CHAPTER

XII

RESUME

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R E S U M E

(1) The Gulf of Khambhat though comprising a very small portion of the west coast provides a fantastic geoenvironmental diversity. This funnel shaped narrow sea inlet forms a Quaternary coast with very well defined geological and geomorphological features in its different onshore segments and is marked by equally complex offshore processes.

(2) It forms an area characterised by strong and powerful tidal action, marking a site where the tide-rise is the highest along the west coast. The high and low tides during different parts of the season in combination with the extensive addition of the detritus laden waters of the

rivers of Mainland Gujarat have generated a very complex pattern of erosion and deposition of sediments since the advent of the Quaternary period. The present thesis is an endeavour towards understanding the Gulf of Khambhat especially from the point of view of what is happening today and what happened in the immediate geological past, the approach being essentially that of a geologist.

(3) The Gulf of Khambhat very well reflects the control exercised by the numerous major and minor faults related to the Tertiary Cambay Basin. The major lineaments of the east and west basin bounding faults as well as a number of cross cutting faults have been found responsible for the existing configuration and geological and geomorphological evolution of the Gulf of Khambhat and the coastal areas facing the Gulf. The Gulf of Khambhat and its environs, comprise mostly post-Mesozoic depositional sequences dominantly marine. Resting unconformably over the basalts of the Deccan Trap, the Tertiary rocks constitute the Cambay Basin. A large part of the coast is exclusively made up of Quaternary deposits.

(4) The present day Gulf coastline mainly consists of Quaternary sediments, but the existing coastline configuration and coastal geology however have been controlled by the tectonic and depositional processes, marine as well as fluvial, that were initiated much earlier,

almost at the beginning of Cenozoic Era. The Tertiary geology has provided the basic framework which has been acted upon and influenced by the subsequent fluvial and coastal marine processes.

(5) The Gulf coastline can be broadly divided into three blocks namely (i) Saurashtra block (ii) Bhal block and (iii) Mainland block. These divisions are based mainly on geology, physiography and terrain characteristics. The three blocks have been further subdivided into numerous segments as under:

1. Saurashtra block
   a) Methla-Gopnath segment
   b) Gopnath-Ghogha-Bhavnagar segment
   c) Bhavnagar-Dholera segment
2. Bhal block
   Dholera-Khambhat segment
3. Mainland block
   a) Khambhat-Dahej segment
   b) Hansot-Hazira segment

(6) The various landforms comprise :(i) Recent mudflats, (ii) raised mudflats, (iii) salt waste dryland (iv) beaches, (v) wave cut platform (vi) rocky cliffs, (vii) Recent coastal dunes, (viii) older dunal ridges (ix) relict alluvial patches, (x) river mouth bars and offshore banks, (xi) islands and point bars, (xii) alluvial cliffs and (xiii) alluvial plains.

Rocky cliffs and wave cut platforms, are restricted to Saurashtra coast only whereas alluvial cliffs are the characteristic of the Mainland. Beach development is better seen on Saurashtra coast. The diversity of landforms along the coast provides good evidences of sea level changes and neotectonism.

(7) The Saurashtra coast shows a well developed Cenozoic sequence comprising of Deccan Trap and laterites overlain by Tertiary and Quaternary sediments. The Bhal block which comprises a depressed zone separating the Gujarat Mainland from Saurashtra, is made up of Quaternary sediments only, the major bulk of which is an older alluvium overlain by tidal mud deposits. The Mainland Gujarat coast, also shows only Quaternary deposits mainly a thick alluvium. Tertiaries have been reported only in the sub-surface.

(8) On account of the controls exercised by the factors of geology (structure and lithology), sea level changes, climatic variations (rainfall and wind) and strong tidal currents, which have acted in a variety of combinations, the different coastal segments exhibit a wide variety of erosional and depositional landforms. Whereas the coastal areas on the Saurashtra side consist of landform related to the Tertiary and Quaternary periods, those on the Mainland are exclusively within the Quaternary deposits.

(9) The rivers and streams that flow into the Gulf can broadly be classified into two main categories: (A) Rivers like Sabarmati, Mahi, Narmada and Tapi which originate far away from the Gulf, drain several hundred kilometers of geologically diverse terrains before meeting the Gulf, and (B) Relatively smaller rivers of Saurashtra like Shetrunji, Bhogavo and of Mainland like Dhadhar, Kim and Mindhola, which have near by preovenances and smaller catchment areas.

(10) All these rivers characteristically follow well defined tectonic lineaments, and except for the smaller rivers of Saurashtra, rest are all perennial and bring a lot of water and sediments. The mouths of various major rivers are replete with estuarine mudflats and mouth bars, and their funnel shaped morphology points to their evolution under a fluctuating strandline.

(11) Ponds, all along the Gulf coast constitute an important source of sweet water. Essentially comprising impounded bodies of rain water, the ponds not only provide water for domestic needs but also considerably influence the behaviour of shallow phreatic aquifers along the coast. Locations of ponds in the coastal areas have been controlled by factors of topography, nature of sediments and the rainfall. Broadly, the ponds fall into three categories. To one category belong most of the ponds of the Mainland coastal areas, which represents reservoirs of impounded rain water ,

built at suitable sites along paleo-channels. The second category is that of manually dug ponds along some relict channel features. The third category of ponds comprise man-made depressions manually dug for storing direct precipitation; no natural topographic advantage is availed of.

(12) A delicate balance exists between the unconfined sweet water and the underlying saline groundwater in the coastal areas, and in the various segments of the Gulf coast it is observed that the hydrogeological conditions from segment to segment vary, and in turn influence the availability of sweet water. Irrespective of the hydrogeological conditions prevailing in the different parts of Gujarat especially in the vicinity of the coastal areas of the Gulf of Khambhat the most relevant aspect of the groundwater studies of the Gulf coast is that which pertains to the nature of unconfined or phreatic groundwater occurrence, in the form of shallow dug wells.

(13) Groundwater circulating in different lithologies has developed chemical characters conformable to the constituent minerals. Contamination of fresh water by sea water too has added significantly to the dissolved constituents which is ultimately reflected in the chemical quality of the ground water.

(14) Tidal mudflats which constitute, by far the most extensive deposits of the Gulf appear to be the products

of strong tidal currents operating within the Gulf. It is found that the major bulk of tidal mud in all segments is made up of silt sized particles, their proportion varying from 60% to 75%. The sand fractions are always less than 6%, while clay fraction varies from 15% to 30%. The chemistry of the mud does not point to any marked and conspicuous trend or variation. Perhaps, this is expected in an environment where the tides are constantly churning up the suspended particles. It has been also deduced that provenances and source rocks, have been responsible for the chemical variations observed. The tendency of relative increase in SiO_2 and decrease in Al_2O_3 contents from south to north, can best be explained by taking into account the fluvial detritus brought by the various rivers up to the Gulf. From the data obtained it is observed that four major clay minerals, viz. montmorillonite, illite, chlorite and kaolinite are almost universally present, the first one however is most predominant almost 70% to 80%. In all areas, of the Gulf coast, except in the northernmost part the proportions of various clay minerals are more or less constant.

(15) So far as the beach deposits are concerned it is found that the Saurashtra beach has a different mode of origin from that of Mainland coast. On Saurashtra side the carbonate sands of Gopnath, Methla beach comprise calcarenite transported by long shore drift, generated by wave action and tidal currents. The beach to the north of Shetrunji, however is made up of very coarse sand, and

shingles, revealing the phenomenon of accumulation of land derived particles, the finer sediments having been washed away to the deeper parts. The beach deposits of the Mainland reveal the accumulation of sands in those areas which are under the influence of waves generated by southwesterly winds. The author has observed that the sizable proportion of the present day beach sand is derived from the erosion and reworking of the ancient dunal material.

(16) Studies on suspended sediments from representative locations have furnished information on the aspects of (i) concentration of suspended sediment load, (ii) grain size variations and (iii) mineralogical characterisics.

(17) The gulf offshore alongwith its deposits like mudbanks, shoals and under water ridges reveal a high tide domination, strong tidal currents, low wave energy together with other variables like coastal physiography, tidal prisms, fluvial sediment influx and riverine input. The Gulf of Khambhat perhaps comprises one of the very few coastal areas in the world where tide rises as high as twelve meters (12m). Apart from the phenomenon of the rise and fall of water level, the tide generates very strong tidal currents. These currents during the flood and ebb tides have been responsible for most of the depositional and erosional features in the Gulf.

(18) The tidal current directions as observed on satellite imagery establish following facts:

i) The current directions during flood and ebb tides have almost identical paths.

ii) The tidal currents bothways follow the bathymetric features of the Gulf.

iii) The fanning pattern outside the mouth of the Gulf is closely related to the presence of numerous underwater rythmic linear ridges which regulate the entry and exit of the tidal waters.

iv) The uneveness of the inner Gulf bottom characterised by numerous mudbanks and shoals, and the obstruction caused by the Piram Island are also the factors that govern the movement of tidal waters.

v) During flood tide conditions the inner part of the Gulf becomes heavily charged with suspended sediments . This is on account of the churning up of the bottom sediments as well as those of the tidal flats, mudbanks and shoals.

vi) The sediment laden tidal waters on reaching the inner parts of the Gulf tend to spread and inundate all lowlying (inter-tidal) areas and river mouths. On account of the spreading out accompanied by stagnation, the waters leave behind a part of their load while receding.

(vii) The pattern of concentration is also indicative of the trends of tidal currents and bathymetry.

viii) The sediments are carried by tidal currents, such that the influx is both from the south Saurashtra coast as well as from the south Gujarat Mainland coast.

ix) During receeding tide there is an overall decrease in the sediment content. At the peak high tide the stagnation of water would cause settling of the suspended sediments especially the sand and silt size particles.

x) Heavier concentration during ebb tide is restricted to the inner tidal muddy areas only. The median portion of the Gulf shows only moderate to slight concentrations, except where the tidal water flow over the submerged ridges.

xi) Following approximate figures indicate the sediment load concentrations:

Slight	= upto 100 gm/100 liters
Moderate	= 100-250 gm/100 liters
Heavy	= 250 and above gm/100 liters

xii) The nature and amount of suspended load appears to be controlled mainly by the river discharge from the Mainland coastal areas, which in turn, might depend on the season's rainfall.

(19) The Gulf by and large comprises an area of low wave energy. Unlike the other coastal areas of Saurashtra and of South Gujarat which experience strong southwesterly winds, the Gulf is protected by the Saurashtra landmass.

(20) The topography of the Gulf bottom comprises a large number of shoals, underwater ridges and deep channels. The floor of the Gulf as well as some of the ridges are seen to rise above the low water line. The tectonic and sedimentation factors have played dominant roles in imparting diversity to the gulf bathymetry. The features of Gulf bottom are essentially the product of (a) Graben faulting related to the tectonics of the Cambay Basin and (b) accumulation and distributed deposition of sediment load by tidal currents.

(21) The development of extensive underwater linear sandy ridges of the order of 30 to 80 km long, outside the mouth of the Gulf is typically illustrative of the phenomenon of transport and deposition by tidal currents. Though the tidal current ridges occurring at the head of the Gulf of Khambhat, themselves originated by the process of transport and deposition related to the tidal currents, today they are now performing an equally important role in controlling the tidal current directions and the pattern of sediment transport and deposition.