

Notes and Comments

Exploration for Polymetallic Nodules in the Indian Ocean

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Abstract *A study of polymetallic nodules in the Indian Ocean taken up as an R & D Project has been extended into an exploratory programme for nodule resources. Recognition of India as a Pioneer Investor by the UNCLOS led to the acceleration of the programme to meet time targets. Planning and coordination ensured accuracy and success of the programme by diversification of available expertise and procuring vessels and equipment from the international market. With this approach it has been possible within a period of four years to survey an area of 4 m. sq. km. and file a claim with the U.N. for a pioneer area in the Central Indian Ocean in January 1984. A revised application submitted in July 1987 has been considered by the General Committee of the Preparatory Commission, and India became the first pioneer investor to be registered for the development of a mine site in the international seabed area.*

Introduction

On-shore resources of manganese, copper, nickel and cobalt are limited, and the future requirements of these metals will be met by alternate sources, such as the discovery of new deposits, substitutions, and by conservation and technological advances or by the polymetallic nodules from the ocean bed. The National Institute of Oceanography (NIO) under the Council of Scientific and Industrial Research (CSIR) initiated planning for the surveys for polymetallic nodules as a research and development (R & D) project in the mid 1970s. The research vessel *R V Gaveshani* during the cruises 86 and 87 in January 1981 collected polymetallic nodules in the Indian Ocean. The project attained great importance due to the metals present in the nodules.

Indian Interests

The reserves of manganese, copper, nickel and cobalt in India, their domestic demand, export/imports, and production are shown in Tables 1, 2, 3, 4 and 5. Though traditionally regarded as an exporter of manganese ore, the present rate of production will deplete the deposits to negligible reserves within a period of 20 years. India imports about 65% of its copper requirements and 100% of its nickel and cobalt.

Exploration on land for these metals has been continuing, but no significant deposits

Table 1
Estimated Reserves as of April 1986 (Million Metric Tons)

Ore/metal	Proved	Probable	Possible	Total
Manganese	18	31	86	135
Copper (estimated content of recoverable metal)	1.8	2.5	2	6.3
Nickel ore (with cut off grade 0.7 to 0.8% and average grade 1%)	16.7	59.5	84	160.2
Cobalt not estimated			

Source: Indian Bureau of Mines, Nagpur, Ministry of Steel and Mines, Government of India.

were added in the recent past (except for the nickeliferous laterites that have not been mined due to their complexity in character and inconsistency in composition¹). India's per capita consumption of these metals is substantially lower than that of the industrialized countries as well as the world average and even low compared to other developing countries. In a bid towards industrialization, India laid ambitious projects to expand the industrial, transportation, power, and communication sectors which are expected to grow rapidly in the future.² The present low-level consumption of the nodule type minerals which are vital for industrial development will substantially increase in the years to come. The estimates of the demand and growth rates computed by Manjula Shyam suggest that even with a modest increase in consumption, India will have to make large outlays of foreign exchange in order to purchase non-ferrous metals.³ Thus a slight increase in the per capita consumption places India high as a potential consumer of these metals.

Preparatory Commission and Pioneer Investors⁴

Resolution I that was annexed to the United Nations Convention on the Law of the Sea in the final session of the Third United Nations Conference on the Law of the Sea established the Preparatory Commission (Prepcom) to draw up the rules, regulations, and procedures for the International Seabed Authority (ISA) and the International Tribunal on the Law of the Sea (ITLOS). This Prepcom came into existence upon signature or accession to the Convention by 50 states within a period of 60 to 90 days. In fact 117 states and two other entities signed the Convention on December 10, 1982, and Prepcom held its first meeting in March, 1983.

Table 2
Projected Domestic Demands^a (Thousand Metric Tons)

Metal	1986-87	1990-91
Manganese ore ^b 7000	
Copper	122	148
Nickel	11.62	14
Cobalt	N.A.	N.A.

Source: Indian Bureau of Mines, Nagpur, Ministry of Steel and Mines, Government of India.

a: As per planning Commission subgroup estimates.

b: Projected for 7th Five Year Plan period.

N.A.: Data not available.

Table 3
Exports^a (Thousand Metric Tons)

Ore/metal	1983-84	1984-85
Manganese ore	405	646

a: As per MMTC report.

Resolution II designates as pioneer investors France, India, Japan, and the USSR because these states signed the Convention and before January 1, 1983 expended an amount equivalent to at least US \$30 million in pioneer activities. India signed the Convention, met the investment criterion, and has been recognized as a pioneer investor.

Acceleration of the Programme

After establishing the Prepcorn, a time schedule was adopted that involves various steps leading to the authorization of production. These steps are in two series, and each step follows its precedent as connected in Figure 1.

- (1) Establishment of Preparatory Commission (Prepcorn) for the International Seabed Authority (ISA) and International Tribunal on the Law of the Sea (ITLOS) under Resolution of the Final Act.
- (2) Prepcorn came into existence after 60 days and no later than 90 days of signature or accession to the convention by 50 states (on December 10, 1982, 117 states and two other entities signed the Convention).
- (3) Prepcorn began to function, and any state that signed the Convention and met the investment criterion was enabled to apply for registration as a Pioneer Investor.
- (4) The Commission within 45 days designates one part of the area to be reserved in accordance with the Convention for ISA and allocates the other to the Pioneer Investor as a pioneer area.
- (5) The Pioneer Investor is to relinquish 20% of the area allocated by the end of the third year from the date of allocation.
- (6) An additional 10% of the area allocated is to be relinquished by the end of the fifth year from the date of allocation.
- (7) An additional 20% of the area allocated is to be relinquished or such larger amount as would exceed the exploitation area decided upon by the Authority after eight years from the date of allocation of the area or the date of the award of the production authorization, whichever is earlier.
- (8) Prepcorn prepares draft rules, regulations, and procedures as necessary to enable the Authority to commence its functions.

Table 4
Imports (Thousand Metric Tons)

Ore/Metal	1981-82	1982-83
Copper Metal, alloys & scrap	141	117
Nickel Alloys & scrap	13.379	10.586
Cobalt	0.107	0.113

Source: Indian Bureau of Mines, Nagpur, Ministry of Steel and Mines, Government of India.

Table 5
Production During 1985

Ore/metal	Quantity (Thousand metric tons)
Manganese ore	1240
Copper metal	35.557
Blister electrolytic	18,270
Nickel	Not produced
Cobalt	Not produced

Source: Indian Bureau of Mines, Nagpur, Ministry of Steel and Mines, Government of India.

- (9) Deposition of 60 ratifications of the Convention with the Secretary General of the United Nations.
- (10) The Convention comes into force and effect one year after 60 ratifications are deposited.
- (11) A Pioneer Investor so registered applies to the Authority for approval of a plan of work for exploration and exploitation in accordance with the Convention within six months of its entry into force.
- (12) The Authority approves the application of the plan of work for exploration and exploitation if it satisfies the rules, regulations, and procedures of the Authority.
- (13) The Pioneer Investor notifies the authority that it will commence commercial production within five years.
- (14) Production authorization is issued within 30 days of notification.

After coming into existence (step 2), the Prepcom had a dual responsibility of registering the Pioneer Investors (step 3) and allocating the Pioneer area (step 4), on one hand, and preparing the draft rules, regulations, and procedures necessary to enable the Authority to commence its functions (step 8) on the other.

The relinquishment of the area at various stages (steps 5, 6, and 7) is connected to step 4, as the time frame for relinquishment is stipulated from the data of allocation of the Pioneer area. Relinquishment of an additional 20% of the area allocated at step 7, however, is also dependent on the date of the production authorization if it is issued earlier than the stipulated time for relinquishment, i.e., after eight years from the date of allocation to the Pioneer area.

The Prepcom held its first session during March 15–April 8, 1983 and its second

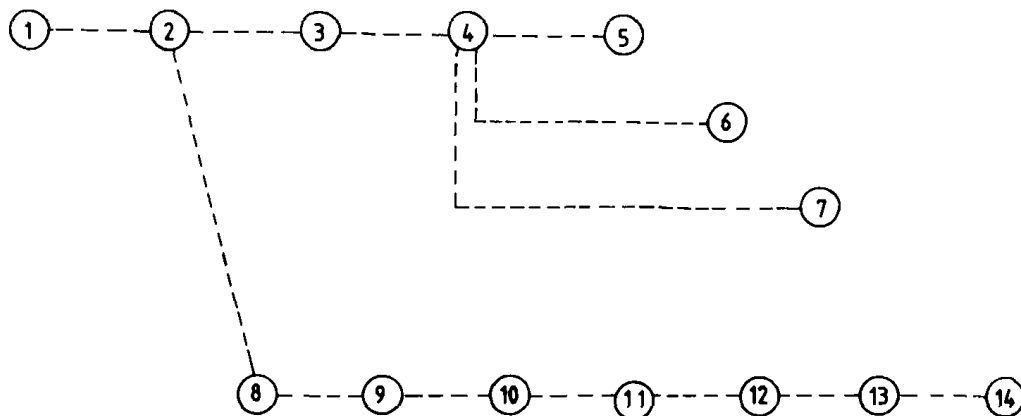


Figure 1.

during March 19–April 13, 1984, when it was decided to accelerate the work so as to begin registering the Pioneer Investors. India, one of the recognized Pioneer Investors, had the opportunity to submit an application for registration. The Indian programme for exploration was accelerated to demarcate an area of 300,000 sq. km. as a basis for filing a claim for a Pioneer area.

Financial Support

Science and technology in India are state activities. Organizations like the CSIR, Indian Council of Agricultural Research, and the Indian Council of Medical Research are financed and controlled by the Government through the Ministries of Science and Technology, Agriculture, and Health. The other departments involved in highly sophisticated and advanced technology areas such as the Department of Electronics (DOE), Atomic Energy (DAE), Ocean Development (DOD) and Space (DOS) are under the Government. Organizations such as the Oil and Natural Gas Commission (ONGC) and the Geological Survey of India (GSI), which are involved in petroleum and mineral exploration, are Government bodies. Funding and monitoring of the development of science and technology are state controlled functions and are dependent on the overall policy formulated by the Government.

In the initial stages, the nodule project started as an R & D activity with the existing facilities in the NIO and with the funds provided by the CSIR. Once the DOD was established in 1982, however, and the decision was taken to accelerate the exploration programme, DOD became the major source of funding. Funds for chartering vessels, purchasing equipment and for consultation were provided by the DOD whereas the CSIR contributed man power and infrastructural facilities (Table 6).

Planning

The first stage of planning of the surveys involved the collection of the existing data and literature on the polymetallic nodules in the Indian Ocean.^{5,6} The nodules cover an area

Table 6
Source of Inputs

Year	Man-power	Equipment		Vessels		Infra-structural facilities	Consultancy
		Expl.	Anal.	Ind.	Chart.		
Up to 1981	C	C	C	C	—	C	—
1982	C	C,D	C,D	C	D	C	D
1983	C	D	C,D	D	D	C,D	D
1984	C	D	C,D	D	D	C,D	D
1985	C	D	C,D	D	D	C,D	D
1986	C	D	C,D	D	—	C,D	D
1987	C	D	C,D	D	D	C,D	D

Expl—Exploration

Anal—Analytical

Ind—Indian

Chart—Chartered

C—CSIR

D—DOD

of 10–15 million sq. km. The evaluation of the data indicated that there are only about 120 chemical analyses available in the published literature and over 700 unpublished analyses in data banks, i.e., an analysis is available for 12.5 thousand sq. km. In addition to the collection of data, samples of nodules obtained from Oceanographic Institutes of other countries, such as the Institute of Oceanology of the Academy of Sciences of the USSR, the Scripps Institute of Oceanography, the Woods Hole Oceanographic Institution, and the Lamont Doherty Geological Observatory were also analysed. On the basis of the compilation of all the available data, maps showing the distribution of the deposits into paramarginal (Ni + Cu + Co 2.47%), sub-marginal (Ni + Cu + Co 1.63 – 2.47%), and marginal were prepared and used in identifying the target areas for exploration (Figure 2). The analyses of the available data indicated that para-marginal deposits in the Indian Ocean occur mainly in the Central Indian Ocean Basin (CIOB) and some small deposits in the other basins.

This was followed by an intense study of the exploration programmes in the Pacific Ocean to estimate the quantity of work. The study indicated that the initial surveys in the Pacific were carried out at a spacing of about 100 km, and these were followed by surveys at 50, 25, and even 10 km. This led to an estimation that the total ship-time required for the reconnaissance surveys was of the order of over 1000 ship days.

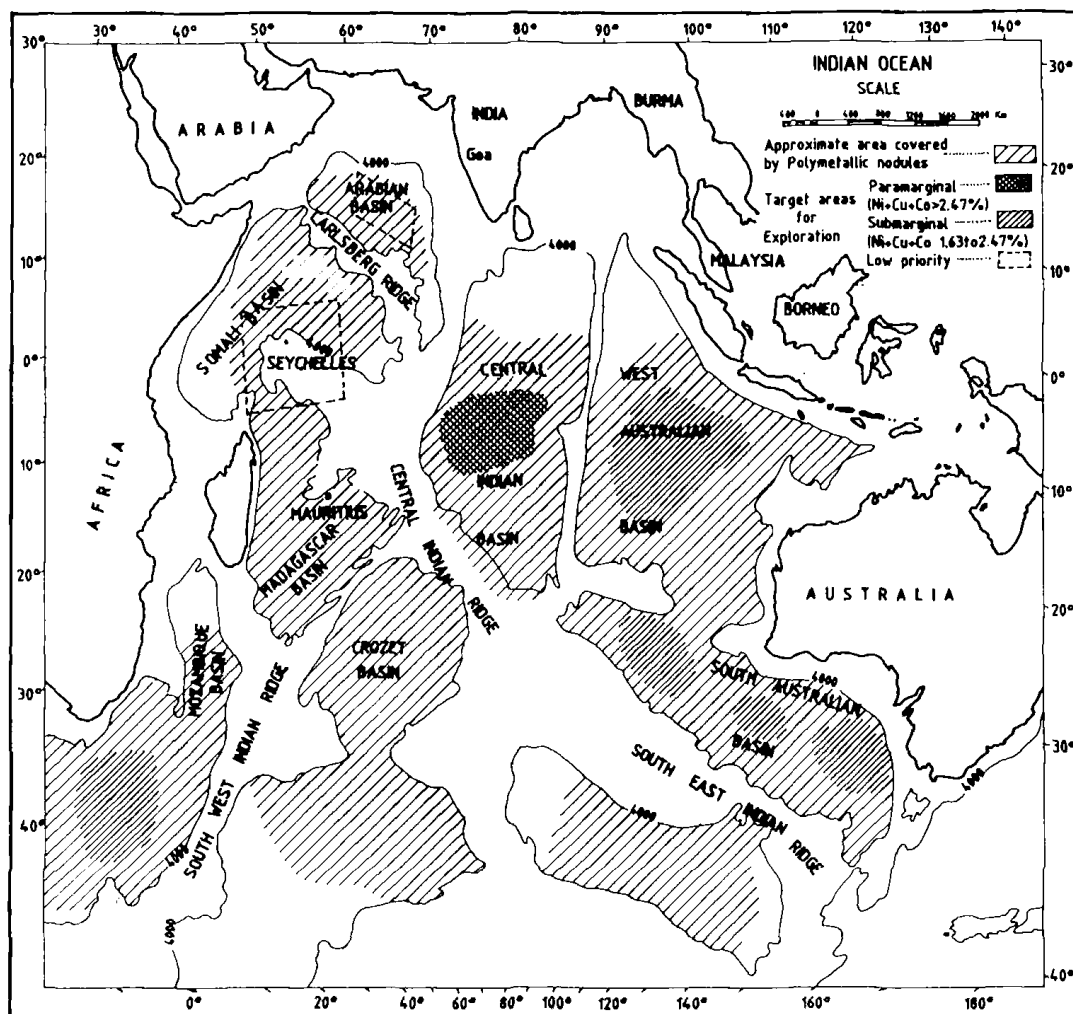


Figure 2.

Requirements for Surveys

The requirements for surveys are (1) Manpower, (2) Equipment and (3) Vessels.

Manpower

The Institute in 1981 had 18 Geologists, 5 Geophysicists, 4 Marine Surveyors and 6 Electronic Engineers besides Physical, Biological and Chemical Oceanographers. Over the years these had acquired extensive shipboard experience for the surveys carried out for the Institute's R & D projects⁷ as well as the time-targeted projects for the Oil & Natural Gas Commission and the various ports and harbours. The projects include surveys for living and non-living resources, physical and chemical oceanographic parameters and environmental studies extending from continental shelf regions to deep seas. With the chartering of additional vessels to accelerate the surveys, additional staff has been recruited. The newly recruited staff (20 geologists, 4 Geophysicists, 10 Oceanographers, 10 Electronics Engineers/Technicians and 10 Marine Surveyors) along with the senior trained personnel (pre-1981) as the nucleus, formed teams for the surveys and cruises.

Equipment

The most important components of the equipment were position fixing systems, deep bathymetric systems, deep sea winches, sampling equipment and underwater cameras.

These were to be procured from the world market. The specifications of the equipment drawn up by a committee of technicians, engineers (operation and maintenance), and oceanographers (users) were advertised in the trade columns. Quotations received from various manufacturers were scrutinized, and those not meeting the requirements were rejected. The short listed offers were studied in great detail by a group of experts and suitable systems selected based on the utility potential and cost effectiveness.

Vessels

In 1981 the Institute had only research vessel *Gaveshani* which had limited endurance. An examination indicated that if this vessel had to be used, each cruise would be limited to no more than 20 days. To complete the surveys in a stipulated period, therefore, additional vessel or vessels would have to be chartered from the international market. Thus at various stages three vessels were chartered (one vessel repeating for a second time) from the global market. Specifications such as laboratory facilities, deck space, cranes, A frame, jib boom and accommodation for scientists and technicians of a suitable vessel were listed, and quotations were invited. These quotations were screened by a committee represented of DOD, NIO, shipping Corporation of India, and other maritime agencies. The selection was based on these criteria: (1) vessel satisfying all the specified requirements; (2) vessel's stability and capability of positioning for various operations; (3) fuel economy and endurance; and, (4) cost effectiveness. This chartering was considered as a stop-gap arrangement until the country's own multidisciplinary oceanographic research vessel, *Sagar Kanya*, which was being built with FRG assistance, was delivered. Chartering continued, however, even after *Sagar Kanya* was delivered, as a large quantity of work had to be completed.

Table 7
Role of Participating Organisations

Organisation	Exploration	Chemical Analysis	Studies Related to Mining	Studies Related to Metallurgy	Data Processing
I. COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH					
a. National Institute of Oceanography*	+	+	-	-	+
b. Regional Research Laboratory, Bhubaneswar#	+	+	-	+	-
c. National Geophysical Research Institute#	+	+	-	-	-
d. Operational Research Unit (CSIR)	-	-	-	-	+
e. National Metallurgical Laboratory#	-	+	-	+	-
f. Central Mining Research Station	+	-	-	-	-
g. National Chemical Laboratory	-	+	-	-	-
h. Regional Research Laboratory, Jorhat	+	-	-	-	-
II. OTHER GOVERNMENT R & D AND SURVEY ORGANISATIONS					
a. Geological Survey of India#	+	+	-	-	-
b. Indian Bureau of Mines#	+	+	-	+	-
c. India Meteorological Department	+	-	-	-	-
d. Defence Research & Development Organisation	+	-	-	-	-
e. Naval Physical Oceanographic Laboratory	+	-	-	-	-
f. Indian Institute of Geomagnetism	+	-	-	-	-
g. Bhabha Atomic Research Centre	-	+	-	-	-
h. Central Water & Power Research Station	-	-	+	-	-
i. Centre for Earth Science Studies	+	-	-	-	-
j. Physical Research Laboratory	+	-	-	-	-

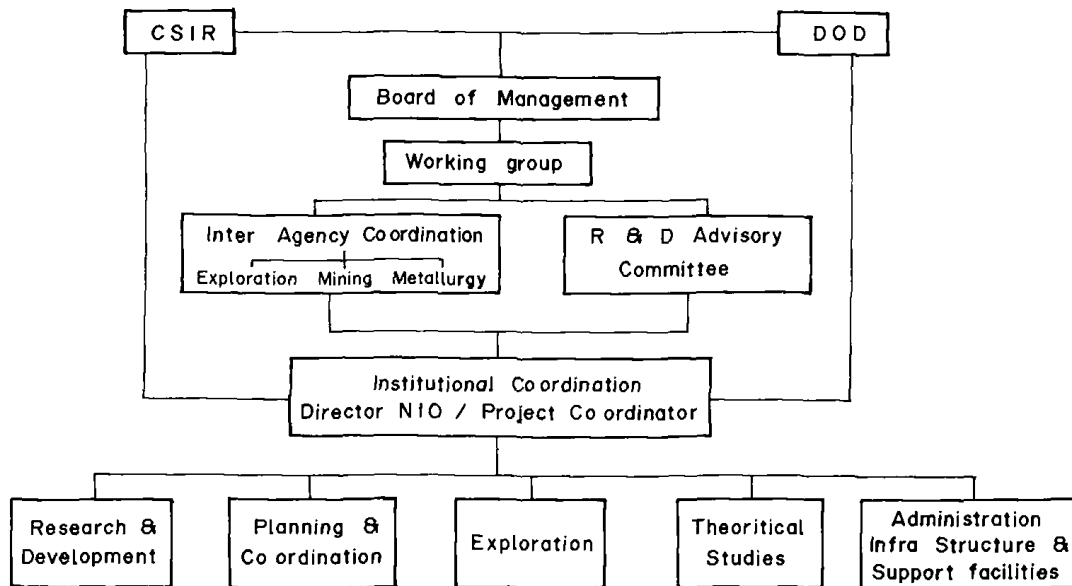
III. PUBLIC SECTOR UNDERTAKINGS						
a. Hindustan Zinc Limited#	-	+	-	+	-	-
b. Hindustan Copper Limited#	-	+	-	+	-	-
c. Engineers India Limited#	-	-	+	-	+	-
d. Metallurgical & Engineering Consultants (India) Limited#	-	-	-	-	-	-
e. Bharat Heavy Electricals Limited	+	-	-	-	-	-
f. Mazagon Docks Limited	-	-	+	-	-	-
IV. UNIVERSITIES						
a. Andhra	+	-	-	-	-	-
b. Cochin	+	-	-	-	-	-
c. Mangalore	+	-	-	-	-	-
d. Pune	+	-	-	-	-	-
e. Anna	+	-	-	-	-	-
f. Tuticorin	+	-	-	-	-	-
g. Venkateswara	+	-	-	-	-	-
h. Calcutta	+	-	-	-	-	-
i. Aligarh	+	-	-	-	-	-
j. Delhi	+	-	-	-	-	-
k. Jadavpur	+	-	-	-	-	-
V. INDIAN INSTITUTE OF TECHNOLOGY						
a. Madras	+	-	+	-	-	-
b. Bombay	+	-	-	-	-	-
VI. OTHER EDUCATIONAL INSTITUTES						
a. Goa Polytechnic	+	-	-	-	-	-
b. Dhempe College	+	-	-	-	-	-

+ involved; *lead agency; # major role

ORV Sagar Kanya was the result of the joint effort of the Indian and West German governments within the frame-work of Indo German Economic co-operation. The government of FRG through its Ministry of Economic co-operation extended financial cooperation (construction of the vessel) and technical co-operation (scientific equipment fitted on *Sagar Kanya*) to the government of India. The vessel has been designed and equipped with most modern and sophisticated equipment in order to perform tasks with maximum possible efficiency. The vessel is capable of carrying out geo-scientific, meteorological, biological, physical, and chemical oceanographic research. She has four laboratories on the second deck, five on the main deck, and four on A and B decks, equipped with basic equipment (both sampling and analytical for oceanographic research).⁸ *Sagar Kanya* was delivered to the Department of Ocean Development, Government of India on March 25, 1983. She has completed more than 30 cruises collecting oceanographic data and samples of the seabed, water column, plankton and fish from different depths and environmental data including meteorological parameters.

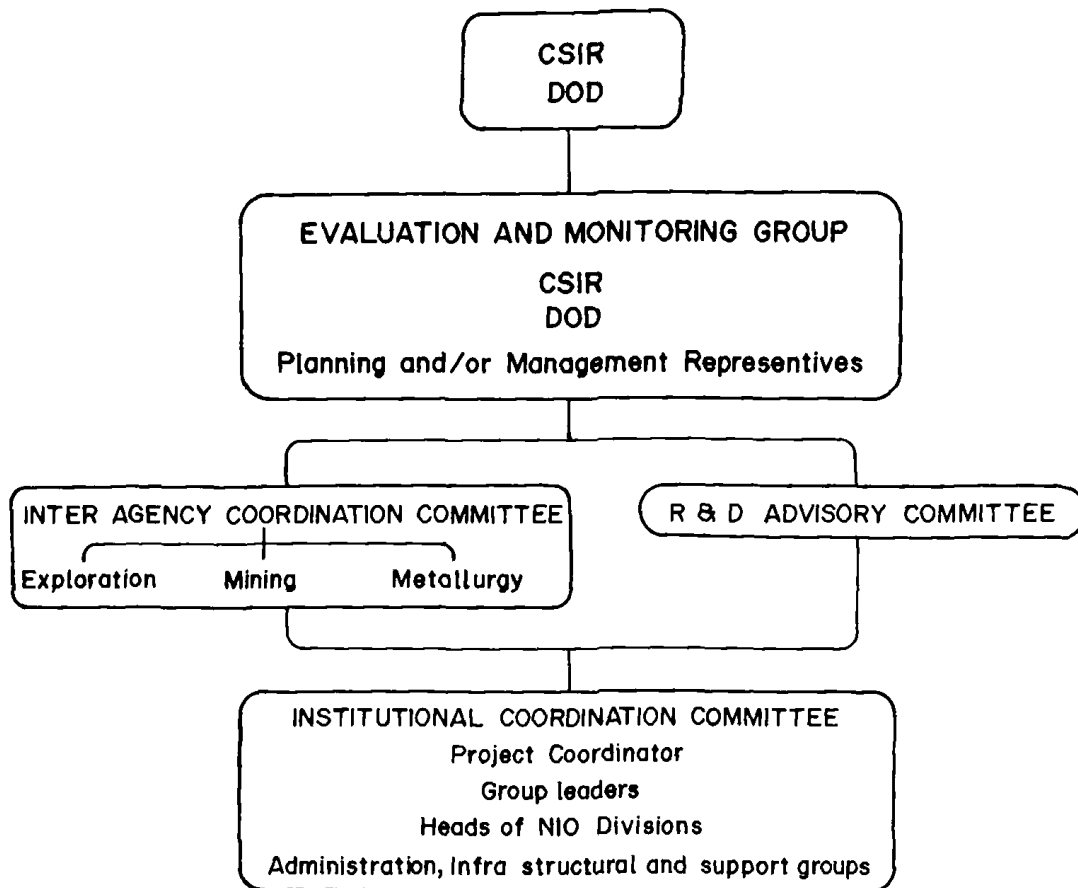
Management

The ultimate exploitation of polymetallic nodules would involve exploration, mining, and metallurgy. Since a decision was taken that the programme has to be accelerated, a study was carried out of the programmes operated by other countries for polymetallic nodules in the Pacific Ocean. An analysis indicated that the programmes do not involve a single organisation but are being operated by a consortia of companies specializing in different fields. Clearly many of these specializations lay outside the purview of a single institu-



Abbreviations : CSIR : Council of Scientific and Industrial Research
 DOD : Department of Ocean Development
 NIO : National Institute of Oceanography

Figure 3. Exploration for polymetallic nodules national and institutional coordination



Abbreviations = CSIR - Council of Scientific and Industrial Research
DOD - Department of Ocean Development

Figure 4. Exploration for polymetallic nodules national and institutional coordination

tion and in ensuring the success of the programme, association with other institutions or agencies was desirable. India, with a wide base of scientific manpower and a chain of laboratories specializing in diverse fields under the CSIR, provided an alternate programme for exploration and exploitation of polymetallic nodules by forming an association similar to the consortia between the laboratories of the CSIR and different organizations. In all 39 laboratories and organisations were involved of which ten played a major role in collection and analysis of data (Table 7).

This necessitated a system of coordination both at national and institutional levels (Figures 3 and 4). Since the analytical work was being carried out by a number of laboratories in order to ensure the accuracy of analysis, an Indian Ocean polymetallic nodule sample standard was prepared, and each sample was analyzed by more than two laboratories.

The initial planning and coordination ensured that not only the work would be carried out smoothly and with the desired accuracy but the time targets could also be adhered to. With this approach it has been possible within a period of four years to survey an area of 4 million sq. kms. and to file a claim for a pioneer area in the Central Indian Ocean Basin on January 12, 1984.

Conclusions

India's participation in ocean exploration gives an opportunity to build up capabilities in this technologically advanced area. In its bid to become self-sufficient in high technology areas, India is likely to continue vigorously its deep seabed exploration programme. Even after the application was filed in January, 1984, surveys continued, and a revised application was submitted in July, 1987. With the decision of the General Committee of the Preparatory Commission which met on August 17, 1987, India has been registered as a Pioneer Investor, and an area of 150,000 sq. kms. has been allocated as a pioneer area to the Government of India. The surveys in the future would be concentrated in the area of allocation for determining the areas to be relinquished and development of a mine-site. The next phase of the programme involves the preparation of the application for the approval of the work plan for exploration and exploitation.

Indian efforts indicate that the initial development of institutional capabilities and infrastructure takes a longer time, but once the base is developed and a nucleus of expertise formed, diversification to other related areas takes less time.

Acknowledgments

The exploration for polymetallic nodules in the Indian Ocean was carried out with the financial support from the Department of Ocean Development under their Polymetallic Nodules Programme. This paper has greatly benefited by the reviewer's comments.

Notes

1. Sahu, K.C., "Mineralogical Monitoring for Optimum Exploitation of Lateritic Nickel Ores in India" in National Mineral Convention—1981, Federation of Indian Mineral Industries, 1981, p. 129.

2. As per the 7th V year plan budget allocations made (Rs. in million) Industry and minerals—2246.083 (12.48%), Transport—2297.102 (12.76%), Communications, Information and Broadcasting—647.246 (3.6%). Percentage indicate the public sector outlay.

3. Manjula R. Shyam., "Deep Seabed Mining: An Indian perspective." *Ocean Development and International Law* 17(4): 325–349.

4. Final Act of the Third United Nations Conference on the Law of the Sea. *The Law of the Sea* (New York, United Nations, 1983): 177–182.

5. Siddiquie, H.N., D.R. Das Gupta, N.R. Sengupta, P.C. Shrivastava, and T.K. Mallik, "Manganese—Iron nodules from the Indian Ocean". *Indian Journal of Marine Sciences*, vol. 7, (1978) 233–253.

6. Siddiquie, H.N., and G.V. Rajamanickam. "Surficial mineral deposits of the continental shelf of India". *Proceedings of the International Seminar on the Offshore Mineral Resources, Orleans, (France), Documents BRGM*, 7, (1979), 233–258.

7. Besides the nodule project NIO is involved in

- (i) Coastal zone management
- (ii) Oceanography of the Northern Indian Ocean
- (iii) Remote-sensing of oceanographic features/parameters
- (iv) Ocean modelling
- (v) Chemical oceanography and marine environmental studies in the seas around India
- (vi) Bioactive substances from the seas around India
- (vii) Regional geological, geophysical, paleoclimatic and foraminiferal studies of the continental margins of India
- (viii) Assessment, evaluation and generation of biological resources in the seas around India
- (ix) Studies on the marine fouling, wood preservation, and corrosion along the Indian coast

- (x) Evolution of environmental parameters for the development of off-shore oil fields and coastal works
- (xi) Development of marine instrumentation systems including data buoys

8. *ORV Sagar Kanya* is capable of operating in all weather conditions including the monsoon period and is provided with all facilities to perform worldwide voyages up to 10,000 sea miles. The vessel is equipped with fin stabilisers improving the behaviour of the ship even in rough seas. The twin screw propulsion, two fin rudders, and bow thrusters give the vessel excellent manoeuvring ability. A navigation computer is fixed which receives data from satellite navigator, omega, decca and other radio navigation systems and also from compass, echo-sounder, echolog and doppler as well as from all essential scientific appliances. From this computer system it is possible to combine gross data with navigational data and output can be taken on magnetic tapes in whichever combination is required.

Major scientific equipment on *ORV Sagar Kanya* include

- (i) Integrated satellite navigation system
- (ii) General purpose computer system
- (iii) Multipurpose data logging system
- (iv) Under water T.V.
- (v) Under water still photography system
- (vi) Various dredges, corers and other samplers
- (vii) Marine magnetometer
- (viii) Marine gravimeter
- (ix) 24-channel digital seismic equipment
- (x) Side scan sonar with sea floor mapping system
- (xi) 3-frequency narrow beam echosounder
- (xii) Shallow water echosounder
- (xiii) Radiosonde equipment
- (xiv) CTD-O profiling system
- (xv) Combined wind weather radar
- (xvi) Meteorological buoy
- (xvii) Various analytical equipment