

SEABED SURVEYS FOR THE DEVELOPMENT OF PORTS AND HARBOURS CASE STUDIES FROM TUTICORIN AND MANGALORE, INDIA

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ABSTRACT

Analyses of echosounding (230 Line Km), side scan sonar (180 Line Km), high-resolution seismic profiling (170 Line Km) and surface sediment sampling (70) data collected in the Tuticorin and New Mangalore harbour areas have revealed the following.

Tuticorin: Echograms and surface sediment distribution show rough topography (0.5 to 3 m) and 0 to 62 percent gravel in dredged area and even topography with 95 to 99 percent sand in the remaining area. Isopachs indicate pockets of sand (0.5 m thick) and rocks (limestone) sporadically to 12 m water depth, beyond which 1.5 m thick sand overlies the rock. Sonographs of the area and boreholes confirm the areal extent of irregular rock exposures, gravel and sand, and also show strong imprint of dredging.

New Mangalore: Echograms show similar topographic variations as in Tuticorin in the dredged area of the harbour. By contrast, the bed of the approach channel is even and 0 to 8 m thick clayey silts overlie compact sand and weathered rock (granite). Sonographs show typical dredging furrows and dredge debris in sediment covered areas and they confirm the hard seabed regions. The presence of fairly thick clayey silts, except in some regions, overlying the bedrock off Mangalore favour the deepening of channel, whereas the occurrence of hard rock below a thick veneer of sand off Tuticorin may restrict deepening and necessitate special dredging strategies.

INTRODUCTION

India has 10 major ports - 5 each on east and west coasts (Fig.1). Some of these ports envisaged widening and deepening for deep draught vessels to cope up with the increased trade in future.

Recently, marine geological and geophysical surveys were carried out at the major ports of Visakhapatnam, Tuticorin, Mormugao and New Mangalore after the first phase of capital

dredging and at Karwar for the development of an all weather port. The paper synthesizes the results of surveys in Tuticorin and New Mangalore ports - both artificial deep-sea harbours, but significantly different in surface and subsurface geological features.

Physical, Geological and Environmental Setting

The port of New Tuticorin (Lat 8° 48'N and Long 78° 10'E) is an artificial deep-sea harbour located along the western margin of the Gulf of Mannar near the Southeastern tip of the Indian Peninsula (Fig.1). It has two rubble mound type parallel breakwaters, north and south of 4103 m and 3888 m, respectively. The northern breakwater constructed with indigenous materials and technical know-how is the longest breakwater in the world. Its approach channel is about 2.25 Km long and is 152 m wide at the entrance. The port has been designed to take 9.14 m draught vessels at all stages of tides in the first stage of development and 10.7 m draught vessels after expansion. It handles break bulk and dry cargo, POL products, Coal and fertilizer raw material.

The Tuticorin area is bordered by 16-25 Km wide coastal plain composed of recent alluvium. Further interior peninsular gneisses, charnockites and khondalites are extensively exposed (Anonymous 1974). The river Chittar joins the Gulf of Mannar a little south of the study area. This river originating in the western Ghats, drains through charnockites and peninsular gneisses in the upper reaches and through alluvium in lower reaches (Anonymous 1974). Beach rock occurs in and around Tuticorin. The study area is fringed by coral reefs at about 8 Km away from the shore. Extensive studies were carried out on the distribution of corals in the Gulf of Mannar. Recently, Hashmi *et.al* (1982) have discussed the topography, sediments and carbonate mineralogy of the region seaward of more than 20 m water depth, while Venkatesh and Ray (1981) studied the grain size characteristics of the sediments of a small area in front of the harbour entrance. In general, the sediments in the shelf upto 20 m water depth are composed of sands with negligible percentage of silts and clays.

The port of New Mangalore is situated at Lat 12° 55'N and Long 74° 50'E midway between Goa and Cochin on the west coast of India (Fig.1). It has two breakwaters each of about 570 m long. Its approach channel is 5.5 Km Long and 250 m wide. The port has been initially developed as a lagoon type harbour catering for vessels of 9.15 m draught. Subsequently, it is developed to accommodate vessels of 12.5 m draught. The port handles iron ore, general cargo, oil and fertilizer raw material.

The Mangalore region is bordered by western Ghats. However, the coastline is separated from the ghats by 78 Km wide coastal plain. The rivers Netravati and Gurupur join the sea a little south of the study area. The former rising in the western Ghats flows over a metamorphic terrain largely consisting of granite gneisses in the upper reaches. In the lower reaches the river drains plateaus covered with laterite and Tertiaries. The Gurupur river mainly drains a terrain consisting of granite gneisses and

laterite (Anonymous 1974).

Mineralogy of the Mangalore nearshore sediments was studied by Siddiquie and Mallik (1972). Studies on the nature of bottom topography and the distribution of sediments show that the innershelf off Mangalore is generally smooth and feature less and is covered by modern silts and clays (Nair et.al 1978).

Rainfall in the Tuticorin area is very scanty, being of the order of 640 mm and most of it occurs during the months of November - January when the Northeast monsoon is active. Excepting the river Chittar, no major rivers contribute to the Gulf.

In contrast, the rainfall over Mangalore is about 3000-5000 mm. Maximum precipitation occurs during the Southwest monsoon of June to September. As a consequence of this fresh water discharge into the sea through various river systems is considerable. Associated with heavy rainfall, the high relief and low physiographic maturity of the western Ghats, the detritus released from the mountain tops, hill slopes, or low lands is collected and transported further into the sea through these rivers.

Although both the regions fall under mixed semi diurnal tidal environment, Mangalore region experiences slightly higher tidal range (0.4-1.6 m) as compared to Tuticorin (0.3-1 m). The two study areas with marked variations in their physiography, environmental conditions and geological setting also exhibit significant differences in their surface and subsurface geological features.

METHODS

A total of 230 km of echosounding, 180 km of side scan sonar and 170 km of high-resolution seismic profiling data was collected during the surveys. An Atlas Deso-10 dual frequency (30 and 210 kHz) echosounder was used. A 105 kHz EG&G side scan sonar system consisting of a dual channel recorder and tow fish was used. The transducers in the tow fish were set for 10 deg. beam depression and 20 deg. vertical beam width. A 50 m light weight tow cable was used and the fish was towed just beneath the sea surface because of the shallow depths in the areas surveyed. The surveys were carried out on a 50 m scanning range to provide good resolution. Subbottom profiling was carried out with an O.R.E Mud penetrator consisting of Transceiver, over the side mounting transducer assembly coupled with an EPC graphic recorder. Surficial sediment samples were collected with a Van Veen grab (scoop area 480 sq.cm). The positions during the surveys at New Mangalore were plotted by obtaining sextant angles of known shore objects. However, during the Tuticorin port surveys a miniranger III precision system was used.

RESULTS AND DISCUSSION

Tuticorin Area

Approach Channel: Echograms show that the channel bed is relatively smooth shoreward of Ch400 m and seaward of Ch1500 m where marked change in gradient is seen (Fig.2a). The channel topography is uneven between Ch400-700 m and Ch 1100-1500 m. It is quite irregular and complex between Ch 700-1100 m. The area of

Irregular floor is characterised by numerous topographic depressions with relative variations of 0.5 to 3 m. These depressions have been clearly indicated in the echograms (Figs.2a and 2b) and also in the seismic reflection profiles (Fig.8c). The depressions might have been formed due to dredging. On the other hand, beyond Ch 1500 m the topography is smooth and slopes gently towards the offshore region.

The side scan sonar records (sonographs) show marked tonal differences due to variations in channel bed material and its topography. Sonographs are lighter in tone and show granular appearance where sands / or gravel occur while they are characterised by strong acoustic signatures in areas of hard strata. The latter which appears as 'striations' or 'streaks' on the sonographs have been interpreted as rocks. The hard surfaces, often, are very distinct and exhibit a linear trend. The striations have sharp boundaries and cast prominent acoustic shadows. A large part of the approach channel is marked by these striations (Fig.2c). Amidst these striations there occurs small pockets of sand, gravel/ or boulders. The overall distribution pattern of these features shows that the channel floor between Ch 700-1100 m is marked by hard strata (rocks) while between Ch 525-700 m and beyond Ch 1100 m it is partly covered by sands (Fig.3). The striations become indistinct in areas of smooth channel floor especially at Ch 400 and Ch 1500 m, where sands overlie the rocky floor (hard strata).

The sonographs also reveal distinct variations in configuration of the channel floor between Ch 700-1100 m. This rough topography which is indicated as highly erratic trace in the bottom profile of the side scan sonar records (Fig.2c), is also confirmed from the echograms of the area. Further this region is characterised by prominent depressions. The topographic depressions have sharp contrast with the adjacent channel floor and appear lighter in tone on the side scan sonar records and suggest that they have been partially filled by acoustically transparent fine sandy sediments (Fig.2c).

The high-resolution seismic profiling revealed apparently very poor seismic penetration in a large part of the surveyed area, presumably due to hard strata/or rocks at shallower depths (Fig.8c). However, at places the seismic profiles indicate small pockets of sand overlying the hard strata. These are, in general confined to either side of Centre Line of the approach channel between Ch 300-700 m and Ch 1200-1400 m. On the other hand, the seismic profiles of the area east of Ch 1500 m show a prominent acoustic reflector about 1 to 1.5 m below the channel floor (Fig.8c). This reflector shoals to the west and is exposed between Ch 1500 - 1700 m where the presence of rough topography is clearly seen. Between this prominent reflector and the surface of the channel floor there occurs an acoustically transparent zone indicating probably soft sediments. The isopachs (Fig.3) show in general, that the sediment thickness ranges from <0.5 to 2 m. The area near east breakwater and east of Ch 1600 m is covered with 1 to 2 m thick sediments whereas the remaining part of the area is floored by <0.5 to 1 m thick sediments with least sediment thickness being present between Ch 500-1100 m where

numerous depressions occur (Fig.3).

The distribution pattern of surface sediment texture shows that the channel bed is covered predominantly by sands with varying proportions of gravel. Fine grained sediments i.e. silts and clays occur at few isolated locations. The channel bed is rocky ~Ch675 m. On either side the sediments are predominantly gravel. Gravelly muddy sands occur between Ch 1425-1700 m and muddy sands close to North breakwater pier heads. Excepting these the approach channel bed is characterised by either sands or gravelly sands.

The occurrence of thin veneer of sediments underlain by hard strata inferred from seismic data and surface sediment distribution is very well confirmed from the lithology of the shallow bore holes.

Harbour Basin : In the harbour basin area the depth increases from near the shore towards the east breakwater signal station region. The echograms show that the basin floor is relatively steep between the shore and the 4.5 m and also around 9m, beyond which it slopes gently (Fig.2d). It is somewhat uneven ~6 m water depth.

The sonographs show that ~250 m wide zone near the shore is characterised predominantly by gravel (Fig.4). Further east, the basin floor is carpeted by sands or clays. The side scan sonar records indicate anchor drag marks in front of the east breakwater and south of the Coal and Oil jetties, some of which have been partly filled up by sediments.

The high-resolution seismic profiling shows two prominent reflectors - the first one indicating either sands or a thin veneer of acoustically transparent sediments, while the second one the underlying compact sands or hard strata. The isopachs show <0.5 to ~2.5 m thick sediments (Fig.4), the later being present west of passenger terminal and in the region between coal jetty and east breakwater. The inbetween region is characterised by low seismic penetration probably due to the underlying hard compact lime stone which attenuates seismic signal considerably. Surficial sediment distribution reveals that the basin area is characterised by varying proportions of gravel, sand, silt and clay. The western part is floored dominantly by gravelly sands and muddy sands. These grade into gravelly mud, mud or clay towards the north breakwater.

Nea Mangalore Area

Analyses of echosounding and seismic profiles revealed that the configuration of the harbour bed is characterised by smooth topography in areas of soft sediments / or where apparently sediment deposition occurred. On the other hand, the topography is uneven or irregular in dredged areas where hard grounds are exposed. The echograms also indicated in some regions the presence of fluid 'mud' presumably due to re-siltation (?). The fluid clay is underlain by compact sands/ or silty sediments below which soft clays are encountered.

Extension Lagoon : The sonographs show ripples between the Kudremukh iron ore berth and the Centre Line. The area is also characterised by the occurrence of hard ground at a few

localities notably south of Centre Line. The rest of the floor of the Extension Lagoon is marked by extensive dredging furrows/ drag marks (Fig.6).

The high-resolution seismic profiler records indicate two distinct acoustic reflectors- one at about 1 to 2 m below the lagoon bed and the other at about 5 to 7 m depth. The shallow reflector indicates the thickness of very soft and acoustically transparent clay (possibly fluid clay) (Fig.5a). Between the shallow and deeper reflectors the sediments are probably compact. The deeper reflector does not continue between the Centre Line and the Kudremukh iron ore berth where the seismic penetration is apparently minimum (Figs.5a and 6). The lack of penetration in this region could be due to the very compact fine sand/ silty clay. The acoustically opaque zone could also have been due to "double handling" in the area (M.M.Kamat, Personal communications) i.e. the sandy material dredged from the southern bank of the lagoon for the development of Kudremukh iron ore berth has been dumped in this region. The sonographs show that at a few places, ripples have been formed on the surface of the sandy material. However, this material has been subsequently removed. The isopach pattern (Fig.6) shows that the sediment thickness is maximum in the north eastern part of the area, i.e. just at the entrance of the Dock arm. The sediment thickness is minimum near the northwestern part and it increases to ~10 m towards the south. Below this layer the subbottom is irregular and appears to be composed of compact sediments or weathered rock (Fig.5a).

Lagoon : The sonographs of the area indicate that the lagoon bed is characterised by (i) ripples (ii) dredge/ anchor drag marks and (iii) variation in lagoon bed characteristics i.e. hard ground/weathered rock (Fig.5b). The hard bed has been delineated at a few places as for example north of the Centre Line where a large region is occupied by hard ground/weathered rock. Dredging furrows are prominent between Ch 400-700 m of the Centre Line, especially off the Oil jetty. At places, surficial sediments form large scale ripples (Fig.5b).

The seismic profiles show highly variable penetration (0-12 m) in the area. The lagoon is characterised by two more or less, East to West trending subbottom depressions (basins/ or buried channels) one on the southern side and the other on the northern side of the Centre Line (Fig.5c). It is broad and is flanked on either side by weathered rock (Fig.5c and 7). The hard ground outcrops around Ch 500 m and Ch 700 m while it occurs at a deeper level in the intervening area. The seismic records also show hard/compact sediments at a few places whose areal distribution is shown in Fig.7. Underwater blasting subsequently carried out to clear these hard ground patches revealed that they consisted of cemented conglomerate. The debris released from underwater blasting indicated that south of the Centre Line at Ch 500 m weathered rock occurs at deeper level. Similarly north of Ch 200-400 m of the Centre Line, the subbottom is characterised by laterite.

The lagoon floor is also characterised by a few areas with apparently very little seismic penetration (Fig.7). These regions of very little subbottom penetrations are characterised by compact sands due to "double handling" operations. Similarly, subbottom

also appears to be hard east of oil jetty presumably due to sands admixed with pebbles below which weathered rock occurs.

Approach Channel: The sonographs of the area show that the seabed is characterised by marked tonal differences due to artificial features such as dredge marks and numerous sediment patches due to dredging. The dredging has left a strong imprint on the seabed as wide elongate patches (dredge scars) at several places. At places it is dominated by minute lense shaped stiff clay lumps (Fig.8a) of dredged materials. The sonographs also show wide elongate patches more or less parallel to the channel axis in the southern part of the Centre Line between Ch100-1500 m, whose areal distribution is shown in Fig.9 as wide and prominent dredge marks. These appear to be furrows created by the cutting edges of the drag head of Trailer suction dredger. The sonographs also show distinct change in slope of the channel in the northern part of the Centre Line between Ch 1000-2000 m (Fig.8a)

The seismic profiles show an average penetration of 2-4 m and a maximum penetration of about 10 m in the area. The records show two prominent reflectors the first reflector occurs over a large part of the area at 2-3 m depth and the second one at 5-8 m (Fig.8b). The channel area between Ch 0-1000 m shows 0-3 m thick clays (Fig.9) which increase to about 8 m at the seaward end. Along the Centre Line the clay thickness varies between 2 to 3 m upto Ch3000 m and further seaward increases to about 8 m. The clays/silty clays are underlain by hard (compact) bottom which occurs over a large part of the surveyed area.

CONCLUSIONS

The geological and geophysical surveys in the Tuticorin and New Mangalore harbour areas have provided a broad understanding of the distribution of surficial sediments and their extension below the seabed. The extent of dredging carried out has also been delineated very clearly.

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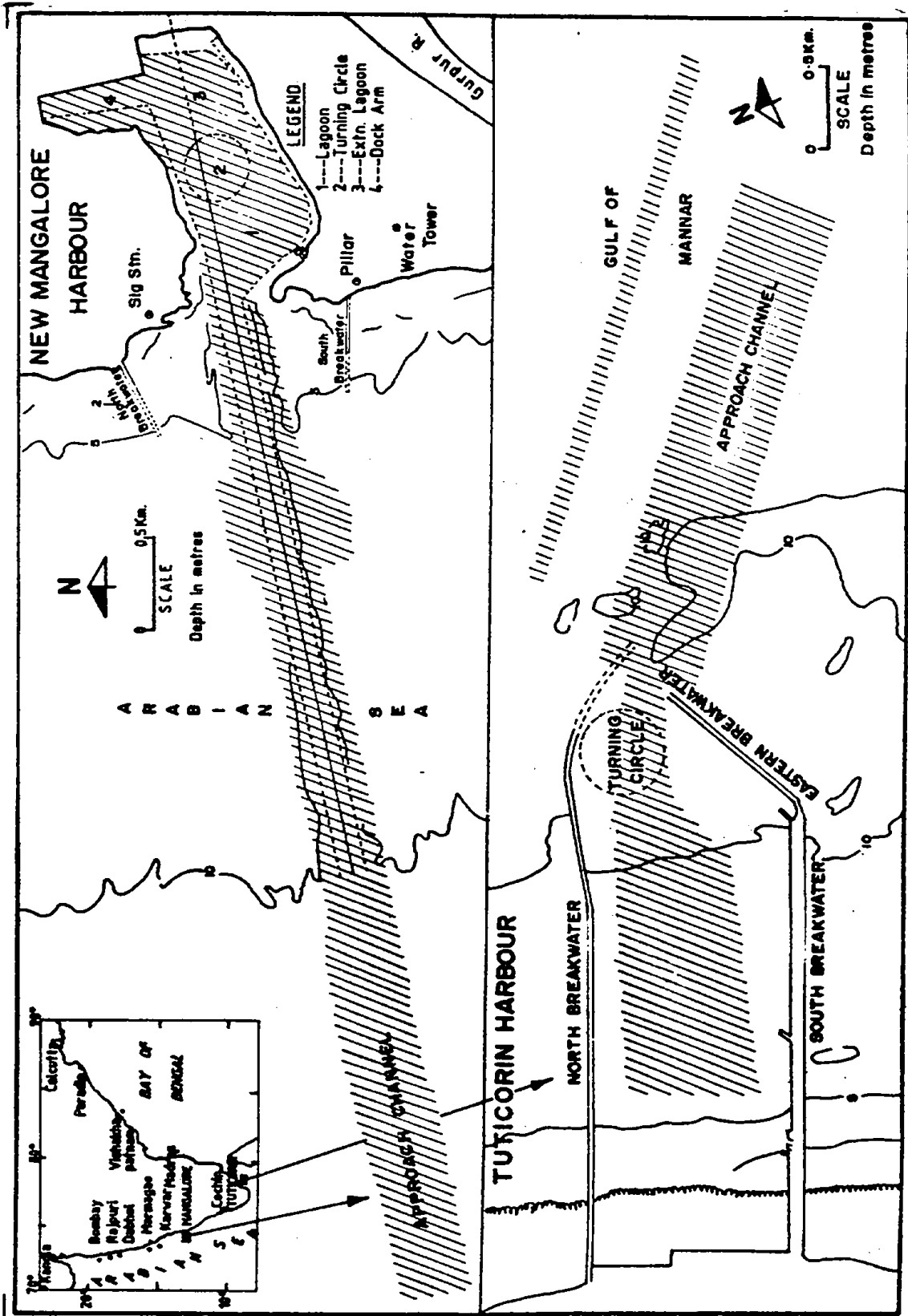


Fig. 1 Location map of Tuticorin and New Mangalore harbours showing the areas surveyed. Inset shows Indian ports

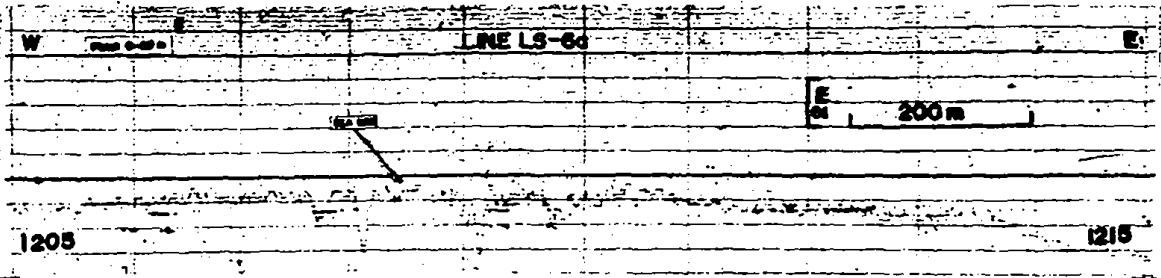


Fig. 2a. Echogram showing irregular topography between fixes 1207-1210. East of fix 1216 the bed slopes gently (Tuticorin approach channel)

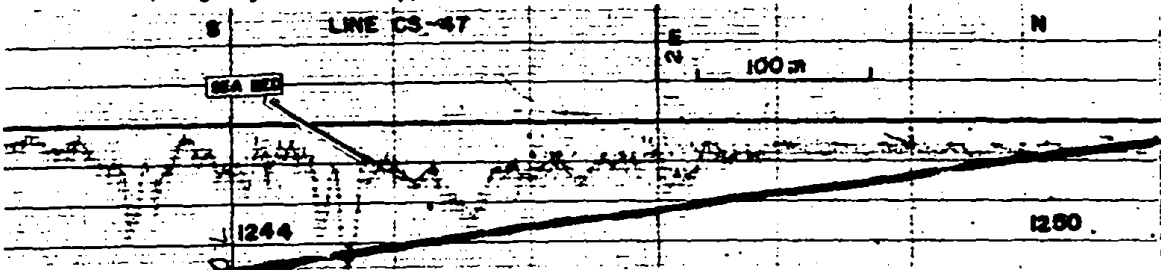


Fig. 2b. Echogram showing irregular topography and prominent depressions between fixes 1244-1246 (Tuticorin approach channel)

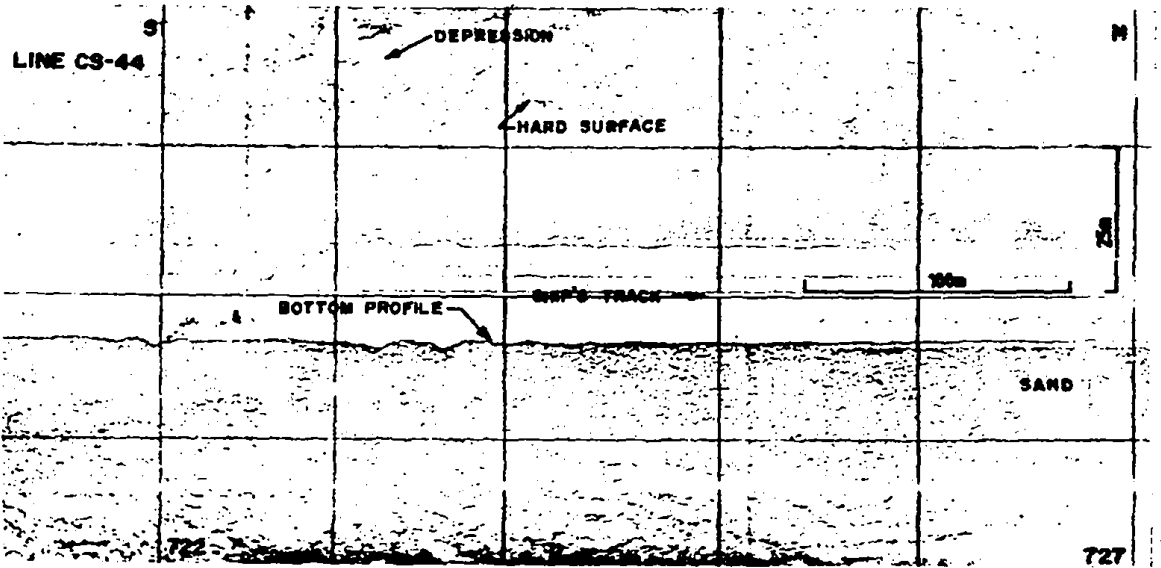


Fig. 2c Sonograph indicating uneven topography marked by hard surface (rocks) & sediment filled depressions in the southern part of the approach channel. Marked variation in bottom profile in the south is also clearly seen (Tuticorin)

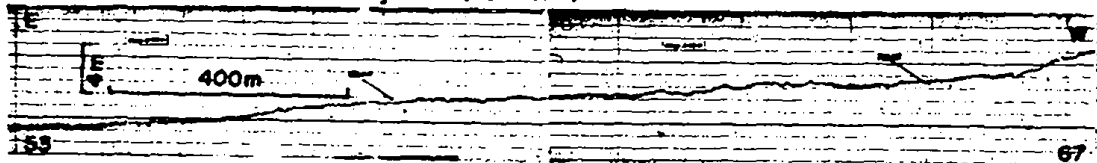


Fig. 2d Echogram showing relatively steep topography on the west and gently sloping topography on the east (Tuticorin harbour basin)

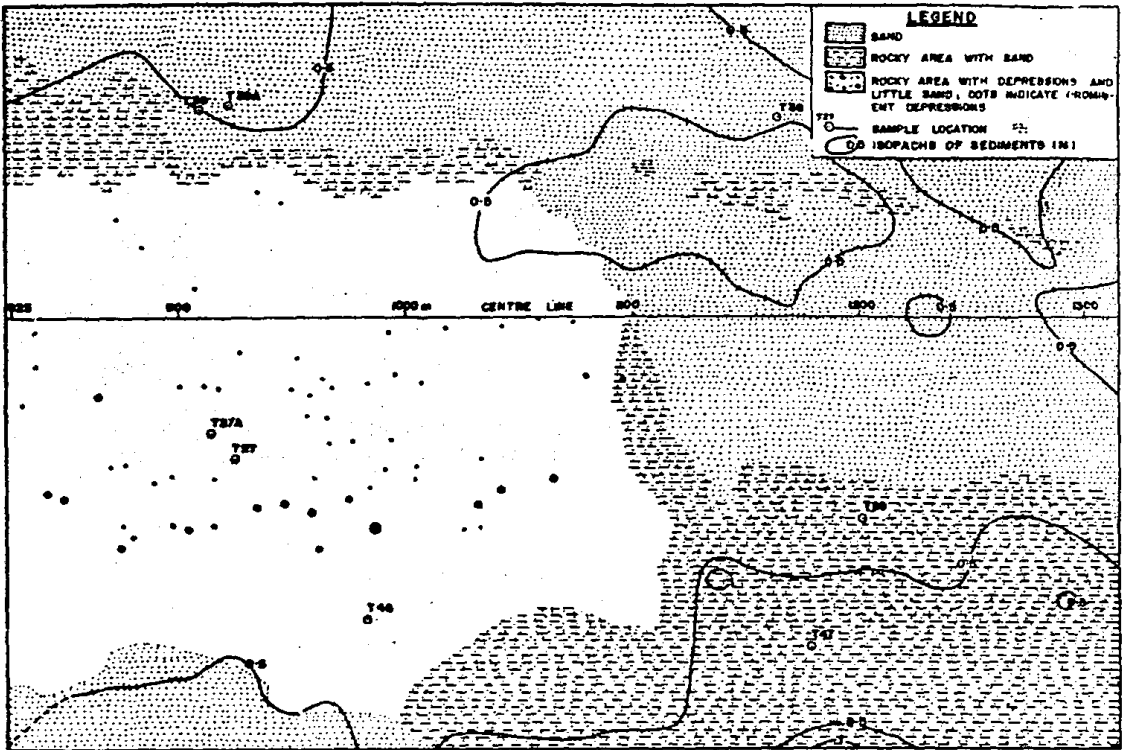


Fig. 3 Isopach map of sediment thickness together with surficial features based on side scan sonar surveys in Tuticorin harbour Approach channel

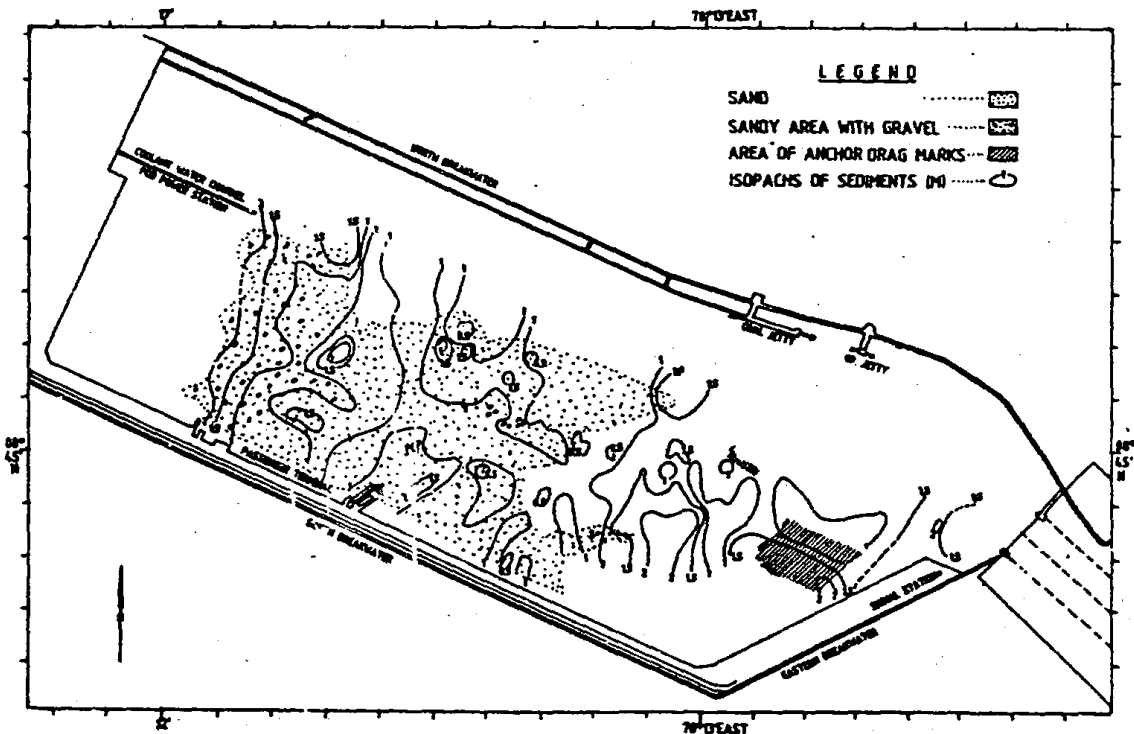


Fig. 4 Isopach map of sediment thickness together with surficial features based on side scan sonar surveys in Tuticorin harbour basin

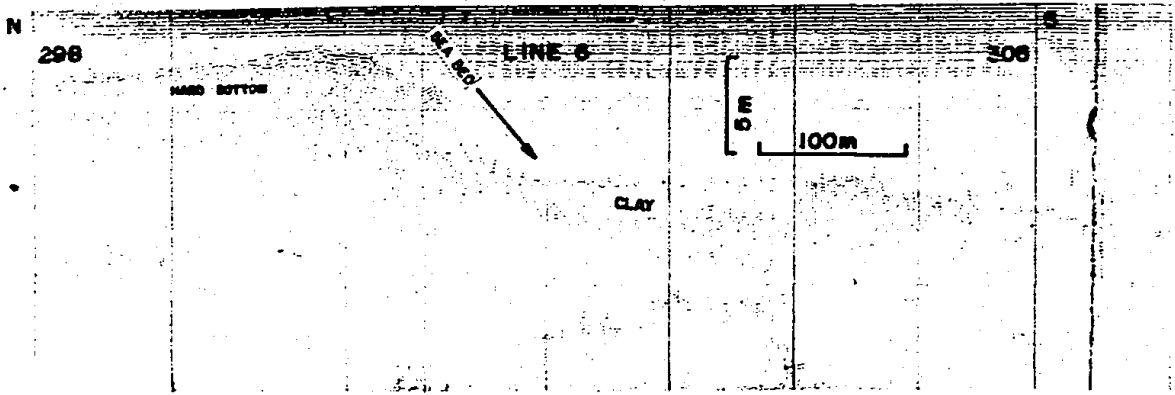


Fig. 5a 3.5 kHz seismic profile (Dock arm & extrn. Lagoon, New Mangalore) shows hard ground in the north. The thick sediments overlying the hard bed extend from the entrance to the Dock arm to a little south of the Centre line.

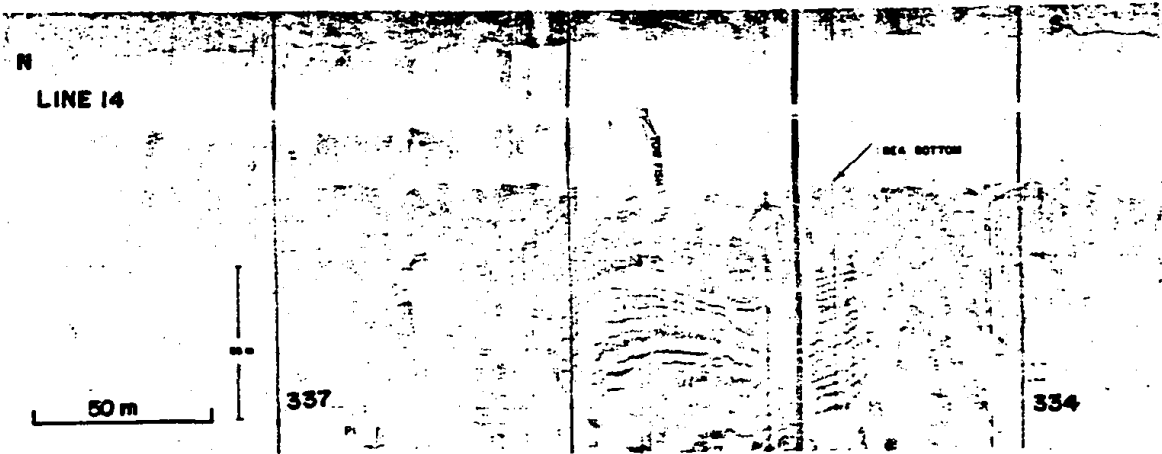


Fig. 5b Sonograph (Lagoon area, New Mangalore) showing ripples and dredge marks in the south and clay covered region in the north.

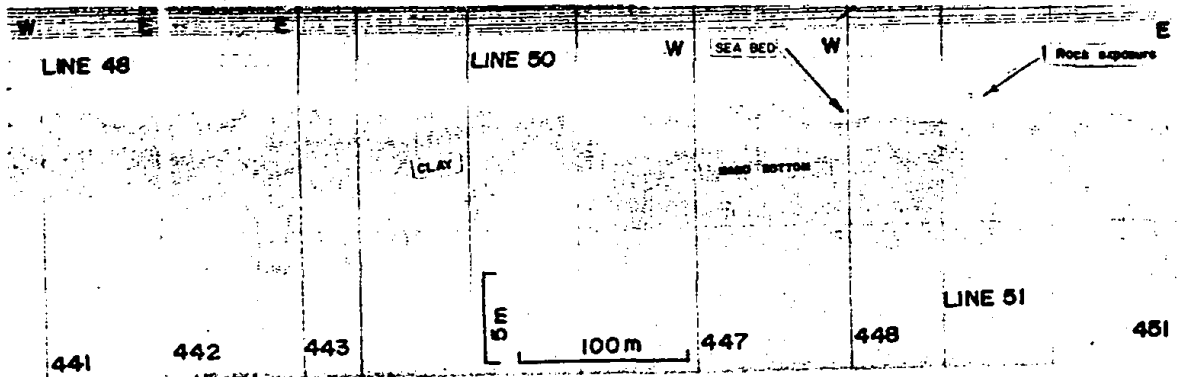


Fig. 5c 3.5 kHz seismic profile (Lagoon area, New Mangalore) showing thick clays along the eastern part of line 50. The underlying hard horizon surfaces between fixes 445-446 (line 50) and 449-450 (line 51)

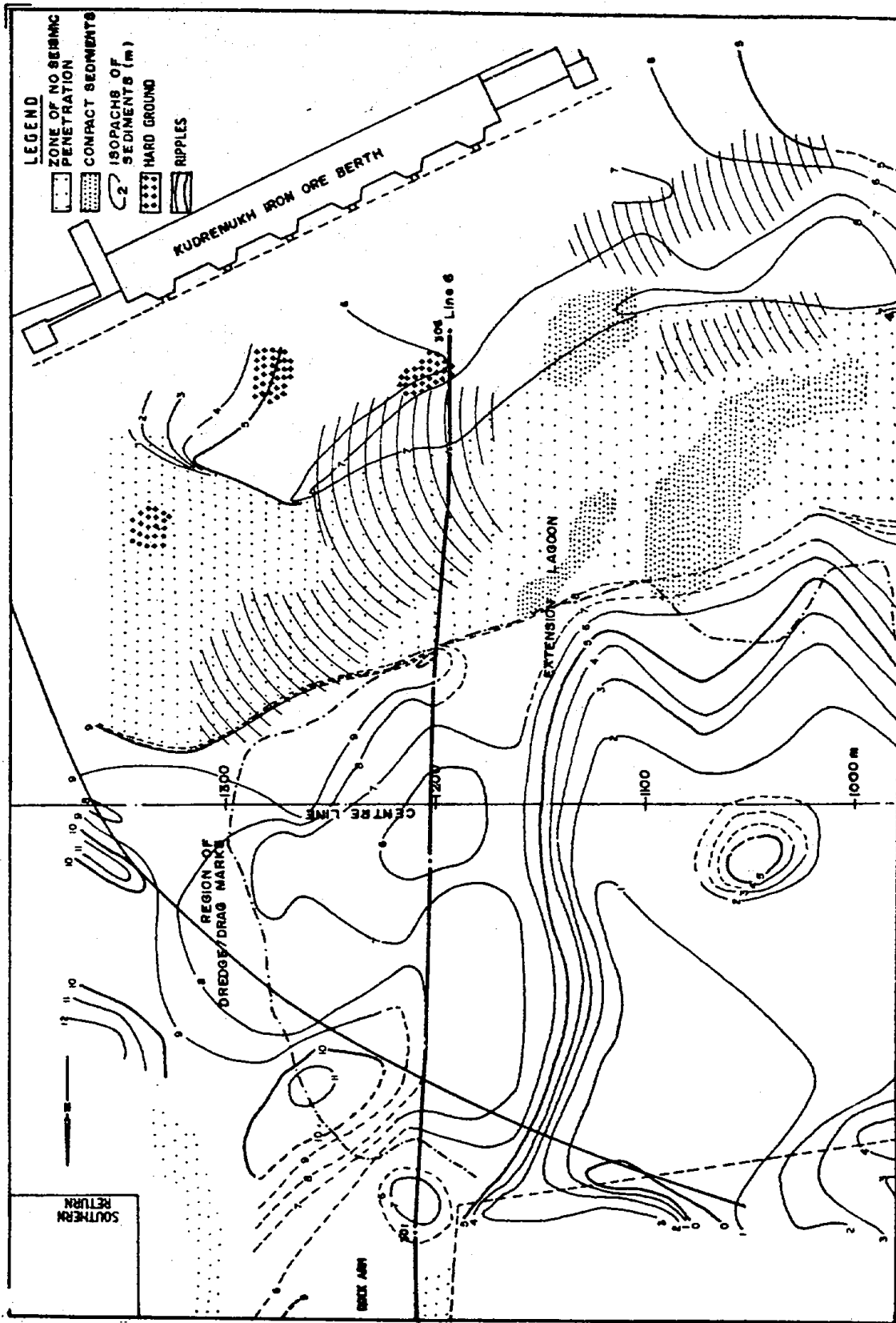


Fig. 6 Isopach map of sediment thickness together with surficial features based on side scan sonar surveys in Extn. Lagoon, Mangalore harbour

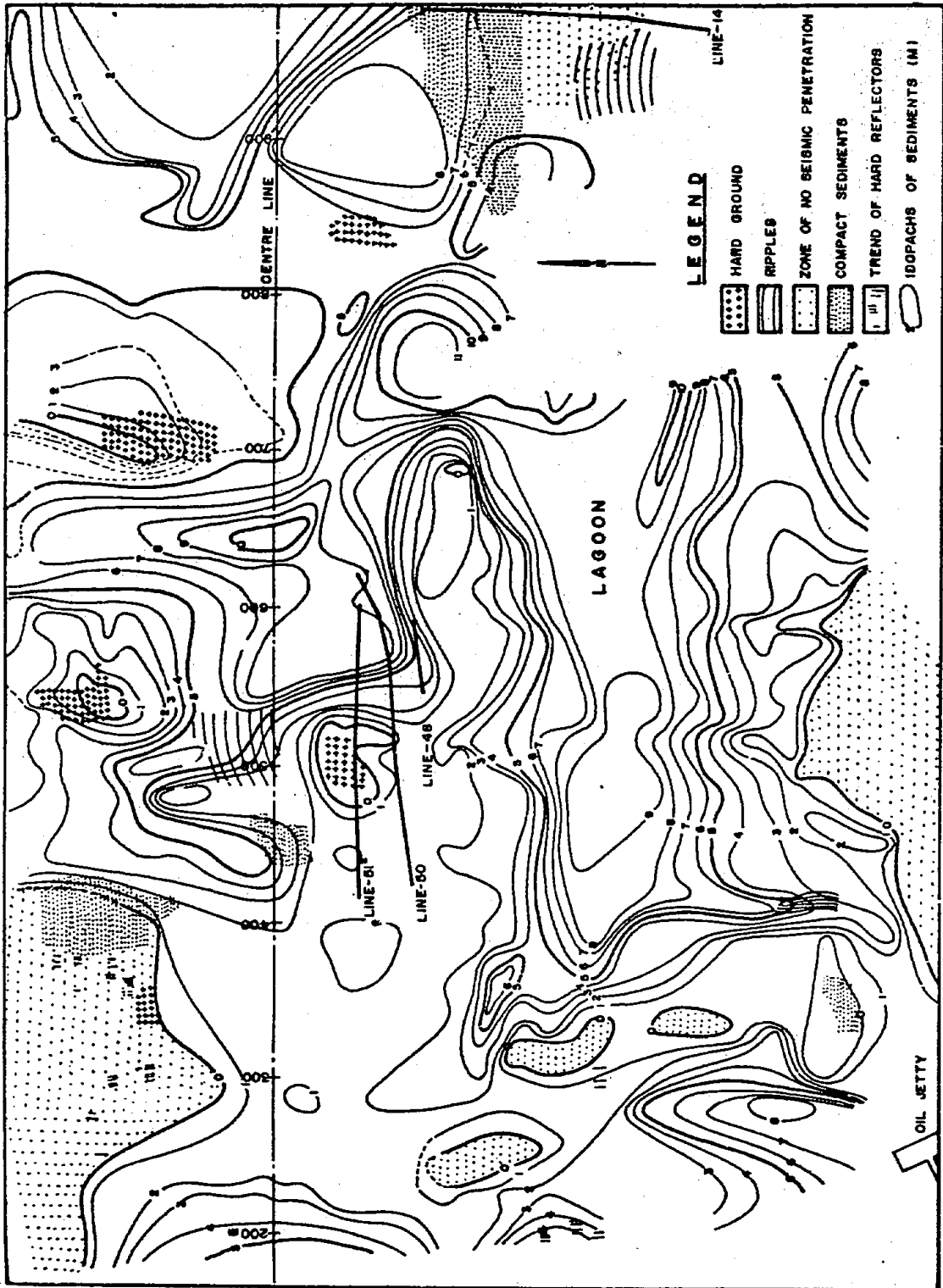


Fig. 7 isopach map of sediment thickness together with surficial features based on side scan sonar surveys in Lagoon, Mangalore harbour

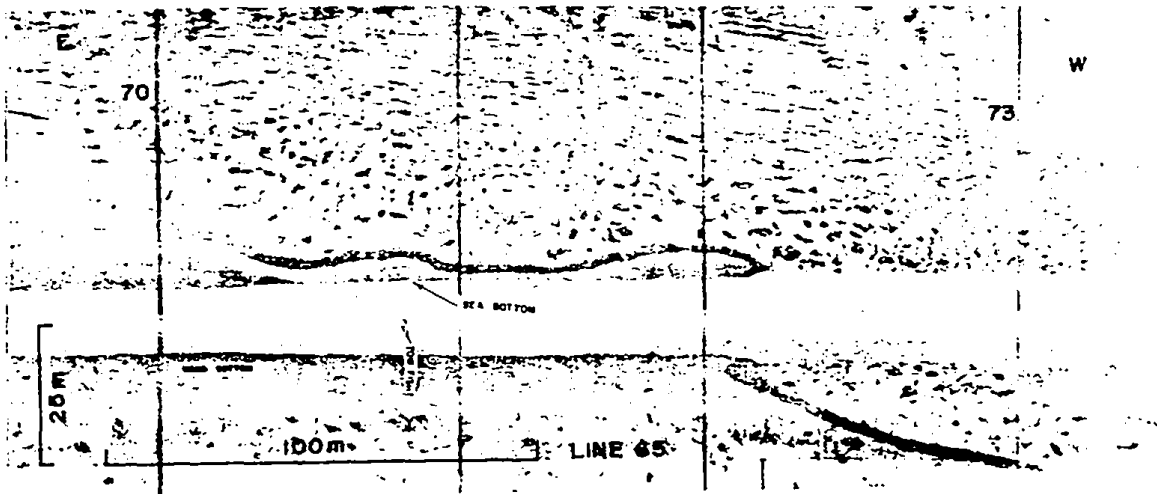


Fig. 8a Sonograph showing stiff material (as lumps of stiff clay) and the dredging furrows at far north (Approach channel, New Mangalore)

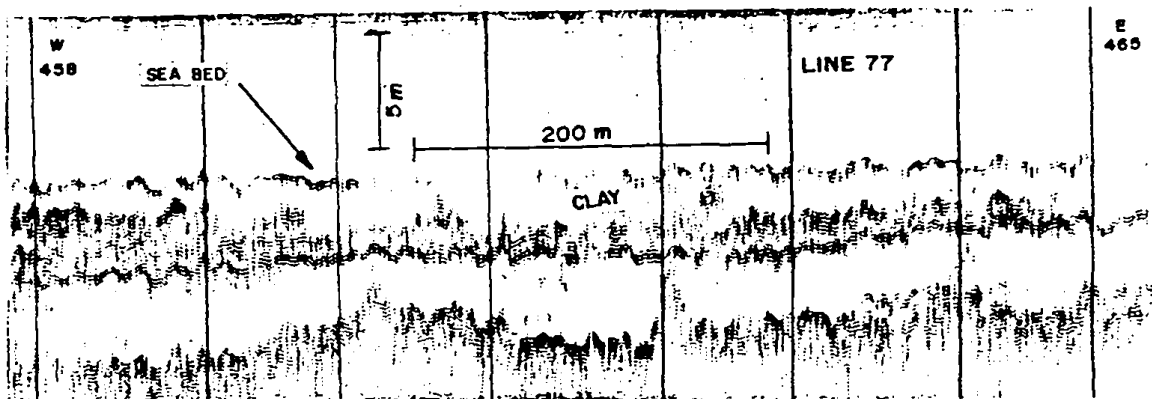


Fig. 8b 3.5 kHz seismic profile showing clays underlain by hard ground (Approach channel, New Mangalore)

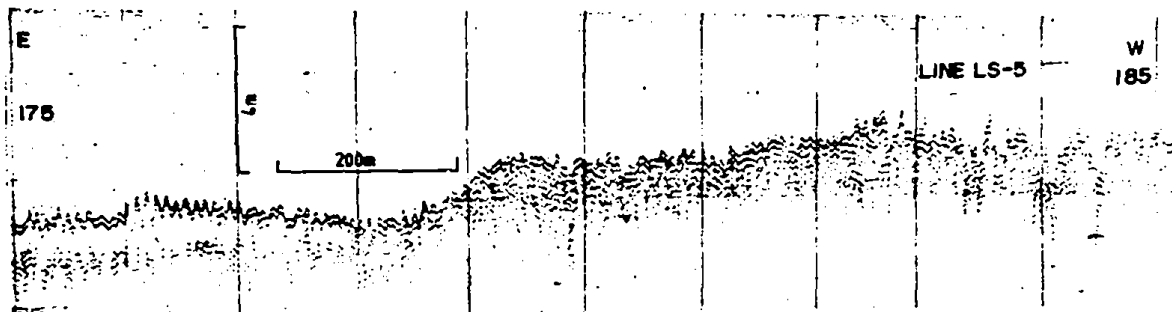


Fig. 8c 3.5 kHz seismic profile indicating very thin veneer of sediment covering the bedrock at fix 178. Western half of the profile is marked by hard ground (rock) / or isolated pockets of sediments (Approach channel, Tuticorin)

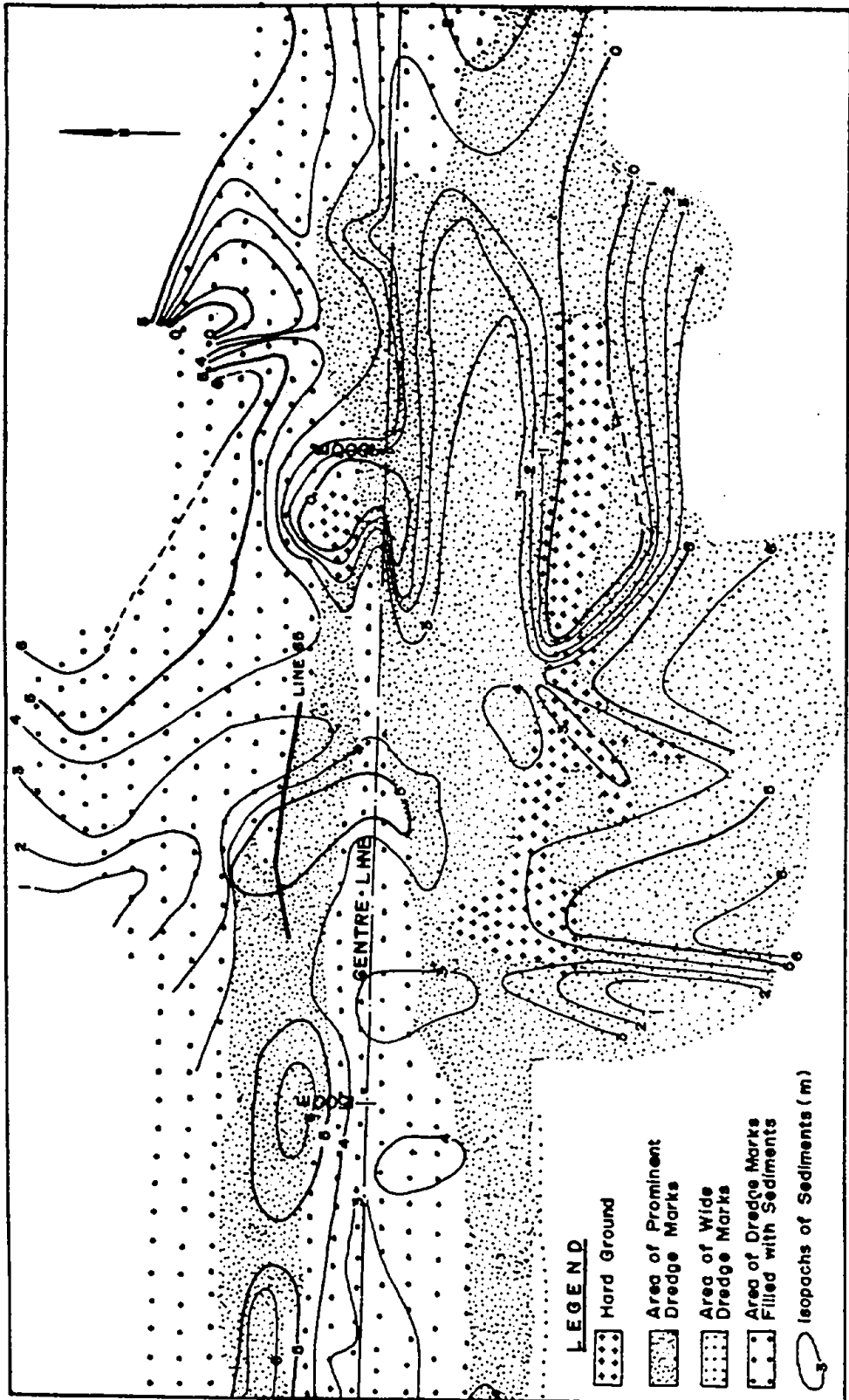


Fig. 9 Isopach map of sediment thickness together with surficial features based on side scan sonar surveys in Approach channel, Mangalore harbour