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Critical Minerals and the Legacy Mine Environment: A Proposed Data Collection Program to Help Address the U.S. Critical Minerals Gap

By Elizabeth Holley, Robin Bullock, Priscilla Nelson, Erik Spiller, and Sara Hastings-Simon

The United States is in the midst of a robust national debate regarding supply chains for the critical minerals needed to facilitate, support and drive the clean energy economy, and to anchor national security. The issue is well-categorized in the recent White House 100-Day Task Force Report under EO 14017. As with most energy and resource topics, opinions vary widely – buy from trusted allies and foreign sources, source via recycling, accelerate U.S. mineral exploration, process from unconventional feedstocks (coal and coal ash), and search for more readily available alternatives. Ultimately, we will likely need all of these options, operating simultaneously, to provide the minerals and materials necessary to ensure national and economic security, generate jobs, and stimulate economic growth.

We propose a rapid assessment of an additional, often overlooked resource category: mining waste from approximately 500,000 legacy and abandoned sites scattered throughout the country. Cleanup of these sites would cost about $54 billion, since historic mining practices left a legacy of environmental damage including heavy metal pollution of soils and water, sedimentation of waterways and wetlands, and hazardous excavations and slopes. Only a small percentage of such sites have been remediated thus far, and the recently advanced (with impressive bipartisan support) infrastructure bill would allocate $3 billion to remediate legacy hardrock mines. In addition to addressing these historic mine environments, we need to make sure that we do not leave behind critical minerals of important national value.

Mine wastes represent a valuable resource of critical minerals. Recovery of these materials could
1) Self-fund reclamation of mine waste sites.
2) Lessen the environmental and social impacts of mining by reducing the need for new mines and by improving conditions at abandoned sites.
3) Rapidly generate critical minerals without the typical 10-30 year wait for discovery, definition, and permitting of new mines, and

4) Strengthen the U.S. economy while reducing dependency on foreign sources of critical minerals.

Our proposed approach is to quickly conduct mapping, analyses, targeted R&D, and chemical characterization of critical minerals in these mine wastes, to quantify their potential to satisfy much of the energy and national security demand for these materials. A multi-year dedicated $100 million federal program would allow informed, science and technology-based decisions on this US resource. Before we abandon these wastes to fixation and permanent disposal, we need to determine which may have critical national value as a strategic resource.

Valorizing mine wastes requires an understanding of mine history, including what types of materials were placed where and when. Why is this material of interest or value? The U.S. has a long and rich history of mining, driven by the economics and needs of the day. For example, legacy silver mines in northern Idaho were not concerned with the valuable critical minerals which we need today, so they did not analyze for them. This pattern is consistent throughout the country. Just as the list of critical or important and valuable minerals and metals has grown and changed significantly over the years, so has the need to comprehensively look at past and overlooked mine-environment materials.

Who Needs Critical Minerals?

Critical minerals are vital for a clean energy transition and used in numerous technologies including batteries, magnets, solar panels, alloys and specialty metals, and electronics. For example, rechargeable batteries for smartphones, laptops, and electric vehicles use cobalt, graphite, and lithium; solar cells require tellurium; LEDs rely on gallium, indium, and yttrium; neodymium and dysprosium are essential for magnets used in wind energy and defense applications; and advanced communications use dysprosium, erbium, and europium. Computer chips contained 12 chemical elements in the 1980s, and now over 60 elements are required. We need critical minerals if we care about defense and national security, clean energy, meeting the climate change challenge, and electrifying transportation. The U.S. urgently must meet growing demand for these materials, as well as diversify current sources of supplies, which in many cases are highly dependent on a small number of exporting countries. Although most assessments to date clearly document the problem, few offer a clear and do-able solution.

What Are Mine Wastes?

Tailings and mine waste are byproducts of the mining process, regardless of the material and commodity. In most cases, the waste includes overburden and waste rock– the material above and around the ore body that was uneconomic to mine at the time; tailings or processed waste remining after removal of the targeted commodities; and slag or post-processing waste from smelting and refining. These materials end up in tailings ponds, dry piles, and in various locations and depths dependent upon the mine history. Importantly, they are also frequently a source of long-term environmental risk due to acid drainage, leaching, and water or wind-borne redistribution. Weathering and biogeochemical activity in the mine wastes may result in critical minerals becoming easier or harder to recover and may also affect the potential for additional environmental impacts.

Where Are These Materials?

Simply put, legacy mine tailings and waste exist wherever there are old mines. While we often think they are just in the western US, (Arizona, Colorado, Utah, Nevada, etc.), in fact the US's half million mine waste sites are distributed across almost all 50 states. As a result, this is a bi-partisan challenge on a national scale. The scale varies from large, multi-decade mine sites to the smaller, historic mines that are scattered throughout the country.

What is Already Being Done, and Why Isn't it Enough?

The U.S. urgently needs to identify viable sources of critical minerals required for green technologies to meet the goals for reduced greenhouse gas emissions and to support an environmentally and socially just energy transition. Mine wastes represent a potential domestic resource that could be developed quickly, but we lack the data to determine which sites should be targeted or what the total resource might be. Our proposed program represents a step-change, building on the current trajectory of federal programs that have begun to examine domestic sources of critical minerals, but accelerating progress towards rapid critical mineral production at the pace demanded by the administration. We believe that an accelerated timeline is needed.

Through excellent ongoing efforts, the USGS has gathered the scientific data that would enable our proposed rapid assessment. In the Systems Approach to Critical Minerals project, USGS has developed an informed model for the genesis of mineralogic systems, which allows more focused attention on certain regions or districts based upon where previously overlooked critical minerals might be expected. The USGS only has about 100 samples of tailings from various mines and deposit types, although the associated geochemical and mineralogical characterization of trace elements (including critical minerals) will address key knowledge gaps related to the nature of critical minerals in the mine waste environment. Although not a systematic survey, these data would help inform whether particular commodities would be recoverable given the mineralogy of the mine wastes.

Finally, the Department of Energy has a robust program to assess rare earth potential from both coal ash and existing coal sequences, which ranges from basic R&D to pilot plants. In addition, State geologic surveys are a vital and highly informed resource for information, as are current and historical mine and industry records. However, it is important to emphasize that the current USGS portfolio and budget, as well as the DOE and state efforts, are nowhere near sufficient to address this issue in a timely fashion –this issue has been less of a national-level priority than it currently is today.

What is the Proposal?

In a nutshell, the proposal is for $100 million over 3 years, to collect analytical data which the U. S. does not have but vitally needs: chemical, mineralogic, metallurgic, and spatial data on these available materials, which could go a long way towards addressing US critical mineral needs. The data collection needs to be comprehensive, detailed, and thorough, as well as publicly available. Analysis will include geology and geochemistry, metallurgy, areal and volumetric extent, coupled with modelling and analysis on possible economic recovery.

Who would do this work? While it includes the USGS and key National Labs, it also includes states, academia, tribal communities, and industry. State geologists and their staffs know their respective states well, and have unique access to data, samples and local knowledge. Industry partners in many cases will have historical records of immense value, and they are keenly tuned to a commercial pathway.

The assessment must begin with an initial screening to identify the most prospective sites, based on a geometallurgical framework which considers ore deposit type, size, historic mining and processing methods, and likelihood of critical minerals remaining in the wastes. Prospective sites will then be examined using physical and chemical analyses, as well as remote sensing techniques such as LIDAR and multispectral sensors. In some cases, samples will need to be taken by drilling, to analyze deeper early-generation wastes which may be the most valuable. Analyses need to be done to a common set of standards and should be tailored to fit the type of material and the likely critical minerals at each site. For in progress abandoned mine cleanup efforts, critical minerals should be added to the existing suite of federally required environmental and human health data. Additionally, environmental considerations such as water quality as well as the social contexts of these sites, including employment prospects and community involvement in any proposed development must be considered to ensure a just and sustainable energy transition.

Upsides and Downsides

The upside is that overall, these targeted materials are at the surface – they would require comparatively minimal excavation to access. Reprocessing the material would remediate the historic landscape disruption and address long-standing environmental pollution. The mine wastes are in the US, not halfway around the world. In many cases there is some existing information on the grade and quality of these materials – this lessens the "exploration risk" and decreases the cost of the proposed assessment. Developing these resources would provide well-paying jobs and positively impact former mining communities, which in many cases become economically depressed once the primary extraction process is concluded. Overall, it has the potential to be a strategic, economic, environmental and social justice "win".

Any extraction process opens the risk of exacerbating an already challenging situation. However, the federal government is charged with cleaning up such abandoned sites, and mine waste valorization offers the potential to channel that operational and financial responsibility towards a different cleanup scenario. It would be irresponsible to not assess these potential resources while the country is searching for long-term and reliable mineral resources, both domestically and elsewhere in the world.

How does this fit with current policy?

This proposal conforms with current and developing US policy on the critical minerals supply chain, in every way. First, it targets an under-assessed, domestic US resource. Second, it will evaluate a surface or near-surface resource category, meaning both the potential for faster and cheaper access, and less reliance on longer term and higher risk exploration. Third, successful identification of key, economic minerals in legacy mine waste offers the potential for a robust and durable extraction, processing and manufacturing sector which would provide jobs and stability in economically challenged portions of the country. Finally, the proposal lies firmly on the path to addressing the long-term and social challenges of abandoned mines and mine waste throughout the country. Critical mineral recovery from mine wastes could lessen reliance on foreign or unstable sources, forming a key component of a strategy integrating both domestic and trusted ally sources for the materials required for national and economic security.

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