OCEAN MINERALS: THE BUREAU OF MINES ROLE IN MINING AND RESOURCES RECOVERY

Donald G. Kesterke

Department of the Interior
Bureau of Mines
Washington, D.C. 20240

Abstract

Bureau of Mines research groups have had a long and active involvement with ocean-floor resources, ranging from work on recovery technology for manganese nodules to recent studies aimed at extracting metals from polymetallic sulfides from the Juan de Fuca Ridge. Highlights of these activities are presented. Also discussed are the current research capabilities of the Bureau, and its probable role in the future for contributing to a better understanding of the resource potential of the U.S. Outer Continental Shelf.

Introduction

Assessment of the minerals potential of the Exclusive Economic Zone (EEZ) will represent one of the major technological challenges of the 20th century. As the Nation’s chief agency for research on mineral mining and processing, the U.S. Bureau of Mines is prepared to help meet this challenge. Since its creation in 1910, the Bureau has conducted scientific, technological, and economic investigations of land-based mineral resources to improve mining and processing efficiency, and to promote conservation of our resources. Similar studies of ocean-floor minerals represent a logical extension of these activities, particularly since the minerals are known to contain strategic and critical materials essential to the U.S. economy and national security.

Historical Overview

Metallurgical investigations by the Bureau of Mines involving marine minerals began in 1966 as part of a program to stimulate domestic production of gold, in which offshore mineral deposits along the Pacific coast, including Alaska, were sampled and analyzed for gold and other heavy metals. In the early 1970's, process development studies were conducted to devise methods for recovering manganese and associated cobalt, copper, and nickel from manganese nodules (2).

In 1975, the Bureau began participating in coordination meetings with the now disbanded Ocean Mining Administration of the Department of the Interior, and with the National Oceanic and Atmospheric Administration. The meetings were attempts to define the roles that each would play in relation to the Government's involvement with industrial mining consortia and with its position vis-a-vis Law of the Sea issues (14). Initially, within the Mining Research function of the Bureau, an effort was established to track the status of deep-sea mining activities. This effort continues today, but has been restructured to provide a technical information base on manganese nodules and other ocean mineral deposits.

During the late 1970's Mining Research funded contract studies on operational systems for ocean floor mining (3),(4),(5),(11),(12) designed to analyze mining systems, regulatory factors and standards, and to identify mechanisms for transferring the technology to various user groups. Meanwhile, in-house research continued on processing technology for manganese nodules, and included studies relevant to the mineralogy and elemental composition of Pacific Ocean nodules (2), and to the disposal of waste materials (5). Updated process flowsheets were published (8), and the use of SO2 as a leachant for metals recovery was studied (10). In more recent research, chlorine-oxygen leaching procedures developed by the Bureau were successfully applied to polymetallic sulfides from the Juan de Fuca Ridge, resulting in almost complete recovery of the zinc and silver contained in the samples (15).

As a note of interest, in 1976, the Bureau obtained a prototype mining system that had been designed for use on vessels such as the Glomar Explorer. However, the system was never tested by the Bureau, and it remained in storage until it was disposed of in the early 1980's.

Currently, the Bureau is following closely all activities in seabed mining, particularly those associated with the polymetallic sulfide deposits. We have an agreement with the USGS that we will assist in characterizing samples provided by them, and are prepared to initiate on short notice, metallurgical research that will help define the resource potential of any offshore area.
The Prospective Role of the Bureau of Mines in Future Research

A definition of the future role of the Bureau of Mines in ocean mining is based on the premise that conventional surface mining methods will be adapted to seafloor use. A corollary premise is that subsequent metallurgical processing will be based on state-of-the-art methods. Nevertheless, in both areas, there are technological obstacles to overcome. Those associated with mining and processing of hard minerals are discussed in the proceedings of a 1983 symposium sponsored by the U.S. Department of the Interior (16). Conclusions reached during this symposium of particular relevance to the research capabilities of the Bureau of Mines are noted below:

Mining Research

Technology is not well developed for mining mineral deposits in the waters of 100 to 10,000 ft that occur in the EEZ, and adaptability of existing systems for dredging or deep sea node mining to EEZ deposits is virtually unknown. For example, no technology has ever been tested for commercial harvesting of nodules in waters several thousand feet deep as on the Blake Plateau. However, one industrial company has harvested the modules in small but significant amounts (tons of tons) with a prototype, reduced-scale ocean mining system for sampling/characterization purposes. Although the system operated reasonably successfully, its reliability for adaptation to commercial mining is unknown. For R&D purposes, other system options could be conceptualized which might become successful and possibly reliable under commercial conditions. These would involve adaptation of dredging technology to the deeper waters through use of cutter and/or suction heads. Another adaptation might involve dragnet systems.

For seafloor crusts, no technology exists to raise crusty and blocky fragments in commercial quantities through water columns of 100 to 10,000 ft, although elaborate dredging methods exist for water less than 100 ft deep, and a proven flexible pipeline lift system exists for raising deep-sea nodules from 10,000 and 20,000 ft of water.

Finally, in regard to placer deposits, some commercial technology has been developed and is in practice to raise dredged sediments in waters less than 100 ft deep under commercial conditions, and some limited prototype technology exists for testing purposes only in waters 3,000 to 15,000 ft deep. However, no technology has been developed to raise placer sediments in waters over 100 ft deep.

Despite the general lack of proven equipment and methods for recovering ocean floor minerals, component technology does exist that will make it possible to engineer mining and materials-handling systems which can mine and transport one to the surface for further processing. Several decades of experience in the design and testing of land-based mining equipment, make the Bureau ideally qualified to contribute to closing the technological gaps. Specifically, the Mining Research arm of the Bureau is prepared to address the following areas, drawing on the expertise of its more than 600 personnel, stationed at four research centers:

A. Consolidated Deposits

- Research to determine how existing fragmentation technologies can be adapted to different physical conditions in the EEZ, and how these or parts thereof can be combined with new ideas for breaking up the deposits (crust, ledges, mounds, etc.) efficiently. Also, research on the adaptability of existing explosives and techniques or their modifications, to rubblization of the deposits.

- Development of collection systems that are compatible with fragments from the broken-up deposits, including bucket scoops, rakes, scoops with gathering arms and suction devices.

- Development of lift systems that are compatible with collection systems options, such as remotely controlled containers, pipelines or continuous line buckets.

- Integration of conceptual fragmentation and collection and lifting systems into candidate total mining systems.

B. Unconsolidated Deposits

- Research to develop deep water dredging systems and to adapt existing dredging technologies, or parts thereof, to mining nodules and placers. The studies would include concepts for extending and controlling dredge heads and adapting borehole mining techniques to water depths of 100 to at least several thousand feet. Consideration also would be given to rakes, drag-nets, and bucket scoops, particularly in terms of their control and maneuverability.

- Efforts to develop lift systems that are compatible with collection system options, such as segmented, flexible pipes, or continuous bucket lines.

- Integration and testing of all system components.

Metallurgy Research

Experience has indicated that the ways in which minerals respond to treatment for recovery of the valuable constituents is generally independent of the mineral's origin or current location. For example, the metallurgy and chemistry associated with the processing of the various forms of copper, cobalt, nickel, and manganese found in seafloor nodules is basically the same as it is to recover the same...
constituents from deposits found on dry land. Similarly, massive copper sulfide deposits on Cyprus, which are thought to have originated in a tectonic setting similar to that now seen in the spreading centers of the Pacific, respond the same to metallurgical processing as sulfides whose origin was in a non-aqueous environment. Based on this, design of effective metals recovery technology is viewed as being among the lesser problems associated with ocean minerals processing.

This is not to say that there will be no role for scientists and engineers in defining a metallurgical treatment sequence. In fact, the success of the endeavors proposed for the EEZ hinges on having an understanding of what is on the seabed and of how to go about converting it to useful products. For example, site-specificity will be a major factor in resource development. This is equally true for both the mining and minerals processing operations. As with land-based minerals, there will be variations in the make-up of the raw materials from one deposit to another, and even within individual deposits. Thus, there is no single process that will work equally well for all types of deposits likely to be found on the ocean floor. As such, key to the development of effective process flowsheets is an understanding of the physical and chemical characteristics of the resource mix. Arriving at this understanding is a role for which the Bureau of Mines is ideally suited. For example the Bureau has six metallurgy research centers, staffed by over 500 scientists and support personnel that can contribute to the examination of the raw materials, mineralogically and chemically, to ascertain how the minerals are put together and what they contain. From Bureau scientists and engineers can suggest a rational selection of comminution, physical and chemical separation, and purification steps that ultimately will lead to metals recovery.

In addition, complementary studies can be conducted to provide data relevant to disposal problems, to address environmental impact which may arise from the processing of the mineral deposits, and to determine ranges of concentration of potential waste materials. Also, within the scope of Bureau activities is the ability to determine optimum process conditions for recovering mineral constituents in onshore pilot plant operations, and to conduct experimental investigations on techniques for partial concentration at sea, emphasizing the development of multimineral recovery systems along with acceptable waste disposal technology.

Non-research Support Capabilities

Emphasis thus far has been on the actions that could be undertaken by the research arm of the Bureau in support of minerals development in the EEZ. However, there are non-research groups that also can make significant contributions. For example, the Bureau has a strong mineral data analysis capability within which, the problems and policies that affect minerals supply and demand can be addressed. The functions of this group include analyses of minerals-related issues having economic, environmental, regulatory, and national security implications; and could readily be expanded to include issues relevant to ocean minerals. Also within the purview of mineral data analysis is a function performed by the Minerals Availability System (MAS) designed to provide data development/collection and analysis of the worldwide availability of nonfuel minerals (1). Of particular relevance is the computerized mine-specific resource and cost information data base which provides a profile of minerals availability under various economic conditions. The MAS data base now includes information on ocean minerals (2),(3), and could be further enlarged to incorporate additional resource information based on survey work and sample gathering from the ocean floor.

Summary

The mineral resource potential of the ocean floor is no doubt vast and very diverse, and overcoming the technological obstacles to development will require the combined efforts of industry, academia, and the Federal Government.

For its part, the Bureau of Mines offers extensive experience in the engineering and development of mining machinery and methods that provide a solid base of information for use in designing and engineering seabed mining systems. In addition, its experimental expertise in characterizing and processing ocean nodules and polymetallic sulfides is unique in the Federal sector.

This combination of talent in mining and metallurgy technology, plus broad experience in the mitigation of environmental and health and safety impacts associated with minerals processing, assures the Bureau of a key role in defining the resource potential, and in contributing to the orderly development of ocean floor mineral resources.

References


