C H A P T E R II

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GENERAL CONSIDERATIONS

The geomorphic evolution of the study area exhibits a very distinct impress of the various geological factors. No doubt, the different subaerial agencies like rain, wind, temperature changes and running water have played a dominant role in carving out the landscape as it is to-day, but the strong control exercised by the lithology, structural features and the processes of neotectonism and eustasy during Quaternary period, cannot be minimised. The distribution of the different rock types belonging to successive stratigraphic periods of Cenozoic Era, the major and minor lineaments, fracture patterns and the differential responses of the coastline and fluvial processes to sea level changes, all these have combined to evolve the landscape with all its diversity. The study area provides an ideal example of a terrain that has evolved in the course of last 60 - 70 million years by geological processes of volcanism, marine transgressions and regressions and subaerial processes of construction and distruction. Since geology has played an important role in the landscape evolution, it is most appropriate that before the present author proceeds with the systematic description and analysis of the topographic features of the different parts of the study area, it is most relevant to give a brief account of the area's geological framework.

STRATIGRAPHY AND ROCK TYPE DISTRIBUTION

The stratigraphic sequence given in Table II 1 shows the geological set up of the study area based on the surface and subsurface information provided by the various workers in the course of last several decades. (Krishnan, 1968, Chandra & Chaudhary, 1969, Bedi 1976). The distribution of the exposed formations is shown in the geological map of the area (Fig. II 1).

Metamorphics and Granitic Gneisses

These are the geologically oldest the rocks of the Precambrian age and have been correlated with the Champaner Series (= Group) equivalent to the Aravallis of Rajasthan. Within the study area, these form only a few sporadic outcrops as under :-

1. Exposures of phyllites, quartzites and crystalline limestones in the river bed of Heran, at Ghantoli and Sandara.
2. Quartzites and phyllites of Kankua and Lachhras hills.
3. Quartzites and phyllites of Chosalpura hill, about 3 to 5 km south of Ghantoli (capped by Bagh sandstones).

Table II 1. <u>Stratigraphy of Study area</u>

QUATERNERY	Holocene (Recent to sub-recent)	Soils, coastal sand-dunes, Beach sands, tidal muds, Newer Alluvium (Flood Plain deposits)	
	Pleistocene	Older Alluvium	
UNCONFORMITY			
TERTIARY	U.Miocene	Jhagadia Formation	(Exposed)
	M.Miocene	Kand Formation	(Exposed)
	L.Miocene	Babaguru Formation	(Exposed)
	UNCONFORMITY		
	M.Eocene	Ankleshwar Formation	(Subsurface)
	L.Eocene	Cambay Black shale	(Subsurface)
	Palacocene	Olpad formation	(Subsurface)
	Palaeocene	Laterites	
UNCONFORMITY			
U. CRETACEOUS TO L. EOCENE		Flows of basalts and dolerite dykes.	(Exposed)
	Middle to upper Cretaceous	Bagh Beds	(Exposed)
UNCONFORMITY			
	PRECAMBRIAN	Metamorphics, Granitic Gueisses etc.	(Exposed)

4. Granite hill of Vajiria, capped by Bagh Sandstones.

5. Naswadi hill of phyllites and quartzites capped by Bagh sandstones.

6, Granite - gneiss exposures in the extreme NE around the villages of Sajwa, Karajwat and Jitnagar.

Except the outcrops in the Heran river bed and those of granites in the NE, almost all occurrences form conspicuous hills, bound by ENE - WSW faults, which have uplifted these Precambrians along with the cappings of Cretaceous sandstones. The meta-sedimentaries show very steep dips at most of the places.

Precambrian rocks are significantly absent from the terrain south of Narmada.

Bagh Beds

These Lower Cretaceous rocks are encountered either as outliers within the Precambrians or as inliars within the Deccan Trap. The former always comprise cappings of sandstone resting unconformably over the upthrown fault bound blocks of Precambrian rocks. In the latter case, these form elongated (ENE - WSW trending) patches within the basaltic terrain. Generally speaking, either the southern flank is fault bound or in some cases both flanks are marked by faults. Geomorphically, these sedimentary rocks do not form any conspicuous landform. At most places they are sub horizontal or show dips of a few degrees either due N or S. Broadly speaking, these Lower Cretaceous marine rocks show following sequence :

4. Limestones with shales.
3. Shales with limestones.
2. Shales with sandstones.
1. Gritty sandstones with a well defined basalt conglomerate.

The change over from arenaceons through argillaceous to calcareous facies is clearly recorded from N to S.

The outcrops to the north of Narmada do not show any significant vertical thickness, never exceeding 30 to 40 m. But on crossing the Narmada river, the Bagh beds show a gradual increase in thickness, so much so that at Surpaneshwar the total vertical thickness is of the order of 2000 m. Bagh sedimentaries do not extend further south or east of the Devganga river. The various outcrops of these Cretaceous rocks are shown on the geological map (Fig. II 1).

Deccan Trap

The basaltic rocks belonging to the Deccan Trap (Upper Cretaceous to Lower Eocene) comprise the most dominant component of the hilly terrain of the study area. Typically characterising an elevated rugged terrain marked by flat topped hills and ridges, with intermontane valleys, these volcanic rocks show an enormous thickness, rising to about 900 m above the M.S.L. The total thickness of the Deccan Trap in this part could be almost 1000 m, resting over the Precambrians or the Bagh beds. The main bulk of this formation consists of horizontal lava flows of variable thickness, ranging from 5 m to 15 m. Hard compact basalts, porphyritic basalts and amygadaloidal basalts are encountered, and quite often tuffaceous or agglomeratic layers are seen intervening the flows. Depending on the response of the different varieties of lavas to weathering agencies, the Deccan Trap has given rise to plateau like topography with flat areas at successively decreasing altitudes, thereby imparting a step-like topography at quite a few places. Extensive jointing of these trappean rocks has not only facilitated their weathering and erosion, but the various joint sets have also controlled the drainage pattern.

The basaltic flows are traversed by numerous doleritic dykes which trend mostly ENE - WSW, and these have given rise to distinctive topographical features in the form of linear groups of hills.

At several, places, the differentiates of basalts (trachytes etc) have been reported, but these do not have significant geomorphic expression, except in the case of (i) Phenai Mata hill in the north, and (ii) Amba Dungar hill in the east.

To the west, the basalts progressively lose prominence, so much so that north of Narmada, they go beneath the alluvium, while to the south of the river Narmada, they become almost subsurface, overlain by Tertiary and Quaternary rocks, and change over to uplands and coastal plains in succession. Ofcourse theuplands and coastal plains in succession. Ofcourse the uplands are dotted with sporadic groups of trappean hills and linear, dyke rock exposures.

Laterites

The subaerial weathering of the basalts have given lateritic rocks, which form a distinct horizon below the Tertiary sequence. Laterites are better developed elsewhere in Gujarat viz. in Saurashtra and Mandvi area of S. Gujarat. In the study area these show rather poor development and only occasionally small thin patches, never exceeding a metre or so in thickness are encountered. More common is a thin venear of lateritic soil in some exposed area of the basalts.

Tertiary Rocks

Only the Olpad Formation (= Vagadkhol Formation of Sudhakar & Basu, 1973), Ankleshwar Formation (= Tarkeshwar formation of Bose, 1908), Baba Guru Formation, Kand Formation and Jhagadia Formation are exposed around Jhagadia - Tarkeshwar area (Fig. II 1). The Olpad formation unconformably overlies the Deccan Trap and is seen to consist of grey clays, tuffaceous sandstones and conglomerates. They are in turn overlain by 'Nummulitics' composed of foraminiferal, impure, argillaceous limestone, clays and marls. The limestone and marls are yellowish in colour. The unfossiliferous to poorly fossiliferous Ankleshwar Formation overlies the Olpad rocks with a well defined unconformity. The constituent rocks are grey and variegated bentonite days with thin lateritized bands. It is overlain by Baba Guru Formation consisting of ferruginous and current bedded sandstone, conglomerates and greyand white sandstones and clays. The next unit, the Kand Formation overlies conformably the Baba Guru, and is seen to be made up of grey clays with thin bands of fossiliferous marks and limestones and subordinate sandstones. The Jhagadia Formation that overlies conformably the Kand formation, is composed of white and greyish white calcareous, micaceous and current bedded sandstone with occasional conglomerates. These are overlain by a variety of Quaternary deposits.

Quaternary Rocks

Quaternary sediments of diverse origin and occurring in varied geomorphic set ups form a major portion of the study area, mostly the coastal plains and shoreline deposits.

Stratigraphically, these rest over Deccan Trap or Tertiaries with a marked unconformity and can be classified as under :

Holocene (Sub-Recent to Recent)	Residual Soils, flood plain deposits (Newer Alluvium), coastal beach and dune sands and estuarine mud flats.
Late Pleistocene	Older Alluvium

--------- Unconformity --------

Deccan Trap / Tertiary rocks

The Older Alluvium, which represents the ancient flood plain deposits of Narmada and Tapi rivers, forms a soil horizon of varying thickness, the maximum being about 100 m in its western parts. Ideal sections of this alluvial deposit are seen in the various cliff sections of Narmada and Kim. Mostly consisting of silty clays, on account of its grayish black colour and derivation from the basaltic rocks, it is generally referred to as black cotton soil. Its top surface, upto the depths of several metres invariably contains thick lime concretions of Kankar. The Newer Alluvium mainly constitutes materials of the present day flood plains and is restricted to the broader portions of the channels of the rivers like Narmada and Kim. Generally, it forms well defined terraces at levels lower than that of the main alluvial plains (older).

These flood plain deposits are highly fertile. The constituents are the usual silts and clays, but do not contain any significant organic matter or Kankar. The older and Newer alluviums are easily distinguished on the basis of their altitudes, organic content and presence or absence of Kankar.

Apart from the Newer Alluvium, other Holocene sediments are all restricted to the shoreline. Depending on their sites of deposition and the processes responsible, these could be described as (1) Foreshore beach sands (ii) Backshore coastal dunes and (iii) tidal mudflats and lagoonal deposits. Lithologically, the beach as well as dune material consists of sand-size grains of basalt, quartz and molluscan shells.

Residual soil cover, which also forms a Holocene deposit is restricted to the trappean areas, where it is encountered on the plateans gentler slopes of the hills as well as on their flat hill tops. It never exceeds a metre or two in thickness, and consists of coarse sandy ferruginous soil replete with bigger fragments of basalts.

STRUCTURAL ASPECTS

As already stated earlier, the structural features of the rocks and the tectonic history during Cenozoic period, has played a significant role in the geomorphic evolution of the study area. The present author has made a critical evaluation of all available information on the tectonic framework of this part of the West Coast, and has also worked out the fracture pattern of the area on the basis of toposheet and satellite imagery studies. The structural controls of the geomorphic evolution have been broadly studied under two main heads viz. fracture pattern and neotectonism. (Fig.II 2)

Fracture Pattern

This includes major faults and joint system. Two major fault zones lie within the limits of the study area. The Narmada fault zone, which represents a very important geofracture system, falls within the study area, and appears to be represented by two 'en-echelon' ENE-WSW trending faults, Ankleshwar Fault and Hanfeshwar Fault, Also, an offshore fault referred by several workers as West Coast Fault (Powar 1981, Biswas 1982) is supposed to extend along the shoreline. The more dominant and effective fractures are represented by the extensive jointing of the Deccan Trap basalts. Several sets of joints provide an intricate network of minor fractures which have controlled the drainage pattern, especially of the 1st, 2nd and 3rd order streams.

Neotectonism

Quaternary tectonism also appears to have played a significant role in the landscape evolution, especially of the uplands and the coastal plains. The author has delineated areas of 'highs' and 'lows' in the uplands which reflect the subsurface features (anticlines and synclines in the Tertiaries) which show very clear evidences of Sub-Recent uplifts. The entrenchment of the meandering streams that drain the depressions ('lows') typically exhibit this neotectonic phenomenon. The recent earthquake of Bharuch (March 1970) also points to crustal adjustments to the differential stresses generated during the uplifts (Fig.II 3)

EUSTASY

The eustatic sea-level changes during the Quaternary period have also left significant imprints not only along the coastline, but are also recognised in the alluvial coastal plains. The rise and fall of sea-level related to glacial and inter-glacial stages of the

Quaternary, are indicated by following two significant geological features :

1. Entrenchment of the meandering streams flowing across the alluvial plains. This phenomenon points to a period of regression during which the streams extended their channels further west for several kilometers.

2. Estuarine river mouths of the present day, which point to a transgression during which the dissected alluvial coastline was drowned.

3. Occurrence of three generations of coastal sandy ridges, pointing to a sequence of regression - transgression - regression.

According to Patel et al (1982) the above coastline features, point to following chronology of glacio-eustatic sea-legel fluctuations :

1.	Regression (Late Upper Plistocene)	- 20 m below the present sea-level.
2.	Transgression (Early Holocene)	- 8 to 10 m above the present sea-level.
3.	Regression (Recent) and stabilisation of strandline.	- Present day sea-level.