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Sedimentation and sea level variations in Nizampatnam bay, east coast of India

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Nizampatnam bay is a shallow marine environment just south of the Krishna delta on the east coast of India. Holocene transgression and subsequent progradation of the Krishna delta played a major role in the evolution of the bay. Though there is wide range in the sediment types, the bay is predominantly occupied by sandy clays and sands. Coarse sandy sediments (Mz 0.96-1.4ϕ), which are better sorted and negatively skewed, are mostly confined to offshore bar. Poorly sorted and positively skewed sandy clays cover the central and some nearshore areas of the bay. Coarse sand in the offshore bar and geometry of the sand body indicate a rapid rise in the sea level and overstepping of the bar. ^{14}C dating gives an age of about 8000 y BP for the ancient strandline located at about 25 km from the present coastline. Following the sea level rise, the bar blocked off the sediments supplied by the river and led to the deposition of fine sediments throughout the bay. Widespread occurrence of sandy clay and poor sorting of the sediments give testimony to the low energy conditions in the bay caused by the offshore bar. Sand bodies in the coastal region particularly in the northwestern part of the bay are considered to be due to wave induced longshore drift of the sediments to the south. Continuous infilling of the bay is indicated by decrease in the depths during the last century.

Studies on Nizampatnam bay are scarce[1] compared to the adjacent Krishna river and its delta. As the bay has developed recently during the Holocene transgression, sedimentological studies on the bay throw light on the origin of the bay and its historical development. Further, the data may provide information on the sea level fluctuations and the associated sedimentation patten in the Bay. Keeping these in view an investigation on textural characteristics of the bay sediments has been undertaken.

The Nizampatnam bay is a marginal sea located in the western part of the Bay of Bengal just south of the mouth of the Krishna river (Fig.1). The southern distributary of the Krishna river joins the bay and forms the main source of sediment and fresh water. Besides the Krishna river, small rivers like Gundlakamma, Romperu and Upputeru join the bay at different places. The bay which covers an area of about 1825 km^2 is in general shallow with depths < 15 m. Depths of > 15 m are encountered seaward of the offshore bar. The bottom topography of the bay is rather smooths and gradually slopes towards the open sea. However, this trend is interrupted at about

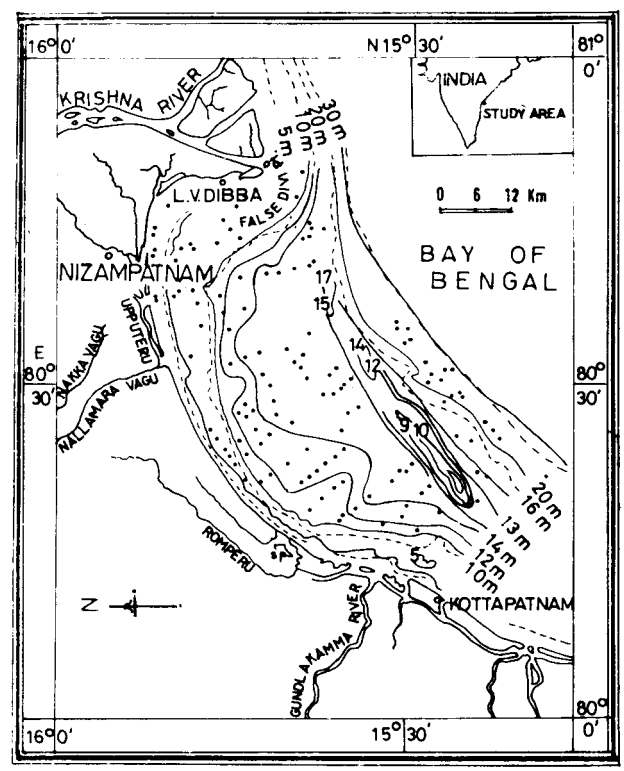

Fig. 1—Bathymetry and sampling location in the Nizampatnam Bay

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25 km from the coastline by an offshore bar, where depths of the order of 8 m occur. In the northern part of the bay, the bar is absent and the bay floor is steeper than in other parts. In contrast with the bay topography, the sea floor off the Krishna delta exhibits a steep slope with a fall of > 35 m within 14 km from the coast.

During most part of the year the wave directions in the bay are S and SW. Normal wave heights are moderate ranging from 0-1.75 m. In the monsoon season, the nearshore currents are directed towards north with an estimated speed of 1 km h^{-1}.

Materials and Methods

Bottom sediment samples (250) from the Nizampatnam bay were collected by Lafond-Dietz snapper and Peterson grab operated from a mechanical boat. The sampling was done along 26 profiles positioned perpendicular to the coastline. Bathymetry of the bay was measured using a single frequency high resolution echosounder (Raython, 3.5 kHz).

Sieve and pipette analyses were used to determine the sand, silt and clay percentages. In describing the sediment texture, the nomenclature of Shepard[2] was adopted. Representative portions of the sediment samples obtained by sample splitting were subjected to grain size analysis using $\frac{1}{2}\phi$ interval sieves. The statistical parameters such as mean grain size, standard deviation (sorting), skewness and kurtosis were computed[3].

Results

Sand, silt and clay percentages of the bay sediments are plotted in Fig.2. Distribution of different textural

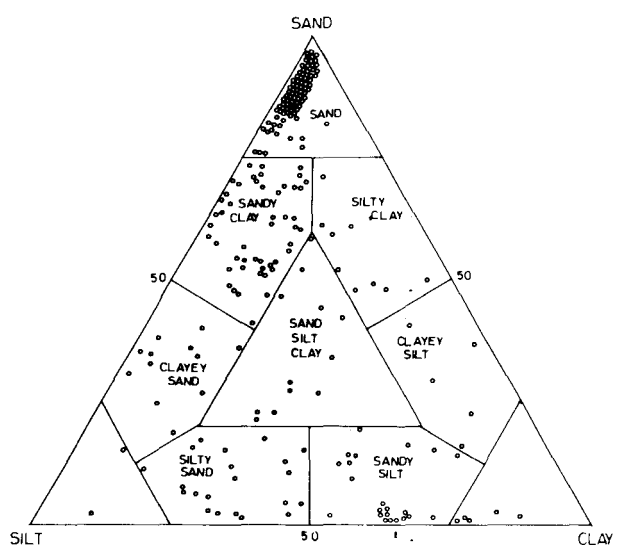

Fig. 2—Trilinear diagram showing sand-silt-clay percentages in the Nizampatnam Bay

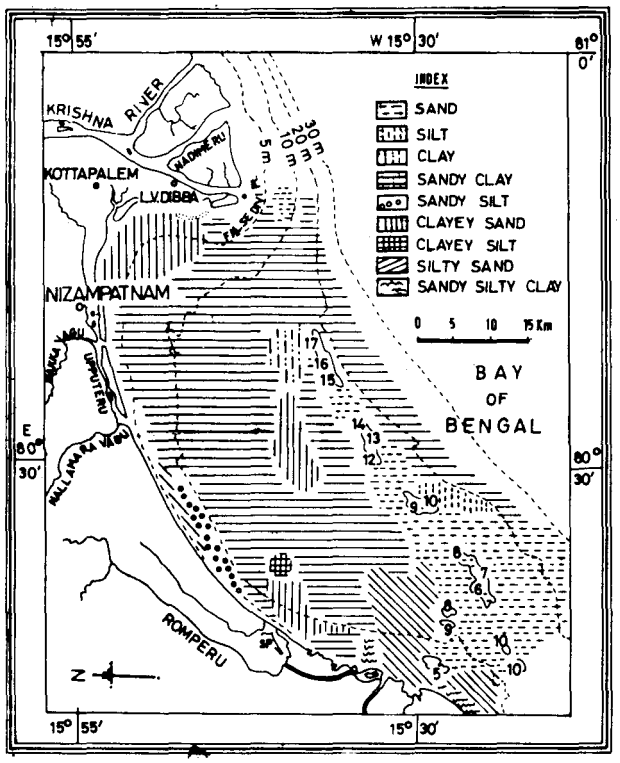

Fig. 3—Distribution patterns of different sediment types in the Nizampatnam Bay

types of bay sediments is shown in Fig.3. A major part of the bay is covered with sands and sandy clay. In the inshore region (< 5 m depth) sandy sediments are rather rare. Silty sand and clayey sand also occupy considerable area of the bay. There is no systematic variation of the different sediment textures either with depth or distance from the shore. However, statistical analysis of the data shows that a major part in shallow bay (< 5 m) is covered with clayey sand. Further, deeper areas (5 to 13 m) are occupied by sandy clay. The predominant sediment within the depth range of 13-17 m is the sand, which amounts to 23% of the bay area. Beyond 17 m, sandy clay again reappears as a dominant sediment type.

The Nizampatnam bay sediments exhibit a wide range in the phi mean grain size from 0.96 to 10 ϕ. Coarser sediments in the bay are confined to the offshore bar, where the phi mean size of the sediments vary from 0.96 to 1.4 ϕ. Further, some isolated patches in the inshore area (< 5 m) have sediments with phi mean size < 2 ϕ. A major part of the bay is covered with fine sediments having phi mean size values > 6 ϕ. The bay sediments are poorly sorted and positively skewed. The patchy inshore sands and the offshore bar sands are relatively better sorted than the fine sediments in the bay. These sands are nearly symmetrical to positively skewed (0.01 to −0.5) compared to the fine grained bay sediments of the bar,

which are more positively skewed (0.25-0.8). The kurtosis values of the bay sediments vary from 0.3 to 2.5. The offshore sands are platykurtic (0.3-1) whereas the silty sands and clayey sands bordering the bar are very leptokurtic (1.5-2.5). The inshore sediments are leptokurtic and mesokurtic in nature (1-1.25).

Discussion

Recent sediments on the continental shelf of the east coast of India, indicate temporary pauses in the general rise in the sea level since the late Pleistocene[4-6]. Besides the textural patterns of the shelf sediments, submerged features identified by irregularities in the shelf topography offer evidence of intermediate stillstand positions. The lenticular sand body located at about 25 km from the present coastline in the Nizampatnam Bay is interpreted as one such shoreline representing a stillstand position during the Holocene transgression. Such an inference is substantiated by the similarity in the textural characteristics of the bar and the present day beach ridges[7]. Curray[8] and Morton and Winker[9] state that the paleoshorelines, formed during brief lulls in the Holocene transgressions, can be delineated by abnormally high concentrations of coarse sediments. ^{14}C dating of mollusc shell from the bar gave the age of 8200 ± 120 y BP suggesting a Holocene strandline of -17 m. There appears to be a rapid rise in the sea level on the east coast around 8000 y BP, when the barrier island was drowned and the shore zone skipped landward. Though exact datings are lacking, occurrence of coarse sand in the innershelf of Visakhapatnam[10] and Bhimunipatnam-Kalingapatnam[11] on the east coast of India at about 20 m depth substantiates the above inference. In the Gulf of Mexico[12] and in the Long Island area of New York[13] stillstands at about -16 m with a corresponding age of around 8000 y BP were recorded. The rise in the sea level seems to be rapid and therefore the bar did not apparently migrate landward with the rising sea level. Rampino and Sanders[14] report overstepping of bars by rapid sea level rise at Long Island, New York, preserving their morphological characteristics. Fairbridge[15]. considers that Holocene transgression was episodic but not smooth asymptotic rise as suggested by Shepard[16].

The regional spread of the offshore coarse sand in the Nizampatnam Bay indicates a little reworking and transport of sand with the rising sea level landwards from the bar. But the later deposition of fine sediments from the Krishna river covered the sands in the northern parts, whereas the southern bay sands are still exposed almost up to the present coastline. Perhaps the rising sea level slowed the delivery of river sediments to the shelf by trapping a greater part in the bay. Moreover, the offshore bar provides shelter from the open sea waves and favours infilling of the bay. Such a sedimentation pattern is indicated by the occurrence of widespread sandy clay and the absence of significant sorting of the sediments in the bay. The continuous infilling of the bay and the slowly rising sea level aided by the shelter provided by the offshore bar make the Nizampatnam bay a shallow, low energy environment. Further the seaward progradation of the Krishna delta[17] (3.34 m y^{-1}) in the northern parts of the bay due to abundant sediment supply and deposition dampened the open sea processes to a great extent. Occurrence of fine sediments even in the coastal area substantiates such low energy conditions, which are incapable of reworking the sediments. Davis and Cliffton[18] record a reduction in the tidal prism of the coastal embayments due to their infilling by sediment and slowing of sea level. A further reduction in the energy conditions can be expected in the Nizampatnam bay as it fills with the sediment.

The small sandy sediment patch at False Divi Point is considered to have resulted from the wave induced longshore drift of the sediments to the south. Though the net transport of the sediments in the coastal region is towards north[19], the southerly currents produced by wave divergence[20] might move the sediments towards south developing the False Divi Point.

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