

BIOLOGICAL AND GEOPHYSICAL ASPECTS OF COASTAL STRUCTURES

M.V. Ramana
National Institute of Oceanography
Dona Paula, Goa

Geological processes, that occur in the nearshore environment : The nearshore, environments have been strongly influenced by sealevel changes throughout the geological history. Much of the shallow-water region is also strongly affected by waves, tides and shallow currents. Thus the sedimentary history of the shelves and nearshore environments reflect the ever-changing relationship between tectonic subsidence, sea level oscillations and the dynamic processes acting at these water depths. These environments also lie within the photic zone so they are influenced by biological processes and productivity that do not occur in most other parts of the ocean.

The near shore environments and the continental shelves have played a major role through time in the storage or redistribution (or both) of land derived, or terrigenous sediment to deeper ocean. Rock weathering on land produces particulate matter like sand and clay as well as dissolved material. This matter is carried to the continental margins and some is deposited in the deep sea. It was estimated that each year some 250×10^{14} gm of material is carried into oceans. Rivers carry about 85 to 90 percent of this material, ice transportation accounts for about 7 percent, ground water for 1-2 percent and wind less than 1 percent. About 80 percent of river load is particulate matter and the remainder is of dissolved form. This vast amount of terrigenous

sediment delivered to the marine environment is discharged by a few rivers.

Because of the diversity of oceanographic influences in shallow marine areas it is not surprising that there is so much diversity of sedimentary environments grading into each other. Sands are generally restricted to the shore zone at maximum depths of about 20 m while muds are not distributed much beyond 30 km from the shore line, except where sediment input is more. The development of shore line sedimentary environments is a function of numerous parameters including rate of influx of terrigenous sediment, tidal regime, exposure to waves, current patterns, climate and tectonism. The character of the modern shoreline deposits reflects the balance between the rate of injection of sediment and ability of marine processes to redistribute the material. This balance in turn determines the chemical character of shelf sediments. Where terrigenous input is large, terrigenous sediments dominate (clastic shore lines), as terrigenous sediment input declines, carbonate sedimentation begins to become important and in some areas it becomes dominant (carbonate shore line).

Sediment disequilibrium of Modern Coastal zones

The character of the world's continental shelves varies considerably in structure, sediment type and topographic evolution. The development of these shelves has ranged from the truncation of older rocks to the deposition of roughly

conformable sediment sequences of Mesozoic to Recent age. The broad, flat character of the shelf has resulted from erosional activity related to a series of transgressions and regressions. Both erosion and sedimentation are concentrated in the nearshore areas, and the repeated sea level migrations have leveled the margins forming the shelf surface.

When the sea level is high, shelf width is at its maximum : Shelves act as storage areas for sediments or influence coastal processes that trap material in estuaries, coastal barriers or inner shelf shoals. This is the present state and has been amplified by the rapidity of the glacio-eustatic rise in sea level during the last 10,000 years. The morphology and sediment cover of most of continental shelves is a relict of the previously lowered sea level. This is because, since the Holocene transgression, insufficient time has elapsed for return of a typical shelf equilibrium with present day environments. During this transgression the shore line migrated so rapidly that rates of sand supply were insufficient for appreciable beach deposits or ridges to develop over the shelf surface. The effect of the Holocene transgression is major transgressive or drowned coasts around the world, perhaps best noted along the Atlantic coast line of north and south America. This coast line exhibits extensive barrier-lagoon coasts, drowned estuaries and other features created by rapid inundation.

Because the shallow water environments are in a state of disequilibrium and because sediments are trapped in the

near shore areas most continental shelves are covered with relict sediments and are still dominated by morphology related to the quaternary low stands of sea level. Relict sediments are those that are related to past conditions even though they lie at the surface of the ocean floor.

THE NEARSHORE ZONE

Estuaries : An estuary has been defined as a semi enclosed coastal body of water freely connected to the ocean and within which sea water is measurably diluted with fresh water from the land. Estuaries are dominant features along many modern coastlines as a result of Holocene transgression. Present day estuaries are forming near tidal flats, barrier islands and river deltas.

Estuaries represent one of the most important modern geological features controlling the flow of terrigenous sediment from land to ocean. Most estuaries and associated coastal marshes represent sediment sinks or areas of entrapment.

Tidal processes are of the utmost importance in controlling estuarine sedimentary conditions.

Lagoons : Lagoons are highly variable, shallow marine environments separated from the open sea by barrier island complexes composed largely of well sorted sand. The barrier may be an island with dunes or no more than an offshore bar

exposed only at low tide. Lagoons are largely found along transgressive coast lines in association with estuaries. A typical estuary is a narrow elongate embayment while a typical lagoon is parallel to a sand barrier. As lagoons are filled with sediments they become tidal flats. Lagoonal sediments are generally fine grained since they are deposited largely from suspension. However, sands are also deposited as wash over fans and small scale deltas. Carbonate muds can be deposited where sedimentation is especially low, and evaporites may form in hyper saline lagoons.

Deltas :

The term delta was first applied by Herodotus in the fifth century B.C. to the triangular shaped body of land between the branching channels of Nile river. Because deltas form where rivers transport more sediment to the sea they can be redistributed by longshore currents, they produce a regressive shore line. Where longshore currents effectively redistribute this terrigenous material, bars and beaches parallel to coast line. The river flow maintains enough momentum to carry the sediment load upto several kilometers into the ocean as a jet before the current dissipates. The jet loses the momentum most rapidly near its margins due to shear stresses with the surrounding seawater. This leads to deposition of sediment at the margins, forming submarine levees (Shallow embankments). Ridges may also form below the jet flow because of similar shear stresses developed along its lower surface.

All deltas exhibit a system of branching "distributary channels" flanked by levees.

The top of delta consists of a radiating network of distributary channel sands flanked by levee sills. These radiating series of distributary sands are referred to as bar-finger sands.

Coarse sediment deposition in deltas is concentrated at the subaerial "delta front". Beyond this much finer sediments are deposited in the "prodelta" which is entirely below sea level.

As the deltaic system is prograded it gives rise to the classic cross section of topset, foreset and bottom set beds.

Topset beds : Topset beds are mixture of coarse sands deposited in the delta front and deltaic plain areas and finer, organic rich sediments of the interdistributary areas. Foreset beds are fine marine sediments of the prodelta facies. Bottomset beds are finer sediments deposited on the distal areas of deltaic complex and grading into sediments of the adjacent continental shelf. Fig. 1 describes the features more vividly about the delta morphology.

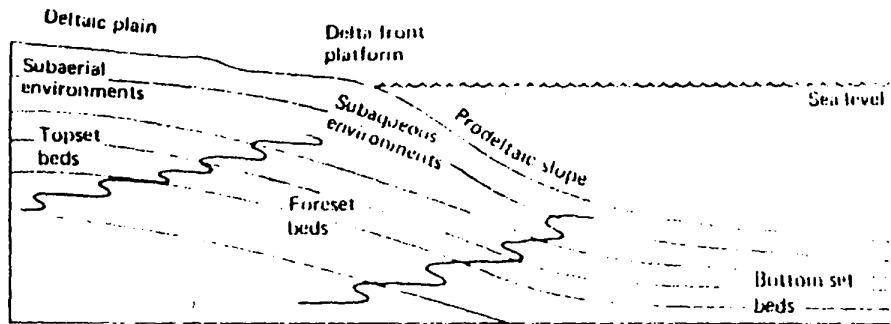


Figure 1.1 Gross features of delta morphology in greatly exaggerated cross section. (After R. K. Matthews, 1974)

Beaches : The most dynamic of all marine environments are located at the intersection of sea and land - beaches. Because beaches are constructed largely by wave processes, they are constantly changing at rates dependent upon individual waves, different tides, different seasons and different years. In strict sense a beach is an accumulation of unconsolidated sediment (sand, shingle, cobbles) from mean low tide to a physiographic change such as a dune field. But a beach is considered by geologists to include the nearshore area below sealevel (to a depth of 10 to 20 m) which is actively under the influence of surface waves.

When waves approach a shore line, the crests are bent to conform with the contours of the seafloor. This is called "wave refraction". The effect of this process is to distribute wave energy, focus energy on head lands, and reduce wave energy coves or embayments. At depths where the waves cannot complete their orbital motions, they increase in high and steepness and eventually begin to break creating the "breaker zone". The "surf zone" is a zone in which a shallow high velocity transition wave or "bore" is propelled up the beach face. This uprush of water produces sediment transport and sorting.

The "swash zone" represents the zone of maximum penetration of a shallow wave. Fig. 2 represents wave action in the near shore regions.

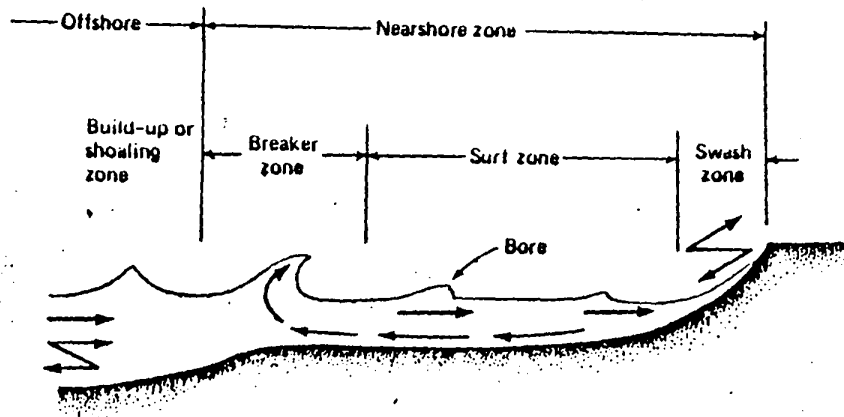


Figure .2 Terminology used to describe wave action in the nearshore regions.
 (From Paul D. Komar, *Beach Processes and Sedimentation* © 1976, pp. 12-13.
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Beaches develop a profile that reflects the changing conditions. Four zones within the littoral or nearshore environments have been distinguished from landward to seaward. They are back shore -> Fore shore -> Inshore -> offshore.

The backshore is that part of the beach that is covered by water only during storms, and thus is above normal high tide. The backshore area consists of one or more gently sloping "berms" deposited by the receding waves. The seaward limit of the berm is marked by an abrupt change in slope at the "berm crest", or edge, which indicates the highest point of normal wave activity. The beach face is a part of the "foreshore zone", although the foreshore zone may include additional flat portions of the beach profile. The "innershore zone" is the wider subtidal part of the profile extending to just beyond the breaker zone or the limit of the bar and trough topography. Terminology used to describe the beach profile has been shown in figure 3.

Continental margin is the zone encompassing a wide transition zone that separates oceanic from continental realms and it includes continental shelf, slope and rise and also embraces the landward extension of the geological provinces. Mineral deposits that are found on the continental margins are mainly classified into consolidated and unconsolidated deposits which can be grouped further on the basis of their genesis as terrigenous, biogenous and chemogenous. Terrigenous mineral deposits are considered to be mainly derived from the land sources. Placer minerals are the main constituents of the terrigenous group. The common placers are tin stone (cassiterite ?), chromite, ilmenite, rutile, zircon, magnetite, monazite, kyanite, silliminite, native metals like platinum, gold and gemstones like diamonds and garnets. These can be located either in the recent beaches and river beds or in the shelf as buried placers of ancient beaches and river beds. Coral shells and calcareous sands are the biogenous products which can be commonly expected on the ocean beds. Barytes, phosphorites and manganese nodules are considered to be chiefly chemogenous deposits.

Since the placer minerals have higher specific gravity, they are not transported over long distances and are always found in the river beds, beaches and nearshore areas like innershelf.

Terrigenous minerals deposited in the sea undergo further sorting and grading continuously through waves and currents. In addition to the above occurrences, pre existing coastline is yet another place to be considered on the innershelf for such minerals.

Placer deposits can be defined as alluvial and colluvial material which contain economic quantities of some valuable minerals such as gold, platinum, tin, diamonds, zircon, rutile, monozite, ilmenite etc. Chemically stable minerals are not decomposed by weathering processes. As the surrounding rocks are dissolved and disintegrated, these stable minerals remain unaffected and are carried away by rain, streams waves or wind. The lighter particles are moved and dispersed, but heavy stable minerals either remain as residual particles in the soil or got transported as sands and gravel by streams. Further agitation within the stream or beach environment will cause the heavy particles to settle to the bottom and continuously enrich the deposits by removing the lighter and more brittle gangue. The net effect is concentration of heavy, chemically stable minerals. Such concentrations are called placers.

Heavy mineral sands popularly called black sands occur between Quilon and Cape Comorin in Kerala, Tinnavelli, Ramnad and Tanjore districts of Tamil Nadu, Visakhapatnam and Bhimunipatnam beaches of Andhra Pradesh and some coastal areas of Orissa state. The occurrence of ilmenite on the

beaches of Ratnagiri (Konkan coast) was documented in 1945 by M.S. Krishnan.

The National Institute of Oceanography, undertook offshore exploration programme along the Konkan coast and reported the presence of large deposits of ilmenite and magnetite along the beaches of Konkan. The work extended over a stretch of 130 km covering nearly 13 bays, Jaigad in north to Vijaydurg in south. Preliminary results of the above investigations have proved to be very encouraging in that mineable deposits have been found in good number. Detailed multi sensor geophysical investigations carried out for the first time on the west coast have been summarized down below:

Layout of the cruise tracks

Since the onshore structures and geology are supposed to be extending laterally towards offshore, the cruise tracks are planned nearly perpendicular to the main landmass. The profiles (east-west) were planned in such a way that wherever the beaches are exposed, the track spacing was kept at 200-250 m. The spacing between two tracks was increased (400-800 m) wherever promontories are exposed. Criterion for this sort of track spacing is that the surface sampling clearly indicated soft clays distributed off promontories where sands are totally absent or a very thin layer of sand underlie the clays.

Geological Framework : The Konkan coast comprised of 13 bays forms the coastal stretch of Maharashtra state. The

geological formations of Maharashtra state include those of Pre-Cambrian, Paleozoic, Tertiary and Quaternary periods. Most of the state is covered with a thick pile of Deccan Trap basalt flows. The coastal regions are characterised by laterite formations. Hills, valleys and scarps characterize the coastal stretch. The cliffs of the hills are extending into the sea as in Jaigad and Warori bluff. Basalts are found to occupy the lower levels and are topped by laterites. Fresh exposures of basalts are seen below the scarps. The Deccan Trap basalts which are extensively spread over the central Indian plateau along with dikes and sills belong to upper Cretaceous to lower Eocene age. Boulders and pebble beds, quartzites with minor conglomerate shales and lime stones of Kaladgi formations and newer laterites, uralitised gabbros, dolerites, schists and gneisses of Dharwar group and crushed conglomerates, granulitic gneisses, quartzites, mica schists, amphibolites etc. of Archaean age are classified under Pre-Cambrian group.

The most conspicuous structural deformations documented over the trap covered areas are fractures, dykes, alignment of hot springs and earthquakes. Fractures extending several kilometers in length are recognized all along the mainland. Most of these features trend NW-SE, NNW-SSE, N-S. However, the fractures between the Narmada-Son lineament and the west coast show a prominent ENE-WSW trend with NNW-SSE and WNW-ESE orientations. Majority of the dykes trend NNW-SSE, N-S, NE-SW and NNE-SSW directions.

Equipment used

1. Positioning : Motorola Miniranger MRS III
2. Bathymetry : Atlas Deso 10 (Dual frequency) echosounder.
3. Earth's magnetic field : Proton precession magnetometer, Barringer, OM-1.
4. Shallow seismics : 9 electrode EG&G spark array with power supply and other peripherals.
5. Side scan sonar : EG&G Model 272
6. Geological sampling Devices (Vanveen grab, gravity piston corer, Augar).

Qualitative interpretation

1. Magnetic field : A total intensity earth's magnetic anomaly contour map in general depicts the spatial variation of total magnetic intensity of the geomagnetic field together with that of anomalous magnetic field caused by the changes in the magnetization of the crustal rocks down to the curie point isotherm. The magnetic map also provides evidence on the spatial distribution of magnetic susceptibility besides intensity of magnetization of the underlying rocks which in turn depends on the distribution of magnetic minerals either because of their large magnetic susceptibility or because of their ability to hold a fair amount of remanant magnetization. Among the naturally occurring magnetic minerals, magnetite is the most abundant. Geological processes involved in the formation of various igneous and sedimentary rocks and the subsequent metamorphism undergone

by them under vastly different physico-chemical conditions tend to alter, destroy, generate and redistribute the magnetite in the rocks. They in turn impart a pattern to the magnetic map. Interpretation of magnetic map is therefore an attempt to understand this inherent pattern and related the same to the underlying geology. Qualitative interpretation is essentially an exercise in pattern recognition. The figure (4) is characterised by N-S, NW-SE and WNW-ESE magnetic lineaments of these, NW-SE and near N-S trends predominate and they persist for considerable lengths. The small anomaly closures confine themselves to few traverses only.

The trend of the magnetic anomalies recognised in the northern part of the map are indicative of dislocations and block movements along NW-SE/WWN-ESE oriented weak planes. The N-S, NW-SE, WNW-ESE and NNW-SSE magnetic anomaly trends are probably fractures fissure zones, faulting and dislocations through which magmatic material might have been emplaced and latter altered by perlocating waters and other processes.

Thus, the magnetic anomalies may be viewed as due to the structural disturbances in the Deccan Trap basement and its weathered derivatives in the form of dislocations and shear zones besides other topographic irregularities affected by erosion and cut and fill type paleochannels and other type of favourable ground for the accumulation of placer deposits.

Seabed topography and sediment distribution

We made use of the echograms for not only the preparation of bathymetric map (Fig. 5) but also to identify the nature

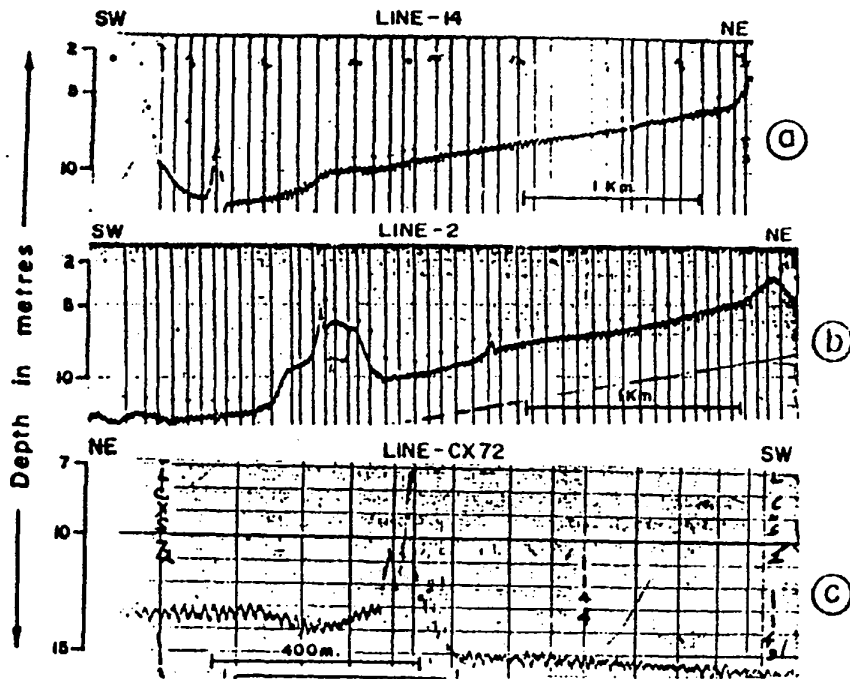


Fig.3 Echograms showing (a,b) steep seafloor near Binge shore (NE) and (c) rugged topography SE of Anjadip Is.

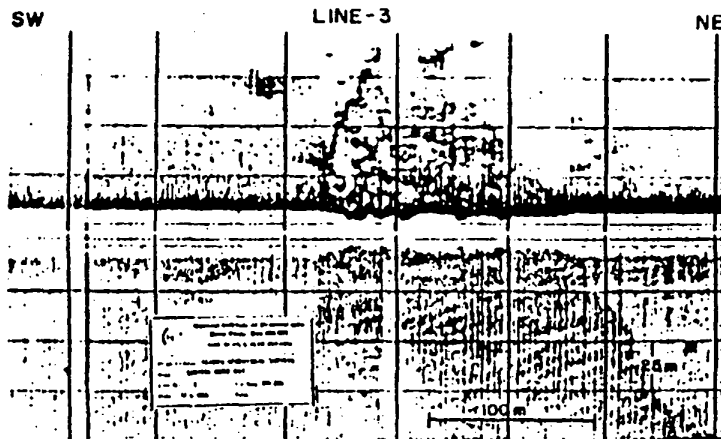


Fig. 5 Sonograph showing surface expression of submarine ridge 0.8 km. NE of Round Is.

of the sediment cover and rock out crops on the seabed. The seabed topography is even and gentle over large area except near promontories. The seabed is largely covered by sands, silty sand, sandy silt and clay. The echograms (Fig. 6) depicted opaque and transparent sediment patterns for sand and clay respectively. Sand cover the seabed upto the water depths of 9-12 m and beyond this depth clay overlies the sands and the thickness of clays increases offshore.

Cores collected from the seabed distinctly showed the clay sand contact. The top 40cm of the cores consists of reddish brown clay below which is seen live grey clay which inturn overlie heavy mineral rich sands. It was also found from the grain size distribution studies that the sediments are mostly well sorted and unimodal whereas the sediments at river mouths are poorly sorted and polymodal representing a mixed depositional environment.

Shallow seismic studies: The character of seismic records, penetration depth and strength of the bottom reflections, provide adequate subsurface information. The seismic sections (Fig. 7) show three to four well defined stratal surfaces characterised by high amplitude and continuous reflections the bottom most reflector is recognised as an acoustic basement, mainly represent in the seaward extension of Deccan Traps locally representing the upper weathered/altered trap or a reworked surface. With the help of borehole data available in the vicinity of the study area, it has been identified that bottom most reflector represents

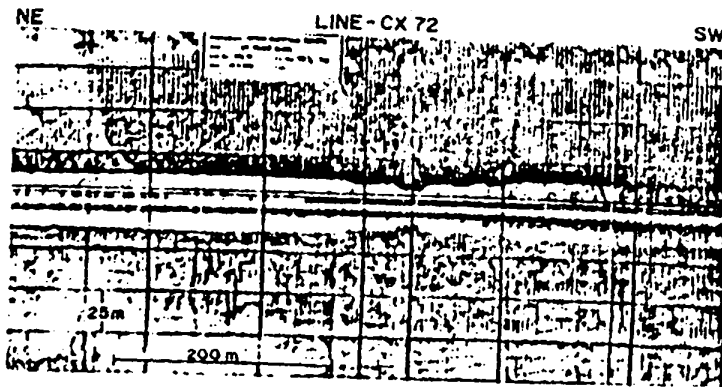


Fig.4b Sonograph showing irregular rocky seafloor SE of Anjadip Is.

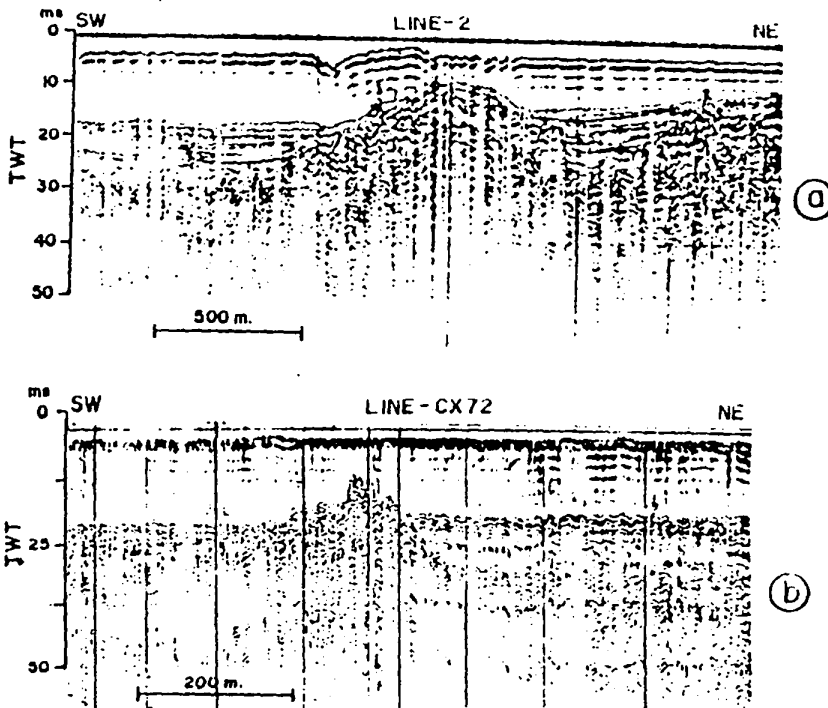


Fig.7 Sparker records showing the surface expression of (a) Round Is. and (b) rock outcrop SE of Anjadip Is.

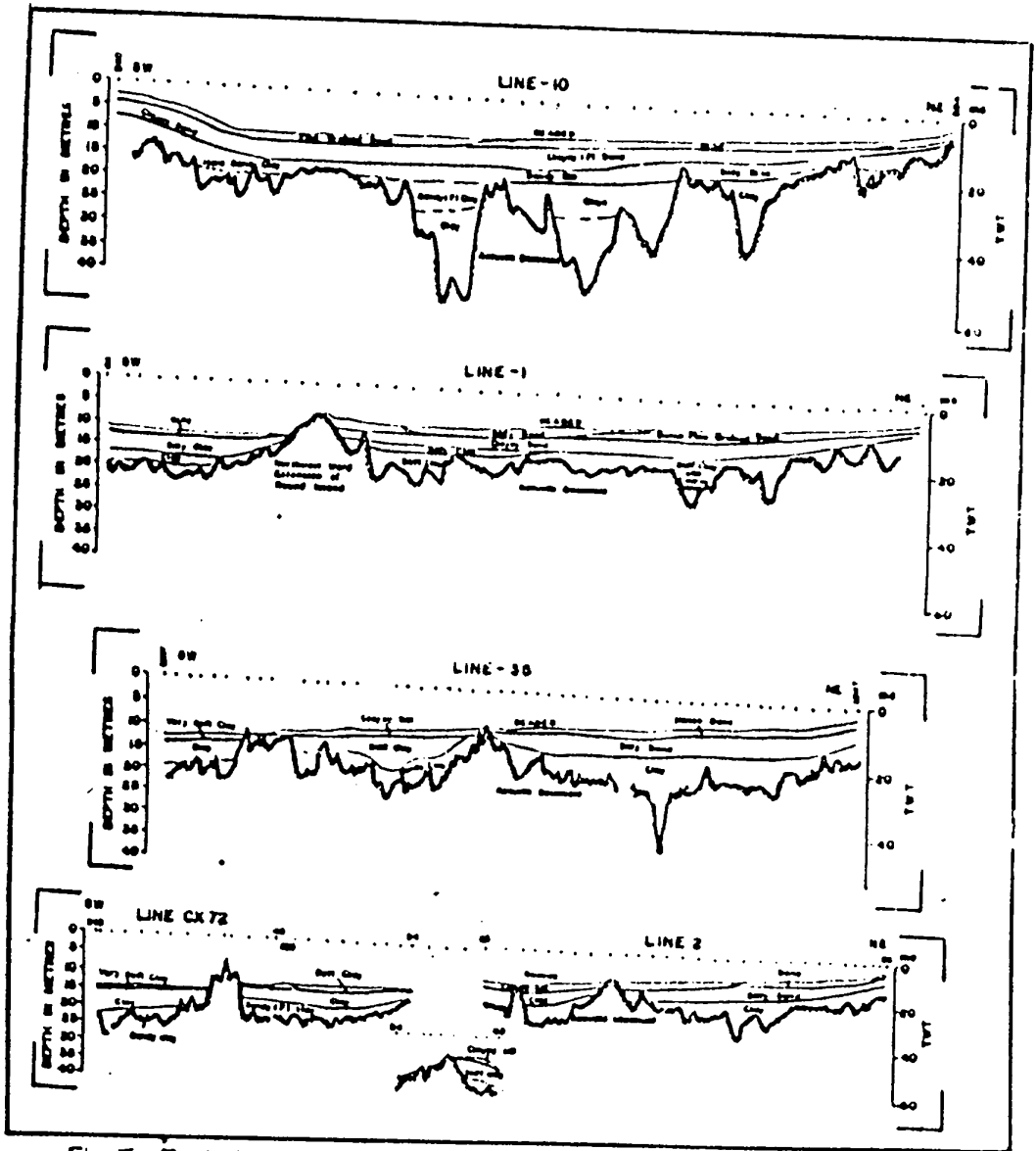


Fig. 7a Typical seismic sections along selected NE-SW profiles showing 3-4 prominent reflectors and basement.

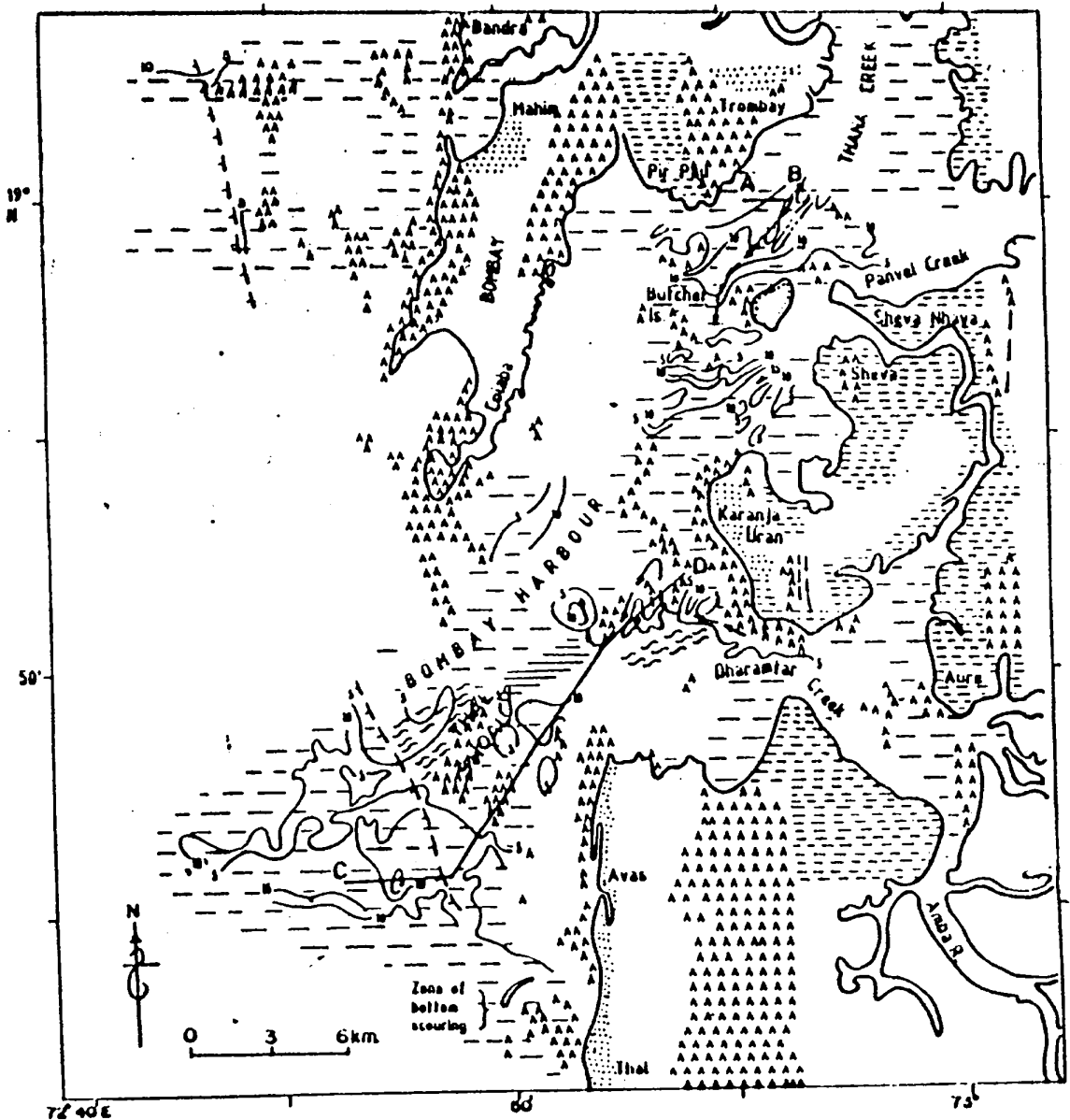


FIG. MAP SHOWING MAIN SUBMARINE GEOLOGICAL FEATURES IDENTIFIED FROM THE PRESENT STUDY. (Onshore geology & fracture lineaments after Das & Ray, 1976; Powar 1981).

either top of the Deccan Trap or its weathered derivative. The reflector immediately above this acoustic basement comprised of boulders, sand and silts. The top layers comprised of sand (in the nearshore area, 9-12m) and beyond this depth they are either clay/silty clay. It was established that the sand and clay contact zone occurs at 9-12m water depths.

To sum up, the marine geophysical studies helped in delineating the horizontal as well as vertical distribution of heavy mineral placers in the nearshore areas. These placer sands deposits are recognised by their high frequency short wavelengths with 120-200nT amplitudes. Magnetic model studies suggest that the thickness range from 10-20m with varied concentrations of magnetites and ilmenites.

Using the geophysical methods the subsurface geology of Bombay harbour, Konkan offshore and off Karwar have been inferred to a fair degree of accuracy which are confirmed by the lithological data of bore holes.

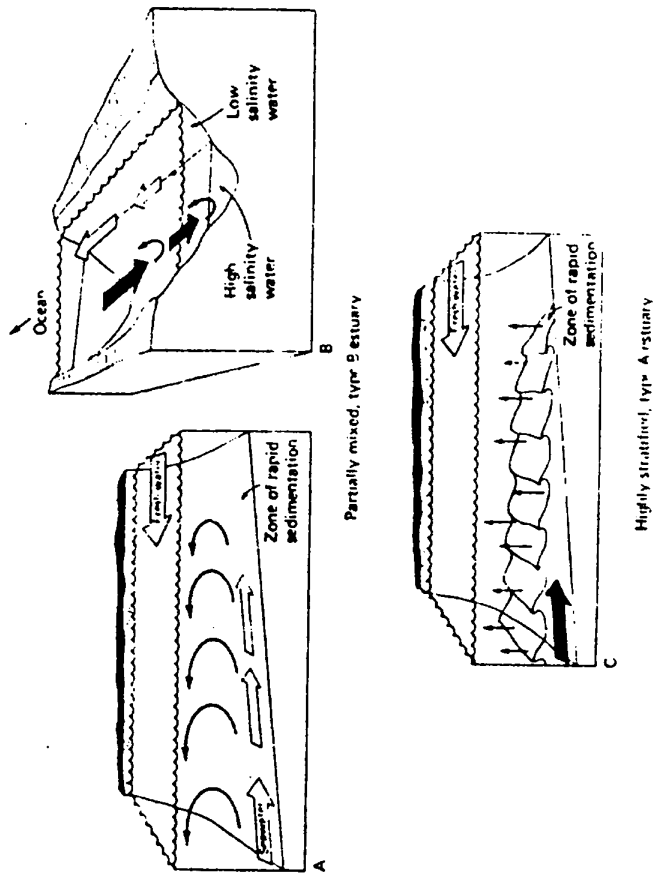


Figure Top figure shows schematic views of partially mixed type B estuary (A) side view; (B) view looking seaward in the Northern Hemisphere; (C) view of a highly stratified, type A estuary. (From I. R. Schubel and D. W. Pritchard *Journal of Geol. Education*, vol. 20, pp. 60-66, 1972.)

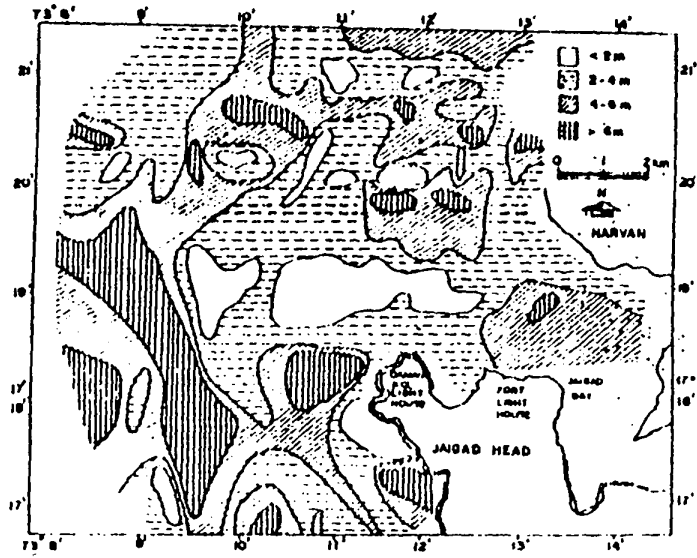


Fig.8. Isopach map of heavy mineral rich sands (Alter Rajamanickam et al. 1988)

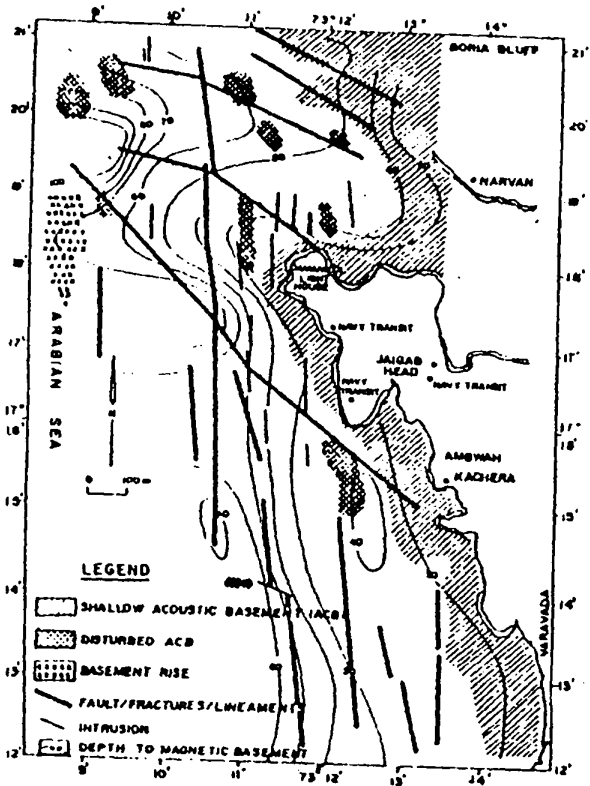


Fig. : Structural map of Jaigad, Ambwah and Varavada bays and the depth to the magnetic basement.

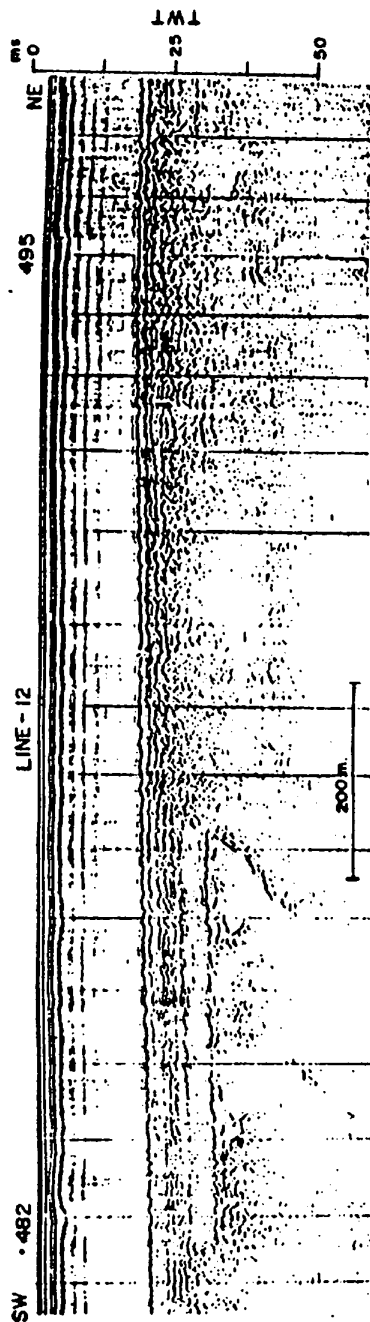


Fig. . . Sparker record showing stratified sediments, deep in-filled valleys and acoustic basement north of Arge Is.

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