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COMMITTEE ON THE PEACEFUL USES OF THE SEA-BED AND THE OCEAN FLOOR BEYOND THE LIMITS OF NATIONAL JURISDICTION

SEA-BED MINERAL RESOURCES: RECENT DEVELOPMENTS

Progress Report

by the

Secretary-General

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PREFACE

22 June 1973

1. The General Assembly, in resolution 2750 (XXV), of 17 December 1970, requested the Secretary-General to "identify the problems arising from the production of certain minerals from the area beyond national jurisdiction", and "to keep this matter under constant review so as to submit supplementary information annually or whenever it is necessary".

2. Recalling this provision, Sub-Committee I of the Committee on the Peaceful Uses of the Sea-Bed at its sixty-fifth meeting on 23 March 1973 requested the Secretariat to prepare for the summer session of the Committee a brief report on economic and technological developments relating to sea-bed resources. A more detailed report should be prepared for consideration in 1974.

3. Accordingly, the Secretary-General submits to the Committee on the Peaceful Uses of the Sea-Bed and the Ocean Floor beyond the Limits of National Jurisdiction this progress report, which is divided into three sections:

I. New scientific insights into sea-bed geology;

II. Recent trends in the offshore petroleum industry;

III. Recent advances in deep sea-bed mining.

4. The scope of the report is limited and does not purport to cover the subject in a comprehensive manner. It merely reflects some of the latest developments that have taken place since the presentation of the previous report of the Secretary-General on the question (document A/AC.138/73).

I. New scientific insights into sea-bed geology

A revolution in scientific thinking known as sea floor spreading or "the new global tectonics" has, over the past ten years, changed our view of the Earth and is advancing our understanding of the resources of the sea-bed. This concept no longer subscribes to the old idea of a static Earth, on which continents and ocean basins are permanent features, but replaces it with a dynamic Earth model on which continents are constantly moving and ocean basins are opening and closing. The processes responsible for sea floor spreading would tend to concentrate metallic mineral deposits along boundaries where sections of the Earth's rigid outer shell move together (converge) or move apart (diverge) (see figures 1 and 2). Petroleum deposits which also tend to form along these active boundaries have frequently been preserved when the areas became stable continental margins.

We can summarize the expected patterns of mineral distribution which are emerging from this new conceptual framework to aid the search for mineral deposits as follows:

1. Opening Ocean Basins (Divergent Boundaries):

(a) The early stage of opening of an ocean basin is thought to create conditions which favour the accumulation of metallic sulfides. For example, the Red Sea is interpreted as an early stage of an ocean basin opening, splitting Africa and Eurasia apart. The rich submarine metallic sulfide deposits (average percentage of metal content: 1.3 copper, 29.0 iron, 0.1 lead, 3.4 zinc, and associated 0.005 silver and 0.00005 gold) were found in Red Sea basins. Also found were indicators of petroleum: organic-rich sediments and thick layers of rock salt deposited during stages of evaporation within the enclosed sea. The Atlantic Ocean which is continuing to grow must also have progressed through such an early opening stage. As a result, prospects may exist for metallic sulfide deposits near the mid-Atlantic ridge. The petroleum that has been found off the coast of West Africa occurs in basins that may have formed when the continent first started to split apart. Diapiric structures that are interpreted as salt domes have been discovered to extend as far as the continental rise (to water depths of 5,500 meters) along both the eastern and western margins of the Atlantic. These may represent structures favourable for accumulation of petroleum.

(b) The opening stage of an ocean basin, in this view creates conditions which favour the accumulation of metallic minerals. The Troodos ore bodies on the island of Cyprus (average percentages: 2.2 - 4.2 copper, 43.0 iron, 48.0 sulphur, 0.4 zinc, 0.25 - 2.12 ounces per ton gold, 0.25 - 12.96 ounces per ton silver) now being exploited are believed to exemplify the type of metallic sulfide deposits that may occur near divergent boundaries in ocean basins (e.g. the Mediterranean).

2. Closing Ocean Basins (Convergent Boundaries):

Processes associated with continental margins and volcanic islands at convergent plate boundaries appear to favour the deposition of metallic minerals and to be associated in various ways with the accumulation of petroleum. For example, the majority of known metallic sulfide ore bodies are concentrated at convergent boundaries including the belts of deposits which extend along the western cordillera of North and South America, the deposits of Japan and the Philippines and those from the eastern Mediterranean to Pakistan. The island chains along the convergent boundary forming the western margin of the Pacific enclose numerous small ocean basins including the

Bering Sea, the Sea of Okhotsk, the Sea of Japan, the Yellow Sea, the East China Sea and the South China Sea; these areas are considered promising for petroleum accumulation.

It is reasonable to expect that the growing understanding of worldwide patterns of mineral distribution that are emerging from the concepts of sea floor spreading will accelerate the discovery of mineral resources not only on the sea-bed but also on the continents. However, the realization of economic benefits from discoveries produced by these new insights is contingent on considerable improvement in methods of exploration and exploitation of the sea floor. It should be noted, however, that the above views are the subject of continuing discussion and controversy.

II. Recent Trends in the Offshore Petroleum Industry[1/]

1. Exploration Technology

(a) Surveys

The total of oceanographic research activities has now yielded a general picture of the appearance, geological nature and history of the ocean basins. Research efforts are now continuing to emphasize more detailed, localized studies rather than the rapid traverses of broad areas which characterized early investigations.

Geophysical methods rely increasingly on electronic and computer sophistication. The miniaturization of electronic components has lowered costs and led to the development of unattached instrument packages which can collect detailed data and be retrieved after weeks or months. Self-propelled instrument platforms now under development are capable of moving freely without a cable under the control of acoustic signals from a surface ship.

Computer utilization for data gathering and processing increases the efficiency and density of sampling and allows smaller sea floor features to be revealed. The application of deconvolution techniques enhances the signal and permits extraction of information otherwise irretrievable.

Improved underwater television and photography produce new insights on the nature of the sea floor[2/] and side-scanning sonar systems which are designed to make the

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1/ A good overview of marine technology today can be gained by reading the preprints of the Fifth Annual Offshore Technology Conference held in Houston, Texas, from 30 April - 2 May 1973.

2/ A system used aboard the German research vessel, R/V VALDIVIA, incorporates a TV camera, two photographic cameras for stereo images and illuminating devices. It is towed by a 8000-meter long coaxial cable in water depths up to 6000 meters at ship's speeds up to 6 knots and is capable of taking 3000 colour or stereo photos during a single lowering.

equivalent of aerial photographs of the sea floor, using sound instead of light, have been improved to resolve objects as small as 3 cm and sweep an area of sea floor 30 degrees wide and 10 degrees deep. Refinement of existing seismic reflection equipment using a towed 3.5 KHz sub-bottom profiler system has located natural hydrocarbon seeps[1/] as discrete reflections.

Techniques to rapidly sample the surface layers of the ocean floor to determine the detailed geological setting have progressed. A device developed in the Federal Republic of Germany to sample unconsolidated materials on the sea-bed in water depths to 5000 meters is capable of taking discrete samples 100 to 1000 meters apart.

Improved navigation systems which augment satellite navigation now achieve positional accuracies of about 50-100 meters. Satellite navigation systems are being miniaturized and prepared for commercial marketing at an anticipated cost of less than $10,000 (US) per unit.

(b) Drilling Equipment and Techniques

Recent technological breakthroughs indicate that in the near future economics and not water depth will be the limiting factor in petroleum exploitation. Exploratory wells will soon be drilled wherever there is a chance of striking a major discovery the size of which would justify the cost of recovery.

The GLOMAR CHALLENGER, operated by Global Marine Inc., continued the Deep-Sea Drilling Project with the added capability of hole re-entry and deeper penetration into the sea floor at abyssal depths for scientific purposes. The successful reoccupation of a drill hole, pioneered by the GLOMAR CHALLENGER, has been accomplished by several companies using a sonar pinger, computer directed dynamic positioning and underwater television.

The success of the GLOMAR CHALLENGER has nurtured the development of dynamically positioned drilling ships and rigs. SEDCO 445 has been built and is the first ship equipped with dynamic stationing for drilling exploratory wells. Seven new ships with drilling capabilities in water depths ranging from 100 to 300 meters were either under construction or delivered during 1972. Other improvements have been directed towards permitting year-round exploratory drilling in the arctic with an ice-breaking drill ship.[2/]

1/ Along the north shelf of Santa Barbara Basin in California, as reported by P.J. Fischer of California State University and A.J. Stevenson of Stanford University in the 1973 Offshore Technology Conference Preprints.

2/ Global Marine Engineering Co. has designed a model with pneumatically induced pitching and rolling that permits continuous breaking of moving ice without interfering with normal drilling operations.

2. Exploitation Technology

(a) Platforms

Progress in platform drilling operations is in the direction of deeper water operations and more efficient and reliable operations at current depths under severe weather conditions. A new offshore drilling rig called a column-stabilized semi-submersible[1/] (SEDCO 702) is capable of drilling in 1000 meters of water under near arctic environments and in the face of 100-knot winds, 30-m. waves and 2-knot currents.

A development of possible future importance is the supporting of platforms over the surface of the sea on a cushion of air which is now being tested with loads up to 95 tons.

A self-elevating super "jack-up" type offshore drilling platform designed by engineers from the US firm of George G. Sharp Inc. to operate in water depths up to 250 meters under hurricane conditions would cost about US $25 million (if built in the US).[2/] Another US company, Raymond International Inc., is working on a self-elevating drilling, producing and processing platform to be installed in about 100 meters of water; they claim the capability of designing a structure for water depths of 330 meters that would withstand 125-knot winds and 40-meter waves.

Operating drill platforms which rest on the ocean floor are supported by marine risers. Recent improvements in their construction now allow operations to 500 m. while current design limits extend to 700 m.[3/].

A new safety completion system has also been developed to prevent costly blowouts by automatically shutting down platform operations.[4/] Steps have also been taken to develop better survival systems for platform crews.[5/]

1/ The semi-submersible concept includes improved mobility for long tows and field moves; capability of anchoring in deeper and rougher water; capability of being self-propelled and/or dynamic positioned; minimal wind, wave and current resistance. Daily costs for operating and supporting one of the new semi-submersible rigs total about $50,000 (US).

2/ As reported by R.P. Giblon and V.U. Minorsky in the 1973 Offshore Technology Conference Preprints.

3/ In the Santa Barbara Channel holes have been drilled in water depths up to nearly 500 m from platforms supported by marine risers.

4/ The Cameron Iron Works Inc. (US) system was reported in Ocean Industry, April 1973, page 108; a Veteo Offshore Inc. system was reported by A.G. Ahlstone, B.F. Baugh and L. Reimert "Mudline Emergency Shutoff System", in 1973 Offshore Technology Conference Preprints.

5/ Ocean Industry, April and May, 1973.

(b) Diving

The scuba diving and manner submersible industry is closely allied with offshore petroleum activities. Simulated dives to 650 m by the CNEXO - Comex research programme seem to indicate the feasibility of under-water industrial work at about 500 m depth.1/

The submersible ARGYRONETE, built in France, can carry four divers and lock them out at depths as great as 330 m while deep diving from a dynamically positioned drill ship with a small Comex Marine Service submersible can now take 3 divers to a maximum work depth of 300 m.2/ Oceaneering International built the first explosion-proof 300 m saturation diving system for custom installation aboard a semi-submersible (the new SEDCO 702). Other manner submersibles operate to depths of 2000 m.

New tools and techniques are constantly being developed and perfected for underwater work and communications. Welding, photography, writing and even painting are now possible.

Sub-Sea Oil Services, S.p.A., Milan, has announced the development of a submersible vehicle for operation in 1974 with the following capabilities: 750 km underwater range, 375 m operational depth, 540-625 horsepower, 7-day endurance, 7-man capacity.

(c) Undersea Completion

There are still less than one hundred oil wells in the world which are completed with subsea wellheads but this number is expected to increase rapidly. Two new operational units which apply standard land techniques to subsea wellheads have been produced by Flopetrol (France) using remote control with minimal diver assistance to depths of 200 m with greater depths expected shortly. Standard Oil of California has been developing techniques for diverless deepwater subsea completion by means of tools lowered through the drill pipes.

Subsea production techniques may require considerable on-site maintenance if many wells are drilled with close spacing and individual well production is moderate (1,000 barrels per day). Seal Petroleum Corporation (US) has developed the manned work enclosure to permit skilled men, but not necessarily divers, to perform maintenance operations in a dry environment on the sea floor. Tests have shown these systems to be economical at water depths to 150 meters in a variety of environmental conditions.

1/ C.A. Agarate and A.J. Jegou in the 1973 Offshore Technology Conference Preprints.

2/ R. Beaufort in Under-Sea Technology, April 1973.

A total sub-sea oil well completion and production system, built by Lockheed Petroleum Services Ltd., is in operation with a 400 m depth range for placing men and well head hardware on the ocean floor.1/

A British firm, Wilson Walton International, has developed a module which permits completion of wellheads in water depths up to 300 m at atmospheric conditions.

(d) Storage and Transportation

Significant advances in techniques of laying and connecting underwater pipelines between wellheads and shore-based facilities under severe environmental conditions in the North Sea have been reported.2/

The design and construction of a one million barrel oil storage island provides a practical and economic solution to offshore crude storage and export. One of these storage tanks is being installed in the Norwegian sector of the North Sea.

New concepts in transportation emphasize economy and environmental protection. As an alternative to the supertanker, Ocean Towing Systems Inc. (US) has proposed a barge train composed of superbarges linked together in a 5-mile long chain to move crude oil in unprecedented volume.

3. Summary

Offshore petroleum technology has continued to perfect its techniques for drilling in deeper waters and in more hostile environments. Paralleling these efforts are the improvements in speed and efficiency in the gathering of detailed sea floor information. Although the exploitation of a giant oil field might be possible anywhere in the world regardless of location or water depth, the economics of drilling in deep water will continue to favour shallow water work for many years to come.

III. Recent advances in deep sea-bed mining

1. Evaluation of possible economic deposits

Recent information has made possible a more realistic assessment of potential economic nodule deposits. Extensive surveys have indicated that between 25 to 50 per cent of the abyssal plains (which total 138,000,000 km^2) and small areas in the mid ocean ridges3/ are covered with nodules. However, only a small proportion of nodule occurrences may turn out to be potential mine sites.4/

1/ W.B. Bleakly in the Oil and Gas Journal, August 7 and October 24, 1972.

2/ See 1973 Offshore Technology Conference Preprints.

3/ The process of metal precipitation and accumulation at the sea floor also takes place over large areas of the ridges. However, metal accumulation on the rocky substrate of the ridges tends to form crusts which will not be of economic interest in the foreseeable future. But in those areas of the ridge with a sedimentary substrate, such as valleys, nodule deposits have formed.

4/ See United Nations document A/AC.138/87.

A rudimentary approach to estimating the total area of potential economic nodules should begin in the general area of siliceous ooze sediments of the North Pacific, which has been identified as probably the largest concentration of high grade nodules[1/]. In this general region it is reported that nodule grade is fairly constant over wide areas (though nodule density may vary significantly) averaging about 1.25 per cent Ni, 1.0 per cent Cu and 0.22 per cent Co, while over 25 per cent of the sample analysis available contain more than 1.5 per cent Ni and 1.3 per cent Cu[2/]. The siliceous ooze region is roughly bounded by the 6° and 20° N parallels of latitude and the 110° and 180° W meridians of longitude, thus comprising an area of approximately 12 million km^2. If it is assumed that about one-third of this area is covered with high grade mineable nodules, it would mean an area of approximately 4 million km^2 of mine sites in the North Pacific. It is known that several areas of potentially economic nodules have been found in the South Pacific and the Indian Ocean, which might add 30 to 50 per cent more potential mine site area for a total of 5 to 6 million km^2. These figures are, of course, mere approximations but are thought of as realistic by some industry officials.

Several private and public organizations of many nations are actively engaged in nodule surveys in an attempt to map out the best mine sites. These surveys are quite costly and time-consuming, requiring expertise in several disciplines and the use of very sophisticated instruments to maintain accurate records of the ship's position where photographs or samples are taken. Many devices have been built to photograph and observe nodule deposits on real time closed-circuit TV. These and sampler devices are either towed by a support ship or are of a free-fall pop-up type, and may cost up to half a million US dollars.

1/ The high grade of some nodules deposits in this general region can be inferred by the following statement received with a nodule sample, courtesy of the Summa Corporation, Ocean Mining Division (Howard Hughes):

> "We are pleased to present you with a cross sectioned nickel nodule that grew on the floor of the East Central Pacific Ocean. This was recovered by trawl from a water depth of approximately 16,500 feet during our most recent 1972 general survey using the R/V SEASCOPE.
>
> It was selected on the basis of its larger size for better display purposes rather than its high metal content. This type analyse about 30% Manganese, 6% Iron, 1.4% Nickel, 1.0% Copper, 0.2% Cobalt, and 0.06% Molybdenum, and represent a medium grade ore."

2/ See Annex tables in UN document A/AC.138/87.

2. Recent Activities

Several interested groups are continuing to press on with their surveys for mine sites and developmental work in mining and metallurgical systems. Little or no information is available on the activities of some groups which, it is rumoured, have an active interest in nodules. The Soviet Union, for example, has conducted extensive surveys of nodules in the Indian and Pacific Oceans[1/]. Nothing is known, however, of plans to develop nodule mining systems in the Soviet Union. Several firms and groups from the United States, Canada, France, Japan, Germany and Australia are involved to some degree on developmental work related to location, recovery and processing of nodules. The following groups seem to be more advanced (or more information is available on their activities)[2/].

Summa Corporation - Ocean Mining Division

This firm (ex Hughes Tool) seems to have spent more funds (60 to 70 million dollars on nodule mining than any other. A 36,000 ton[3/] prototype ocean mining ship, Hughes Glomar Explorer, designed and built under the direction of Global Marine Inc. by Sun Shipbuilding and Dry Dock Company was launched in November 1972 and is presently being outfitted with mechanical and electronic equipment, much of which was manufactured and tested by Honeywell[4/]. The mining system is being built according to designs of Lockheed Missile and Space Company's Ocean Systems Division. The launching of the dredge head, its periodic servicing and possible retrieval, requires a submersible launching barge. This barge, the world's largest submarine, is the length of a football field and is covered with an oval-shaped metal roof that stands 8 stories high; it is presently docked at Lockheed's facilities in California. Global Marine has been retained to conduct nodule surveys (with research vessel R/V SEASCOPE) and provide the management for operation of ocean mining and test ships. Pilot plant tests of a metallurgical processing system is under way. It is reported that the complete mining

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1/ See G.T. Glasby, "Indian/Antarctic Nodules", in Manganese Nodule Deposits in the Pacific, Proceedings of a symposium held in Honolulu, Hawaii, October 16-17, 1972.

2/ Much of the following information was obtained from an article by A.J. Rothstein and R. Kaufman, "The Approaching Maturity of Deep Ocean Mining - The Pace Quickens", 1973 Offshore Technology Conference Preprints, pp. I. 323-344.

3/ Tonnage of "light ship displacement".

4/ "Howard Hughes backs development of complete mining system for mining ocean floor", Engineering and Mining Journal, January 1973, p. 21.

system could be ready for nodule mining tests in 1974[1/]. Commercial production might come a few years later, pending construction of a metallurgical plant[2/].

Kennecott Copper Corporation (USA)

The first nodule survey cruise of Kennecott was carried out in 1962, and over the years the company has built up a data bank of several thousand samples, and defined various alternative mine sites in the North Eastern Pacific Ocean. On the strength of its extensive metallurgical experience, Kennecott investigated a number of nodule processing techniques and is now successfully operating one pilot plant. A sizeable research programme in nodule mining techniques and systems is underway at the company's facilities in San Diego, California. As a result of this intensive development programme and scale tests, Kennecott has apparently decided on a hydraulic system for lifting the nodules from the sea floor to the mine ship. Kennecott, like Summa Corporation, contemplate mining operations of 3 to 4 million tons of dry nodules per year (15 to 20 thousand tons/day), recovering Ni, Cu, Co, Mo and several trace metals found in nodules. Marne A. Dubs, Director of Ocean Resources Department of Kennecott, recently stated that his company, and probably other US firms, could be processing deep sea-bed nodules within 30 months, if it went on a crash schedule now (May 1973)[3/].

Deepsea Ventures Inc.

This subsidiary of Tenneco Inc. (USA) has been investigating nodule deposits and mining systems since 1962. Much has been reported about Deepsea Ventures activities[4/] thanks to its intensive public information programme. Deepsea Ventures has identified several candidate ore body nodule deposits in the Pacific Ocean; has successfully demonstrated its air-lift hydraulic dredging technique, with a complete system, in 750 meters of water on the Blake Plateau; has operated several one ton/day hydro-chlorination chemical process pilot plants[5/] designed to extract, in addition to Ni, Cu, Co and trace metals, pure manganese metal. It seems that, after more than one

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1/ Ocean Science News, May 18, 1973, p. 3

2/ Paul Reeve, general manager of Summa Corporation's Ocean Mining Division, stated in a press release of November 4, 1972, that: "While commercial production operations may be several years away, we are proceeding with confidence, maintaining appropriate options and proceeding in as systematic and rapid manner as we can. It is abundantly clear that a great deal of work remains to be done".

3/ Statement in a hearing of the US Senate Interior Subcommittee on Minerals, Materials and Fuel, May 19, 1973. Reported in Ocean Science News, May 18, 1973.

4/ See United Nations documents A/AC.138/36 and A/AC.138/73.

5/ Rothstein and Kaufman, op.cit., p. I-325.

decade and 20 million dollars expenditure on development work, Deepsea Ventures and its parent company Tenneco are at the threshold of decisions on commitments of substantial funds for construction of a commercial scale nodule mining system and metallurgical plant, which could amount to more than 100 million dollars. Unlike Summa Corporation, which has access to internal funds, Deepsea Ventures and the rest of the US industry would have to borrow funds from banks or resort to stock subscription for major capital expenditure projects. It seems that in the present state of uncertainty about the legal regime to govern deep sea-bed minerals, financial institutions are not only reluctant to lend funds but also the board of directors of the companies developing nodule mining systems are not yet prepared to commit the necessary equity capital to build the mining hardware, ships and processing plants[1/].

Sumitomo Group/MITI (Japan)

Several Japanese companies and the Japanese Government have shown an active interest in nodules since 1967. The Sumitomo Group has been a major supporter of a continuous line bucket (CLB) system conceived by Yoshio Masuda. The US firm Ocean Resources Inc. (Dr. John L. Mero), has conducted exploration cruises and assisted the Sumitomo Group in developing and testing the CLB system. A deep water test of a 1/10 scale CLB system was successfully carried out in 1970 in 3,700 meters of water off Tahiti. A larger test was carried out during August-September 1972, with the financial support of 32 firms (from USA, Canada, France, West Germany, Australia and Japan). The results of this test have not been divulged but they seem to have fallen short of expectations. Repeated tangling of lines may have been partly caused by underpowered thrusters designed to move the ship sideways. The sponsors feel that these problems can be overcome and it is reported that in January 1973 Japan's Ministry of International Trade and Industry (MITI) proposed the creation of a US $220 million semi-public venture to pursue mining and processing of nodules using the CLB system[2/]. The tentative target date for commercial operation is reported to be 1977[3/]. The Sumitomo Group seems to be experimenting with a trawler-like adaptation of the CLB system designed to open the span of the cable loop at the surface while at the same time permitting the mine ship to move forward (rather than sideways). A metallurgical process to extract

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1/ This situation perhaps explains the efforts to obtain "interim legislation" from the US Congress (bills H.R. 9 and S. 1134).

2/ "Japan pushes for deep-ocean venture", Metals Week, January 15, 1973, p. 9.

3/ Ditto, p. 9.

metals from nodules, including manganese dioxide, seems to have been developed. Sumitomo Metal Mining has erected a test plant at its Sisakajima Smelter with a partial subsidy from the Agency of Industrial Science and Technology of Japan[1/].

<u>Deep Ocean Minerals Association - DOMA</u> - (Japan)

A group of 27 Japanese firms, including steel mills, engineering and trading firms, announced in April 1973 that it had established a new body to promote exploration of deep ocean mineral resources. The Deep Ocean Minerals Association will work out plans to survey and develop nodules, and will request financial assistance from the Japanese government. Participating members of DOMA include Nippon Steel Corporation, Sumitomo Metal Mining Co., Mitsubishi Heavy Industries, Mitsui and Co. and Mitsubishi Corporation[2/].

<u>AMR (Arbeitsgemeinschaft Meerestechnischgewinnbare Rohstoffe)</u>

West German commercial interest in nodules started in the late 1960's. Some of the leading German companies in metallurgy and ocean systems have formed a joint venture: AMR. The member companies of this group are: Metallgesellschaft AG, Preussag A.G. and Salzgitter AG[3/]; Krupp and Demag may soon join AMR[4/]. Another group (Interessengruppe "Meer und Technik", INTERMEER) has been established but so far has not been very active in developmental work for nodule mining. AMR has conducted nodule surveys in the Pacific in 1970, 1971 and 1972, supported by government funds. It is reported that several potential mine sites have been located in the Central Pacific with nodule grade of over 3.0 per cent combined Ni and Cu[5/]. Metallgesellschaft has successfully tested the metallurgical processing of nodules. Several alternative nodule mining systems have been suggested and are now being evaluated. The group is presently spending over 3 million dollars a year, including a considerable government subsidy, and fast progress is expected in the development of a total nodule system. AMR has recently been approached by Kennecott Copper to set up a joint venture, for which the German group was asked to contribute 30 to 50 million dollars per year, starting in 1974[6/].

1/ "Manganese Nodule Project", <u>Mining Journal</u>, June 30, 1972, p. 545.

2/ <u>Mining Journal</u>, April 13, 1973, p. 301.

3/ Wirtschaftsvereinigung Industrielle Meerestechnik e.v., <u>Marine Technology: Industries in the Federal Republic of Germany</u>, 1972.

4/ <u>Metals Week</u>, March 12, 1973, p. 10.

5/ <u>Ditto</u>

6/ <u>Ditto</u>

CNEXO - Societé le Nickel

The main French effort in commercial recovery of nodules is being conducted by CNEXO, though recently Societé le Nickel has arranged to participate in joint studies. CNEXO has conducted exploration cruises in 1970, 1971 and 1972 and seems to have located potential nodule mine sites primarily in areas close to French Polynesia[1/]. CNEXO was a participant in the CLB syndicate (1972) and is presently continuing further development work on the CLB system. They are trying to overcome some of the difficulties encountered in the 1972 test by using an auxiliary vessel next to the mine ship in order to open the cable loop as needed. Much of the scientific and technical support for the French industrial effort will be provided by CNEXO's Pacific Oceanologic Center, which was completed in the island of Tahiti in 1972.

International Nickel Company (Canada)

INCO was one of the first companies to establish a nodule study project in the early 1960's. This company has made several research cruises on charted vessels; it has supported nodule processing research and development at the University of California and done internal processing studies as well. INCO has prepared a feasibility study of nodule mining and is now studying potential hardware. INCO was a member of the CLB Syndicate in 1972 and it is reported that Mr. John Shaw, INCO's director in charge of Ocean Development, was instrumental in assisting the successful completion of the test[2/].

Finally, it may be of interest to note that some countries in the Pacific Ocean region have proposed the creation of multi-national groups to explore sea-bed resources. One such group was recently organized under the sponsorship of the Committee for Co-ordination of Joint Prospecting for Mineral Resources in Asian Offshore Areas (CCOP/SOPAC), to delineate economic nodule deposits in the Central Pacific Region[3/].

1/ Rothstein and Kaufman, op cit., p. 326.

2/ Sumitomo Shoji Kaisha Ltd., "Historical review of manganese nodule development by the Sumitomo Group", September 25, 1972, pp. 3-4.

3/ ECAFE, "Report of the Ninth Session of the Committee for Co-ordination of Joint Prospecting for Mineral Resources in Asian Offshore Areas", document E/CN.11/L.348, January 1973.

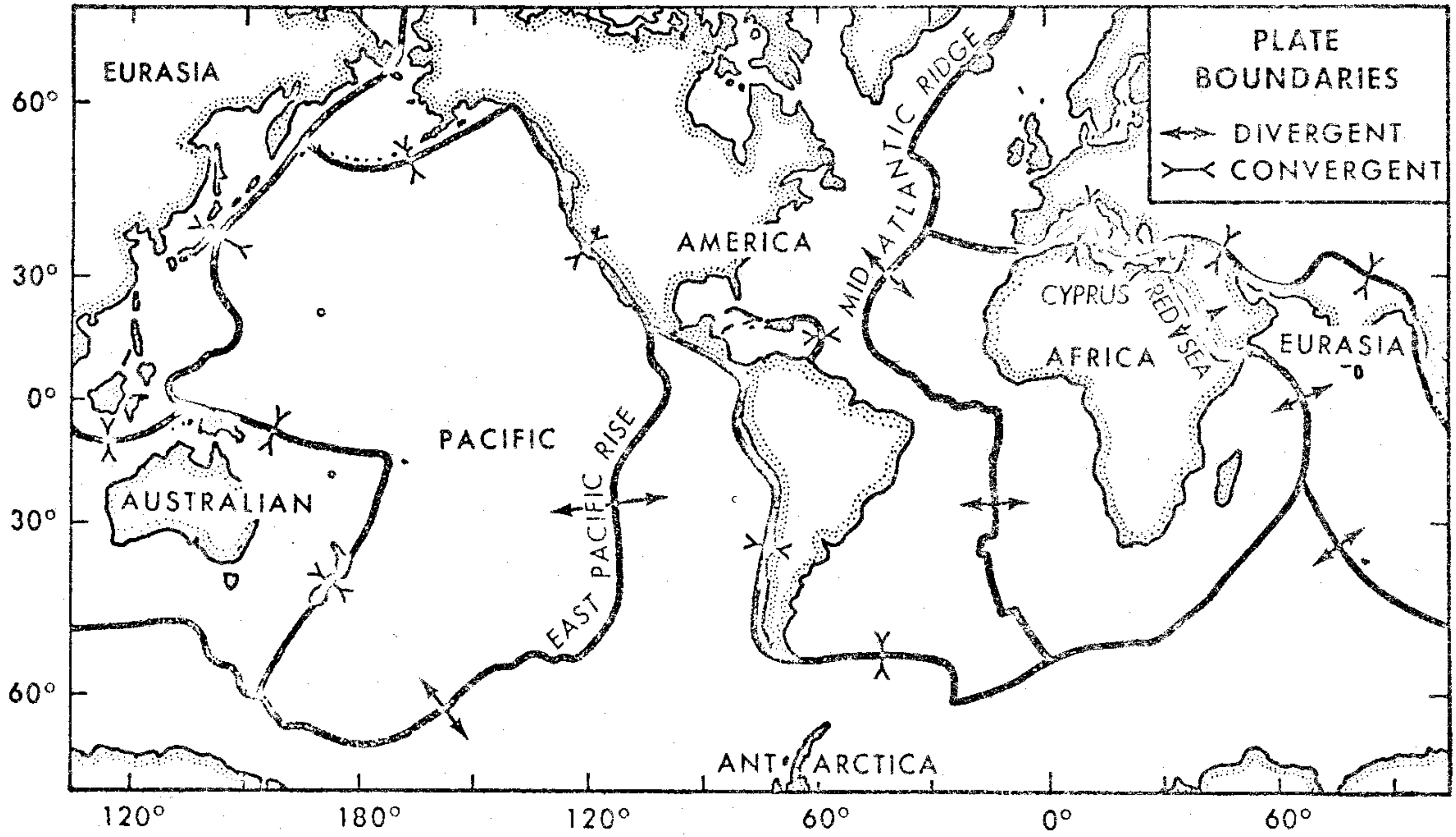

Figure 1. Boundaries of six principal lithospheric plates (after Le Pichon, 1968). Convergent and divergent plate boundaries are indicated (after Isacks et al., 1968).

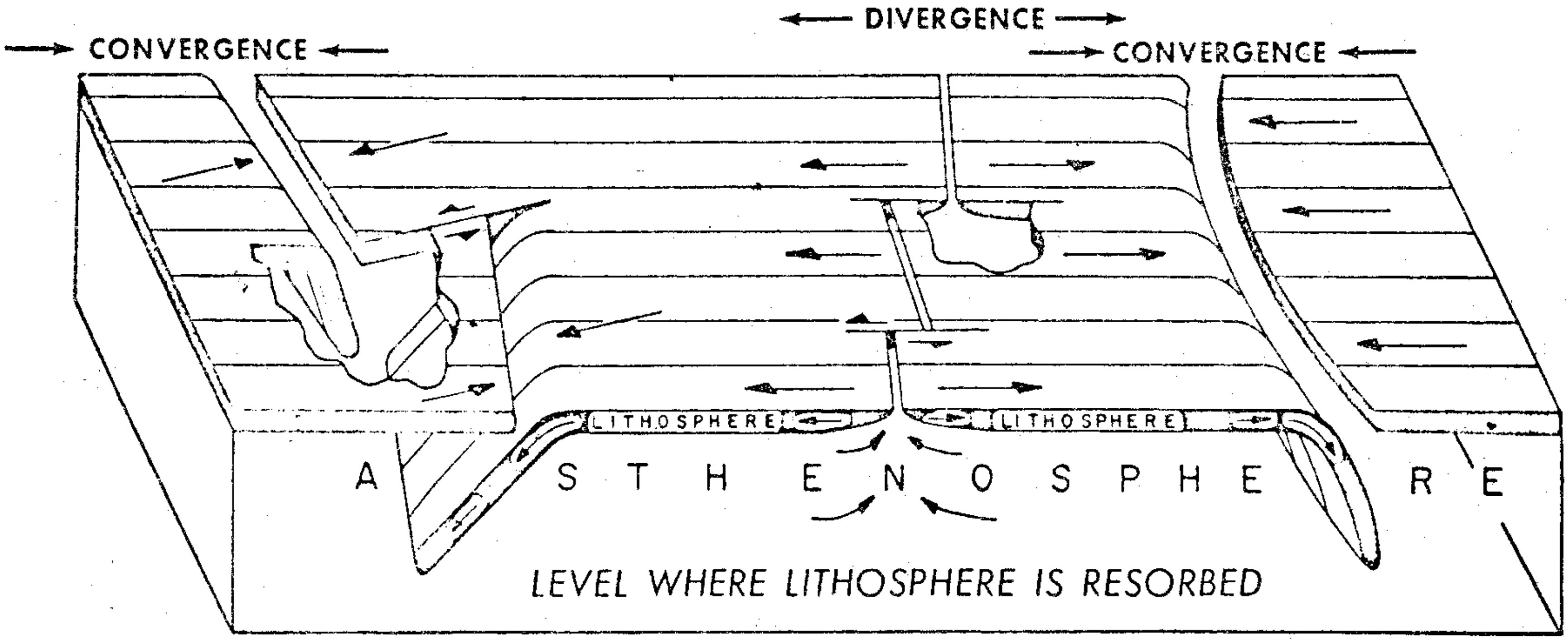

Figure 2. Block diagram illustrating schematically how convergent and divergent lithospheric plate boundaries work (after Isacks et al., 1968). One-hundred-kilometer-(60-mile)-thick lithospheric plates move like conveyor belts from mid-ocean ridges (divergent plate boundaries) and plunge downward beneath deep-sea trenches (convergent plate boundaries).