MARINE MINERALS FOR THE 21st CENTURY

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Summary

Looking forward into the 21st century, the most common materials of continental margins, sand and gravel and freshwater from seawater will undergo accelerating development worldwide in response to population growth. Placer deposits including heavy metals and gems will undergo more selective development in response to market forces. Fields of manganese nodules will be selectively mined for strategic and commercial purposes. Both massive sulfides and bioproducts of chemosynthetic organisms will be mined from hydrothermal sites on the deep seafloor (Figure 1). The most effective way to avoid destruction of the associated chemosynthetic ecosystems is to limit mining to relict massive seafloor deposits separate from active hot springs. A major theme of the 21st century will be to reconcile the conflict between societal benefits and environmental impacts of marine mining.

Introduction

A new view of marine minerals exclusive of hydrocarbons (oil, gas and gas hydrates) is emerging that links inorganic with organic processes, that juxtaposes exploration/development with environmental issues, and that operates within the framework of the United Nations Convention on the Law of the Sea (UNCLOS) which entered into force in 1994. Marine minerals exist in consolidated, unconsolidated and fluid state and are distributed in the seabed of continental margins and ocean basins and in seawater (Figure 1). Consolidated deposits can be recovered by drilling and excavation if insoluble like metallic ores in bedrock, or solution mining if soluble like sulfur and salts. Unconsolidated deposits occur as sediments or nodules that can be recovered by dredging techniques. Dissolved or particulate matter or freshwater can be extracted from seawater by various techniques. Major types of marine minerals are considered according to their occurrence in shallow water of the near shore area (water depth < 200 meters) of continental margins within national jurisdiction (200 nautical mile Exclusive Economic Zone or EEZ), or deep water of the ocean basins within and beyond national jurisdiction.

Legal Regime For Marine Minerals

The sustainable development and the optimum utilization of marine minerals in the 21st century will be fostered by the legal order for the world's oceans and seas established by the UNCLOS, which also incorporates a legal regime for marine minerals. Investment for marine mineral development is promoted by well-defined and efficiently functioning regimes, which, among other things, specify the rights, including property rights, and duties, including duties regarding conservation of resources and protection and preservation of the marine environment, of coastal States and other States. Under the UNCLOS, marine mineral regimes vary according to maritime zones - territorial sea, Exclusive Economic Zone (EEZ), continental shelf, international seabed Area and high seas.

Continental Margin

The diversity and abundance of minerals of continental margins within the EEZ of adjacent coastal states reflects that of adjacent continents. Consolidated deposits including metals, coal, sulfur, salts, potash and phosphorite may extend seaward beneath continental margins and are largely untapped (Figure 1). Unconsolidated deposits comprise industrial materials, and mineral sands. The principal industrial material recovered globally is sand and gravel for use in construction (concrete), coastal protection, and beach replenishment. The mineral sands may contain heavy metals and gems concentrated as placer deposits by moving water.

Mineral sands may contain small percentages of gold, platinum, precious gemstones, tin-or titanium-bearing minerals derived from erosion of continental rocks and concentrated as placer deposits by waves and currents. The valuable constituent is separated from the mineral sand and the bulk of the material is returned to the mining site as waste. Mining of mineral sands containing tin remains is a viable industry at sites off southeast Asia (Thailand, Indonesia). Diamonds have developed into a vigorous mining industry offshore the Namibian and South African coasts in water depths up to 500 meters with annual output approaching US$1 billion. New deposits of mineral sands will be targeted and traced further seaward with possible increase in concentration of the valued constituent by sorting during transport into the ocean basin.

Seawater is a resource for contained solids (3.5 weight percent) decreasing in concentration from sodium chloride to gold, and for fresh water (96.5 percent). Extraction of freshwater for consumption, agriculture, and industry will increase in response to regional need and cost-effectiveness of energy used for the desalination process.

Ocean Basin

Deposits of the deep seabed of ocean basins comprise polymetallic manganese nodules (manganese, copper, nickel and cobalt in various amounts; water depths 4000-6000 meters), ferromanganese crusts (manganese, cobalt, nickel, and platinum in various amounts; water depths 500-2500 m), and massive sulfide deposits (copper, iron, zinc, silver and gold in different concentrations; depths 1000-4000 meters; Figure 1). Polymetallic manganese nodules are generally precipitated from seawater at slow rates over millions of years and grow as fields in areas of abyssal plains of all the ocean basins of the world. The most economically interesting metal concentrations (nickel + copper > 1.8 weight percent) occur in nodules in the international Clarion-Clipperton area of the eastern equatorial Pacific between Hawaii and Mexico where multinational claims/licenses have been filed, feasibility mining tests have been run, but mining has yet to occur. Like manganese nodules, ferromanganese crusts are precipitated from seawater. They occur as encrustations up to 40 cm-thick on rocky seabed elevations such as seamounts, flanks of islands, and oceanic plateaus where they may be difficult to harvest.

Massive sulfides are deposited by high-temperature (200-400 degrees C) sub-seafloor hydrothermal systems driven by magmatic heat at discrete sites in ocean ridge and fore-and back-arc settings. The hydrothermal fluids transport metals, geothermal energy, and chemical energy utilized by heat-tolerant chemosynthetic bacteria and archaea to manufacture their food at the base of an ecosystem linking inorganic with organic processes. The single-celled bacteria and archaea occupy a subsurface biosphere integral to the hydrothermal systems and are themselves being investigated as sources of novel organic compounds for use in industrial processes and pharmaceuticals, and for their genetic relations to the base of the evolutionary tree of life. Massive sulfide deposits are being discovered on the seafloor corresponding to the types (volcanic- and sediment-hosted) and size range of ancient massive sulfide deposits on land. Most deposits are consolidated, although metalliferous sediments like those being concentrated by hot springs in axial troughs of the Red Sea may have formed at an early stage in opening ocean basins like the Atlantic and underlie terrigenous sediments of passive continental margins. Seafloor massive sulfide deposits are being evaluated as alternative sources to land deposits driven by cost and environmental considerations and leasing has already begun. Mining of the metallic minerals and bioproducts produced at seafloor hot springs has the potential to benefit society and to destroy the associated ecosystem.

Commercial Activities at the Beginning of the 21st Century

Licenses have been approved by the International Seabed Authority (ISA), the organization responsible for administering the mineral resources of the international seabed, for exploration for polymetallic manganese nodules by seven corporations/state enterprises. These license-holders are carrying out exploration activities aimed at delineating commercial mine sites; R&D activities for the refinement of technologies for mining, lifting and processing the nodules; and feasibility studies to estimate the commercial profitability of nodule mining and to examine the fulfillment of strategic and market objectives. With respect to ferromanganese crusts and massive sulphides in the international seabed Area, a regulatory framework is being developed to promote commercial activities. In maritime areas within national jurisdiction, the first exploration licenses for massive sulphides have been granted by Papua New Guinea. Studies are underway about possibilities of granting exploration licenses by other coastal States, especially in the South Pacific region. Studies are also being undertaken about the granting of exploration licenses for polymetallic manganese nodules and ferromanganese crusts by several coastal States.

Conclusions

Looking forward into the 21st century, the most common materials of continental margins, sand and gravel and freshwater from seawater will undergo accelerating development worldwide in response to population growth with more selective local development of placer deposits in response to market forces. Fields of manganese nodules will be selectively mined for strategic and commercial reasons. Both massive sulfides and bioproducts will be mined from hydrothermal sites on the deep seafloor. The most effective way to avoid destruction of the associated chemosynthetic ecosystems is to limit mining to relict seafloor massive sulfide deposits separate from active hot springs. A major theme of the 21st century will be to reconcile the conflict between societal benefits and environmental impacts of marine mining.

References

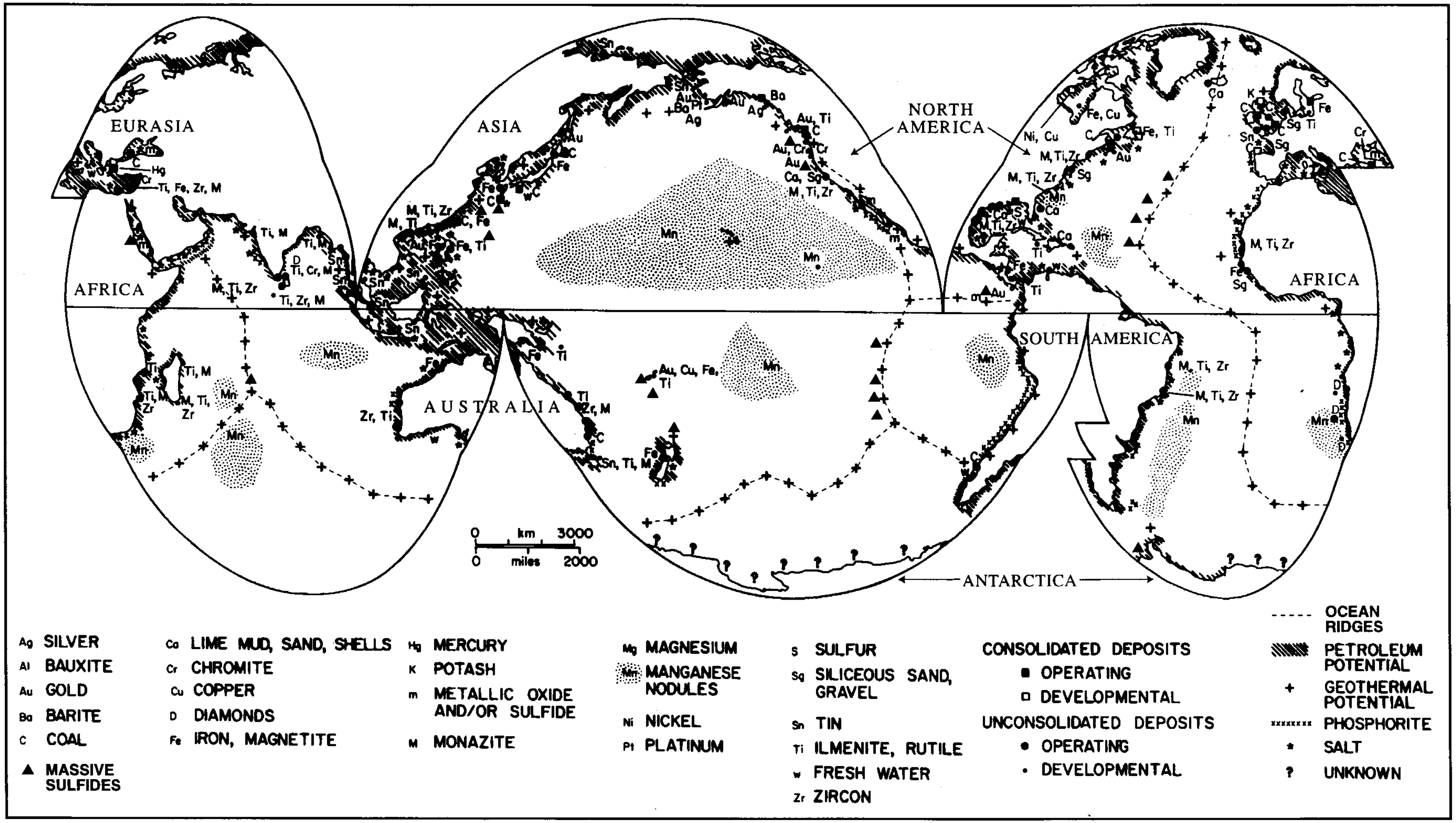
Lenoble, Augris, J.-P., Cambon, R., and Saget, P., 1995, Marine mineral occurrences and deposits of the Economic Exclusive Zones, MARMIN: a data base, IFREMER, 7 p., 274 data sheets.

Rona, P. A., 1981, Marine mineral resources, Natural Resources Forum, 1: 89-95.

Rona, P. A. and Scott, S.D., 1993, A special issue on sea-floor hydrothermal mineralization: New perspectives, Economic Geology, 88(8): 1935-1976.

Figure Caption:

Figure 1. Global distribution of marine minerals exclusive of oil, gas and gas hydrates (Rona. 1981; Rona and Scott, 1993; Lenoble et al., 1995).



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