B. A BRIEF HISTORY OF THE RANN'S EVOLUTION

As it is important to know the evolutionary history of the Rann to understand the inundation phenomenon in full, the salient features of the various stages of the growth of Rann have been discussed below. His account is based mainly on the investigations of the earlier workers and on his own observations.

Initially the Mesozoic rocks were laid down perhaps over a Pre-Cambrian basement of Kathiawar, Kutch and the western regions of Rajasthan. Then came the lavas flows of Deccan Trap. After this volcanic activity, while the early Tertiary marine sediments were still being deposited over the Indus valley and in areas extending upto the Indian shield in Rajasthan, parts of Kutch and Kathiawar began to emerge out as islands, and this position of emergence has more or less been maintained until to-day.

From the tectonic map of Kutch it is clear that the structure of Kutch appears to be controlled by fault zones. They have led to the formation of a series of 'horsts' and 'grabens' with hill massifs of Kutch mainland, Pachham, Khadir, Bela and Chorar as the 'horsts' and the Great Rann and the Banni plains as the sites of 'grabens'. Biswas and Deshpande (1970) have given the term 'uplifts' to the hill massifs and 'residual depressions' to the low grounds of the Great Rann and Banni. During the geological past the Great as well as the Little Rann areas were undoubtedly a part of the shallow sea. Rogers (1970, p.118) and Fedden (1884, p.130) have reported the presence of a small and brackish water lake called the Nal Sarover containing eustarine shells of

Cerithium and situated along the line containing Gulf of Cambay and the South-east Rann. Similar estuarine shells (Potamides) were also reported by Oldham (1893, p. 430) in the Lake of Umarkot about 90 miles north of the Great Rann. These reports very clearly substantiate the fact that the Rann was an arm of the sea having a greater extent in those geological periods. Even during the early historic times, a large part of the Rann was under the sea. Upto the time of Alexander's invasion (4th Century B.C.), the Great Rann was still a marine gulf, and had several ports in the area what is now barren salt encrusted terrain, just north of Pachham hill massif. It is thus so obvious that the Rann gradually emerged out of a shallow sea during the last few thousand years only.

The gradual recession of sea level, apart from historical and archaeological evidences, is also clearly shown by the presence of marine calcareous grits and oysters beds at a height of several metres above the present water level at Lakhpat (Oldham, 1893, p.409). Biswas and Deshpande (1970) observed similar oysters beds at Pachham island. Also swash marks and water lines at the height of 6 to 8 metres above the present Rann level have been observed in the north cliff-face of the Pachham island. Wadia (1926, p.31) believed that "even within historic times the Rann of Cutch was a gulf of the sea, with surrounding coastal towns, a few recognizable relics of which still exist." The mud etc. that were spewed out during the 1819 earthquake contained ships' nails and irons providing a good evidence of the prevalent navigation in proto-historic times. With a further recession of the sea, the area changed over to an estuary. An important river (Indus or probably one of its main tributaries) flowed through the existing site of the Great Rann and emptied itself into the Arabian Sea via the Kori Creek. The nature of the heavy minerals in the sediments north of the present Allah Band, points to a fluviatile or a rather mixed environment prevailing during the time of their deposition. Heavy mineral analysis revealed an interesting assemblage of minerals in which mica predominated. The minerals in order of abundance (sampled from different locations) were biotite, muscovite, hornblende, tourmaline, zircon, rutile. These reflect a provenance that was purely gneissic and schistose and only a river like Indus (or one of its tributary) draining from the Himalayan gneissic terrain could have provided the Rann with this lot of heavy minerals. Sivewright states (1907, p.533) that "that silt of the Greater Rann is unmistakably an Indus valley deposit, that of the Lesser Ran is as easily recognized as the black cotton soil of its source of origin in Kathiawar." Blanford (1869) interpreted the Rann as a basin filling up with sediments from the inflowing streams. That a major river network was existent in the very recent years is so evident from the geomorphic observations on air-photos as well as on the ground. The recognition of the relict of a prominent channel, whose course can be roughly traced back into Sindh (Pakistan) to its north and into the Kori Creek to its south, is a conclusive indication of a river that once flowed from north into what is now Kori Creek. It is obvious from air photos (as indicated by the presence of meander scars etc.) that whatever river flowed, shifted its course progressively further westward along with the Indus(which also migrated in that direction). Platt (1962, p.95) states that "the Indus turns sharply to the West at Hyderabad in Sind, in its present course to the sea. Perhaps in earlier times the entire river poured into the estuary which has become the Runn." Progressively as the main river migrated westward, a minor tributary drained through the Kori Creek even during recent historical times. It was only as late as 1819 when a major earthquake finally destroyed the river's connection with the Kori Creek. The mound of Allah Band, that arose during the earthquake cut off the main channel leaving a remnant of dry channel network to its north with the relict of the main channel. Obviously, the final touches to the existing Rann configuration were given by that earthquake almost 150 years ago.

CHAPTER 3

G E O M O R P H O L O G Y

Geomorphic processes always leave their distinctive imprint upon the earth's surface, and each geomorphic process develops its own characteristic land-forms. In the Rann of Kutch also, the various processes have played a vital role in the evolution of its peculiar landscape, which in turn control the pattern and causes of inundation. It is significant that the development of landforms in Rann is not haphazard but comprises an assemblage of several geomorphic features all inter-related and genetically controlled by processes often similar. The author has observed that in the Rann, the landforms afford very good clues to the degree and manner of water movement. Thus, a detailed and systematic study of the geomorphology of the Rann, enabled the author to understand the complexities of the phenomenon of inundation fairly well.

The author has classified the Rann on the basis of various landforms present, and divided the terrain into various geomorphic Facets and Sub-Facets. In Chapter 6, he has discussed as to how these landforms control the inundation.

GENERAL DESCRIPTION OF THE RANN

The Great Rann proper is a vast expanse of salty waste rising barely above sea level (Plate 3.1). Some portions of the tract, perennially wet and marshy (Plate 3.2), are subjected to the action of tidal waters which sweep in during heavy tides, aided by strong winds. It is on the whole, a remarkably flat terrain, being dotted with 'island-like' elevated regions called bets. These bets in comparision to the actual Rann, support vegetation of some sort. Apart from these bets, there

PLATE 3.1

Panoramic view of the Great Rann showing the imperceptible gradient.
Location: Sub-Facet B_3. Region west of Kuar bet.

PLATE 3.2

Perennially water-logged patch
Location: South of Kuar bet, in Sub-Facet B_3

are certain shallow depressions, perennially wet, especially to the north of the hill massifs. The gradient is slight and even inland at places like Kuar bet, the mean level is as low as 1.1. The Kutch mainland to the east, and the Island belt rises very abruptly from the Rann surface, into the four individual hill massifs namely Pachham, Khadir, Bela and Chorar (Fig. 1.2). The highest range of hills in the Kutch district, known as 'Kala Dongar' with its highest peak 465 m above sea level, is situated in the Pachham island (Fig. 1.2). Evidence of a remarkable and very late uplift is the 'Allah Band' which is a linear mound-like feature running approximately eastto west and is encountered in the western portion of the Great Rann (Fig. 1.2). The Rann surface especially in the north-western part, above the Allah Band, is criss-crossed by numerous relict stream channels and distributaries indicating the presence of an erstwhile flowing river.

Below the Rann surface, the sediments are mostly clay to clayey silt and are highly impregnated with salt throughout the profile. It is however wrong to conceive of the Rann to be entirely salt-caked. The salt crusts are of varying thickness ranging from a thin veneer (encountered around Bedia bet, Chota and Bada Sarbelos) to as much as 5 cm thick layer crusts found in the areas east of Kuar bet and north of the hill masses of Pachham, Khadir and Bela. Salt crystals, mostly gypsum and anhydrite, are found disseminated along the profiles at certain places.

During dry season, a major portion of the Rann surface becomes hard and compact. In many places spectacular growth of mud-cracks is observed. During such seasons vehicles can travel easily. However during rains, the streams, sea and rain waters flood this region to varying depths, causing the sediments to turn wet and slushy, and the region is rendered inaccessible for many months.

The sediments of the Rann are also very unique and interesting. The sediment cover of a region reflects its geomorphic history, and in some areas it does so better than even the landforms. Furthermore, sediment formation reflects certain conditions such as climate, topography, external and internal drainage.

Rann sediments, broadly speaking are of the fine-grained type (i.e. silty and clayey), the proportion of silt and clay depending on the location of the particular region (Fig. 3.1). Sediments in the north-western part of the Rann, are silty-clay containing a high proportion of mica and occur as uniformly laminated deposits which at times were found to extend upto 7 metres or more. In areas marking local depressions, clay-pans are encountered, where the clay proportion is relatively higher. On the other hand, the sediments of the bets are relatively coarser, containing a high admixture of fine sands. In general, the sediments encountered in the depressed regions of the Rann are boggy in nature and are found to be organic clays. In the region of tidal influence, the sediment is typically marine comprising marine silts and clays while those at the junction of Rann and the rocky mainland are generally of the mixed type, consisting of a coarser admixture of rock particles washed down by streams debouching onto the Rann surface from the rocky mainland.

GEOMORPHIC DIVISION OF RANN

The various landforms like vast depressions, old channels, meander scrolls and broken drainage etc play important roles in controlling water movement over the face of the Rann, each landform playing its appropriate role. The author has been able to study these various landforms in fair detail. By means of field work and air photo studies, he has not only delineated the major landforms but has observed a number of interesting and significant geomorphic features, so vital in understanding the inundation problem.

The Rann is obviously not a homogeneous terrain, and comprises a number of geomorphic Facets and Sub-Facets, each showing a distinct assemblage of landforms. The Rann area, accordingly, has been classified into following three main Facets : (Fig. 3.2)

FACET A : Bet-zone

The area west of line joining Kuar and Bediya bets and comprising complex network of bets. The southern limit of this Facet is marked by the 'Allah Band'. To the north, it merges into the sand-ridges of Sindh (Pakistan).

FACET B : Trench like depression

The trench-like feature stretching westwards from Kuar bet extends upto Kori Creek, the northern boundary of which is Allah Band. To the south, it is bounded by the mainland rocks in the west and the plains of Banni in the east (Fig. 3.2).

FACET C : Great Barren Zone

This Facet comprises the Great Barren area east of the line joining Kuar and Bediya bets and north of the hill massifs of Pachham, Khadir, and Bela (Fig. 3.2).

Of the above three main Facets, the Facets A and B are found to consist of two and three Sub-Facets respectively. They are as under:-

Facet A : A_1 Western part: a zone of complex drainage network.

A_2 Eastern part: a zone of comparatively simpler drainage network.

Facet B : B_1 Region of regular marine influence (western part).

B_2 Region of marine influence during monsoons (central part).

B_3 Region of very restricted marine influence, during stormy conditions (eastern part).

Apart from the above geomorphic Facets, there are certain features in the Rann, which are of special significance. They are (1) Allah Band (2) Kori Creek (3) Inland 'Sebkhas'.

Associated features include (i) Mainland rocks with their own drainage characteristics, (ii) Island belt of Pachham, Khadir and Bela and (iii) the Banni.

FACET A: (BET ZONE)

Characteristics of Sub-Facet A_1:

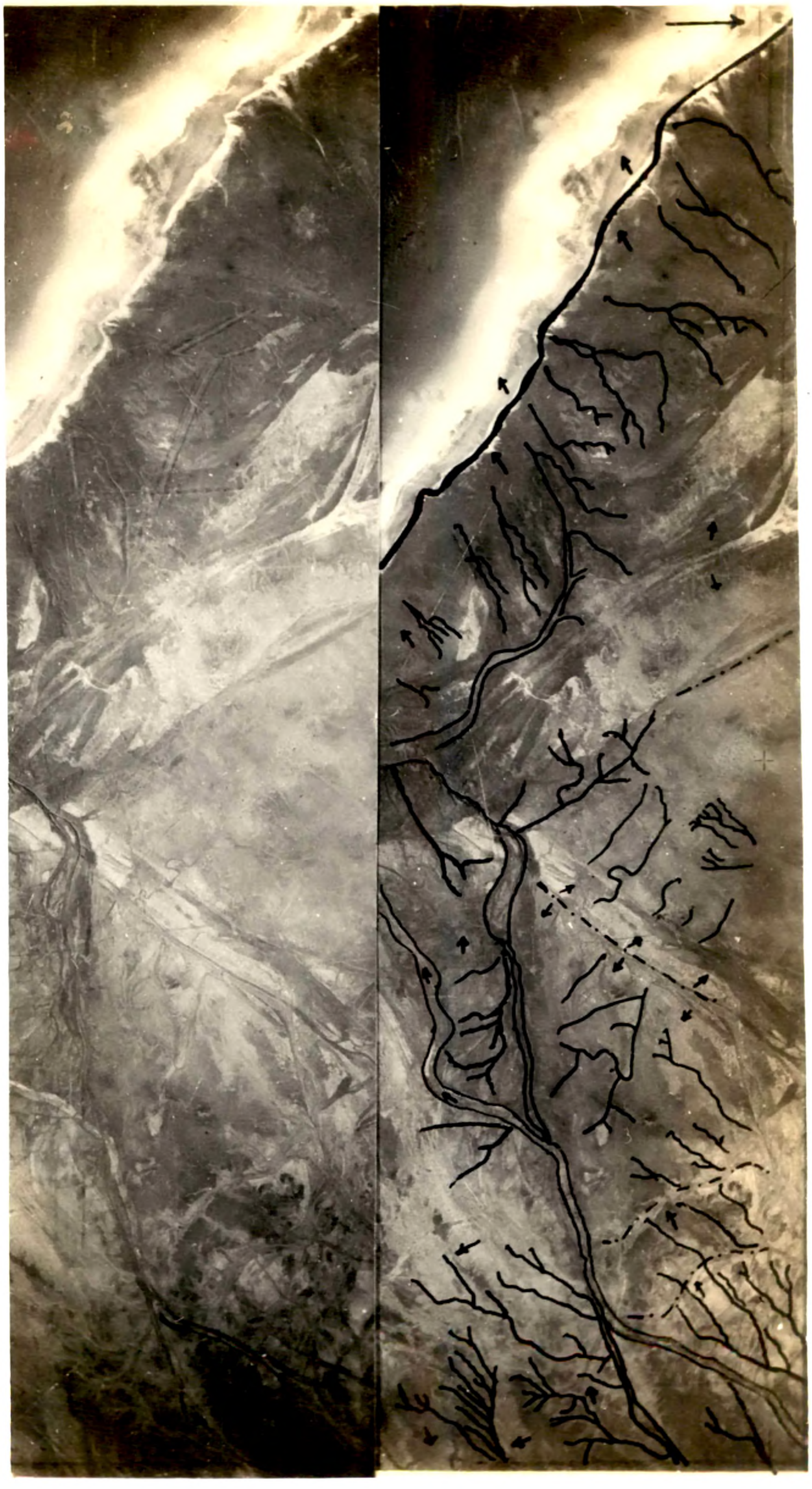
In this region, various old channels representing the old courses of a major stream and its distributaries are seen in the field as well as on the air photos. The main channel approximately trends north to south and its pattern is shown in Fig. 3.3. This is clear from the fact that to the west and east of this channel other abandoned channels representing the shifts in the stream's course is observed. The drainage density of these abandoned channels is observed to be more complex and dense towards this Sub-Facet.

The southern ends of the various drainage lines in this Sub-Facet terminate at the Allah Band (Stereo Plate 1) and appropriately reveal that the sudden rise of this mound resulted in the abrupt shifting of the river's course to the west. To the north, the major abandoned channel can be traced back as far as to the old course of the River Nara (now a part of which flows in Sindh, Pakistan).

Streams seldom follow a straight course, and even in this present case, a great deal of complexity is observed. What is retained today, represents a typical 'braided-pattern', where the main stream clearly splits up into numerous intertwined channels separated from each other by 'islands' or 'channel bars'. This pattern very clearly indicates that in the past, the stream during certain periods, carried a considerable load all of which it was unable to dump in the sea. It is very obvious that this region of the Rann was a 'delta'. Braided pattern indicates a loss of transporting power - a condition very much prevalent in the mouth of a 'delta' and the branch-like network of minor channels across its face typically represents the 'distributaries'.

STEREO-PLATE 1

Stereo-plate showing western extremity of Allah Band. Inked lines represent old channel courses which terminate abruptly at the Allah Band. At the south of Allah Band is the wet Rann, which comes under the influence of sea water.



The complexity of the stream pattern, increases southwards, where the braiding pattern is very conspicuous. In this region, the number of distributaries multiply so much that the overall pattern here spreads out in the shape of a 'fan' or an 'inverted triangle'. Furthermore, the complexity of stream pattern reflects the relative spacing of drainage. This can also be referred to as 'drainage texture' or 'stream frequency', and accordingly the 'stream frequency' is seen to increase southwards. In the past, southward the main channel (Fig. 3.3) was connected with the Kori Creek, till the earthquake of 1819 which resulted into Allah Band uplift, changed the course of the main river.

At present, the depths of these channels vary to a considerable extent. The main channel (Fig. 3.3) is around 3.60 metre in depth with steep side walls. Its smaller distributaries are around 1 metre to 1.5 metres in depth but mostly seen filled up by wind-borne materials. Occasionally, these pre-existing channels are observed more clearly only after a light shower and they are seen to be few cm in depth. During dry periods they lie hidden under a cover of loess.

Air-photo studies and field reconnaissance have revealed the presence of numerous 'broken-drainage' lines. The author during his field work observed that these features comprise relatively shallower channels, isolated from the main abandoned channel (Fig. 3.3). Most of these channels were observed in the process of being filled up by wind-borne deposits. Such broken drainage lines are typical of this Sub-Facet (Fig.3.3). They are easily indentified in the field especially during the receeding phase of inundation. The author came across several such isolated channels (Plate 3.3) containing some water.

Sub-Facet A_2 :

In contrast, the drainage density decreases in the Sub-Facet A_2, and instead the terrain is characterised by larger bets separated from each other by inter-bet depressions.

Most of the inter-bet depressions appear to be the sites of channels, and probably represent the older systems of channels which have been partially filled up subsequently by sediments after the main stream progressively shifted westwards. Some of these are of considerable

PLATE 3.3

Isolated channel on the Rann surface carrying rain water. Trend of channel NNE-SSW.
Location: In Sub-Facet A_1

width (as that between Kuar bet and Mori bet - 600 m) and that between Gainda bet and Mori-bet (2 km). These are at times quite deep (R.L. 1.1 and 1.95 metres). They adjoin or surround the bets and play an important role in inundation, as they serve as conduits transferring rain water from one point to another. In the field, these inter-bet channels were observed to be invariably more clayey and on air-photos they were distinguished by a distinct dark tone (Stereo Plate 2).

General characteristics of the Facet

Evidently the drainage pattern of the Bet zone appears to have been inherited from a wetter past, such that the channels carved out by flowing rivers, now exist as relicts, partly filled or at times obliterated by wind-borne material. Glennie (1970, p.198) has designated such channels in a desert environment as 'wadis' or 'intermittent channels'. According to him, such drainage lines reveal their origin from the past, during times of greatly increased water flow to be dried and left abandoned due to some change which stopped the perennial water source. At places it was observed that deflation resulted in the removal of finer sediment from the more exposed part of the channels and wind-transported

STEREO-PLATE 2

Stereo-plate showing a inter-bet channel. White tone indicate salt encrustations formed in areas between 'bets'.

B : Bets S.C.: Salt crust


A.
B.
S.C.

'loess' deposited in the more sheltered part.

This drainage pattern also reflects the nature of sediments and the relief over which the streams flowed. What Horton (1945) has called 'infiltration capacity' is probably an important factor in influencing the drainage texture. The intricate branch-like network of drainage pattern yet retained in the western portion of this Facet (Sub-Facet A_1) is attributed to the fact that the streams flowed over a material that was more or less impermeable. Braiding was further accentuated by the low and almost imperceptible gradient of the terrain which prevented any quick transfer of the load carried by the stream to the sea.

The Bet-zone, especially its western part, around the main abandoned channel, shows a wide array of geomorphic features each typical of a braided or shifting type of stream. Fisk (1944, 1947) has recognised the following features that would deposit under similar conditions:-

(1) <u>Meander Belt deposits</u>

(a) Abandoned channel deposits,

(b) Point bar deposits,

(c) Natural levee deposits.

(2) Backswamp deposits

(3) Braided stream deposits

The above deposits according to Fisk come under the title of non-gravelliferous deposits and consist mostly of sand, silt and clay. In this part of the Rann, the gravelliferous deposits which form the basal portion of any alluvial fill are not encountered and described, as their existence and nature can be known from well-logs only, and no such data could be obtained. Moreover, this information had little relevance to the present study.

A fairly detailed study of landforms of this zone was carried-out on air photos and 1 inch topo-sheets. Based on this, a regional geomorphic map (Fig. 3.2) marking the positions of these landforms is shown. A good representation is given in the various stereo pairs.

The most prominent features are the channel bars and the point bars. Other important observable features recorded are

(1) Natural levees

(2) Flood-plain scour routes

(3) Abandoned channels and meander scars

(4) Backswamps

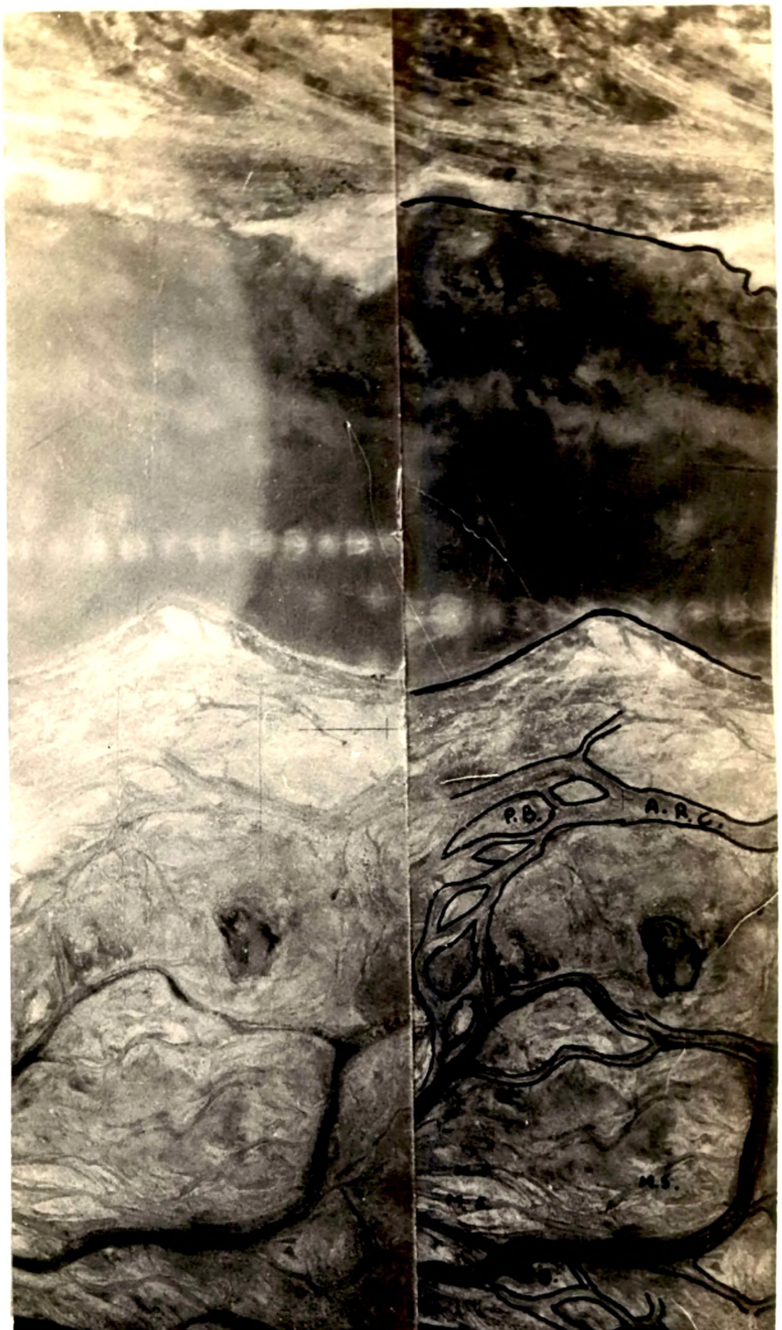
(5) Channel fill deposits or abandoned channel deposits.

Channel bars: The most striking depositional features are the 'channel bars' located along the stream courses and more characteristic in the braided section of the channel (Stereo Plate 3). A look at this plate will show a number of such 'channel bars' that developed as the braiding continued. In fact the author would include majority of the 'bets' as 'channel bars'. (with the exception of Kuar bet which is a rocky outcrop). This fact comes out very clearly on the air-photos, and the various bets show an arrangement typically of channel bars. They are easily identified by their conspicuous relief and considerable areal extent. At times they attain heights as much as 4 to 5 metres from the ground level and on most occasions, they support vegetation of some sort, some of it of considerable size. At some places (Fig. 3.4), the height of these bet regions attain R.L. 4.0 and at depressions, representing the inter-bet channels, the R.L. is around 3.0. Near Vigukot, the bets or 'bars' attain R.L. 4.65 while the

STEREO-PLATE 3

Stereo-plate showing 'point bars' and other features.

P.B.: Point bars
M.S.: Meander scars
A.R.C.: Abandoned river chennel
S.M.: Salt marsh



P.B.
A.R.C.
M.S.

R.L. is around 3.5 in the depressed channels. Other spot heights of these elevated bets are shown in Fig. 3.4.

The two most fundamental causes of stream deposition are (i) loss of transporting power and (ii) inability of the streams to transport all the material added to it by its tributaries (Thornbury, 1954, p.164). In his analysis of the Bet zone, based on the study of topographic sheets and field reconnaissance he has observed that most of the depositional features could be attributed to the loss of velocity of streams which once carried suspended materials. The decrease in velocity could be due to a sudden change in the gradient. As has been mentioned before, this zone was probably a delta mouth where development of features like 'bars' would be quite common. Furthermore, other features such as meander scars and abandoned channels, typically suggest their origin due to a combination of tectonic as well as climatic changes.

Point bars: These 'bar' deposits develop on the inside of a meander bend, and grow by the slow addition of individual accretions accompanying migration of meander (Thornbury, 1954, p.168). Davis (1913) called such features as 'meander-bars' or 'meander scrolls' and Melton (1936) calls them 'scroll meanders'. During their growth, these form a series of alternating ridges and sloughs. The latter at times become sealed off and provided sites of lakes or swamps which gradually get filled up with finer sediments deposited during flooding.

These bars probably originated as point bars, developed at the convex bends of the streams, and continued to grow for some time. Then some change in the regime of the stream occurred (probably changes in the slope-discharge relationship) which changed the meandering stream into a braided one. Studies by Leopold and Wolman (1957) and Sarkar and Basu Mallick (1968) have shown that a change from a meandering to a braided pattern is quite possible as a result of a change in the slope-discharge direction. Thus meander bars, subsequently continue to grow as 'channel bars' until they attain such height that they never get submerged. Vegetation flourishes over them and thus they are converted into 'channel islands'. The bets of this region typically represent these channel islands as one sees them today. In the field, it was observed that these forms are composed mainly of material that is predominantly sandy, Rann sediments in comparision have a greater proportion of silts and clays, and contain less proportion of salt impregnations. Borings from the surface of bets upto a depth of 6 metres and more have revealed a gradual decrease in size with depth. The various factors clearly point towards the fact that the depositional history of the bets is different from that of the Rann sediments and the bets represent deposits characteristic of braided streams.

<u>Natural levees</u>: These are ideally developed at several places and form low ridges always parallel to the stream courses such that their faces towards the stream are highest with steep gradients, and with a gradual slope, of the face, away from the channel (Stereo Plate 4). At places, two generations of natural levees - the older one at times in a fragmentary state, are encountered, and they typically represent the position of an erstwhile flowing river during some period of its geomorphic history. The development of the levees was found to be restricted to the upper

STEREO-PLATE 4

Stereo-plate showing the main abandoned channel with associated features.

S.P.: Salt playas	C.I.: Channel islands
N.L.: Natural levees	T : Terraces
S.M.: Salt marsh	E.C.: Erosional channels


S.P.
E.C.
E.C.
E.C.
T
T
S.P.
N.L
N.L.
A.R.C.
C.I.
N.L.
T

zone owing to the braided pattern of the stream in the lower reaches. Natural levees, as it appears, developed along straighter stream courses. Wherever developed, these levees have caused the later meander belt of a river to stand up above the floodplain (?) as low alluvial ridges. Furthermore, these are easily recognised not only by their heights and characteristic slopes, but also because of their silty character. On air photographs, they are usually of lighter tone and often display a fine network of radial drainage lines pointing away from the main channel. Quite often these levees are broken and show crevasses (Stereo Plate 4).

Flood-plain scour routes and abandoned channels: Quite often on air photographs, shallower channels are seen branching off from the deeper channels. This feature is more conspicuous in the western edge of the Sub-Facet A_1 (Plate 3.4). Their origin could be attributed to various factors. The author would consider them as "flood-plain scour routes" affording sites for flowing water during periods when the erstwhile flowing stream carried a considerable volume of water, all of which it could not retain within its walls, thus cutting new routes.

PLATE 3.4

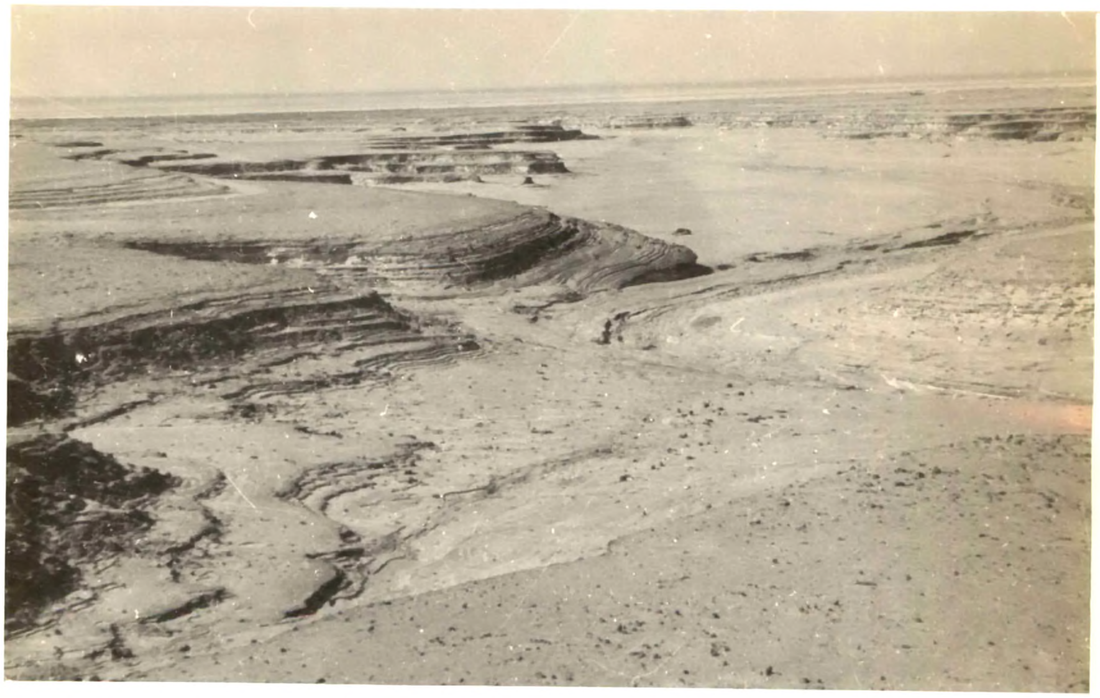
Typical abandoned channels.

Location: West of Vigukot in Sub-Facet A_1

Some of them are definitely 'abandoned channels' or 'meander scars' which probably reflect the shifting nature of the stream during some period of its geomorphic history (Plate 3.5). In comparision to the 'flood-plain scour routes' which at times are seen to branch off at odd angles, these channels reflecting shifts of the stream always appear to be parallel to the main stream. At times, the 'meander scars' representing meanders abandoned by cut-offs, are observed. Most of these 'cut-offs' are seen to be wet patches and relatively deeper, forming sites for salt-lakes and swamps. The back-swamps are invariably recognised on air-photos by their depressed nature and the dark tones, on account of the dark coloured boggy material they contain, at times these attain appreciable dimensions (Stereo Plate 3). Salt lakes are recognised by their lighter tones and in all cases occur randomly (Stereo Plate 4).

Channel-fill deposits: These deposits are always encountered in the abandoned channels mentioned above and in comparision to 'point bar' or 'channel bar' deposits, they are basically very fine grained and often characterised by laminations. A reduction in grain-size from base upward is commonly recorded. The author has analysed the nature

PLATE 3.5



Typical abandoned channels of Sub-Facet A_1
(Depth of channels around 1 metre)
Location: West of Karimshahi

of these channel fills, and found that often the top layer showed some coarse admixture on account of material brought down by wind action or saltation. As these channels are at present 'dead', they serve only as conduits during rainy seasons, and are generally dry in summer. However, after rains they retain water and remain moist for many days, thus rendering such spots extremely treacherous. In some places, especially during summer, these channels were found to be partly or even completely filled up by wind-blown loess.

To summarise, it may be stated that this Facet especially its western part, contains a levee complex with associated point bar and channel bar deposits of fine sand and sandy loam. Away from the main channels, the levees grade into silty loam and thence into clays, peaty clays and the peats of the intervening back swamps. These deposits bear witness to the numerous shifts in stream courses in the past and typically indicate the 'deltaic' nature of this region during some time in its geomorphic history. Van Andel (1967, p.297) working in the Orinoco delta region observed similar conditions and a sequence of "channel deposits from where the levees grade into the finer materials of the swamp deposits".

FACET B : LINEAR TRENCH ZONE

This trench like feature lying between the rocky mainland and the Bet-zone, is rather unique in configuration. It is a linear, depressed terrain along which sea water is able to travel eastwards as far as Kuar bet, about 90 km inland. This ingress is partly tidal and partly due to the action of strong winds.

This trench is restricted on both sides by high grounds. To the north, the mound of Allah Band rises steeply (4.50 metres in its western edge and dying away to less than 0.5 metre near Kuar bet at its eastern extremity), while to the south, it is flanked by the mainland rocks with near vertical faces and the higher plains of Banni. Position of this Facet is shown in Fig. 3.2.

Based on the extent of inundation by tidal current and strong winds this area has been sub-divided into three Sub-Facets.

Sub-Facet B_1: Region of regular marine influence

This portion comprises the westernmost portion nearer to the sea, and includes the region in the proximity of the Kori Creek. The coast line here, in marked contrast to the open Arabian sea, is very well sheltered. The Kori Creek progressively tapers of in a ENE direction finally merging into the vast mud flats that abut against the rocks of the mainland. These mud-flats are deposited between normal high and low tides and regarded as a littoral mud flat, extend upto a distance of approximately 25 km from the edge of the Kori Creek. The extreme and the narrower extension of the Kori Creek is the Kadoara Creek.

The surface sediments of these tidal flats consist mostly of clay and silt laminations with occasional sand stringers. These clay horizons often show development of gypsum crystals, and a proliferation of such crystals is observed along the edge of the mainland. In the central part of this Sub-Facet, owing to constant wetness and the fineness of sediments, crystal growth is inhibited. In this part, it was not possible to dig profiles below 1 metre because water oozed out and there was a tendency of the sides to cave in.

The sediments of the region appear have been derived from many sources. A major portion seems to have been brought by the creeks during the tides.

The hills in the background, mostly consisting of Eocene limestone contribute to the sediments mainly near the fringes. Also some sediments are definitely derived by the scouring action of the high tides striking against the Allah Band in the north. Such scouring action is ideally shown at the base of the ruins of Sindree fort (Fig. 3.2).

This Sub-Facet is a highly treacherous region, being perennially within the influence of the tide, and is therefore always wet, and its accessibility is limited to camels during fair weather only. During low tides, surface tidal channels that mark the remnant extension of the Kori Creek and the ancient channel to the north, characterise probably the ancient course of the river Nara (Fig. 3.2). These relict channels, always retain some water owing to their slightly greater depression. On air-photos, which appear to have been taken during a low water phase, a prominent tidal channel (partly obscured now) trending approximately NNE-SSW is seen. These channels probably reflect the submergence of the once prominent delta distributaries by the sediments carried during tidal ingress.

This Sub-Facet even at its eastern extremity has a gradient which rises very slightly due east and is thus almost at par with the sea level. R.L. along this route is shown in Fig. 3.4. Sindree depression is the deepest part of this Sub-Facet.

Sub-Facet B_2 : Region of marine influence during monsoon high tides:

This region is further inland from the edge of the Kori Creek and comes under the influence of high tides only during monsoon. This area is just an extension of the above Sub-Facet, maintaining its overall characteristics. However, owing to the fact that the tidal water ingress here is only during monsoons, it allows evaporation of the sea water during drier periods to form a rather continuous layer of salt crust which stretches as far as Kuar bet to the east. This salt encrusted plain shows a typical crinkled surface (Plate 3.6), and the thickness of the salt crusts often reach as much as 2.5 cm, always resting over soft oozy, peat-like clay. This peat-like clay is conspicuously absent in the Sub-Facet B_1 because the constant tidal action did not favour peat formation.

PLATE 3.6

General view of salt encrusted Rann.
Location: 9 km west of Kuar bet.

Salt crusts become thicker eastwards, while gradually disappear to the west as the normal water line appears.

This salt encrusted region is flanked to the south by the Miocene hills of clays (Plate 3.7), marls and siltstone, intervened by a zone of narrow outwash plain. This zone is cut by numerous gullies of intermittent streams. The outwash plain gradually merges into the salt encrusted plain with gradual change in the nature of sediments from silty sands, sandy silts to the clays in the central depressions.

The relative level (RL) is very low and even on an average spots 30 km away from the Kori Creek, barely rise to 2.50 R.L. The local depressions (Fig. 3.4) have R.L. as low as 1.1. This indicates the very gentle gradient of this trench-like feature, west to east.

<u>Sub-Facet B_3 : Region of restricted marine influence</u>

This region is farthest from the Kori Creek, somewhat more depressed as compared to the Sub-Facet B_2 to its west (Fig. 3.4). It is never affected by normal

PLATE 3.7

Salt encrusted region in Sub-Facet B_2
(Just after sea water recession)

tides because of the slight elevation of the ground comprising the Sub-Facet B_2, which prevents tidal ingress during normal high tide conditions. Only during heavy tides in monsoons, sea water aided by stormy winds blowing from west to east reaches upto Kuar bet and stagnates in this depression giving rise to an extensive salt-encrusted plain. The author made day to day observations at the two ends of the main Facet, i.e. at Lakhpat in the west and Kuar bet in the east, and observed that standing water never exceeded 30 cm in depth around Kuar bet. During other periods, it provides an excellent scene of an unending salt crusted terrain stretching westwards. As in the adjacent Sub-Facet, salt crust development may reach upto 2.5 cm to 3.5 cm. Invariably, the salt crusts rest over soft, oozy mud like clay.

The region of this Sub-Facet is somewhat wedge-shaped with the narrow end, pointing to Kuar bet. It widens out westward. Its R.L. is very low, around Kuar bet as low as 1.1 which reflects the depressed nature of this region. Owing to the extreme salinity, there is no vegetation except on a few 'dhois' (Fig.3.2).

The southern extremity of this region merges into the Banni plains which show a higher elevation. To the north, it merges into the elevated tract comprising the eastern extremity of Allah Band and thence into the higher regions of the Bet-zone (average R.L. around 3.5 and 4.65), which is free from sea water ingress.

FACET C : THE GREAT BARREN ZONE

The eastern portion of the Great Rana, lying to the east of the north-south line joining Kuar bet and Bediya bet (Fig. 3.2) is always free from the inundation of sea water. It forms a vast, barren area where little vegetation flourishes except for some special variety of grass growing in isolated pockets. Only one rocky outcrop projects out of this barren plain (Maruda Thakkar) - an outcrop of Archaean nepheline syenite rising to a height of about 12 metres from the desolate, bare surroundings. To the north, this plain merges into the sand ridges of Sindh, and southward it abuts against the rocks of Pachham, Khadir and Bela islands (Stereo Plate 5).

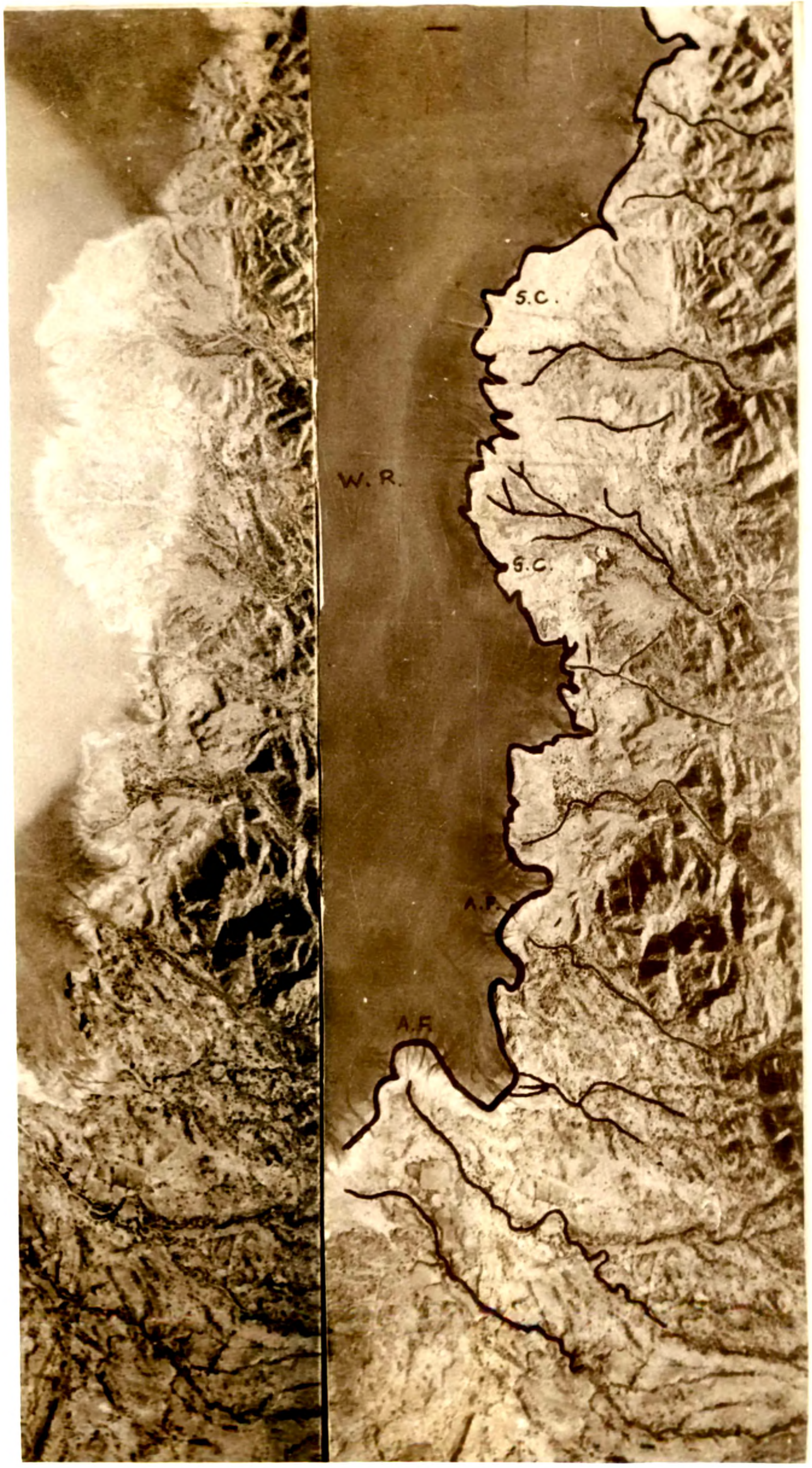
Topographically, this Facet comprises a vast shallow depression with minor smaller depressions

STEREO-PLATE 5

Stereo-plate showing the position of Rann with respect to the hill massifs of Island belt. Note abrupt transition into the depressed Rann. Inked lines represent streams.

A.F.: Alluvial fans W.R.: Wet Rann

S.C.: Salt crust



S.C.
W.R.
S.C.
A.P.
A.F.

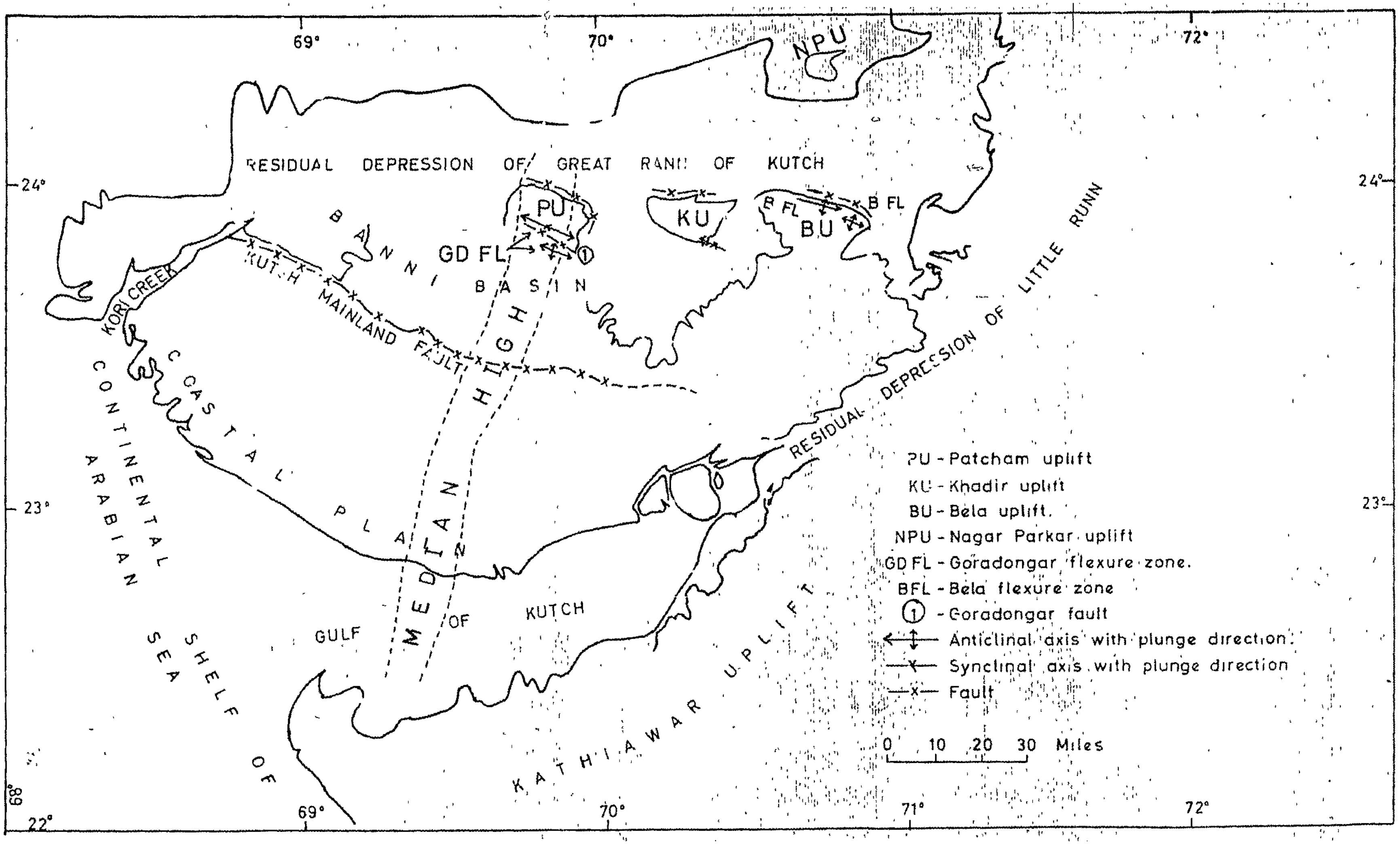
within it. Surface channels and 'bars', encountered in the adjoining Facet A, are totally absent here. Even detailed air-photo studies failed to bring out any such features. In fact, this region has a very conspicuous inward slope, from the distinct higher ground of the Bet-Zone. Even though some spots are as far as 100-125 km inland, their R.L. at times is as low as 2 to 1.25.

This depression with its smaller depressions, appears to be tectonically controlled by the basement configuration. This control is very much evident by the fact that the individual depressed areas are always situated to the north or around the individual hill massifs of Pachham, Khadir and Bela (Fig. 3.5). Biswas and Deshpande (1970) have termed them as residual depressions related to the hill massifs which indicate 'uplifts'. The two authors further state that the massifs could be regarded as 'horsts' such that the Great Rann and its depressions are the sites of corresponding 'grabens'.

The smaller and somewhat deeper depressions are the sites of 'inland sebkhas' (discussed later), where

Fig. 3.5.

TECTONIC MAP OF KUTCH



salt thickness at times reaches 5 cm. The profile observation, especially in these 'sebkhas' point to an upper layer of salt crust underlain by bottle-green to dark-coloured clays. In places of water stagnation, initial formation stage of peat is also observed.

Owing to its depressed nature, this region, acts as a bowl, which gets inundated by rain water that falls directly and to a certain extent by the water carried down by streams from the rocky island to its south. As a result, this region remains wet, after heavy rains, for many months. The subsidiary depressions that hold more water are almost perennially wet. On air-photos, these showed a distinct dark tone (Stereo Plate 5). Even during the extreme dry months of December and January, many parts of this Facet are inaccessible owing to the moist clays present.

SPECIAL GEOMORPHIC FEATURES

Kori Creek

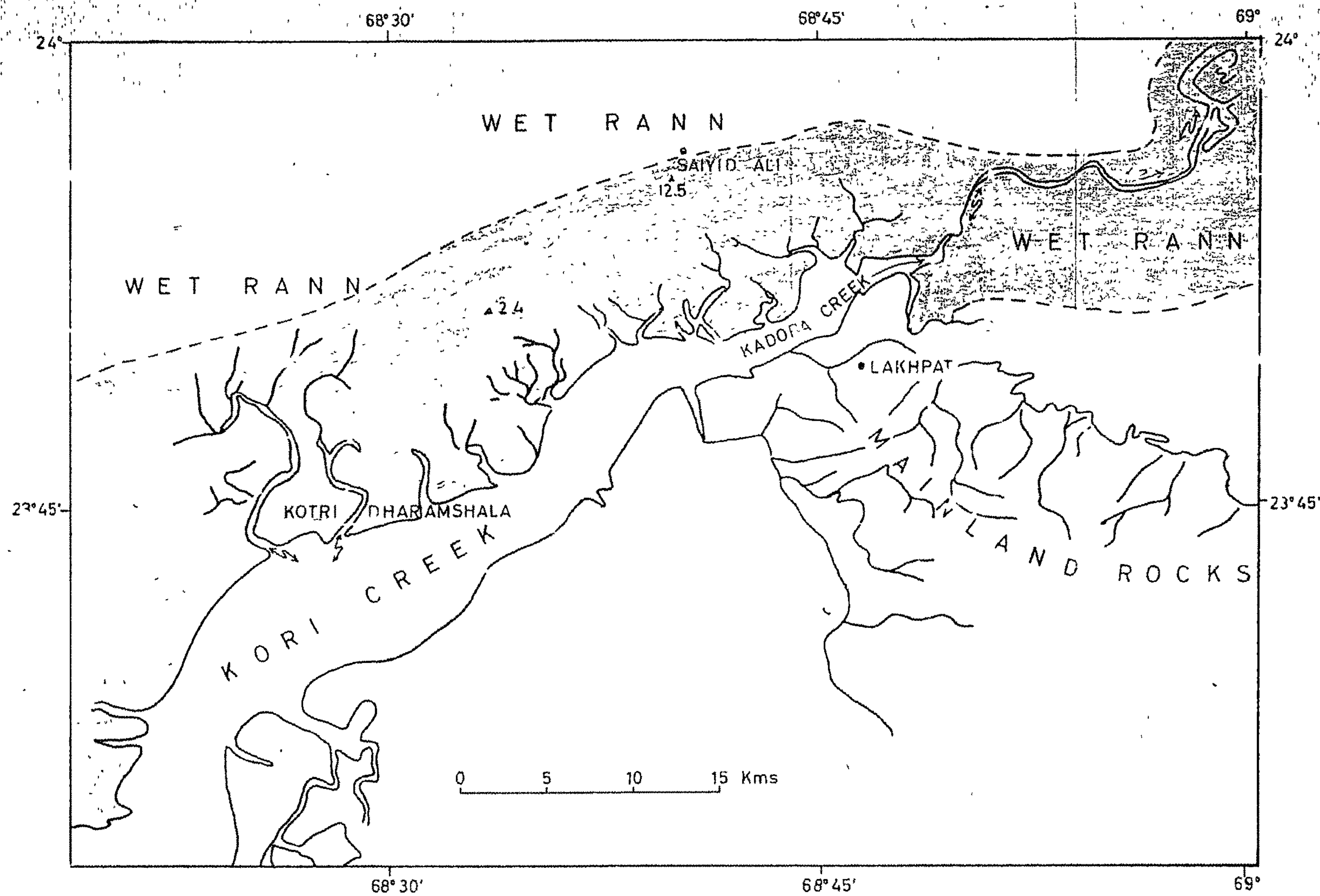
The Kori Creek which probably represents an original mouth of a main tributary of the River Indus, can now in its present stage, best be described as a tidal channel with a very characteristic nozzle-shaped configuration (Fig. 3.6). It tapers almost to a point (via the Kadoara Creek) into the Rann and opens out considerably into the Arabian Sea (Fig. 3.6). It carries sea water inwards during tides, its extent depending on the season and the velocity of the prevalent wind. The tidal currents, in this creek, locally attain velocities high enough to transport material inwards, but the accumulation is of minor geomorphic significance. (The silts and clays that are carried inwards gives rise to the littoral mud-flats).

Thornbury (1954, p.430) writes that in funnel-shaped bays or creeks (as the Kori Creek), tidal range may be large because of the piling of water. According to him (1954, p.430), in the Bay of Fundy, which also has a very wide tidal range, the flow of the tide is commonly marked by a front of advancing water known as tidal bore which may be as much as 2 metres high.

Similar tidal bores have been reported in the estuaries of Severn and Trent in southern England, and tidal bores 5 metres high have been reported in Tsientan River in China by Kuenen (1950). Johnson (1925) concluded that in the Bay of Fundy there was more

Fig. 3.6.

REGION AROUND KORI CREEK



Δ Spot height.

Region under the regular influence of creek overflow.

evidence of deposition rather than erosion by tides. Shepherd (1948) has stated that the tides are responsible for very rapid movement of sea water in suck creeks, and according to Thornbury (1954) tidal bores with velocities as high as 12 knots are possible.

Similar conditions exist at the Kori Creek also, where bores attain heights even as much as 5.5 metres (Fig. 3.7). Furthermore, the piling up of water is also very evident, especially where the Creek tapers off to a point, to be 'ejected' as it were, from its narrow mouth, aided by strong winds many kilometres inland. Also, the processes of deposition and erosion appear to be moving side by side. Tidal erosion is typically shown by the development of numerous subsidiary creeks that are progressively invading the Rann (Fig.3.6). Observations have shown that the tidal currents locally transport debris inward as far as the eastern limits of Kuar bet (Plate 3.8), and carry-out considerable scouring action in the region of the now abandoned Sindree Fort, at the base of the western limit of the Allah Band (Fig. 3.2).

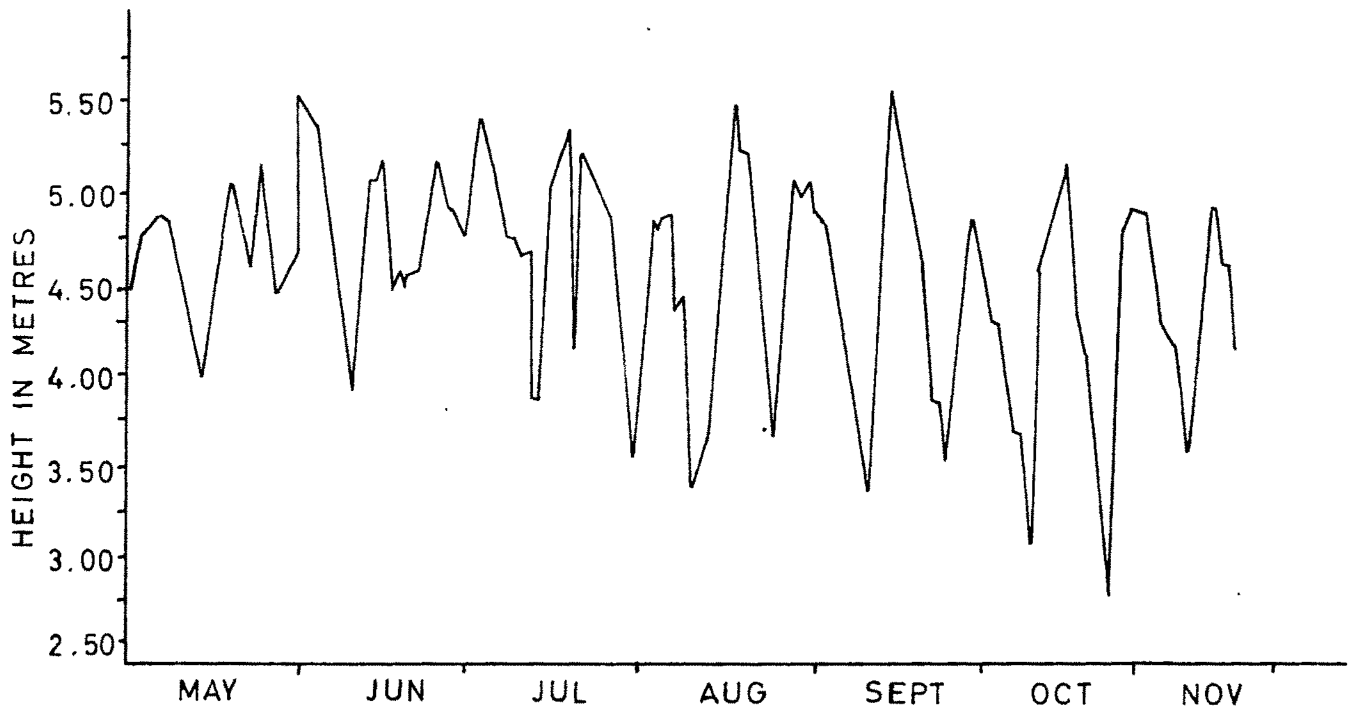
<u>Allah Band</u>

Sandwiched between Facet A and B is a linear mound-like feature known as Allah Band. It is a remarkable

PLATE 3.8

Debris brought down by sea-water.
Location: About 3 km SSW of Kuar bet

TIDAL FLUCTUATION AT KORI CREEK
(BASED ON DAILY RECORDS OF 1968)



geomorphic feature on the Rann's surface and has caused the Rann to be divided into two distinct geomorphic units - the elevated region to the north and the shallow trough-like depression to its south. Allah Band is an unique example of a recent tectonic uplift which took place during the 1819 earthquake. With this uplift a corresponding depression to its south was formed and which further deepened the already existing trough-like feature. It is said that several subsequent minor earthquakes have added to the height of Allah Band in recent years. On air photos and during field reconnaissance, Allah Band is seen to resemble a low scarp of unconsolidated material. Its southern face is sub-vertical with dip around 80° towards south (Stereo Plate 1) and with the north side showing a peculiar topography. The area immediately north of the scarp is seen to consist of a linear 3/4 km wide terrace (flat-topped) criss-crossed with numerous erosional channels and gullies, all cutting due southwards (Stereo Plate 1). This terrace has a very slight southerly slope. Beyond it, the ground gently slopes northwards and is seen dissected into a number of smaller terraces or step like features (Plate 3.9) which gradually

PLATE 3.9

Complex network of gullies and channels.
Location: Allah Band (South of Karimshahi)

merge into the Bet zone. The trend of the Allah Band is approximately east-west, though sharp locals swings are noticeable. It gradually dies away eastward in the vicinity of Mori bet. It reaches a maximum height of around 5 metres in its western extremity, decreasing to a mound less than 1/2 metre high to the east (Stereo Plate 6).

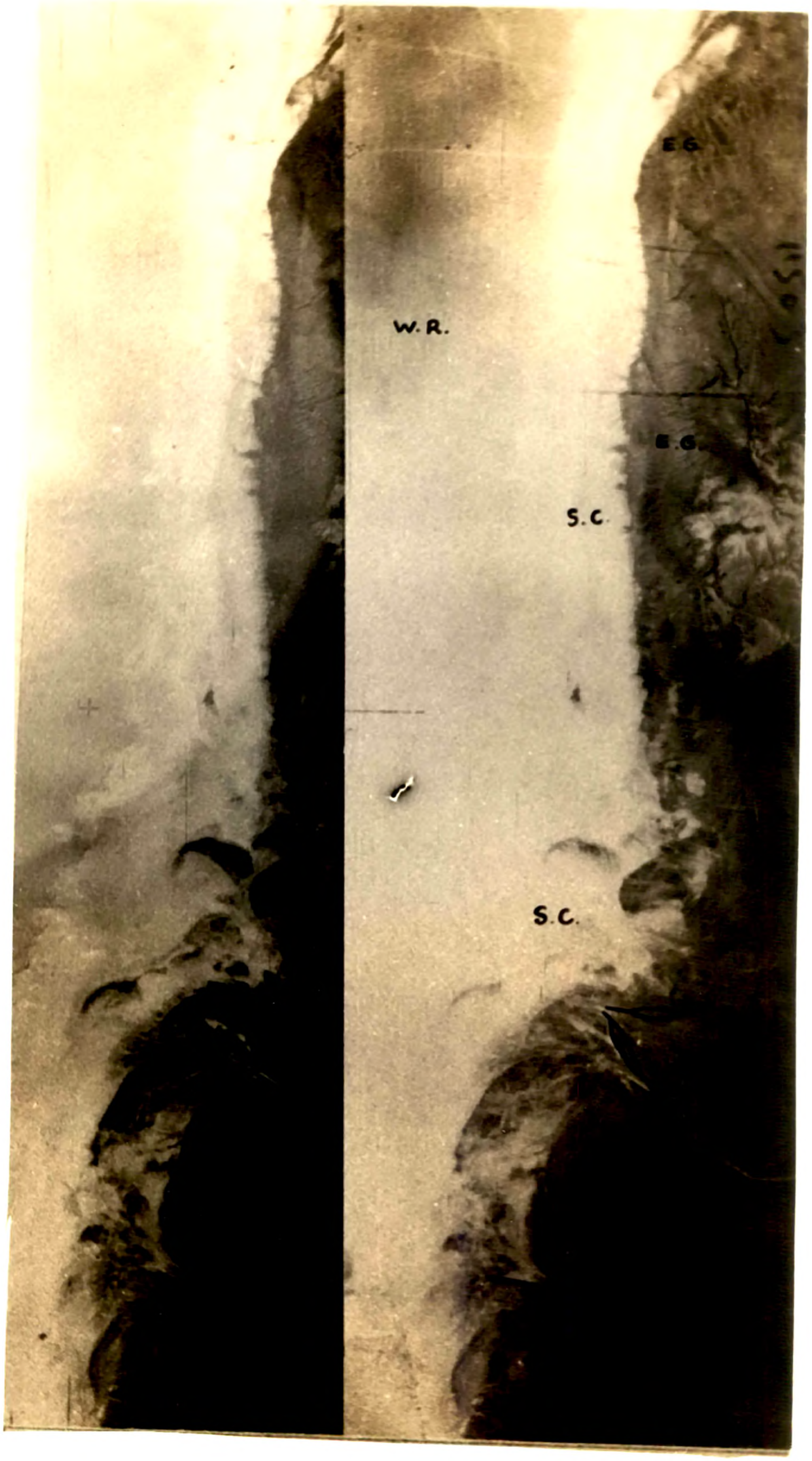
Though Allah Band would not fall under the usual terminology for tectonic scarps involving rock masses as visualised by Davis (1913) and Johnson (1939), it can better be regarded as an "alluvial scarp". Such alluvial scarps are generally low. Gilbert (1928) has designated these as 'piedmont scarps', and believed that they were produced largely by slumping movement along a fault plane. The Allah Band typically reveals evidence of recent uplifts, because alluvial scarps tend to get obliterated very soon due to their unconsolidated nature.

The drainage feature of this region is very fascinating (Plate 3.9). Of all the regions of the Rann, nowhere is the drainage texture so fine. The author is sure that these drainage features are mostly

STEREO-PLATE 6

Stereo-plate showing the eastern extremity of the Allah Band. Note the gentle slope in this region.

S.C.: Salt crusts
E.C.: Erosional channels
W.R.: Wet Rann
E.G.: Erosional gullies


E.G.
W.R.
E.G.
S.C.
S.C.

post-uplift as they resemble erosional gullies that have cut the surface of the Allah Band into a complex, dissected pattern (Plate 3.9). Under normal conditions, no water is present in these gullies, and during rains they not only carry water but also tend to be further deepened by the action of water. Thus the Allah Band provides an ideal example of the rejuvenation of a landscape with the present highly dissected pattern indicating a rapid rate of peneplanation.

Rocky Mainland

This region, to the west, flanking the Great Rann is rocky and comprises sequences of mostly sandstones, limestones and shales of Mesozoic age. They stand up from the face of the Great Rann in the form of cliffs with near vertical faces. In fact the junction of the mainland and the Rann is marked by a major fault (Fig. 3.5).

The streams of the mainland, though ephemeral in nature do carry some water during the rainy seasons. Apart from carrying water, a good amount of dissolved salts and sediments, is transported which is added to the Rann at places where the streams debouch over the

Rann surface. The overall drainage pattern is dendritic to sub-dendritic represented by irregular tributary streams branching in many directions and at almost any angle. The complexity of the stream pattern reflects the weatherable nature of the rock type through which the streams flow. In spite of the low gradient of the streams, a great deal of downcutting is observed, and this striking feature reflects the softness of the rock type. Drainage density is medium and the stream frequency is intermediate. Most of these north flowing streams and tributaries, flowing into the Rann or the Banni (Fig. 1.5) are not perennial. However, even during rains, when they carry water, a major portion of the water never reaches the Rann as it is absorbed by the dry river bed. The streams never exceeded 6 to 7 metres in width and have a sandy base. At places pockets of saline water are retained even during the dry periods.

The north flowing streams of the mainland have given rise to alluvial fans. Thornbury (1954, p. 173) has considered such alluvial deposits to be somewhat similar, in their mode of deposition, to those at the mouth of deltas. During rains, the mainland streams passing through soft sedimentary rock formations get loaded with sediments. When these loaded streams debouch into the Great Rann from the mainland, there is a marked drop in the gradient, resulting in deposition of the transported material, apexing at the point of emergence and spreading out in fan-like forms onto the low land. As the rainfall is always scanty, the alluvial fans have not assumed any appreciable size, because the total volume of material debouching itself onto the Great Rann has never been considerable. At places, the author observed in the field that the points of emergence of alluvial fans, were blocked owing to the collapse of the surrounding walls of the stream. Often two generations of alluvial fans were also observed.

The material comprising a fan is seen to vary in texture from coarse boulders and pebbles at the head to finer material down the slope. The silt and clay fractions are seen washed out further north by rain right into the main Rann, such that the finest size clays, were always found settled in the central depressions of the Great Rann. This phenomenon is responsible for contamination of Rann sediments with relatively coarser materials, resulting into an admixture all along the Rann and the Mainland junction.

Island Belt

The island belt of Kutch, rising within the Rann, comprises three prominent dome-like structures represented by Pachham, Khadir and Bela. As with the mainland rocks, they stand out vertically from the face of the Rann forming sheer cliffs, at times around 45 to 50 metres high. In fact, this island belt rocks form the highest points in the entire Kutch. They consist of well-bedded rocks of Jurassic age consisting mainly of sandstones and limestones with occasional intrusion of basic rocks. The northern face of these massifs are all marked by faults. Biswas and Deshpande (1970) have termed them as Pachham, Bela and Khadir uplifts in contrast to the residual depression of the Great Rann situated to the north.

Drainage pattern of this island belt is relatively simple being of the parallel type. Typical of the Kutch region, there are no perennially flowing streams. All carry water during rains, and debouch into the Great Barren zone. During dry seasons they are dry with occasional pools of saline water. In all cases, these streams have cut steep faces through the surrounding rocks.

Banni

Flanking the Great Rann to its south, the plains of Banni form a low-lying tract of alluvium deposited by the streams flowing northwards from the rocky mainland. It can be regarded as a slightly elevated portion of the Rann. In comparision to the Great Rann, the sediment of Banni is less saline, though its salinity is high enough to render it unsuitable for cultivation. For the most part, the sediments are sandy and silty with a coarse open texture. The heavy clays and the organic horizons encountered in the Great Rann are totally absent here. Furthermore, surface salt encrustations are absent, though salt crystals are seen to develop along profiles. Overall gradient of the Banni is very low and it has some areas of depressions where water tends to collect during rains. It is totally free from the effects of tidal water, owing to its higher elevation. Inundation is mainly by river water and direct precipitation during heavy rains only. Compared to the Rann, where the vegetation is scanty and in most cases totally absent, Banni has comparatively better vegetation comprising stunted bushes and occasional trees typical of desert region (Plate 3.10). The transition from the Banni to the Great Rann to its north is abrupt (Plate 3.11) and

PLATE 3.10

Typical Banni shrubland

PLATE 3.11

Photograph showing abrupt transition
from Rann to Banni.

is conspicuous by the distinct thinning of vegetation, gradual decrease in elevation and the change in the sediment type.

Efflorescence deposits and Sebkhas

The aridity and the morphology of the Rann has favoured accumulation of salts in varying forms in scattered patches, and the author, in the course of his work recognised the following types of salt deposits:

(1) Efflorescence deposits of the nature of thin salt veneer resulted from the evaporation of moisture brought to the surface by capillary action.

(2) Disseminations of salt crystals along the profiles and comprising mainly gypsum and anhydrite.

(3) Thick surficial deposits occuring in the depressed patches on the Rann surface and in areas of marine flooding. They result from the evaporation of the stagnated water.

Efflorescence deposits: Efflorescence is a phenomena connected with the evaporation of moisture (saline in the case of the Rann) brought near or to the surface by capillary action. The salt encrustations usually due to efflorescence occur as thin veneer or as wafer-like crusts on the surface which always crumble readily under pressure. The undersurface of these crusts, very often, consists of thin needle-like salt crystals (Plate 3.12). This form of encrustation is most common all over the Rann, except in areas of thick salt crust development, and appears to be more conspicuous in the fine-grained Rann sediments which favour moisture rise by capillary action. This veneer-like salt crust tends to disappear from many places, subsequently by the action of wind, and at times is covered under a blanket of loess. During fierce desert storms, a lot of this salt is removed by deflation and often carried many miles inland.

Salt crystals along profile: The development of sub-surface salt crystals is often quite prominent. This growth is obviously the result of direct evaporation of apparently saline interstitial water and is observed to be more in the sediments which have a coarse texture and which are less compact and less moist. The crystals are mainly of gypsum and anhydrite. The size of the gypsum crystals appear related to the grain-size of the sediments in which they grow, the coarse fractions giving

PLATE 3.12

Close-up of friable top surface of salt crust with needle-like crystal development on the undersurface.
Location: About 2 km east of Dharamshala

more space for their growth. Furthermore, this sub-surface crystal development is found to be absent in the wet Rann. This crystal development, when taking place, is invariably restricted to the top 1.25 m of a profile and, only in rare cases like the transition zone sediments near Banni, crystal development is seen to proceed beyond 2 metres. The gradual decrease of crystal development with depth appears to be correlated with wetness of the sediments which increases progressively with depth. Examples of good development of crystals are seen in the zone around the various bets, where the silty clay sediments appear to favour the formation of these salt crystals. This phenomenon is best seen in dry seasons. The author has recorded two distinct types of the crystals formed. One types is that of acicular crystals oriented in near vertical position and found in the more clayey profiles. The other form is the development of perfect cubical crystals with hopper-like faces.

Sebkhas: These are surface deposits of appreciable thickness and formed by the direct evaporation of standing water bodies resulting in the formation of salt playas or to use Glennie's nomenclature 'sebkhas'.

In the Rann the term 'sebkha' appears to be a more appropriate than playa. Glennie (1970, p.60) has said that "inland sebkhas develop where water flowing in wadis intermittently floods low-lying depressions to leave behind damp salt-encrusted sediments". Shearman (1963, 1966) specified the use of the prefix 'inland' to those sebkhas that developed inland, and 'coastal' to those characterised by marine flooding and evaporistic conditions. The author has included the salt-crusted regions of the Great Barren zone (Facet C), free of sea water inundation, as 'inland sebkhas', while the salt encrusted area around Kuar bet and stretching west of it (Sub Facets B_2 and B_3) have been regarded as 'coastal sebkhas' as it comes under the reach of tidal water.

The evaporites around Kuar bet and to its west, are generally as much as 2.5 cm thick, and form a biscuit like crust traversed by polygonal wave like ridges (Plate 3.13). The ridges perhaps indicate buckling up due to the expansion during crystallisation. The crests of these waves are generally broken (Plate 3.13) and often the cracks are filled with dust into which capillary action has brought salt from below. Thus

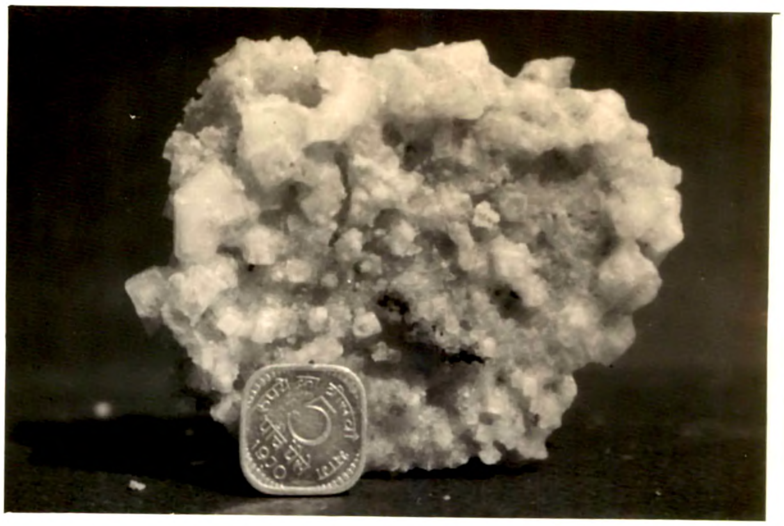
PLATE 3.13

Ridged and buckled appearance of salt crusts.
Location: About 10 km WSW of Kuar bet in
Great Rann (Sub-Facet B_3)

there could occur two generations of salt crystals. The salt in the coastal sebkha is halite and good crystal development is often seen (Plate 3.14 and 3.15). The crusts invariably incorporate a considerable amount of wind blown material. They have fairly hard surfaces and at times can withstand high pressure. These salt crusts invariably rest over marine clays which always contain enclosed lenses of salt water. The author came across several such spots where trapped sea water occurred and oozed out when pits were dug there.

On the other hand, inland sebkhas encountered in the region free from the present day tidal influence, indicate an origin due to the evaporation of standing water that collects in the depressions. The collected water is mainly rain water, which is rendered saline subsequently on account of numerous reasons. In the various depressions north of Pachham, Khadir and Bela islands, the collected rain water during monsoons gets saline by dissolving the salts which are present, in the underlying sediments. In the depressions adjacent to the hill massifs, a lot of salt particles are added

PLATE 3.14



Development of halite crystals.
Location: WSW of Kuar bet in the Great Rann.

PLATE 3.15

Development of cubic halite crystals from evaporation of sea water.
Location: South of Kuar bet in the Great Rann.

together with wind blown dust. In contrast, the surface of the salt crusts are generally smooth and free from any buckles. The salt crusts rest over soft, oozy mud which is impregnated with bittern. The development of these crusts is further accentuated by the high temperature in the region and fierce evaporation especially during the summer months (Table 3.1).

TABLE 3.1

OPEN PAN EVAPORATION

Date	Time	Depth of evaporation (mm)
April 1969		
1	8.00 A.M.	10.5
4	"	12.6
7	"	10.2
10	"	9.8
13	"	13.4
16	"	13.4
19	"	14.4
22	"	11.0
25	"	14.0
28	"	14.5
	Average: 12.45	
May 1969		
1	8.00 A.M.	15.6
4	"	14.2
7	"	13.8
10	"	12.9
13	"	12.5
16	"	13.8
19	"	14.6
22	"	15.8

TABLE 3.1 (contd.)

Date	Time	Depth of evaporation (mm)
May 1969		
25	8.00 A.M.	16.2
28	"	16.3
	Average: 14.57	
June 1969		
1	8.00 A.M.	18.5
4	"	18.3
7	"	19.2
10	"	16.3
13	"	15.2
16	"	15.2
19	"	17.2
22	"	17.2
25	"	16.2
28	"	14.2
	Average: 16.75	
July 1969		
1	8.00 A.M.	20.2
4	"	17.8
7	"	16.5

TABLE 3.1 (contd.)

Date	Time	Depth of evaporation (mm)
July 1969		
10	8.00 A.M.	15.8
13	"	17.4
16	"	18.2
19	"	20.3
22	"	22.3
25	"	21.2
28	"	20.3
	Agerage: 19.00	
November 1969		
16	8.00 A.M.	6.3
17	"	6.3
18	"	6.5
19	"	6.8
20	"	7.4
21	"	7.0
22	"	6.0
23	"	6.7
24	"	7.6

TABLE 3.1 (contd.)

Date	Time	Depth of evaporation (mm)
November 1969		
25	8.00 A.M.	8.0
26	"	6.0
27	"	5.7
28	"	4.0
29	"	5.7
30	"	3.2
	Average: 6.2	
December 1969		
1	8.00 A.M.	1.7
2	"	5.5
3	"	5.7
4	"	5.0
5	"	4.0
6	"	4.8
7	"	4.7
8	"	4.0
9	"	5.6
10	"	7.9
11	"	5.3

TABLE 3.1 (contd.)

Date	Time	Depth of evaporation (mm)
December 1969		
12	8.00 A.M.	5.5
13	"	5.4
14	"	4.6
15	"	4.6
16	"	4.7
17	"	5.0
18	"	5.0
19	"	5.2
20	"	5.0
21	"	2.8
22	"	4.0
23	"	4.7
24	"	4.0
25	"	4.0
26	"	5.2
27	"	2.6
28	"	3.7
29	"	4.0
30	"	4.0
31	"	4.0

Average: 4.6

TABLE 3.1 (contd.)

Date	Time	Depth of evaporation (mm)
January 1970		
1	8.00 A.M.	1.6
4	"	2.8
7	"	4.2
10	"	3.8
13	"	5.2
16	"	6.9
19	"	2.5
22	"	3.4
25	"	4.2
28	"	4.2

Average: 3.88