

Benthic Environmental Baseline Investigations in the Manganese Nodule Area of the Central Indian Basin

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ABSTRACT

In order to exploit the manganese nodule deposits in future, an assessment of the environmental impact due to potential mining activity, has been undertaken in the Central Indian Basin. Under this programme, seabed surveys in five selected areas have been conducted to study the bathymetry, nodule distribution and benthic fauna. Each of the areas, having dimensions of 10x10 nautical miles, has a total relief of 160-200 m with variable undulations (30-60 m) and few elevated features (50-100 m). The sites with relatively flat topography have higher sediment thickness (50-100 m) than those with uneven topography (20-35 m).

Nodules in areas of thicker sediment cover have low abundances (32 out of 39 locations: <3 kg/sq.m, average abundance: 1-2 kg/sq.m), as compared to those with relatively thin sediment cover, (11 out of 25 locations: 5-12 kg/sq.m, and average abundance: 3.5-5.0 kg/sq.m). Almost all nodules appear to be buried under these sediments. Nodule exposure ranges between 0 and 2%, except in one station with 50% coverage.

The sediment underlying the nodules is predominantly radiolarian ooze with occasional burrows (mainly thalassinoid type). Out of the 22 cores studied for benthic activity, five displayed pronounced layered structure in the top (8-15 cm) layer and a comparatively coherent sub-layer (below 15 cm). In three cores, evidence of partial induration/lithification has been noticed, leading to hard ground formation.

Quantitative estimates of deep-sea benthos recorded from core samples indicate moderately rich fauna. The meiofauna density ranges from 3-45/10 cm², dominated by Nematoda. Similarly, the macrofaunal density ranges from 2-16/0.25 m² and was dominated by Polychaeta (>50%). The ratio of macro- to meiofauna in the total population was 1:500.

KEY WORDS: Nodules, benthic environment, baseline studies, Indian Ocean.

INTRODUCTION

Several studies have been carried out in the Pacific Ocean, such as DISCOL (German), BIE (American), and JET (Japanese). All of them have focussed on selecting a test site and monitoring large-scale experimental pre- and post-disturbance environmental conditions (Fueh, 1990; Trueblood, 1994; Fukushima, 1995).

In order to evaluate the potential environmental impact due to nodule mining, a multidisciplinary program, named as the 'Indian Deepsea Environment Experiment' (INDEX) was initiated in 1995 in the nodule area of Central Indian Basin.

In this program, baseline studies have been carried out for collecting information on various parameters of the seafloor in the Central Indian Basin. This information will be used to identify potential test and reference areas as well as to assess the existing conditions on the seafloor.

MATERIALS AND METHODS

Bathymetric maps generated from hydrosweep surveys in the Central Indian Basin were used to select five study areas (Fig. 1). Each one covers an area of 10x10 nautical miles. Their co-ordinates are as follows:

T1 : 10°00' - 10°10'S, 75°10' - 75°20' E
R1 : 10°00' - 10°10'S, 75°35' - 75°45' E
A1 : 10°00' - 10°10'S, 75°55' - 76°05' E
T2 : 12°15' - 12°25'S, 75°45' - 75°55' E
R2 : 11°55' - 12°05'S, 76°00' - 76°10' E

Four cruises were conducted onboard RV A.A. Sudarshana during April-May, 1996 and September-October, 1996 for the collection of benthic baseline data. The study areas were surveyed by echosounding, sub-bottom profiling, as well as by box corers and Ocean grabs with camera for nodule and sediment samples (Fig. 2). The photographs (Fig. 3) were evaluated for nodule coverage and seafloor features, such as sediment cover, nodule exposure and biological activity.

From the core samples, the overlying water was siphoned off and the interface water was collected with syringes in small plastic bottles. Four large PVC tubes with a diameter of 15 cm were inserted into the box and the sediment was retrieved for porewater studies. Tubes with 10 cm diameter were inserted for geochemical, micropaleontological, sedimentological and geotechnical studies. All the sediment cores were uniformly sectioned at 0-2 cm, 2-4 cm, 4-6 cm, 6-8 cm, 8-10 cm, 10-15 cm and 15-20, 20-25, 25-30 cm intervals for porewater studies.

Macrobenthic (~0.5 mm in size) samples from 29 grabs and 16 box cores and meiobenthic samples from 16 box cores were collected during these cruises. A sub-core (diameter 4.5 cm, length 10 cm) was taken from box-cores after removing the supernatant water and sub-sampled at 2 cm intervals. The sediment was sieved through a mesh size of 0.5 mm and 0.062 mm for separating meiobenthos from macrobenthos. All samples were preserved in Rose-Bengal formalin (5%) buffered solution for further analysis. Sorting and counting of the samples were completed under binocular microscope.

RESULTS

(a) Bathymetry

The echosounding records were digitised and merged with ship's navigation data, and depth contours were plotted. In general, the depths in the study areas range between 5120m and 5400m, each having a specific range, average and standard deviation (Table 1). In the northern areas (T1, R1 and A1), the topography is gently undulating with reliefs of 30-40 m, and a few knolly features of 50-100 m relief. The undulations in the southern areas (T2 and R2) are higher (50-60 m), more abundant and have more peaks.

The morphometric analyses show lower average slope angles in longitudinal (1-1.4 degrees) as well as latitudinal (0.68-0.93 degrees) directions in the northern areas, compared to those in the southern areas (1.67-1.76 degrees in longitudinal, and 1.02- 1.36 degrees in latitudinal direction). The average vertical difference between 1 minute positions in northern areas is lower (12-22.6m) than in the southern areas (14.2-30.5m) in longitudinal as well as latitudinal directions. The average number of peaks (>10 m) in the northern areas are also less (2.9-4.7), as compared to southern areas (4-7.8).

Whereas the depths do not vary drastically between different areas the average slopes, vertical differences as well as the number of peaks between digitised points at 1 minute interval, are lower for the northern areas as compared to southern areas, demonstrating that the northern areas are less rugged than the southern ones.

(b) Nodule distribution

Exposed nodules are limited in the northern areas, with most of the locations showing occurrence of no or few nodules (0-2% coverage) on the sediment surface. Similarly, most of the locations in the southern areas also show no or very few (0-2% coverage) nodules except for one location in T2 (~50% coverage).

The overall nodule distribution in all areas (Table 2) shows that the northern areas have relatively lower nodule abundances (average = 1-2 kg/sq m) compared to the southern areas (average = 3.7-5 kg/sq m). Most of the locations in the northern areas (32 out of 39) have <3 kg/sq m whereas the southern areas have 14 out of 24 locations with >3 kg/sq m abundance.

The locations with higher abundance (>3 kg/sq m) show the occurrence of exposed nodules in the photographs, whereas the remaining locations show no nodules exposed on the seabed. Hence, whereas the burial of nodules is controlled by the sediment cover, their exposure also depends on the quantity or abundance of nodules available at these locations.

(c) Sediment thickness

The photographs in all the areas invariably show the occurrence of sediments on the seabed. The complete to almost complete penetration of the camera trigger weight into the sediment indicates the soft, watery nature of the sediment layer, which is probably responsible for burial (or non-exposure) of many of the nodules occurring in these areas.

The sediment thickness observed from subbottom records is higher in the northern areas than the southern areas. In the north generally the sediment thickness is between 25 and 60 m, which is reduced to almost 0 m on the peaks of abyssal hills, and increases to 100 m in flat regions and negative reliefs. Whereas the southern areas have sediment thicknesses generally between 20-40 m, with a maximum of 50 m and many locations with <20 m, due to undulating topography.

(d) Sediment characteristics

In all cores from areas T1, R1, and A1, the top 0-10 cm sediment is either moderate brown (SYR 3/4 of rock colour chart) or moderate yellowish brown (10YR 5/4) in colour followed by 10- 20 cm of light to yellowish brown coloured sediments. While the top layer (0-10 cm) is always uniform, the second layer (10-20 cm) has mottled features with light intercalations, probably due to the benthic mixing and bioturbation (Fig. 4a,b,c). At places, streaks of light grayish or olive greenish intercalations were noticed in deeper layers (20-30 cm) indicating microenvironments of low oxygen levels. The sediments are mostly silty clay to clayey silt in size (Rao and Nath, 1988).

Three cores each were collected from Areas R2 and T2. The cores recovered from Area R2 contain a homogenous layer of moderate brown (SYR 3/4) varying in thickness between 7 and 9 cm with grayish orange (10YR 7/4) intercalations. One core (# 145) composed of 27 cm of grayish orange coloured sediment as second layer with intercalations and mottling and a distinct grayish band at 25 cm. The cores recovered from area T2 are similar to the ones from R2, all the three have three units viz: Unit I- moderate brown, Unit II- mixed zone and Unit III- grayish orange specks and lenses in brown matrix. One of the cores (# 151) had open burrows of 0.5-1 cm diameter on the surface.

All the porewater components were higher in concentration than the overlying water. The porewater profiles reflect typical deep-sea sedimentary environment. High nitrate values, low phosphate concentrations and high sediment Eh indicate the redox conditions within the top 15-20 cm with suboxic conditions in the deeper zones with higher mottling. Porewater silica values are very high due to the dissolution of radiolarian tests which is the typical sediment type in the present area (Nath et al. 1989). A semi-indurated incipient pelagic hard ground was encountered at location # 172 characterised by several open empty burrow holes over gently hummocky relief (Fig. 4d). A number of grayish coloured lumps resembling oolites, larger than 1 mm in size were also recovered from the mottled layer (Fig. 4e). These lumps indicate the processes of syndimentary lithification leading to the formation of incipient pelagic hard ground (Gupta, 1995).

(e) Megabenthos and bioturbation:

Traces of megabenthos was observed in many of the photographs in the form of reworked sediments, bioturbation, as well as fecal casts, pellets, trail marks and Thalassinoides type burrows of benthic organisms (Fig 4c). A single polychaete specimen in dead condition was recovered from location #180, which may be responsible for sediment mixing and burrowing in the general area.

Some of the prominent features observed in photographs are circular fecal coils, locomotion trails. Observations of megabenthic activity associated with nodules from the Central Indian Ocean have been reported earlier by Sharma and Rao, (1987)

(f) Benthos

The preliminary results indicate the dominance of Polychaetes and Nematodes in macro and meiofauna respectively. The fauna is moderately rich, comprising 6 macrofaunal and 3 meiofaunal taxa. The population density varies from 3.45/10 cm² for meiofauna and 8.64/m² for macrofauna. Among the meiofauna taxa, Nematodes with a 100% occurrence were observed, followed by the Harpacticoid copepods. Harpacticoid larvae were also recorded in some samples, their average density varying significantly between the sites.

The vertical distribution of meiofauna in different sediment layers shows that the Nematodes were regular in their occurrence at various depths, although the density decreases with increasing depth. The Harpacticoid copepods on the other hand, were confined to the top 5 cm. This pattern was however, not consistent. It is important to mention that meiofauna samples, used here, were collected from box corers which also enclosed the supramental, thick layer of water.

Among the macrofauna, Polychaetes were the most important group, followed by peracarid Crustaceans (Amphipods, Tanaidacea), Bryozoa and Rhizopoda. The abundance of macrofauna varied within a modest range of 5-15%, as compared to metazoan meiofauna.

The biomass varied significantly due to the presence of large specimens of crustacea at some locations. No significant differences in the depth distribution of macrofauna were observed. Based on few benthic samples, Neyman et al. (1973) reported low benthic biomass in the abyssal region of the tropical Indian Ocean. According to them the present study area falls into the oligotrophic zone. Occurrence of rich benthic fauna associated with manganese nodules has been reported (Parulekar et al. 1982)

CONCLUSIONS

Evaluation of echosounding, sub-bottom profiling, sampling and photography data, has revealed the baseline conditions of the benthic environment in selected areas. The bathymetric variations, sediment thickness and nodule concentrations will be used for selection of the Test and Reference Areas for the Indian Deep-Sea Environmental Experiment (INDEX). The sediment characteristics as well as benthos data will constitute reference information for the environmental impact assessment.

ACKNOWLEDGEMENTS

The authors acknowledge the support of Dr. F. Deka, Director and Mr. R. R. Nair, Deputy Director, NIO, during the course of the study. The officers, scientists and crew of RV A. A. Sankar are thanked for data collection. Hydrosweep maps were processed by Dr. V.N. Kodagali. The study was carried out under the 'PMN-EIA studies in Central Indian Basin', funded by the Department of Ocean Development, Government of India.

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Table 1: MORPHOMETRIC CHARACTERISTICS OF THE SEAFLOOR IN THE STUDY AREAS (at 1 min interval from echosounding records)

Area	No. of data Points (n)	Depth Range (m)	Average Depth (m)	SD	Average Slope		Average Vertical Difference		Average No. of Peaks	
					Longi-tude	Lati-tude	Longi-tude	Lati-tude	Longi-tude	Lati-tude
T1	1668	5150-5340	5217	34	1.07	0.78	19.3	22.6	4.0	2.9
R1	1857	5200-5400	5330	37	1.40	0.93	19.6	20.4	4.7	3.1
A1	1739	5180-5400	5327	25	1.00	0.68	16.2	12.0	4.3	2.9
T2	1581	5120-5320	5217	41	1.76	1.02	30.5	20.8	5.8	4.0
R2	3035	5200-5380	5297	32	1.67	1.36	20.4	14.2	7.8	7.8

Note : Long = longitudinal direction
 Lat = latitudinal direction

Table 2: NODULE DISTRIBUTION CHARACTERISTICS IN THE STUDY AREAS (Number of samples per weight class)

Area	No. of data points	Frequency of abundance (kg/sq.m)						Average abundance
		0	<1	1-3	3-6	6-10	>10	
T1	13	2	5	2	2	2	-	1.94
R1	13	4	7	-	1	1	-	1.14
A1	13	4	5	1	-	2	1	2.1
T2	13	3	4	-	1	4	1	3.41
R2	12	1	1	2	2	6	1	5.05

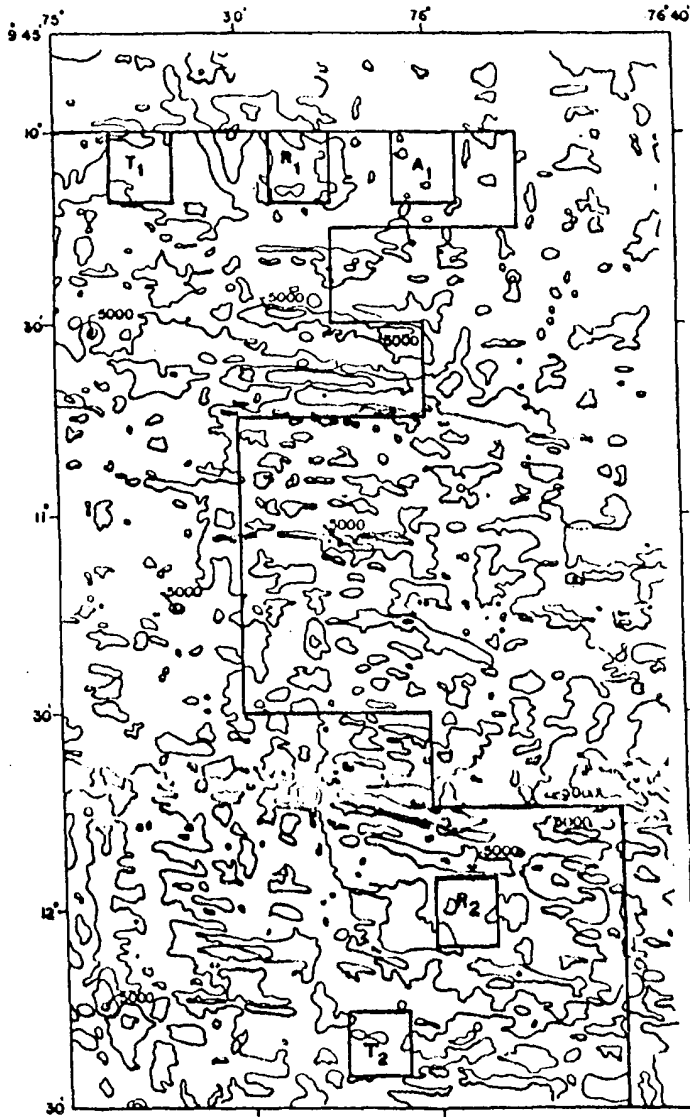


Fig.1 Locations of study areas

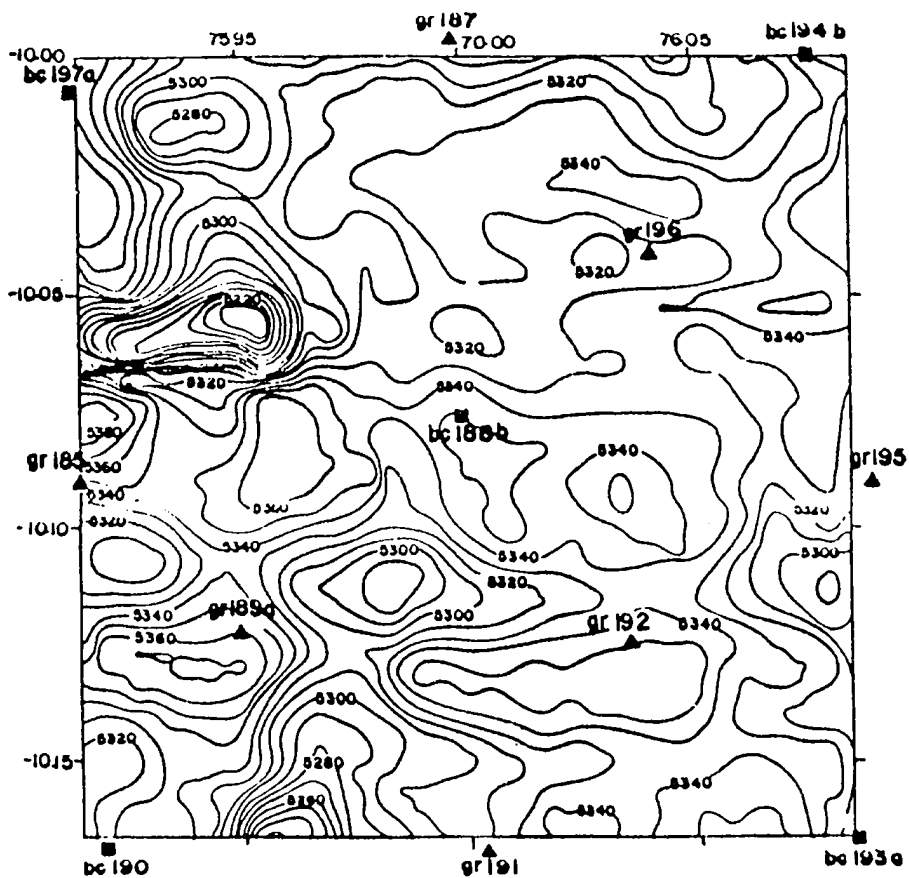


Fig 2 Bathymetry with sample locations in area A₁

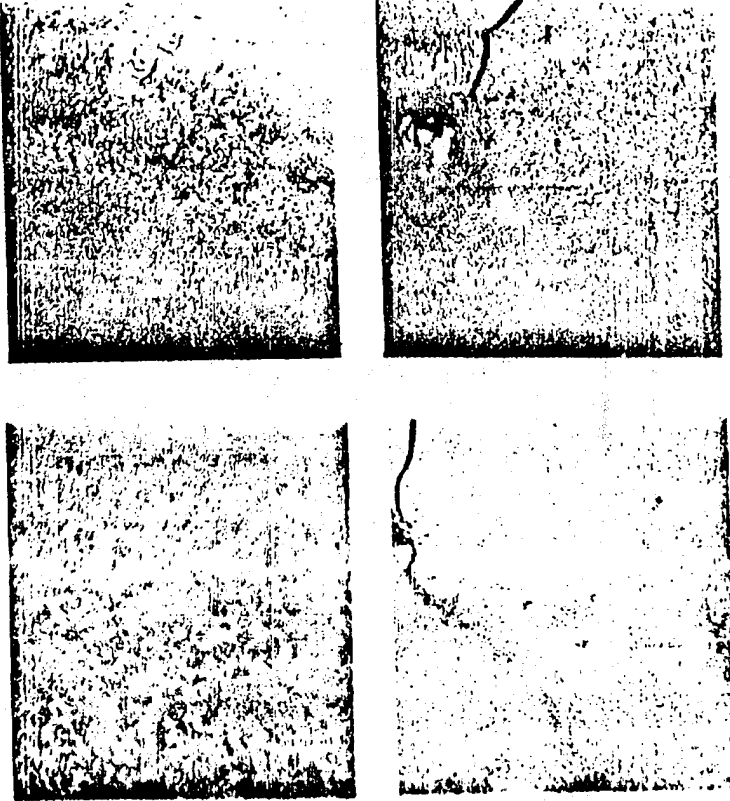
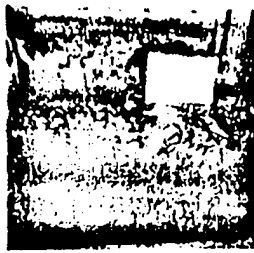


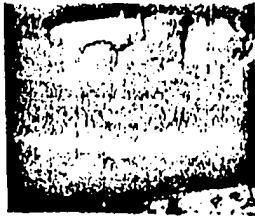
Fig. 3 : (a) Area T1 (# 178) - Traces of benthic biological activity with reworked sediment and fecal casts. (b) Area R1 (# 161) - Reworked sediment with biological activity. (c) Area T2 (# 156) - Exposed nodules (50 % coverage) with sediment. (d) Area R2 (# 138) - Reworked sediment with burrow openings and fecal casts.



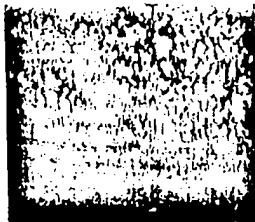
(a) Vertical section of box core (type - Reineck) AAS, # 159b showing top 10 cm homogenous brown buff-coloured pelagic ooze overlying the partially mottled grayish brown coloured sub-surface layer in 10-20 cm sediment depth.



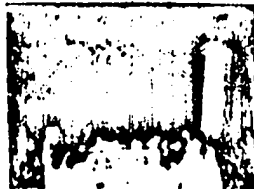
(b) Vertical section of core AAS # 160a, with top 10 cm homogenous, 10-20 cm mottled gray brown, 20-30 cm brown pelagic clay with gray coloured lenses. An elliptical lensoid burrow of unknown origin in the lower left corner suggests intense reworking of the sediment.



(c) Vertical section of another core with typical stratification and a gently curving vertical hollow (empty structure) of thalassinid type of burrows. Plastic syringe is 2.5 cm in diameter. Burrow diameter is 1-1.3 cm. Mottling seems to be the result of bioturbation.



(d) Surface view of the box core AAS #172 with hummocky micro relief with micro depressions filled with slurry at sediment water interface associated with manganese nodules, several burrow openings are visible on the hummocky mound.



(e) Coarse granular fraction >1 mm, with lumpy aggregates of diagenetically lithified intraclasts suggesting formation of an incipient pelagic background encountered in core AAS # 172.

Fig 4 Sedimentary structures and bioturbations feature observed in box core samples.