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Environmental Research Laboratories

Deep Ocean Mining Environmental Study Cruise Report on MOANA WAVE Cruise 74-2: April-May 1974

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Office
BOULDER,
COLORADO
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**UNITED STATES
DEPARTMENT OF COMMERCE
Rogers C.B. Morton, Secretary**

NATIONAL OCEANIC AND
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Environmental Research
Laboratories
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THE ENVIRONMENTAL IMPACT OF DEEP-SEA MINING

CRUISE REPORT ON MOANA WAVE CRUISE 74-2 : APRIL-MAY 1974

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FOREWORD

This document presents basic data to be used in assessing the environmental impacts of deep-sea mining for nodules containing manganese, copper, nickel, and cobalt. It supplements information presented in NOAA Technical Report ERL 290-OD 11, "The Environmental Impacts of Deep-Sea Mining. Progress Report," May 1973.

Originals of photographs reproduced herein are available for inspection at the Marine EcoSystems Analysis Program Office (MESA), ERL, Boulder, CO., 80302.

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DISCLAIMER

CRUISE REPORT

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1 INTRODUCTION

1.1 Environmental Protection and Safety

There is no doubt that environmental considerations and arguments--with or without sound technical basis--will be used in international legal, political and economic deliberations concerning the exploitation of the mineral resources of the sea floor, as has already been the case in the United Nations Seabed Committee.

Several mining tests have already been completed, many more are in preparation and at least one full-scale mining vessel is undergoing sea-trials. The prospect of imminent extensive deep-sea mining requires serious consideration of the environmental impact of this activity, since it could affect the benthic and pelagic environments. It is essential that the environmental implications of manganese-nodule mining from the deep-sea floor be thoroughly understood, evaluated and documented before such mining is attempted on a large scale.

The proposed mining of manganese nodules from the deep-ocean floor has triggered a perhaps unique collaboration in the United States between the government, mining industry, academic institutions, and public-interest groups to determine the environmental impact of the proposed mining operations before their start. This is in great contrast to other important industrial developments, where environmental concerns have usually only arisen after--sometimes serious--

damage to the environment. By taking preventive action, it should be possible to reduce greatly or completely eliminate potential environmental hazards due to the mining operations.

Collaboration between government, industry and academia to ensure safe deep-sea mining methods could lead to the development of mining techniques with beneficial environmental effects.

The emphasis of this study is on the consideration of the impact of manganese-nodule mining on the marine environment. The metallurgical operations to extract the valuable metals such as copper, nickel and cobalt from manganese nodules should be comparable in their environmental effects to land-based operations of a similar nature. However, if the ore processing takes place at sea, special precautions would have to be taken for the discharge of waste materials. Since secondary land use (including land-based processing plants and tailings disposal sites) and social and demographic patterns affected by marine mining or ore processing are not exclusive problems of deep-sea mining, they are outside the scope of this report. Similarly, the environmental impacts of alternative means of obtaining metal ores and the environmental analysis of the utilization of minerals obtained from the marine environment are not considered here. It is recognized that there will be environmental impact associated with on-shore activities that accompany off-shore mining. Some of these will be associated with the transport of minerals (marine terminals and support facilities, stock-piling of materials, truck movements, etc.) and others will be associated with the processing of the minerals. Assessment of the environmental impacts of both of these types of activities should proceed before there is a move to license full-scale off-shore mining. However, since regulation of this kind of activity falls under the jurisdiction of the coastal states, this work does not address this facet of the off-shore mining operation.

Manganese nodule deposits of current commercial interest lie mainly on top of the sediments covering the ocean bottom underlying oceanic water masses of very low biological productivity; therefore, no deep penetration of the sediments will be required to retrieve them. Manganese nodules are rare in areas where there is rapid sedimentation, e.g., on those parts of the sea floor underlying areas of high biological productivity in the water column, giving rise to rapid sedimentation of biogenic oozes.

The areas to be mined will be limited, therefore, by the distribution of manganese nodules on the ocean floor and by technical and economic factors governing their retrieval from the depths. Our study area, therefore, was located on a relatively flat, sediment-covered part of the ocean floor with a high density of manganese nodules on, or very close to, the surface of the sediment.

1.1.1 Mining Methods

In the mining operation, the manganese nodules are collected from the ocean floor, usually from great depths, and transported through the water column to a surface vessel. The collection of manganese nodules will result in the removal and redistribution of sediments and benthic organisms on the ocean floor. In all mining operations, it is likely that there will be considerable resuspension of sedimentary materials in the near-bottom waters. During the mining operation, a sediment plume will be generated in and around the mining head which will settle out in the general area of the sea bed which has been mined. The amount of scatter of the particles will depend upon the design of the mining head, its velocity, Stoke's Law, and prevailing ocean currents.

An example of the maximum amount of sea-bed soil which may be disturbed as a result of ocean mining can be computed using the following assumptions:

Nodule concentration = 2 lbs/ft^2
Mining rate = 5000 tons/day
Mining swath = 50 ft
Depth of swath = 4 inches
Velocity = 1.25 ft/sec

This gives, on a daily basis, a soil pick-up of 1.7×10^6 ft^3, along a 19-mile swath of 50 ft width. For a 300-day year, this equals a 1.4×10^7 m^3 soil disturbance. This yearly rate is approximately equal to slumping due to turbidity currents at the mouth of the world's large rivers when the rivers are flooding and wave-stirring is at a maximum. For example, the Mississippi River Delta sediment transfer is estimated to be 2×10^8 m^3/yr (Shepard, 1973).

The self-propelled mining equipment has an interaction with the sea bed to a much greater extent than towed equipment.

The self-propelled approach suggests some form of mobility and trafficability which, in turn, must consider wheels, tracks, or other forms of propulsion. This disturbance of the sea bed is probably more uniform with a self-propelled approach than with a towed dredge, but also is more likely to disturb a greater volume of sea bed when both are operating properly; this is primarily due to swath width and burial depth of the propulsion equipment. As opposed to nodule pick-up and mud removal, the mobility function will compress the sea bed along with stirring up particles. Using the assumptions previously given, i.e., that of a 5000-tons/day unit traveling 19 miles/day, and further assuming:

One 72-inch wide track per side
Burial depth of 36 inches

the amount of disturbed soil per day is 7×10^6 ft^3, or 2.1×10^9 ft^3/year for a 300-day year.

All of the different techniques under consideration for nodule mining will try to avoid as much as possible the retrieval of sediments with the nodules. The continuous-line-bucket (CLB) system tested in the Pacific in 1971 and 1972, used buckets of 40-cm depth with a maximum penetration into the sediment of about 20 cm, but probably much less in practice (Masuda, Cruickshank and Mero, 1971). The other systems propose to utilize bottom-gathering devices connected to hydraulic or airlift pumping systems to transport the nodules to the surface through a pipeline (Welling, 1972; Garland and Hagerty, 1972). All of these devices have components which contact the ocean bottom to make a first separation of the nodules from the surrounding sediment. This first separation is achieved by a chute with water jets, heavy spring-rake tines, a radial tooth roller, harrow blades and water jets, or spaced comb teeth. Many of the machine concepts employ adjustable collecting elements so that changes can be made during the mining operation to accommodate variations in the nodule deposit and sediment characteristics. A second important feature of all of the collecting devices is a controlled digging depth into the ocean bottom, as interest is usually centered within the upper few inches of the sediment.

1.1.2 Effects of Mining on the Sea Floor and Near-Bottom Water Mass

It is obviously in the interest of a mining operation to separate nodules from sediment as well as possible on the ocean floor and to disturb the sediment as little as possible where compatible with efficient collection of the nodules. However, it is equally obvious that significant disturbance of the sediment and the sessile benthic organisms, which cannot escape the oncoming dredge, will occur. A cloud of sediment will undoubtedly be stirred up in the near-bottom water layers. The distribution and resedimentation of the stirred-up particles will obviously be governed by their density and other sedimentation characteristics as well as by the near-bottom currents. This resuspension of sedimentary materials will influence the near-bottom water mass, certain areas of the ocean floor from which sediments have been removed, as well as other areas where redeposition of the sediment will occur.

The near-bottom water mass may retain in solution certain compounds leached out from the sediment or from the interstitial water. For instance, in manganese-nodule areas, it is conceivable that the trace-metal content of the near-bottom water could be increased by the resuspension of sediment. This enrichment of the near-bottom water in certain compounds may have stimulatory or inhibitory effects on organisms living in the deep ocean near the sea floor. On the whole, important effects seem unlikely, both in view of the relatively low density of the near-bottom prowlers and the fact that the sedimentary material arrived on the sea floor as a result of natural sedimentation processes. It has been argued that the redistribution of sediment on the ocean floor resulting from natural phenomena exceeds by many orders of magnitude on a worldwide scale, any disturbances caused by all the dredges ever likely to be utilized in deep-sea mining (Welling, 1972). However, it remains equally clear that local disturbance of sediment may have a certain impact on the deep-sea fauna and flora. This is particularly the case for sessile animals which may have a very slow reproductive cycle. However, it is unlikely that any mining operation will cover 100% of a given area of the sea floor; thus, seafloor bands of adequate width should be left undisturbed in a mined area to enable the re-establishment of deep-sea fauna and flora in those areas where the dredge heads have destroyed it. This process of recolonization would be quite rapid on a geological timescale. It is believed that the biomass of the sessile fauna on the deep-sea floor is generally very low, particularly in manganese nodule areas and, therefore, the quantitative impact of deep-sea mining on the marine flora and fauna should be quite small.

1.1.3 Effects of Mining on the Water Column

Another possible result of the disturbance of the sediments and their resuspension in the water column is the transplantation of spores or other dormant or live forms of microorganisms from one area, where they rest in the sediment to another—transported by water currents in the overlying water masses after resuspension from the dredged sediments. Initial observations on some viable phytoplankters occurring in deep-sea sediments have been described (Malone *et al.*, 1973).

After the manganese nodules have been collected from the sea floor (with certain quantities of sedimentary material) they are transported through the water column to the surface mining vessel, either in the buckets of a continuous-line-bucket system or in a water stream through a pipeline (e.g., airlift). In both modes of transport, some or all of the accidentally gathered sediment and near-bottom water may be discharged either at the surface or at intermediate depths in the water column. The effect of these discharges at the surface has been measured or forecast (Amos *et al.*, 1972). To date, there is no information concerning the rate of sedimentation of discharged particulate matter. We have some information concerning the influence of deep-sea sediment on the productivity of waters in the euphotic zone. The influence of dissolved nutrients from interstitial water, or from near-bottom water, on the chemical composition of the overlying water column can be calculated from the rate of mixing and the fate of near-bottom water at the time of discharge, as well as by the salinity and temperature of the receiving water mass.

1.1.4 Additional Systematic Factors of Environmental Interest

A mining rate of 5000 metric tons per day appears to be a reasonable model for analysis of future ocean mining systems in terms of viable economies and for use in determination of loads placed upon the environment by ocean miners. This rate requires the handling of 1.5×10^6 metric tons of raw material per 300-day year. The handling and transport loads must be moved from the sea floor, up the nodule-transfer conduit, stowed aboard ship, ultimately transported to shore, offloaded from a barge (or the mining ship), and land-transported to a shore-based processing plant. Since the nodules, as recovered from the ocean floor, are 30% entrained water (by weight), there may be reduced tonnage rates for handling as drying occurs, this lower limit being 4.5×10^5 metric tons/year of the nodules, completely dried. The amount of water transported from the ocean floor for a hydraulic lift system can be computed using the rule of thumb of a maximum of 20% solids concentration, or four times the nodule tonnage rate which is 6 x 10^6 metric tons of sea water per 300-day year. Excess water will likely be discharged at depths of 1000 to 3000 ft below the surface, depending upon the sensitivity of the water-column ecology to this function.

The processing and extractive metallurgy of manganese nodules at sea, and the discharge of waste materials resulting from this processing, could be far more dangerous unless adequate precautions are taken. However, most major concerns involved in the development of manganese nodules have determined that, at least for first-generation plants, economical processing can only be accomplished ashore (Cardwell, 1973). The principal reasons for this are that the reagent transportation costs will be equal to, or greater than, the nodule transport costs, and problems of waste disposal and environmental protection will be much greater at sea than on land. However, should all processing take place at sea, the care taken in waste disposal resulting from metallurgical processes should be, at the very least, equal to that of land-based operations of a similar nature. We should have learned the lesson that we cannot willfully damage our environment without jeopardizing the quality of life.

Consideration should also be given to the possibility of introducing foreign species of phytoplankton to the surface and upper water column--species which were dormant in the sediments but which may revive when discharged into suitable temperature, light and oxygen conditions.

From the admittedly incomplete results of published work to date, it appears that the effect of the mining operation and of the vertical transport of manganese nodules, sediment and near-bottom water to the surface, and its discharge at the surface or at intermediate levels in the water column, is small (Roels *et al.*, 1973).

1.2 Field Work in Manganese Nodule Mining Impact Studies

1.2.1 Outline of Concepts

The concepts for studying the environmental impact of deep-ocean mining developed by our group have been to monitor a potential mining area or specific mining site before, during and after mining operations are carried out. All parameters of the water column and ocean floor that may be influenced by mining must be measured at each site. These include the physical, chemical and biological properties of the entire water column, local bottom topography, and the sedimentology and benthos of the ocean floor and substrate, and trace metal concentrations in the water column and sediment. Where the near-surface waters may be affected by mining effluent, seasonal variations in the upper water column must be studied. At each location, an area is monitored that is comparable in size to the area that a mining ship will exploit in the course of a few years (Ocean Science News, 1974). Station locations within the study areas are chosen to allow the local dynamic topography of the water column to be computed from the hydrographic observations, while at the same time obtaining adequate coverage of bottom samples and photographs to describe the benthos and sedimentology. Accurate mapping of the nodule coverage, benthos and sedimentology in a limited area at the center of each study site is obtained using a bottom-mounted Acoustically Transponding Navigation (ATNAV) system. The ATNAV also permits the direct monitoring of dredging operations and their effect on the ocean floor by the use of a submersible transponder that is first attached to the dredge-head and afterwards to a bottom camera so that it can be maneuvered to cross the dredge path several times. The recoverable bottom-mounted beacons also serve as release devices for mooring arrays of current meters placed at different heights above the sea floor. These give us a profile of bottom currents above the bottom, essentially at one location which will aid in understanding the disposition of sediment stirred up by mining operations.

1.2.2 Previous Field Work Done by the LDGO/CUNY Group on Environmental Aspects of Deep-Ocean Mining

August 1970: Monitored effects of surface-discharged effluent from the experimental mining vessel DEEPSEA MINER of Deepsea Ventures, Inc., during a pilot mining test on the Blake Plateau.

July 1972: Baseline study in a manganese nodule province in the North Atlantic Ocean from the R/V CONRAD.

August-September 1972: Monitored effects of experimental continuous-line-bucket (CLB) dredging in equatorial Pacific Ocean from R/V KANA KEOKI.

Publications arising from our work are listed in section 1.4.

1.3 References

Amos, A.F., C. Garside, K.C. Haines and O.A. Roels 1972. Deep-ocean mining: some effects of surface-discharged deep water. In: *Papers from a Conference on Ferromanganese Deposits on the Ocean Floor*, D.R. Horn (ed.) IDOE/NSF, Washington, D.C., pp. 271-281.

Cardwell, P.H. 1973 Extractive metallurgy of ocean nodules. Mining Convention/Environmental Show., American Mining Congress, Sept. 9-12, Denver, Co.

Garland, C. and R. Hagerty 1972 Environmental planning considerations for deep-ocean mining. Eighth Ann. Marine Technology Society Mtg., Sept. 11-13, Washington, D.C.

Malone, T.C., C. Garside, O.R. Anderson and O.A. Roels 1973 The possible occurrence of photosynthetic microorganisms in deep-sea sediment of the North Atlantic. *J. Phycol.* *9*:482-488.

Masuda, Y., M.J. Cruickshank and J.L. Mero 1971. Continuous bucket-line dredging at 12,000 feet. Offshore Technology Conference, April, p. 1410.

Ocean Science News 1974 November 15, vol. 16, no. 46.

Roels, O.A., A.F. Amos, O.R. Anderson, C. Garside, K.C. Haines, T.C. Malone, A.Z. Paul, G.E. Rice 1973 Environmental Impact of Deep-Sea Mining, NOAA Tech. Rept. ERL-290-OD-11, U.S. Department of Commerce, Boulder, Co., U.S. Government Printing Office, Washington, D.C. 20402, 185 pp.

Shepard, F.P. 1973 Submarine Geology (3rd Edition), New York: Harper and Row.

Welling, C.G. 1972 Some environmental factors associated with deep-ocean mining. Eighth Ann. Marine Technology Society Mtg., Sept. 11-13, Washington, D.C.

1.4 Publications Arising from Our Work

Roels, O.A., A.F. Amos, C. Garside and K.C. Haines 1972 Effects of surface-discharged deep-sea mining effluent. Am. Soc. Limnol. Oceanogr., 35th Ann. Mtg., March 19-22, Tallahassee, Fla.

Amos, A.F., C. Garside, K.C. Haines and O.A. Roels 1972 Effects of surface-discharged deep-sea mining effluent. Mar. Tech. Soc. J. 6(4):40-45.

Amos, A.F., C. Garside, K.C. Haines and O.A. Roels 1972 Deep-ocean mining: some effects of surface-discharged deep water, In: Papers from a Conference on Ferromanganese Deposits on the Ocean Floor, D.R. Horn (ed.), IDOE/NSF, Washington, D.C., pp. 271-281.

Roels, O.A., A.F. Amos, C. Garside and T.C. Malone 1972 The environmental impact of deep-sea mining. Preprints, Eighth Ann. Conf. & Expos., Marine Technology Society, Sept. 11-13, Washington, D.C., pp. 369-373.

Malone, T.C., C. Garside, A.Z. Paul and O.A. Roels 1973 Potential environmental impact of manganese nodule mining in the deep sea. Offshore Technology Conf., April 29-May 2, Houston, Tx., OTC 1735.

Roels, O.A., A.F. Amos, C. Garside, K.C. Haines, T.C. Malone, A.Z. Paul and G.E. Rice 1972 Environmental impact of two manganese nodule mining tests, In: Proc. Symp. Manganese Nodule Deposits in the Pacific, Oct. 16-17, Univ. Hawaii, Honolulu, Hawaii, pp. 129-146.

Amos, A.F., C. Garside, R.D. Gerard, S. Levitus, T.C. Malone, A.Z. Paul and O.A. Roels 1973 Study of the impact of manganese nodule mining on the sea floor and water column, In: Inter-University Program of Research on Ferromanganese Deposits of the Ocean Floor, Phase I Report, NSF/IDOE Seabed Assessment Program, Washington, D.C., pp. 221-264.

Roels, O.A. 1973 Environmental impact of deep-ocean mining, In: Proc. 1973 Mining Convention/Environmental Show Sept. 9-12, Denver, Co., Am. Mining Congr., Ring Bldg., Washington, D.C. 20036.

Malone, T.C., C. Garside, R. Anderson and O.A. Roels 1973 The possible occurrence of photosynthetic microorganisms in deep-sea sediments of the North Atlantic. J. Phycol. 9(4):482-488.

Roels, O.A., A.F. Amos, O.R. Anderson, C. Garside, K.C. Haines, T.C. Malone, A.Z. Paul and G.E. Rice 1973 *The Environmental Impact of Deep-Sea Mining*, Progress Report, NOAA Tech. Rept. ERL 29-OD-11, U.S. Department of Commerce, Boulder, Co., 185 pp.

Roels, O.A. 1974 A suggested procedure to ensure the safe development of deep-sea mining. Conf. Preprints, Tenth Ann. Conf. Marine Technology Society, Sept. 23-25, Washington, D.C.

Roels, O.A. 1974 The environmental impact of deep-sea mining: A suggested procedure to ensure the safe development of deep-sea mining. *2nd Internatl. Colloq. Exploit. Oceans*, Bordeaux, France, Oct. 1-4, Vol. 4, Bx-203, 7 pp.

Amos, A.F., S.C. Daubin, Jr., C. Garside, T.C. Malone, A.Z. Paul, G.E. Rice and O.A. Roels 1974 The Environmental impact of manganese-nodule mining: Preliminary report on a cruise to study baseline conditions in a manganese nodule province. *2nd Internatl. Colloq. Exploit. Oceans*, Bordeaux, France, Oct. 1-4, Vol. 5 (in press).

Amos, A.F., S.C. Daubin, Jr., C. Garside, T.C. Malone, A.Z. Paul, G.E. Rice and O.A. Roels 1975 Report on a cruise to study baseline conditions in a manganese nodule province. Offshore Technology Conf., May 5-8, Houston, Tex., OTC #2162.