CHAPTER III

GEOMORPHOLOGY OF PARTS OF THE NORTH CAMBAY BASIN

Geomorphological studies of the Quarternary landforms have been carried out in some parts of the northern Cambay basin (study area) to relate these recent landforms with the products of late tectonic movements and denudation which in turn are correlated with the tectonics of the Tertiary period. The study is made with the aerial photographs and spot checking on the surface. The land forms have been mapped and categorised under their mode of orgin such as structural, denudational, fluvial and aeolian and are identified by geographic names. This classification has helped in the correlation of various land forms formed at different times in the Quarternary period. A chronological order has been established among the structural plateau, denudational bad lands and slopes, pedimented landscape, levees, terraces, flood plains, channel

sands, river bank deposits, fossilised sand dunes, recent sands, etc. A systematic analytical approach to understand the evolution of the neotectonic stage of the Cambay basin through morphographical (appearance), morphogenetical (genesis or origin), morphometrical (relief and slope characteristics) and morphochronological (age) methods of study has been attempted. The present analytical study yielded data on the dimensions of various land forms on the surface of the basin, the processes through which they have been created, their sequential development and age relationships and the degree of influence of neotectonics on these land forms. The data helped in reconstructing the Quaternary history of the basin.

I. LANDSCAPE ANALYSIS

The area under study exhibits a flat landscape with a westerly regional slope and a hilly terrain towards the east beyond the area.

The topographic elevations range from 40 m to 150 m above mean sea level. The hilly terrain to the east of Himatnagar is a part of the footslope of the Aravalli mountain range. Towards the west of Himatnagar, a pedimented landscape is observed which is subjected to strong gully erosion by the Sabarmati river system. A few terraces and old levees follow the slope towards Mehsana and a thin sand and alluvial cover is seen further west. On the whole, the area is flat with minor undulations and low relief features.

Sabarmati, the main river passing in a southerly direction

is just near the eastern boundary of the area. In the northern part of the area, Saraswati river flows in a westerly direction. There is hardly any good drainage system in between these two rivers. Several stream courses flow in the westerly direction but are dry for most of the year. The drainage pattern is dendritic which follows the slope rather than any structure. However, in several localities fault trellis pattern is indicated in the drainage.

Radial pattern of drainage is noticed around minor relief forms. At several places meandering stream courses, rectilinear stream courses, ox-bow lake formation and anastomising patterns are observed.

II. GEOMORPHIC LANDFORMS AND THEIR RELATIONS

A. MORPHOGRAPHICAL STUDY

Six geomorphic surfaces are identified namely 1. the badland surface, 2. the pediment surface, 3. the old levee surface, 4. the flood plain surface, 5. the swamp surface and 6. the sand dune surface (fig. III.1). These flat and undulating surfaces are punctuated by lineaments and morphostructures which are structural in origin. Thus the area exhibits landforms evolved due to various geomorphic processes such as structural, denudational, fluvial and aeolian. In places landforms derived by structural process have been subjected to denudation and are covered by fluvial or aeolian deposits. This is a very clear example of the multiplicity of the area wherein superimposition of geomorphic cycles occur. This is also indicative of neotectonic movements and

readjustment of structures within the recent past. These movements are clearly depicted by surface expressions which are referred to as 'Morphostructures'.

1. **The Badland surface**

It is identified along the Sabarmati river to the east of Ransipur and Vijapur. The base is a structurally controlled plateau, the topography is flat to gently undulating with a tendency to dip to south west. The Cretaceous sandstone and the Deccan Trap group of rocks, the Post Trappean gritty arkosic sandstone with subhorizontal bedding constitute the bed rock. These rock types are very well exposed in the badlands. The badlands are knife edged and are characterised by a very fine drainage network and short steep slopes with narrow interfluves. Badlands are a descriptive term indicating nothing of the time of formation but denoting the ruggedness of the terrain. This surface borders outcrop area of the eastern margin of the Cambay basin and the recent alluvial cover. It is developed due to differential campaction and erosion of the bed rock and surface soil. Two major sets of fault pattern (NE-SW and NW-SE directions) which are active in the recent past (46 A/14) have influenced the area.

2. **The Pediment surface**

Pedimented landscape is indicated in the area between Visnagar, Ransipur and Laddl next to the badland surface. In the literature pediment is described as a cut rock surface with thin sand or clay cover. Eventhough

the area does not strictly follow this definition, based on many indirect evidences it is surmised that the Deccan Trap group of rocks might be present underneath the levee sands here. Several terraced features, large positive structural anomaly and total basence of any drainage are some of the indirect evidences (46 A/10).

3. **The old levee surface**

This covers a large part of the area under study. Remnants of levees, highlighted by their relief, shape and size in the otherwise monotonous, flat alluvial soil constitute the old levee surface. This is predominantly observed in the area around Visnagar, Tarabh, Mehsana, Balol, Akhaj and Vijapur. It is indicative of a southwesterly palaeo-drainage.

Levee features varying in heights from 15 m to 20 m are seen to the north of Vijapur and south of Ransipur (46 A/14). Highly dissected levees of heights varying from 10 m to 15 m are noted around Janthral which gradually reduce in height southwestwards. These remnants of levees are 5 m to 10 m high near Dabhla. There is hardly any drainage in the area and the rivulets and minor streams which are existing are all in the southwestern slope direction. The trend of the remnants indicate a NE-SW paleodrainage system.

The levee remnants to the east of Mehsana, around Kherwa, Mohanpura, Sangampur, Mitha etc. are about 20 m in height and are very prominently situated in the flat terrain. They trend in NE-SW

direction. Near Valam, Khandosan and towards Tarabh, Ranchodpura levee sands constitute a N-S ridge pattern and are strongly eroded by recent streams resulting in a gullyed landscape. The maximum height is around 15 m. To the south of Nadasa, the Masi Tibba is a remnant of old levee. It is about 25 m high from its surroundings. Near Kunsagar, levee features of about 5 m height are exhibited in a semi-circular pattern. The levee deposits in the area are yellowish, brownish, greyish consolidated clayey sands with patches of minor clays.

There are sporadic relief features seen in Linch-Kadi area which resemble levee remnants. However, they are completely covered by recent sand dunes.

To the east of Detroj, NE-SW trending sand hills of 20 m height indicate a former levee feature. However, it is totally covered by recent sand dunes. It is doubtful whether it represents an old levee remnant or a fossilised sand dune.

4. <u>The flood plain surface</u>

While the pedimented and arid landscape around Visnagar, Vijapur, Kadi and Detroj areas is devoid of any drainage system, the area to the west of Mehsana exhibits a drainage system with dendritic and fault trellis stream pattern. The Rupen nadi, the Pushpavati nadi and the Khari nadi are streams flowing southwestwards just to the west of Mehsana. The Saraswati river flows southwestwards with a wide floodplain associated with ox-bow lakes and other similar features

denoting a subsided basinal situation. These streams contribute channel sand deposits along their river beds and intermittent silts and clays.

Sabarmati river contributed channel sands to the south of Vijapur. The river makes steep vertical erosion to the north of Vijapur and as such no deposition occured there.

Repen nadi and Khari nadi contributed channel sands to the west of Mehsana and the Pushpawati nadi near Unjha and Dhinoj. The Khari nadi and the Pushpawati nadi further contributed channel sands towards the downstream around Mudhera, Maniar etc. The Saraswati river is the major contributor of channel sands in the northern part of the area.

5. The Swamp surface

The southwestern part of the area under study depicts a landscape which is a dessicated barrenland. Drainage is almost nonexistent. It has a swampy look with scrubs here and there and a number of water logged low land areas. The effect of the little Rann which is situated further southwest can be visualised here.

6. The sand dune surface

This surface is seen around Sidhapur in the north, around Visnagar-Vijapur, around Detroj and around Linch-Kadi area.

Fossilised sand dune hills and shifting sand dunes are observed

around Sidhapur to the north of the Saraswati river. The fossilised sand dunes are at heights of 10 m to 15 m above their surroundings.

The pediments of Visnagar-Janthral area have a very good coverage of shifting sand dunes of about 5 m thickness.

Large accumulation of sand dunes which are fossilised now over ancient levees are noted to the east and northeast of Detroj. Thin laminated sand layers of wind origin are noticed above levee sands near Gebi Timba (a hill southeast of Detroj). The heights vary from 20 m to 30 m from their surroundings.

The Linch-Kadi area is mostly covered by fossilised sand dunes. These are probably remnants of old levees covered by subrecent to recent wind blown sands which are presently stabilised and hold vegetational growth. The area totally devoid of any drainage is predominently covered by recent wind blown sands.

The lithological descriptions in brief of various landforms are as follows :

Badland - Purple, yellowish brown kaolinised sandstone, gritty arkosic sandstone with white, grey, reddish clay pockets, weathered basalt pieces embedded in purple clay and silt and dried up mudflows.

Pediment - Thin cover of yellowish, unconsolidated sands over weathered basalt type of rock and loamy soil.

Levee	-	Yellow, brown, red, semi consolidated to consolidated loamy sand occasionally with minor clay pockets associated with slightly carbonised vegetal matter.
Channel Sand	-	Coarse to fine, quartzitic, well sorted, current bedded, laminated, alternating with thin sheets of grey, greenish, black muddy clay mixed with pebbles and coarse grained sand.
Alluvial silt and clay	-	Greyish, greyish black, fine, sticky amorphous clays often silty, covered by cultivation and orchards.
Shifting sand dunes	-	Reddish, yellowish brown, well sorted, unconsolidated sands having different shapes and sizes based on the wind direction.
Fossilised sand dunes	-	Reddish, brownish well sorted laminated sands with subparallel bedding slightly indurated with silty cement hosting shruby vegetation.

A schematic section of recent sediments is as follows :

Subsoil, loose unconsolidated, brownish, greyish alluvial sands, clays, often lateritic, saltish and with vegetal matter.

Lateritic, cherty, gritty, pebbly gravelly sands with Kaolinitic clayey pockets.

Younger levee sands, yellowish, brownish, reddish semi-consolidated clayey sands with slightly carbonished vegetal matter.

Kankary, gritty pebbly sandstone beds.

Older levee sands, brownish, dark greyish, consolidated clayey pockets with little induration.

B. MORPHOGENETICAL STUDY

The nomenclature given below to landforms is based on their location, nature, genesis and the relative age.

Units of structural origin

1. Ransipur-Sardarpur horizontal bed rock with tilts (46 A/14)
2. Jantral-Ransipur levee terraces (46 A/10)
3. Dhinoj river banks (46 A/6)
4. Jiliya river bank (46 A/2)

5. Kunsagar levee feature (46 A/2)
6. Nadasa masi tibba (46 A/2)
7. Ganglasan river bank (46 A/5)
8. Akhaj sand bank (46 A/7)
9. Mathasur sand feature (46 A/7)
10. Gunjala surface anomaly (46 A/3)

Units of denudational origin

1. Ransipur-Vijapur badlands (46 A/14)
2. Jantral dissected levee (46 A/10)
3. Khandosal gullyed landscape (46 A/6)
4. Siddapur-Lukhasan gullyed landscape (46 A/5)
5. Detroj sand hills (46 A/3)

Units of fluvial origin

1. Sabarmati channel sands (46 A/14)
2. Ransipur/Jantral old levee sands (46 A/10)
3. Dabhla levee sands (46 A/10)
4. Mehsana-Khari nadi channel sands (46 A/6)
5. Mehsana/Rupen nadi channel sands (46 A/6)
6. Dhinoj-Pushpavati nadi channel sands (46 A/6)
7. Mohanpura levee sands (46 A/6)
8. Sangampur levee sands (46 A/6)
9. Maniar-Khari nadi channel sands (46 A/2)
10. Mudhera-Pushpavati nadi channel sands (46 A/2)
11. Metrasen-Rupen nadi channel sands (46 A/2)

12. Saraswati river channel sands (46 A/5 & A/1)

13. Pushpawati nadi channel sands (46 A/5)

14. Ranchodpura-Tarabh levee sands (46 A/5)

15. Linch-Kadi sporadic levee sands (46 A/7)

16. Detroj levee sands (46 A/3)

Units of aeolian origin

1. Linch-Kadi fossilised sand dunes (46 A/7)

2. Detroj fossiled sand dunes (46 A/3)

3. Visnagar-Vijapur sand dunes (46 A/10)

4. Sidhapur fossilised sand dunes (46 A/5)

C. MORPHOCHRONOLOGICAL ANALYSIS

The geomorphic landforms are all generated during the Post Miocene period. Since sampling is not done for accurate dating, a comparative dating is attempted.

It is surmised that over the bedrock surface a pedimented landscape has developed in the marginal part of the area. A massive, regional drainage system from the Aravalli ranges brought down levee sands and interdistributary silts and muds. This is followed by an arid climate which must have eroded the silt and mud part of the country and entrenched in the levee sands. These being more resistant, are left as remnants and resulted in the present day mound/ridge features. Subsequently, climatic fluctuations occured and a new drainage system

has developed depositing channel sands and silts. Another stage of levee development followed by erosion might have occured. The denudational stages also witnessed wind depositional environment resulting in sand dunes. Some of these sand dunes are stabilised and fossilised. However in the recent times, channel sands, wind blown sands and soil formation simultaneously developed.

III. NEOTECTONICS

Study of aerial photos and landsat imagery, drainage pattern and relief features brought out a neotectonic understanding of the area under study. The geomorphological map depicts an accurate graphic representation of the landforms and the indication of the wide range of influences both past and present that have made it. It is generally believed that the shapes of the geomorphic features are not accidental but are imposed by the sum total of external, internal and stored energies. Minor relief and local uplift at the surface are reflected in anomalous tonal and textural values. Tectonic movements which developed during the latest geological periods (the post Miocene) are of great importance in the formation of recent morphostructural elements. Morphostructure consists of those forms of the earth's surface which are produced by the interaction between endogenetic and exogenetic forces, the endogenetic factor being predominant in the tectonic movements of the earth's crust.

Number of anomalies are identified in the study area. It is understood that many of them reflect the subsurface movements.

This is supported by the reflections in the seismic sections. The anomalies are classified under units of structural origin as they reflect neotectonic movements (Morphostructure, Escarpment, Lineament). Some of them are described below.

Ransipur-Sardarpur horizontal bed rock with tilts

Fault trellis pattern of drainage is exhibited by the tributary system of the Sabarmati river whereas the main river meanders along its course. The asymmetric pattern of the river over a tilted plain is evident by the presence of numerous tributaries from the eastern part and lack of any tributaries from the western part. The terrace development trending in NE-SW direction is situated to the west of the river around Ransipur and Sardarpur and gradually disappears towards south. The terrace is atleast 10 m high and appears to be the margin of an old levee belonging to that of old course of the river. The present position of the main river clearly indicates a shift towards the margin which is only possible due to faulting and tilting caused by neotectonic disturbance. The Sabarmati river between Ransipur and Sardarpur has also undergone deep cut erosion. Escarpment feature along Jantral, Gundrasan, Sardarpur and Ransipur and a major positive anomaly to the northwest of Jantral indicate either tectonic disturbances or shallowness of the basement rocks. This area is placed under Pediment landscape due to the above reasons.

Pushpawati river bank section near Dhinoj

6 m to 7 m deep cut river banks, deep cut ravines, asymmetrical river bed, incised meanders, fault trellis type of drainage are noticed. Two recent movements at different stages are indicated due to the presence of old levee and younger levee cuts, slump features, etc.

Khari nadi river bank near Jiliya

Similar to above.

Kunsagar levee feature and entrenched meanders

Khari nadi and Rupen nadi appear to have incised into their former levees and made semicircular patterns. At several places the streams are cut and the former levees obstruct the normal flow of water. These features are all due to recent movements.

Nandasa Masi Tabba

The levee deposits have covered this hilly feature with varying trends. The trends are probably due to denudation based on differential movements. A certain amount of recent tectonics is envisaged here.

Miyani nadi section near Ganglasan

This section indicating neotectonic activity has developed between two major rivers Amardasi and Saraswati. Deep cut gorges, gullyed channels, entrenched meanders have all develo ped 5 m high

river bank in the recent subsoil. This appears to be the result of a second neotectonic movement which precedes the first one which affected the levee and floodplain deposits.

Akhaj sand bank feature

It is circular positive anomaly presently covered by sand dunes.

Mathasun sand feature

It is a positive oblong feature covered by sand dunes.

Gunjala surface anomaly

In the otherwise low lying water logged area an oblong uplifted feature indicating recent movement.

Lineaments

There are two sets of major lineaments in the area under study, one in NE-SW direction and the other in NW-SE direction. The NE-SW directional lineaments are predominent towards the eastern part showing the influence of Aravalli craton margin whereas the NW-SE directional lineaments are predominent in the basinal part showing the influence of graben tectonics. Normally maximum number of lineaments are associated with uplifts indicating zones of maximum development of tectonic strain. Lineaments are very prominent in the floodplain surface as exhibited by the fault trellis drainage pattern. In the old levee surface and sand dune surface, lineaments are observed sporadically. They are probably covered by recent sand cover.

IV. MORPHOSTRUCTURES

Two geomorphic cycles are identified namely, uplift phase (erosion) and the other subsidence phase (accumulation). A neotectonic stage includes both. The erosion and accumulation phases are clearly seen in the river bed and flood plain facies of the sediments deposited along the streams of the area under study. The morphostructures indicate uplift zones.

Relationship between Morphostructures and Gravity anomalies

Ganglasan morphostructure appears to have been influenced by the NE-SW trending Gravity high trend situated to the north of Sidhapur.

Saraswati river bank to the northeast of Sidhapur indicate gulley development, vertical erosional features, entrenched meander etc. These features are associated with a regional NE-SW fault zone indicated by gravity picture.

Ranuj morphostructure is associated with saddle feature inferred in the gravity map.

Dhinoj and Jiliya morphostructures are associated with NW-SE trending fault zone inferred from Gravity map.

Kunsagar and Nadasa Masi Tibba morphostructures are associated with flexures indicated by the gravity contours trending in NNW-SSE direction. Gunjala and Detroj morphostructures are probably influenced

by NW-SE trending faults inferred on the gravity map.

Mathasur feature appears to be over gravity high trend.

Gravity trends

The Bouguer anomaly map exhibits gravity high and low trends forming certain patterns which are suggestive of the basement configuration in the area under study.

Gravity high trends in the NE-SW direction are observed around Sidhapur and Visnagar and extend eastwards. They are in conformity with the Aravalli trends. The lineament patterns in this area are correlatable.

In the basinal area to the west of Mehsana an elongated gravity high trend in NW-SE direction is present along Chhatral-Jotana-Jiliya areas. Parallel to this gravity high trend, on either side, gravity low trends are present. The major lineament pattern is in the NW-SE direction. The morphostructural and lineament pattern trends are generally influenced by these gravity trends.

Relationship between Morphostructures and Seismic trends

Presence of faults in NNW-SSE direction and quick changes in the palaeotopography (highs and lows) are interpreted from the seismic lines at the Deccan Trap level and Middle Eocene level in the area around Dhinoj and Jiliya. These are supporting the morphostructures as their subsurface tectonic counterparts.

NW-SE trending faults, highs and lows at Deccan Trap level and a structural high at Miocene top have probably influenced the morphostructural pattern around Nadasa and Kunsagar areas.

The other morphostructures are not supported by seismic features in a direct way but indicate a qualitative relationship between the two.

Seismic trends

Regional seismic study indicates an eastern marginal gradual slope between Vijapur and Mehsana, a deep basinal low to the west of Mehsana and an abrupt hilly terrain towards Bechraji at the Deccan Trap level. Sediments were deposited in this basement configuration and local high and lows have developed. Structures and faults are in a NNW-SSE direction with minor variations to NNE-SSW direction.

Relationship between Morphostructures and Miocene sediments

The sediments of the Miocene age which are encountered in the deep wells are analysed. The structural trends are in the N-S direction and only towards south of Jotana they change to NNW-SSE. The configuration of the sediments indicate structural highs around Lanwa, Balol, Bechraji, Jotana, Nandasan, Langhnaj, east of Mehsana, north of Sobhasan and east of Jagudan. Saddle features are noticed between Lanwa and Balol structures between Santhal and Kadi. A regional low trending towards north is seen in the central portion denoting a

synform in that area. Sand channel appears to have come from the northern part of the area. Steeper dips are recorded to the west of Lanwa and towards Mudhera.

Maximum thickness of the Miocene sediments are recorded in the central low portion along Dhinoj, Warosan, Linch, Nandasan. The thickness decreases towards the eastern flank and towards the western part of Lanwa, Balol and Asjol. A regional N-S trend is seen for the sediments. Areawise maximum amount of sediments occur around west Sobhasan, Nandasan and North of Kadi. A fault zone is noticed along Linch-Dholasan-Kherwa area in the NNE-SSW direction and to the south of central Kadi wells and south of Jotana area. The sediments are subjected to structural disturbances in Kadi, Jotana area and Dholasan, Sobhasan area.

Concluding remarks

The tectonics since the Deccan Trap time appear to have influenced the younger sediments and maps are prepared to demonstrate this phenomenon. The geomorphological map indicates morphostructures and lineaments which are mostly supported by the subsurface structural configuration.