CHAPTER - X

G E O L O G I C A N D G E O M o R P H I C E V O L U T I O N

REGIONAL PICTURE

The study area that falls within the westernmost part of the Narmada tectonic belt where the Cambay basin is superimposed over it, reveals a complex and protracted geological evolution, involving complicated tectonics.

The Indian platform essentially consists of very ancient crystallines and metamorphics. The uneven surface of which has been found to be dissected by basement faults that have controlled the positive and negative structures

of various ages. This crustal tectonic caused periodic subsidences followed by marine transgressions and regressions associated with uplifts. It was in such a tectonic setup that in the negative areas marine and continental sediments were deposited during Upper Proterozoic (Vindhyans etc.) and Paleozoic (Gondwanas). A period of uplift followed the Vindhyan sedimentation causing a long break in deposition. The origin of the Indian peninsular configuration is related to the breaking up of the Gondwana land. During this major tectonic upheaval a system of faults had developed giving rise to several narrow grabens. Of these graben structures in the central and southern parts of the Indian Shield, the Narmada graben was the largest. The complex fault system of the Narmada graben had divided the Indian peninsula into two parts which could be termed as subplates, namely the northern and the southern by their latitudinal orientation. The grabens of the southern block namely Godavari and Mahanadi were limited to the north by this fault system. The Narmada graben extending right across the Indian Shield had a complex structural history. It experienced differential subsidence during different geological periods.

The latitudinal Narmada rift basin possibly came into being as a result of tensional basement faults that had resulted by the counterclockwise rotation of the Indian plate in mid-Jurasic. The Late Mesozoic sediments that were deposited in the basin had been covered up by Deccan Trap

basalts during Late Cretaceous to Early Paleocene. The lava flows had occurred along a large number of fissures and vents which were related to tensional deep seated faults trending parallel to the Narmada rift basin thereby indicating the rejuvenation of the pull-apart tectonic activity. The Deccan Trap basalt flowed over a vast area of the Indian peninsula, and in the western part covered up the area of the Cambay basin, Saurashtra and parts of Kutch. In the study area as well, the Deccan Trap lies under the Tertiaries and the Quaternaries, and are exposed to the east.

Another cycle of tectonic activity is envisaged during Paleocene soon after the outpouring of Deccan Trap basalts in the western part of the Indian peninsula in a N-S trend forming the Cambay rift basin extending in the Arabian Sea to the south. This rifting was superimposed over the Narmada rift basin in its westernmost part, and the study area lies in that part of cross-trend. The down-faulted N-S trending linear depressions with parallel horst blocks became the locale of early Tertiary sedimentation. In the depressions, essentially the derivatives from the erosion of basalts were deposited under continental environment. Gradually the lows were levelled up and there after some of the horst blocks were also covered up by these trap wash material.

There are indications of folding, faulting and uplift of the trap-wash sequence followed by partial erosion. The

Lower and Middle Eocene marine transgression in the Cambay basin was a major event depositing a thick sequence of marine black shales which were the main source rocks for the generation of hydrocarbons in the Cambay basin. The basin margin drainage became prominent specially from the east and the northeast, and brought in arenaceous sediments during regressions. The Miocene and Pliocene fill of the basin in the northern part was essentially of sands and minor clays. In the south Cambay basin estuarine to marine environment prevailed accumulating argillaceous sediments, and further south in the Bombay offshore area the Miocene is represented by calcareous facies. The Quaternaries are represented by a mix of gravels, sands and clays in the northern part of the basin whereas in the offshore area marine sedimentation is still continuing.

GEOLOGICAL EVOLUTION OF THE STUDY AREA

Since the study area lies within the westernmost part of the Narmada rift basin at its crossing point with the Cambay basin, the evolutionary stages of both these basins are of direct relevance to the basin evolution, sedimentation and tectonic processes that influenced the geological history of the study area during the Tertiary and Quaternary periods. Although the exposed sedimentary sequences in the study area are only of Tertiary and Quaternary ages overlying the Deccan Trap basalts, a perusal of the occurrences of

Cretaceous inliers to the east in the Narmada valley area, Himatnagar sandstones and Cretaceous of Saurashtra, and from the Deep Seismic Sounding investigations, occurrence of older Mesozoic sediments below the Deccan Traps in the study area cannot be ruled out. It will, therefore, be appropriate to highlight the geological evolutionary history of the area right from period of the formation of the Cretaceous basin.

The mode of occurrence of the Cretaceous sediments in the Narmada valley clearly suggests that they were deposited in a rifted basin. The width of the basin ranges between 100 to 150 km and there had been a number of parallel to subparallel fault blocks within the rift basin bounded by normal tensional faults forming lows and highs. The marine trangression from the west and subsequent gradual regression deposited the Cretaceous sequence in the basin. The rifting along Narmada had occurred in Late Cretaceous during the northward migration of the Indian plate after its break-up from the Gondwana land in Late Triassic or early Jurassic, and that the basin had opened up as a result of the counter-clockwise drift of the Indian craton.

It is quite likely that the Narmada rift basin extends further the southwest at least as far as the continental shelf in the Cambay offshore area in Arabian Sea. After the Cretaceous sedimentation in the Narmada rift basin through

marine transgressions and regressions depositing limestone, shales and sandstones, the basin was once again subjected to tensional tectonic activity along the pre-existing E-W trending basement faults and perhaps other sets of faults as well through which the lava flowed out and covered up a vast area of the Indian Shield. The Dedan ($21^{\circ}3'$: $70^{\circ}16'$) cluster of dykes and other dykes in Gujarat are sub-parallel to the Satpura trend which is nearly ENE-WSW (Auden,1949). The alignments of the acid volcanics in Saurashtra and Gujarat is also subparallel to the Satpura trend and indicate a late Mesozoic to Paleocene event of major tectonic importance in the western India (Auden,1949).

The trap-wash sediments deposited in the downfaulted blocks of the study area were subjected to folding and faulting followed by partial erosion during Early Eocene. This tectonic event could be correlated with the first collision of the Indian plate against the Asian plate resulting into the push of the fault blocks generating differential vertical fault block movement folding, faulting and the upliftment of various rock sequences (Agarwal,1984).

During this, the down-to-basin normal faults, bounding the fault blocks, were reactivated as reverse faults. The Tertiary sedimentation which was continuing in the northern and the southern parts of the study area was resumed by an extensive Middle Eocene marine transgression, and continued

till Late Tertiary. It is presumed that during the final welding of the Indian plate with the Asian plate and a near halt of the Indian plate in Late Cenozoic, the Narmada tectonic belt, including the study area, again experienced a tectonic activity due to the push of the southern Indian subplate against the northern subplate, resulting in the deformation of the varied rock sequences of the study area and adjoining it. As a result of this the Tertiaries of the study area have been folded into narrow anticlinal folds and latitudinal faults trending ENE-WSW to NE-SW (Agarwal,1984). The faults are of reverse type and occur along the SE limb of the anticlines. North of the Ankleshwar anticline, in the area of Narmada river and beyond, the Tertiary sedimentation had continued followed by Quaternary deposits but in the study area erosion of the uplifted Tertiaries was taking place. Over the Ankleshwar anticline the present thickness of the remaining Tertiary sequence is around 1.5 km whereas the total thickness of the Tertiary and Quaternary in the area north of Narmada river in Broach depression is over 5 km. This clearly suggests that while the uplift and erosion of the Ankleshwar high and other parts of the study area was taking place, the block north of it i.e. Broach depression was sinking (under buckling) thereby continuing to receive sediments throughout the Cenozoic period.

GEOMORPHOLOGICAL EVOLUTION OF THE STUDY AREA

From the various geomorphological features and evidences of neotectonic activity in the study area involving the Tertiary and Quaternary rocks and the adjoining Deccan Traps, the occurrence of Late Cenozoic tectonic activity is well marked. A number of subtle geomorphic highs and lows in the partially exposed Tertiaries and occasionally involving thin cover of Quaternaries in the study area, have been delineated. These features invariably trend NE-SW to ENE-WSW, the structural grain of the area. The deformation of the sediments was related to the continuing Late Cenozoic tectonic activity in the area. Some of the structural features like Ankleshwar and Kosamba anticlines in the western part of the area had been eroded to such an extent that the area over these structures appears as if it has been nearly peneplained and presently represent subtle topographic highs as observed on aerial photographs, Landsat Image and ground elevations from topographical maps. The reverse faults also trending parallel to the longer axes of these anticlines along their SE limbs, are represented on seismic two-way time sections extending almost up to the surface (Fig.IX.2). Presence of several other structural features in the area with geomorphic expressions have been outlined and discussed in the preceding Chapters. The subtle nature of all these structural features and their relationship with the surface drainage, point to their Quaternary age. The NE-SW trending linear doubly

plunging Dinod and Dungri anticlines with characteristic expressions on aerial photographs and on ground are other geomorphic features evolved during Quaternary times as a result of the continuing Late Cenozoic tectonic activity.

The drainage pattern of the area ideally reveals its adoption to the change in the topographic expressions related to the late uplift of the Tertiary and Quaternary sequences. The study of the present day drainage pattern has in turn demonstrated the evolution of various geomorphic features and slopes. The drainage divide of the tributaries of the Narmada and Kim rivers in the study area represent a rising geomorphic high constituting the Kosamba , Dinod and Dungri subtle highs. Convincing evidences have been found which point to the northward migration of the Narmada river to the north as a result of the continuing uplift of the area to its south represented by the Ankleshwar and Jhagadia high trend. The evidences of this geomorphic evolution remain preserved in the form of the Narmada river paleo-bank observed prominently on aerial photographs, Landsat Image and on ground in the form of raised abandoned cliffs. Additional evidences are found from the trend of the Aliabet Island and the way in which the Narmada river flows round it through two channels, and the gradual shift of flow along the northern channel as described in detail in the preceding chapters.