

SEDIMENT AND SEDIMENTARY PROCESSES ON THE CONTINENTAL SHELF OFF BOMBAY

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ABSTRACT

The study of the sediments and sedimentary processes operating on the continental shelf off Bombay revealed that the continental shelf in general and the area of study in particular is floored with three distinct sedimentary facies. The boundaries between these are gradational to each other. The first two facies of sand and mud are geologically recent while the outer shelf relict carbonate sediments are of late Pleistocene, formed at the time of lowered sea levels. Evidence of these lowered sea levels are the presence of oolites and shallow water foraminifers. Sedimentary processes prevailing on the inner shelf are those of deposition, whereas, on the outer shelf erosive processes dominate.

INTRODUCTION

During the sixth cruise of R.V. *Gaveshani*, 22 surficial and 21 core samples were collected off Bombay over a distance of about 150 km from the coast (Fig. 1). These samples enabled the authors to study the sediments of the area in detail. The study was restricted to those aspects of the sediment which aid in the meaningful interpretation of the sedimentation processes operating on the western continental shelf and in particular in the study area (between $18^{\circ}45'19^{\circ}45'$ and $71^{\circ}00' : 73^{\circ}00'$). Some of the sedimentological characteristics of the continental shelf off Bombay have been studied (Nair and Pylee,

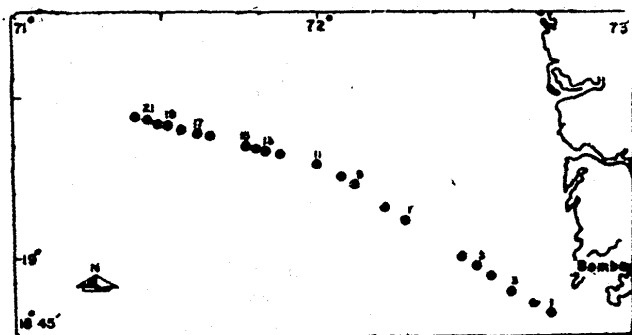


Fig. 1. Sample location.

1968; Schott, 1968; Nair, 1971; Nair, Murali and Kidwai, 1971; Kidwai and Nair, 1972; Stackelberg, 1972; Siddiquie and Rajamanickam, 1974; Nair, 1975; Hashimi, and Nair, 1976 and Nair, Hashimi and Guptha, *in Press*. The earlier studies will be briefly discussed in order that the sediments of the area may be placed within the overall sedimentary framework of the shelf.

General sedimentary framework of the continental shelf off Bombay: The continental shelf off Bombay is approximately 280 km wide. The shelf edge occurs at depth of 90 m. This shelf is floored with three distinctly different types of sediment. The first of these is the nearshore sand zone extending

from shore to the water depth of 5–10 m. These sands consists in parts of quartz and heavy minerals such as ilmenite and magnetite. The shore zone is subjected to seasonal variations associated with changes in the nearshore oceanographic processes. Succeeding these sands are the muds (silt and clay) which extend to a water depth of 60–70 m. Seaward of this mud zone and extending to the shelf edge are calcareous sediments camposed of shells of various organisms, oolites and algae. The boundary between these three sediment zones cannot be defined precisely because they grade gradually into each other. Relative to the shore zone sands, the mud and calcareous sediments do not undergo significant seasonal variations. However, under the influence of storms and cyclones, changes of major nature may take place.

The sediment of the inner shelf (0-60 m) are geologically recent. They represent the contribution made by the present day rivers of the west coast. The outer shelf carbonate sediments (60-90 m) have been dated to be 11,000 years (Nair, 1974). These sediments were deposited at a time (late Pleistocene) when the sea levels was much lower than at present. Since these carbonate sediments are older, they provide the surface over which the inner shelf muds whose thickness varies from 5–30 m (Siddiquie, Rao, Veerayya, Wagle, Almeida and Bhattacharya, 1977) are deposited.

METHODOLOGY

The surficial and core samples were collected by using La Fond-Dietz snapper and piston corer respectively. The logging for the colour and texture in all the snapper and core samples were first carried out visually on board the ship. In laboratory both the parameters were rechecked and lithological logs were prepared (Fig. 2). The colour

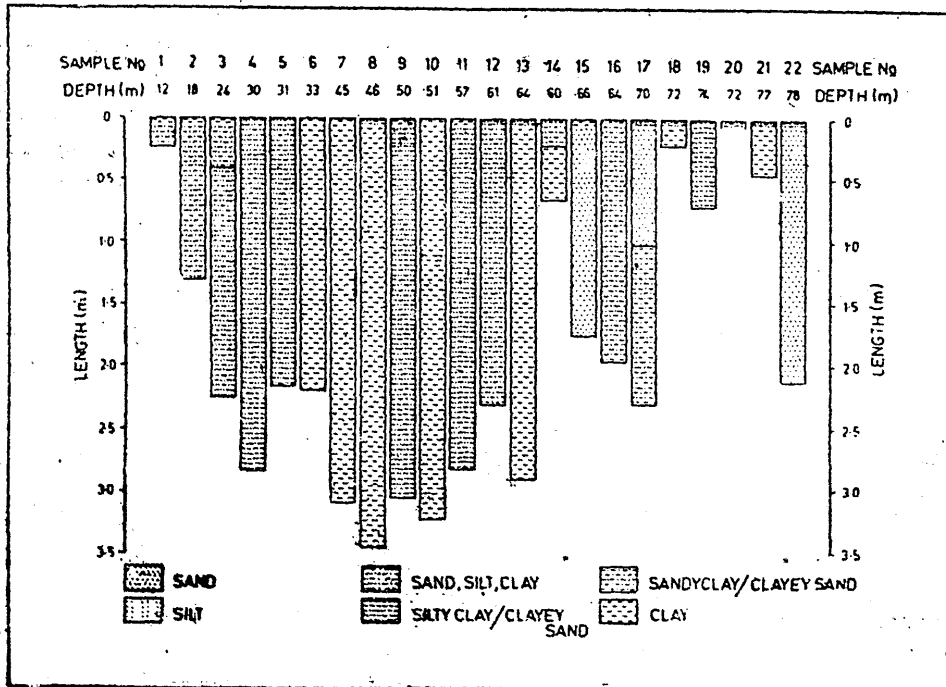


Fig. 2. Lithological log of samples.

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of the samples were compared with the standard colours of the Rock colour chart (1970) and the texture of the sediment was classified according to Shepard (1954).

A sub-sample of the coarse fraction ($>62\mu$) was taken after coning and quartering and was spread over a graduated tray for examination under the stereo-binocular microscope. 300 grains were counted from each sample and were grouped into the following: (a) skeletal components, (b) oolites, (c) quartz, (d) opaques and other minerals and (e) lithoclasts. The skeletal components include molluscs, foraminifers, bryozoa, corals, etc.

In addition to this, the foraminifera from the sand sized fraction was also examined. In some of the samples, where the fauna is little in quantity, the samples were subjected to floatation method using carbon tetrachloride to separate the foraminifera.

RESULTS AND DISCUSSION

In the area under investigation, three sediment colours have been found, namely, various shades of grey, brown and green. Over the greatest part of the area upto a depth of 60 m the surface sediment samples are muds with varying proportions of silt and clay. Beyond this depth, the texture of the sediment undergoes some change. The proportion of sand increases to 72.4% in (sample 14) in the surficial sample and as much as 97.8% in one of the core samples (sample 15). From Fig. 2 it may be observed that (a) the surficial samples show silts and clays with occasional clayey sand or sandy/silty clay, (b) beneath the surface, as seen from the core samples, layers of sand are present.

Coarse fraction analyses

The analyses of coarse fraction (the fraction of the sediment which is greater than 62μ) is frequently used to understand the depositional environment of the sediment (Shepard, 1973). The constituent of the coarse fraction studied are skeletal components, oolites, quartz, opaque minerals and lithoclasts. Calcareous shells of foraminifera, molluscs, coralline algal fragments and other skeletal carbonate fragments are present in all the samples and range from 9.5% to 98% (Fig.3). Their distribution is neither related to depth nor to sediment texture.

The oolites (ooides) found on the western shelf sediments have been radiocarbon dated to be between 9,000-11,000 years old (Nair, 1974) implying that at time that the waters on the shelf were shallow enough for oolite formation. Oolites (Fig. 3) are absent in samples 1-11 and found only seaward of 60 m depth (samples 12-22). The 60 m isobath is therefore taken to be not only the border line between the mud and carbonate zone but also as marking one of the low stand of sea level during the late Pleistocene.

Quartz grains are more abundant in the samples 1-11 (Fig. 3). Since these are essentially terrigenous silts and clays, their high quartz content is not surprising. However, basalts which form the rocks of the hinterland are poor sources of quartz. Therefore the principal source of the mineral may be the Gulf of Cambay. Excepting for stray high values (samples 15 and 17) quartz is found in lesser quantities in the

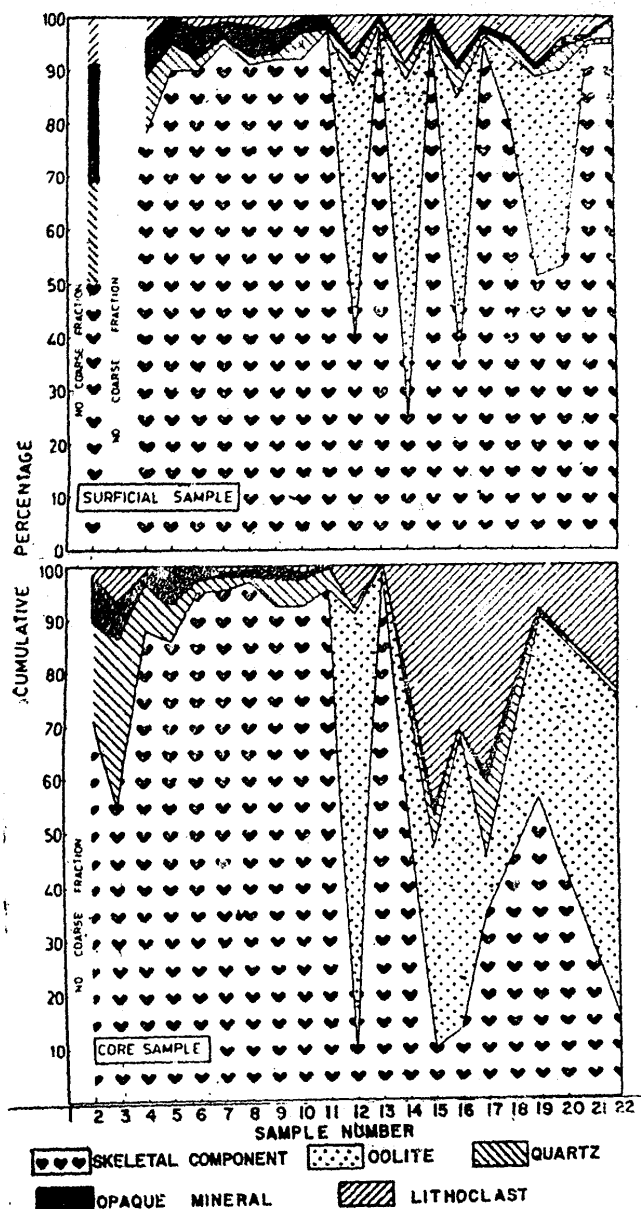


Fig 3. Abundance of coarse fraction constituents.

Foraminiferal analyses

The coarse fraction of the surficial sediments in the depth range of 15-60 m consists largely of benthonic foraminiferal sand. Except for *Ammonia beccarii*, an euryhaline and shallow water form and a few species of *Elphidium* and *Nonion*, rest of them are diminutive. From the water depth of 55 to 70 m this facies passes into an oolitic sand facies with a very poor distribution and diversity of fauna comprising about ten species. The fragmentation of tests is very conspicuous suggesting biological breakdown, transportation or the prevalence of intense surf action at the time of deposition during the time of lowered sea level.

samples 12-22 (Fig. 3) reflecting the decreasing influence of terrigenous sediments on the outer shelf carbonate sands. In other words, much of the fine sediment that is contributed by the coast to the sea is deposited within a relatively short distance (50-60 km off Bombay) from the coast.

The distribution of the opaque minerals closely follows the quartz distribution essentially for the same reason. Lithoclasts in the present instance consists of oolitic and coralline algal limestones. The distribution of lithoclasts is low in the samples 1-10 and high in the samples 11-22 (Fig. 3). They may have been derived by erosion from the carbonate horizon. Therefore, where the mud zone thins out, as at depth greater than 60 m, the carbonate horizon is exposed and their abundance increases. Pyrite in the form of infillings of the foraminiferal tests are found in samples 4 to 11 and 15 to 17. This distribution of pyrite is reflected in the chemical analyses of the samples which show a high percentage of sulphide-sulphur (Paropkari, Rao and Murty, 1977). Authigenic pyrites are common in rapidly deposited fine grained sediments such as those on inner shelf.

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Miliolids are commonly found in the inner shelf and outer shelf regions excepting in the middle shelf between 40 and 45 m. In samples greater than 55 m depth on the outer shelf, it was observed that many of the tests are discoloured greyish black to brown. It was also noticed in one of the core samples (sample 3) between 205-215 cm that about 50% of the planktonic foraminiferal tests present were jet black with shiny appearance and this may be due to the pyritization.

In the depth range of 55-70 m on the outer shelf, the coarse fraction has low diversity and poor distribution of foraminifers. From 70 m (samples 19-22) they exhibit a gradational change from a predominance of oolite and low diversity and poor foraminiferal content to increasing abundance of foraminifers both in distribution and diversity with about 35 species. Broadly, the fauna decreases gradually from top to bottom in the cores. Besides, at the bottom some of the cores at depths beyond 70 m a few species of *Calcarina* (*C. calcar*, *C. spengleri*, *Peneroplis pertusus* and *Cymbaloporetta*) are found. These are typical lagoonal assemblage suggesting a downward change in the biofacies and lagoonal conditions of deposition at the time represented by the bottom sediments of the core. *Calcarina* is an Indo-Pacific type restricted to reefs in their occurrence. It is believed to be mainly an inhabitant of the surface of reefs that are awash at low tides (Todd, 1957).

Surface sediment map

A surface sediment map (Fig. 4) of the present study area was compiled by utilising the results of the present study and taking into account the previous data, the bottom notations of the available hydrographic charts and the regional sediment maps. The lithology of the cores collected by various organisations including N.I.O. are also shown on the map. The surface sediments are classified broadly into two types, namely clays which include sandy/silty clay, mud/soft mud and sands with varying proportion of silt/clay.

Sedimentary processes

The sedimentary processes taking place on the seafloor are the processes of erosion and deposition of the various types of sediment, rates of sediment accumulation, topographic and hydraulic controls like wave induced and tidal currents.

Erosion and deposition

Qualitative rates of deposition may be obtained from the nature of the bottom topography and the texture of the sediment. On the outer shelf the echogram shows the presence of compact sediments and this is supported by the poor recovery of piston core samples, most of which are short lengths of calcareous sand with a thin layer of clay on top of the core. The topography consists of small scale (1-10 m in relief) features. These features have not been buried under the recent sediments on the outer shelf. The absence of recent sediment accumulation can reasonably be attributed to the presence of bottom currents. The magnitude of the near bottom tidal currents on the outer shelf at the depth of 70 m is of the order of 21 cm/sec (C. S. Murty—personal communication) which by itself is incapable of sediments transport to any great extent. However, in combination with wave induced currents, the resuspension and removal of sediment is a possible. These

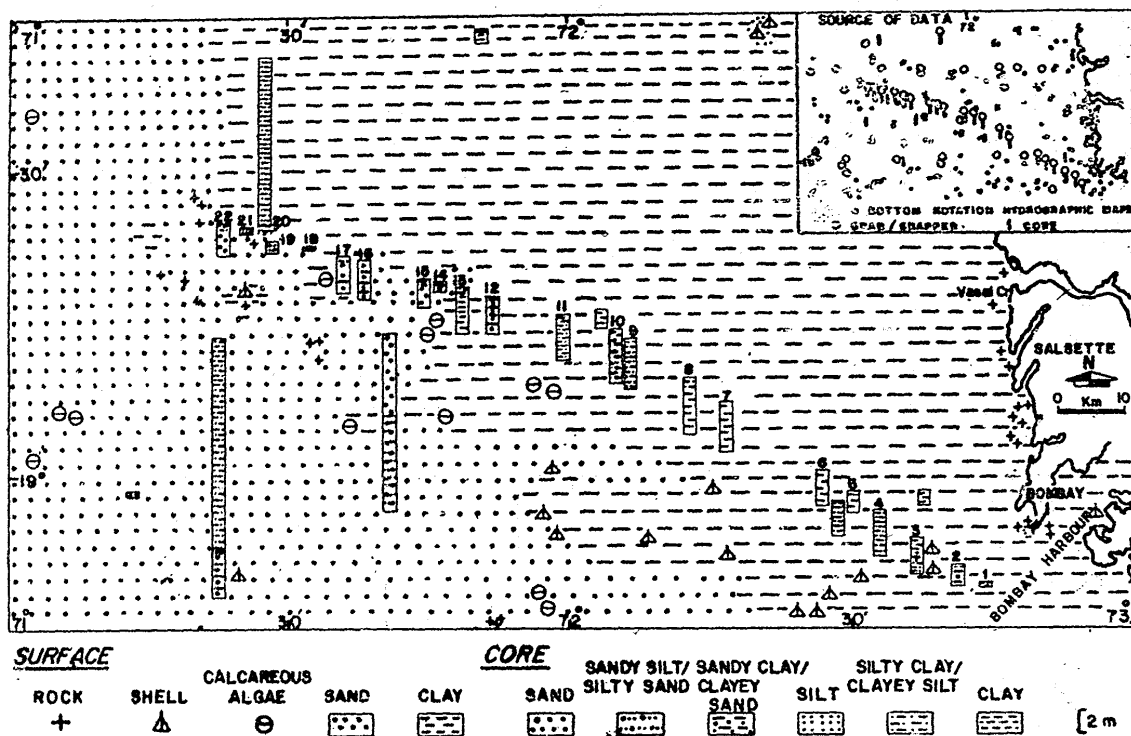


Fig. 4. Surface sediment distribution map of the area.
(The cores without numbers are from other sources.)

processes in turn suggest the possibility of current scour on the outer shelf. Assuming an average age of 10,000 years for the Holocene surface over which the muds are deposited and a mud thickness of about 30 m (Siddiquie, Rao, Veerayya, Wagle, Almeida and Bhattacharya, 1977) the sedimentation rate works out to be about three metres/1,000 years. The texture of the sediment of the inner shelf precludes the possibility of strong currents. Depositional rates moreover are to apt show seasonal variations, high rates are expected during the monsoon because of peak river discharge and low rates during non-monsoon or fair weather. An additional factor which may bring about re-distribution of sediments is the process of onshore transport of sediment from the offshore regions. The magnitude of such onshore transport processes is not known for the area under investigation. However, onshore transportation of sediment was evidenced by the abundant occurrence of planktonic foraminifera in the Cochin backwaters (Siebold, 1972). Hashimi and Nair (1976) indicated the possibility of the processes of onshore transportation of sediment on the western continental shelf based on the presence of grapestone in the nearshore regions off Ratnagiri.

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