IDENTIFYING CRITICAL MINERAL RESOURCES

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Society for Mining, Metallurgy, & Exploration

Technical Briefings

 Critical and Strategic Minerals Importance to the U.S. Economy

- https://www.smenet.org/What-We-Do/Technical-Briefings/Critical-and-Strategic-Minerals-Importance-to-the
- Rare earth elements
 - https://www.smenet.org/What-We-Do/Technical-Briefings/Rare-Earth-Elements

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.



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

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Figure 2. – 2021 U.S	Net Import Reliance
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https://www.usgs.gov/centers/ nmic/mineral-commoditysummaries

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/ dav salt was used as a preservative tanning leather, stock, minin

salt was used to preserve Egyptian mummies'

minerals

Article

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

Ran Motoori *, Benjamin C. McLellan^D and Tetsuo Tezuka Graduate School of Energy Science, Kyoto University, Kyoto 606-8501, Japan; b-mclellan@energy.kyoto-u.ac.jp (B.C.M.); tezuka@energy.kyoto-u.ac.jp (T.T.) * Correspondence: motoori.ran.45m@st.kyoto-u.ac.jp; Tel.: +81-75-753-3300

Received: 9 October 2018; Accepted: 26 November 2018; Published: 1 December 2018



MDPI

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 are critical minerals so important?

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

Share of each element's global production from various countries



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).











From Nassar and Fortier (2021)

61. Department of the bindler 62. Generation States

Feldspar

Mica



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

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

The Role of Critical Minerals in Clean Energy Transitions



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	•	0	0	0	0	0	0	0	•
Wind	•	0	0	0	•	۲	•	0	•
Hydro	0	0	0	0	0	0	0	0	0
CSP	0	0	۲	0	0	•	\bigcirc	0	•
Bioenergy	•	0	0	0	0	0	0	0	0
Geothermal	0	0	٠	0	0	•	0	0	0
Nuclear	0	0	0	0	0	0	0	0	0
Electricity networks	•	0	0	0	0	0	0	0	•
EVs and battery storage	•	•	•	•	•	0	0	0	•
Hydrogen	0	0	•	0	0	0	0	•	•

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.

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Transitions





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





- 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.

Carbon Management







Projects increased purity of MREOs being produced up to 99%

Quantity MREO Produced Annually						
		2018	2019	2020	2021	
UK	UKY (Refuse)	0.6 kg	1.5 kg	0.5 kg	0.5 kg Processing	
(Re		80% purity	>90% purity	~98% purity	Begins in Fall	
wv	WVU (AMD)		44 g	Field Pilot Construction		
(AN		S	95 – 99% purity	(Facility Start Up January 2022		
, DCI	PSI (ASH)	0.01 kg MRES	0.149 kg MRES	1.06 kg MRES	1.76 kg MRES	
(AS		≤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		
UN			30 -85% purity			
(Lig		5 - 15%	4000 g	Start – Up October 2021		
		purity	4 - 9 % purity			

Carbon Management



Prepared as part of a joint research program between the U.S. Geological Survey, Geological Survey of Canada, Geological Survey of Queensland, and Geoscience Australia

Deposit Classification Scheme for the Critical Minerals Mapping Initiative Global Geochemical Database

HOME WHAT ARE MINERAL SYSTEMS?				
Find mineral systems by process Find mineral systems by commodity	Home / WHAT ARE MINERAL SYSTEMS? / Find mineral systems by	process		
Primary data layers + Structures +	Find mineral systems by process			
Tectonic units Image: Constraint of the second se	 > Basin-related fluid flow > Deformation and metamorphism > Magmatic-related hydrothermal > Orthomagmatic 			
Rare-element pegmatite Layered intrusion-hosted vanadium	 Sedimentary Weathering and regolith 			
DOCUMENTATION CONTACT US	The Minerals Systems Atlas groups known (Australian) mineral deposit typ system context on the basis of perceived common, regional-scale metallog proposed by Geoscience Australia (Table 1; Fraser et al., 2007; GA Record mineral deposits may have occurred in more than one geodynamic (tector	bes (mine genic pro d 2007-1 nic) settir		
	setting is not required in order to select data.			

nineral systems by process

- rmation and metamorphism
- natic-related hydrothermal
- magmatic
- nentary
- hering and regolith

ystems Atlas groups known (Australian) mineral deposit types (mineral subsystems') within a mineral on the basis of perceived common, regional-scale metallogenic processes, following the scheme eoscience Australia (Table 1; Fraser et al., 2007; GA Record 2007-16). These processes and resultant ts may have occurred in more than one geodynamic (tectonic) setting, but a knowledge of the specific quired in order to select data.

Open-File Report 2021-1049

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

Mineral Systems Approach Example: Porphyry Copper-Molybdenum-Gold System



Some of the challenges in producing critical minerals



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 oversupplying 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)

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



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.

Demand for nearly every mineral (and energy) commodity is high. 16,000 14.000 Copper Copper production 12.000 World population (million ~22X more production Per capita cons than 100 years ago 10,000 (g/persi 8,000 6,000 1 000 ~6X more per capita consumption than 2.000 100 years ago 1960 1980 2000 duction statistics mostly from USGS/USBM

	Mine pro	duction	Refinery p	roduction	Reserves
	2020	2021 ^e	2020	2021 ^e	
United States	1,200	1,200	918	1,000	48,000
Australia	885	900	427	450	793,000
Canada	585	590	e290	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	e810	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

- Ready availability of copper
- Import only 45% of our consumption
- Abundant reserves

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

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





