U.S. Critical Mineral Security Cannot Rely On Mine Waste Alone

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Policymakers are increasingly emphasizing secure critical mineral supplies for clean energy development and U.S. technological competitiveness. Thanks to claims that the U.S. already mines all that it needs, recovery of critical minerals from mine waste has emerged as a policy priority. However, critical mineral policy built on misperceptions that waste recovery can eliminate the need for conventional mines risks deepening mineral import dependence by devaluing support for new mine projects.

Waste recovery offers valuable opportunities for mineral production, but remains unproven for the vast majority of critical minerals. Of the 60 elements on the critical mineral list, only a few—such as gallium, germanium, and tellurium—are demonstrably extracted from mine waste. A handful more possess promising potential for waste recovery based on geologic correlations, like rare earth elements in iron ore.

Studies that tally trace amounts of critical minerals in mine tailings imply tantalizing theoretical volumes. Yet, most of these samples consist of low-grade material that remains uneconomic to recover. The disappointing reality is that every rock contains a little of every element—no different than garden soil.

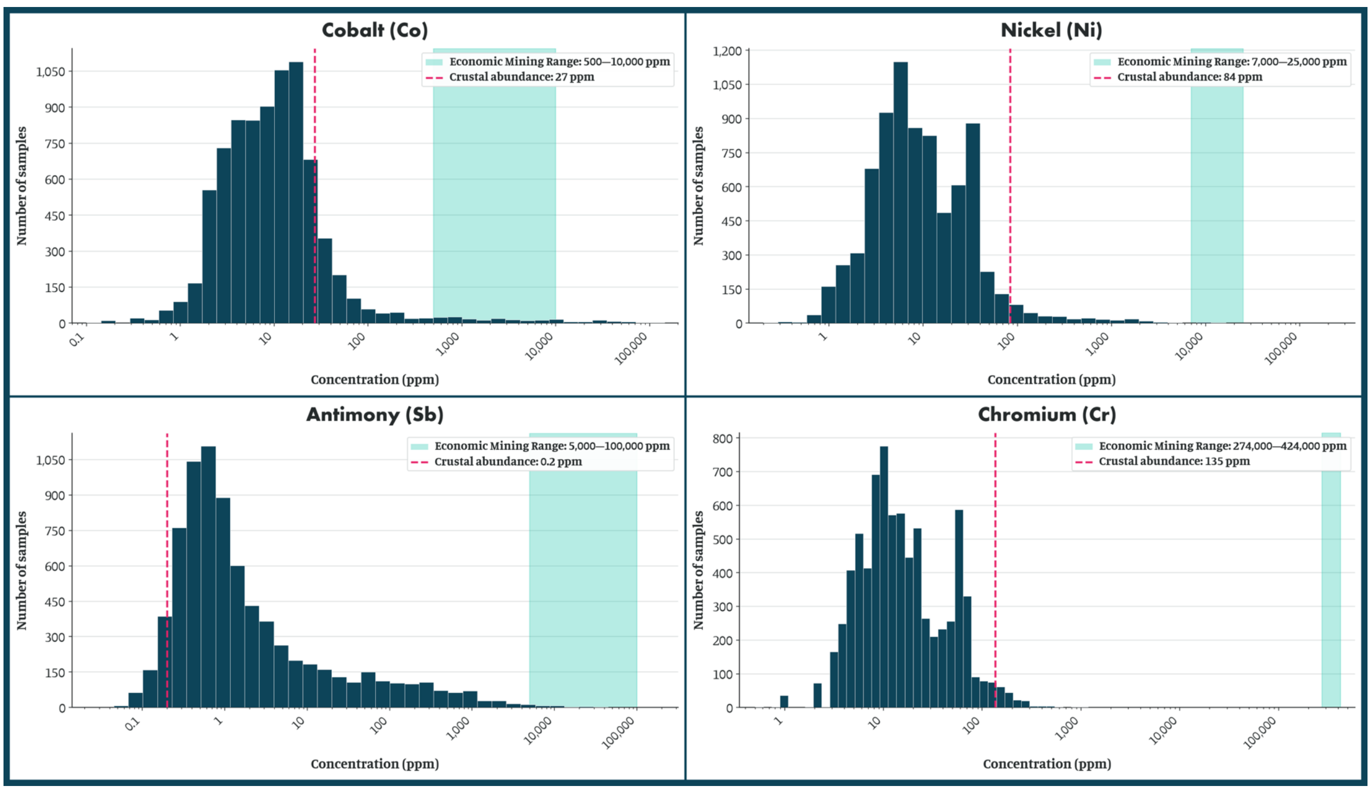

Figure 1: Distribution of critical mineral concentrations in U.S. mine tailings (dark blue) compared to the range of concentrations that conventional mines and mills require for economically favorable recovery (light blue).

The U.S. cannot rely solely on uncertain recovery pathways that may never materialize or that may only meet a small fraction of national demands. Waste recovery must therefore expand in parallel with policies to support new conventional mining, as one component of a comprehensive strategy.

Ultimately, feasible waste recovery will vary mineral by mineral, and site by site. Even then, production from mine waste may only prove practical under exceptionally high prices. Mine waste initiatives must therefore prioritize critical minerals with:

- existing and proven recovery techniques;
- potential for economically favorable production; and
- ability to supply minerals at a meaningful scale.

SMELTER BYPRODUCTS—PROVEN TECHNOLOGIES

Mine waste policies should prioritize recovery capabilities at processing facilities, targeting critical minerals that occur as byproducts of major commodities. Byproduct recovery benefits from:

- **Demonstrated feasibility.** In contrast to theoretical mine waste recovery options that may take years of research, industry routinely evaluates and recovers byproduct elements from processing waste streams. Waste provides the only source of production since byproduct elements do not form mineable deposits on their own.
- **Minimal infrastructure requirements.** Byproduct elements exist within the minerals that contain the primary commodity of interest and are thus co-transported to smelters and refineries for processing. Investments thus target a few centralized facilities for upgrades rather than numerous mine sites.
- **Potential to meet U.S. demand.** Niche metals operate in small markets relative to commodities like aluminum, copper, or zinc. The sole operating domestic alumina facility, for example, could satisfy current U.S. gallium demand of 20 tons a year following in-progress facility upgrades (compare this to annual U.S. copper demand of nearly 2 million tons).

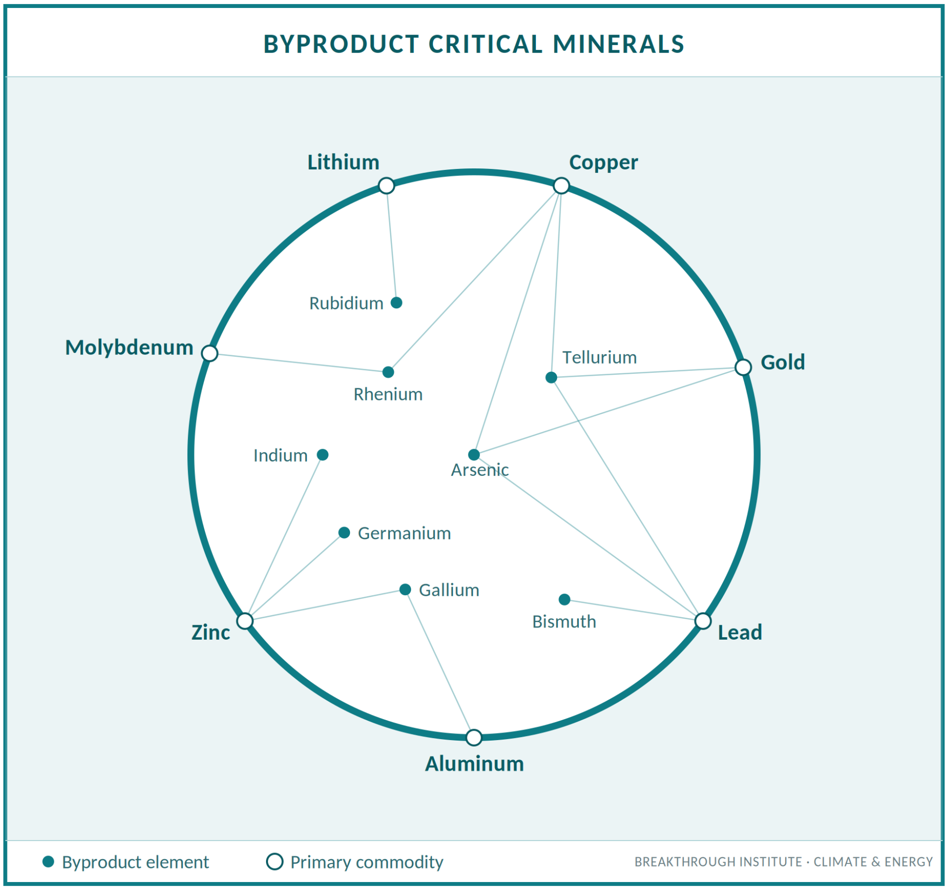

Figure 2: Byproduct elements that processing facilities could extract while smelting or refining other commodities.

Policy support could equip existing and future processing facilities with byproduct recovery capabilities by providing grants or low-cost loans to reduce capital costs. These facilities focus on processing primary commodities and may not have installed byproduct recovery capabilities when originally built. Even now, marginal revenue from byproducts may not justify investments in recovery infrastructure, especially given market disruption risks posed by China which dominates processing of many critical byproducts.

PRIORITIES FOR MINE SITE WASTE EXTRACTION

Critical minerals recovery from mine waste confronts a number of barriers. Significant shares of many elements in mine waste occur in minerals that are nearly impossible to process, like copper in micas. Generally, low concentrations make cost-effective recovery difficult. Individual sites must contain sufficient recoverable volumes to justify the costs of new processing infrastructure, rendering many sites unproductive.

Given these challenges, research funding and pilot studies must prioritize elements that:

- **Exhibit strong geologic correlations with a mine's main target commodity.** Correlations offer more consistently elevated concentrations relative to traces of other elements. Cobalt, for example, commonly occurs in mineral deposits that industry targets for nickel or copper.
- **Possess strong abandoned mine site recovery potential.** Compared to active mines, waste recovery from legacy sites will require either construction of new infrastructure or hauling of large volumes of material offsite to processing facilities. Some legacy sites may offset added costs thanks to particularly high concentrations, since historic operations often targeted higher grade ores, recovered minerals less efficiently at mills, and/or neglected to recover secondary minerals that have only recently gained value.
- **Possess few conventional production opportunities.** For example, the U.S. lacks meaningful conventional chromium ore reserves. Wastes and unconventional resources may not exhibit high concentrations, but even minimal, high-cost production may provide strategic benefits.

In some cases, industry already leverages geologic correlations to extract secondary minerals like cobalt from nickel mines. In other cases, feasible extraction methods do not yet exist or remain exclusive to China. Rare earth elements, for example, occur at elevated concentrations in iron deposits like China's infamous Bayan Obo deposit. Such associations indicate promising recovery potential from iron mine tailings and new iron mines.

Critical Mineral	Host Commodities
Rare earth elements	Aluminum, iron, phosphate
Uranium	Copper, gold, phosphate
Vanadium	Aluminum, phosphate
Zirconium	Phosphate

Table: Promising geologic associations between critical minerals and primary commodities with significant U.S. production. Funding research into mineral deposits could identify additional promising targets for waste recovery.

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