

## SUBSURFACE GEOLOGY OF THE BOMBAY HARBOUR

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### ABSTRACT

As part of engineering pre-design investigations, high resolution geophysical surveys were carried out in and around Bombay harbour. The depth in the area varies from dries over the mudflats to about 14m towards the offshore end. The seabed topography is smooth over the clay covered areas and is uneven where either the bedrock outcrops or the sea floor is formed of stiff clay. Recent sediments, comprising mostly of unconsolidated clay (max. 16m) overlie generally on a fractured, weathered/eroded bedrock which is the continuation of the onshore Deccan flood basalts. Buried channels, interbedded sand bodies, small scale ripples, scouring of the seabed and gas charged sediments were identified. The subsurface geology of the area, relevant to offshore engineering projects is discussed.

### INTRODUCTION

Since last two decades, the offshore engineering activities in the Bombay harbour area witnessed remarkable growth. In connection with this, the National Institute of Oceanography, Goa, carried out several high resolution geophysical surveys and provided the engineering project designers with the required subsurface geological information.

An area over 65 sq. kms. (Fig.1) extending from shallow tidal mudflats to about 14 m isobath was investigated. The area was traversed by a large number of survey tracks covering 840 lkm of echosounding, 650 lkm of side scan sonar and 750 lkm of high resolution shallow seismic profiling. In addition several seabed samples were also collected using grab, dredge and corer for outcrop control, sediment identification and soil testing.

Earlier, Bhattacharya et.al. (1981) presented a preliminary geological framework of the offshore Bombay harbour area. The present paper includes the results of subsequent investigations and reports updated information on various geological features noticed in the area which have some relevance for planning and designing of offshore engineering projects.

### GEOLOGICAL FRAMEWORK

The Bombay harbour is bordered by a group of islands in the west, whereas to the north and east lies the mainland. The coastline in the Bombay harbour area is characterised by number of bays, beaches, cliffs, marine platforms, marshy tidal flats and creeks (Subramanyam, 1981). In the inner harbour several shoals, islets and islands are present. The rock types exposed on adjacent onshore areas comprise of Deccan flood basalts and associated rocks (Sukeshwala and Poldervaart, 1958). From the analyses of seismic reflection sections, no evidence of tectonic disturbance is observed in the Bombay Harbour area since Pleistocene (Bhattacharya et.al., 1987).

### METHODS

The vessel's positions along the survey traverses were obtained with a Motorola Miniranger III radio navigation system and in some areas with the conventional sextant angles of the shore features. Bathymetry and seafloor topographic data were collected with an Atlas Deso 10 or a Raytheon echosounder. Acoustic imaging of the seafloor was carried out by deploying a side-scan sonar (EG & G mark 1B) system whereas the subbottom geological cross-sections were obtained with a Huntac Hydrosonde 2A system having a 5 KHz boomer as the acoustic energy source.

Finally, the shallow subbottom geological situation was derived through a synthesis of all the above mentioned data.

#### RESULTS AND DISCUSSION

From the high resolution shallow seismic profiles the following subsurface geological information has been derived (Fig.2):

The overburden covers an acoustically opaque reflector, i.e. the acoustic basement (subsequently mentioned as bedrock in this paper). The overburden material comprises of:

- i) marine clay (Recent) of different stiffness,
- ii) coarse sand bodies and
- iii) localised broken shell fragments/pebble beds, etc.

Almost in the entire area, the top 2-3 meters sediments are acoustically transparent soft clay, whereas the lower sedimentary layers exhibit stratification. At places, the seafloor is characterised by ripple marks which suggest the mobile nature of the sediments. Seafloor scouring is observed along a narrow zone off Thal. This phenomenon is attributed to intensification of bottom currents due to funneling during its passage between the islands of Khanderi and Underi (Subrahmanyam and Bhattacharya, 1984).

The acoustic basement reflector may represent the following lithofacies:

- i) Dense consolidated sediments or gravel/shell beds,
- ii) Deccan flood basalts or its weathered or altered derivatives and
- iii) Intrusive igneous rocks.

Analysis of borehole rock samples collected in and around Bombay harbour area show that the Deccan Traps extend to the offshore area and their petrographic studies indicate the presence of basalts, olivine basalts, spilitic basalts and dolerite (Karisiddaiah, 1988). Further, the borehole logs also indicate, that the fresh rock is capped by a zone of weathered rock. The thickness of this weathered/alterd rock cover varies from less than a meter to about 6 meters (Anonymous, 1978). The ridge and valley like features on the bedrock surface are possibly due to differential weathering. The geological situation prevailing in different parts of the Bombay harbour (Fig.3) is described below.

In the northern inner harbour, Elephanta and Butcher are the two main islands. Deep channels are present on either side of the Elephanta Island. The water depth varies from around dries over the mud flats to a maximum

of about 13 m in the channels. Extensive rock outcrops are seen in the vicinity of the islands and as isolated patches in between Butcher island and Pirpau. The seismic records show that most of the area is carpeted by soft clays and at places by sand ribbons. The bedrock is mainly in the form of ridges and valleys. Along some apparently linear zones, the acoustic basement is either disturbed or abruptly truncated, sometimes giving rise to graben like features. We infer that these features might have been caused by weathering of linear zones of altered rocks and not due to faulting. Some of these features also coincide with the reported onshore lineaments (Das and Ray, 1976) indicating a possible zone of tectonic weakness. The partially filled bedrock valleys around Elephanta island are presently in the form of open channels. The undulatory nature of the bedrock surface causes rapid variation in the overburden thickness (maximum 16 m). The seismic records show buried channels between Trombay and Nhava-Sheva and between Butcher and Elephanta Islands. These buried channels perhaps represent the subaerially developed drainage system and are in part filled with sand bodies. Near Pirpau, the seismic records show no subbottom penetration possibly due to presence of some biogenic material/gas charged sediments.

In the southern inner harbour area (between Colaba and Karanja), the water depth varies from less than a metre to a maximum of around 11 m. About 6 m thick acoustically transparent clay overlies the bedrock. Onshore rock continues as submarine outcrop near Colaba and extends over 2 km towards east and 4 km towards south. The bedrock surface here has a relief of the order of 1 - 2 m. From Karanja towards offshore, the onshore rocks continue for about 12 km either as submarine outcrop or as subcrop below a thin veneer of clays. The bedrock in this area is also characterised by considerable relief. About 16 m thick acoustically transparent clay overlies the valley like features. From the trend of the isopachs and depositional pattern, a buried meandering channel is inferred off Karanja. Further, the acoustic basement is conspicuously flat near the Dharamtar creek and is covered by a uniform 2 - 3 m thick clay. This reflector has been interpreted as thick shelly/sandy deposits. A large bedrock outcrop known as Thal shoal stands as a positive bathymetric feature at the entrance of the harbour. The topography over this shoal shows unevenness of the order of 2 - 3 m and it exhibits steep seafloor gradient. The sediment overburden in this area occurs as thin veneer or pockets on the bedrock. Around Thal shoal large patches of well defined ripple marks are present on the seafloor

(Almeida and Bhattacharya, 1980). A series of faintly stratified layers which onlap against bedrock as they approach shore are seen in this area. West of Thal Shoal, the bedrock deepens rapidly and could not be traced further. The overburden thickness gradually increases to a maximum of about 12 m towards the western limit of this area.

Outside the harbour, off Bandra, the bedrock continues westwards either as extensive outcrop or as a subcrop beneath thin sediment cover and outcrops even upto 9 km away from the shore line. A NNW - SSE trending sub-surface lineament about 10 km west of the coast was identified as fault (Bhattacharya et.al, 1987). Along this lineament, the gradually westward dipping bedrock surface shows an abrupt increase in its slope. At places some faint reflectors could be seen below the acoustic basement and therefore it is inferred that here the lowermost reflector represents the dense consolidated or cemented overburden or weathered basalts. Shorewards of 10 m isobath the overburden thickness is less than 2 m except for some pockets where considerable sediment thickness is noticed. Seaward of 10 m isobath the bedrock deepens rapidly and the sediment cover increases to a maximum of about 12 m towards the western limit of this area.

#### CONCLUSIONS

The shallow submarine geological situation of the Bombay harbour can be summarised as follows:

1. An average of 2-3 m soft clay covers most of the area.
2. Stratified layers of stiff clays underlie the soft clay layer.
3. Several buried channels are present in this area.
4. The bedrock mostly comprise of Deccan trap or its weathered derivatives. In the northern inner harbour area it shows relatively more relief as compared to southern or outer harbour area.
5. Surficial sediments bear evidence of scouring and mobility. At some places sediments also appear to contain biogenic gas at shallow depth.

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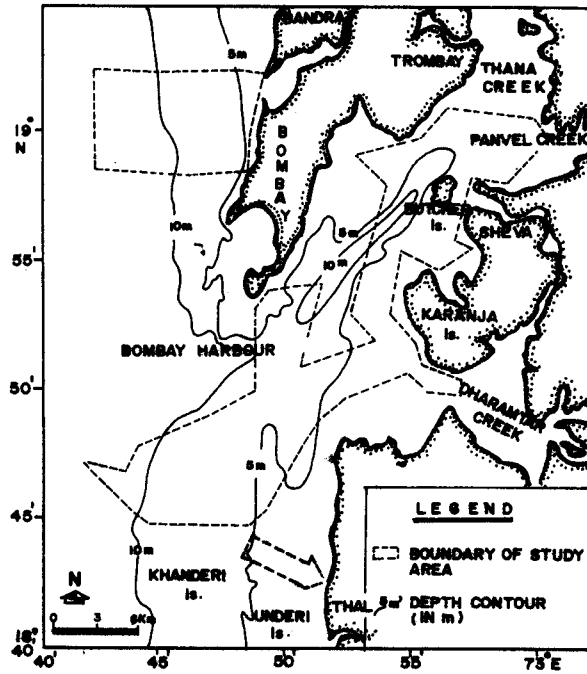


Fig.1 LOCATION OF THE STUDY AREAS.

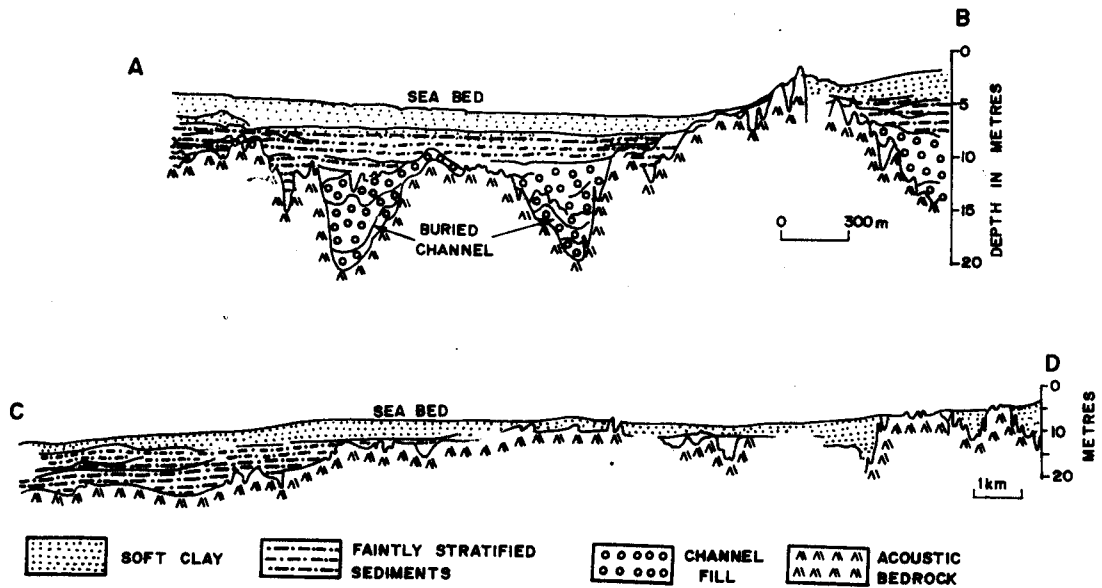


FIG. 2 SCHEMATIC LINE DRAWINGS OF SEISMIC PROFILES FROM NORTHERN AND SOUTHERN BOMBAY HARBOUR. LOCATIONS IN FIGURE 3.

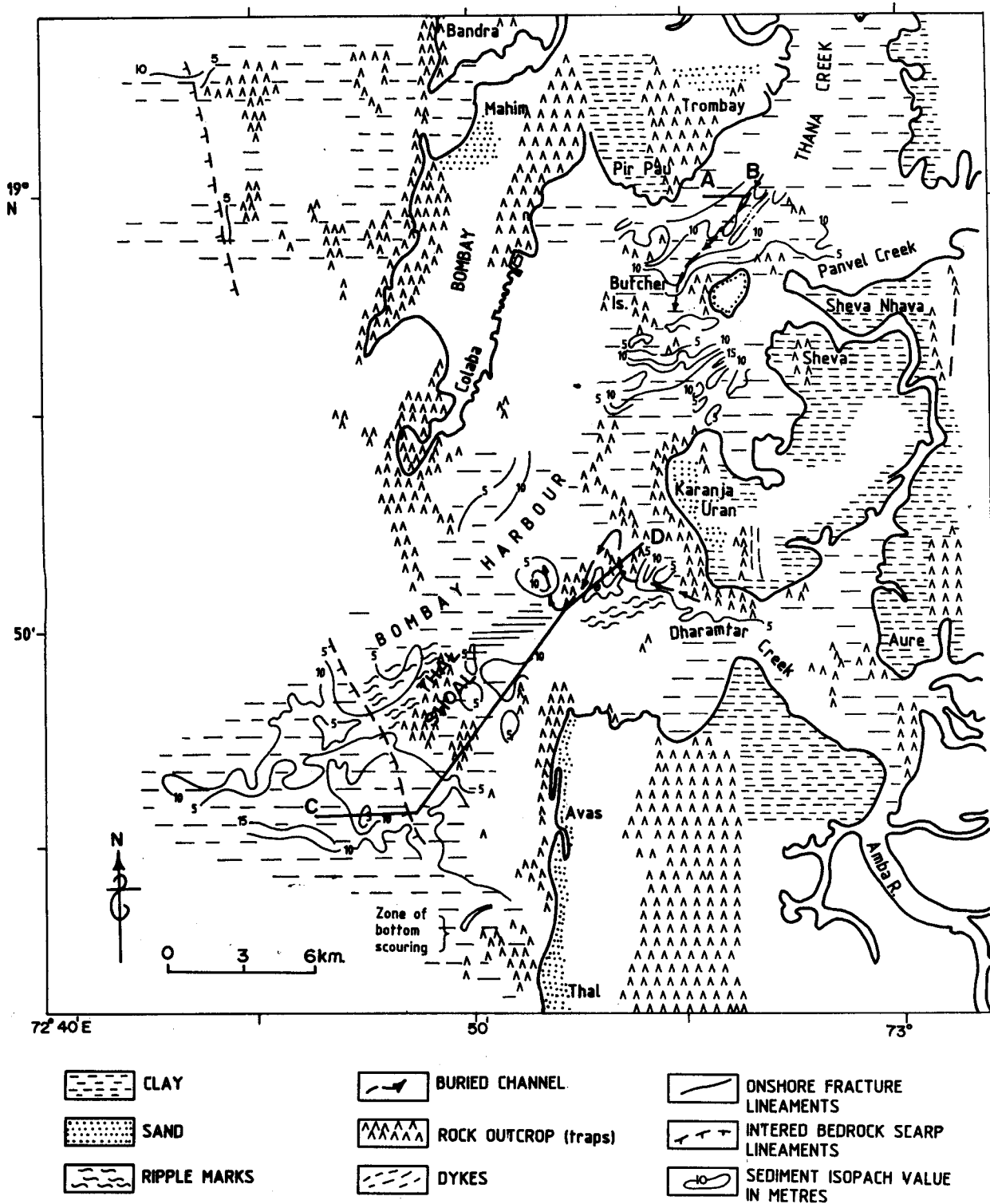


FIG. 3 MAP SHOWING MAIN SUBMARINE GEOLOGICAL FEATURES IDENTIFIED FROM THE PRESENT STUDY. ( Onshore geology & fracture lineaments after Das & Ray, 1976; Powar 1981 ).