

Marine Geoscientific Surveys in Ports and Nearshore Regions of the Arabian Sea off Central West Coast of India

L. V. SUBBA RAJU, P. DIVAKAR NAIDU and F. ALMEIDA
National Institute of Oceanography, Dona Paula

ABSTRACT

Bathymetric, side scan sonar and shallow seismic surveys were carried out in ports and adjacent nearshore regions of the Arabian Sea off the central west coast of India.

It is observed that the geological strata in the approach channels, creeks, river mouths and nearshore regions differ considerably in their nature and formations. In the regions of rivers confluencing the sea, the thickness of clays varies from 2 to 10 m and they cover the underlying harder formations (rock/consolidated sediments). Other features like sandbars, U-Shaped furrows and ridges, composed of loose and compact sands, are also recorded at the river mouths. Ripples and lineations are noticed in some of the clay covered channels and adjacent regions. Steep scarps and depressions are observed at a few places in the approach channels.

The thickness of the unconsolidated clays near the river mouths represents the extent of sediment transport by rivers and their tributaries. Sandbars, U-Shaped furrows, ripples, ridges and lineations are considered to have been formed by the wave action and tidal currents whereas steep scarps and depressions are due to erosional stages of fractured/altered rock formations during lowered sea levels or minor neotectonic activity.

The observed formations and features of the seabed can be suitably utilised for the development of existing harbour channels, new harbours, jetties and other landing places of vessels.

INTRODUCTION

The central part of the west coast of India is endowed with major ports like Bombay and Mormugao, minor ports such as Redi, Vengurla, Devagarh, Vijayadurg, Dabhol, Bankot, Murud-Janjira, Revadanda, Daman and many other jetties. The Konkan region which is an integral part of the above, still remains a comparatively underdeveloped area despite its vast natural resources. The hinterland is rich in iron, ilmenite and other mineral deposits. About 30 major and minor rivers flow westwards in this region and join the Arabian Sea. Development of the bays, creeks and other suitable river

mouths into ports, suitable for vessels, would provide the much needed facilities for coastal traffic and help decongest the main ports of Bombay and Mormugao. The bays and creeks are infested with seasonal shoaling, bar formations and other marine obstructions rendering navigation difficult and thus posing serious limitations on port activity. At times, transhippers require selection of a suitable site for jacking up in the shallow waters. Moreover, river mouths can be developed for inland transportation of the shallow vessels. Keeping the above necessity in view, the surveys are conducted at Mormugao and Bombay ports, Dabhol and Rajpur minor ports

and at nearshore regions of Redi, Vengurla islands, Ratnagiri, Nawapur, Umbargaon and Umbhrat by National Institute of Oceanography as a part of research and sponsored projects. This paper aims at giving a brief picture of the nature of the bottom and subbottom in these regions along the central west coast of India, the geology of which is given in Fig. 1 along with the places where the surveys have been carried out.

TECHNIQUES

The techniques employed and the instruments deployed in the surveys are:

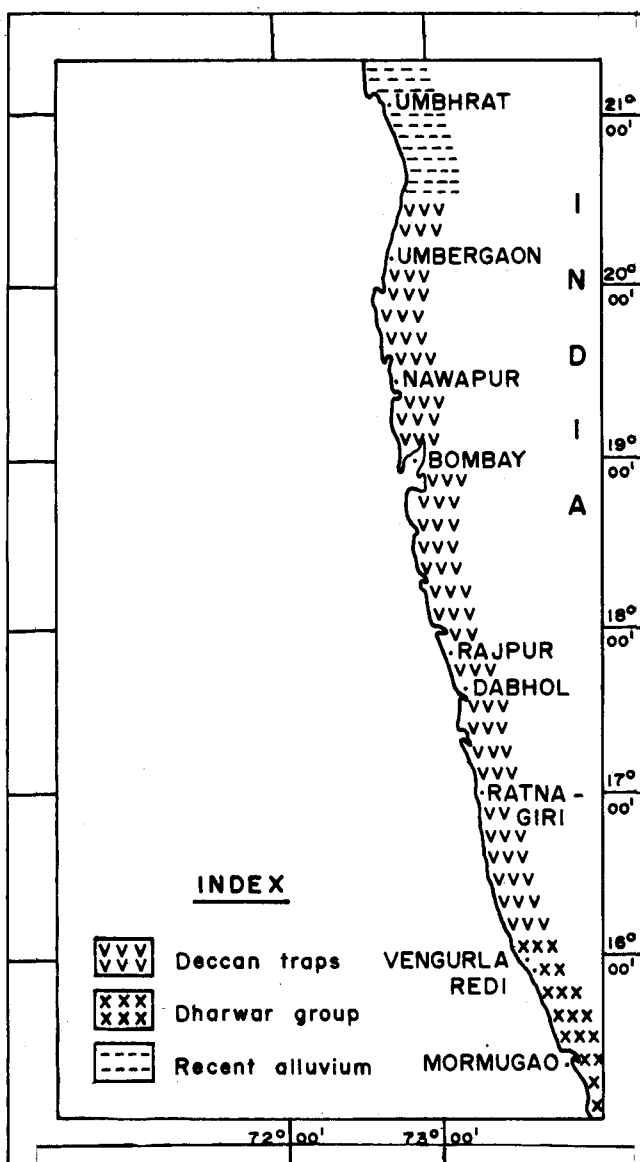


Fig. 1 Geology of the coastal tract and sites where the surveys have been carried out.

Position Fixing

Positions of the survey tracks were determined earlier by sextant angles of shore objects, whose UTM coordinates are known. Depending upon the type of the survey and the scale of the chart, positions were taken at regular intervals of time and plotted to fix the position of the track. The vessel was steered accordingly along the predetermined track. Repeatability and accuracy of the surveys are highly increased by systems like MINIRANGER and SHORAN that are used for these surveys.

Bathymetry

The surveys were carried out with a dual frequency Atlas Deso - 10 Echosounder (30 and 210 KHz frequencies; basic scale of 0 - 20 m with a maximum range of 280 m) for providing a good resolution and sub-bottom penetration in geologically favourable areas. A bar check is carried out everyday at the time of commencing and ending the surveys and the records are corrected for tides.

Shallow Seismics

The surveys were carried out either with Huntco Hydrosonde 2A boomer, EG & G uniboom or sparker systems or ORE mud penetrator depending upon the water depth and the requirements. In these systems, the recorders are operated at various sweep rates depending upon the required resolution and penetration.

Side scan sonar system

The EG & G system consists of a dual channel graphic recorder, a tow fish and a tow cable. Tow fish was operated with 10° beam depression and 20° beam width. The height of the tow fish above the seabed is controlled from the length of the cable paid out and the towing speed of the boat. Surveys are carried out in 50 or 100 m distance range for good resolution.

Grab Sampling

A van Veen grab (area 0.04 m²) sampler was used for the collection of surficial seabed sediment samples at stations selected after an examination of the echograms and the seismic records.

RESULTS

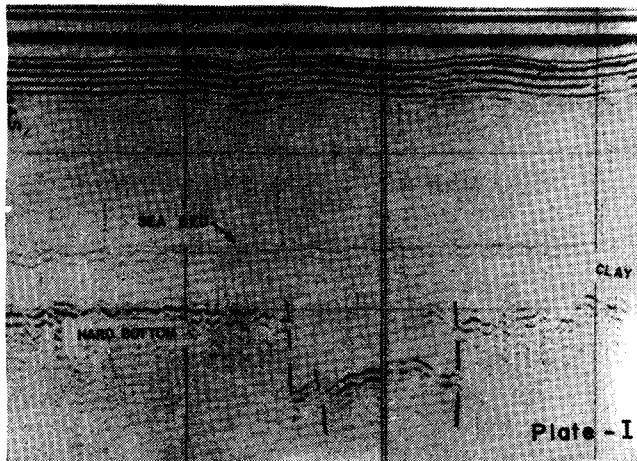
Mormugao

The survey area lies in the channel area of the port. The inner channel is covered by thick clays ranging

from 4 to 6 m. Acoustically transparent clays mask the underlying hard formations except at few places with sharp pinnacles of hard rocks. The thickness of clays decrease towards the shore and moreover, they become relatively hard and compact in central region of the channel. An unconsolidated sediment cover of 1 to 4 m thick overlies the hard strata at comparatively shallow depths in the outer channel region as given by Wagle *et al.*, (1988).

Redi

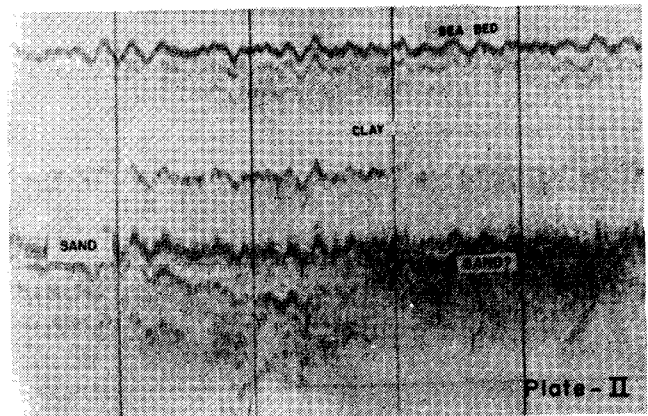
The survey region lies at a distance of about 10 km from the coast in water depths of 10 to 18 m. The bathymetric contours in the area almost in NW-SE direction trend parallel to the coast. The seabed gently slopes to the west. Near the coast, thick clays rest on the hard strata, which is a continuation of the rocky formations of the land and exposed on the seabed in the nearshore waters. The area is marked by clays reaching its maximum thickness of 9 m in southern part of the area investigated. The thickness of sediments varies from 3 to 8 m in the central part where the disappearance of the subbottom layer (hard rock ?) below the clay zone is observed prominently (Plate I).



Vengurla Islands

The survey region lies at a distance of about 20 km from the coast. Bathymetric contours of the region trend in NW-SE direction, sub-parallel to the coast. The depths of water in the area vary from 30 to 38 m with a gentle gradient of the seabed towards west of Vengurla Islands. The seabed is characterised by acoustically transparent clays. The thickness of clays varies from 15 to 17 m in which relatively hard strata (sand ?) with a maximum thickness of about 1 m is sandwiched (Plate II). In addition,

pockets of hard strata are also observed within the clay zone at some places. Few other places in the central part of the area investigated are marked by a prominent reflector (rock ?) at a maximum depth of 27 m from the seabed. Near the islands, the transparent clays with a maximum thickness of around 13 to 14 m rest on the hard strata which are likely to be the extension of the rock formations of the islands. In addition, the sub-bottom is traversed with palaeo channels below the clay cover of 12 m thick in NE-SW direction.



Placer rich bays of Ratnagiri

The region between Malwan and Dabhol consists of many bays out of which the ilmenite placers are enriched in a few bays (Ray, 1958). Occurrence of offshore ilmenite placers have been reported in Ratnagiri, Mirya, Jaigarh and Ambwah *etc.*, bays. Since the thickness of the heavy mineral bearing sands range from 2 to 10 m and they spread over an area of 435 km², their total reserves were estimated to be large (Siddiquie *et al.*, 1982).

Dabhol

The water depth in the creek and mouth of river Vashisti near Dabhol vary from 2 to 18 m. The seabed is even and gentle. A sand bar is observed near the mouth of the river and it extends on a step like feature towards offshore in N 70° E direction. Study in the sand bar area indicated three reflectors (Fig. 2), upper one being the sand layer, the middle and bottom are likely to be altered and hard traps. The area other than sand bar region, is marked by clays overlying the above three reflectors. The acoustic basement is rugged and the depressions are filled with sediments. A step like feature to the west of the sandbar is observed to be the transition zone between sands of the bar and offshore sandy clays (Divakar Naidu, 1987).

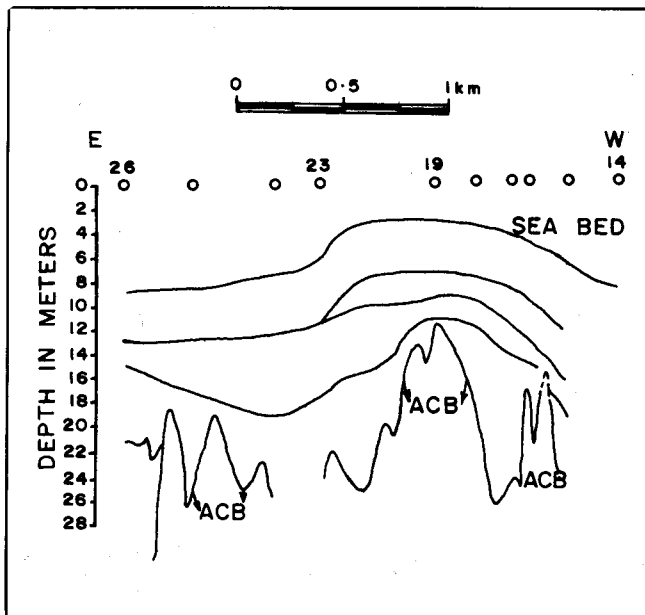
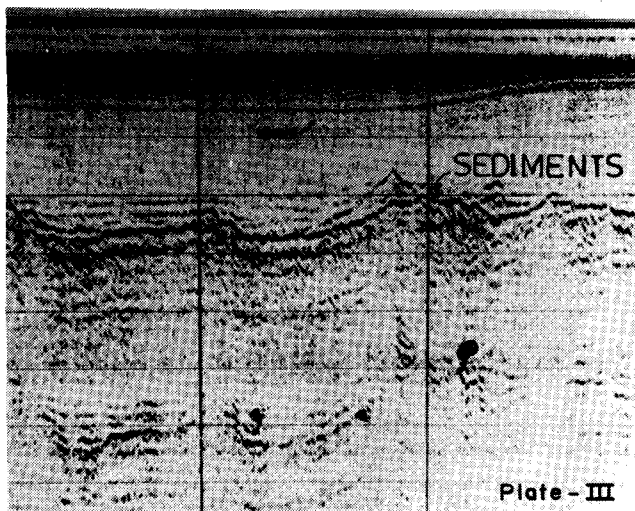


Fig. 2 Shallow seismic profile representing prominent seismic reflectors and interpreted acoustic basement (ACB)

Rajpur

The water depth in the region varies from 2 to 8 m. The seabed is even and gently sloping. The eastern and western sides of the creek are carpeted by a maximum of 16 m thick unconsolidated sediments probably overlying gravel while the middle part of the creek has a varied thickness of 8 to 16 m of sediments underlain by boulders. At a few places, the strata is hard and uneven (Plate III). Moreover, the southern part of the creek is covered with clays while the northern part is covered



by silty clays. Towards offshore, the thickness of clays vary from 8 to 14 m (Divakar Naidu, 1987 a).

Bombay

The area surveyed lies towards south of the Bombay port where the depth ranges between 2 and 12 m extending towards west. The seabed is generally even except in the nearshore areas. A large area of the seabed in the nearshore and in the vicinity of the rock exposures off Karanja islands and Thal shoal area marked by well defined ripple trains (Almeida and Bhattacharya, 1980) with varied wavelengths of 130 to 280 cm trending in ENE-WSW direction. The crests of the ripple trains are straight, continuous and well defined with uniform ripple height and spacing.

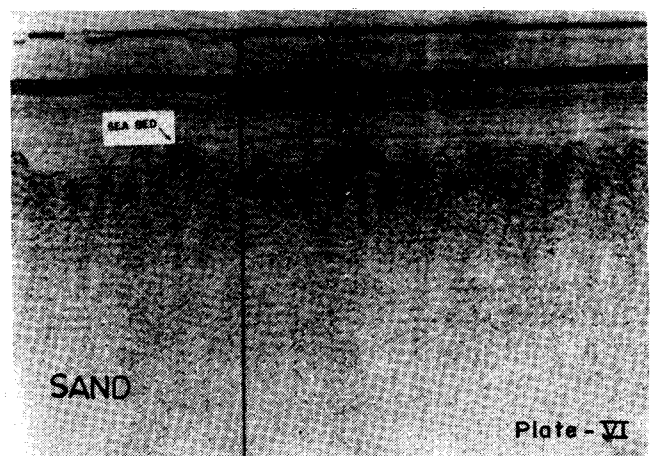
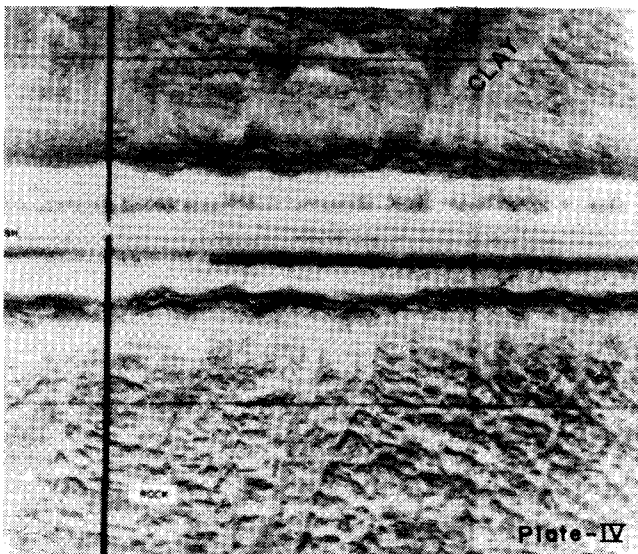
The seismic reflection records show four distinct reflectors, the lowermost being the acoustic basement mainly representing the Deccan traps followed by an erosional surface probably of an unconformable zone which is succeeded by a reflector representing the dense sediments, above which clays are noticed. However, faint reflectors are seen from below the basement. The bedrock reflector continues for a length of 2 km offshore which lies about 10 m below the seabed, and shows lateral variations (Bhattacharya *et al.*, 1987).

Nawapur

The survey area lies within a distance of about 15 km from the coast in water depths of 6 to 13 m. The topography of seabed is even in the offshore areas upto the distances of 12 to 15 km from the shore and uneven in the nearshore areas due to the sharp pinnacles of hard rock with elevations of 1 to 2 m. The offshore area is covered by 0.5 to 3 m thick clays followed by acoustic basement, but in the nearshore areas, the bedrock (basalt ?) is exposed on the seabed at a few places.

Umbargaon

The survey area lies within a maximum water depth of 13 m at a distance of nearly 15 km from the coast. In the nearshore areas, sub-bottom information is not discernible at a few places as the area contains hard rock whereas the rest of the area is covered by sediments with a maximum thickness of 2 m, overlying the hard rock. Northern portion of the area often shows sudden changes in depth from 3 m to less than 1 m due to rock outcrops compared to the southern portion of the same. The offshore region is bordered by rock outcrops and depressions with about 1 m thick sediments (Plate IV). U-shaped furrows and lineations are observed here below which especially in the fringes of outcrops, 1 m penetration is discernible.

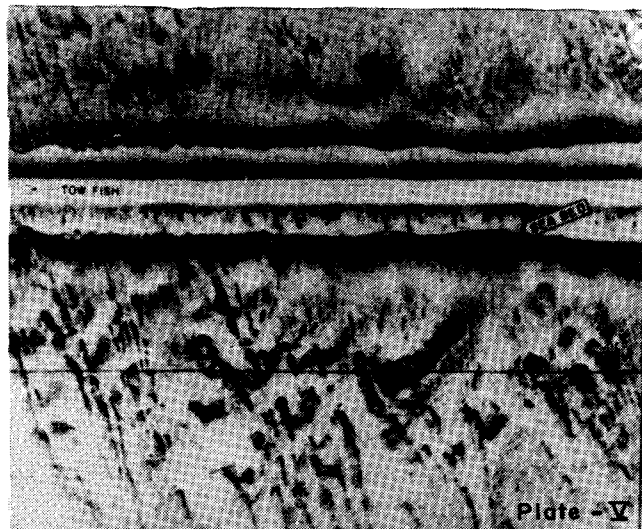


Umbhrat

The survey area lies within the maximum water depths of 8 m and is at a distance of about 11 km from the coast. The seabed in the vicinity of Umbhrat upto a distance of about 5.5 km (water depths 2 to 5 m) from the coast is uneven and further to a distance of 11 km it is even. Few places in this uneven zone are covered by 2 to 3 m thick acoustically transparent clays overlying the denser sands. These sands exposed on an uneven topography are recorded in sonograph as ridges (Plate V & VI) trending in NE-SW direction.

DISCUSSION

In the Mormugao port, the inner channel clays are not



disturbed due to the weak currents. In the central part of the channel, hard formations are exposed due to dredging which is quite often carried out for safe navigation and development of the harbour area. It is indicated by Wagle *et al.*, (1988) that the sediments are washed away due to the circular currents existing in the outer channel leaving only thin sediment cover over the harder formations.

Off Redi, at depths of 10 to 18 m, the sudden disappearance of sub-bottom layers (laterite ?) below the clay zone can be due to the subsidence on account of neotectonic activity. Off Vengurla Islands, around 30 m water depths, the sub-bottom is traversed with palaeochannels. Karai Keral creek flows into the sea from the adjacent land and the extension of its rivulets are recorded offshore at water depths of 30 to 38 m below the clay cover of about 12 m thick. These extensions can be confirmed if the shallow seismic surveys are undertaken right from the mouth of the creek to this region. It may be recalled that the International Indian Ocean Expedition (IIOE) had indicated a 50 fathom flat as the standstill of the sea level for a longer duration around that region. It is surmised that rivers, channels, creeks *etc.*, were flowing upto the present shelf break in those periods. It is quite reasonable to assume that these channels were covered with the deposition of later sediments with consolidated/unconsolidated formations that are sufficiently wide and acoustically different from the surrounding formation. This corroborates earlier findings that Vengurla Islands, which once formed part of the main land were cut off due to severe erosion and weathering (Anonymous, 1962) and ferruginous quartzites, micaceous rocks of the Dharwarian age of these islands are likely to be beneath these palaeochannels.

The heavy mineral placers off Ratnagiri, Mirya, Jaigad and Ambwah bays *etc.*, are derived from the Trap terrain

and brought to the sea by rivers flowing over the adjacent land (Siddiquie *et al.*, 1979). The palaeochannels are also observed beneath the seabed right from the shallow waters in these areas as evidenced by Rajamanickam and Subba Raju (1987).

The acoustic basement noticed in the Dabhol creek is the extension of onshore basalts towards offshore. The sandbar at the mouth of the Dabhol creek is likely to have been formed due to breaking of waves during low tidal period. Visual examination of the surficial sediment samples in the Rajpur creek showed that the northern part of the creek has more percentage of silt in the seabed than that of southern part. It is likely that the silt has been deposited due to weak currents in the northern part while the same could not get settled due to high current movements in the southern part of the creek.

Bombay harbour area, shoal areas off Thal and near-shore areas off Karanja islands are marked by well defined ripple trains. They appear to have been formed by the wave action during the fair weather and maintained by the tidal currents. Steep scarps and minor faults observed at a few places are attributed due to differential erosional stages of highly fractured/ altered rocks or neotectonic activity by Bhattacharya *et al.*, (1987). The pipelines exposed between Trombay and Butcher islands near harbour area and noticed through the sonar surveys are due to the difference in the current velocities existing in opposite directions in that region (Subba Raju and Vora, 1987) which may be responsible for erosional stages of rock formations.

Exposed formations are eroded due to the wave action in the nearshore regions of Nawapur, at some places. In the offshore area, the thickness of clays is minimum due to the low sedimentation rate (Borole, *personal communication*). U-Shaped furrows and lineations observed in the nearshore regions off Umbargaon are considered to have been due to strong tidal currents and wave action prevailing there. Off Umbhrat, the sand ridges are formed due to the strong tidal currents and the best of them are seen in the west close to the eastern bank off Daman (Vora *et al.*, 1980).

CONCLUSIONS

1. In the channels of the harbours, the hard formations cropping out of the clays giving rise to sharp pinnacles should be dredged/blasted out for safe navigation.

2. Before deploying any transhippers in the offshore regions, drilling should be carried out to ascertain the

hard sub-bottom for the selection of suitable sites for their jack up to avoid any untoward incidents due to the misleading nature of the recorded formations.

3. Pockets of sand zones and sand ribbons sandwiched in the clay layers should be studied in the light of palaeoenvironment for confirming their origin.

4. Attempts should be made to utilise the reported ilmenite rich deposits for economic development.

5. Since the sand bars are formed seasonally, trials should be made to mitigate the accumulation of sediments at the mouths of the rivers for safe navigation.

6. The hard rock on the surface or at shallow depths, can be utilised for purposes of underwater tunnels after taking the economical aspects into account.

7. U-Shaped furrows, lineations and ridges should be properly delineated for the study of the underwater currents and the formations associated with them.

8. Before laying pipelines, cables *etc.*, beneath the seabed, the current measurements should be undertaken in the region.

The observed bottom and sub-bottom geological formations can be studied further in detail and utilised properly to ensure safe navigation and for rapid development of socio-economic and commercial activities off central west coast of India.

ACKNOWLEDGEMENT

The authors express their gratitude to Shri P. S. N. Murthy, Head, Geological Oceanography Division for his encouragement in this work, to Dr. Ch. Madhusudana Rao for going through the manuscript and for constructive criticism, and to the referee whose comments and suggestions have greatly improved the quality of the manuscript. The authors also express their sincere thanks to Dr. B. N. Desai, Director, National Institute of Oceanography for his permission to publish this paper.

REFERENCES

- Almeida, F. and Bhattacharya, G.C., 1980. Ripples on the seabed in the Bombay harbour area. *Ind. Jour. Mar. Sci.*, 9, 212-214 p.
- Anonymous, 1962, Physical features and natural resources. In *Maharashtra State Gazetteer*, Govt., of Maharashtra, 1027 p.
- Bhattacharya, G.C., Almeida, F., Vora, K.H. and Siddiquie, H.N., 1987, Subsurface geology of Bombay with palaeoclimatic inferences interpreted from shallow seismic profiles. *Jour. Coast. Res.*, (in press).
- Divakar Naidu, P., 1987, Shallow seismic surveys at Dabhol minor port in Maharashtra. *Proc. Sec. Nat. Conf. Dock & Harb. Engg.*, I.I.T., Madras, 344-348 p.
- Divakar Naidu, P., 1987 a, High resolution seismic surveys in Rajpur creek, Maharashtra, west coast of India. *Abst. Sem. Expl. Geophys.* 16 p.
- Nio Tech Rep, 1987, Seabed surveys and current measurements off Mormugao and Vengurla islands (in preparation).
- Ray, B.C., 1958, Ilmenite sand along Ratnagiri coast, Bombay, *Rec. Geol. Surv. Ind.*, 87, 418-432 p.

- Siddiquie, H.N., Rajamanickam, G.V. and Almeida, F.A., 1979, Offshore ilmenite placers of Ratnagiri, Konkan coast, Maharashtra, India. *Mar. Min.*, 2, 91 - 118 p.
- Siddiquie, H.N., Rajamanickam, G.V., Gujar, A.R. and Ramana, M.V., 1982, Geological and geophysical exploration for offshore ilmenite placers of the Konkan coast, Maharashtra, India. *Proc. Off. Tech. Conf., Houston, Texas*, 749 - 761 p.
- Subba Raju, L.V. and Vora, K.H., 1987, Surveys for marine inspection near the Bombay harbour area. *Proc. Sec. Nat. Conf. Dock & Harb. Engg., I.I.T., Madras*, 339 - 343 p.
- Rajamanickam, G.V. and Subba Raju, L.V., 1987, Application of high resolution shallow seismics for underwater archaeological investigations. *Abst. Fir. Nat. Conf. Mar. Archae. of Ind. Ocea. Count., Jamnagar, Gujarat*, 5 - 6 p.
- Vora, K.H., Gujar, R.R. and Karisiddaiah, S.M., 1980, Sand waves of the gulf off Khambhat. *Ind. Jour. Mar. Sci.*, 9, 90 - 93 p.
- Wagle, B.G., Gujar, A.R., Subrahmanyam, V. and Mislankar, P.G., 1988, Seabed surveys of Mormugao harbour, Goa, India. *Ind. Jour. Mar. Sci.*, (in press).