PART : 2

CHAPTER : IV

KHADIR ISLAND - BACKGROUND INFORMATION

BACKGROUND INFORMATION :

The Khadir Island, which forms the main topic for the present investigation lies in the Survey of India Toposheet No. 41.I/5 and part of 41.I/1 [1:50,000 scale], between latiitude 23°45'00" to 24°00'00" North and longitude 70°10'00" to 70°30'00" East. In addition to the main Island region, the Author has extended his investigations to the satellite island Chhariya Bet [23°56'15" : 70°20'15"]. The Khadir Island further has a strategic importance being on the Indo-Pakistan boarder. Recently it has acquired importance for the archaelogical finds in the village Dholavira situated at its westernmost extremity. This site presently is being excavated for its rich Harappan culture and is thought to be next in importance to that of Harrapa in Pakistan.

The isolated Chhariya Bet standing singularly on the vast expanse of salt flats is important from the point of view of its sedimentation history and its material possibly drawn from the hill called Meruda Takkar [Fig.1] which is about 16 to 17 miles [26 km.] north of Chhapari Tala at the northern edge of Khadir Island [Latitude 24°07'30", Longitude 70°18'00"]. The Meruda hill comprises pinkish, brown grey syenitic rocks. Yet another exposure in the vicinity having similar syenitic exposure is the Kalinjar hill of Nagarparker at the south-western edge of the West Pakistan - Rajasthan peneplain. These two hills are thought to be the provences of the basal, polymictic granite-cobble-conglomerate exposed at Chhariya Bet [the oldest Mesozoic sedimentary unit in Kutch].

Wynne [1872] was the first to comment on basement rocks in Kutch. He believed that the outcrop of syenitic rocks in Kalinjar Hill of Nagarparker [Pakistan], is the only outcrop forming the basement of the Jurassic deposits in Kutch. Wynne, also mentioned the occurrence of some conglomerates with metamorphic pebbles from the Rann Island of Bela and suggested that such conglomerates indicate an unconformity between the Jurassic rocks and the underlying metamorphic rocks. Biswas and Deshpande [1968] believed that syenitic rocks of Kalinjar Hill of Nagarparker and Meruda Hill of Kutch are perhaps related and form different parts of the same intrusive bodies in the Precambrian Complex. According to them, these portion of the intrusive masses have withstood erosion during the periods of peneplanation. The Precambrian rocks of the Aravalli and Delhi systems and Erinpura granites, are extensively exposed in the neighbouring areas of south-western Rajasthan and Eastern Gujarat. Extension of these rocks beneath the Bathonian sediments in the Rann of Kutch as suggested by Biswas and Deshpande [1968] thus may quite be possible.

Biswas, later in a series of papers [1971 to 1977] proposed a separate stratigraphic division which he named Khadir Formation, the name derived from Khadir Island itself. According to him, the lithostratography of Wagad, Bela, Khadir and Chorar areas is comparable and lithologically corelatable. He termed the Khadir Formation to the rocks exposed in Khadir, Bela and Chorar and divided five members in ascending order [1] Chhariya Bet Conglomerate Member; [2] Hadibhadang Shale Member;

[3] Hadibhadang Sandstone Member; [4] Gadhada Sandstone Member; and [5] Bambanka/Gangta Member.

Agrawal and Tripathi [1980] studied the Bathonian-Callovian rocks in the neighbourhood of the village Umrapur of Khadir Island. They gave the term "Umrapur Formation" to the rocks of Umrapur and divided into Lower, Middle and Upper Member after recognising fifteen beds. Their study was mainly based on fossil bivalves.

GEOLOGY AND STRATIGRAPHY OF THE AREA [KHADIR ISLAND] :

In Khadir Island the first record of Mesozoic sedimentation is observed in the polymictic conglomerate of Chhariya Bet. This, in succession is followed by sub-arkosic sandstones, silty shale and sandstone, calc arenite, sandy limestone, ferruginous sandstone, Oolitic limestone, alumina rich clays, laterite, agate and chert pebble conglomerate, and gypseous clays. All these rocks are grouped as Khadir Formation by Biswas [1977].

The base of Khadir Formation is not exposed but the upper contact is conformable with the Wagad sandstone and seen only on the ridge between Nagalpur and Gedi [Biswas 1977]. The boundary is quite sharp between fossiliferous sandstone of this formation and unfossiliferous ferruginous sandstones of the upper one.

As claimed by Biswas [1977] Khadir Formation includes both the Patcham and younger beds. Based on the occurrence of **Corbula lyrata** and **Gervillia** assemblage [Cox, 1940], Bathonian to Callovian age for the lower part of the Khadir Formation has been established. As claimed by Biswas [1977] the age of Khadir Formation [including the exposed rock of Gangta Bet] extends upto Argovian [its upper part] which as suggested by him is isochronous with the upper part of the Jumara Formation of the Mainland. Khadir Formation is exposed strikewise in Patcham, Bela and Chorar Islands.

Biswas [1977] divided Khadir Formation into five members. Brief description of all these members is given in the following paragraphs :

[1] Chhariya Bet Conglomerate Member :

It consists of haphazardly occurring lenses and wedges of immature, polymictic granite-cobble-conglomerate in grey arkose sands with pockets of red and green mottled siltstone. The name of this member is derived from Chhariya Bet which is situated in close proximity to the North of Khadir Island. The Chhariya Bet comprises extrabasinal clast-supported polymictic conglomerate including clasts of granite, syenite, quarzite, granophyre etc. The provenance of these casts is thought to be syenitic and granitic rocks of Meruda Takkar Hill and Kalinjar Hill of Nagarparker [Pakistan].

[2] Hadibhadang Shale Member :

This member is named after Hadibhadang Hill [derived from Hadibhadang Pir] comprises mutually inter-digitating gypseous laminated shale and buff massive sandstone [felspathic arenites].

Shales contain interbeds of flaggy, fossiliferous, calcareous sandstones and yellow coquina limestone. The fossiliferous bands in Hadibhadang shales are full of **Corbula** and **Gervillia** besides other lamellibranchs, gastropods, corals and local occurrences of rhynchonella.

[3] **Hadibhadang Sandstone Member :**

It occupies the upper part of the northern escarpments of the Island and consists of sandstones in the lower and bedded limestones in the upper part. The limestones become thinly bedded and flaggy eastwards. This member is almost similar in its lithology to Raimalro limestone member of Patcham Formation. The limestone bands in Hadibhadang sandstone member are full of crinoid stems and plates, besides rhynchonellids, gastropods and pelecypods.

[4] **Gadhada Sandstone Member :**

This member is named after the type locality in Gadhada. It comprises sandstone [ferruginous quartz arenites] with purple concrentionary ferruginous sandstone or ironstone bands intercalations of shale, lamellar sandstones and flaggy fossiliferous calcareous sandstones. The lithology and alternating sequence of this unit resemble the Bhuj Formation of the Mainland.

The lower part of Gadhada Sandstone Member is fossiliferous with **Corbula-Gervillia** bands occurring near the base and a 4 m.

ferruginous Oolitic limestone band full of pelecypods [of which pholadomya dominates] and some ammonites fossils.

[5] **Bambanka/Gangta Member :**

It consists of thick sequence of shales with thin sandstone interbeds some of which are calcareous and fossiliferous, and bands of intraformational conglomerate containing flat pebbles and balls of sandstones. The Bambanka shales are highly fossiliferous with remains of belemnites, ammonites, pelecypods and gastropods. Bambanka member is well exposed around the village Bambanka.

As advocated by Biswas [1981], the lithology and biological chacteristics of different members in Khadir Formation indicate piedmont, littoral and sub-littoral environment and indicate deepening of the basin with continued sedimentation.

KHADIR ISLAND : STRUCTURE AND TECTONICS :

Khadir Island like the other disconnected Islands [viz. Patcham, Bela and Chorar] represent an individual uplifted zone separated by the residual depression of the Great Rann. However, the marginal faults or flexures which are exposed in all the other uplifts are absent in Khadir. It is quite possible that the marginal fault, in Khadir is concealed under the sediments of Rann [Biswas, 1982]. The most common feature of all the uplifted island zone [except Wagad] are characterised by northern faults and/or flexure bounded margins that have been upthrown. Such a structural geometry in Khadir signify fault block tilted north side up. Two faults are found in the north of village Bambanka trending in N60°W - S60°E, and N30°W - S57°E respectively. Three major joint systems were confirmed. These trend in NE-SW, NW-SE and E-W direction.

Basic intrusives and dolerite in form of dyke and sills are found to exist in Khadir Island. Two dolerite dyke are found at the foothill of escarpment face of Khadir Island [Fig.2] with N-S and NNW-SSE trends. Highly weathered, greenish grey, basic intrusives are located in the northern area of village Janan. Another course grained basic intrusive in the SSW of Bhagat-Ki-Wandh is also located. These intrusives show both concordant and discordant relationship with the country rock.

As a whole, the Khadir uplift appears to be simple in structural composition trending east-west. It has resulted in a huge "half dome" sloping to the south with radial dip pattern. The basin is deepest adjacent to the proximity of the uplift in such a way that the profile of the structural relief between the basin and uplift is very steep. The beds rise up very gently towards the north in east-west trend to form the back slope along the entire Khadir uplift.

As mentioned earlier the structural style of Khadir appears to be responsible in controlling the overall topographic trends and the drainage patterns in the entire Island region.

CHAPTER : V

GEOMORPHOLOGY OF THE AREA

INTRODUCTION :

Geomorphology is mainly concerned with the study of evolution of landforms especially those produced by the process of erosion. Recently, added attention is found on such phenomenon as drainage basins, river valley systems, hill slopes and areas of uniform rock types. Consideration is also given to the internal and external forces operating on the earth's crust including tectonic activity, volcanicity etc. Often external forces originating in the atmosphere and hydrosphere control surface processes such as weathering and erosion in shaping the landforms. Specific geomorphology of any region is thus the final output of many above mentioned complex interactions.

In order to trace various events that have shaped the present landform configuration in Khadir the Author first prepared a geomorphological map to the scale 1:50,000, utilizing details on the Survey of India Topo Sheet [No. 41.I/5 and part of I/1], areal photographs and landsat imageries. The geomorphological map so finalized is presented in Fig.6. Following important geomorphological features can be described from these studies.

[A] Landforms

[B] Drainage Patterns

[C] Features resulting from bedrock structures and tectonic events

[A] LANDFORMS :

Following prominent landform features can be distinguished from the region [Fig. 6].

[a] Large Scale Cliffs

[b] Hogback Structure

[c] Alluvial Fan Topography

[d] Apparent breaks and change in slope

[a] Large Scale Cliffs :

An outstanding development of large scale cliff section can be observed on the northernmost part of the Khadir Island. This section which almost runs in E-W direction is parallel to the northern extremity of the Khadir Island, occupying a total length of about 32 m.

Development of cliffs as claimed by various workers are assigned to : [1] wave undercutting some deeply cut river valleys, [2] escarpment faces in massive rocks, and [3] in mountain areas due to faulted landscapes.

Cliffs whenever are steep, 40° or more, the products of weathering for the most part fall immediately to the base, and there is little or no accumulation of detritus on the cliff surface. According to Small [1978], such cliffs are to be

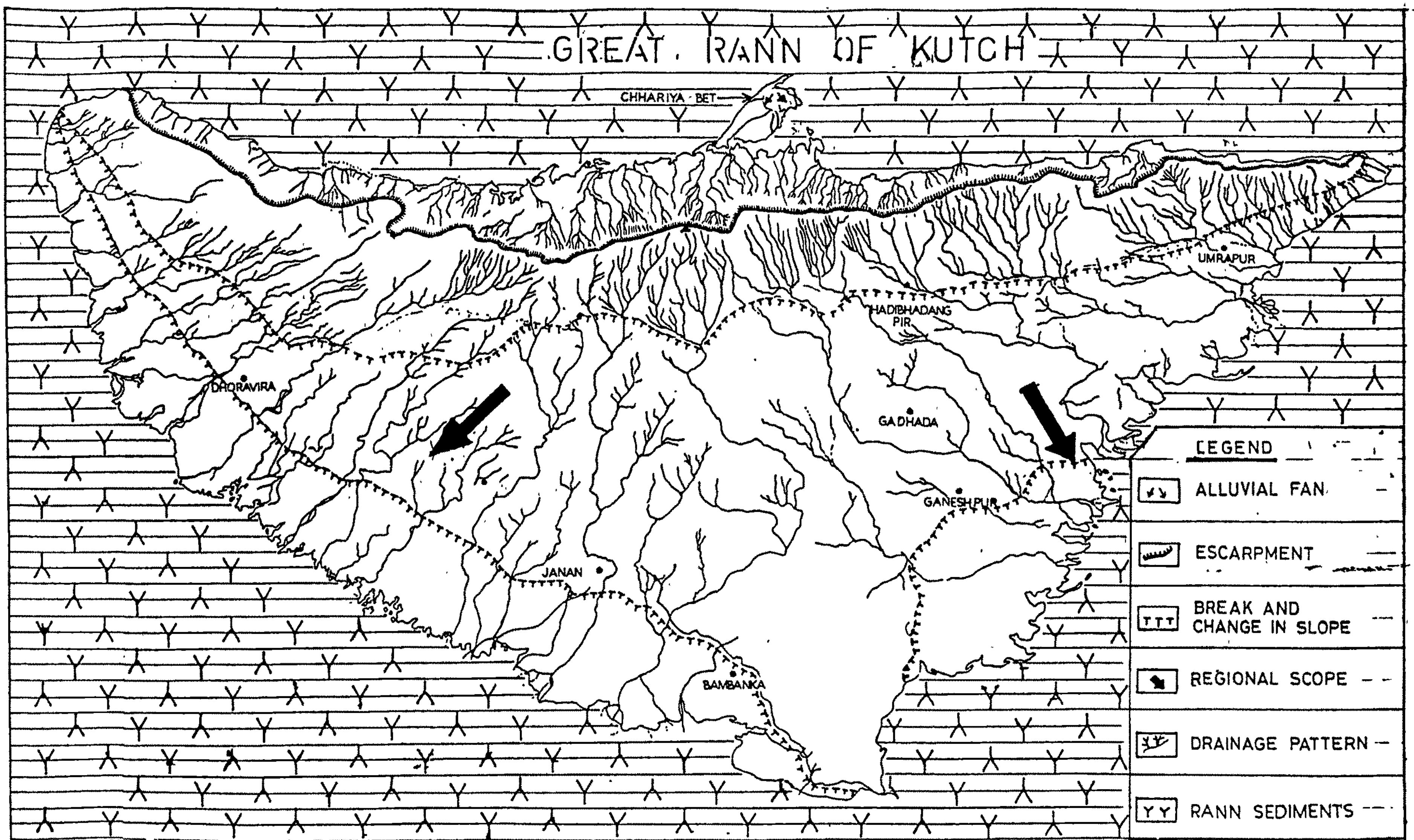

FIG. 6 GEOMORPHOLOGICAL MAP OF KHADIR ISLAND

assigned to the category of free face cliff [Fig. 7 and 8]. In such cases the weathered material directly accumulates at the front of the cliff, and with the passage of time a scree slope develops at an angle controlled by the size and shape of the weathered fragments. The growth of the scree slope again leads to a reduction in the height of the free face, the lower part of which will be submerged beneath detritus.

Analogous characteristic development of the cliff can be observed at the northernmost boundary section of Khadir Island. This geomorphological feature when analysed with the tectonic details of the region [Fig.5] leaves no doubt being formed as a result of block upthrusting on the E-W regional fault line, most probably after the upper Jurassic time.

[b] Hogback Structure :

The extreme top resistant beds along the cliff section in Khadir Island prominently exhibit Hogback structure [Fig.6]. Hogback structure is a form of homoclinal structure. When the rocks in the homoclinal structure are beds varying in resistance to weathering and erosion they often develop a topographic feature where major differences are related to the steepness and resistance of rocks. The fundamental differences among hogbacks, homoclinal ridges, cuestas and mesas are related to the steepness in the dip of the resistant beds responsible for them and to their geographic extent. Such comparable features on the rock crests that could be assigned to the Hogback Structure are noted by the author along the Khadir cliff section.

Furthermore, there are sharp crested ridges possibly developed due to high steepness in the rock dips in the front slope [scarp face] as compared to the moderate to gentle steepness in the regional back slope of the island. Most of the rocks along the front slope are steep exceeding 45 degree dips. Thus front slope in case of Khadir hogbacks are steeper than the back slope. Hogbacks structures in Khadir has remained well fixed in the position for a long duration of time.

[c] Alluvial Fan Topography :

As depicted in the geomorphological map prepared by the author [Fig.6], the entire land mass of Khadir including Chhariya Bet which forms its northernmost extremity apparently reveal a distinct alluvial fan to fan delta topography. As a matter of fact the whole region outcrops in merely a semi circular outline. It is quite likely that the whole topography could have been formed when a heavily loaded stream or river emerging from nearby hills or mountains draining through lowland gradients spread its sediment load on the lowland regions. As it could be logical, material comprising polymictic conglomeratic fan, systematically would vary in the down current direction from coarse boulders and pebbles to finer material down to the slope as is the case with the sediments in Khadir.

In this context it is particularly interesting to note the occurrence of coarse boulders and pebbles of granite, granodiorite, syenite etc. mixed with subarkosic sand in Chhariya Bet, gradually changed down the dip direction into coarse and fine grained siliciclastic-carbonate sediments along the southernmost portion of Khadir.

In areal view, the radial profile of the fan has a concave appearance whereas its cross profile looks convex [Fig. 7 and 8]. The extreme southern portion of Khadir Island thus marks lower fan morphological division which apparently is free of any major topographic relief and may correspond to ponded basin plain environment.

[d] Apparent Breaks and Change in Slope :

In order to support the Alluvial-Fan-Delta hypothesis, the author carried out slope analysis for the entire Island of Khadir including Chhariya Bet. As is well known profile form of slopes develop under a variety of conditions including variety of rock types, their structures and can be analysed as a function of process and relative rock resistance and the effects on the slope on the erosional products. Davies [1969] argued that slopes tend to decline in steepness as the cycle of erosion proceeds towards the stage of old age. The rate of slope development according to him vary from rock to rock and from area to area. Following Troch [1965], Thornbury [1969],

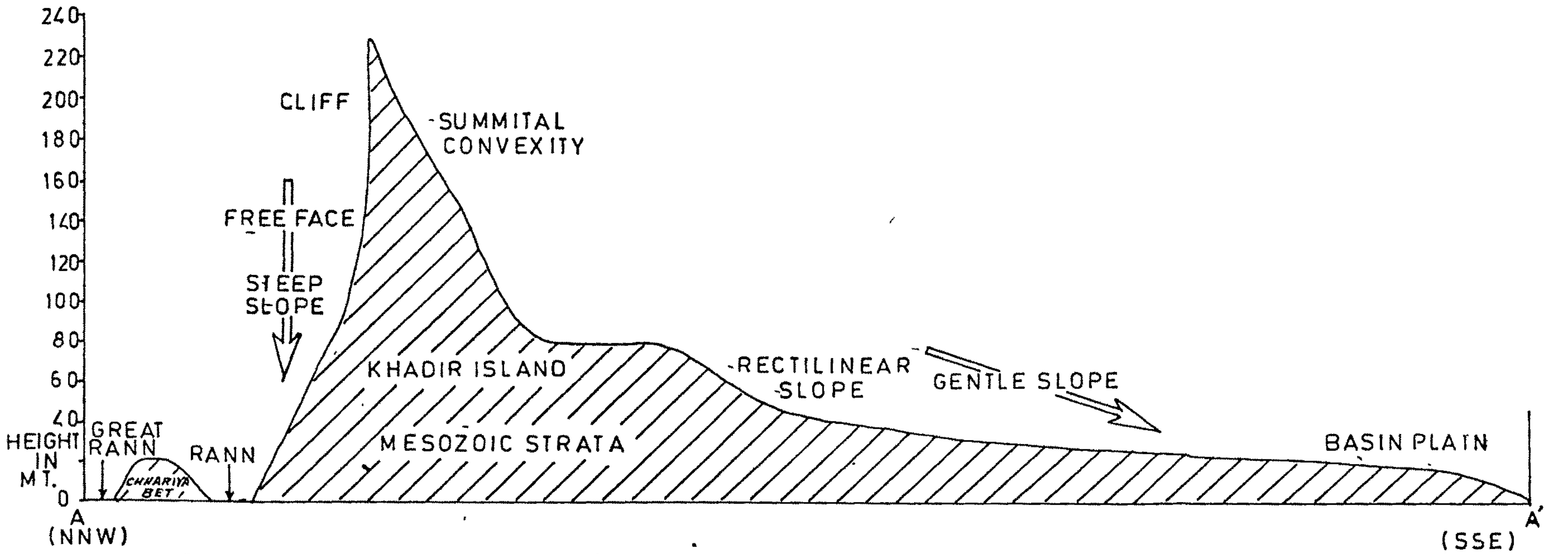

FIG. NO. 7 COMPOSITE SLOP FORMS OF KHADIR ISLAND (INCLUDING CHHARIYA BET) ALONG NNW-SSE: A-A' PROFILE
(VERTICAL SCALE :- 20 M = 1 CM)

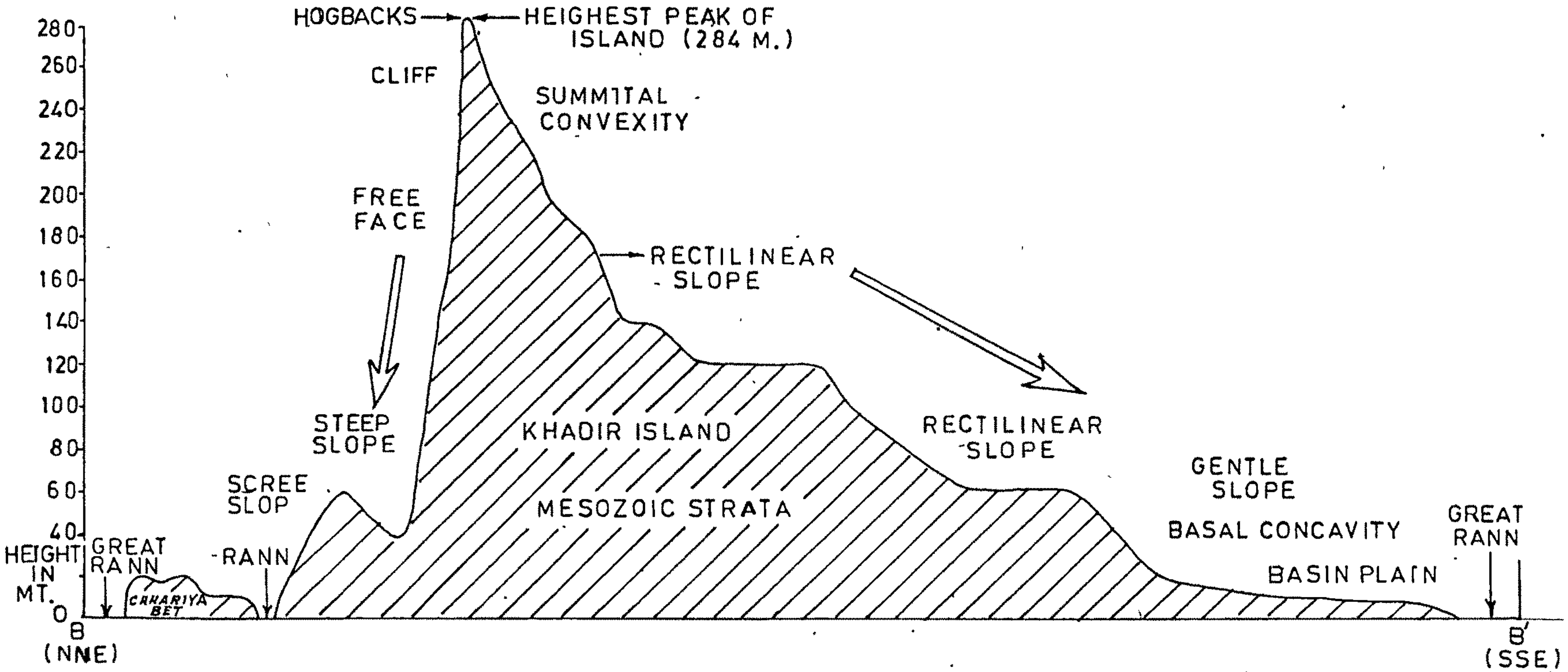

FIG. NO.8 COMPOSITE SLOP FORMS OF KHADIR ISLAND (INCLUDING CHHARIYA BET) ALONG NNE-SSE: B-B' PROFILE
(VERTICAL SCALE :- 20 M = 1 CM)

Young, A. [1972], Small [1978], Davies [1969] and Gerrar [1988], profile studies were made by the author along the line A-B and A'-B' in NNE-SSW and NNW-SSE direction respectively across the Khadir Island region. Following interpretations are based on these studies :

[1] In the NNE extremity, Chhariya Bet has developed maximum elevation of 20 m. with low small peaks, a small saddle between these two and a convex back slope profile, which finally merges into the great Rann and the Khadir Island sediments.

[2] The Khadir Island as a whole shows two contrasting forms of profiles one along the NNE direction and the other towards SSW direction. Details of the geomorphological features along NNE profiles are already discussed in detail. The SSW profile feature often combine alternations of convex and concave slopes.

[1] CONVEX SLOPES :

Convexity of slope is found on southern portion of the Island profile. The convexity is developed on the upper part of the slope which can be termed as 'Summital Convexity'. This may have resulted as the result of denudational processes.

[2] RECTILINEAR SLOPE :

Many slope profiles display a marked rectilinear [or straight in profile section] outline which may vary a good deal in its dimensions to sometime dominates the whole slope. This has been the case which seems to have developed in the central southern portion of Khadir Island. This rectilinear section separates a convexity above and concave section below in southern profile of the Island.

[3] CONCAVE SLOPE :

In the lower part of southern Khadir Island, a slope profile commonly exhibit a concave section. It ultimately merges with the Rann sediments. This concavity appears to have resulted from denudational processes. The lower part of slope may become lowered in angle through the washing downslope of finer material which has an angle of repose less than that of the majority of the scree segments.

In arid and semi-arid lands as suggested by Small [1978] slopes are characterised by a sharp break of gradient between the concave and the much steeper slope section above. On the other hand Baulig [1950] suggested that the nature of the rock is of fundamental importance in the development of the slope convexity and concavity. Thus, lithology, actual length and height of the slope are the major controlling factors in the slope developments in Khadir.

[B] DRAINAGE PATTERNS :

Drainage analysis include consideration of drainage system, drainage textures, and distribution pattern of individual streamlets. Drainage studies are most useful for structural interpretation in undulating topographic region. Moreover, drainage analysis is also an important tool in photogeologic interpretation and provides clues to inactive structural features exposed at the surface, to structural features currently rising and, possibly to buried structural features as well. Detail studies often reflect and reveal information on original slope and structure and the successive episodes by which the surface has been modified, including uplift, depression, tilting, warping, folding, faulting, and jointing as well as deposition by the sea, glaciers, volcanoes rivers etc.

As claimed by Zernitz [1932] most of the basic drainage patterns are controlled by regional structures, and include : Dendritic, Parallel, Trelis, Rectangular, Radial and Annular drainage systems. As regards to the Khadir Island zone the Author was able to confirm the following drainage patterns from his aerial photographic and landsat imagery studies :

[1] Parallel Drainage

[2] Dendritic Drainage

[3] Radial Drainage

[1] Parallel Drainage :

In the area of study both parallel [basic] and subparallel [modified basic] types of drainage patterns are distinct and dominating [Fig.6]. The concentration of the two patterns are found along the crested portion of the Island. Here the parallel drainage indicate pronounced regional slope or a slope controlled by parallel topographic features such as faulted structures. In the context, it is interesting to note that a major fault does occur beneath the Rann of Kutch [Fig.5]. In contrast, on the southern side of this fault, stream courses are typically controlled by the slope of the ground. According to Zernitz [1932] the resulting streams in such cases display parallel drainage patterns.

Subparallel type of drainage in Khadir lacks the regularity of the parallel pattern. These are oriented almost in a northern direction and can be located along the entire escarpment face of Khadir [Fig.6]. Here, the subparallelism between streams may be due to slope control. As argued by Zernitz [1932] in regions of high relief, steep slopes of major valleys frequently give a subparallel type of drainage pattern. This view supports our observations in Khadir.

[2] Dendritic Drainage :

Another feature, the dendritic type of drainage is comparatively less developed in the area under study. Dendritic drainage is characterized by irregular branching of streamlets in all directions with tributaries joining, the main steam at all angles. The streams are insequent in origin. Insequent drainage often develops into a perfect dendritic pattern. Such a pattern is called "Dendritic" because it branches like a tree. This is further developed where rocks offer uniform resistance in horizontal direction. The central part of Khadir marks an area where low-order streams exhibit dendritic arrangement. As it appears such a development has resulted from dissection and weathering of the basinal area that is small enough to be underlain by essentially homogeneous rock.

[3] Radial Drainage :

Radial drainage pattern can be seen in Chhariya Bet. Here the streams radiate from a central area like the spokes of a wheel [Fig.6].

GENETIC STUDIES OF DRAINAGE SYSTEM :

The following two main factors determine the initation and subsequent evolution of drainage system in the island region of Khadir. Firstly, it is found that depending on the nature of the surface on which the streams begin to flow and then follow the line of steepest gradient, in other words, their courses are consequent upon the form of the land surface and these streams can be referred to as consequents. Secondly, there are streams distinctly developed on both the sides of the E-W escarpment of Khadir. The close-spaced contours on the escarpment face, gradually increase and indicate steep slope on northern side. The southern side display two different gentle gradients, one in SE and another in SW. Thus, the consequent drainage pattern in Khadir vary gently in its complexity, depending on the degree of irregularity of the instral surface. This instral surface in Khadir is produced by the uplift and gentle clockwise tilting of the Island, having fault escarpment along E-W line [marked on map] which has resulted into a series of parallel streams.