

Some Geological Processes in the Macro-tidal Regime of Gulf of Kachchh, Northwest Coast of India

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Echosounding and subbottom profiling, supplemented by side scan sonar profiling have been carried out followed by sediment sampling in the inner gulf of Kachchh. The results show the presence of sandwaves with a height of 3-6 m and wavelength of about 150-350 m in the Kandla creek. The Sara, Sanu and Phang creeks exhibit uneven to rugged topography with about 4 to 12 m deep V-shaped channels. The seismic profiles across these creeks show 10-15 m thick clays. The channels are cutting across the reflectors. The axial part of the Hansthal creek is uneven to rugged and is devoid of soft sediments, the flanks, however, show 2 to 8 m thick clays. The outer anchorage area in the south, by contrast, has smooth and even topography and stratified layers with maximum thickness of about 18 m. The acoustic basement is uneven but major channel cuttings are not noticed. Based on the results of the investigation it is concluded that the erosional processes are operating in the creeks while the outer anchorage area is undergoing the deposition. The area has, perhaps, witnessed more frequent climatic fluctuations recently as evident from shallow seismic records.

The site investigations to supplement the data required for modernisation of a port or planning an offshore structure are generally restricted to a few boreholes in an area. This does not provide the complete picture of the geological processes that are operating in the area. The purpose of this paper is to present the surface and subsurface geological set up of the inner gulf of Kachchh and to indicate different geological processes that are operating in the area and their implication on the geomorphic features, such as channels, sandwaves or sediment overburden, which in turn, will be useful for the overall development of the area including Kandla and Navlakhi harbours.

Study Area

The Gulf of Kachchh (Fig. 1) presents a complex set up due to presence of shoals, channels, creeks and islands. The inner part of the gulf primarily bifurcates into two creeks namely Kandla and Hansthal. The port of Kandla is a major port with a natural Harbour, located on the western bank of Kandla creek. The tidal range at Kandla port is 5.88 m and the maximum current velocity is about 3.26 knot during spring tide¹. The maximum wave height near anchorage point, west of Kaladara shoal, is about 2 m with a wave period of about 4-7 sec. In the Hansthal creek the maximum current velocity during spring tide is 3.49 knot and the maximum wave height near Navlakhi is about 2 m. The sediment load in the waters between premonsoon and monsoon period² varies from 0.19-0.51 to 0.11-3.6 g.l⁻¹ and salinity from 33-40 to 19-35 × 10⁻³.

Geological formations ranging from middle Jurassic to Holocene over a crystalline basement are present in the area³. However, the most conspicuous sedimentary formations bordering the study area are predominantly marine, tidal or littoral and sublittoral, fluvial and aeolian deposits of Quaternary age. The sediments of the outer Gulf are generally composed of silt and shelly material and fine sand^{4,5}.

Materials and Methods

Surveys were carried out using an Atlas Deso-10 echosounder for bathymetry and ORE profiler for obtaining subbottom information. A side scan sonar system (EG & G) was deployed for obtaining plan view of the seafloor in some area. Motorola Mini-Ranger, MRS III, system was used for position fixing. The seabed samples were collected at locations selected after examination of underway data, using gravity corer (2 m length) and Petterson grab, to correlate with the seismic data. The echograms were also used for identifications of geomorphic features and nature of seafloor.

Results and Discussion

Topography of the entire Kandla creek is highly uneven to rugged (Fig. 2). The northern end of the creek shows 4 flat topped platforms which are 4 to 6 m high and vary in length from about 60 to 500 m. These platforms have scour channels at the base. The remaining creek is marked by presence of sandwaves of varying sizes which can be broadly classified into three zones viz. (i) in the north, the sand-

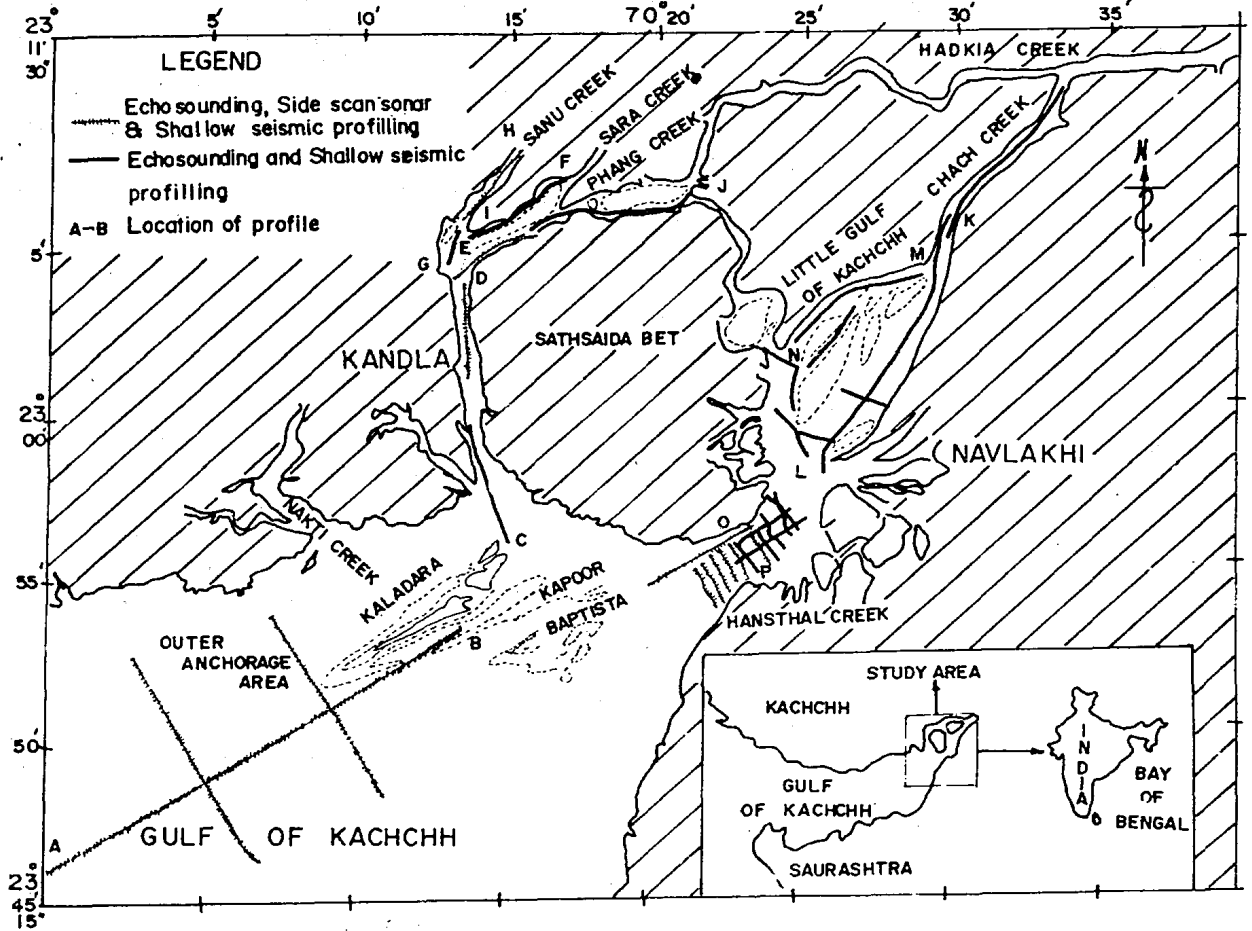


Fig. 1—Inner Gulf of Kachchh showing survey tracks (Inset shows the location of the study area)

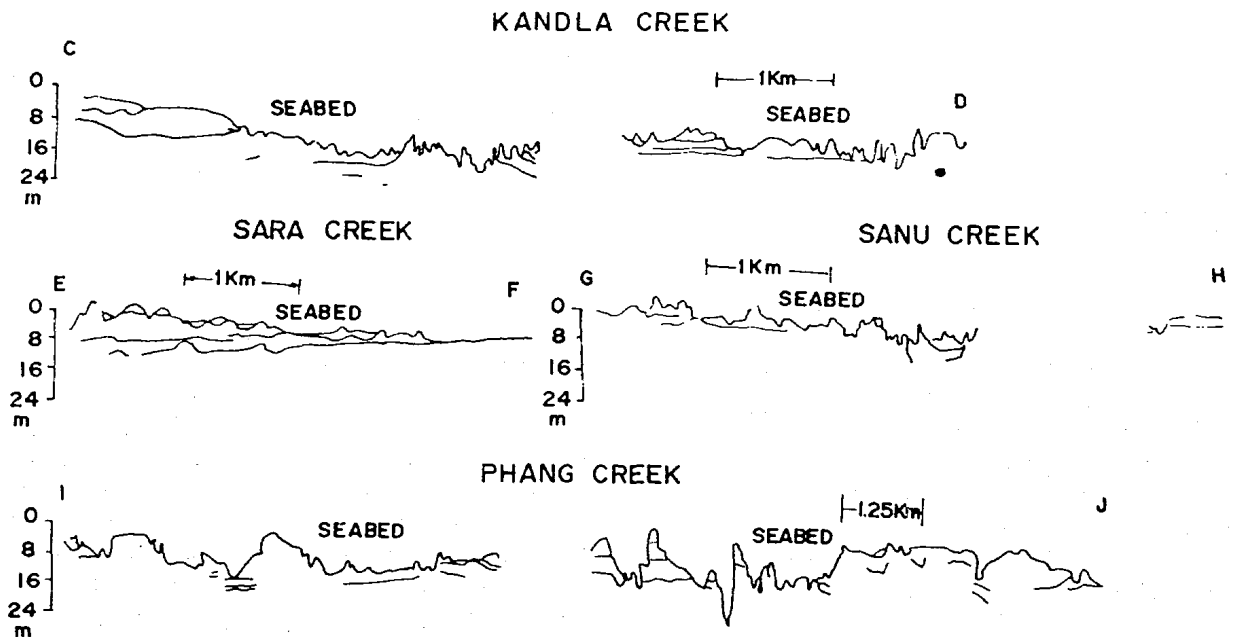


Fig. 2—Shallow seismic profiles from Kandla Sara, Sanu and Phang creeks (Locations of profiles shown in Fig. 1)

waves have an average 4 m height and 130 m wavelength; (ii) in central region, they are of greater magnitude with the average height of 5 m and wavelength 320 m; and (iii) in the south, off Cargo jetties, the sand waves have average height of 3 m and wavelength 50 m. The sand waves in the northern and central parts are highly asymmetric while in the southern region they are symmetric. It is interpreted that in the southern region quantum of sediment transport during the ebb and flood tide is same while in northern and central region more sediments are transported during ebb tide. The sonographs from the area do not indicate larger lateral extension of the sand waves. The presence of sand waves is but expected where coarse unconsolidated sediments are present in high energy environment and are indicative of sediment movement. The above observations are in agreement with Evans⁶ who has reported sand waves of 9 m height and 300 m wavelength from the Severn estuary having macro-tidal regime.

The shallow seismic data from the vicinity of the mid shoal show a maximum penetration of about 8 m. The lowermost reflector exposes out after about 3 km towards Kandla creek and represents sand. Further north, the seismic penetration shows 2-4 m thick sediments. The samples collected from the creek confirm that the seafloor is covered by coarse sand with shells, gravels and pieces of conglomerates. Further northwards the Kandla creek as well as Sanu, Sara and Phang creeks are extremely uneven and rugged. The abrupt truncations of layers (cuttings) of about 10-12 m deep are noticed in the Sara creek (Fig. 2). The Phang creek also shows presence of a scour channel having depth of about 26 m (Fig. 2).

Most of the Little Gulf of Kachchh is even and above the chart datum except the channels and cuttings which are down to 10 m deep. The area is marked by presence of number of islands of varying sizes (Fig. 1). The survey tracks across the axis of gulf show uneven topography and presence of V-shaped channels which extend through underlying layers (Fig. 3). The seismic data show 10 to 15 m thick acoustically transparent clays. The reflectors in the seismic profiles are horizontal but at places indicate variations in the sediment thickness due to removal of overburden by erosion thereby causing uneven topography. The acoustic basement, when discernible, shows erosional features.

The Hansthal creek shows steeply sloping flanks and rugged seafloor in the centre. Profiles across the creek show typically 3-4 reflectors on the flanks with the lower most reflector nearly at the same level as the creek base indicating that the layered se-

quence has been eroded away (Fig. 3). The uneven topography, therefore, appears to have been caused by currents scouring. The sonographs from the area indicate the presence of mobile sediments and current furrows. The isopach map⁷ clearly shows that down to 8 m thick clays (soft sediments) are present only on banks while the axial part of the creek is devoid of soft sediments and has rugged topography. Thus the creek acts as funnel to incoming and outgoing tidal flows which has led to scouring and transportation of sediments. The degree of scouring varies from place to place depending on the hydrographic regime. The results of surveys when compared with those of the past (30 years old²) indicate that the creek floor has achieved stability to some extent but the flanks are prone to continuing erosion.

In the outer anchorage area the seafloor is even and smooth in contrast to the creek systems. The area in general is sloping gently towards south. The shallow seismic profiles reveal number of closely spaced horizontal reflectors and penetration of about 16-18 m. The acoustic basement however, shows undulations of about 2-4 m.

From the above observations it is clear that the acoustic basement is overlain by parallel reflectors, the top of which forms the seafloor in most cases.

The acoustic basement (the lowermost reflector which is acoustically opaque to the seismic energy used) lies at about 8-10 m in the inner Gulf of Kachchh and at about 18 m in the outer anchorage area. This reflector is undulating and uneven. However, presence of major cuttings or channel similar to present day seafloor are not observed in the sub-surface.

Overlaying the acoustic basement are parallel reflectors. These are invariably even, smooth and horizontal. The spacing between these reflectors and characteristics, however, vary from the creeks to the outer anchorage.

In the creeks, number of these reflectors are generally limited to 2-3 which are spaced at about 4 m interval. Often these reflectors are seen abutting to channels or cuttings. In the outer anchorage area, on the other hand, there are number of reflectors, very closely spaced at the top giving appearance of alternate dark and light bands. However, the reflectors are less frequent just above the acoustic basement. The spacing of the reflectors can be co-related with the then prevailing climate. Climatic variations, to a large extent influence supply of material by affecting rates of erosion, transportation and deposition. The homogeneity of the deposited material does not vary if the prevalent climate does not change consequently, seismic records show absence of reflector.

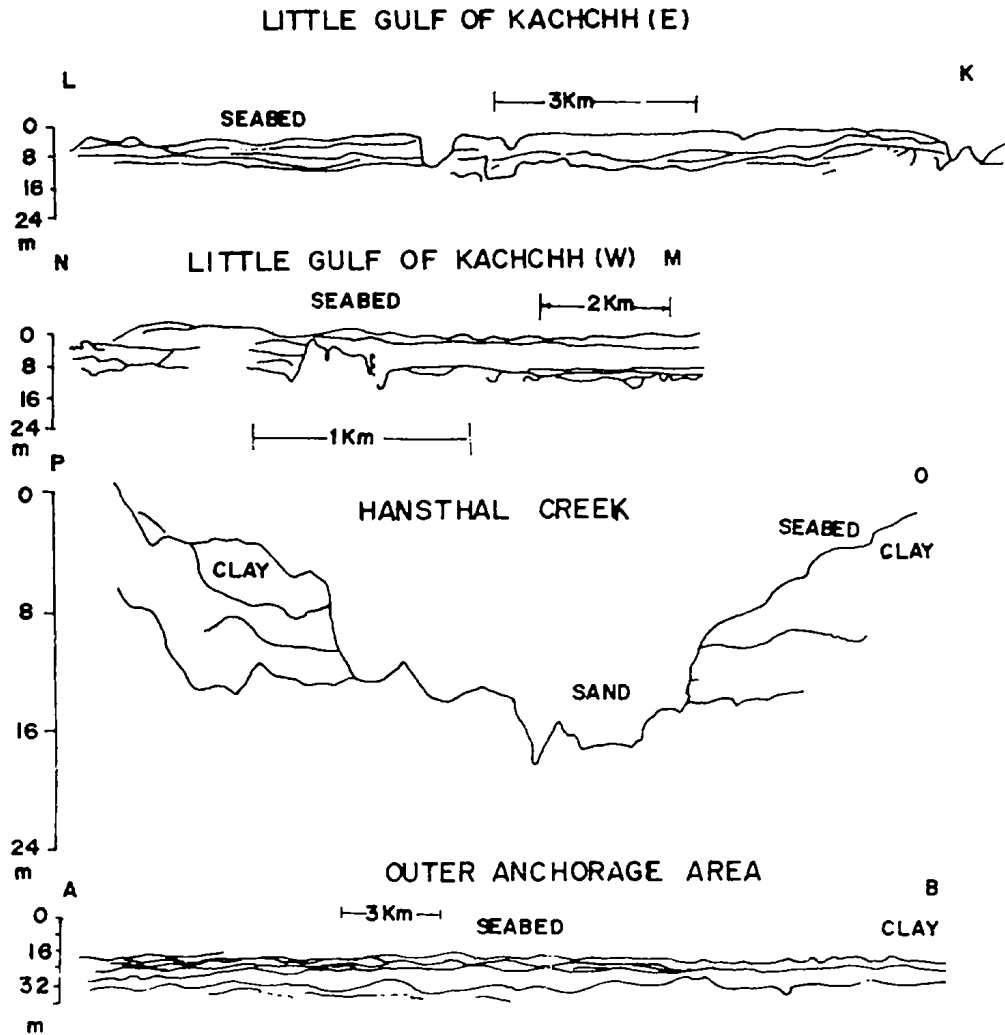


Fig. 3—Shallow seismic profiles from the Little Gulf of Kachchh, Hansthal creek and outer anchorage area (Locations of profiles shown in Fig. 1)

Based on the above shallow seismic studies from the area it can be inferred that the climatic fluctuations may be more when the top 3 m of clay/silty clay is deposited then prior to that. Further, the parallel reflectors in the creeks are even and horizontal which implies absence of any significant tectonic activity since deposition.

Presence of channels and cuttings on the seafloor and their conspicuous absence in the acoustic basement perhaps indicates major change in the prevailing hydrographic regime with time. It can be surmised that the necessary strong currents to cut a channel were not prevailing before the deposition of surficial clay and the tide and currents were not strong enough to leave their mark behind or the tectonic activities had changed the physiographic setting of the area. In other words, there is a distinct change in the hydrographic regime in the gulf of

Kachchh from low energy to that of high energy in recent past.

From the geological and geophysical investigations in the Gulf of Kachchh, two distinct regimes that of erosion and deposition can be identified. The creeks are experiencing erosion and the outer anchorage area is undergoing deposition. Based on these results it is concluded that in the Hansthal Creek, the channel has more or less achieved equilibrium and therefore can be maintained at present level with minimal dredging. The presence of varying kinds of sandwaves in the Kandla creek indicate high energy regime and detailed studies may be required to determine their dynamics.

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