Chapter 1.
INTRODUCTION

Oceans have fascinated man all through the history. Sound of the waves and lure for adventure have had powerful influence on shaping the destiny of countries and mankind. From salt to gold and platinum to uranium, the ocean has the abundance of everything. Seas are the mineral-mines of the future.

Fast depleting land resources have pushed mankind into rigorous search for alternative sources. The deep seabed is the most promising and rewarding of the future living and non-living resources. Non-living resources of the deep seabed promise to make an enormous contribution to the world’s resource base. Manganese nodules are the resources of immediate interest to mankind.

The discovery of marine manganese nodules dates back to the 'Challenger' expedition in 1873, on 18th February. This heralded the multidisciplinary investigation on these nodules world over. Nero (1965) suggested the manganese nodules as an alternative source of metals to the existing land deposits. The possible economic importance of these nodules in future has been attributed to the substantial concentration of certain elements e.g. nickel, copper, cobalt etc. Because of the availability of all these metals in nodules, the manganese nodules are popularly referred to
as 'polymetallic nodules'. The mineral resources of the deep sea bed beyond the limits of national jurisdiction, was declared as the 'Common Heritage of Mankind' by the United Nations Law of the Sea convention. This generated additional commercial interest in these nodule deposits on the deep-sea floor. Since then a large amount of data have been collected, mainly from the Pacific, on the mode of occurrence of the ferromanganese nodules, their chemistry and other related parameters in order to assess the economic feasibility of these deposits.

Though the Pacific ocean, especially the Clarion-Clipperton fracture zone area is regarded as the most promising area, the Indian Ocean also boasts of large reserves covering over 15 million sq. kms. Table 1.1 lists the area occupied by polymetallic nodules in three major oceans of the world.

Table 1.1

Distribution of nodule resources in different oceans. (After Moore and Cruickshank, 1973)

<table>
<thead>
<tr>
<th>Ocean</th>
<th>Area covered by nodules</th>
<th>% share</th>
</tr>
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<tbody>
<tr>
<td>Pacific</td>
<td>23</td>
<td>50</td>
</tr>
<tr>
<td>Indian</td>
<td>15</td>
<td>33</td>
</tr>
<tr>
<td>Atlantic</td>
<td>8</td>
<td>17</td>
</tr>
</tbody>
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The ferromanganese nodules are reported to be generally present between 3500 and 6000 meters water depth in all the ocean basins. Initially the nodules were estimated to cover an area of nearly 46 million square kilometers in the world oceans (Moore and Cruickshank, 1973; Table-1.1). Later studies indicate that nodules are present over an area of about 55 million km² accounting for about 15 percent of the total area of the world ocean floor (Archer, 1985). However, all these areas will not be of economic interest in the future.

The estimated total reserves of ferromanganese nodules in the world oceans range from 1.7 to 3.0 trillion tons. Moore and Cruickshank (1973) calculated the reserves of these nodules in the Pacific, Atlantic and Indian oceans to be of the order of 1.7 trillion tons, of which 1.5 trillion tons are in the Pacific and 0.15 trillion tons in Indian and 0.50 trillion tons are in the Atlantic oceans. As regards the actual metal resources in the nodules, it is estimated that about 430 million tonnes of copper, nickel and cobalt together are available. Table 1.2 lists the metal resources in nodules of world oceans.

In addition to the assessment of the commercial viability of ocean-floor nodules, the studies carried out so far have enormously expanded the knowledge not only on the physical and chemical attributes of the nodules.
themselves but also on the oceanographic parameters that directly or indirectly control nodule generation.

Table 1.2

Metal resources in nodules of the world oceans.
(from Archer, 1985)
(All figures in Million tonnes)

<p>| | |</p>
<table>
<thead>
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<tbody>
<tr>
<td>Nodules (wet)</td>
<td>25,000</td>
</tr>
<tr>
<td>Nodules (dry)</td>
<td>17,500</td>
</tr>
<tr>
<td>Copper</td>
<td>175</td>
</tr>
<tr>
<td>Nickel</td>
<td>215</td>
</tr>
<tr>
<td>Cobalt</td>
<td>40</td>
</tr>
<tr>
<td>Manganese</td>
<td>5,000</td>
</tr>
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</table>

The ferromanganese nodule deposits occur mostly at the sediment-water interface in the deeper part of the oceans on red clay, siliceous and carbonate-rich sediment substrates. The slow detrital sedimentation rate in the deeper part of the ocean basins and the oxidizing Antarctic Bottom Water current are vital factors for the genesis of these nodules. Availability of nucleus also plays an important role in the nodule formation (Horn et al., 1973).

Different theories have been proposed for the genesis of ferromanganese nodules, but none of them alone can explain the variable nature of chemistry, morphology, mineralogy and growth-rate of the nodules in different oceans or even within any single basin. Multiple sources
of metal supply for the formation of the nodules have been proposed by the majority of the workers. Comparing the slow growth rate \((1-5\text{mm}/10^6\text{year})\) of nodules vis-a-vis a much faster detrital sedimentation rate \((1-10\text{mm}/10^3\text{years})\) at the same location, it is intriguing to see the persistence of ferromanganese nodules at the sediment-water interface. The role of bottom currents and deep-sea benthos in retaining the nodules at the sediment-water interface, has been considered viable by a number of workers, but these factors may not explain every situation of nodule occurrence. Buried nodules are however also common in sediment columns.

Investigations on the different aspects of ferromanganese nodules were confined mainly to the Pacific for a long time. Even in early eighties the density of data coverage on nodules in the Indian Ocean was much less than that of Pacific. India, realising the importance of polymetallic nodules plunged into nodule exploration in 1980 and since then lot of new data and information has been collected on Central Indian Basin nodules and it's morphology. As a result of extensive work carried out in the field of survey and exploration in Central Indian Basin and also by meeting other financial criteria, India was registered as a 'Pioneer investor' and subsequently became, in 1987 first country to be allotted a
mine site measuring 1,50,000 sq. kms for exclusive
development work. This has rendered India as a leader in
the new and challenging field of deep seabed exploration.

During the surveys for polymetallic nodules by the
National Institute of Oceanography since 1982, large amount
of echosounding data has been collected. This has thrown
more light on the hitherto unknown morphology of the
Central Indian Basin. With the acquisition of multi-beam
swath bathymetric system (Hydrosweep), a major part of the
deep seabed in the allotted area has been mapped. This has
provided accurate topographic map of the seafloor which
will help determining the mineable blocks. Before
commencing commercial mining, a detailed picture of the
seafloor is essential. The seamounts, hills and valleys
have to be identified to mark inaccessible areas. Morphometric study, slope angles etc. will help in pre-
determining the dredge paths. Bathymetry is also known to
influence the distribution of polymetallic nodules. Keeping
all these in mind, detailed morphologic study and influence
of topography on distribution of polymetallic nodules in
Central Indian Basin is carried out in this thesis.
Objectives:

The main objectives of the present study are

1. To study the geomorphology and morphometry of the Central Indian Basin, and
2. To establish relationship between seafloor topography and distribution of polymetallic nodules in the study area.

Depth data for the study was collected from the echosounding (both single beam and sophisticated multibeam techniques). For navigation, dual channel satellite navigator was used for single beam echosounding and Global Positioning System (GPS) for multibeam studies. The nodule sampling was carried out using the free fall grabs, dredges and Petersson grabs. Underwater photographic data was collected using the cameras mounted on the free fall grabs.

During the course of the present study, a number of new techniques and computer programs were developed. Procedure for underway data processing was evolved. Program to plot bathymetric profiles, sampling stations on bathymetric profiles, to generate slope angle data from digitised depth data and from multibeam sounder (Hydrosweep) data, cluster analysis to plot dendograms, calculation of statistical parameters, improvement on existing post-processing package- Hydromap for Hydrosweep data etc. are some of the
programs developed during the course of present study which will make underway data processing easier and faster. For the assessment of the seafloor environment and all related parameters, a system called 'SPHINCS' (Seabed Photographs Interpretation and Cataloguing System) was prepared which uses a specially developed format for the storage of the data acquired from the seafbed photographs using dBase III+ database management system.

Based on the enormous echosounding data collected, a comprehensive bathymetric map of the Central Indian Basin is prepared which will serve as a base map in future for the researchers and navigators. Also, detailed morphology of the basin from multibeam sounder data depicting the presence of 79° E fracture zone, east-west lineations and a graben is presented. Numerous seamounts have been identified in the basin. Detailed morphology of a seamount and that of three chains of seamounts is described. Morphometric studies on some part of the basin is also carried out.

Topographic control of the polymetallic nodule distribution is studied using the echosounding data and the nodule sampling data. Nodule distribution in different topographic domains is studied. Influence of regional and local topography, 79° E fracture on the nodule distribution
is deliberated. Factors controlling the nodule distribution based on photographic evidences is also presented. The importance of detailed bathymetric studies prior to and for selection of mine sites is discussed and a method for identifying unfavorable blocks in the mine site is given.

Thus, this study addresses a wide range of new and unknown aspects covering geomorphology of Central Indian Basin, nodule distribution and topography and nodule mining and will fill the void in these fields.