alumina</td>
<td>56</td>
<td>Brazil, Australia, Jamaica, Canada</td>
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<tr>
<td>Garnet (industrial)</td>
<td>56</td>
<td>South Africa, China, India, Australia</td>
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<td>Magnesium compounds</td>
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<td>China, Brazil, Israel, Canada</td>
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<tr>
<td>Abrasives, crude silicon carbide</td>
<td>&gt;60</td>
<td>China, Netherlands, South Africa</td>
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<td>Germanium</td>
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<tr>
<td>Iodine</td>
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<td>Tungsten</td>
<td>&gt;60</td>
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<td>Cadmium</td>
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<td>Magnesium Metal</td>
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<tr>
<td>Nickel</td>
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For more information, visit: [https://www.usgs.gov/centers/nmic/mineral-commodity-summaries](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

SALT
• NaCl
• table salt
• essential to life (man 2-5 gr/day)
• salt was used as a preservative, tanning leather, stock, mining
• salt was used to preserve Egyptian mummies
Why isn’t copper a critical mineral in the U.S.?

- 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.

Minerals used in selected clean energy technologies

**Transport (kg/vehicle)**
- Electric car
- Conventional car

**Power generation (kg/MW)**
- Offshore wind
- Onshore wind
- Solar PV
- Nuclear
- Coal
- Natural gas

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

|                              | Copper | Cobalt | Nickel | Lithium | REEs | Chromium | Zinc | PGMs | Aluminium*
<table>
<thead>
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<td><strong>Solar PV</strong></td>
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<td><strong>Wind</strong></td>
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<td><strong>Hydro</strong></td>
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<tr>
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<td>○</td>
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<tr>
<td><strong>EVs and battery storage</strong></td>
<td>●</td>
<td>●</td>
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<td><strong>Hydrogen</strong></td>
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<td>○</td>
<td>●</td>
<td>○</td>
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</tbody>
</table>

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

Share of each element’s global production from various countries

- China
- D.R. Congo
- Russia
- South Africa

Australia
Brazil
Canada
Chile

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.
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

Lanthanide series
- La
- Ce
- Pr
- Nd
- Pm
- Sm
- Eu
- Gd
- Tb
- Dy
- Ho
- Er
- Tm
- Yb
- Lu

Actinide series
- Ac
- Th
- Pa
- U
- Np
- Pu
- Am
- Cm
- Bk
- Cf
- Es
- Fm
- Md
- No
- Lr
Uses of critical minerals

Electric vehicles:
- Global EV fleet size is projected to increase 30% a year to 2050
- Battery:
  - lithium
  - cobalt
  - nickel
  - graphite
- Permanent magnets:
  - rare earth elements
  - copper

Renewable energy generation:
- Global wind capacity is projected to increase 6% a year to 2050
- Permanent magnets use neodymium, praseodymium, and dysprosium

Energy storage:
- Global stationary battery storage projected to increase 8% a year to 2050
A World of Minerals in Your Mobile Device (usgs.gov)

**Display**

A mobile device's glass screen is very durable because glassmakers combine its main ingredient, silica (silicon dioxide or quartz), with ceramic materials and then add potassium.

Layers of indium-tin oxide are used to create transparent circuits in the display. Tin is also the ingredient in circuit board solder, and cassiterite is a primary source of tin.

Gallium provides light emitting diode (LED) backlighting. Bauxite is the primary source of this commodity.

Sphalerite is the source of indium (used in the screen's conductive coating) and germanium (used in displays and LEDs).

**Electronics and Circuitry**

The content of copper in a mobile device far exceeds the amount of any other metal. Copper conducts electricity and heat and comes from the source mineral chalcopyrite.

Tetrahedrite is a primary source of silver. Silver-based inks on composite boards create electrical pathways through a device.

Silicon, very abundant in the Earth's crust, is produced from the source mineral quartz and is the basis of integrated circuits.

Arsenopyrite is a source of arsenic, which is used in radio frequency and power amplifiers.

Tantalum, from the source mineral tantalite, is added to capacitors to regulate voltage and improve the audio quality of a device.

Wolframite is a source of tungsten, which acts as a heat sink and provides the mass for mobile phone vibration.

**Battery**

Spodumene and subsurface brines are the sources of lithium used in cathodes of lithium-ion batteries.

Graphite is used for the anodes of lithium-ion batteries because of its electrical and thermal conductivity.

**Speakers and Vibration**

Bastnaesite is a source of rare-earth elements used to produce magnets in speakers, microphones, and vibration motors.
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.

TOUCH SCREEN
It contains a thin layer of Iodine (I₂), highly conductive and transparent, allowing the screen to function as a touch screen.

MICROPHONE, SPEAKERS, VIBRATION UNIT
Nickel is used in the microphone diaphragm that vibrates in response to sound waves. Alloys containing neodymium, praseodymium, and gadolium are used in the magnets contained in the speaker and microphone. Neodymium, terbium, and dysprosium are used in the vibration unit.

DISPLAY
The display contains several rare earth elements. Small quantities are used to produce the colors on the liquid crystal display. Some glue the screen to its glass.

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

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

BATTERY
The majority of smartphones use Lithium-ion batteries.
Wind turbines

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

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

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**

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.

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
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**

**Table:**

<table>
<thead>
<tr>
<th>Light rare earths</th>
<th>Heavy rare earths</th>
</tr>
</thead>
<tbody>
<tr>
<td>La - Lanthanum</td>
<td>Eu - Europium</td>
</tr>
<tr>
<td>Ce - Cerium</td>
<td>Gd - Gadolinium</td>
</tr>
<tr>
<td>Pr - Praseodymium</td>
<td>Tb - Terbium</td>
</tr>
<tr>
<td>Nd - Neodymium</td>
<td>Dy - Dysprosium</td>
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<tr>
<td>Sm - Samarium</td>
<td>Ho - Holmium</td>
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<tr>
<td><strong>ER</strong></td>
<td>Er - Erbium</td>
</tr>
<tr>
<td><strong>TM</strong></td>
<td>Tm - Thulium</td>
</tr>
<tr>
<td>Yb</td>
<td>Yb - Ytterbium</td>
</tr>
<tr>
<td>Lu</td>
<td>Lu - Lutetium</td>
</tr>
<tr>
<td><strong>Y</strong></td>
<td>Y - Yttrium</td>
</tr>
</tbody>
</table>

**Figure:**

- **Magnets**
- **Catalysts**
- **Polishing**
- **Batteries**
- **Others**

Rare earth elements are used for a variety of applications.

**Graph:**

*Projected rare earths consumption by end use*

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

59% of cobalt is used in batteries

- Laptops: 5-15 grams cobalt
- Mobile phones: 5-10 grams cobalt
- Electric cars: 10-20 kilograms cobalt

Refined cobalt metal
- China: 34%
- Finland: 13%
- Canada: 12%

Refined cobalt chemical
- China: 85%
- Finland: 9%
- Belgium: 2%

End Uses (29%):
- Nickel alloys: 13%
- Tool materials: 8%
- Magnets: 4%

End Uses (71%):
- Batteries: 55%
- Catalysts: 8%
- Pigments: 6%

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

Figure 3.4: Projected cobalt consumption by end-use
Vanadium in batteries

Figure 5.4: Projected vanadium consumption by end-use – including steel
Why are supply chains important in understanding critical minerals?
How much raw material does a 30GWh NCM Li-ion Megafactory consume?

- Lithium: 25,000 tonnes
- Nickel: 19,000 tonnes
- Graphite anode: 33,000 tonnes
- Cobalt: 6,000 tonnes

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Some of the challenges in producing critical minerals
<table>
<thead>
<tr>
<th>Dimension</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geologic Availability</td>
<td>✅ Does the mineral resource exist?</td>
</tr>
<tr>
<td>Technical Availability</td>
<td>✅ Can we extract and process it?</td>
</tr>
<tr>
<td>Environmental &amp; Social Availability</td>
<td>✅ Can we produce it in environmentally and socially responsible and acceptable ways?</td>
</tr>
<tr>
<td>Political Availability</td>
<td>✅ How do governments influence availability through their policy and actions?</td>
</tr>
<tr>
<td>Economic Availability</td>
<td>✅ Can we produce it at a cost users are willing and able to pay?</td>
</tr>
</tbody>
</table>
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’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
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

\(^{40}\text{Ar}/^{39}\text{Ar}\) 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 \([(\text{Ce,La})(\text{CO}_3)\text{F}]\) 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.
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
## Small Scale Pilots: Proving Technical Feasibility

### Projects increased purity of MREOs being produced up to 99%

<table>
<thead>
<tr>
<th></th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UKY (Refuse)</strong></td>
<td>0.6 kg</td>
<td>1.5 kg</td>
<td>0.5 kg</td>
<td>Processing Begins in Fall</td>
</tr>
<tr>
<td>80% purity</td>
<td></td>
<td></td>
<td>~98% purity</td>
<td></td>
</tr>
<tr>
<td>&gt;90% purity</td>
<td></td>
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</tr>
<tr>
<td>WVU (AMD)</td>
<td>44 g</td>
<td></td>
<td></td>
<td>Field Pilot Construction (Facility Start Up January 2022)</td>
</tr>
<tr>
<td>95 – 99% purity</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>PSI (ASH)</strong></td>
<td>0.01 kg MRES</td>
<td>0.149 kg MRES</td>
<td>1.06 kg MRES</td>
<td>1.76 kg MRES</td>
</tr>
<tr>
<td>≤10% purity</td>
<td></td>
<td></td>
<td>≤67% purity</td>
<td>≤91% purity</td>
</tr>
<tr>
<td>≤14% purity</td>
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</tr>
<tr>
<td>0.004 kg MRES equivalent</td>
<td>0.057 kg MRES equivalent</td>
<td>0.41 kg MRES equivalent</td>
<td>0.67 kg MRES equivalent</td>
<td></td>
</tr>
<tr>
<td>UND (Lignite)</td>
<td>5-10 g</td>
<td>500 g</td>
<td>30 -85% purity</td>
<td>Pilot Construction (Facility Start-Up October 2021)</td>
</tr>
<tr>
<td>5 – 15% purity</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>4 – 9% purity</td>
<td></td>
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</tbody>
</table>

**U.S. DEPARTMENT OF ENERGY**

Fossil Energy and Carbon Management
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

Bastnasite [(Ce,La)(CO₃)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?