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SEABED TOPOGRAPHY AND DISTRIBUTION OF MANGANESE NODULES IN THE CENTRAL INDIAN OCEAN

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ABSTRACT

The relationship between seabed topography and distribution of nodules, recovery of free fall grab samplers, nodule size and chemical composition of manganese nodules in the Central Indian Ocean have been studied. Nodule abundance was greater (4.2 kg/m^2) in *rugged topography (hill tops, slopes,* and valleys) than in the abyssal plains (2.3 kg/m^2). Similarly, the recovery of grab samplers was more from rugged topographic areas (66%) than from *the plains* (47.5%). Nodules of <40 mm size was greater in number in all the topographic environments. Mn/Fe ratio was least (2.2) for nodules from hill tops whereas it was maximum for those from the plains (4.4). Cu+Ni+Co compositioin varied antipathetically with nodule abundance in the Central Indian Ocean.

Key-words: Nodule abundance, topography, size and chemical trend.

INTRODUCTION

Manganese nodules are distributed in all the world oceans. The factors responsible for their varying abundance, chemistry and growth rates are not yet fully understood. For assessment of economic feasibility of these nodules it is important to study the variations in their distribution and chemical composition. Bathymetry is an important factor governing the distribution of manganese nodules. In the Central Indian Ocean manganese nodules occur at an average depth of 5130 m (Cronan and Moorby, 1981). Considerable amount of work has been carried out on the relation between bathymetry and distribution of manganese nodules in the Pacific Ocean (Zenkevitch and Skornykova, 1961; Margolis and Burns, 1976; Piper, Cannon and Leony, 1977; Karas, 1978; Craig, 1979; Frazer and Fisk, 1981 and Stackelberg, 1982). The present study deals with the relation between the distribution, size and composition of the nodules encountered in different topographic domains in the Central Indian Ocean.

MATERIAL AND METHODS

The present study is based on the data collected in the Central Indian Ocean by the National Institute of Oceanography during surveys for polymetallic nodules onboard MV *Skandi Surveyor*. Echosounding was carried out by a Raytheon echosounder at 12.5 KHz frequency. Bathymetric profiles with a vertical exaggeration of 30 times along North-South traverses are shown in Figure 1. Sampling was carried out using free fall grabs. At each station 7 free fall grabs were deployed in a hexagonal pattern with one grab at centre. The distance between each grab was approximately 200 m. The free fall grabs used had a rapid rate of sinking (80 m per minute) which minimises the effect of currents. Sample location can therefore be determined accurately. The nodule abundance (kg/m^2) was calculated from the total weight of the nodules recovered from the grab divided by the area of the grab (0.13 m^2). The percent recovery was computed as the percentage of number of grabs successful in bringing the nodules out of the total grabs operated. Size analysis of the nodules have been carried out with callipers. Nodules are classified into <40, 40-60, 60-80 and >80 mm size classes.

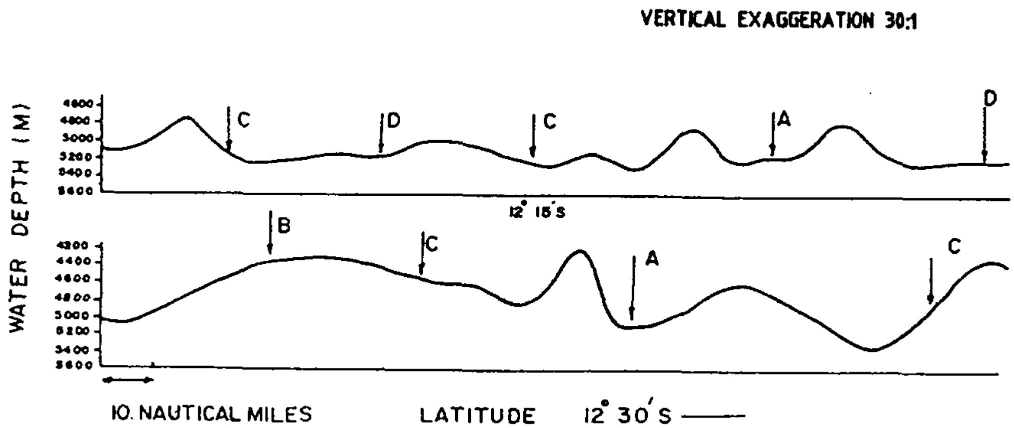

Fig.1. Bathymetric profiles showing sampling locations. (A–Valleys, B–Hill tops, C–Hill slopes, and D–Plains)

RESULTS AND DISCUSSION

From the location of the free fall grabs on the traverses, the topographic domains can be categorised into four types viz. the top of the abyssal hills, the slopes of the abyssal hills, the valleys and the plains. From the Table I it can be noticed that the per cent recovery was more from the rugged topographic domains such as hill tops (73%) and least from the plains (43%) and the nodule abundance was more on rugged topography (4.18 kg/m^2) (average of all the domains indicated in Table I). The number of nodules with <40 mm was higher (Table II), however it was much less in the rest size classes. From the chemical studies it was noticed that nodules from the hill top have low Mn/Fe ratio (2.17) and maximum in the nodules from the plains (4.37).

Rugged topography had abundance of 4.18 kg/m^2 while plains 2.3 kg/m^2. According to Horn, Horn and Delach (1973) more abundance of nodules on hill tops is an indication of availability of more nucleus material,

Table I — Average per cent recovery of manganese nodules by free fall grab samplers and abundance of the nodules from different topographic domains of Central Indian Ocean.

Topogr. domain	No. of attempts	No. of successful FFG	Per cent recovery	Total weight (kg)	Average weight (kg)	Abundance (kg/m^2)
Hill Tops	108	79	73.0	60.8	0.56	4.3
Hill Slopes	130	71	54.6	57.6	0.44	3.4
Valleys	127	77	60.6	79.5	0.62	4.8
Plains	160	69	43.1	47.4	0.29	2.2

Table II — Average per cent values of nodule size classes in different topographic domains of Central Indian Ocean.

Topogr. domain	Results based on No. of stations	Nodule size (mm) <40	40-60	60-80	>80
Hill Tops	16	84.3	9.5	3.6	2.6
Hill Slopes	10	77.4	12.8	6.5	3.2
Valleys	15	57.3	23.7	9.6	9.4
Plains	13	72.9	17.8	5.4	3.9

probably originating from volcanic activity or breaking down of basalts by weathering process. The echograms indicated variable sediment penetration from 5 m on hill top to around 50 m on the plains which might be due to the movement of sediment along with nodules from topographic highs to low lying areas by slumping or winnowing. On hill tops, usually the influence of currents is more and hence most of its surface is exposed to seawater but it is not so in the case of hill slope nodules (Margolis and Burns, 1976).

Results of size analysis indicate that the smaller size nodules (<40 mm) are more in all the environments. Number of larger nodules (40-60, 60-80 and >80 mm) are much less. Nodules of <40 mm were particularly more on the hill tops. This trend of decreasing number with increasing size may be due to slumping or may be burial or fragmentation of some large nodules (Margolis and Burns, 1976). Lesser number of smaller nodules (<20 and 20-40 mm) were noticed on hill tops but more in valleys of the Pacific Ocean (Margolis and Burns, 1976). But this is not true in case of the Indian Ocean. Heye (1974) noticed less number of smaller nodules on the plains than the seamounts in the central Pacific Ocean.

Chemical studies of nodules from different topographic settings have been carried out and the values are given in Table III. Nodules from plains, valleys and slopes showed more Mn, Ni and Cu, while those from hill tops showed more Fe and less Mn, Cu and Ni. There is not much variation in cobalt content. One of the criteria to distinguish hydrogenous nodules

Table III – Chemical composition (%) of manganese nodules from rugged topography* and plains of Central Indian Ocean.

		Mn	Fe	Mn/Fe	Co	Ni	Cu
Hill top* (8)	Max	25.01	14.69	3.69	0.25	1.26	1.11
	Min	20.64	05.58	1.43	0.10	0.82	0.40
	Av	22.46	10.34	2.17	0.14	0.98	0.86
Valleys* (15)	Max	29.96	10.97	4.92	0.29	1.39	1.22
	Min	17.15	06.14	1.89	0.09	0.60	0.58
	Av	24.16	08.08	2.99	0.14	1.06	0.95
Slopes* (11)	Max	31.43	11.76	6.23	0.34	1.42	1.56
	Min	17.15	06.14	1.87	0.10	0.78	0.55
	Av	23.58	07.31	3.22	0.14	1.19	1.17
Plains (9)	Max	29.12	07.51	5.58	0.14	1.62	1.55
	Min	16.25	04.73	2.22	0.08	0.79	0.64
	Av	25.56	05.85	4.37	0.11	1.26	1.32

Number in parenthesis denotes the number of stations.

from diagenetic ones is the Mn/Fe ratio. According to Halbach, Scherhag, Hehisch and Marchig (1981) Mn/Fe ratio of 2.5 is the dividing point for nodules from hydrogenous to diagenetic origin. Nodules from the hill top had low Mn/Fe ratio (2.17) which lies in the hydrogenous field of the three component diagram of Bonatti, Kraemer and Rydell (1972). This hydrogenous accumulation is caused by direct precipitation of colloidal compounds from near bottom seawater. It is commonly assumed (Calver and Price, 1977; Halbach, Scherhag, Hehisch and Marchig, 1981; and Dymond, Lyle, Finney, Piper, Murphy, Conard and Pisias, 1984) that nodules on elevations represent a hydrogenous end member, where no sediment interactions are involved. Reasons attributed for the low Mn/Fe ratio are (Cronan, 1977): (1) lack of sediment cover at the top of hills or with outcropping volcanic rocks limiting diagenetic supply of Mn, and (2) more supply of iron containing solution by weathering of volcanic rocks or by submarine volcanics. The Mn/Fe ratio of nodules from valleys (2.99), slopes (3.22) and plains (4.37) is above 2.5 and hence they are of diagenetic origin (Bonatti, Kraemer and Rydell, 1972). This diagenetic origin is caused by remobilisation of metals and subsequent precipitation in the peneliquid layer, which makes nodules rich in Mn, Ni and Cu. This diagenetic reactions causing change in Mn/Fe ratio takes place in the sediment with which nodules are associated. Recent work on the chemistry of sediment pore water has confirmed that Mn and Fe are involved in the post depositional chemical reactions and are recycled between dissolved and solid forms during diagenesis (Calvert and Piper, 1984). In the Pacific Ocean (Halbach, Scherhag, Hehisch and Marchig, 1981) it was observed that Mn/Fe ratio decreases upwards the slopes, (1.5) for the slopes of seamounts, (2-2.5) for the base of seamount and upto 4 for the nodules from the basin. Low Mn/Fe (< 2) ratio for the nodules from the slopes and more from the basins (> 5) was noticed by Stackelberg (1982). Further, the chemical concentration is inversely related to the nodule abundance in the Central Indian Ocean

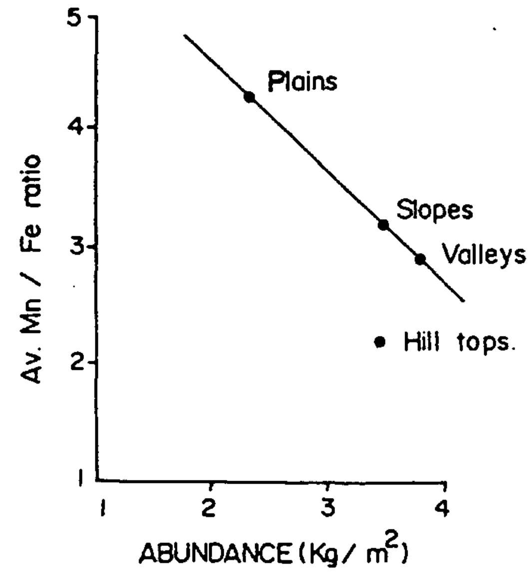

Fig.2. Relation between nodule abundance (kg/m^2) and Av. Mn/Fe ratio

(Fig.2). Menard and Frazer (1978) and Glasby, Thissen, Pluger, Friedrich, Mangini, Stoffers, Domnic, Frenz, Andrews and Roonwal (1983) also noticed similar relation for Pacific Ocean nodules. The abyssal seafloor of the Central Indian Ocean exhibits a variety of bathymetric settings ranging from smooth plains to abyssal hills. Therefore topography is one of the factors controlling the distribution, size and chemical composition of the manganese nodules in the Central Indian Ocean.

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