PART-IV

CONCLUSIONS

CHAPTER

XI

MAIN OBSERVATIONS AND FINDINGS

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GENERAL

The turbulence of the waters of Gulf of Khambhat have fascinated and intrigued everyone. Strong tides, sediment laden currents and their interaction with the coastline, have been matters of observations, not fully understood in terms of their causes and effects. The present study, though quite preliminary in many ways, has thrown much light on the various geo-environmental processes that have controlled the evolution of the Gulf coast, Gulf bathymetry and the marine processes

operating within the Gulf. No doubt, a lot of gaps in the knowledge still remain, yet through the present study, the author has been able to identify and describe the factors and parameters controlling the Gulf processes. What stands out so glaringly is that this relatively small portion of the West Coast of India, is unique in many ways. Its coastal areas are made up of geologically diverse rocks and show a varied landscape. The geomorphic features of the coast typically reveal various combinations of geological factors like lithology, structure, and sea-level changes due to neotectonism and glacio-eustasy. These factors have not only controlled the Gulf configuration and bathymetry, but are responsible for the generation, and controlling the behaviour, of offshore processes like tides, tidal currents and wave action. It has also been observed that the factors of climate and fluvial regimes have played effective roles in the past and are playing today also. From the present study, an important fact that has emerged is that all the environmental parameters of the Gulf, are essentially the different manifestations of the geological factors. The author, at this stage of summarising, is in a position to highlight the role played by the factors of geology, manifesting in many forms and processes. The information and data provided, and the various observations and inferences arrived at by the present author, in the various chapters of this thesis

when synthesized together, amply confirm the above statement.

The factors which need to be highlighted are those pertaining to (1) Tectonic framework vis-a-vis Gulf configuration and geological evolution, (2) eustatic sea-level changes, (3) Gulf bathymetry, (4) action of tides and tidal currents, (5) impact of Mainland rivers, and (6) role of climatic factors.

ROLE OF TECTONISM AND EUSTASY

The present study illustrates a strong geological control on evolution of the Gulf and points to a sequence of geological events initiated with the advent of the Cenozoic Era. The development and configuration of the Gulf is obviously related to the Cambay Basin a tectonic basin, formed with the close of the Cretaceous period. The various basin-bounding faults as well as those transverse faults which have delineated the different blocks of the basin; controlled the shape size and depth of the Gulf. Obviously, the Gulf today represents remnant of a much larger depositional basin that came into existence at the begining of the Cenozoic Era. The geological characteristics of the various coastal segments show different depositional histories, each segment representing its own sequence, the most important

factor responsible for this diversity being the various faults which criss-cross the Gulf region. The striking difference between the geology and stratigraphy of the coasts of the Saurashtra and the Mainland, is attributable to differential uplifts and subsidences along these faults. This geological diversity is in turn, reflected in the coastal landscape. The rocky coast of S. Saurashtra, extensive mudflats of Dholera, Khambhat and drowned alluvial coast of Mainland, point to the control exercised by tectonism on landscape. The drainage of the coastal areas, especially the large and medium-sized rivers is, also governed by the structural features.

Another dimension to this aspect of Gulf evolution, has been added by the eustatic sea-level changes. Previous studies (already quoted earlier) have invoked a fluctuating strandline during Late Quaternary and, according to Merh (1980), the Gujarat coastline points to a sequence of following sea levels:

Phase	Height	Period
1. Transgression	+ 40 m	? Tyrrehenian
2. Regression	- 20 m	? Würm
3. Transgression	+ 80 to 100m	Flandrian
4. Regression	0	Present day

Merh (1980) has further suggested that the present heights of the past sea levels, indicate a combination of vertical tectonism, glacio-eustasy and isostasy.

The Gulf of Khambhat has preserved indications of last three events only. The submerged miliolite dunes of Methla-Gopnath segment, extension of the Gujarat alluvium within the Gulf are reasonably good evidences to point to a low strandline. The major contribution towards the evolution of coastal as well offshore features, is however related to the last two events, viz- the Flandrian transgression (about 10,000 BP) and the subsequent regression to the present level. It was during the last transgression that the major portion of saline tracts of Bhal and raised mudflats which are now several meters above the H.W.L., came into existence. The present author is also inclined to attribute to this factor, to some extent, the extensive mudbanks and shoals, which now comprise offshore reminants of more extensive tidal mud accumulations of the past, now exposed due to a fall of sea level. The present day mud thus could be the part and parcel of the vast accumulation of five detritus in a gulf or a bay of Flandrian sea, which over-ran the then existing alluvial topography. During this last transgression which drowned vast areas, the Gulf was connected through a shallow bay to the Gulf of Kutch and joined to the Little and Great Ranns of Kutch. The

subsequent shrinking of strandline to its present level, is evidenced by numerous features all over the Gulf coast.

The combination of lithology, tectonism and sea-level fluctuations is the primary factor that has controlled the landscape diversity of the Gulf coast. The coastal cliffs, beaches and mudflats, estuarine river mouths, offshore banks and shoals, all these geomorphic facets of the Gulf, reflect the diverse response of the different coastal segments to the tide-dominated marine processes operating within and around the shallow Gulf. In fact, the wide variety of erosional and depositional landforms associated with the Gulf, typically point to the effective role played by sea-level changes over a geologically diverse terrain, which in turn, was affected by differential movements along planes of structural weaknesses, not only during the whole of Tertiary period, but during the Quaternary as well.

TIDES, TIDAL CURRENTS AND BATHYMETRY

These three offshore environmental parameters are inter-related, mutually dependent, and if the author is allowed to use the word, show a sort of "symbiotic" relationship with one another. As already alluded to earlier, the Gulf experiences very high tidal range, of the order of a maximum of 12 m. The generation of such

high tides, is partly due to the narrow configuration of the Gulf, its shallowness and its location in the widest portion of the West Coast continental shelf. The differential movement of the tidal waters has given rise to high velocity tidal currents with well defined movement paths. The original unevenness of the Gulf bottom, possibly the submerged topographic features (tectonic as well as erosional), must be the other factor responsible for the tidal currents. Interestingly, the tide-generated channels and sub-surface linear-ridges, are now themselves providing paths and controlling velocities of the tidal currents. This phenomenon of tidal action, outside the mouth of the Gulf is reflected in the development of rhythemic linear tidal current ridges of considerable extension. Inside the Gulf, the tidal currents experience resistence from the shoreline and the influx of river water from the Mainland, interferes with the tidal currents, and creates conditions for extensive spreading and stagnation of sediment-laden tidal waters. This fact is illustrated in the development of vast tidal flats and mudbanks of more or less uniform in nature and content all over the inner Gulf.

One very significant fact that has emerged from the study is that the muddiness of the tidal waters of the Gulf is mainly due to churning up of the Gulf sediments,

which represent accumulations of the sediments mainly brought by the rivers during the Late Quaternary. The author has observed that the incoming tidal currents do not bring with them much sediments from the open sea; also the receeding tidal waters take back only a small bulk of sediment load. The addition and removal of sediments are no doubt there, but they are not very significant. On the other hand, there is a progressive filling up of the Gulf, and even in the historical times in the course of last few hundred years, the various sea-ports in the Gulf like Bhavnagar, Dholera, Khambhat and Bharuch etc. have been rendered unfit for navigation on account of heavy siltation. To keep some of the existing Gulf ports in use, constant dredging has to be carried out.

The most effective action of tidal current in combination with the inflowing river water, is that of constant redistribution of fine silts and clays, the net result being an overall uniformity in the nature and mineralogy of Gulf sediments, of tidal flat accumulations in different parts. Even the sediments carried by tidal waters in suspension are not much different. This is not unexpected because the tidal currents do not add much, but mainly lift up the pre-existing material from the gulf bottom ridges, mudbanks and tidalflats during high tide, churn and mix them up by eddy currents and leave them behind while receeding. This fact has been adequately

established by satelite imagery studies as well as the analyses of the onshore and offshore sediments. The grain size studies as well as the bulk mineralogy and geochemistry of sediments points to an overall uniformity.

X-ray studies have thrown some light on the clay mineralogy of the Gulf sediments. The clay minerals recorded are montmorillonite (smectite), illite, chlorite and kaolinite; of these the montmorillonite predominates. These clays appear to be land-derived through rivers. In order to establish th.s fact, the present author analysed undoubted fluvial clay samples from Sabarmati and Mahi and found them to be dominantly montmorillonite. Sabarmati sample was found somewhat richer in illite, because of its derivation from the N. Gujarat Precambrians. The Narmada and Tapi have also been reported to carry mainly montmorillonite (Naidu et al. 1985). Patel, K. (1985) ~~who~~ has hinted at the presence of some marine-derived clay minerals. He has however not given quantitative or semi-quantitative data and evidences to support his statement in the absence of which the present author is not in a position to comment on Patel's findings. On the basis of his own observations, the present author would prefer to keep his options open.

The Gulf environment is not controlled by strong tidal action alone. The role played by major inflowing

he has generated considerable data on the Gulf, which will be useful to future workers. It is hoped that future workers will take up from where the author is stopping, and in coming years generate more information.