

## Seafloor mapping of large areas using Multibeam system- Indian Experience

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### Abstract:

India, since 1982 has been carrying out detailed bathymetric mapping and sampling operations in the Central Indian basin (CIB) as a part of Manganese nodule project. Using over 400,000 line km of single beam echosounding data in CIB, a detailed bathymetric map was prepared in 1989. As this data was spaced at 30 nm intervals, a lot of interpolation had to be done and also, features of lesser dimension could not be identified.

To identify unproductive and difficult terrains, a detailed picture of the seafloor was essential. Hence, the area was resurveyed using the multibeam system- Hydrosweep during 1990-93. A Total of 300,000 sq.km area has been mapped. As the average depth in the basin is about 5100 m, a line spacing 5 nm ensured 100 % coverage of the entire area. Over 31 million depth data points were collected from the multibeam sonar system in the CIB. By developing new software, data from different lines were averaged and merged to produce large area maps. Maps were generated in the scale of 1 mil. and 1.5 mil covering area of about 2 mil sq.km in single map. Also, depth contour maps of different scale and contour interval were generated. A computer program was developed to convert the depth data grid into slope angle grid and slope angle maps of the area were also prepared.

Numerous prominent seamount and abyssal hills ( total of about 157) were identified from the survey. Clear topographic signature for the southern extension of the 79° E fracture zone was also obtained. Generally, it was observed that the northern part of the basin ( 10° - 12° 30' S) was plain while the southern part of the basin ( 12° 30' to 15° S) was rugged.

### Introduction.

Indian ocean is considered to be the most complex of the three major oceans (Schlich, 1982). It has many features which are unique (like the 90 East Ridge) and a host of other physiographic features not found in other oceans.

Different types of topographical features such as banks, plateaus, ridges, seamount chains or rises are present in the Indian Ocean. These features were called as Oceanic Ridges by Udinstev (1975), microcontinents by Heezen and Tharp (1966), and are grouped as aseismic ridges by Loughton et al. (1970). These may represent the continental fragments which have been separated from the main continental blocks by seafloor spreading (like the Madagascar island, Seychelles island, Seychelles Bank, Kerguelen Plateau, Agulhas Plateau etc.) or to the uplifted blocks of oceanic crust (like Chagos-Laccadive oceanic

Plateau, Crozet Plateau, Ninety East Ridge etc.). The submarine plateaus or aseismic ridges, striking north-south, and located in different parts of the western Indian Ocean, along with the active ridges and the surrounding continents, divide the Indian Ocean into a number of deep ocean basins such as the Arabian Basin, the western and eastern Somali Basins, the Mascarene and Madagascar Basins, the Mozambique Basin, the Agulhas Basin, the Central Indian Basin and the Crozet Basin.

Three major morphological features of the Indian Ocean are the major active ridge systems- the Central Indian Ridge (CIR), South East Indian Ridge (SEIR) and South West Indian Ridge system (SWIR). Also, there are several fracture zones which offset these ridge systems. The three ridge systems join at the Indian Ocean Triple junction. Prior to the International Indian Ocean expedition (IIOE, 1959- 1966), there was not much work done on Indian ocean as regards its morphology and bathymetry. First report on physiography of Indian Ocean was by Heezen and Tharp (1966). Le Pichon and Beirtzler (1968) and Loughton et al (1971) contributed further information to this. First general atlas of geology and geophysics of Indian ocean was prepared based on these studies (Udintsev, 1975) which, till date is the only one of its kind. However, later years witnessed increasing interest in Indian Ocean, as a result of which detailed bathymetric surveys were carried out in different parts of Indian Ocean. Most of these studies are concentrated either at the mid-ocean ridge systems- triple junction or at and near the continental margins of different countries. The continental margins of India have been extensively covered by geological and geophysical surveys (Siddiquie et al., 1987). Other parts of the Indian Ocean, especially the Central Indian Basin had not been surveyed extensively. Central Indian Basin (CIB) lies between the Central Indian ridge and 90 degree east ridge and is bounded in the south by SEIR and Indian Ocean Triple junction. CIB has complex evolutionary pattern because of existence of aseismic ridges and fracture zones. Varied spreading rates of CIR, SEIR and SWIR also have contributed to its complexity.

The National Institute of Oceanography, Goa India as a part of the program on manganese nodules exploration embarked on the detailed bathymetric survey of Central Indian Basin. Initially, the survey was carried out using the single beam echosounders. Detailed depth contour map CIB was generated using this data (Kodagali et al., 1992). Later, after acquiring the multibeam swath bathymetric system, the area has been mapped extensively.

The bathymetric map of Central Indian Basin generated from the single beam echosounding data though unique and first of its kind, is more of a reconnaissance map. As there is a lot of interpolation done in areas between the survey lines, there is some ambiguity and features of less dimension are not represented on this map. After the allocation of 1,50,000 sq. km of area in CIB to India by the International seabed authority, the exploration activities have been intensified in the allotted area. 50% of the allotted area has to be surrendered phase wise to the United Nations in three years. To identify the unproductive areas and topographically unsuitable terrains, a more detailed bathymetric

picture of the area is necessary. Also, to aid exploration activities that will be intensified with the help of deep towed equipments (Underwater Television and Underwater photography and sub bottom profiling) a detailed depth contour map is prerequisite. To meet these requirements and to obtain more comprehensive bathymetric picture of the allotted area, use of state of art technology like the multibeam swath (MBS) bathymetric system was felt essential. Hydrosweep- the multibeam swath bathymetric system manufactured by M/S Krupp Atlas Elektronik, Germany was acquired and installed on ORV Sagarkanya in early 1990. This system works on 15.5 Khz frequency and provides 200% coverage obtained from 59 pre-formed beams (for technical details of the system, see Grant and Schreiber 1990 and Gutbertlet and Schenke, 1991).

An area of over 300,000 sq. km (between latitudes 10° S to 16° S and longitudes 72° E to 80° E) was covered by multibeam mapping during the period 1990-1993. As the general depth in the area is over 5100 m, the coverage in the area will be about 10,200 m. 5 nautical mile (about 9300 m) spacing between the survey lines ensured that not only the coverage was 100% but also there was a slight overlap of 700-800 m. 90% of the survey lines were North-south while the rest were East-west. Over 30 million data points were collected during a total of 140 ship days in the survey area. Details of the multibeam data in the Central Indian Basin are tabulated in table I.

Table I

Details of multibeam data in the Central Indian Basin.

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 1. NO. OF DATA POINTS IN THE AREA.

PER CRUISE SOUNDING (AVERAGE)	85,000
TOTAL SOUNDINGS ( FOR SIX CRUISES)	51,0000
NO. OF DEPTH POINTS PER SOUNDING	59
TOTAL NO. OF DEPTH DATA POINTS	30,10,0000
	OR
	30.1 MILLION

2. NO. OF MAPS GENERATED  
 ( DIFFERENT SCALES AND CONTOUR INTERVALS)

103

3. NO. OF RAW DATA TAPES.

54  
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The original Hydromap post processing package was inadequate to handle large data sets like the one used in the present study. Only about 40 hours data could be combined to generate one combined map. New software was developed to add any amount of data to generate big maps covering large areas (Kodagali 1990, SK 58 cruise report). Data from different lines were averaged and merged to produce large area maps. Maps were generated in different scale and contour interval covering large part of the survey areas. Also, new computer programs were developed to plot cross section profiles at user selectable scale and

vertical exaggeration, to plot station/areas on the Mercator chart, to plot the depth contour map for a part of the grid generated, to split the big Hydrosweep data files into line wise data files which will help in storing and later retrieval of the processed data from magnetic data tapes. A technique was also developed to convert the depth data grid into slope angle grid.

#### Salient features.

Numerous features hitherto not reported from the Central Indian Basin (CIB) have been identified from the multibeam data. Numerous seamounts, valleys, fracture zone, graben etc. have come to light for the first time. Generally, it is observed that the northern part of the basin ( $10^{\circ}$  S -  $12^{\circ} 30'$  S) is plain while the southern part ( $12^{\circ} 30'$  S -  $15^{\circ}$  S) is rugged. One of the major features in the area is the fracture zone at  $79^{\circ}$  E. Unmistakable evidence for the southern extension of  $79^{\circ}$  E fracture zone, deciphered earlier from magnetic data (Kamesh Raju and Ramprasad, 1989) is obtained. The depths on the west of the fracture zone is around 5100 m where as on the eastern side (the downthrown side), it is about 5400 m. Thus the overall relief along the fracture zone is around 5400 m. It is less at the southern side while is more at the northern latitudes. Along the fracture zone, the gradient is very high, indicated by very close north-south trending contours. The fracture zone has a typical ridge-trough topography, which is clearly seen in cross section profiles across the fracture zone. These profiles have been drawn using the depth value grid created for drawing the combined depth contour map. Profile EW-1 along the  $13^{\circ} 15'$  S latitude has high relief of 585 m and the southern most profile EW-5 (along  $14^{\circ} 15'$  S latitude), has a relief of about 385 m. Relief across a fracture zone is a factor of evolution of sedimentary fill in elongate bathymetric trough typical of many fracture zones. Other conspicuous feature is the East-west bathymetric lineaments which are more pronounced in southeastern and north western quadrants of the map. Bathymetric character of these lineaments in the southeastern quadrant between  $13^{\circ}$  S and  $14^{\circ}$  S latitudes and a similar bathymetric character in the northwestern quadrant between  $11^{\circ}$  S and  $12^{\circ}$  S latitudes, show a correlation of the bathymetric signature with the crustal age (anomaly A24, as described in Kamesh Raju et al., 1993) and indicate the right lateral offset of the oceanic crust across the  $79^{\circ}$  E fracture zone. Age difference of volcanic crust on either side of a fracture zone results in a depth difference and also in different subsidence rates on two sides. The E-W trending bathymetric lineaments appear to flex towards south against  $79^{\circ}$  E fracture zone in the west. The magnitude of these flexures tend to reduce south of the area where there is high concentration of seamounts. The overall change in the bathymetry across the fracture zone is over 300 m, depicting a ridge and trough topography, this resembles the major topographic character of the Pacific fracture zones (Sandwell and Schubert, 1982). Numerous seamounts and abyssal hills are found in the fracture zone region especially in the south. Positions of major seamounts/abyssal hills along with their height and area are listed in table II.

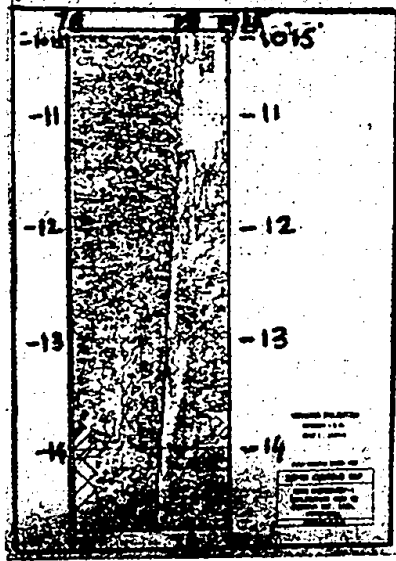


Figure-1. Depth contour map (Contour interval 100m) clearly showing the 79° E fracture zone

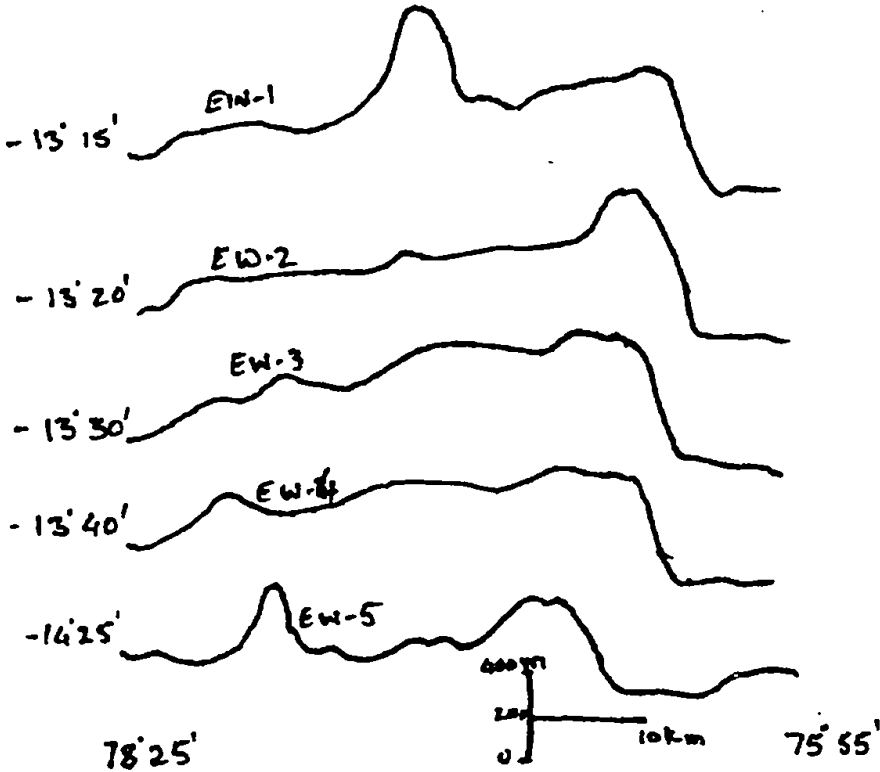


Figure -2 Cross section profiles across 79° E fracture zone showing the ridge-crest topography.

Table II.  
Table showing the positions of major seamounts  
and abyssal hills around the 79° E fracture zone.

S.No.	Center Position	Minimum depth (m)	Height (m)	Area (sq.km)
1	14° 10' S 79° 17' E	3925	1175	76
2	14° 05' S 79° 18.8'E	3975	1150	84
3	14° 08.5'S 79° 43' E	4125	900	32
4	14° 39.7'S 78° 35.7'E	4640	500	53
5	14° 43.4'S 78° 35' E	4425	675	20
6	14° 29.4'S 78° 31.2'E	4390	700	63
7	14° 33.6'S 78° 27' E	3925	1175	75
8	13° 50' S 78° 38' E	4170	850	38
9	13° 59' S 78° 37' E	4610	400	160
10	13° 16' S 78° 38' E	4440	600	40
11	14° 26' S 79° 05' E	4650	375	40
12	14° 17' S 78° 34.5'E	4180	850	30
13	12° 48' S 79° 41.5'E	4520	500	66
14	12° 41.5'S 78° 40.6'E	4580	520	15

Combing the entire 300,000 sq. km of the CIB has resulted in identifying numerous seamounts and abyssal hills. A total of 157 features having heights above 200 m are present. The tallest feature is 1850 m and the largest feature occupies over 430 sq.km of area. The seamounts in Central Indian Basin show a variety of morphological characters- with pointed cone to flat tops. About 5 large seamounts also have cratered tops. Frequency distribution of seamounts/abyssal hills in different height ranges are tabulated in Table III.

Table III

Frequency distribution of Abyssal hill/ seamount heights.

Height range	No of features
200-300 m	33
300-400 m	26
400-500 m	18
500-600 m	17
600-700 m	17
700-800 m	7
800-900 m	12
900-1000 m	2
over 1000 m	25
total no. of features	157

Summary :

1. Over 400,000 lkm of single beam echosounding data was used to generate depth contour map of Central Indian Basin.
2. CIB was later mapped using the Multibeam system- Hydrosweep. Over 300,000 sq.km area was surveyed during 1990-1993.
3. Numerous bathymetric features hitherto not known in CIB are identified.
4. Clear bathymetric expression for the southern extension of the 79° E fracture zone is seen. The western side is the downthrown side with varying downthrow of 300-585 m.
5. About 157 seamounts/ abyssal hills with varying morphology are present in the surveyed area.

#### REFERENCES

- Grant, J.A. and Schreiber, R. 1990. "Modern Swathe sounding and subbottom profiling technique for research application: The Atlas Hydrosweep and Parasonde systems". *Marine Geophysical Researches* Vol. 12. 9-19
- Gutberlet, M. and Schenke, H.W. 1989. "Hydrosweep- New era in high precision bathymetric surveying in deep and shallow waters". *Marine Geodesy*. Vol. 33(1),1-24.
- Heezen, B.C. and Tharp, M. 1966. "Physiography of the Indian Ocean". *Philosophical Transactions of Royal Society of London*. A259, 137-149.
- Kamesh Raju, K. A. and Ramprasad, T. 1989. "Magnetic lineations in the CIB for the period A24-A21: A study in relation to the Indian Ocean triple junction" *Earth and Planetary Science Letters*, Vol 95, 395-402.
- Kamesh Raju, K. A., Ramprasad, T., Kodagali, V. N. and Nair, R. R. 1993. "Multibeam bathymetric, gravity and magnetic studies over 79° E fracture zone- Central Indian Basin." *Journal of Geophysical Research* Vol 98 B 9605-9618.
- Kodagali, V. N. 1990. "Report on the 58th Oceanographic cruise of ORV Sagarkanya", National Institute of Oceanography Goa Technical Report. PP 14.
- Kodagali, V.N., Kamesh Raju, K.A., Ramprasad, T., George, P. and Jaishankar, S. 1992. "Detailed bathymetric surveys in the Central Indian Basin". *International Hydrographic Review* Vol. LXIX(69). 143-150.
- Laughton, A. S., Mathews, D. M. and Fisher, R.L. 1971. "Structure of Indian Ocean". In: *The Sea, Vol.4 'New concepts of seafloor evolution'*. John Wiley and Sons, NY. 543-580.



Lepichon, X. and Heirtzler, J. R. 1968. "Magnetic anomalies in the Indian Ocean and seafloor spreading." *Journal of Geophysical Research*. Vol 73, 2101-2117.

Schlich, R. 1982. "Indian ocean: Aseismic ridges, spreading centers and oceanic basins. In: *Ocean Basins and Margins*". A E M Neirn and F G Stehli (Eds). Plenum Press, New York. Vol 6, 51-147.

Siddiquie, H.N., Hashimi, N.H., Vora, K. H. and Pathak, M. C. 1987. "Exploration of the continental margins of India." *International Hydrographic Review*. LXIV(1), 91 - 110.

Udintsev, G.B., 1975. "Geological and Geophysical Atlas of the Indian Ocean". Moscow Academy of Sciences, 151pp

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