



MULTI SENSOR SURVEYS FOR OFFSHORE CONSTRUCTIONS OFF BOMBAY ISLAND

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ABSTRACT

A number of multi sensor high resolution geological and geophysical surveys were carried out off Bombay during the last few years. These comprised echosounding, side scan sonar and subbottom profiling followed by seabed sampling with grabs, corer and dredges. Based on an integrated interpretation of echograms, side scan sonar records and seismic profiles; subbottom profiles, bathymetric, isopach and surficial geological maps were prepared and used for the evaluation of seabed conditions. The surveys indicated that in large areas of the seabed off Bombay down to a depth of about 15 m hard rocks are exposed. The hard subbottom constitutes different lithological types and at places these represent an extension of onshore basaltic and associated rocks i.e., tuffs or with weathered basalt and cemented sands or gravel. Extensive outcrops of these basalt occur on the Thal Shoal, off Karanja Island, Colaba and the western shore off Worli and Bandra. The rocks are overlain by clays. On the western shore, thin 1-3 m clays intermittently cover route to a distance of 1 km from the shore and a depth of 11 m after which the clay thickness rapidly increases to more than 10 m. The seabed in area from Thal Shoal to Karanja is covered by 2-4 m clays between extensive rock outcrops. The clay thickness increases to 10-12 m near Bombay Floating Light and 16 m in the channel between Butcher and Karanja Islands. The results of these surveys specifically with reference to offshore constructions are discussed.

INTRODUCTION

The increasing demand for exploration and exploitation of offshore non-living resources of oil, a growing need for disposal of sewage and effluents in the sea and development of deeper harbours and anchorages has led to an increase in the numbers and complexity of offshore engineering projects.

The planning and designing of these offshore constructions requires comprehensive data on seabed and environmental conditions (Miller, 1965; Brownfield, 1973). The seabed surveys require an integrated collection and analyses of data by different acoustic techniques followed by sampling.

The scientists of the National Institute of Oceanography (NIO) have carried out several multi sensor high resolution geological and geophysical surveys off Bombay Island and in the Harbour during 1976-1977. These comprised 646 line km

of echosounding, 567 line km of side scan sonar and 590 line km of shallow seismic surveys. In addition, a large number of samples were collected for outcrop control, sediment identification and soil testing by grab, dredges, and corers. Based on these surveys several maps were prepared depicting the surficial and sub-surface geology. The methods and results of these surveys with reference to various offshore constructions are presented in this paper.

METHODS

The equipment used for the high resolution geophysical surveys mainly include a source, a receiver processor and a suitable graphic recorder. The objective of the present surveys was surficial geological mapping and shallow subbottom profiling. The various acoustic systems are generally with high frequency characteristic, whose primary aim was resolution rather than penetration. Usually, more than one such device was used simultaneously in the

surveys. Table I summarizes the various acoustic systems used for the surveys off the Bombay Island and in the Harbour.

Position Fixing during the Survey:

The position fixing during a survey for offshore construction projects is of considerable importance. For the initial surveys in the area positions were fixed by conventional sextants while an electronic position fixing system (Motorola Mini Ranger with an accuracy of ± 3 m and a range of upto 75 km) was used for the final survey.

Bathymetry:

The echosounding was carried out mainly with an Atlas Deso 10 echosounder (frequency 210 KHz). The water depths obtained were corrected for tidal variations and plotted in the survey chart. This led to the preparation of a bathymetric map of the survey area. In addition to this, the echograms were also used to classify the seabottom into even, uneven and rugged. The nature of the seabottom i.e., even, uneven or rugged provided an indication of sediment (sand or clay) cover or rock exposures on the seabed.

Side Scan Sonar:

While both Echosounder and Subbottom Profiler provide data directly beneath each transducer giving vertical sections, the side scan sonar system provides graphic records showing a plan depicting the topography and sediment and rock distribution view of the seafloor. Side Scan Sonar surveys were carried out with an EG & G Mark 1B system (11" wide, dual channel 259 recorder and tow fish 272). The tow fish was operated with transducers set for 10° beam depression and 20° beam angle. The tow fish was submerged and towed at speeds of 3 to 5 knots. The system was operated on a 100 m range. The side scan sonar records were interpreted on the basis of the tone of the

records and bed forms. Based on the data collected the areal extension and trend of the rock outcrops and their jointing patterns and distribution of different types of sediments were mapped. Areas where periodic wave forms (sandy wave rippled seabed) and areas where man-made features (e.g., dredge spoils, otter board and anchor marks) are present were also demarcated.

Subbottom Profiling:

Subbottom profiling was carried out with an Huntac Hydrosonde 2A System. A Boomer with a predominant frequency of the main beam pulse as 5 KHz was used as the energy source. All the shallow seismic profiling recorded at 62.5 millisecond sweep rate. In determining depths to the reflectors no correction had been applied for the velocity of sound in water or in the sediments. P - wave velocity measured from several core samples collected in the area showed little difference from the speed of sound in water, hence the factor 1500 m/sec was used to convert the time sections into depth sections. Using the records of the subbottom profiler the thickness of the clay overburden, subcropping rocks, shallow tectonically disturbed areas, buried channels, nature of the acoustic basement etc., were demarcated and determined.

Sampling:

Based on the subbottom profiling and side scan sonar records, sites were selected for sampling. The surficial sediment samples were collected by grabs and corers while rock outcrops were sampled with dredges. The sampling information complimented the echosounding, side scan sonar and subbottom profiling data and then it was possible to interpret the records and map the distribution of different types of sediments and rocks.

SURFICIAL AND SHALLOW SUBSURFACE GEOLOGY OFF THE BOMBAY ISLAND AND THE HARBOUR

The surveys covered the following areas in the present paper (Fig. 1).

- i) Off Bandra : East west track upto 11 km offshore.
- ii) Off Haji Ali : East west tracks upto 10 km offshore.
- iii) Off Colaba : 3 tracks towards inner harbour, each about 3 to 4 km in length.
- iv) Off Karanja : Several tracks extending upto Bombay Floating Light 18 km offshore.
- v) Between Karanja Island and Butcher Island.
- vi) Between Butcher Island and Trombay.
- vii) Between Butcher Island and Mora Jetty.

Based on the integrated interpretation of echosounding, side scan sonar and shallow seismic records; subbottom profiles, bathymetric, isopach and surficial geological maps were prepared (Fig. 2).

In the area off Bandra the seabed for a distance of 1.5 km from the shore to a water depth of 4-5 m is covered with clay of about 2 m in thickness. After this rocks (Deccan Traps) outcrop and extend to a water depth of 5 m. Beyond these outcrops and to a distance of 3-4 km westward, the thickness of sediment (with exception of some pockets) is less than 2 m. At depths of 8 - 9 m there is again extensive (about 1-3 km wide) outcrop of rocks. The rock outcrops show a general N-S trend. Westward from this rocky area, the thickness of clay increases rapidly from 1 m to about 12 m.

The seabed in the area off Haji Ali to a distance of about 1 km westward is marked by an extension of coastal rock outcrops. These rocks outcrop for about 1.5 km are covered by about 2 m thick sediments, followed by another rock outcrop of 400-500 m wide. Seaward for 3-4 km the rock is covered with about 2 m thick sediments. Further seaward this sediment thickness rapidly increases from 3-9 m.

In the areas surveyed off Colaba the rock outcrops extend over 1.5 km eastwards towards inner harbour and southwards beyond 4 km.

Between Bombay Floating Light to Karanja Island, the Thal Shoal area represents an extensive rock outcrop with uneven topography. The water depth in this area ranges between 6-10 m, the gradients are very steep and range between 1:750 to 1:50 and the clay in this area occurs either in pockets or as thin layers. Westwards towards Bombay Floating Light the thickness of sediment gradually increases and near Bombay Floating Light it is about 10-12 m. Shoreward from the Thal Shoal to the Karanja Island the shallow subsurface is little complex. Near Karanja Island the onshore rocks (Deccan Traps) continue offshore for 12 km as submarine outcrop, further offshore the rocks are covered by sediments (clays) of varying thickness (Fig. 3). The seismic profiles show that the underlying bedrock is dissected with deep valleys and ridges. The ridges at several places are exposed as extensive NNE-SSW trending outcrops. The valleys are filled with thick (at places more than 14 m) clay. This complex setup is bounded in west and south by escarpments. Beyond this escarpment the bedrock is flat with almost uniform sediment cover of 3-4 m.

The seabed in the nearshore areas between Karanja Island and Butcher Island are predominantly rocky. Thick acoustically transparent clays (about 16 m) overlie the rocks in the deep channel between Butcher and Karanja Islands. Beyond the channel and towards Karanja Island the clay thickness decreases to 5 m and the clay largely covers an uneven bedrock. Rock outcrops on the seabed midway between Butcher and Karanja Island and extends till the Karanja Island.

In the area between Butcher Island and Mora an acoustically transparent clay overlies the bedrock. The clay 2-5 m thick at the Mora end increases to about 15 m in the channel after which it decreases gradually to 5 m near the Butcher Island Jetty.

Between Butcher Island and Trombay an acoustically transparent clay about 3-4 m thick overlies an uneven bedrock at the Trombay end. The clay thickness increases to about 9 - 10 m near a rocky patch halfway to Butcher Island, thereafter decreases from 1-3 m near Butcher Island.

The islands of Bombay, Salsette and Trombay expose basalts and associated rocks belonging to Upper Deccan Group (Sukeshwala and Poldervart, 1958). Based on the sediment and rock samples collected it was deduced that most of the cases the bedrock in the Bombay Harbour area is also the continuation of the Deccan Plateau Basalts exposed onshore. Near Bandra the bedrock identified in the seismic records may represent the dense, cemented overburden material or weathered rock. The bottom sediments consists of sand, clayey sand, shelly sand or clay and even at places clay mixed with gravel. The clay appears to be covered with a thin layer of sand or gravel in the near shore areas near Karanja Island and around rock outcrops on Thal Shoal. The side scan sonar survey indicated the presence of well defined ENE-WSW trending ripple trains in these areas (Almeida and Bhattacharya, 1980).

DISCUSSION

The data collected from different seabed surveys off the Bombay Island and in the Harbour can be used for the planning for various offshore construction projects i.e., (i) development of the Harbour, (ii) selecting sites for sewage outfalls and (iii) selection of suitable routes for laying submarine pipelines for transporting crude and finished oil product.

The future development of the Port would require provision for handling of larger vessels i.e., deepening of navigation channels, anchoring and berthing of deep draft vessel. In order to minimise the cost of dredging it is advisable as far as possible to locate area with thick unconsolidated sediment cover. This would minimise the cost of blasting and trenching in hard rocks. An examination of the isopach map shows that the eastern shores of Bombay Island off Colaba are marked by extensive rock outcrops while the area extending from Thal Shoal to Karanja and the nearshore area west of Karanja also shows extensive rock exposure. The intervening area between these i.e., the

channel between the Karanja Butcher Islands shows thick transparent clays and offers possibilities for deepening which may be examined. However, large area are still unsurveyed and detailed survey would provide data on the sediment cover in western part of the area.

From the environmental point of view, it is obvious that the sewage and effluents should not be discharged in the harbour area and the likely suitable sites are in the sea to the west. The present surveys have provided some data on the seabed conditions on two transects off the western coast. The data indicates that the seabed on the line off Haji Ali is relatively devoid of rocks and has a thin sediment cover which may be useful laying a submarine sewage outfall.

In contrast to the requirements for deepening for the harbour development, the laying of a submarine pipeline would require a comparatively thin sediment cover i.e., 3-4 m. The western part of the Bombay Harbour i.e., to the east of the Butcher Island channel is largely developed for shipping and it would be impractical to lay pipeline in the area because of the risk of damage by shipping. In addition the pipelines have also to be routed below the projected dredging depths for the Port approaches and therefore, they will be to the south of Bombay Floating Light. The area east of the Butcher Island channel extending from Thal Shoal to Karanja is marked by extensive rock outcrops between which some thin clay filled pockets and channels can be demarcated for routing pipelines. However, amount of trenching and blasting at the landfall points is unavoidable.

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TABLE 1

Summary of different acoustic systems used

Acoustic System	Frequency	Purpose
Echosounder (Atlas Deso 10)	210 KHz	Water depth, bottom topography and accurate bathymetric map.
Dual Channel Side Scan Sonar (EG & G Mark 1B)	105 KHz	Bottom irregularities, bedforms, sediment distribution, rock outcrops, their extent and trend, man-made features on the seabed, wrecks.
Subbottom Profiler (Huntec Hydrosonde 2A) Electro-Mechanical (Boomer)	5 KHz	Cross section of subbottom geology and detection of shallow gas charged zones.

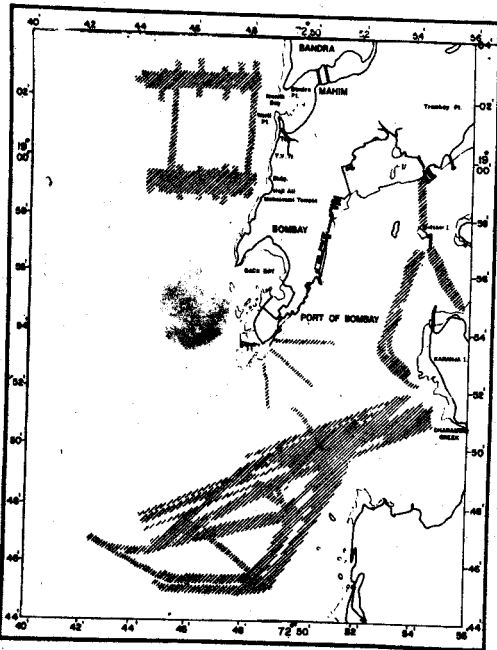


Fig. 1 Map showing the areas surveyed off Bombay Island and in the Harbour. Hatched area indicated the coverage of Side Scan Sonar.

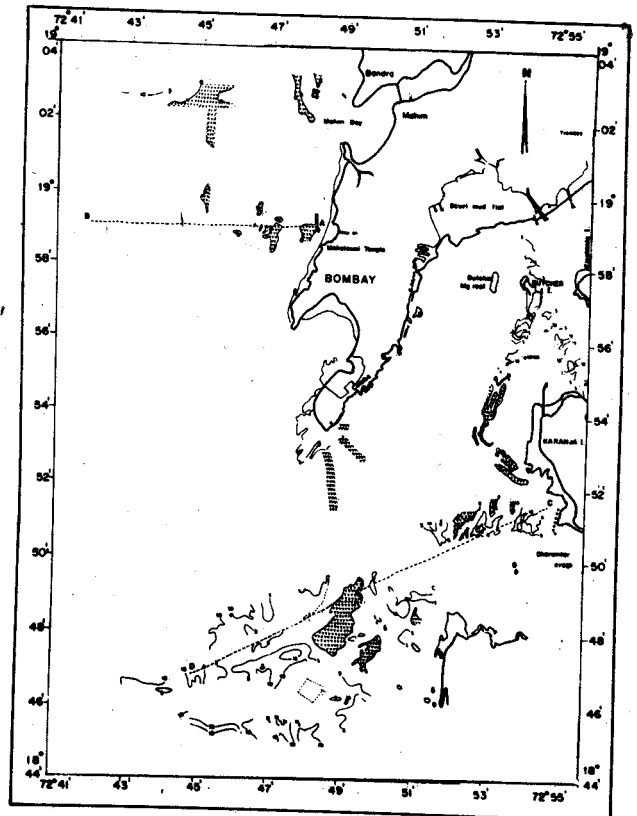


Fig. 2 Map showing the distribution of sediments (values along contours indicate thickness of sediments in m) and rocks (v) in some area off Bombay Island and in the Harbour.

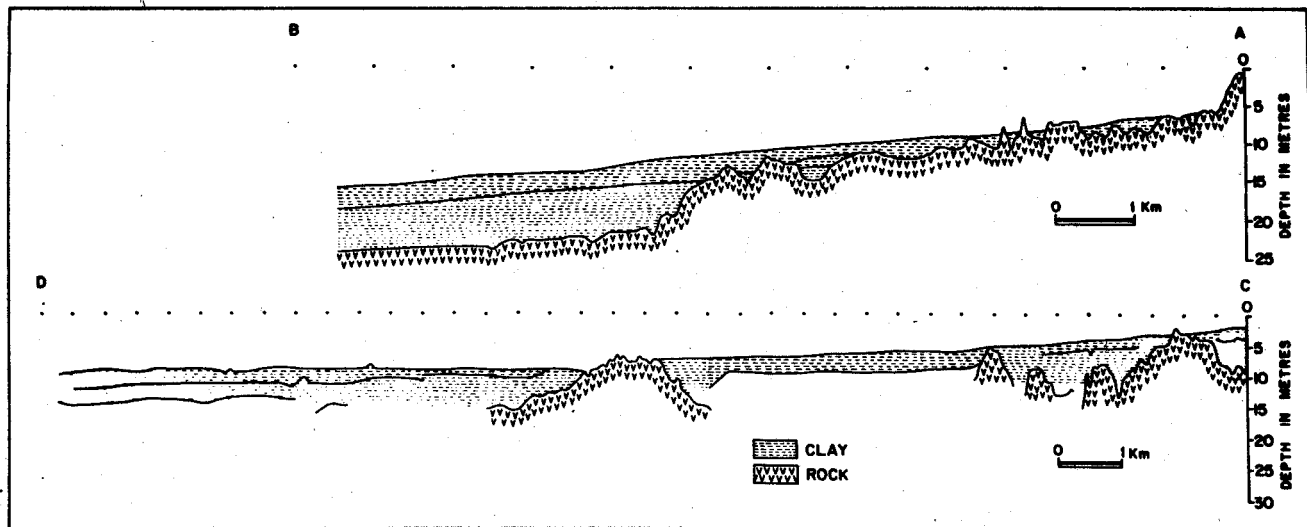
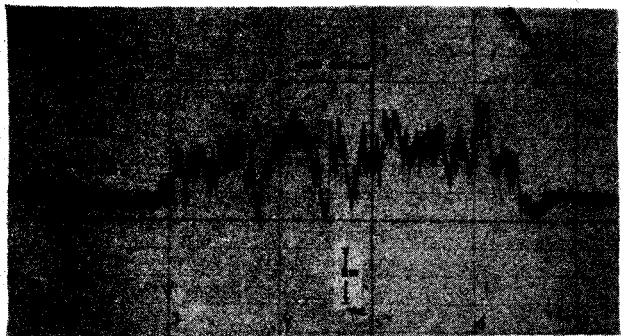
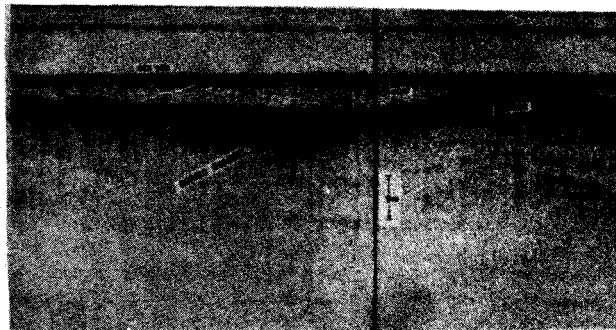


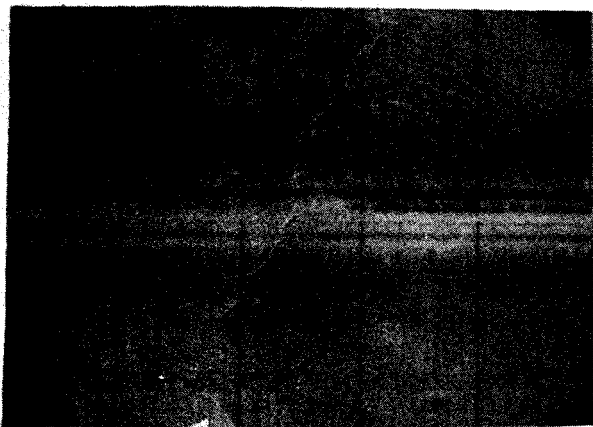
Fig. 3 Line drawing of the representative seismic sections off Bombay Island and in the Harbour. Position of the profiles is shown in Fig. 2 by thick dashed line.



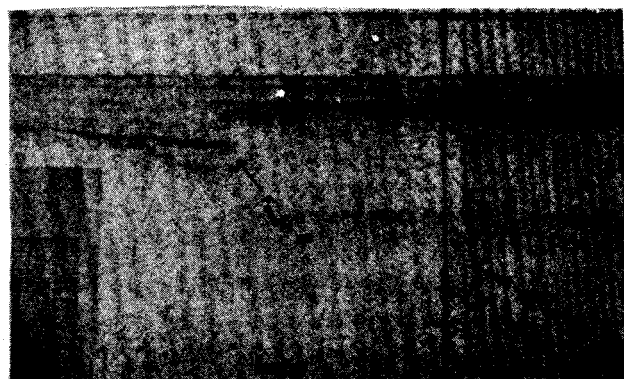
Pl. 1 Echogram showing even (sediment i.e., clay covered) and uneven (rock exposure) topography on the seabed off Thal Shoal.



Pl. 3 Seismic profile acoustically transparent clay overlying uneven bed rock (Deccan Trap) and a buried channel.



Pl. 2 Sonograph showing rock outcrops (Deccan Traps) and ripple marks (sand) on the seabed.



Pl. 4 Seismic profile showing the scarp in bed rock (Fault?) covered by recent sediments.