CHAPTER VII

AN EVOLUTIONARY MODEL OF THE BASIN

The study area is situated in the northern part of the Cambay basin, which is essentially a Tertiary basin. The basinal area before it started receiving sediments experienced tectonic movements in several orogenic cycles the oldest recroded being the Aravalli orogeny. The very proximity of Aravalli granites to the eastern part of the basin denotes the influence of its orogeny on the basin. Gravity data provides more clarity on this aspect. Both in the Bouger gravity map which gives a regional picture and in the residual gravity map which gives more a local tectonic picture, the gravity trends are very obvious and indicate the extension of the Aravalli orogenic features upto western side of the Cambay basin and into the Rann of Kutch and Saurashtra

Peninsula. The Satpura orogeny which is the cause of Narmada geofracture in the southern part of the basin has not affected this part of the basin at all. Throughout the Paleozoic era, the area was a landform with its topography largely influenced by the Aravalli orogeny. It is suggested here that even the paleodrainage direction in the era remained the same as it is today, namely the direction of the flow of Banas and Saraswati rivers. The paleocurrent direction of the Dhrangadhra sandstone of Mesozoic age clearly show that the sediments of these sandstones have come from the Aravalli orogenic mountains. The boundaries of the Cambay basin did not exist at that time and as such the possibility of the sandstones of Mesozoic age occuring along the prersent Cambay basin is very remote. However, in the study area, as the rocks of Mesozoic age are exposed, along both the margins of the basin and as the paleodirection for the transport of the sediments is from northeast to southwest, the presence of similar sandstones in the study area is expected. How far south in the study area and further south in the adjacent area do these rocks extend - the data do not permit a proper interpretation.

While the Mesozoic sediments were getting deposited in the northern part of the basin, the breakup of Gondawana land which probably started in Triassic, was continuing and the Indian plate was moving towards north with an anticlock-wise movement. In the course of this drift, the west coast faulting took place initiating the process of Cambay basin formation. With the help of deep sounding seismic and the Bouger gravity data, it is inferred that the Moho far in the southern part of the basin is shallow and basaltic layer (Sima) is at 6 km depth only.' Being at a shallow depth and in a molten state, the magnetic eruption took place from the weak zones along the west coast fracture north of Bombay upto Surat. No other zones of crustal weakness causing an eruption of this volcanic flow are known from data. The Cambay Tertiary basin is formed largely due to the activation of this weak zone of the earth's crust near Surat along the west coast of India due to which the eastern margin of the Cambay basin is faulted and the basin is formed. The formation of the basin due to the eastern marginal fault is very well indicated by the thick Paleocene deposition along the eastern margin and a general tilt in the basin floor from west to east. The structure contour map on the top of Deccan Trap and the map of the fault patterns in the study area (figs. IV 1 and 9) be referred. Along with the marginal faults, which caused the basin, the other prominent structural features that controlled the sedimentation and the stratigraphic spread are the Mehsana horst with its flank faults, the resultant Mehsana and Patan depressions on the east and the west Mehsana depression on the west. The few prominent anticlines are the result of the faults at Trap only. The subsequent faults in the Paleogene sedimentary section, even if 2000 m thick, are influenced by these faults in the Trap. It is not unlikely that these Trap faults got reactivated at the end of the Paleogene period due to which several parallel faults have affected the sedimentary section. After the initiation of the basin, drainage into the basin was limited and the Olpad formation was deposited in a few parts. The drainage probably covered limited areas but with a heavy load carrying capacity and the transportation of the sediments was for short distances only; one can visualise torrential streams flowing across mountain scarps into lakes formed out of this drainage and depositing coarse unsorted sediment. The broken basaltic fragments have also not been transported for any long distance or otherwise they would have been easily denuded and rounded. From the knowledge of the tectonics of the basin at Deccan Trap level, it can be inferred that such deposition of coarse clastics would have taken place along the margins of the basin and along the flanks of the Mehsana horst. The limited number of wells that penetrated this formation gives the same indication. As Olpad formation was getting deposited in some parts of the basin (study area) other parts remained as positive areas exposed to weathering.

The marine transgression into the basin took place in Paleocene time from the southern direction. The direction is clear from the isopach of the Cambay shale (fig V. 3) which shows increasing thickness of the shale from north to south and from east and west to the middle. The deepest part of the basin in the study area was to the south of Mehsana near Sobhasan extending parallel to the basin and this is also indicated by the faunal studies (fig. V. 8). During the deposition of Cambay shale formation, the Mehsana horst remained as a positive tectonic feature, receiving only a limited deposition of the fine clastics. The very occurrence of such fine clastics over a large area of the basin indicates that the terrain drained for the deposition of these fine clastics is mainly the Deccan Trap and the slope of the drainage is very gentle, carrying the sediments in suspension. The author considers that during the deposition of this formation, the drainage was also from the western margin and the large Trap terrain beyond the western margin, namely Saurashtra craton. During the deposition of the formation, a few breaks in sedimentation are noted particularly to the south of the study area. The top of the formation is a clear unconformity in the western margin of the basin to the south of the study area as seen on the seismic sections but such a clear break is not seen in the seismic sections of the study area.

The sedimentation of Kadi formation commenced with fine clastics by a minor transgression resulting in a thin shale (Viraj shale) of about 30 m. Due to the movements of the Saurashtra craton and the adjacent area connected with the northward migration of the Indian plate, the drainage into the basin from the north western margin of the basin increased, carrying coarse clastics. The isopach map of the Kadi formation with a maximum thickness of 900 m just adjacent to the Mehsana horst and a rapid decrease of thickness to the northeast indicate that the direction of the transport of the clastics for the formation is from north northwest and the basinal sink during this short period is just to east of the Mehsana horst. A study of the sand isolith map of Kadi formation and its two components (Mehsana and Mandhali members) shows a linear trend of thick sand bodies along the eastern flank of Mehsana horst as in Mandhali member. These features are either due to beach and barrier bar complex or due to the stream mouth bar and distributary channel complex. It is unlikely that during the period of deposition of Mandhali member, the Mehsana horst which was exposed could have been the locale of tidal channels from the west and only the barrier bars could have been formed along the flank of Mehsana horst, parallel to the coast line. What is likely is that the drainage system from north northwest skirted the Mehsana horst and the major part flowed on the eastern flank of the horst and this has caused distributary channel and stream mouth bars in Jotana area, in Sobhasan area and tidal mud flats and swamp in between these areas and to the northeast of Mehsana. A subsidiary drainage system, southwest of Mehsana horst near Becharaji, flowing toward southeast caused thick sand deposition in stream mouth bars further cut by channels. In the sedimentological studies of Mandhali member sands, most of the points plotted on bivariate analysis charts show that they group around deltaic regime indicating delta front environment. Only a few samples, some of which are from Sobhasan area tend to fall in the beach area, thereby suggesting effect of wave processes.

The Mehsana member sands are typical channel sands. This is indicated by the bivariate studies and C-M pattern studies of the sedimentological analysis. The electrolog patterns of the sands in Sobhasan area, Jotana area show typically channel sands whereas in Kadi area, some sands are of stream mouth bar type.

It can now be stated that the Kadi formation is formed in a typical deltaic regime of a river system flowing on the northeastern side of Mehsana horst, one arm of which flowed just to the east of

Mehsana horst and another arm flowed further east near Sobhasan area and a little further to the south. Another river system was flowing southeast near Becharaji, on the western and southwestern flank of Mehsana horst, depositing coarse clastics in Kadi area and a little to the south. In the rest of the study area, on the northeastern side near Visnagar inter river mud flats and swamp growth was taking place, due to a subsidiary drainage flowing into the basin from the eastern margin of the basin. It is well-known that these delta front sands are formed in the time of floods when the energy in the medium of deposition is high and the shales are formed in quieter periods. Although the environment of deposition in the study area was delta front in the early part of the basin's geological history, it changed to lower delta plain inthe later part, the strand line receding further to the south.

At the end of the deposition of Kadi formation, the area experienced a transgression, particularly noticeable in the middle of the basin along the strike near Jotana, Linch and Warosan. Drainage into the basin was limited from both flanks of the basin. In these quiscent conditions, the upper tongue of Cambay shale is deposited. In the flanks of the basin, where the transgression has not made an impact, the sedimentation in the mud flats and swamps continued with minor and stagnant drainage into the basin. Even in the area where limited transgression took place, the basin later shallowed up.

The thick sand section of Kalol formation is then deposited with the increase of coarse clastic input into the basin. The formation is more widespread than the underlying coarse clastic unit, Kadi formation. The isopach and sand isolith maps of both the formations are similar thereby indicating that the drainage pattern recurred; the major input of clastics into the area is from north northwest with subordinate input from the northeast; however, the input of fine clastics from the northeast appears to be more than in the Kadi formation. The sand isolith map of the formation clearly brings out the direction of input of coarse clastics, which accumulated and then spread over a large area to the northeast, east and southeast of Mehsana horst, the horst itself having not received any of the coarse clastics, the river system having bypassed the horst and spread out on its eastern flank. Another river system flowed into the basin from northwest near Becharaji bringing in course clastics. This is obvious from both the isopach and sand isolith maps. The fact that the river drainage system including the provenance for the sediments recurred again indicates that the tectonic forces have not changed but only subsided for a short time when the upper tongue of Cambay shale was deposited.

The environmental conditions of deposition of Kalol formation sands are very well brought out both by the sedimentological analysis and the electrolog shapes. Both the bivariate analysis (Skewness Versus Standard deviation) and C.M. patterns of samples from the formation prominently bring out evidence that the river processes were most active during the deposition of the sands of the formation. The Kalol formation is very widespread in the area; atleast the upper part is seen wherever the total section is not identifiable. Each one of Kalol formation sands has typical channel characters namely a flat gamma ray at the base (clean sand), increasing shale/clay content at the top, indirectly indicating a reduction in grain size form bottom to top. Only in Jotana area, some electrologs show stream mouth bar patterns possibly because Jotana area happened to be near the basinal sink and some of the sands were deposited as stream mouth bars in the delta front. During the deposition of the middle part of the formation (Sertha member) the drainage over a large part of the northern Cambay basin became stagnant; clastic input became negligible, swamps grew luxuriously, marshy environment was prevalent all over. This resulted in the formation of thick coal beds which are widespread and recognisable as marker beds in the stratigraphy of the basin.

At the end of this large and widespread delta buildup, the basin experienced a transgression in Late Eocene, covering the entire basin. A marker shale bed (Tarapur shale) is the result of this transgression. The bathymetry in the middle part of the basin along the strike between Sobhasan and Jotana areas increased. Even the Mehsana horst was covered by the transgression and the shale bed is deposited.

At the end of the Late Eocene, the sea started receding and shallowing as evidenced by the occurrence of larger foraminifer, <u>Nummulites fitcheli</u>. In this regressive sea, the deltaic sediments of Late Oligocene and Lower Miocene age accumulated. Sedimentation to this deltaic environment continued and the three formations which are mostly unfossiliferous are deposited. Of this deltaic sedimentary section, the lower part which is a coarse grained arenaceous unit is deposited in a high energy environment in a lower delta plain. The middle part which is represented by arenaceous claystone, is deposited as a delta front sedimentary unit due to a shift in the strand line caused by a change in sedimentary input. The upper part of this sedimentary section is again a coarse grained arenaceous unit which is probably deposited in the upper delta plain of this delta complex.

The most prominent structural feature of the area, namely the Mehsana horst existed till end of Miocene period as may be seen in fig. IV. 8. Gentle anticlinal features are present south of Mehsana near Sobhasan. The deeper part of the basin shifted from the eastern part to the north-western part. This shift is seen in the isopach maps of Oligocene and Miocene sediments (Babaguru, Kand and Jhagadia formations) (figs. V. 11 and 12) which indicates that the drainage with sediment input from the northwestern side in the early part of this section's deposition reduced in the later part when it received a larger sediment input from the northeastern side. Although petrographic study has not been made, from the change in the type of quartz grains noticed in the sediments, it can be surmised that the Jhagadia formation received its sediment input from Aravalli orogenic complex.

The isopach map of Post Miocene sediments shows remants of Mehsana horst and the anticline near Sobhasan faintly persists. These anticlines do not occur at the stratigraphic levels of Late Pliocene and Pliostocene.