ST/ESA/107

Department of International Economic and Social Affairs

SEA-BED MINERAL RESOURCE DEVELOPMENT: RECENT ACTIVITIES OF THE INTERNATIONAL CONSORTIA

UNITED NATIONS
New York, 1980

NOTE

Symbols of United Nations documents are composed of capital letters combined with figures. Mention of such a symbol indicates a reference to a United Nations document.

ST/ESA/107

UNITED NATIONS PUBLICATION

Sales No. E.80.II.A.9

Price: $U.S.2.00

PREFACE

This survey of the deepsea mining consortia was prepared by the United Nations Department of International Economic and Social Affairs under a general mandate in the field of marine affairs that has been laid down in the resolutions of United Nations governing bodies since 1966. 1/ Specifically in the field of sea-bed minerals, the survey is responsive to interest expressed both by the General Assembly and the Economic and Social Council in various aspects of sea-bed mineral resource exploitation and to accompanying directives from these bodies to provide information periodically on latest developments. 2/

Recently, a detailed programme of work on sea-bed minerals was formulated by the Department of International Economic and Social Affairs, consisting of several discrete projects that address at a concrete, technical level a number of prominent issues and problems associated with sea-bed mineral development. One of these projects, which consists of the monitoring of the activities of the international deepsea consortia, has resulted in the present survey. Other projects, under way or soon to commence, deal with the data base for resource evaluation, nodule processing technology and the mine site concept in ocean mining.

An important event in guiding the development of this work programme was the convening by the Department's United Nations Ocean Economics and Technology Branch of a Group of Experts Meeting on Sea-Bed Mineral Resources Assessment in November 1977. The meeting brought together 18 recognized world authorities for the purpose of examining the basic elements that need to be considered in making any estimate of the availability of sea-bed minerals in the future. The proceedings of the Group of Experts Meeting have been published in 1979 as Manganese Nodules: Dimensions and Perspectives by the D. Reidel Publishing Company at Dortrecht, the Netherlands.

Earlier reports by United Nations Department of International Economic and Social Affairs in the field of sea-bed minerals have dealt with a wide range of subjects, including the economic significance of sea-bed minerals, the possible economic implications and impact of their production, hypothetical computations

---

1/ Among these resolutions, the following may be cited as the most important: General Assembly resolutions 2172 (XXI) of 6 December 1966, and 2414 (XXIII) of 17 December 1968; and Economic and Social Council resolutions 1112 (XL) of 7 March 1966, 1380 (XLV) of 2 August 1968, 1537 (XLIX) of 27 July 1970, 1641 (LI) of 30 July 1971, 1802 (LV) of 7 August 1973, and 1970 (LIX) of 30 July 1975.

2/ For example, in resolution 2414 (XXIII), the General Assembly, inter alia, requested the Secretary-General "to pursue the task of collecting and disseminating available information regarding the mineral and other resources of the sea-bed and ocean floor beyond the limits of national jurisdiction ...". In resolution 1380 (XLV), the Economic and Social Council requested the Secretary-General "to follow closely new developments which may occur in fields of marine mineral resources exploration, evaluation and exploitation beyond the continental shelf and the possible implications thereof ...".

of production of the constituent metals of manganese nodules, salient issues and latest developments. Some of these reports - in the form of analytical studies and information notes - were submitted variously to the Economic and Social Council and its Committee for Natural Resources and to the Committee for Development Planning.

However, in recognition of the political importance of the negotiations under way within the context of the Third United Nations Conference on the Law of the Sea, several reports on sea-bed minerals have also been prepared by the Department for submission to the Conference at its request. In rendering this service, the Department has provided economic and technical information on subjects within its competence in order to assist the Conference in addressing the issues within the purview of its negotiations. It is hoped that the present survey will similarly assist Member States in their appraisal of the present situation of sea-bed development and be useful in their negotiations on the future international arrangements to be made concerning these resources.

The objective of the survey is to present, on the basis of available information, 3/ the current status of deepsea mining activities. Following an introductory section I, which very briefly reviews the metal potential of nodule resources in relation to the supply of land-based metals and the current state of technology, the major part of the survey describes in three sections the recent activities of the deepsea mining consortia. Section II profiles the formation and composition of each of the major consortia, and section III focuses on the activities of the consortia during the years 1978 and 1979 in the fields of exploration and the development and testing of mining systems and processing methods. The last section briefly discusses the outlook for deepsea mining.

3/ The information in this report was obtained from various literature sources and communication with prominent people in the industry. Nevertheless, an important deterrent from completeness and full accuracy in the survey stems from the fact that a great deal of information in this field is proprietary.

CONTENTS

List of Tables

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area or of its authorities or concerning the delimitation of its frontiers or boundaries.

I. INTRODUCTORY OVERVIEW OF DEEPSEA MINING 1/

The potato-shaped manganese nodules, rich in manganese, nickel, copper, cobalt and other minerals, are known to be scattered over the ocean floor at depths of 3,000 to 6,000 metres. It is estimated that only about 15 per cent of the sea floor (about 54 million km^2) is covered by nodules. The total volume of nodule resources meeting grade and abundance criteria for first generation mining, may be on the order of 175 billion dry tonnes of nodules. 2/

It should be noted, however, that the 175 billion dry tonnes of nodules represent only the theoretical maximum. A considerable portion of nodule resources may not be mineable for reasons of topography or inadequate abundance in the mineable area. Based on the definition of first generation mine sites, 3/ potential reserves are estimated to amount to 23 billion dry tonnes. This total amount can be translated into 290 million tonnes of nickel, 240 million tonnes of copper, 60 million tonnes of cobalt and 6 billion tonnes of manganese. 4/

Table 1 compares the estimated potential reserves of manganese nodules with the land-based mineral reserve figures. It should be remembered that these categories are not strictly comparable, since land-based reserves exist in known or worked deposits, while no one has yet mined an ocean deposit. As an order of magnitude, however, nickel and cobalt contents in nodule "reserves" appear to be substantially larger than in land-based reserves.

The complete system to transform the nodules into a commercially valuable form may be divided into three major components: mining, transportation and processing. The mining system is comprised of three components: collector, lift system and surface system. Various collectors have been tested, both on land and at sea, on a reduced scale. Presently, it appears that the basic capability of collectors has been proven, although their operational feasibility has to be established, particularly at larger capacities.

1/ For a detailed evaluation of the scientific, technical and economic aspects of the nodule industry, see Manganese Nodules: Dimensions and Perspectives (Proceedings of a United Nations Expert Group Meeting on Sea-Bed Mineral Resource Assessment), Natural Resources Library, vol. II (Dordrecht, D. Reidel Publishing Company, 1979).

2/ Alan A. Archer, "Resources and potential reserves of nickel and copper in manganese nodules", Manganese Nodules: Dimensions and Perspectives ..., p. 79. A billion is 10^9.

3/ A first generation mine site is described as an area where the average combined nickel and copper content is about 2.3 per cent and the average abundance of nodules is about 10 (wet) kg/m^2, and from which about 60 million tonnes of such nodules can be recovered.

4/ Archer, loc. cit., p. 77. The figures represent metal contents, assuming 1.26 per cent of the average nickel grade, 1.03 per cent of copper, 0.25 per cent of cobalt and 27.5 per cent of manganese.

With respect to the methods to raise the nodules collected at the bottom, two list systems - airlift and hydrolift - are under consideration by all consortia, except for the Continuous Line Bucket (CLB) Group. A series of tests to date seem to indicate that the hydrolift system has an efficiency advantage. The hydrolift system, however, has an engineering disadvantage that arises from the use of moving, mechanical parts at great depths, whereas, in the airlift system, the air compressor is mounted on the mining ship.

Processing technology is also a key element for the economic viability of an operation. In commercial operations, the final selection of processing methods will depend on the results obtained from full-scale pilot plant operations, as well as on decisions regarding which metals are to be recovered in what form.

One of the major concerns in international discussions is the possible economic impact of deepsea mining on the land-based production. It is feared that an additional supply of metals recovered from the nodules may substantially reduce metal prices and revenues for land-based producers.

Table 1. Comparison of reserves from land and nodules: nickel, copper, cobalt and manganese

(Million tonnes metal content)

	Land-based reserves	Potential nodule reserves
Nickel	54	290
Copper	498	240
Cobalt	1.5	60
Manganese	5 440 a/	6 000

Source: For land-based reserve figures, United States Bureau of Mines, United States Department of the Interior, Mineral Commodity Summaries, 1979 (Washington, DC, United States Government Printing Office, 1978). Nodule reserve figures are based on table 5 in Archer, loc. cit.

a/ Gross weight.

It is extremely difficult to estimate the magnitude of the likely impact of deepsea mining on the markets of metals, because of the uncertainty associated with factors, including the size of each operation, the number of operations, the starting year of operations and the growth rates of the total demand for the metals, among others. Nevertheless, according to various estimates and sensitivity studies, it appears that the possible impacts of deepsea mining on the markets for cobalt, nickel and manganese could be significant, while the impact on the copper market should be minimal.

Given this observation, the next question relates to examining countries which would be adversely affected by deepsea mining. Countries which are presently major producers of nickel, copper, cobalt or manganese for export would be adversely affected to the extent that their export earnings dropped as a result of price declines. Countries which were in the process of mine development at the time when additional metal supplies from nodules entered the market might experience financial problems from any price declines. Countries which contemplated exploiting smaller deposits before sea-bed mining became a reality might be described as being adversely affected. The brief survey below describes only major producing countries, since world mine production of nickel, cobalt and manganese is concentrated in a few countries. Copper is not included in the following discussion because: (1) world mine production of copper is relatively dispersed among countries, making a short treatment impossible; (2) even under very optimistic assumptions about future volumes of nodule production, the expected impact in the world copper market is relatively small. 5/

The largest producer of nickel is Canada, accounting for about 30 per cent, followed by the Union of Soviet Socialist Republics (17 per cent), New Caledonia (15 per cent) and Australia (11 per cent). These four producers supplied almost three quarters of the world mine production of nickel in 1977. 6/

In the case of cobalt, Zaire is the world's leading producing country accounting for more than one third of the total production. Combined with the following three producers, namely, New Caledonia (14 per cent), Australia (11 per cent) and Zambia (7 per cent), 67 per cent of the world mine production of cobalt in 1978 originated from the top four producing countries. 7/

The geographical concentration for manganese production is even more pronounced than that for nickel and cobalt. The top four producers account for 77 per cent of the world's manganese production in 1978: the largest producer is the USSR (38 per cent), followed by South Africa (23 per cent), Gabon (8.4 per cent) and India (8 per cent). 8/

If the distribution of mine production by the three economic groupings (developing, developed market economy and centrally planned economy) is summarized, one finds that cobalt production is heavily concentrated in the developing countries (67 per cent). On the other hand, 42 per cent of nickel

---

5/ For details, see "Impact of manganese nodule production from the ocean floor: long-term econometric estimated", document issued by the United Nations Conference on Trade and Development, on 10 August 1978 (TD/B/721/Add.1).

6/ World Bureau of Metal Statistics, World Metal Statistics, May 1979.

7/ United States Bureau of Mines, op. cit.

8/ Ibid.

mine production originates from the developed market economies and 43 per cent of manganese mine production originates from the centrally planned economies (see table 2).

Examination of the geographical distribution of ore reserves reveals other features. Although the developed market economies currently produce 42 per cent of the nickel ore, as compared with 34 per cent from developing countries, 61 per cent of nickel reserves are estimated to be in the developing countries.

The reserves of cobalt are even more heavily concentrated in the developing countries than is the distribution of current cobalt production. The developing countries account for 72 per cent of the reserves, with the remainder divided between developed market economies (7 per cent) and centrally planned economies (21 per cent).

Half of the manganese reserves are estimated to be located in the centrally planned economies, primarily in the USSR, while the remaining half is concentrated in the developed market economies (43 per cent, most of which is in South Africa), leaving only 7 per cent in the developing countries (see table 2).

It is well understood that actual developments of the potential nodule resources largely depend on the activities and decisions of the existing consortia. In this connexion, the following two sections, which constitute the main body of the present report, focus on the identification of the major deepsea mining consortia and on their recent research and development activities in various phases of deepsea mining.

Table 2. Geographical distribution of mine production and ore reserves - nickel, cobalt and manganese

(Percentage)

	Nickel		Cobalt		Manganese	
	Mine production	Ore reserves	Mine production	Ore reserves	Mine production	Ore reserves
Developing countries	34 a/	61 a/	67	72	27	7
Developed market economies	42	23	21	7	30	43
Centrally planned economies	23 b/	16 b/	12	21	43	50

Source: For nickel see "Prospects for the development of the raw materials base for the nickel industry and the demand for nickel over the next 10-15 years" (E/C.7/102), 1978 estimates. For cobalt and manganese see United States Bureau of Mines, op. cit., 1978 estimates.

a/ Including Cuba.

b/ Excluding Cuba.

II. DEEPSEA MINING INDUSTRY IN PERSPECTIVE 9/

There are four commercially-oriented consortia: the Kennecott Group, Ocean Mining Associates, Ocean Management, Inc. and the Ocean Minerals Company. In addition, France and Japan launched national programmes: L'Association française pour l'étude et la recherche des nodules (AFERNOD) and the Deep Ocean Minerals Association (DOMA). Another international syndicate, the Continuous Line Bucket Group, was formed to develop the Continuous Line Bucket system.

The Kennecott Group

After 13 years of continued research and development on its own, Kennecott formed a partnership to conduct research and development on a large scale. The consortium, commonly called the Kennecott Group, was formed in January 1974, as an unincorporated joint venture. The original partners in the group were the Kennecott Copper Corporation (United States of America), Rio Tinto-Zinc Corporation Ltd. (United Kingdom of Great Britain and Northern Ireland), Consolidated Gold Fields, Ltd. (United Kingdom), Noranda Mines, Ltd. (Canada), and the Mitsubishi Corporation (Japan). Later, it was joined by the British Petroleum Company, Ltd. (United Kingdom), making it a group consisting of six companies from four countries. Half of the budget has been borne by Kennecott while the remainder is equally shared (10 per cent each) by the other five companies.

The initial programme called for a $50 million budget to be committed over a five-year period between 1974 and 1979. The period was divided into two phases: phase I (1974-1975) was devoted to further exploration and research on mining and metallurgical processing techniques and phase II A (1976 to 1979) to engineering development of mining system components and the metallurgical processing system. The third phase, phase II B, was to undertake large-scale prototype mining tests and to construct and operate a demonstration processing plant, both of which are essential steps before starting commercial operations.

A committee of representatives regularly meets and makes major decisions. Kennecott is the operator for the group. At the end of each phase, participants have the option to either remain or withdraw from the group.

The Kennecott Copper Corporation is engaged in development, production and marketing of mineral resources, largely copper. It ranked fifth in copper mining capacities and third in refining capacities in the market economies in 1978. 10/ Noranda Mines, Ltd. of Canada is also principally engaged in mining and metallurgical activities. It accounted for one per cent of world copper production and its refining capacity ranked sixth in the market economies in 1978. 11/

9/ This section and the next section extends and updates the information presented in The Ocean Economics and Technology Office, "Deepsea Mining Consortia", Department for Economic and Social Information Fact Sheet No. 79/1, April 1979.

10/ See Marian Radetzki and Stephen Zorn, Mineral Processing in Developing Countries, Industry 2000 - New Perspectives, Collected Background Papers, vol. V, 19 December 1979 (UNIDO/IOD.328).

11/ Ibid.

Rio Tinto-Zinc and Consolidated Gold Fields are two large London-based international groups of mining and industrial companies. The activities of Rio Tinto-Zinc include significant production of aluminium, copper, gold, lead and zinc. Consolidated Gold Fields is an international holding company with major interests in gold. The British Petroleum Company is one of the largest vertically integrated oil groups. The Mitsubishi Corporation is one of the leading general trading companies in Japan. Mitsubishi Heavy Industries, Ltd. and Mitsubishi Metal Corporation participate in the consortium through the Mitsubishi Corporation.

Ocean Mining Associates

This consortium evolved out of Deepsea Ventures, Inc., which started as a wholly-owned subsidiary of Tenneco, Inc. (United States), in 1968. Deepsea Ventures, Inc. carried on the early efforts of its predecessor, Newport News Shipbuilding and Drydock Company. Tenneco decided to expand its pioneering work in manganese nodules by organizing a partnership. In May 1974, the group was first formed by Tenneco and Japanese Manganese Nodule Development Company (JAMCO), the latter consisting of five companies: Nichimen Company Ltd., C. Itoh and Company Ltd., Kanematsu-Gosho, Ltd. (all three are Japanese trading companies), Japan Metals and Chemicals and Hitachi. In November of the same year, the group was joined by the United States Steel Corporation (United States) and Union Minière (Belgium).

Ocean Mining Associates (OMA) thus started with four companies with equal participation, to carry out research, development and evaluation programmes using Deepsea Ventures as a service contractor. This consortium, however, went through several changes in its composition. Tenneco and JAMCO withdrew from the group. United States Steel and Union Minière remained in the partnership, sharing the expenses equally until a third partner, Sun Company Inc. (United States), was added in 1977. Under the present arrangement, three equal partners (33 1/3 per cent each) participate through their respective subsidiaries.

United States Steel is one of the largest steel manufacturing companies in the world. In addition to iron and coal mines, United States Steel owns 44 per cent of interests of Compagnie Minière de l'Ogooue in Gabon for manganese ores. It also maintains minority ownerships in Ferroalloys, Ltd. (45 per cent) for ferromanganese and Associated Manganese Mines of South Africa, Ltd. (20 per cent) for manganese ores.

Union Minière, based in Brussels, undertakes international operations in the field of mining and metallurgy through numerous subsidiaries. Union Minière holds 45 per cent shares of Métallurgie Hoboken-Overpelt S.A., whose copper refining capacity accounted for 3.9 per cent of the total in the market economies in 1978. 12/

Sun Company, Inc. is a non-operating parent company with significant interests in oil and gas. Its subsidiaries operate in oil refining and marketing, concentrated in the United States and Canada.

Ocean Management Incorporated

Another multinational consortium, Ocean Management, Inc. was formed in February 1975, with Inco, Ltd. of Canada, the Deep Ocean Mining Company, Ltd.

12/ Ibid.

(DOMCO) of Japan and Arbeitsgemeinschaft Meerestechnischgewinnbare Rohstoffe (AMR) of the Federal Republic of Germany. The group soon brought in a fourth partner, SEDCO, Inc. of the United States. Each partner equally contributed to a budget of approximately $40 million to be spent between 1975 and 1979.

All four partners had accumulated technical expertise in various phases of nodule mining, prior to the formation of the consortium. Inco was one of the first companies to become interested in nodules, as early as 1959. The German consortium, AMR, has carried out extensive prospecting in the Pacific and Indian Oceans, using the sophisticated vessel, Valdivia. The Sumitomo Group in DOMCO actively participated in the Continuous Line Bucket system tests. SEDCO also provided a crew to the mining test on the Blake Plateau conducted by Deepsea Ventures, Inc. in 1970.

Turning to the profiles of the participating groups, Inco, Ltd. is engaged in three principal lines of business: primary metals, batteries and dry cells and formed metals. Inco Metals Company is a major operating unit of Inco, Ltd. and the leading producer of primary nickel in the world. Although its market share has eroded gradually over the past 20 years, Inco still provides 25 to 40 per cent of nickel production in the market economies.

DOMCO was formed under the leadership of the Sumitomo Group for the purpose of participating in the consortium. It consists of 23 Japanese companies in a wide variety of fields. The shareholders include nine companies from the Sumitomo group, three other trading companies, two mining companies, two banks and some manufacturing companies. The Sumitomo Group includes companies involved in the processing of nickel and copper and in shipbuilding.

AMR started with four German companies: Metallgesellschaft AG, Preussag AG, Salzgitter AG and Rheinische Braunkohlenwerke AG, the latter withdrawing in 1976. Metallgesellschaft is engaged in the mining, refining, fabricating and trading of metals. Preussag's business extends from production of non-ferrous metals, coal and petroleum to construction works. It is also engaged in the development of a mining and process system to exploit the Red Sea muds. Salzgitter AG, whose shares are wholly owned by the Government of the Federal Republic of Germany operates as a holding company in steelmaking, shipbuilding and transportation.

SEDCO, Inc. primarily provides specialized services to the international petroleum industries, namely contract drilling and support operation and pipeline construction. The drilling and support operations are principally performed offshore, using specially designed semi-submersible vessels and dynamically stationed drillships, one of which, SEDCO 445, was converted to a mining vessel for use by the consortium.

The Ocean Minerals Company

Under the leadership of the Lockheed Missiles and Space Company (United States), the Ocean Minerals Company (OMCO) was established in November 1977 in Mountain View, California. Technically, OMCO is a partnership between Amoco Ocean Minerals Company (a subsidiary of Standard Oil of Indiana) and Ocean Minerals, Inc. which is composed of the Lockheed Missiles and Space Company, Inc., Billiton B.V. and RBKW Ocean Minerals B.V. and the third partner, Lockheed Systems Company, Inc. (Lockheed's financial subsidiary) which joined OMCO in 1979. Lockheed Missiles and Space Company serves as a prime contractor, being responsible for technical

aspects of the project. Other partners also send their experts to Lockheed. The exact percentage shares of the partners are not available, but it is believed that the combined United States interests (Lockheed and Standard Oil of Indiana) are in the range of 50 to 60 per cent.

Lockheed Missiles and Space Company, Inc. is a wholly-owned subsidiary of Lockheed Aircarft Corporation, whose interests are in aerospace equipment, ocean vessels and petroleum extracting equipment. Its diversification efforts to apply aerospace technology to the ocean has been going on for quite some time. Recently, it also became active in ocean thermal energy conversion (OTEC) technology.

Billiton B.V., is one of the numerous operating companies under the Royal Dutch/Shell Group, one of the largest international oil majors. Located in the Hague, Netherlands, it has an equity interest in the world-wide production of bauxite, lead, zinc and tin.

Royal Bos Kalis Westminster Group N.V., which is a parent company of RBKW Ocean Minerals, grew out of a dredging company to become a public work contractor with world-wide activities. It is engaged mainly in dredging, pipelaying and civil engineering, particularly dock and harbour facilities.

The Standard Oil Company of Indiana is a large integrated petroleum and chemical company that conducts operations on a world-wide basis. Amoco Minerals Company, one of its wholly owned subsidiaries, is engaged in exploration of mineral deposits.

L'Association française pour l'étude et la recherche des nodules

L'Association française pour l'étude et la recherche des nodules (AFERNOD) is an association between French government agencies and private industry. It started first in 1974 with Le Centre national pour l'exploitation des océans (CNEXO), La Société métallurgique le nickel (SLN) and Le Commissariat à l'énergie atomique (CEA). The first two were involved in the test of the Continuous Line Bucket system in French Polynesia in 1972, and this experience eventually led to the formation of the association to develop the mining and processing methods for nodules.

At the end of 1975, AFERNOD was joined by Chantiers de France-Dunkerque and then in January 1977 by Bureau de recherches géologiques et minières (BRGM). Thus, AFERNOD is currently comprised of three government agencies and two private companies.

The Deep Ocean Minerals Association

Established in March 1974, in Tokyo, Japan, Deep Ocean Minerals Association (DOMA) promotes the development of deepsea manganese nodules for the national interest. Although it is not a governmental organization, it maintains close contacts with the Japanese Government, and its activities are financed substantially by the Government. DOMA consists of 35 leading Japanese companies as members, including mining, general trading, shipbuilding and steelmaking companies. About one third of its 35 members also have interests in DOMCO, which is a participant in another consortium with Inco, AMR, and SEDCO. Three companies from the Mitsubishi group which belong to this consortium also participate in the Kennecott group.

The Continuous Line Bucket Syndicate

In 1966, Commander Y. Masuda of Japan invented a cable-bucket system to mine the nodules. A series of tests resulted in the formation of an international syndicate in 1972 by some 20 companies from six countries, namely, Australia, Canada, France, Germany (Federal Republic of), Japan and the United States. The group includes a number of companies which participate in the other consortia, such as United States Steel (United States), the AMR group (Federal Republic of Germany), CNEXO (France), Inco and Noranda Mines (Canada), and DOMCO (Japan).

Table 3 summarizes information on six deepsea mining consortia, including year of formation, country of registration, head office, composition of a consortium, brief profiles of participants and service contractors, if any.

Table 3. Summary table of major deep-sea mining consortia

(a) Kennecott Group

Year of formation	Country of registration	Head office	Service contractor
January 1974	unincorporated	-	-

COMPOSITION OF CONSORTIUM

Participants	Parent company	Country of origin	Share of participation (percentage)	Major activities of parent company
Kennecott Copper Corporation	same	United States	50	Production and marketing of mineral resources, mainly copper
RTZ Deepsea Enterprises, Ltd.	Rio Tinto-Zinc Corporation Ltd.	United Kingdom	10	International mining company in aluminum, copper, gold, lead and zinc
Consolidated Gold Fields, Ltd.	same	United Kingdom	10	International mining finance company with major interests in gold
BP Minerals, Ltd.	British Petroleum Company, Ltd.	United Kingdom	10	Vertically integrated oil majors
Noranda Mines, Ltd.	same	Canada	10	Mining and metallurgy of copper, lead and zinc
Mitsubishi Corporation	same	Japan	10	General trading company

(b) Ocean Mining Associates

Year of formation	Country of registration	Head office	Service contractor
May 1974	partnership registered in Virginia, United States	-	Deepsea Ventures, Inc. (Gloucester, Virginia)

COMPOSITION OF CONSORTIUM

Participants	Parent company	Country of origin	Share of participation (percentage)	Major activities of parent company
Essex Minerals Company	United States Steel Corporation	United States	33 1/3	Steel manufacturing and fabrication
Union Seas, Inc.	Union Minière S.A.	Belgium	33 1/3	International mining company, active in Belgium, Canada, United States, Australia
Sun Ocean Ventures	Sun Company, Inc.	United States	33 1/3	Non-operating company in oil and gas

(c) Ocean Management, Incorporated

Year of formation	Country of registration	Head office	Service contractor
February 1975	incorporated in the United States	administrative office in New York, New York	-

Table 3 (continued)

COMPOSITION OF CONSORTIUM

Participants	Parent company	Country of origin	Share of participation (percentage)	Major activities of parent company
Inco, Ltd.	same	Canada	25	The largest producer of nickel in the world. Also engaged in batteries and formed metal products.
AMR (Arbeitsgemeinschaft Meerestechnischgewinnbare Rohstoffe)	Metallgesellschaft AG	Federal Republic of Germany	25	Mining, refining, fabricating and trading of metals
	Preussag AG			Non-ferrous metals, coal and petroleum Red Sea muds development
	Salzgitter AG			Holding company in steel making and shipbuilding
SEDCO, Inc.	same	United States	25	Contract drilling and support operation for mainly offshore oil
Deep Ocean Mining Company, Ltd. (DOMCO)	23 companies	Japan	25	Including trading, mining, and manufacturing companies and banks

(d) Ocean Minerals Company

Year of formation	Country of registration	Head office	Service contractor
November 1977	incorporated in the United States	Mountain View, California	Lockheed Missiles and Space Co.

COMPOSITION OF CONSORTIUM

Participants	Parent company	Country of origin	Share of participation	Major activities of parent company
Amoco Ocean Minerals Company	Standard Oil of Indiana	United States	N.A.	Ranks sixth among United States petroleum companies. Amoco Minerals concentrates on non-ferrous metals.
Ocean Minerals, Inc.				
Lockheed Missiles and Space Company	Lockheed Aircraft Corporation	United States		Production of aircraft, missiles and spacecrafts
Billiton B.V.	Royal Dutch/Shell Group	Netherlands	N.A.	Oil majors. Billiton is engaged world-wide in all stages of the mineral industry.
RBKW Ocean Minerals BV	Royal Bos Kalis Westminister, NV	Netherlands		Dredging, land reclamation, civil engineering
Lockheed Systems Company, Inc.	Lockheed Aircraft Corporation	United States	N.A.	Financial subsidiary of Lockheed

(e) Association française pour l'étude et la recherche des nodules

Year of formation	Country of registration	Head office	Service contractor
1974	France	Paris	-

Table 3 (continued)

COMPOSITION OF ASSOCIATION

Participants	Major activities
Centre national pour l'exploitation des océans (CNEXO)	French government agencies
Commissariat à l'énergie atomique (CEA)	
Bureau de recherches géologiques et minières (BRGM)	
Sociéte métallurgique le nickel (SLN)	Nickel production
Chantiers de France-Dunkerque	Shipbuilding

(f) Deep Ocean Minerals Association

Year of formation	Country of registration	Head office	Service contractor
March 1974	Japan as a public corporation	Tokyo	-

COMPOSITION OF ASSOCIATION

MEMBERS		MEMBERS	
C.Itoh and Company, Ltd. Kanematsu-Gosho, Ltd. Marubeni Corporation Mitsubishi Corporation Mitsui and Company, Ltd. Nichimen Company, Ltd. Nissho-Iwai Company, Ltd. Sumitomo Shoji Kaisha, Ltd. Toyo Menka Kaisha, Ltd.	trading companies	Hitachi Shipbuilding and Engineering Company, Ltd. Ishikawajima-Harima Heavy Industries Company, Ltd. Kawasaki Heavy Industries, Ltd. Mitsubishi Heavy Industries, Ltd. Mitsui Heavy Industries, Ltd. Mitsui Engineering and Shipbuilding Company, Ltd. Mitsui O.S.K. Lines, Ltd. Nippon Yusen K.K. Sumitomo Shipbuilding and Machinery Company, Ltd.	shipbuilding and heavy industries
Dowa Mining Company, Ltd. Furukawa Company, Ltd. Japan Metals and Chemicals Company, Ltd. Mitsubishi Metal Corporation Mitsui Mining and Smelting Company, Ltd. Nippon Mining Company, Ltd. Nippon Yakin Kogyo Company, Ltd. Pacific Metals Company, Ltd. Sumitomo Metal Industries, Ltd. Sumitomo Metal Mining Company, Ltd.	mining and metallurgy companies	Kawasaki Steel Corporation Kobe Steel, Ltd. Nippon Kokan K.K. Nippon Steel Corporation	steel companies
		Nippon Electric Company, Ltd. Victor Company of Japan, Ltd.	electric appliances
		Kyokuyo Company, Ltd.	fisheries

III. CURRENT ACTIVITIES OF CONSORTIA

This section presents information on current activities by each consortium. It covers the major activities undertaken during the period 1978 to 1979 only. 13/ In principle, three types of activities will be considered: exploration activities and the development and testing of mining systems and of processing methods, even though all the consortia were not necessarily engaged in all three during the period covered by the present report.

The Kennecott Group

This group has been essentially inactive during the period concerned. Its last ocean cruise was conducted in 1977. This group has not conducted a complete mining system test (collector, lifting system and surface ship) at sea as have the other three commercially oriented consortia. Instead, they tested collectors and the lifting system separately. Their model collector was already tested in 1974 at a depth of 5,000 metres in the Pacific Ocean. Concerning the lift system, a series of tests were undertaken on land through early 1978. Both an airlift and a hydrolift system were tested, but the former seems to be favoured by the group because of the engineering simplicity.

With respect to processing activities, they have been inactive since 1976. They completed their work and shut down a small pilot plant in Lexington, Massachussetts. During 1979, a feasibility analysis including complete cost estimates was completed.

The group plans to defer the third phase (large-scale prototype mining tests and operation of a demonstration processing plant) of its work until they feel a suitable legal régime is in place and business conditions improve.

Ocean Mining Associates

The major activity to note during the 1978 to 1979 period was a mining test conducted in December 1978. The ore carrier Weser Ore was selected for conversion

---

13/ For detailed information on their activities before 1977, see Conrad Welling, "The future outlook for the nodule industry", Manganese Nodules: Dimensions and Perspectives, The Ocean Economics and Technology Office, "Deepsea mining consortia", op. cit., p. 139. United States of America, Ninety-fourth Congress, first session, Senate, the Committee on Interior and Insular Affairs, Hearing Before the Subcommittee on Minerals, Materials and Fuels of the Committee on Interior and Insular Affairs, First Session on Briefing by Ocean Mining Industry (Washington, D.C., United States Printing Office, 1975) and United States of America, Ninety-fifth Congress, first session, House of Representatives, Committee on Merchant Marine and Fisheries, Heaings Before the Subcommitee on Oceanography and the Committee on Merchant Marine and Fisheries (Washington, D.C., Government Printing Office, 1977).

to the mining ship, Deepsea Miner II. The converted ship was equipped with a centre well, thruster wells, pipe and dredge handling equipment, among other modifications. The mining test took place in the Pacific Ocean, approximately 1,200 miles southwest of San Diego. Deepsea Miner II successfully raised nodules from a depth of 5,000 metres at the design capacity of 50 tons per hour.

Ocean Management Incorporated

OMI has continued its exploration activities, which began in 1975, by utilizing the vessels R/V Valdivia and Sonne. The high speed exploration system was successfully tested at sea during the exploration cruises.

From the end of the period from November 1977 to May 1978, OMI conducted mining tests at sea. Prior to these tests, a number of tests of the bottom collector had been done in large tanks on land and with the research vessel, Valdivia, at sea. The drillship, SEDCO 445, was converted to a mining ship with minor modifications. Following the shallow water tests in the Gulf of Mexico and in the Pacific Ocean north of Hawaii, the SEDCO 445 successfully pumped up manganese nodules from the ocean floor in the Pacific about 800 miles south of Hawaii, at a depth of around 5,000 metres. Nodules were mined at rates of approximately 30 to 65 tons per hour by using an electro-hydraulic collector. OMI successfully tested both an airlift and a hydraulic lifting system. This test at sea demonstrated the viability of their mining system, although on an approximately one-fifth scale.

Soon after the mining test was completed in 1978, this consortium announced a substantial slow-down of its activities. Technical staff working in Bellevue, Washington, returned to their respective companies.

Regarding the processing activities, some 800 tons of nodules collected during the test mining in 1978 were sent to Inco's facility at Port Colbourn, Ontario, Canada. The first phase of testing their processing methods was completed in October 1979 and further testing is under way.

Ocean Minerals Company

This consortium leased the oceanographic research and survey ship, Governor Ray. The survey operations, started in mid-1978, have concentrated on the Clarion-Clipperton fracture zones. The ship is being used for a series of cruises to plot viable deposits and to obtain sample nodules.

Based on the data acquired by the Governor Ray, mining tests were undertaken in December 1978, using Glomar Explorer, which was leased from the United States Government.

Prior to the mining test at sea, a test miner to collect nodules was developed by Lockheed, and the miner with a capacity of 1,000 tons per day has completed onland system tests in a test tank and in a large sea-floor simulator.

During the Glomar Explorer cruises in late 1978, shallow water tests were undertaken at a depth of 1,800 metres off the coast of California. At the main site of 5,000 metres, a combination of rough seas and mechanical problems caused the cancellation of deepsea tests. In the process of lowering the test miner to the bottom, the doors on the bottom of the vessel malfunctioned. After its repair in

February 1979, the Glomar Explorer successfully completed the tests of the mining system at the selected mine sites as originally planned, furnishing engineering data as well as some nodules. During the mining tests at sea, airlift and hydraulic systems were tested.

The development of processing methods has been conducted at a mini-plant at the Colorado School of Mines, on behalf of Lockheed. The processing equipment testing unit is planned to be constructed on the island of Oahu, Hawaii. This unit, a type of large-scale laboratory, is supposed to test processing equipment. The next step will be to build a pilot plant with a capacity for handling 25 to 50 tons per day of nodules, but no decision has been made concerning a pilot plant.

L'Association française pour l'étude et la recherche des nodules

This group has continued extensive exploration activities in the Clarion-Clipperton zone. In 1977, five cruises were conducted in that area by the research vessel, Le Noroit.

In addition to the continuing exploration activities, the development of mining equipment is also planned. The programme for the period 1980 to 1985 will probably include a project on remote-controlled autonomous shuttle craft - PLA 6000 (Préleveur libre autonome). The novel concept is under study at CEA and Chantiers de France-Dunkerque. The shuttle is not only to collect nodules but also to transport them to the surface, being remotely controlled from a semi-submersible platform. 14/

Regarding processing activities, the group installed a testing facility at CEA in 1978; two hydrometallurgical processing methods are being tested at an intake capacity of 10 kg of nodules per hour.

Deep Ocean Minerals Association

Since 1975, DOMA has been conducting exploration cruises in the Pacific Ocean, south of Hawaii, by using the geological survey vessel Hakurei-Maru. Since only one third of Hakurei-Maru operations has been devoted to the nodule exploration (the remaining two thirds for use of the Geological Survey of Japan), the new ship, Hakurei-Maru No. 2 was recently constructed. Exploration efforts by DOMA are expected to accelerate when this new vessel becomes available.

14/ Gerard Pikketty, "Deepsea operations and mining techniques", Ocean Industry, vol. 14, No. 4 (April 1979), pp. 350-357.

IV. THE OUTLOOK FOR DEEPSEA MINING INDUSTRY

Based on information presented in the previous section, the general picture of the deepsea mining industry may be summarized as follows: It is felt that the extensive exploration activities of the consortia have resulted in the identification of potential nodule deposits which could be exploited as first generation mine sites in the North Pacific Ocean. Regarding the processing techniques, metallurgical problems of recovering metals from nodules have been essentially solved. Concern is now focused on economic and operational feasibility rather than on the technical capability. A series of tests of small-scale plants have narrowed the number of possible processing routes, most of which are based on the hydrometallurgical technique.

Some of the consortia have already tested their mining systems (the collector, lifting system and the mining vessel) at sea and have succeeded in raising nodules from a depth of around 5,000 metres. The capability of each component of the mining system has been more or less proven, although the capacity of the collector has to be scaled up five times or more in commercial operation. The reliability and maintainability of the co-ordinated mining system appear to be the important unknowns to be resolved in the future.

After the scaled-down mining systems were proven to be workable, the next step is the construction and testing of prototype mining equipment and processing plants. The tests of the prototype mining system over extended time periods should assure its reliability and maintainability. The larger demonstration plants should be run to process nodules on a continual basis. More detailed exploration work, including mapping, will be required on the potential mine sites. All these activities will demand substantially larger capital expenditure than what the preliminary research and development work up to now has required. As a result, a substantial slow-down of the research and development work was recently announced by the major consortia which has been considered as industry forerunners.

None of consortia have discontinued their joint activities completely. Since their decisions to slow down current work, no participant has withdrawn from any of the major consortia. It is, therefore, clear that reactivation or disintegration of joint activities by the deepsea mining consortia will largely depend on the future development of international and/or national legal régimes and on the future outlook in the world metal markets.

كيفية الحصول على منشورات الامم المتحدة

يمكن الحصول على منشورات الامم المتحدة من المكتبات ودور التوزيع في جميع انحاء العالم . استعلم عنها من المكتبة التي تتعامل معها أو اكتب الى : الامم المتحدة ،قسم البيع في نيويورك او في جنيف .

如何购取联合国出版物

联合国出版物在全世界各地的书店和经售处均有发售。请向书店询问或写信到纽约或日内瓦的联合国销售组。

HOW TO OBTAIN UNITED NATIONS PUBLICATIONS

United Nations publications may be obtained from bookstores and distributors throughout the world. Consult your bookstore or write to: United Nations, Sales Section, New York or Geneva.

COMMENT SE PROCURER LES PUBLICATIONS DES NATIONS UNIES

Les publications des Nations Unies sont en vente dans les librairies et les agences dépositaires du monde entier. Informez-vous auprès de votre libraire ou adressez-vous à : Nations Unies, Section des ventes, New York ou Genève.

КАК ПОЛУЧИТЬ ИЗДАНИЯ ОРГАНИЗАЦИИ ОБЪЕДИНЕННЫХ НАЦИЙ

Издания Организации Объединенных Наций можно купить в книжных магазинах и агентствах во всех районах мира. Наводите справки об изданиях в вашем книжном магазине или пишите по адресу: Организация Объединенных Наций, Секция по продаже изданий, Нью-Йорк или Женева.

COMO CONSEGUIR PUBLICACIONES DE LAS NACIONES UNIDAS

Las publicaciones de las Naciones Unidas están en venta en librerías y casas distribuidoras en todas partes del mundo. Consulte a su librero o diríjase a: Naciones Unidas, Sección de Ventas, Nueva York o Ginebra.

Litho in United Nations, New York
17457–August 1980–3,650

Price: $U.S.2.00

United Nations publication
Sales No. E.80.II.A.9
ST/ESA/107