

# Morphological features in the Bay of Bengal

K.V.L.N.S.Sarma, M.V.Ramana<sup>1</sup>, V.Subrahmanyam<sup>1</sup>

K.S.Krishna<sup>1</sup>, T.Ramprasad<sup>1</sup> and Maria Desa<sup>1</sup>

*National Institute of Oceanography, Regional Centre*

*176, Lawson's Bay Colony, Visakhapatnam - 530 017*

*<sup>1</sup>National Institute of Oceanography, Dona Paula, Goa - 403 004*

## ABSTRACT

Bengal Fan is one of the world's largest submarine fans having an area of 2.8-3.0 x10<sup>6</sup> sq.km. It extends from Ganges/Brahmaputra delta around 20° N latitude to south of 7° S, with a maximum width of about 1000 km around 15° N latitude. Large volume of continental sediments are being discharged by Ganges and Brahmaputra Rivers into the Bay of Bengal and the finer sediment particles reach even 7° S latitude. The sediments rest on the early Cretaceous ocean floor characterized by the Mesozoic anomalies M11 through M0. Pattern of sediment deposition, tracing the imprints of sediment movement, turbidity current flows, paleo channels, their migration in time and space and sea level fluctuations by facies identification can be used to reconstruct the development history of the Fan. After India's soft collision with the Eurasian plate, these events may have played a critical role in shaping various morphological features since late Eocene in the Bay of Bengal.

The present 12 kHz Echo sounder data collected along the NW-SE trending long profiles spaced at 30 nautical miles aided to improve the bathymetry chart of the Bay of Bengal. The echograms show some important geo-morphological features of the seafloor. One such feature is the "Swatch of no ground" which resembles a deep Canyon/Channel/ valley. Several longitudinal channels appear to drain the sediments from the mighty rivers Ganges and Brahmaputra into the Bengal Fan. Levees and abandoned channels are also present on the seafloor. The eastern continental margin is characterized by narrow shelf followed by steep slope. Bathymetry in the adjacent Bengal fan varies from <500 to >4000 m. The echograms along some profiles depict an irregular and rugged topography immediately beyond the shelf break. The seafloor is very stable and smooth except few places beyond shelf break.

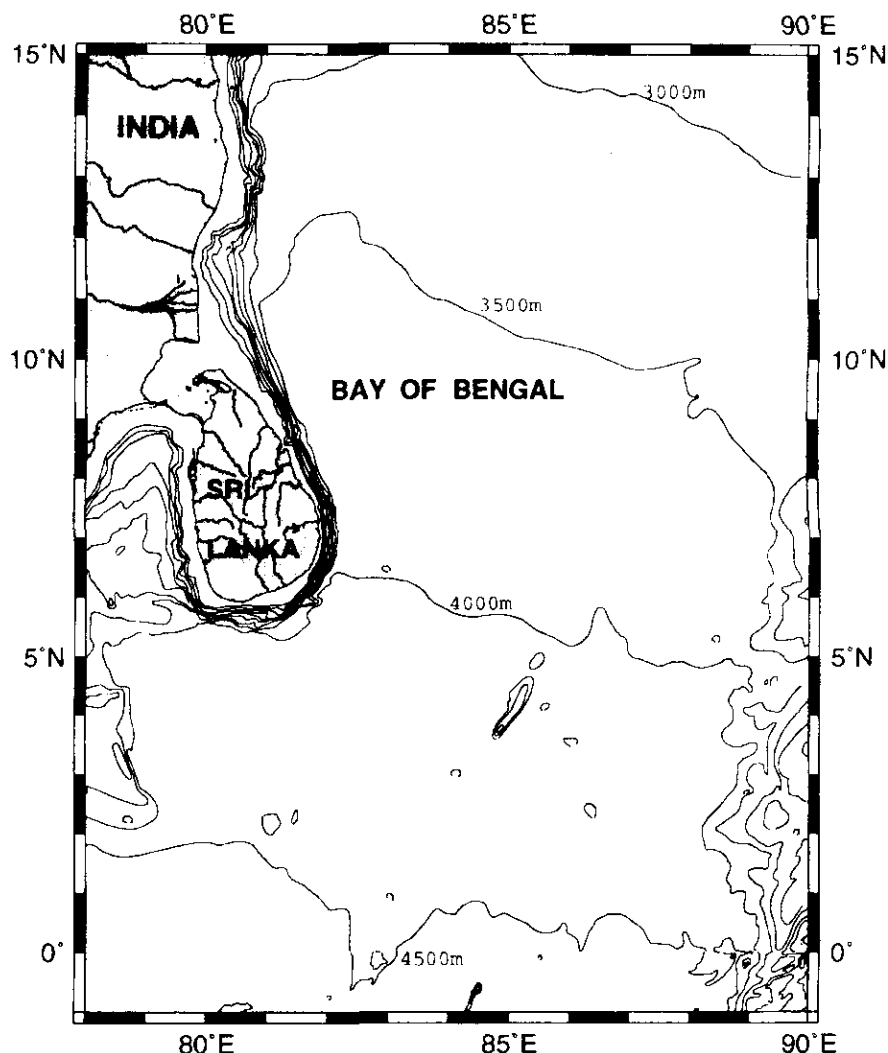
At some locations in the distal Bengal fan, isolated local highs dominate the seafloor with a positive relief of 500 to 900 m from the mean seabed and these features are associated with positive magnetic anomalies. The newly reported bathymetric high (R) is characterized with three peaks, and associated with a positive magnetic anomaly. This positive topographic high is surrounded by abandoned channels with levees and the fan divisions.

## INTRODUCTION

Study of the ocean floor features is essential to understand the history and style of evolution of any ocean basin. Structures in the oceanic volcanic basement (such as fracture zones, aseismic ridges and seamount chains) which may have evolved along with the ocean floor over which they lie, hold keys to the evolutionary history of the ocean basins. The passive continental margins and some times the deep sea basins adjoining them are generally covered by thick pile of sediments which make it difficult to examine the features associated with the volcanic basement of the ocean floor.

The Bay of Bengal is one such region where a thick pile of Bengal Fan sediments covers the entire basement and renders the ocean floor bathymetry virtually featureless. The sediment cover is exceptionally thick (about 21 km) at the apex of the Bengal fan in the Bangladesh offshore region and decreases gradually to about 8 to < 2 km in the

central and southern parts (Curry 1991). In the distal reaches of the fan at 7° S, the sediments are a few hundred meters thick. Very little is known about the features associated with the oceanic basement of the Bay of Bengal. Systematic studies have been carried out by different workers to understand the nature of the basement of the Bay of Bengal on which the morphological features are existing (Ramana et al. 1992). Limited multichannel seismic reflection work along a few regional traverses (Curry et al. 1982; Gopala Rao et al. 1994) reveals two prominent features. They are i) 85° E and ii) the Ninetyeast Ridges both buried under the thick pile of sediments. But for these two from the seismic sections, the basement appears to be associated with minor undulations and occurs at variable depths of 8-10 km or more. Based on the relative displacements of magnetic anomalies, Ramana et al. (1994) inferred some fracture zones. Due to huge sediment overburden in the Bay of Bengal surface expression of these



**Figure 1a.** Bathymetry map of the Bay of Bengal. Contour interval 500 m.

fracture zones could not be seen in the physiographic map of the Bay of the Bengal. While the Ninetyeast Ridge is characterized by the positive topographic expression.

The sediments in the deep sea rest on the early Cretaceous ocean floor characterized by Mesozoic anomalies M11 through M0 (Ramana et al. 1994). Some new morphological features are observed on the seafloor. These features are studied in brief in this short note.

**DATA**

Bathymetry and total intensity magnetic data were collected onboard ORV Sagar Kanya. Geophysical data has been collected using Global Positioning System (GPS) for positioning. Elac narrow beam echosounder (12 kHz) provided the bathymetric data. An EG & G Geometrics

(G 801/3) magnetometer was used for recording the earth's total intensity magnetic data. The magnetic data were corrected for the 1992 epoch of the International Geomagnetic Reference field (IAGA Division V, 1992) and the residual magnetic anomalies were plotted perpendicular to the ship's track.

**RESULTS AND DISCUSSION**

In the northern end of the Bay of Bengal the bathymetry is shallow, and depth to the seabed occurs less than 2000 meters. The bathymetry over central Bay of Bengal is relatively flat. The average depth is around 3000 meters (Fig.1a). The seafloor gradient decreases gradually from north to south. In the northern Bay of Bengal there exists some deep valleys. One such deep valley is known as the

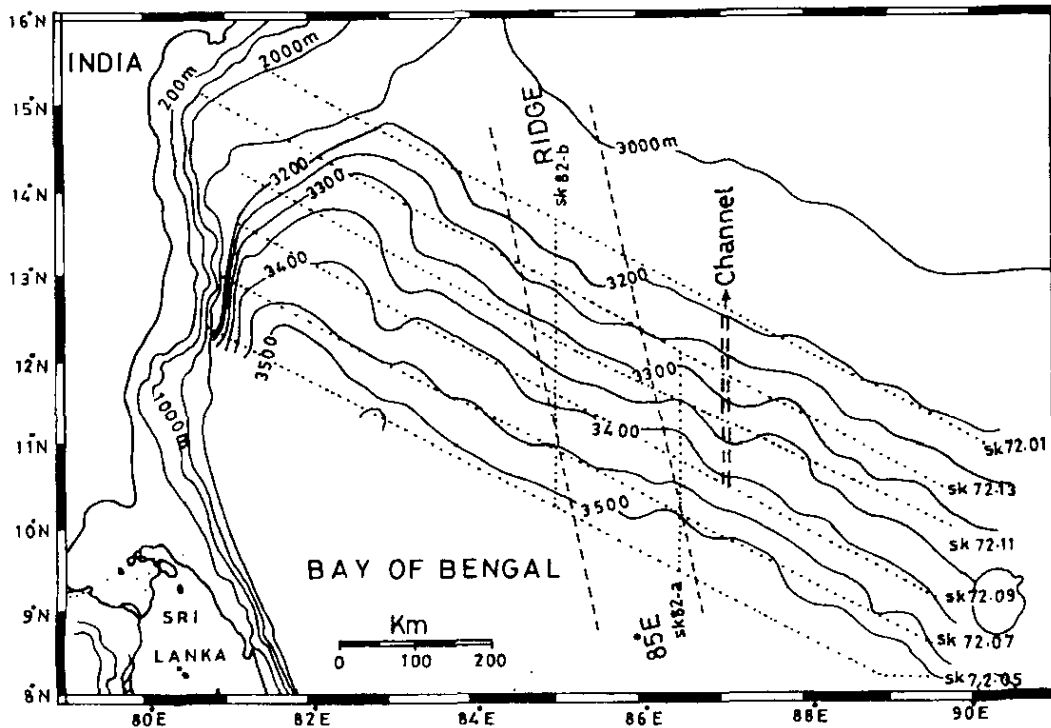


Figure 1b. Detailed bathymetry (variable contour interval) map of the Central Bay of Bengal. Cruise tracks are shown with dots. Boundary of 85°E Ridge is shown with thin dashed lines.

"Swatch of No Ground" (Fig.2a). The deepest portion of the valley is recorded around 1340 m with an overall relief of 400-450 m from the surrounding mean seafloor depth of 1000 m. The width of the Swatch of no ground valley is about 14 km.

Within this part of the deep valley channel, there exists another narrower valley like feature, which runs in NE-SW direction and it changes to N-S direction in South. It requires more systematic bathymetric surveys with Swath bathymetry System to map the geomorphology of this turbidity channel.

Increasing depths are encountered towards south. A maximum of 3500 meters was recorded in the Southwest corner of the study area. An interesting observation is around 12° latitude and 87° longitude the smooth bathymetry deviates by fifty meters from the surrounding very smooth stable seabed. (Fig.1b).

For the morphological development of the fan mass movement turbidity currents, sea level fluctuations and tectonics might have played a vital role. Morphologically the offshore Bengal Basin can be divided into Mahanadi, Krishna-Godavari and Cauvery offshore basins and intermediate non-basinal areas such as Visakhapatnam-Chilika lake shelf and Madras-Pondicherry shelf. Non basinal areas reflect morphological features related to

eustatic sealevel fluctuations since Late Pleistocene (18,000 yr B.P). Four coast parallel strand lines at 130, 80, 60 and 30 m water depths represent the sealevel regressional phases during the period between the late Pleistocene and Holocene.

The deltaic river processes mostly influence morphology of the offshore river grabens, mass movement and turbidity currents. "V" shaped Canyons, fan Valleys, fault valleys etc are some of the prominent morphological features of these basins. The outer shelf of these basins is associated with sediment slumps and neotectonic faults.

In the Central Bengal fan the average depth of the seabed is around 3400 m. Several turbidity channels are noticed in the fan area and some of them are channel levee wedges of abandoned type as reported by Emmel & Curray (1984). The channel widths in general vary from 5 to 27 km in the Bengal Basin.

An interesting feature of the southern Bay of Bengal is the presence of a large number of bathymetric highs/seamounts. Several workers (Kanaev & Turko 1976; Watts 1984; Marova & Alehina 1992; Kamesh Raju et al. 1993; Mukhopadya & Batiza 1994; Sborshchikov et al. 1995) have carried out extensive studies on seamounts from world oceans. The seamounts SM1 and SM2 have been studied in detail using the bathymetry and magnetic data. The

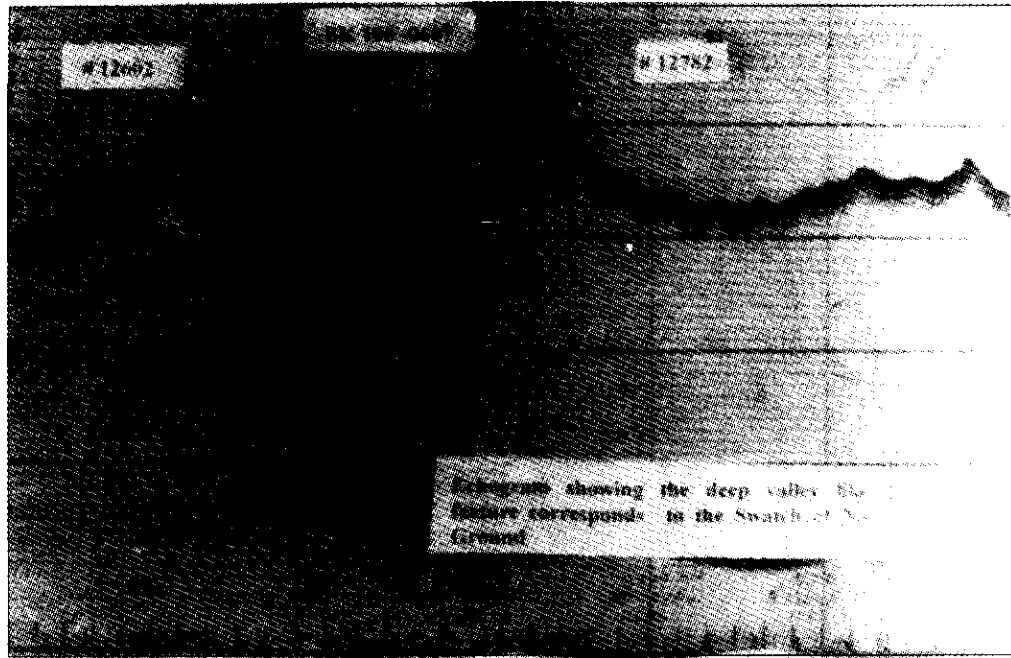


Figure 2a. Echogram showing the "Swath of No Ground".

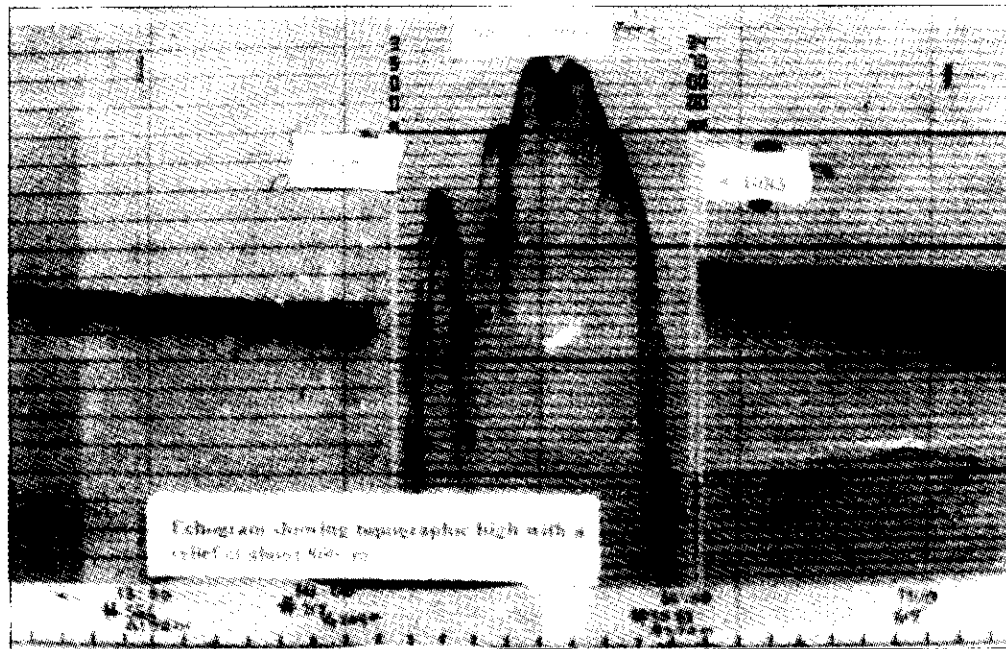
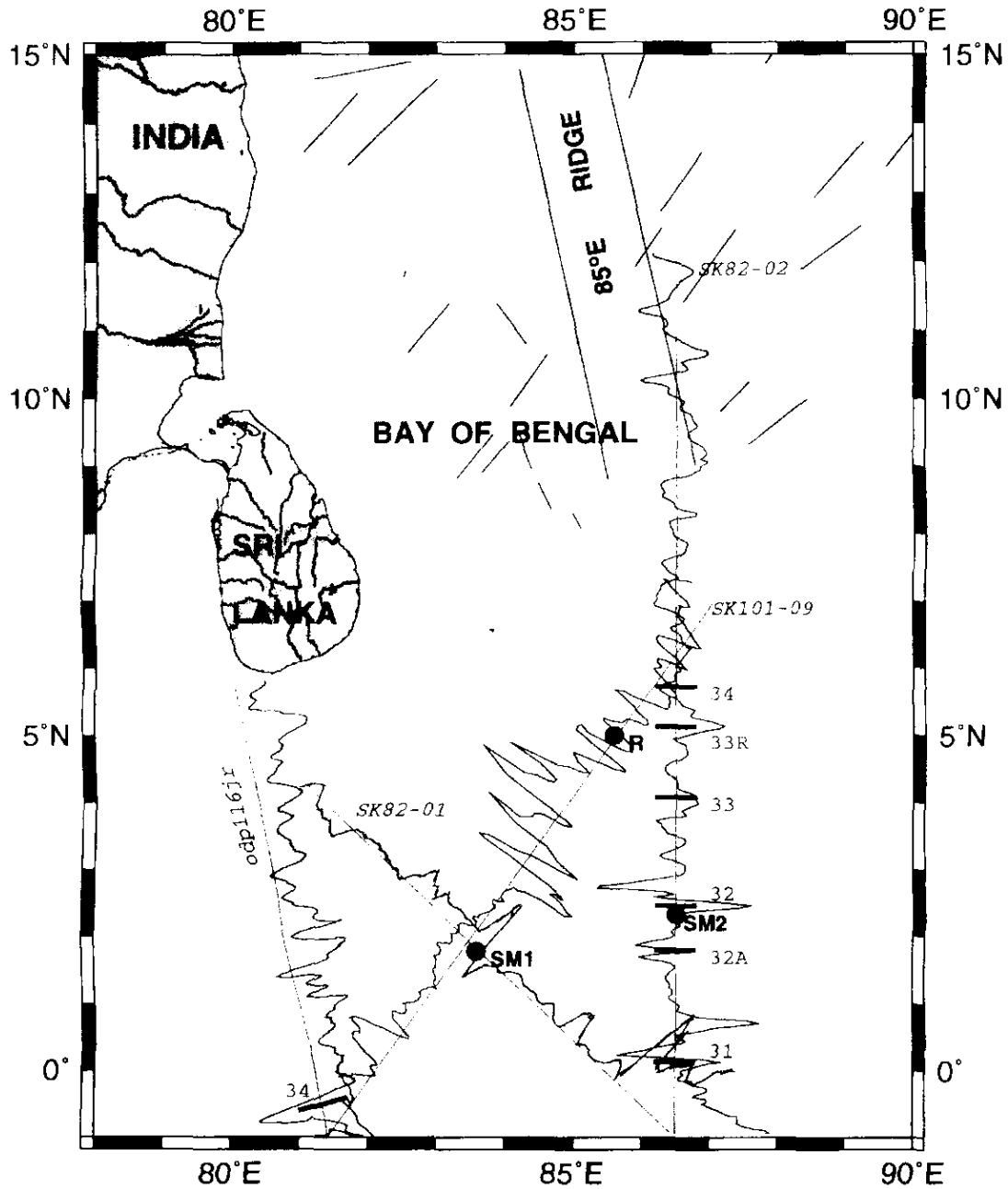


Figure 2b. Echogram showing the positive topography feature in the distal Bengal Fan.



**Figure 3.** Magnetic anomalies plotted perpendicular to the Cruise tracks in the distal Bengal Fan.

studies suggest that the seamount SM1 lies on the Cretaceous Magnetic Quiet Zone Crust and the SM2 is on Late Cretaceous crust (Sarma et al. 1998). The seamount SM1 belongs to Afanasiy Nikitin seamounts chain. Basalts dredged from the seamount chain show affinity towards the hotspot related intraplate sub alkaline magmatism. It appears that the final phase of volcanic activity led to the formation of a high seamount with the top emerging above seabed as a volcanic island (Sborshchikov et al. 1995).

Around latitude  $05^{\circ} 30' N$  and  $86^{\circ} E$  longitude another bathymetric high (Fig.2b) is observed with a positive magnetic anomaly of  $200 nT$ . Seafloor spreading magnetic anomaly studies (Sarma et al. 1998) indicate that bathymetric high (Fig.3) lies on the boundary of magnetic anomaly A 34 Late Cretaceous crust. This bathymetric high (R) occurs north of the Afanasiy Nikitin seamount chain and it is an isolated bathymetric high and is surrounded by abandoned major channels with levees and fan divisions.

## CONCLUSIONS

1) Though the Bengal Fan in general has a smooth topography, there exists several valley like features in the north and isolated highs in the southern Bay of Bengal.

2) The newly reported bathymetric high in the distal Bengal Fan exhibits a positive magnetic anomaly. The generated seafloor spreading type magnetic anomaly in the distal Bay indicates that the seamount SM2 lies on the Late Cretaceous crust.

3) The mass movement, turbidity currents, sea level fluctuations, tectonics and the effect of Himalayan uplift might have played a significant role for the morphological development of the fan.

4) Study of sediments and their depositional history perhaps provide key to decipher the development history of fan in time and space.

## ACKNOWLEDGEMENTS

We thank Dr. Ehrlich Desa, Director, National Institute of Oceanography, Dona Paula, Goa, for his encouragement. We extend our thanks to the officers and crew of the ORV Sagarkanya. We also thank the Department of Ocean Development, New Delhi, for providing ship time. We also thank the reviewers for their valuable suggestions in improving the manuscript. NIO contribution No.3568.

## REFERENCES

- Curray, J.R., Emmel, F.J., Moore, D.G & Raitt, R.W., 1982. Structure, tectonics and Geological history of the northeastern Indian ocean, in *The ocean Basins and margins*, 6, The Indian ocean, pp. 399-450 eds A.E. Nairn, A.E. & Stehli, F.G., Curray, J.R., 1991. Possible greenschist meta morphism at the base of a 22 km sediment section, Bay of Bengal, *Geology*, 19, 1097-1100.
- Emmel F.J. & Curray, J.R., 1984. The Bengal submarine fan north eastern Indian ocean, *Geo Marine Letts.*, 3, 119-124.
- Gopala Rao, D., Bhattacharya, G.C., Ramana, M.V., Subrahmanyam, V., Ramprasad, T., Krishna, K.S., Chaubey, A.K., Murty, G.P.S., Srinivas, K., Maria Desa, Reddy, S.I., Ashalatha, B., Subrahmanyam, C., Mittal, G.S., Drolia, R.K., Rai, S.N., Ghosh, S.K., Singh, R.N. & Mazumdar, R., 1994. Analysis of multi-channel seismic reflection and magnetic data along 13°N latitude across the Bay of Bengal, *Marine Geophys. Researches*, 16, 225-236.
- IAGA Division V, Working group 8, 1992. International Geomagnetic Reference Field, Revision 1991, Special report, *Geophysics*, 57, 956-959.
- Kamesh Raju, K.A.K., Ramprasad, T., Kodagali, V.N., & Nair, R.R., 1993. Multibeam Bathymetric gravity and magnetic studies over 79°E fracture zone, Central Indian Basin, *J. Geophys Res.*, 98, 9606-9618.
- Kanaev, V.F. & Turko, N., 1976. Morphology and volcanism of the Indian Ocean floor, in : *Volcanoes and tectono sphere*, pp.35-60, eds Hitoshi Aoki & Susumu Iizuka, Faculty of marine Sciences and Technology, Tokai University press.
- Marova, N.A. & Alehina., 1992. Seamounts of the Atlantic ocean and their distribution, *Oceanology*, 32, 120-123.
- Mukhopadhyay, R. & Batiza, 1994. Basinal Seamounts and seamount chains of the Central Indian Ocean, probable near axis origin from a fast spreading ridge, *Marine Geophys. Researches.*, 116, 303-314.
- Ramana, M. V, Subrahmanyam, V., Krishna, K.S., Chaubey, A.K., Sarma, K.V.L.N.S. & Murthy, G.P.S., 1992. Marine magnetic studies in the Northern Bay of Bengal. Preliminary results, in : *Oceanography of the Indian Ocean*, pp.519-526, ed. Desai, B.N., Oxford & IBH Publ. New Delhi.
- Ramana, M.V., Nair, R.R., Sarma, K.V.L.N.S., Ramprasad, T., Krishna, K.S., Subrahmanyam, V., Maria D Cruz, Subrahmanyam, C, John Paul, Subrahmanyam, C, Chandra Sekhar, D.V., 1994.
- Mesozoic anomalies in the Bay of Bengal, *Earth planet. Sci. Lett.*, 121, 469-475.
- Sborshchikov, I.M., Murdmaa, I.O., Matveenkov, V.V., Kashintdev, G.L., Golmshtock, A.I. & Almukhameda, A.I., 1995. Afnansy Nikitin Seamount with in the intraplate deformation zone, Indian Ocean, *Marine Geol.*, 128, 115-126.
- Sarma, K.V.L.N.S., Ramana, M.V., Subrahmanyam, V., Krishna, K.S., Ramprasad., T. & Maria Desa, 1998. Seamounts an additional tool to confirm the nature of the crust and to locate possible mineral resources for dredging., *Marine Geo Resources and Geotechnology*, 16, 41-51.
- Watts, A.B., 1984. Introduction to Seamounts, Special section, *J. Geophys. Res.*, 89, 11066-11068.

(Accepted 2000 June 30. Received 2000 June 6; in original form 2000 March 13)