Critical Minerals and Mining

Four Corners Energy & Water Innovation Student Symposium

April 6, 2023

Tanya Gallegos, USGS Mineral Resources Program, Associate Program Coord, tgallegos@usgs.gov

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

Why are critical minerals important?

- Critical minerals are needed for applications in:
  - Defense
  - Advanced manufacturing
  - Consumer technologies
  - Renewable energy generation and storage
- In 2022, the U.S. was 100% reliant on imports for 15 mineral commodities including gallium.

Defense and national security uses

75 Re Rhenium

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

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

Gen. III Ground Panoramic Night Vision Goggles

Photo credit: L3 Technologies, Inc.

32 Ge Germanium

31 Ga Gallium

33 As Arsenic

Transportation

3 Li Lithium

6 C Carbon

27 Co Cobalt

28 Ni Nickel

Photo credit: Telsa, Inc.

Electric and hybrid vehicles

Renewable Energy Generation

49 In Indium

31 Ga Gallium

34 Se Selenium

Thin-film solar PV

Photo credit: Testbourne, Ltd.

Offshore direct drive wind turbine

Photo credit: US DOE

60 Nd Neodymium

66 Dy Dysprosium

USGS

The Energy Act of 2020 directed USGS to update the whole-of-government list of critical minerals

Federal Coordination on Critical Mineral Supply Chains Since 2010

USGS

2022 Final Critical Minerals List

Continuing from 2018:

- Aluminum
- Antimony
- Arsenic
- Barite
- Beryllium
- Bismuth
- Cesium
- Chromium
- Cobalt
- Fluorspar
- Gallium
- Germanium
- Graphite (natural)
- Hafnium
- Indium
- Lithium
- Magnesium
- Manganese
- Niobium
- Platinum group elements
- Rare earth element group
- Rubidium
- Scandium
- Tantalum
- Tellurium
- Tin
- Titanium
- Tungsten
- Vanadium
- Zirconium

Additions to List:

- Nickel
- Zinc
- Rare earth elements and platinum group elements included as individual entries rather than as mineral groups

Removals from List:

- Helium
- Potash
- Rhenium
- Strontium
- Uranium

https://www.federalregister.gov/documents/2022/02/24/2022-04027/2022-final-list-of-critical-minerals

USGS Earth Mapping Resources Initiative
Data Collection and Critical Mineral Resource Assessments

Mineral systems can be used to:

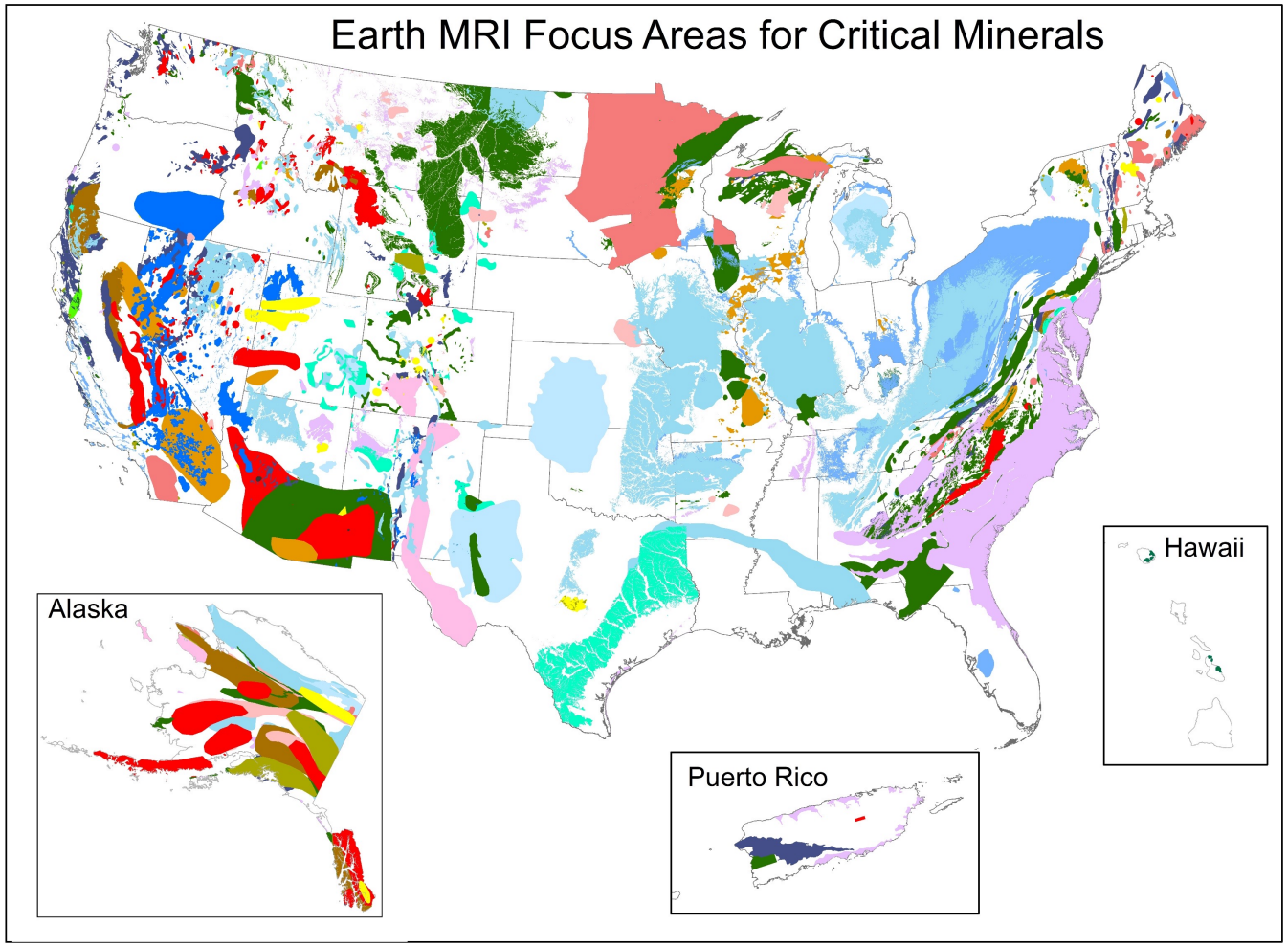
- Guide Earth MRI data collection
- Accelerate assessing critical mineral resources
- Show resource managers and developers where emerging minerals-dependent technologies may create economic opportunities and community concerns

EXPLANATION

Focus Areas

Mineral System

- Alkalic porphyry (27)
- Arsenide (2)
- Basin brine path (85)
- Carlin-type (6)
- Chemical weathering (37)
- Climax-type (70)
- Coeur d'Alene-type (6)
- Hybrid magmatic REE / basin brine path (10)
- IOA-IOCG (23)
- Lacustrine evaporite (14)
- Mafic magmatic (77)
- Magmatic REE (68)
- Marine chemocline (25)
- Marine evaporite (13)
- Metamorphic (26)
- Meteoric convection (3)
- Meteoric recharge (40)
- Orogenic (23)
- Placer (51)
- Porphyry Cu-Mo-Au (109)
- Porphyry Sn (54)
- Reduced intrusion-related (14)
- Volcanogenic seafloor (50)



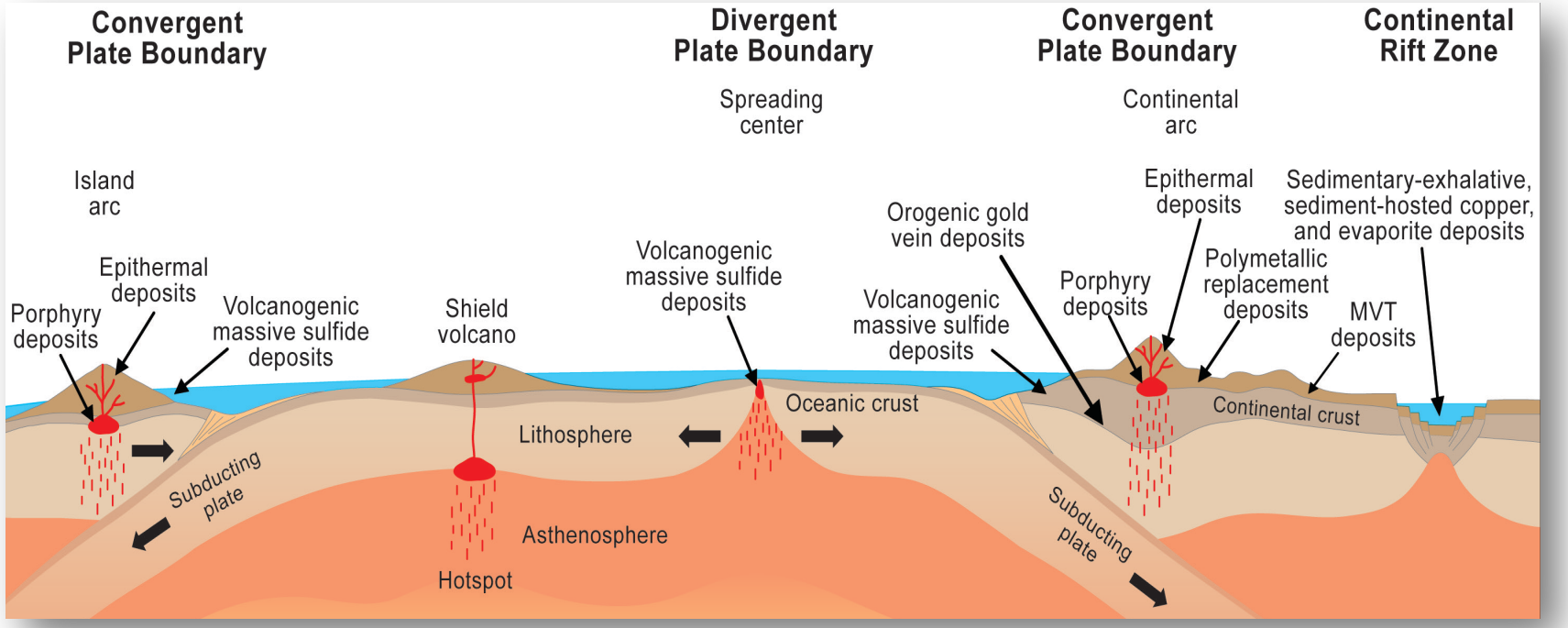
Dicken and others, 2022, GIS, supplemental data table, and references for focus areas of potential domestic resources of critical minerals and related commodities in the United States and Puerto Rico: U.S. Geological Survey data release, https://doi.org/10.5066/P9DIZ9N8.

USGS

USGS Research: Where are critical minerals found? Mineral Systems Framework

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

- Critical minerals occur in a wide variety of **deposit** types that form within larger **mineral systems**.
- They range from commodities that are the **principal mined product** to recovery as **by-products** during processing of other metallic ores.



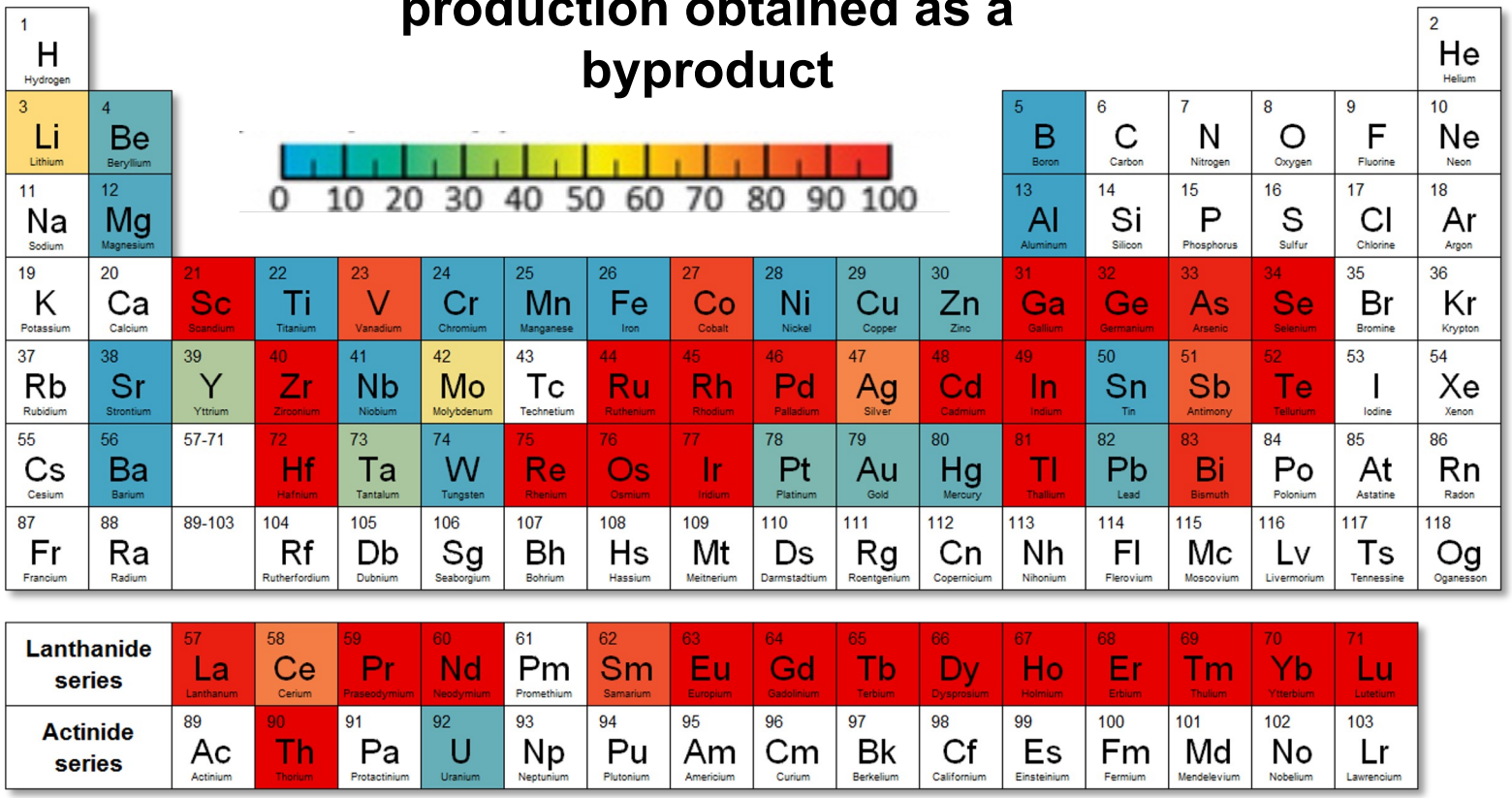
USGS

mineral systems classification: Hofstra & Kreiner, 2020

Secondary Sources of Critical Minerals: Mine Waste

- **Byproducts**. Critical minerals often occur as byproducts or minerals in lesser amounts relative to the target mineral.
- **Waste as Resource**. In many cases, minerals that were not originally economic to mine were considered waste, and sources of contaminants decades ago but are now considered sources of critical minerals.
- **The life cycle approach** to understanding minerals and thinking differently about mine waste will be important for future critical mineral extraction and the sustainability of our environment.

Share of element's primary production obtained as a byproduct

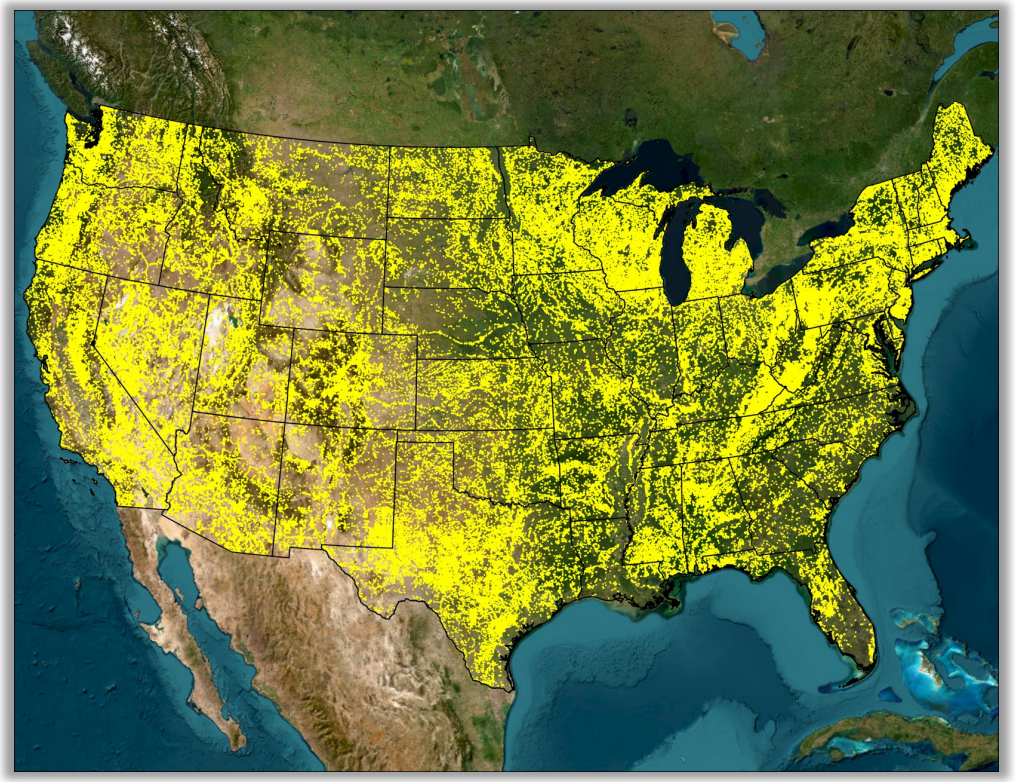


Nassar et al., 2015, By-product metals are technologically essential but have problematic supply, Science Advances 1 (3), e1400180

USGS

USGS Research: Critical Mineral Resource Recovery from Mine Waste and Remediation

- Mine waste is in every state.
- Many legacy mine sites pose environmental and physical hazards.
- Reclaiming mine sites offers co-benefits for remediation and critical mineral recovery.
- USGS Activities:
  - **National mine waste inventory** geospatial database of current and historical mine waste
  - **Mine waste characterization** projects to help inform the potential critical mineral endowments of nonfuel hard-rock mine waste materials and reclamation decisions.
  - **Research on mine waste** and potential for recovery of critical minerals from mine waste in support of reclamation.



New USMIN geospatial database of current and historical mining locations. Yellow dots are mine features captured from historical USGS topographic maps.

Horton, J.D., and San Juan, C.A., 2016, Prospect- and mine-related features from U.S. Geological Survey 7.5- and 15-minute topographic quadrangle maps of the United States (ver. 9.0, January 2023): U.S. Geological Survey data release, https://doi.org/10.5066/F78W3CHG.

USGS

Mine Waste Sampling in New Mexico and Colorado

- Training and geochemistry analyses provided by USGS:
  - Build capacity that benefits the States
  - Expands geoscience workforce through early career employment and collaboration with educational institutions
- Critical minerals in mine wastes in New Mexico, *New Mexico Bureau of Geology and Mineral Resources*
- Critical Minerals in Mine Waste, Colorado, *Colorado Geological Survey*
- Results will help populate the National Mine Waste Inventory and refine methods that can be applied to characterize other mine waste sites.

Scientists from the USGS and the New Mexico Bureau of Geology and Mineral Resources sample the Copper Flat Mine n Hillsboro, NM; photo courtesy of Bob Seal, USGS

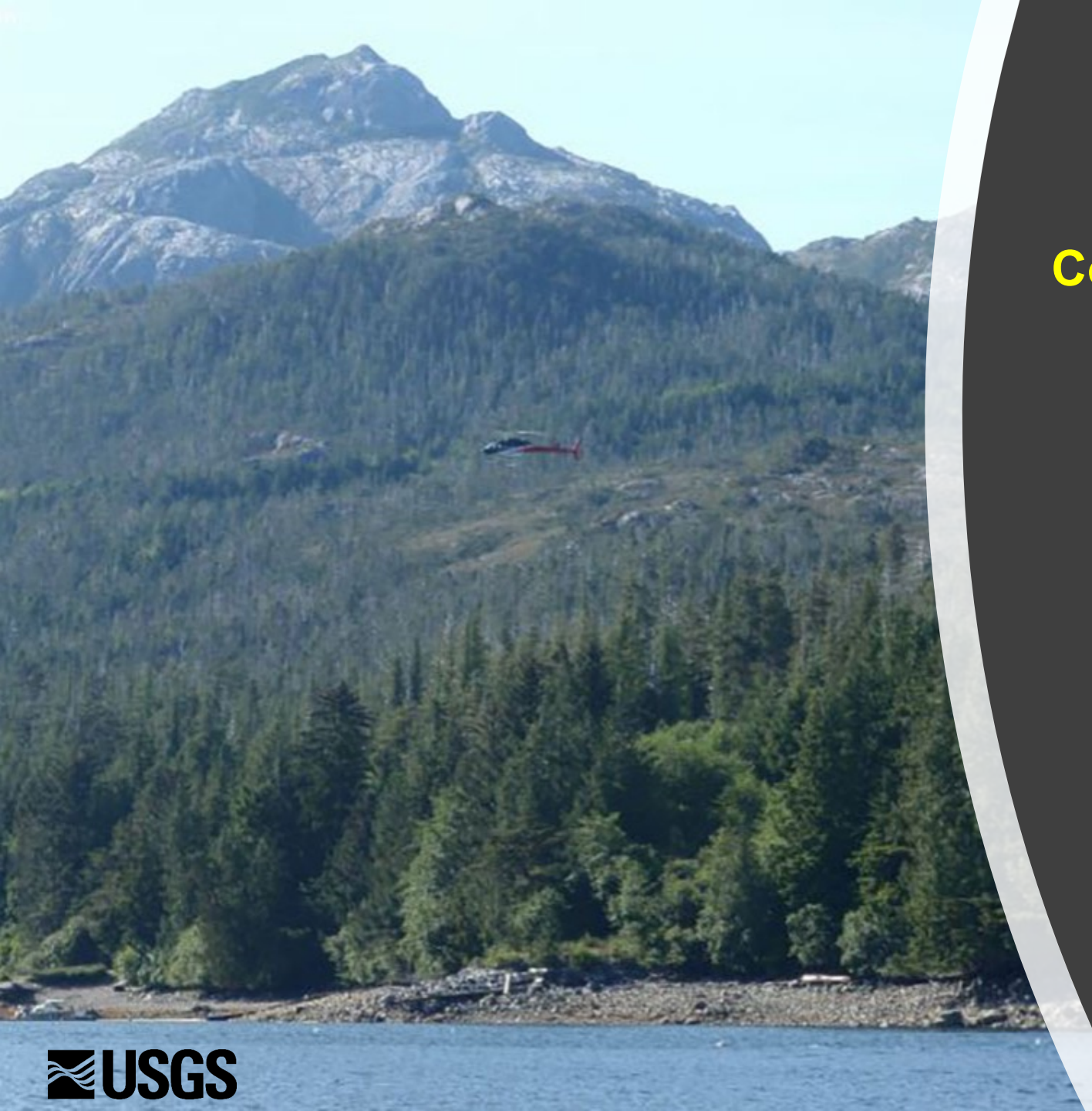
USGS

Water Use in Critical Mineral Mining

- **Water plays an important role** in mining critical minerals in terms of quality and quantity. Water is both used and generated during mining through processes such as drilling and dewatering.
- **Quality**. Mine impacted waters may also have the potential to change the character of drinking water aquifers and surface waters.
- **Availability**. Historically, both the use of water by mining operations and generation of acid mine drainage and other water issues created by legacy mining have affected the mining industry's social license to operate and must be addressed for future critical minerals development.
- **Learn from the past**. We can learn from these historical events to improve future management practices to better support beneficial reuse, recycling, and preservation of this precious resource.

Acid mine drainage at Red Mtn, CO (photo: Katie Walton-Day, USGS)

USGS



Contacts:

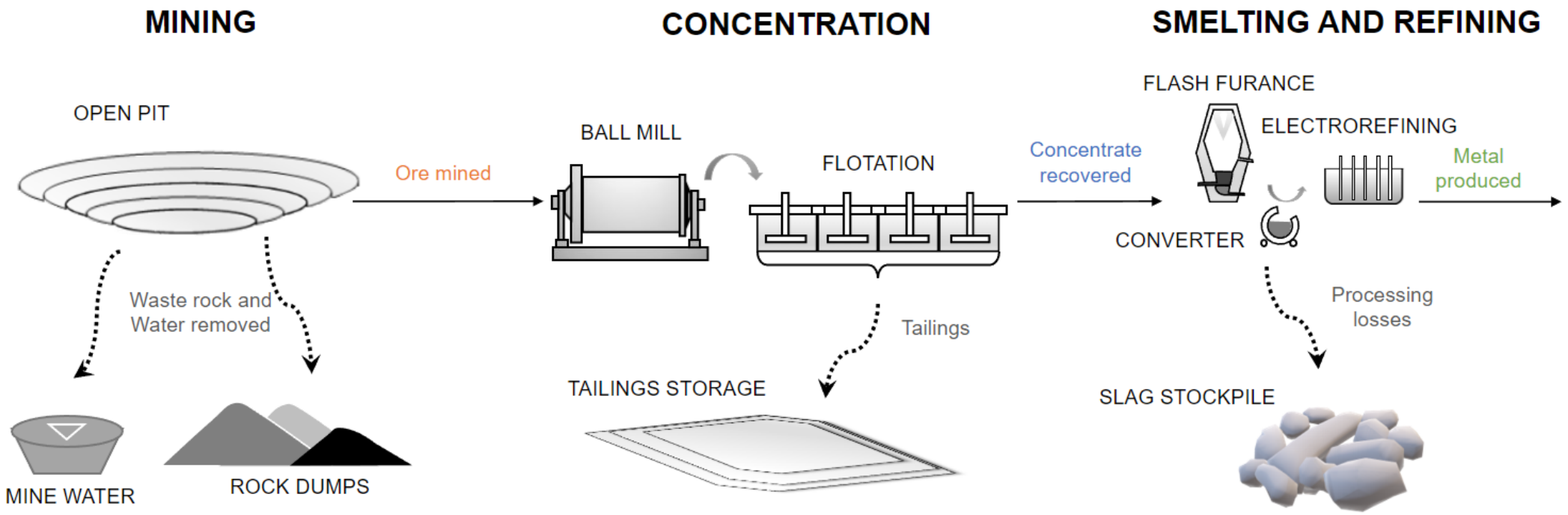
Tanya Gallegos
USGS, Mineral Resources Program
Associate Program Coordinator
tgallegos@usgs.gov

Collin Williams
USGS, Mineral Resources Program
Program Coordinator
colin@usgs.gov

Bokan Mountain, Alaska (rare earth element deposit)
Photo credit: B. Van Gosen, USGS

Extra Slides

An Overview of Mine Waste



Nedal T. Nassar, Graham W. Lederer, Jamie L. Brainard, Abraham J. Padilla, and Joseph D. Lessard
Environmental Science & Technology **2022** *56* (10), 6710-6721
DOI: 10.1021/acs.est.1c07875

USGS

FY23: New USGS Earth MRI Mine Waste Cooperative Agreement Program

- New cooperative agreement program for State geological surveys funded by Bipartisan Infrastructure Law
- Funds projects focusing on 2 priorities:
  - **Providing existing data for the mine waste inventory** and/or
  - **Collecting new data for mine waste characterization**
- Training and geochemistry analyses provided by USGS:
  - Build capacity that benefits the States
  - Expands geoscience workforce through early career employment and collaboration with educational institutions
- State geological surveys are encouraged to work with other State agencies with mine waste management responsibilities

Chateaugay tailings pile, Adirondack Mountains, NY
Photo by Ryan Taylor, USGS

USGS

Critical Mineral Definition

Energy Act of 2020, section 7002(c) and section 7002(a)

- Critical minerals:
  - (i) are essential to the economic or national security of the United States; (ii) the supply chain of which is vulnerable to disruption; and serve an essential function in the manufacturing of a product, the absence of which would have significant consequences for the economic or national security of the United States.
  - EXCLUSIONS.—The term ‘‘critical mineral’’ does not include—(i) fuel minerals; (ii) water, ice, or snow; (iii) common varieties of sand, gravel, stone, pumice, cinders, and clay.

USGS