

CHAPTER - II

B A C K G R O U N D    I N F O R M A T I O N

GENERAL

DECCAN BASALTS IN GENERAL

REGIONAL TECTONIC SETTING

GEOMORPHOLOGICAL ASPECTS

## BACKGROUND INFORMATION

### GENERAL

The geology and geomorphology of the study area have received little attention in the past, and as such, no published literature pertaining to the basaltic rock types and their structural characters is available. Even detailed geomorphic aspects of the terrain have remained uninvestigated. Perhaps, the monotonous basaltic rocks, typically giving rise to a steplike topography did not really attract workers to delve deep into the most vital factor of its landscape evolution viz; the morphotectonic factor. The paucity of previous information has, on one hand, handicapped the author in obtaining views of earlier workers, while on the other hand, provided a good opportunity to investigate an almost virgin area, thereby presenting a substantial of new data on the control exercised by the factors of lithology and structures in the landscape evolution. In this work, the author though, has considerably benefited by a large number of earlier works pertaining to regional aspects of the morphotectonic studies which could be relevant to the present investigation. In the following pages of this chapter, an attempt has been made to summarize all the available data from which the author has derived his conclusions.

### DECCAN BASALTS IN GENERAL

The Deccan Traps cover an area of a little over 500,000 sq.Km, in west central India, spreading over large areas in

Kutch, Saurashtra, Gujarat, Madhyapradesh, Maharashtra and Andhra Pradesh. Essentially comprising basaltic lava flows, these provide a very good example of fissure eruption during upper Cretaceous - Eocene times.

The western part of the Deccan Trap province covering parts of Maharashtra and Gujarat states, is predominantly constituted of thick pile of basalt flows. They issued through long narrow fissures or cracks in the earth's crust from a large magma basin, the lava spread out far and wide as nearly horizontal sheets, the earlier flows filling up the irregularities of the pre-existing topography (Krishnan 1982). The trap country is characterised by flat topped hills and step-like terraces. It has been generally believed that this topography is a result of the variation in hardness of the different flows and of parts of the flows, the hard portions forming the tops of the terraces and plateaus.

Earlier workers (Pascoe, 1964; Krishnan, 1982) classified the traps as Upper, Middle and Lower on consideration of stratigraphy and presence of Inter-trappean beds :

Upper traps ..... (450 m thick)	Maharashtra and Gujarat; with numerous inter-trappean beds and layers of volcanic ash.
Middle traps ..... (1200 m thick)	Madhya Pradesh (Malwa); with numerous ash beds in the upper portion and practically devoid of intertrappeans.

Lower traps ..... Part of Madhyapradesh and Andhra-  
pradesh with intertrappean beds,  
but rare ash beds.

Researches carried out by the NGRI (Hyderabad) have thrown much light on the nature of the Indian plate below the Deccan volcanic province. DSS data (Kaila et.al, 1981), suggest that below the Deccan basalts along the West Coast, the Moho discontinuity is located at a depth of about 30 km. On the basis of palaeomagnetic data the Deccan Traps have been categorized into Upper and Lower traps (Sahstrabudhe, 1962). Pal & Bimashankaran (1972), on the basis of observed direction of palaeomagnetism in the Deccan Traps and the palaeo-latitude derived from them have grouped the Deccan Trap basalt into four groups as under.

- Group A : The Trap flows with reversed magnetic direction in the oldest Deccan Traps (about 70-75 million years).
- Group B : The normal polarity flows of Mahabaleshwar, Nipani, Bombay and Rajamundry, and the reversed lava of Linga and Jalna give similar palaeo-latitudes (about 65 million years).
- Group C : Includes, the uppermost flows of Mahabaleshwar and Gargoti, the two upper flows of Nipani, flows of Sagar and the basalts of Pawagadh hill (about 60 million years).

Group D : Includes two acid tuff sites on Pawagadh Hill (about 40 million years).

Ghose (1976) is inclined to sub-divide the traps into two groups : the Lower and the Upper Traps, on the basis of the chemistry of basalts; the Lower Traps, according to him, occupying the eastern and southern portions of the basalt outcrop, are characterised by tranquil eruptions of chemically uniform quartz- normative tholeiite in horizontal flows, while the Upper Traps, confined to the West Coast, Gujarat and Narmada Valley, in contrast, show explosive activity, floundering of the crust accompanied by faulting and variation in the dip of the flows.

Pascoe (1964) stated, "Like the plateau basalts of other parts of the world, the Deccan flows all show a high percentage of ferrous oxide, a feature thought to be responsible for the high degree of fluidity when molten. Perhaps, the most striking peculiarity is the prevalent vesicular character, the amygdales, sometimes constituting the principal part of the rock".

"Almost throughout their range the Deccan Traps may be recognized by the occurrence of the amygdaloidal basalts with green earth or of the porphyritic rock with crystals of glass felspar".

On the basis of its gross lithology, Konda (1985) has subdivided the Deccan Volcanic province into two : the plateaux sub-province covering the Malwa, and Deccan plateaux and the Sahyadri ranges, and the graben sub-province broadly corresponding to the belt lying to the west of the Panvel flexure axis. The plateaux sub-province is constituted, almost exclusively of basalt flows of both simple and compound types that show considerable variations in their thickness and extent. The simple flows commonly have a thickness from less than a meter to about 10 m, and the compound flows may attain considerable thickness. According to Krishnan (1982), the individual flows vary in thickness, from a few feet to as much as 100 ft or more. A borehole at Bhusawal, 370 m deep, revealed 29 flows, the average thickness being 12 m. In the Chindwara district of the Madhyapradesh 16 flows have been identified with an average thickness of 21 m.

Sukeshwala (1981) has postulated, four magma types, viz; the tholeiite, the rhyolite the carbonatite alkalic magma and the alkali olivine basalt magma, and according to him, these came as independent entities without any known genetic link existing between them, the roots of these magmas being deep in the mantle. The first magma to erupt on a wider scale forming the major part of the Deccan Traps was the tholeiite, followed by rhyolite in fairly large proportions; and the igneous activity closed with the final eruptive phase of minor quantities of the alkali

Olivine basalt magma and the carbonatite alkalic magma occurring as small plugs within the tholeiite.

The most recent work on the Deccan flood basalts is presented by Subbarao<sup>x</sup> (1988) in Memoir 10 of the Geological Society of India. In his introductory remarks, Subbarao has summarised the various aspects related to the stratigraphy, structure, geochronology, palaeomagnetism, mineralogy and petrology of these basalts. A map compiled by him and Hooper (Subbarao, 1988) shows following classification of the Deccan basalt group.

<u>Group</u>	<u>Sub-Group</u>	<u>Formations</u>
D E C C A N  B A S A L T	Wai	Desur
		Panhala
		Mahabaleshwar
		Ambenali
		Poladpur
	Lonavala	Bushe
		Khandala
	Kalsubai	Bhimashankar
		Thakurvadi . . . . .
		Neral
		Igatpuri
		Jawhar

Although his map does not include South Gujarat basalts, but it is obvious that the rocks of the study area that comprise the lowermost portion, may be correlated with his Jawahar and Igatpuri Formations.

### REGIONAL TECTONIC SETTING

"It is now conclusively established that the eruptive source regions of the Deccan Trap were two major lineaments one along the E-W Satpura basin and the other along the N-S Cambay basin" (Sukeshwala, 1981). The dykes system cutting the Deccan Traps in Gujarat trending ENE - WSW and N-S (Auden 1949) also conforms with these two major tectonic lineament trends, Aerial photo-interpretation studies by Das & Ray (1977), have contributed significantly towards a proper understanding of the regional tectonic setting of the Deccan Traps in Gujarat. The lineament map prepared by these authors shows the entire Deccan Trap Country to be "riddled with fractures varying in length from a few meters to several tens of meters. These fractures are not the normal cooling fractures of Deccan basalt, as the latter cannot be of such magnitude as to be visible in the aerial photographs of mentioned scale. These are mostly vertical or steeply dipping and are of the nature of shear joints. Indications of minor, vertical slip movement has been found on field check along many of them, no major vertical movement has been noticed along any of them". According to these workers the intense fracturing of the Deccan Trap surface along with dyke intrusions in Narmada - Tapi valley shows trends that are compatible with the trend of Cambay graben and the Narmada - Tapi graben respectively. These workers have further stated that although the fractures are seen on the surface may not be directed to the basement but they have definitely been formed due to deep seated phenomenon affecting



the mantle. High heat flow values in parts of the western coastal area comparable to that in the ocean ridges are mentioned by Bose (1972), and he suggests that "this would imply an active mantle at a relatively shallow depth", and the gravity anomaly data typically points to a steep rise in gravity values towards the West Coast near Surat and Bombay and as far as Ratnagiri in the south. Das & Ray (1977) argue that in the highly fractured West Coast it would only be logical to say that the fault shear planes will have to extend beneath the Trap presumably in to the basement and through it to the mantle to account for the gravity anomaly.

The post-Mesozoic geological events in Western India are closely connected with the break up of the Gondwanaland and the NNEward drift of the Indian plate. The reactivation of the Narmada geofracture system as well as the formation of the Tertiary Cambay and the Narmada - Tapi basins are the manifestation of the plate tectonics, responsible for the opening up of the Indian Ocean and the collision of the Indian plate with the Eurasian plate. The entire tectonic framework and related structural features, could be related to the Indian plate movement. The Deccan basalt was the fore-runner of these tectonic events. According to Sukheswala (1981), the major events of the geodynamics of the Tertiary Era, viz. the break-up of the Gondwanaland and the uplift of the Tethyan geosynclinal tract had a great role to play in moulding and readjustment of the peninsular crust. The prodigious outburst of igneous activity of this Era- the Deccan Traps, cannot but be linked with these earth

movements. Sykes (1978) has very aptly suggested that the high compressive stresses of the zone of continental collision, were transmitted into the western margin of the Indian plate and that, the tectonism and related peninsular earthquakes along this margin comprised manifestations of the reactivation of older zones of weaknesses; such reactivated areas being the N-S Cambay basin, and the E-W running Satpura basin (= Narmada-Tapi basin).

✓ Krishnaswamy (1981) has correlated these two directions with the "well known triple junction formed by the convergence of ENE-WSW trending Son - Narmada lineament-cum-graben belt, the N-S trending Konkan and off-shore block faulted belt and the NNE-SSW trending Cambay graben belt. There are several shear zones and dyke systems in the Deccan lava pile that parallel the directions of the three major tectonic belts listed above".

An excellent genetic account of these rift basins has recently been given by Biswas (1982, 1987), he has listed three rift basins along the western margin of India, viz., Kutch, Cambay and Narmada, each comprising graben sites bounded by faults related to India's drift history from the time of its breakup from Gondwanaland. According to Biswas (1982), the extension of the marginal rifting along Dharwar trend opened the southern part of the Cambay basin. India's collision with Asia during the Palaeocene and Eocene synchronised with the formation of the Cambay basin. This was preceded by the widespread Deccan Trap volcanicity. He has written "the stages of development of

the western margin rift basins and the stages of India's northward trek from Gondwanaland to Eurasia are synchronous events. The basins opened one after another from north to south as the sub-continent drifted northward at an increasing pace and rotated counter clock wise during the Mesozoic. It may be concluded from this that the tectonic events in these basins are local responses to the major geotectonic events within the continental block".

The tectonic framework of the South Gujarat highlands upon which this account dwells, is closely related to the Cambay basin and Narmada Tapi basin structures, and in fact, they are located on the southeastern flank of the Cambay basin boundary (Fig.II.1). Obviously, the structural grain of the area is a reflection of the Cambay basin tectonics. Most workers who have described Cambay Tertiary basin (Mathur et. al. 1968, Raju, 1968, Biswas, 1982, 1987) have categorically stated that the tectonics of the basin typically reflect structures related to Narmada and Dharwar trends (Fig.II.2). Interestingly, the fracture pattern and the fault trends recorded in the study area, are also related to the above two regional structural trends and they have a significant influence on the entire landscape evolution. Rao (1987) has described the regional framework of the Cambay basin as 'avlakogens' of Russian geologists, according to whom "platform structures (basins) of this type are characterised by pronounced subsidence in the early stages of their development, sometimes accompanied by volcanism. Invariably, zones of elongated elevations (ridges, swells, etc.)

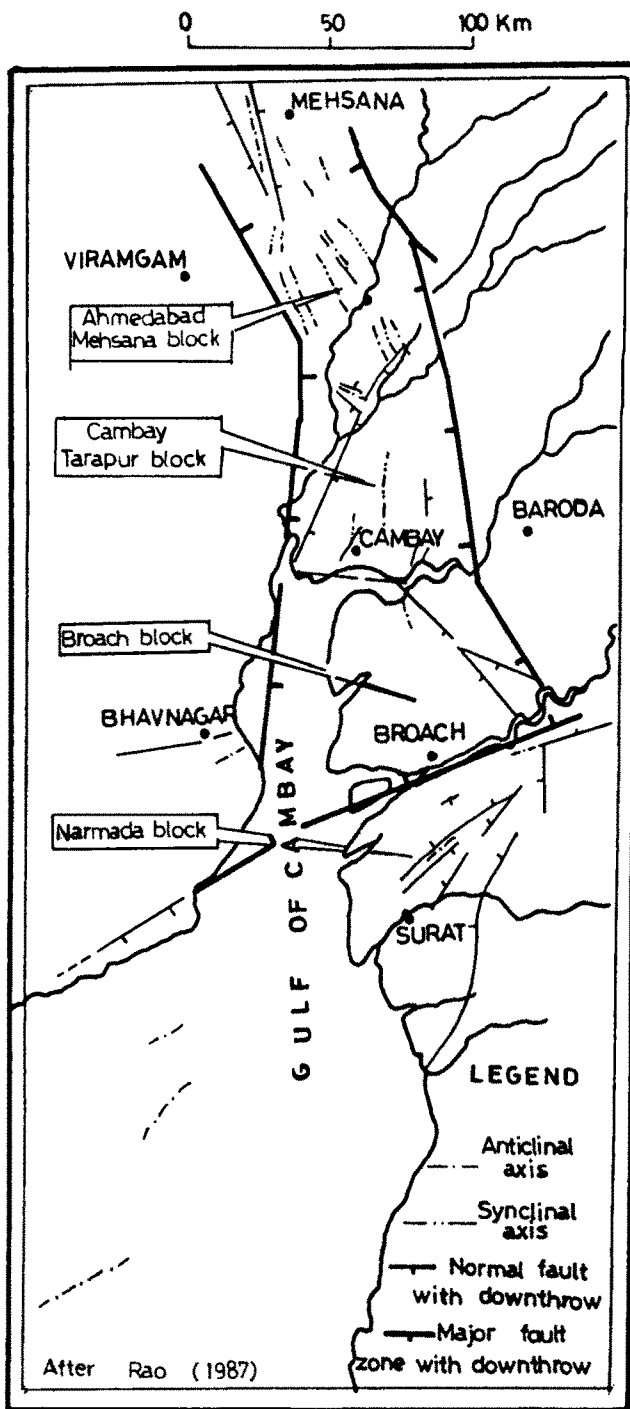


Fig:II.1 TECTONIC MAP OF CAMBAY BASIN

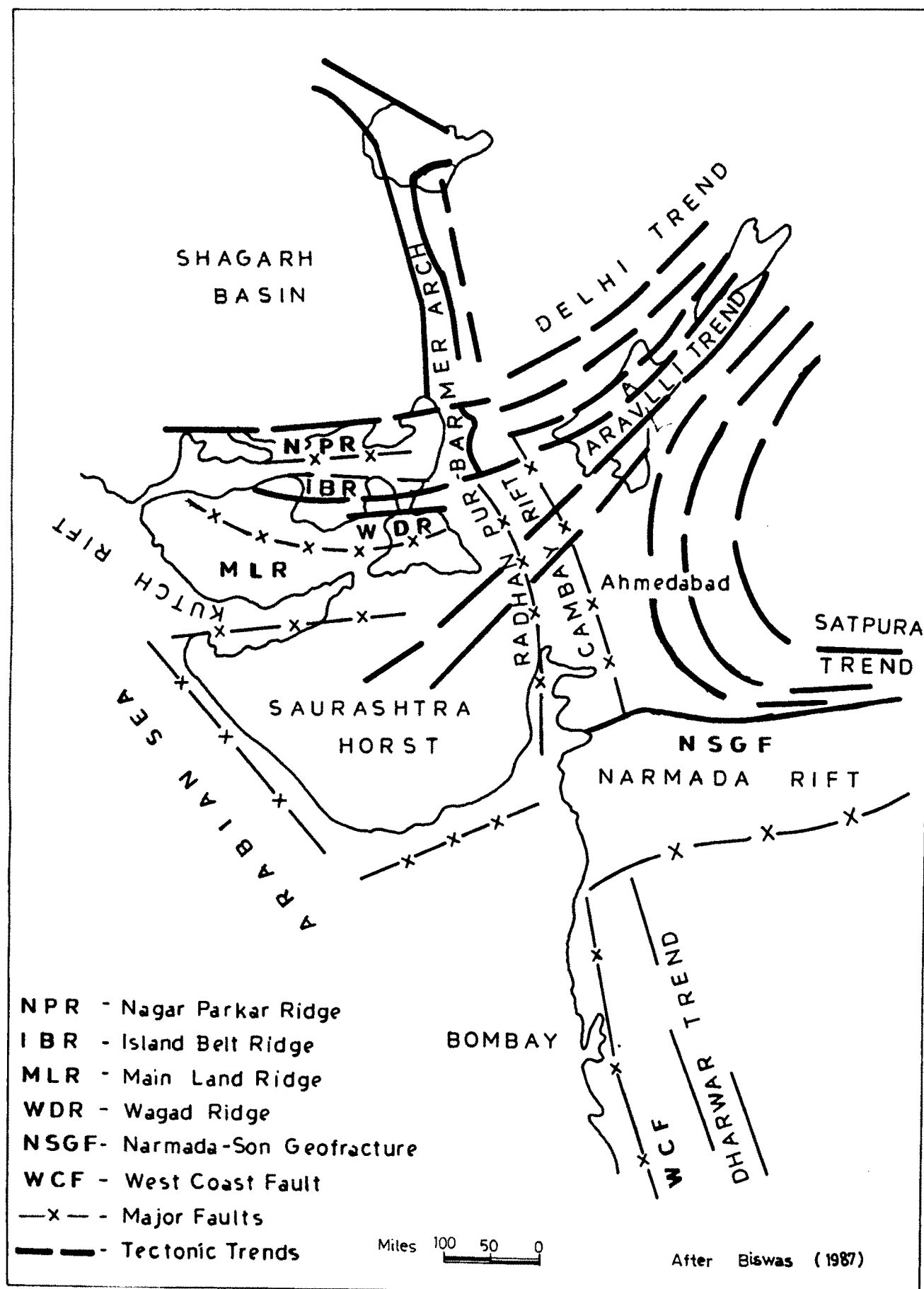


Fig: II.2 PERICRATONIC RIFT BASINS WITH MAJOR STRUCTURAL LINEAMENTS

produced as a result of tectonic inversion are the characteristics of such basins. Fault bounded structures are therefore common. Cambay Tertiary basin is similar to this type of basins".

Sychanthavong (1984) has provided a good picture of the tectonic framework of the study area. He has critically analysed the various lineaments as revealed by ERTS studies, and has concluded that the reactivation of various Precambrian zones of weaknesses during Mesozoic and Cenozoic times has been responsible for the existing tectonic framework of Kutch, Saurashtra and Mainland Gujarat. In his words, "all the above stated first generation of faults have been off-set by the Tertiary (second and third generation) and Quaternary (fourth generation) faults during Late Tertiary and Quaternary tectonic episodes. There are several sets of these smaller faults in Kutch Mainland and in the Great Rann of Kutch bounding the four islands. In Saurashtra too, several such faults are recorded far away from the intersection points of the first generation fractures. The minor faults, traced within the Cambay basin, cutting the Late Tertiary rocks (Mathur et.al 1968; Raju, 1968) are nothing other than belong to this late category of faults".

#### GEOMORPHOLOGICAL ASPECTS

No previous literature on the geomorphological aspects of south Gujarat is available, as no work has been carried out in this part either to study the geology or geomorphology of the

highlands and coastal plains. By and large, there has been a tendency to accept the prevailing concepts of a typical step-like trappean topography, commonly invoked for the Deccan basaltic terrain to the east and the south. Successively rising flat levels separated by steep scarps, have generally been taken as dominantly showing a topography of differential erosion of a horizontally layered lava sequence. Although, structural features of the highlands and the coastal areas did receive some attention, the role of morphotectonics in the landscape evolution was not understood or highlighted. The emphasis has been on the landscape evolution vis-a-vis response of varying lithology to erosional processes.

In the larger context, geomorphically, the South Gujarat, highlands form the northernmost portion of the Western Ghats Escarpment that separates the coastal zone from a high plateau all along the West Coast of India. As early as 2 1/2 decades back, Radhakrishna (1965) made a very significant morphotectonic contribution. He discussed the physiography of the Western Ghats and suggested that the Ghats represented the precipitous edge of an elevated plateau, and they showed evidences of rejuvenation, indicative of uplift. Following observations made by him, are of considerable relevance to the present study : -

- (i) There have been differential movements of certain segments of the trap both during and subsequent to their formation. There are several instances of block faulting in different parts of the trap country. The valleys of the Narbada and

Tapti are of the nature of rift valleys, the result of sag faulting of the traps. The long scarps of the Satpura and Gawligarh hills extending in an east-west direction are considered to be the result of faulting. The traps have been let down to a depth of 8000' in the Cambay area in the form of a north-south faulted through which is now seen as the Gulf of Cambay. Where a whole basin like the one we are considering is affected by vertical movement, there are bound to be differential upwarps and downwarps.

- (ii) The base of the Western Ghats in the Ratnagiri, Colaba and Surat districts is marked by a line of hot springs indicative of faulting.
- (iii) A significant point which emerges from a Bouguer anomaly map by M.N. Qureshi is that the Peninsula is not a stable and homogeneous mass as is generally supposed. It shows regions of positive and negative anomalies indicative of crustal instability.
- (iv) It is again significant to note that the western edge of the Peninsula now represented by the Western Ghats is characterised by large gravity anomalies and lack of equilibrium in the same way as the extra Peninsular region formed by the Himalayan mountains. The reason for this negative anomaly over the Peninsula has not been satisfactorily explained. When it is recognised on the basis of other evidences that the Peninsular region has



suffered from pronounced upwarp at more or less the same time as the uplift of the Himalaya the reason for the significant negative anomaly over this region indicating crustal instability becomes at once apparent.

- (v) The present day occurrence of laterite in India, indicates that they are formed over flat featureless peneplains more or less close to the sea level. Although laterites are found at the present day at different levels they are not necessarily formed at those levels. The differences in the present-day position of laterite is a measure of the uplift and tilting, if any, from the original level at which they were formed.

The Western Ghat escarpment marks the site of a crustal fracture. The DSS profile drawn by Krishna & Kaila (1986) for the Koyna area of Maharashtra shows this deep seated fracture. This fracture is indicated by a line of hot-springs. According to Gubin (1969), these hot springs arise along a fault zone within the basement. Obviously, the western portion of the Deccan Trap seems to hide structural features such as faults and fractures below them. Scheidegger & Padale (1982) believe that the morphology of Western Ghats does not point to pure erosion, but indicates a tectonic control.

According to Ollier & Powar (1985), the Western Ghats comprise a unique morphotectonic feature and characterise a new continental edge at the time of the break up of Gondwanaland that

was accompanied by uplift, and that the continental edge was created in the late Cretaceous, just preceding the Paleocene Deccan Traps. Following the eruption of the basalts the continent was uplifted with tilting from west to east. These authors have made an important observation, which is of much relevance to the present author's findings. They have envisaged that some east-west valleys may be older than the formation of the west coast of India dating back to Gondwanaland and the Paleocene Deccan Traps have the same sort of drainage pattern as non-basaltic areas, and so the drainage pattern is not a peculiarity of the basalt.

Geomorphology of the Deccan volcanic province has been described by Subramanyan (1981). Although, he has taken the various tectonic features and lineaments into consideration yet he has not been able to highlight the influence of tectonic features on the landforms. He appears to be more inclined to give prominence to erosional surfaces. He has stated; "Regarding the evolution of the landscape over the vast Deccan basalt country which is admittedly a highly complex affair, the data on the altimetric frequency and the duricrust point to the operation of four erosional cycles, three of which appear to have produced end surfaces at the following elevation ranges, the oldest between 1600 m and 1500 m the second between 1100m and 1000m and the third between 700 and 500 m. The fourth cycle is operating currently towards the formation of a surface between 0 and 100 m. More work need to be done to confirm these proposed cycles and

surfaces and date them". Obviously, he did not take into account the role played by regional faults in the evolution of basaltic landscape. He has only described a broad relationship between fractures and drainage and stated that, in the lower Narmada Valley, the Narmada has been diverted to the northwest from its southwesterly course by a powerful NW-SE fault. This fault has offset ridges also and brought about many sympathetic dislocations all of which have been picked up by the drainage segments. To the east of this faulted course of the river, a trellis-rectangular drainage has developed on many NW-SE and ENE-WSW trending faults, while to its west, the river flows in and out of NW-SE faults, producing unusual 'box' meanders with straight sides. Many cuestas with northerly dip-slopes run ENE-WSW to the east of this fault.

As already stated earlier, no systematic geomorphological account of the study area or its neighbourhood is available in literature. Recently, Vyas (1984) who studied the region between Tapi and Narmada rivers, just north of the study area, has given a geomorphic account which is of some relevance to the present study. He classified his study area into three divisions viz. (i) Rugged basaltic hills, (ii) Uplands and (iii) Coastal plains: : The rugged basaltic hills broadly comprise the southeastern part of his study area in sensu stricto forming the Rajpipla hills. Geographically, these represent the westernmost offshoots of the Satpura hills. Made up entirely of horizontal lava flows of Deccan Trap, the ruggedness and physiographic diversity of its different parts are mainly on account of degree and extent of

dissection brought about by erosion along different sets of joints and fractures. The degree of erosion in the northeastern part is so high that nowhere the horizontal nature of the original surfaces are recognisable, and the entire landscape is seen to consist of narrow topped irregularly disposed ridges, rising to heights between 400 to 800 m. Southward, the geomorphology shows a change, and in the southern part of the Rajpipla hills, the topography essentially reveal a much dissected plateau whose remnants are still prominently recognised. The existing topographic features consist of flat-topped plateau relics, ridges, hills and intermontane valleys. The summits and crests rise to altitudes between 600 to and 700 m. The farthest portion to the southeast is made up of linear basaltic ridges, the ENE-WSW aligned trappean ridges form four parallel chains of ridges, the height of summits ranging from 300 to 450 m. The most conspicuous and well defined drainage directions are NE-SW and ENE-WSW. Significantly, the entire drainage pattern by and large reflects the various fracture directions which includes N-S direction also.

Regarding the uplands Vyas (1984) has described them as an undulating terrain dotted with low altitude hills and ridges. These uplands occur to the west and southwest of the rugged hilly terrain. They are seen to comprise basalts of Deccan Trap, Tertiary rocks, and alluvial and residual soils of Quaternary Period. The coastal plains, that lie to the west of the uplands end up a highly dissected and muddy coastline. The coastal

plains are characterised by an ascending sequence of Tertiary and Quaternary deposits.

As compared to the highlands and uplands, the coastal areas have recieved more attention in recent years at the hands of the research workers of the Department of Geology of (M.S. University of Baroda). In a series of papers, the various depositional and erosional landforms related to glacio-eustatic sea level changes and neotectonism have been described (Vashi & Ganapathi 1982; Patel et.al. 1982, Al hashimi & Vashi 1988) Several generations of coastal dune ridges, tidal mudflats, and raised beaches, as well as entrenchment of channels and estuarine river-mouths are the typical landforms that characterise the coastal areas. ✓