TESTIMONY ON *MINERALS, CRITICAL MINERALS, AND THE U.S. ECONOMY* FOR THE HEARING "RARE EARTH MINERALS AND 21ST CENTURY INDUSTY"

Statement of

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Committee on Earth Resources
Board on Earth Sciences and Resources
National Research Council
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before the

Subcommittee on Investigations and Oversight
Committee on Science and Technology
U.S. House of Representatives

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Good afternoon, Mr. Chairman and members of the Committee. My name is Dr. Stephen Freiman. A few years ago I retired as Deputy Director of the Materials Science and Engineering Laboratory at the National Institute of Standards and Technology to start a small consulting business. I served on the Committee on Critical Mineral Impacts on the U.S. Economy of the National Research Council (NRC). The Research Council is the operating arm of the National Academy of Sciences, National Academy of Engineering, and the Institute of Medicine of the National Academies, chartered by Congress in 1863 to advise the government on matters of science and technology.

Mineral-based materials are ubiquitous—aluminum in jet aircraft; steel in bridges and buildings, and lead in batteries, to name but a few examples. The emergence of new technologies and engineered materials creates the prospect of rapid increases in demand for some minerals previously used in relatively small quantities in a small number of applications—such as lithium in automotive batteries, rare-earth elements in permanent magnets and compact-fluorescent light bulbs, and indium and tellurium in photovoltaic solar cells. At the same time, the supplies of some minerals seemingly are becoming increasingly fragile due to more fragmented supply chains, increased U.S. import dependence, export restrictions by some nations on primary raw materials, and increased industry concentration.

It was in this light that the U.S. Geological Survey (USGS) and the National Mining Association sponsored a National Research Council study to examine the range of issues important in understanding the evolving role of nonfuel minerals in the U.S. economy and the potential impediments to the supplies of these minerals to domestic users. The study was conducted under the purview of the NRC's standing Committee on Earth Resources. The findings of the study are contained in the volume *Minerals, Critical Minerals, and the U.S. Economy* (National Academies Press, 2008).

In my testimony today, I highlight two parts of the report: its analytical framework and empirical findings, and its recommendations. In addition, I provide answers to the questions you posed in your letter of invitation to me.

Analytical Framework

The analytical framework begins by defining critical minerals as those that are both essential in use (difficult to substitute away from) and subject to supply risk. The idea is illustrated in Figure 1, a 'criticality matrix.' The horizontal axis represents the degree of supply risk associated with a particular mineral, which increases from left to right. Supply risk is higher (1) the greater the concentration of production in a small number of mines, companies, or countries, (2) the smaller the existing market (the more vulnerable a market is to being overwhelmed by a rapid increase in demand due to a large new application), (3) the greater the reliance on byproduct production of a mineral (because the supply of a byproduct is determined largely by the economic attractiveness of the associated main product), and (4) the smaller the reliance on post-consumer scrap as a source of supply. Import dependence, by itself, is a poor indicator of supply risk; rather it is import dependence combined with concentrated production and perhaps geopolitical risk (the first of the four factors above) that lead to supply risk. In Figure 1, the hypothetical mineral A is subject to greater supply risk than mineral B.

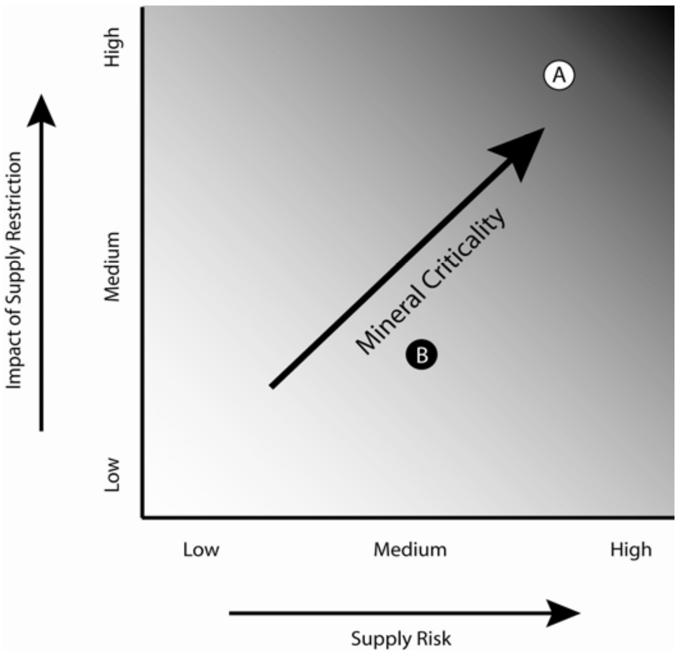

Figure 1. The Criticality Matrix. Source: *Minerals, Critical Minerals, and the U.S. Economy* (National Academies Press, 2008).

The vertical axis represents the impact of a supply restriction, which increases from bottom to top. Broadly speaking, the impact of a restriction relates directly to the ease or difficulty of substituting away from the mineral in question. The more difficult substitution is, the greater the impact of a restriction (and vice versa). The impact of a supply restriction can take two possible forms: higher costs for users (and potentially lower profitability), or physical unavailability (and a “no-build” situation for users).[1]

[1] When considering security of petroleum supplies, rather than minerals, the primary concern is costs and resulting impacts on the macroeconomy (the level of economic output). The mineral and mineral-using sectors, in contrast, are much smaller, and thus we are not concerned about macroeconomic effects of

The overall degree of criticality increases as one moves from the lower-left to the upper-right corner of the diagram. The hypothetical mineral A would be relatively more critical than mineral B.

Implementing the framework requires specifying a perspective and time frame. The perspective of a mineral-using company, for example, will likely be different than that of a national government. The degree of criticality in the short to medium term (one or a few years, up to a decade) depends on *existing* technologies and production facilities. Substituting one material for another in a product typically is difficult in the short term due to constraints imposed by existing product designs and production equipment. Short-term supply risks are a function of the nature and location of existing production. In contrast, over the longer term (a decade or more), the degree of criticality depends much more importantly on technological innovation and investments in *new* technology and equipment on both the demand side (material substitution) and the supply side (mineral exploration, mining and mineral processing, and associated technologies).

Taking the perspective of the U.S. economy overall and in the short to medium term, the committee evaluated eleven minerals or mineral families. It did not assess the criticality of all important nonfuel minerals due to limits on time and resources. Figure 2 summarizes the committee's evaluations. Of the eleven minerals, those deemed most

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restricted mineral supplies. Rather the concern is both about higher input costs for mineral users and, in some cases, physical unavailability of an important input.

critical—that is, they plot in the upper-right portion of the diagram—are indium, manganese, niobium, platinum-group metals, and rare-earth elements.

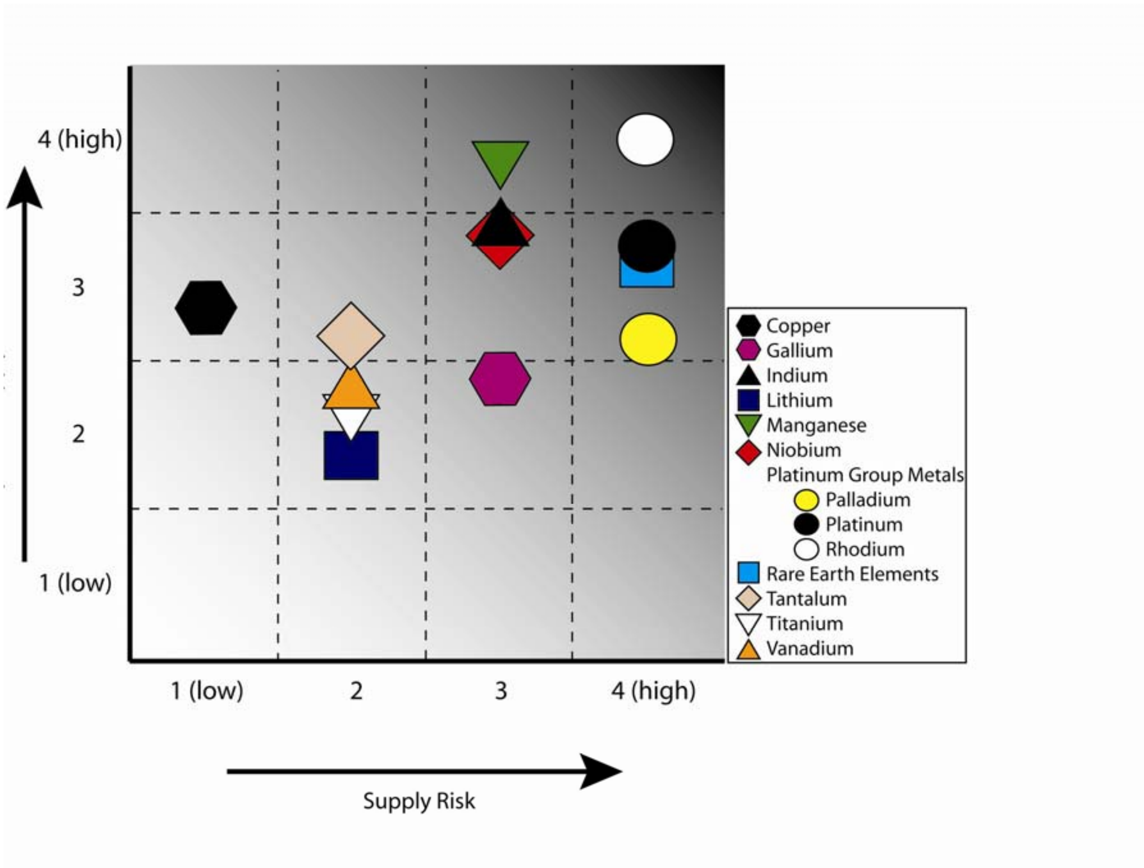

Figure 2. Criticality Evaluations for Selected Minerals or Mineral Families. Source: *Minerals, Critical Minerals, and the U.S. Economy* (National Academies Press, 2008).

A final point: criticality is dynamic. A critical mineral today may become less critical either because substitutes or new sources of supply are developed. Conversely, a less-critical mineral today may become more critical in the future because of a new use or a change in supply risk. Such could be the case with lithium, which the committee did not evaluate as one of the more-critical minerals in its analysis two years ago (Figure 2); if demand for lithium in batteries increases significantly and new sources of supply are in politically risky locations, then lithium could plot in the more-critical region of the figure in the future.

Recommendations

The committee made three recommendations, which I quote below:

1. The federal government should enhance the types of data and information it collects, disseminates, and analyzes on minerals and mineral products, especially as these data and information relate to minerals and mineral products that are or may become critical.
2. The federal government should continue to carry out the necessary function of collecting, disseminating, and analyzing mineral data and information. The USGS Minerals Information Team, or whatever federal unit might later be assigned these responsibilities, should have greater authority and autonomy than at present. It also should have sufficient resources to carry out its mandate, which would be broader than the Minerals Information Team's current mandate if the committee's recommendations are adopted. It should establish formal mechanisms for communicating with users, government and nongovernmental organizations or institutes, and the private sector on the types and quality of data and information it collects, disseminates, and analyzes. It should be organized to have the flexibility to collect, disseminate, and analyze additional, nonbasic data and information, in consultation with users, as specific minerals and mineral products become relatively more critical over time (and vice versa).

3. Federal agencies, including the National Science Foundation, Department of the Interior (including the USGS), Department of Defense, Department of Energy, and Department of Commerce, should develop and fund activities, including basic science and policy research, to encourage U.S. innovation in the area of critical minerals and materials and to enhance understanding of global mineral availability and use.

Questions from the Subcommittee on Investigations and Oversight

What are the major gaps in current Federal policy for minerals and materials?

The committee report does not address this broad question. It does identify gaps in minerals information and recommends enhanced collection, dissemination and analysis of those parts of the mineral life cycle that are under-represented at present including: reserves and subeconomic resources, byproduct and coproduct primary production, stocks and flows of materials available for recycling, in-use stocks, material flows, and materials embodied in internationally traded goods. The committee report recommends periodic analysis of mineral criticality over a range of minerals.

Which aspects of research and development in minerals and materials require enhanced Federal support, and what form should this support take?

See Recommendation 3 above. As part of its detailed discussion of this recommendation, the committee report also recommends funding scientific, technical, and social-scientific research on the entire mineral life cycle. It recommends cooperative programs involving academic organizations, industry, and government to enhance education and applied research.

How should the Federal government improve the collection of information on minerals and materials markets?

See Recommendation 2 above. As part of its more detailed discussion of this recommendation, the committee report suggests that the Federal government consider the Energy Information Administration, which has status as a principal statistical agency, as a potential model for minerals information, dissemination, and analysis. Whatever agency or unit is responsible for minerals information, it needs greater autonomy and authority than at present.

Facing dynamic changes in supply and demand for particular minerals and materials in a global economy, what are the most useful contributions the Federal government can employ to assist industry?

My personal opinion is that federal minerals and materials policy should focus on: (1) encouraging undistorted international trade, (2) ensuring that policies and procedures for domestic mineral development appropriately integrate commercial, environmental, and social considerations, (3) facilitating provision of information on which private and public decisions are made, and (4) facilitating research and development, including on recycling of specialty materials used in small quantities in emerging uses.

Thank you for the opportunity to testify today. I would be happy to address any questions the subcommittee may have.

Dr. Stephen Freiman

Dr. Freiman graduated from the Georgia Institute of Technology with a B. ChE. and a M. S. in Metallurgy. After receiving a Ph.D. in Materials Science and Engineering from the University of Florida in 1968, Dr. Freiman worked at the IIT Research Institute and the Naval Research Laboratory. He joined NIST (then NBS) in 1978. From 1992 to 2002 Dr. Freiman served as Chief of the Ceramics Division at NIST. Prior to his leaving NIST in 2006 to start a consulting business (Freiman Consulting Inc.), Dr. Stephen Freiman served for four years as Deputy Director of the Materials Science and Engineering.

Dr. Freiman has published over 200 scientific papers focusing primarily on the mechanical properties of brittle materials. He was the first Chairman of the ASTM Subcommittee addressing brittle fracture and a past Chair of the Steering Committee of the Versailles Project for Advanced Materials and Standards. Dr. Freiman served as Treasurer, and President of the American Ceramic Society, and is a Fellow and Distinguished Life Member of the Society.