CHAPTER VIII

MORPHO-TECTONIC EVOLUTION

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GENERAL BACKGROUND

The morpho-tectonic history of any area owes its significance to the length of stratigraphic record in time and space and depositional environments, past climatic vicissitudes, palaeo-geographic conditions and tectonic events responsible for imparting manifold changes in terrain conditions. The drainage which is considered to be the architect of terrain modifications is also influenced by these parameters.

The study area represents a rather complex morpho-tectonic setting and history, attributed to the following factors :

(i) The longest sedimentation record stretching between Archaean and Holocene times.
(ii) Undergone the process of all the major orogenic movements in Peninsular India.
(iii) Drastic modifications in geomorphic fabric of the area due to Quaternary climatic changes and neotectonic activity.

Apart from above listed complexities a large chunk of the study area is concealed beneath the active and stabilized dunal sands, thereby the delineation of morpho-tectonic parameters at places is postulated and conjectured.

Looking to innumerable morpho-tectonic inputs and their multiplicity in terms of reactivation and superimposition, the author has strived to provide sequential account of the terrain evolution through a series of conceptualised models. These models have been prepared on the basis of available information, remote sensing data and of course, the author's imaginatory inputs

The entire morpho-tectonic history of the study area has been divided into two major divisions *viz.*,

(i) The pre-Quaternary morpho-tectonics and
(ii) The Quaternary morpho-tectonic evolution.

As the major emphasis of this present study has been on the Quaternary aspects and the watershed hydrogeology, the Pre-Quaternary morpho-tectonic history has been dealt in a concised form.

PRE-QUATERNARY MORPHO-TECTONIC EVOLUTION

From the foregoing account on the geological framework and the tectonic setup of the study area and its neighbourhood it can be noted that the study area from east to west harbours the lithostratigraphic sequences belonging to B.G.C. (Archaean), Aravalli-Delhi (Precambrian), Marwar (Palaeozoic) Supergroups and the lower Tertiary formations. The Precambrians are distinctly characterised by their deformational history and tectonic regime.

The Palaeozoic and Tertiary rocks have distinguished lithofacies, depicting well defined depositional environments and geomorphic setting but tectonically less influenced. A summarised account on the morpho-tectonic history of the study area during Pre-Quaternary period with the help of conceptual model is given as under:

AZOIC ERA (ARCHAEAN)

Owing to highly complex nature and debatable issues, not much information is available on this oldest time stratigraphic basement terrain i.e. Banded Gneissic Complex. However, scrutiny of available evolutionary data which certainly throws some light on land-sea boundary conditions vis-à-vis its ancestral parentage with other continental mass; suggests its separate existence as old as 2100 M.y. (Athavale *et al.*, 1970).

Considering the geological and geochronological evidences, it could be surmised that prior to this period the B.G.C.-Aravalli proto-continent must have been a part of much larger northwestern proto-continent i.e. the Siberian Shield (?) which broke down and started drifting southeastward towards the Dharwar and Singhbhum proto- continents (Sychanthavong and Merh, 1985).

Hence, the rifting of basement mass for paving the way for deposition of the Aravalli must have taken place prior to the separation i.e. Early Precambrian. The distribution pattern of B.G.C. outcrops and their contact with the Aravallis provide substantial evidences of NE-SW and NW-SE fractures (Fig. 8.1), responsible for the development of deep intra-cratonic basins in which the deposition of Aravalli sediments took place (Fig. 8.2).

EARLY - MIDDLE PRECAMBRIAN ERA

The sedimentation of Aravalli sediments under eu-geosynclinal conditions was followed by the first mountain building activity i.e. < 2300 M.y. (Naha and Halyburton, 1974) and upliftment of the Aravalli Mountain Range (Fig.8.3). The uplift of Aravalli has resulted in the development of a sharp NE-SW trending orographic high with a broad low lying undulatory B.G.C. terrain in its western parts.

MIDDLE - LATE PROTEROZOIC ERA

The process of drifting of B.G.C.-Aravalli proto-continent continued up to 1650 M.y. During this interval the western part of the B.G.C. due to faulting has created the Delhi basin (Fig.

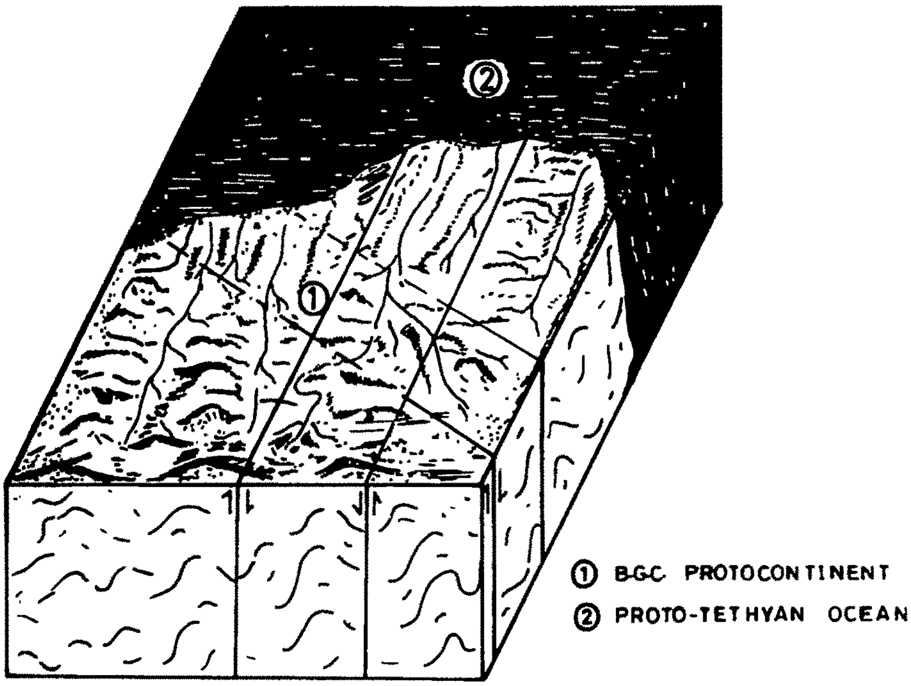

Fig. 8.1. LAND-SEA CONFIGURATION DURING ARCHAEAN - EARLY PROTEROZOIC

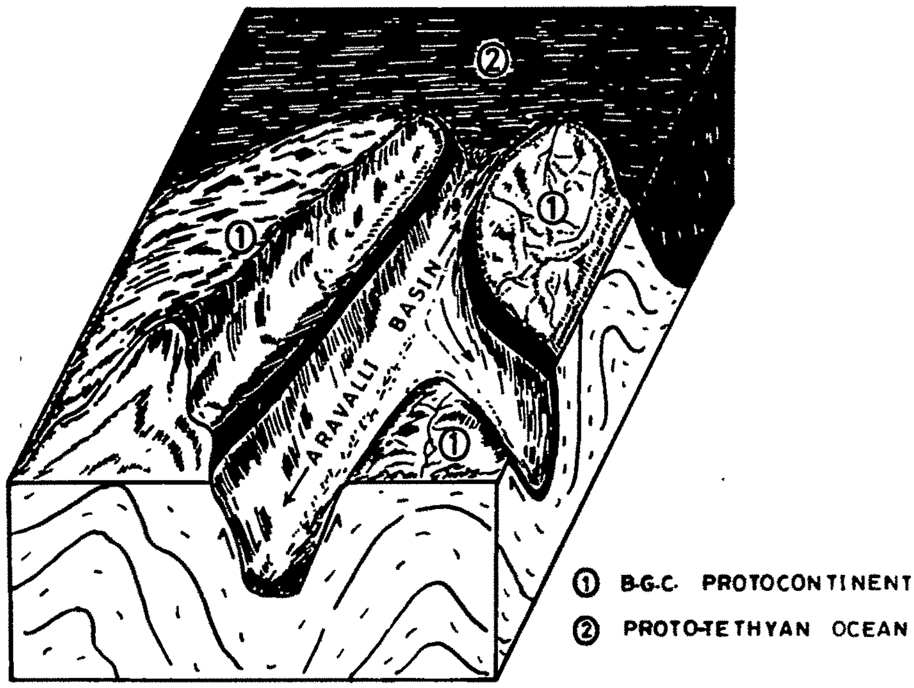

Fig. 8.2. CREATION OF ARAVALLI BASIN DUE TO RIFTING OF B.G.C. PROTOCONTINENT (EARLY PROTEROZOIC)

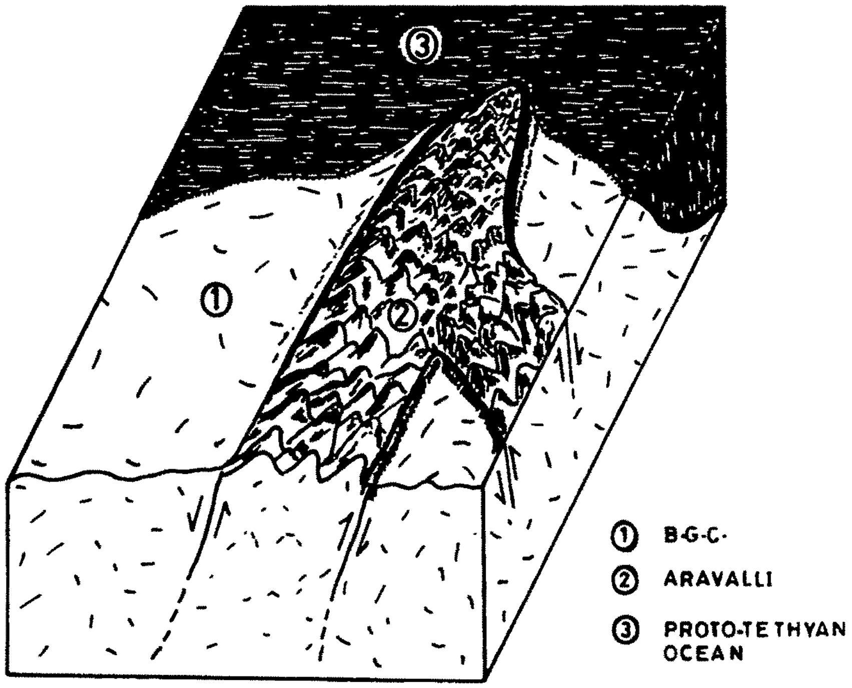

Fig. 8·3. UPLIFTMENT AND MOUNTAIN BUILDING OF ARAVALLI MOUNTAIN BELT (EARLY-MIDDLE PROTEROZOIC)

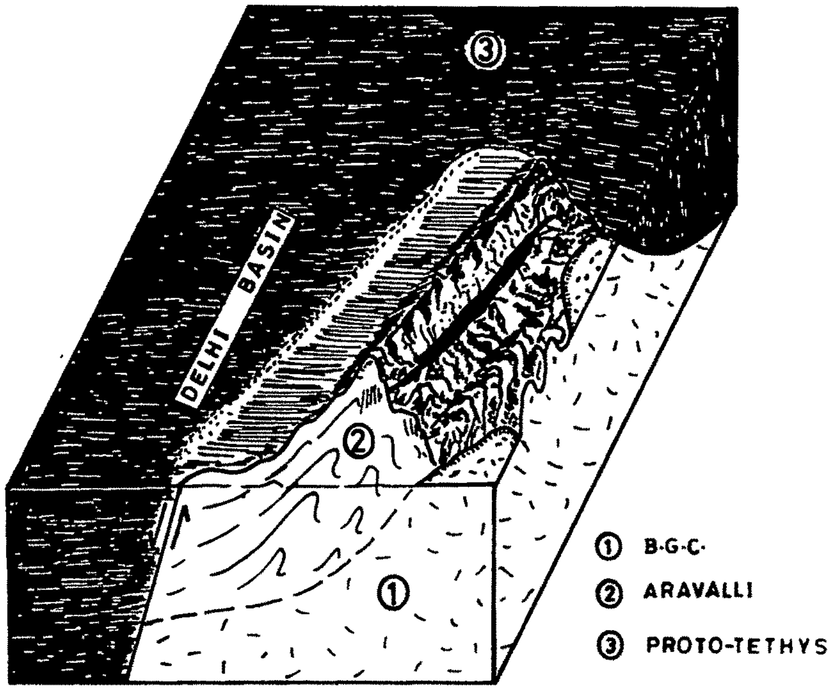

Fig. 8·4· RIFTING OF ARAVALLI B-G-C PROTO-CONTINENT AND CREATION OF DELHI BASIN (MIDDLE PROTEROZOIC)

8.4). Rapid and prolonged denudation of upthrusted Aravalli block has resulted in the deposition of Delhi Supergroup of rocks, the Alwar's on the proto-continental shelf and the Ajabgarh's in the deeper leptogeosyncline. The subsequent orogenic movements were responsible for squeezing and crustal shortening, resultantly the whole Delhi mountain range thrust over the underlying Aravalli-B.G.C. basement (Fig. 8.5). The continual squeezing and crustal shortening has developed series of steep faults in Alwar's and low angle thrusts in Ajabgarh's (Sychanthavong and Merh, 1985). The lineament features are clearly borne out on the satellite imagery.

Even the development of Luni-Sukri lineament couplet representing cymatogenic arch graben (Ramasamy *et al.*, 1991) have been developed during the ongoing process of squeezing of Delhi sediments and crustal shortening. Through series of NE-SW trending longitudinal dislocations/crustal fracturings, the intrusion of Erinpura and Khetri granites and later the Malani's have taken place.

The mountain building activity during Delhi Orogenic cycle (i.e. $DF_1 = AF_2$ to DF_3 folding and magmatism) has resulted into large scale changes in orographic expressions and land-sea boundary configuration. The beginning of Vindhyan's sedimentation in the intra-cratonic basin (auto-geosynclinal), closing up of proto-Tethyean ocean in the west have provided the morphological expression as Delhi-Aravalli-B.G.C. highlands flanked by low lying shelf zone (later developed as Marwar basin) in the west and intra-cratonic basin in the east.

LATE PROTEROZOIC - EARLY PALAEOZOIC ERA

This span of geological history is significant from the point of view of tectonism and palaeo-geographic conditions of the subcontinent, *viz.* the unification of Gondwana-Proto-continents i.e. 700-650 M.y., DF_3 deformation and profused magmatism i.e. Malani Igneous Suite. The acceleration in erosion due to uplift of Delhi-Aravalli-B.G.C. mass has accentuated the beginning of Trans-Aravalli Vindhyan's (Marwar Supergroup) deposition, under shallow marine shelf environment.

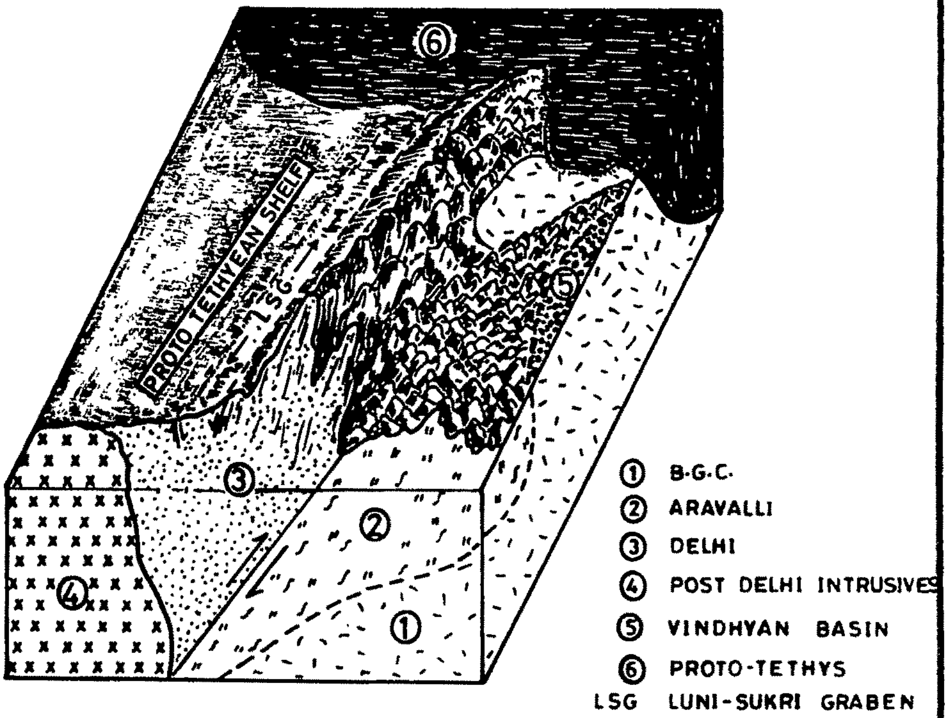

Fig. 8·5· UPLIFTMENT AND MOUNTAIN BUILDING OF DELHI MOUNTAIN CHAIN ERINPURA GRANITE EMPLACEMENT AND CREATION OF VINDHYAN BASIN (MIDDLE-LATE PROTEROZOIC)

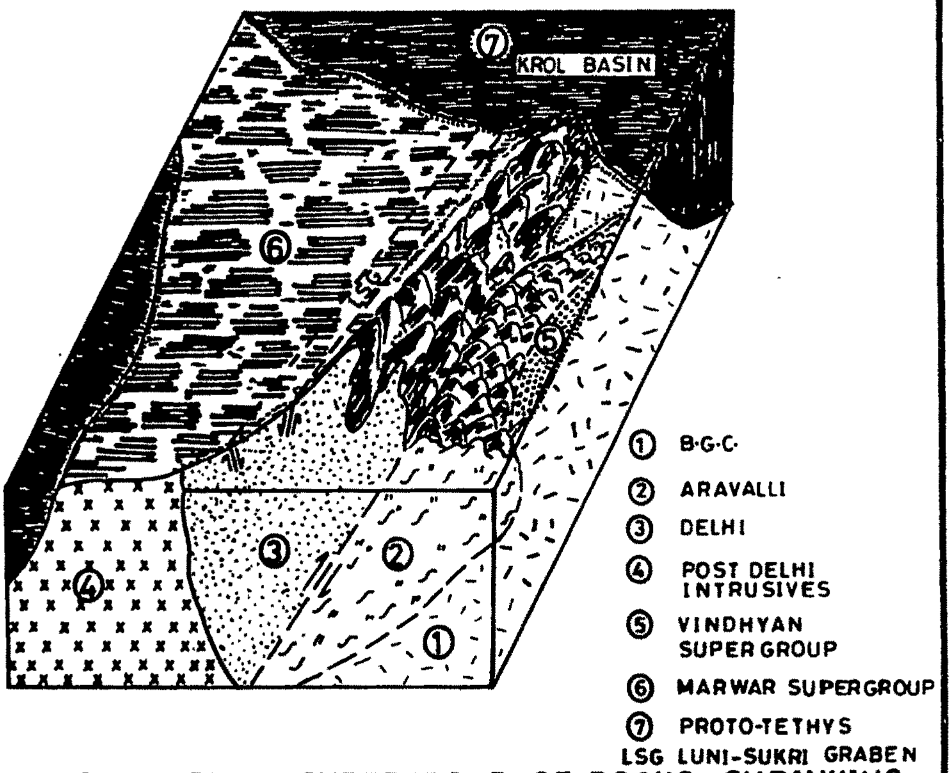

Fig. 8.6. DEPOSITION OF MARWAR SUPERGROUP OF ROCKS SHRINKING OF PROTO-TETHYS INTO KROL BASIN (CAMBRIAN)

The regression or closing of proto-Tethyean sea in the west has brought into emergence these sedimentary sequences of Marwar Supergroup of rocks; typically characterised by a vast tabled land, ultimately merging in the pediment plains of high altitude Delhi-Aravalli mountain chain (Fig. 8.6).

LATE PALAEOZOIC ERA

The palaeo-geographic setup for the period ranging from Upper Cambrian to Middle Carboniferous is represented by a major stratigraphic hiatus. The entire Rajasthan Shelf Zone had experienced regression and vast glaciation phase; the glaciers sloping and drifting northwards to the Indus basin, carrying the Malani rhyolite, granite etc., recognisable now as Bap boulder spread. The sea was disclosed by retreat of ice during Upper Carboniferous and the marine transgression extending from Indus basin to Salt Range through northwestern Rajasthan shelf (Pareek, 1979). This transgression must have been existed for a brief period, which is evident from small patches as Badhaura Formation (in neighbouring area) of Permian age.

THE MESOZOIC ERA

The Mesozoic era has witnessed another phase of regression (Triassic) and transgression (Jurassic-Cretaceous). However, the study area remained a part of land, permitting erosion and source of sediment supply to Lathi basin. The Late Cretaceous-Palaeocene marks an important event in the earth's history i.e. the separation of Gondwana land. Resultantly, the down bending of proto-Tethyean sea was responsible for the first phase of Himalayan uplift i.e. the Karakoram orogeny. This has accelerated the erosional activity in the northern fringe of the study area.

CENOZOIC ERA

The Indian subcontinent has witnessed intensive tectonism and drastic land-sea boundary and topographic modifications during Cenozoic era. The tectonic events were mainly related to the collision of the Indian plate with the Tibetan plate, responsible for imparting NNW-SSE, E-W fracture systems, the development of crystalline nappes along Main Central Thrust and rapid rise of Himalayas under second and third uplifts (i.e. the post-Kirthar and Sirmurian orogenies) during Late Eocene-Middle Miocene period. This rapid rise of Himalayan mountain range was responsible for creation of Himalayan fore-deep zone (Siwalik trough), development of new drainage system and rapid erosion of Himalayan rocks, thereby beginning of Siwalik sedimentation (Fig. 8.7).

During this period, due to Himalayan uplift, the Rajasthan Shelf Zone has witnessed marine transgression, which was limited to the fringe parts of the shelf zone. In the author's study area, along the tectonically formed depression, i.e. the Bikaner-Palana embayment, the sedimentation of Palana- Marh and Jogira beds took place (Fig. 8.8).

QUATERNARY MORPHO-TECTONIC EVOLUTION

The post Eocene period was marked by complete regression of sea from the fore deep zone as well as the Rajasthan Shelf Zone. Continual intra-plate subduction and heaving up of southern Himalayan province once again caused the Himalayan uplift (fourth phase i.e. Siwalik uplift) during Mio-Pleistocene period (Thakur, 1995). This has resulted in the development of Main Boundary Thrust and the rise of Siwalik mountain range (Fig. 8.9).

Similarly, the subsidence of the northern parts of the Indian plate i.e. the northeastern margins of the study area in particular, was responsible for creating the Indo-Gangetic basin, in which rapid sedimentation took place during early Quaternary period. The manifestations of Siwalik orogeny in the peninsular parts were the development of Great Boundary Fault (GBF), reactivation of Luni-Sukri lineaments, which have ultimately generated major fault systems of Didwana-Dausa-Kasganj, Raisinghnagar-Tonk and Sardarshahar-Ganganagar.

Under this morpho-tectonic scenario, and after filling up of the Indo-Gangetic basin, perhaps during Lower Middle Pleistocene period, the major drainage system 'the Proto-Luni' (Proto-Yamuna) was initiated following the regional southwesterly topographic slope, along the western pediment plains of Delhi mountain chain and ultimately meeting the Arabian sea (Fig. 8.9).

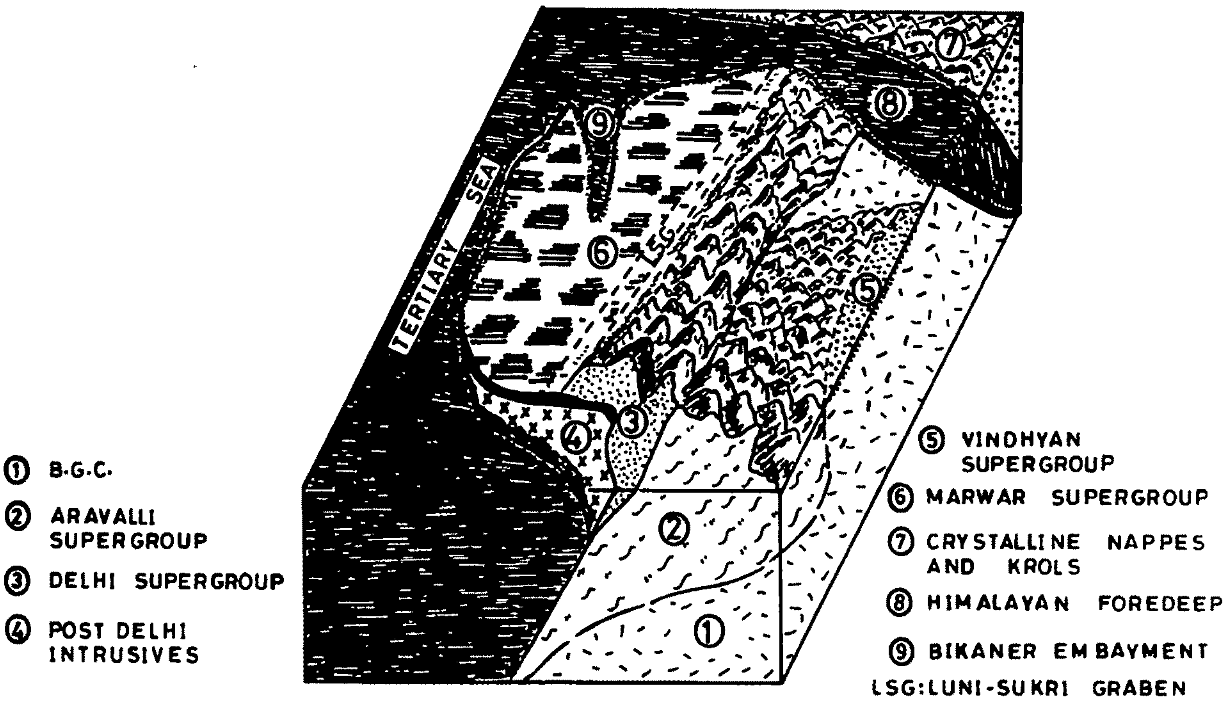

Fig. 8.7. HIMALAYAN OROGENY (POST KIRTHAR), TERTIARY TRANSGRESSION, CREATION OF HIMALAYAN FOREDEEP ZONE (EOCENE-MIDDLE MIOCENE)

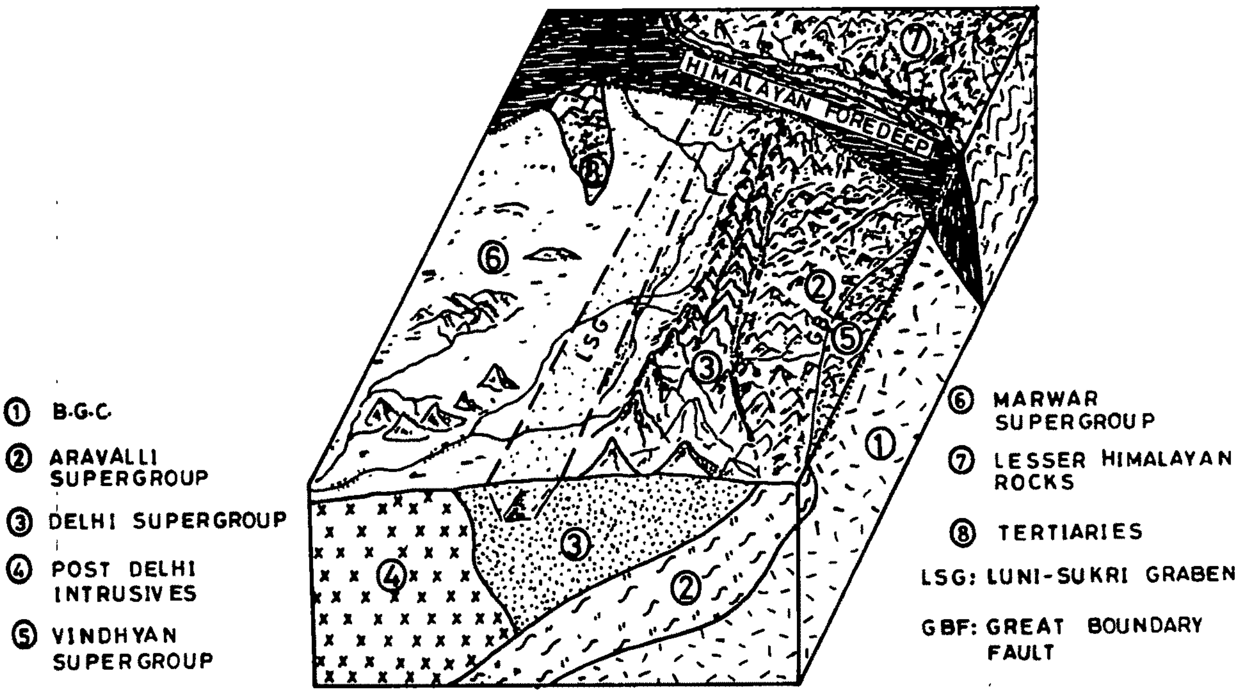

Fig. 8.8. REGRESSION, EMERGENCE OF BIKANER-PALANA TERTIARY FM., THRUSTING OF ARAVALLIS OVER VINDHYANS (NEOGENE)

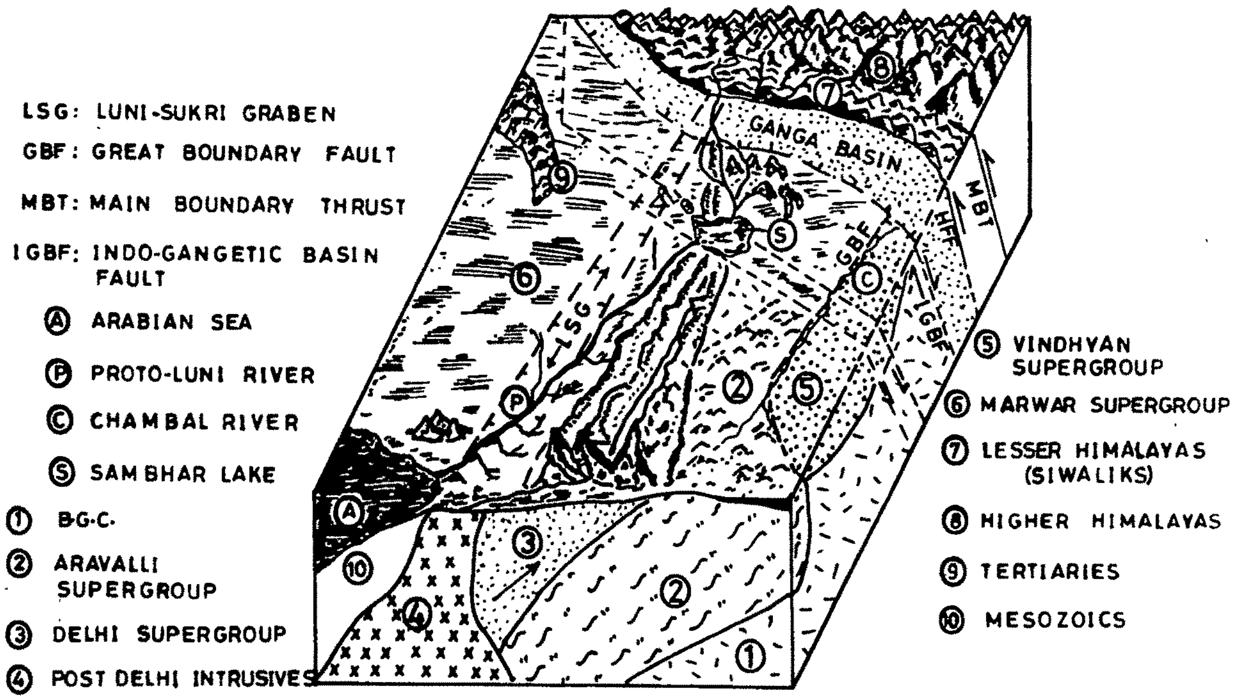

Fig. 8.9. REACTIVATION OF GREAT HIMALAYAN THRUST (MBT), RISE OF SIWALIK RANGE (SIWALIK OROGENY), FORMATION OF INDO-GANGETIC BASIN AND SEDIMENTATION, CREATION OF SAMBHAR BASIN DEVELOPMENT OF PROTO-LUNI DRAINAGE SYSTEM (E-M PLEISTOCENE)

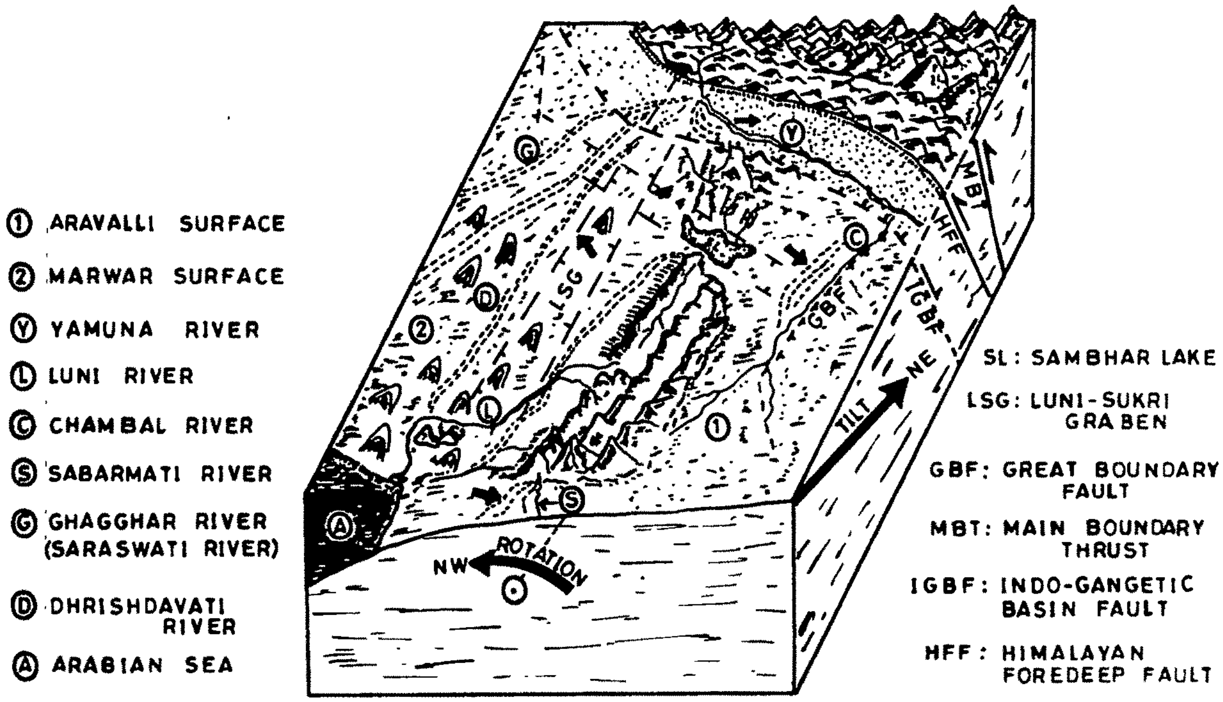

Fig. 8.10. DEVELOPMENT OF SERIES OF NW-SE FAULT SYSTEM, NORTH WESTERLY TILT OF ARAVALLI DELHI MOUNTAIN CHAIN PLUNGING NORTH EAST, PROTO-LUNI DRAINAGE DISRUPTION-MIGRATION, CARVING OF SEPARATE YAMUNA CHANNEL, DHRISHDAVATI, GHAGGHAR ETC. DESSICATION, INCREASE IN ARIDITY, DUNE BUILDING ACTIVITY. (LATE MIDDLE - LATE PLEISTOCENE)

Throughout the Quaternary period this particular part of the Indian subcontinent remained tectonically active. Under the influence of subduction of Indian plate with the Tibetan plate; within the Himalayan collision zone, the reactivation of pre-existing fault/fracture system was inevitable. The whole Aravalli-Delhi mountain range was subjected to gradual and differential upliftment, along the GBF in the east and the Sardarshahar-Ganganagar fault in the west (Ahmad and Ahmad, 1980).

The author's observations on the presence of strong field signatures in terms of past drainage, topographic slopes etc. have led to the conclusion that the uplift of Aravalli mountain range along above mentioned fault systems was with an anti-clockwise rotational tilt (Fig. 8.10). This anti-clockwise northwesterly rotational tilt with 15°-20° plunge due northeast was responsible for gradual migration of drainage system in northwesterly direction in the Trans-Aravalli terrain; southeasterly shift in Indo-Gangetic plains, southeastern basement peneplains and north Gujarat alluvial plains. The topographic slopes also have been modified in accordance to the tilting i.e. gentler in southeastern parts and steeper in Trans-Aravalli sectors.

Subsequent pulses of neotectonic activity have drastically influenced the mountain chain in its northeastern parts i.e. Sambhar lake-Khetri area. The differential uplifts have created alternate horst-graben configuration, drainage disruption and topographic inversion. The overall mechanism and sequential evolution of drainage system of the study area and its neighbourhood has already been discussed in the chapter on Drainage and Playas.

The drainage disruption coupled with climatic change from wet-humid to warm-arid has initiated the dune building activity and the creation of vast desertic plains.

Late Quaternary-Holocene period is characterised by the wet-humid climatic conditions i.e. post-Younger Draya phase. During this period, the vast aeolian terrain has witnessed a lacustral phase characterised by low salinity fresh water phase. However, later climatic changes were responsible for desiccation of these pluvial lakes and playas, resultantly large scale evaporite sequences were developed across the Thar desert.

During the Holocene period i.e. 10,000 Yrs. B.P - Recent, the area is under ameliorating climatic conditions, but dominated by the semi arid climate (Fig. 8.11). Now the rivers are ephemeral, the landscape is subdued and predominated by illuvial weathering rather than the fluvial. Topographic expressions are frequently manipulated in the corridors of active dune fields.

The above discussed morpho-tectonic evolutionary history of the study area, in author's opinion does not provide a total picture, which is obvious due to its large number of inputs, intricacies of tectonism vis-à-vis terrain characteristics etc. At least a beginning is made with a scope for future improvements in the conceptualised morpho-tectonic model of the northeastern Thar Desert and its environs.

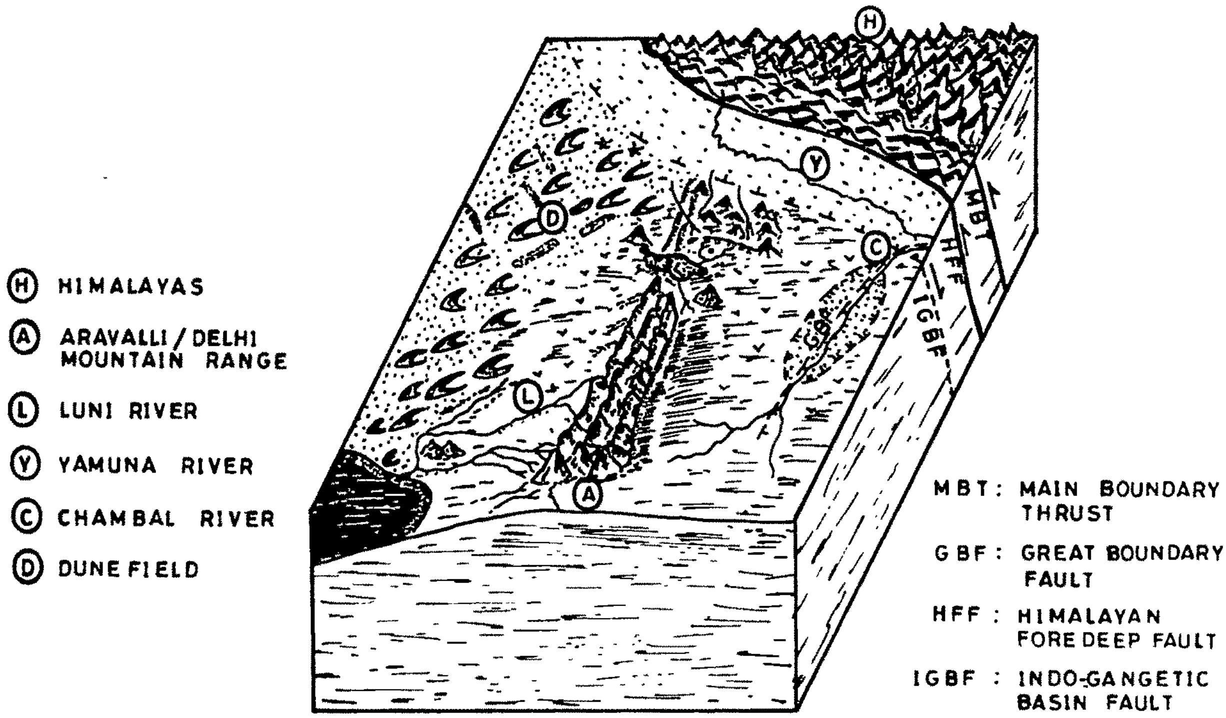

Fig. 8.11. PROGRESSIVE ROTATIONAL TILT OF THE ARAVALLI MOUNTAIN CHAIN, LOCAL UPLIFTS, CARVING OF KANTLI, MENDHA, CHANDRAWATI AND SABI RIVER CHANNELS, ACTIVE DUNE BUILDING PROCESS AND PRESENT DAY LANDSCAPE (HOLOCENE - RECENT)