CHAPTER 3

GEOMORPHOLOGY

The Kachchh Peninsula has been identified as the western margin of pericratonic rift basin of India (Biswas, 2005), exhibiting longest record of the Mesozoic succession in western India ranging in age from Late Triassic- Early Jurassic to Cretaceous (Biswas, 1987). This rift basin at present is under the influence of compressional stresses resulting due to the collision of the Indian plate with Eurasian plate. The landscape of Kachchh is therefore tectonically controlled and is studded with uplifts and subsidences. The Katrol Hill Range, the northern Hill Range in the Kachchh Mainland and Pachchham, Khadir, Bela islands represent uplifts while the Banni plain and Great Rann represent low lying depressions. The uplifts are confined to the major sub-parallel East-West trending faults viz. the Katrol Hill Fault (KHF), Kachchh Mainland Fault (KMF), Island Belt Fault (IBF) and Nagar Parkar Fault (NPF) (Biswas and Deshpande, 1970; Biswas, 1980, 1987).

Geomorphologically, Kachchh Peninsula can be grouped into following geomorphic units:

1. Dissected hills (Deccan traps and Mesozoics)
2. Piedmont zones
3. Pediplains
4. Banni Plains (fluvio-marine)
5. Alluvial plains and alluvial fans
6. Salt flats and encrustations
7. Mud flats

These geomorphic units have been described in different sectors like Kachchh Mainland, Wagad Highlands, Island Belt, Banni plains, alluvial plains, the Great Rann and Mud flats as follows:

1. Geomorphology of the Kachchh Mainland

The Kachchh Mainland has a rocky terrain with two major hill ranges viz. the Northern Hill Range and the Katrol Hill Range (Fig.3.1). These ranges are flanked in the north by major east-west trending faults, the Kachchh Mainland Fault (KMF) and the Katrol Hill Fault (KHF) respectively. The northern faces of the Katrol Hill Range and Northern Hill Range are the ideal examples of fault generated mountain fronts (Maurya et al., 2002), and are characterized by monoclinal flexures, anticlines and cuestas aligned along the southern flanks of East-West trending faults (Malik et al., 2001).

The E-W and WNW-ENE striking KMF marks the northern margin of Kachchh Mainland, where the northern hill range with average altitudes between 130 to 388 m abut against the low lying Great Rann-Banni plains with an average height of 2 to 5 m above MSL. This hill range is characterized by elongated domal structures producing steeply north facing escarpments with northerly dipping beds while in the south the beds are gently dipping towards south. According to Biswas (1980) the KMF is a vertical to steeply inclined normal fault at depth and changes to a high angle reverse fault near the surface. As described by Suppe (1983) this geomorphic expression suggests a phenomenon of fault propagated folding. It is also suggested that the movement is taking place along a south dipping low angle reverse fault (Biswas, 2002).

There are several streams flowing towards north across the Kachchh Mainland debouching into the Great Rann-Banni plain making semi conical alluvial fans in the piedmont zone of this range. The alluvial debris is seen resting unconformably on the Mesozoic rocks with thickness up to 3-15 m and is probably of Late Quaternary age.

The Katrol Hill Range is separated with the Northern Hill Range by a major East-West trending Katrol Hill Fault which marks the major drainage divide in the Kachchh Mainland. Uplift and deformation of this range along the KHF has controlled the development of numerous north and south flowing rivers (Malik et al., 2001). Deformation of this fault zone is similar to that of KMF zone. Intense asymmetric folding of Mesozoic

and Tertiary rocks has given rise to north facing steep forelimbs with gentle back limbs due south (Malik et al., 2001). Folding in the Middle Pleistocene miliolitic rocks (Sohoni et al., 1999) suggest that similar deformation has continued during Upper Pleistocene to Holocene.

In the north of the Katrol Hill Range lies the Bhuj basin, a longitudinal tectonic depression between KMF in the north and KHF in the south. This basin comprises thin veneer of Quaternary fluvial terrace deposits overlying the Bhuj Formation of Cretaceous Period. The pediment zone along the Katrol Hill Range front exhibits occurrence of several colluvial cones consisting of angular fragments of Mesozoic-Tertiary rocks along with some clasts of miliolitic rocks.

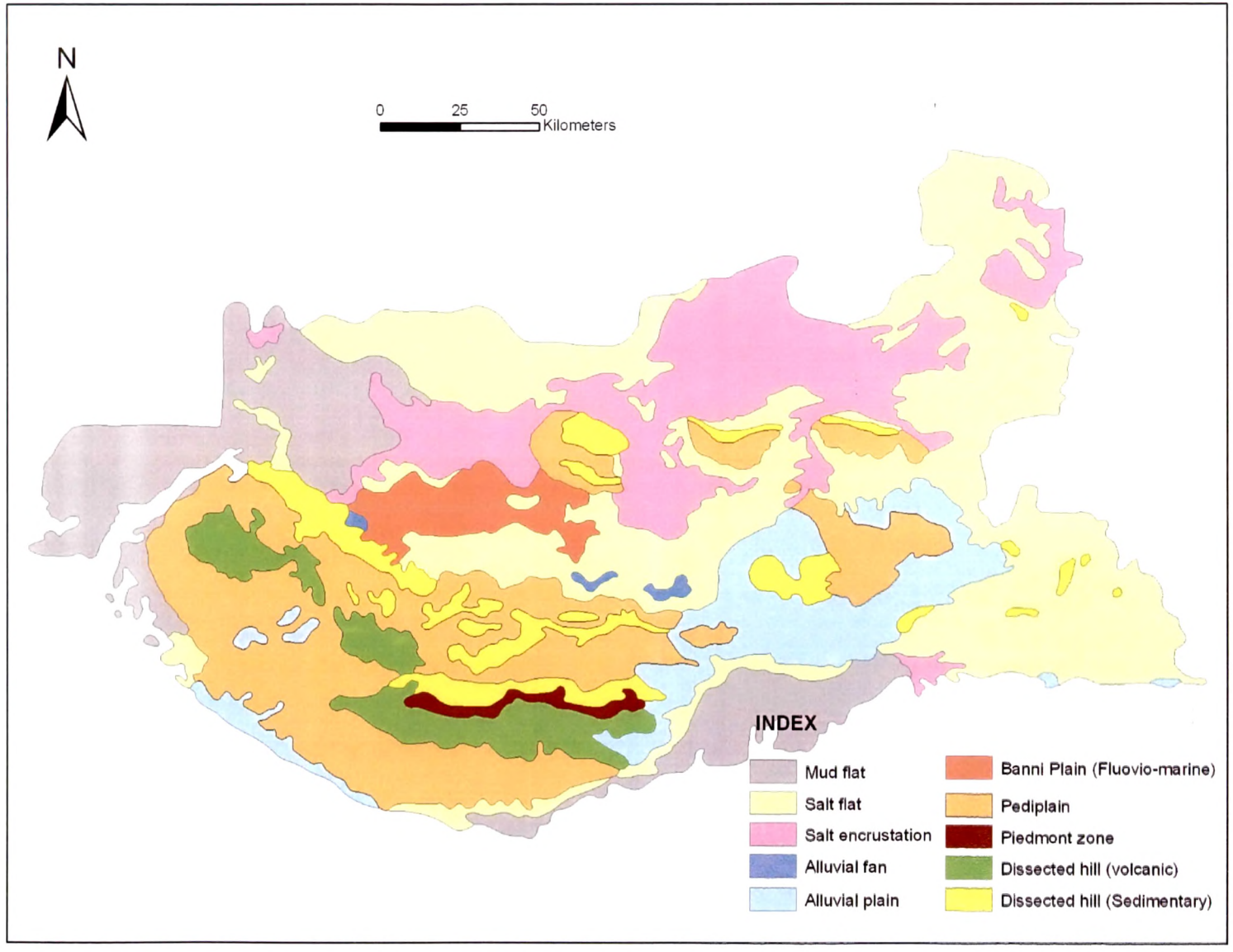

Fig.3.1: Geomorphological map of the Kachchh Peninsula (after ISRO, 1990 and GSI, 2001).

2. Island Belt

The Island belt comprises four isolated highlands in the Great Rann of Kachchh. These highlands viz. Pachchham, Khadir, Bela and Chorar are commonly described as 'Islands' as they stand out isolated in the submerged plains during the monsoon. They lie in the east-west line and are bounded by Island Belt Fault to the north making the northern side very steep while the southern slope is gentler.

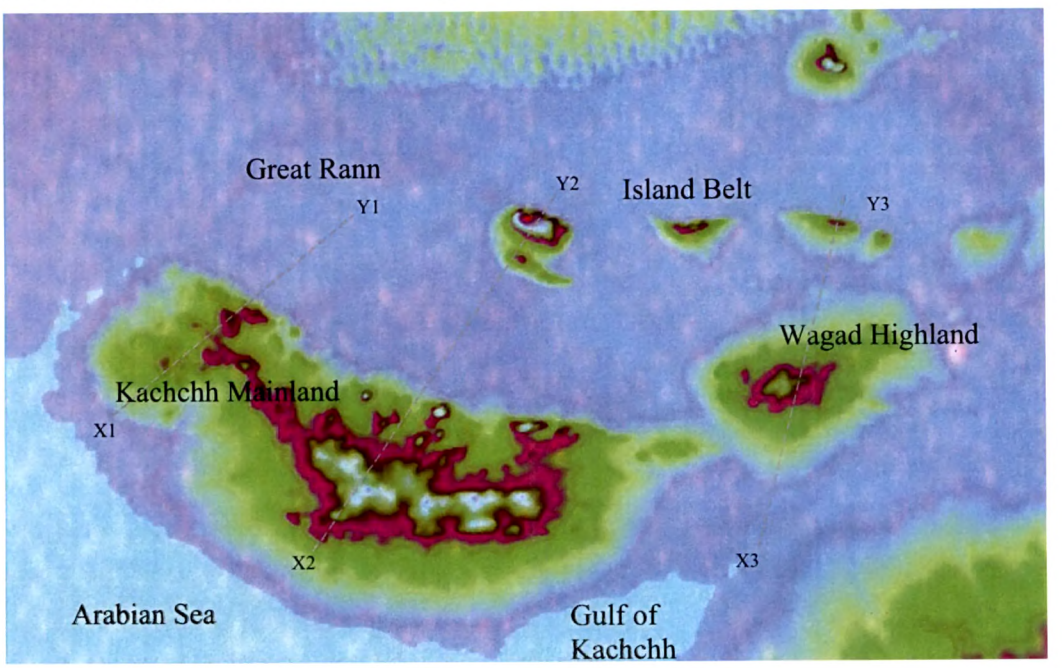

Fig.3.2: DEM of the Kachchh Peninsula depicting the geomorphic units.

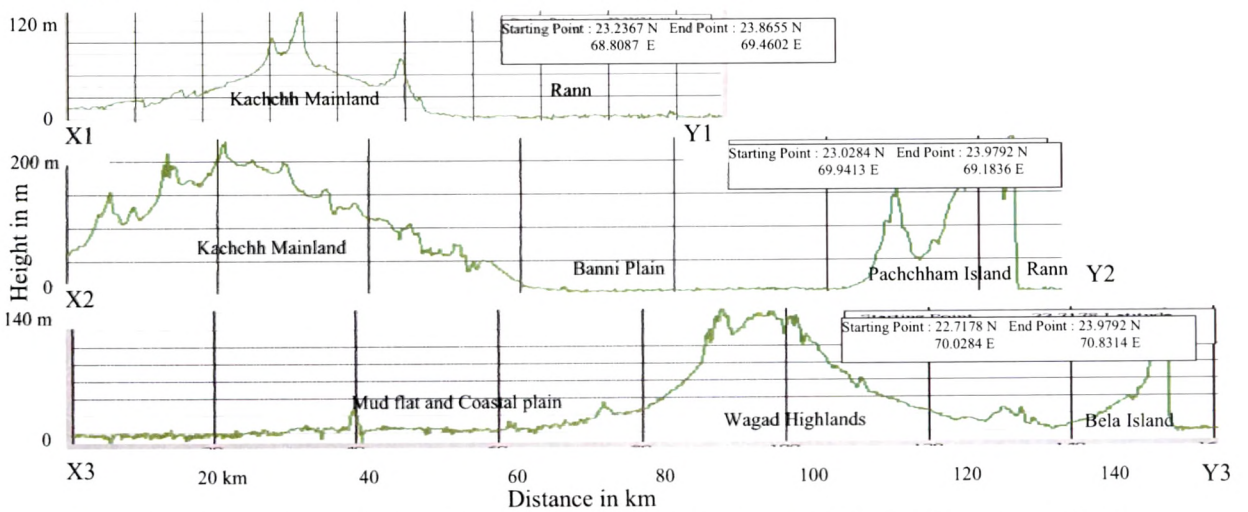

Fig.3.3: Topographic profile showing the general Physiography of the Kachchh Peninsula (Section lines are shown in Fig 3.2).

3. Wagad Highland

The upland region to the south of Khadir-Bela islands and towards the NE of Kachchh Mainland is known as Wagad Highland (Fig. 3.2 and 3.3). The Wagad Highland is separated from the Kachchh Mainland by South Wagad Fault (SWF) while a shallow graben separates it from Khadir and Bela islands in the north.

4. Banni Plain

The raised mud flats lying between the Kachchh Mainland in the south and the Great Rann in the north is known as the Banni Plain (Fig.3.1 and 3.4). It occurs 2 to 5 m above the mean sea level and is almost gradient less saline grassland with acacia and other bushy vegetation spread over it and covers around 3000 sq km of area. It is comprised mainly of silty and sandy sediments of varying thickness which overlie the Mesozoic-Tertiary sequence of rocks.

The Banni plain has been subdivided into three sub-units by Kar (1995) viz. a) high level mud flats, b) undifferentiated sloping and low level mud flat and, c) residual saline depression. The highest elevation occurs in NNW-SSE alignment which coincides with median high, a basement structural high that cuts across the Mainland Kachchh as well. Thus, on the basis of median high, the Banni plain can be divided in the western and eastern Banni Plains. The general slope of the western Banni plain is towards west while it is towards north in the eastern Banni plain. Alluvial fans are deposited along the northern margin of the Kachchh Mainland. Parts of Banni, therefore, could be representing a transitional zone formed by interaction between the marine processes operating in the north and a fluvial deposition by the rivers draining the Kachchh Mainland in the south (Kar, 1995). Presence of gullies, incised channels on the elevated parts of the Banni plains are indicative of the latest phase of uplift (Maurya et al., 2002).

5. Alluvial Plains

A narrow belt of fluvial deposits, up to 20-30 km width, is present along the southern coast of the Kachchh Peninsula fringing the pre-Quaternary rocks. These alluvial deposits are found to extend right up to the coast. These deposits comprise Late Quaternary fluvial deposits which are well exposed along the 10-25 m incised cliffs of the Nagwanti,

Rukmawati (of Mandvi), Phot, Khari, Nira and Rukmawati (west) Rivers (Maurya et al., 2003). These deposits form a distinct geomorphic surface which shows extensive gullies/ ravines around river valleys. In general the sediment succession starts with a cross stratified gravel, with clasts of basalt (cobble to pebble size) and Tertiary rocks. This is overlain by a thick buried soil, which comprises mainly of fluvial sand and silt and abundant pedogenic calcrete (Maurya et al., 2003). Radio carbon dating of pedogenic calcrete nodules from this soil in Nagwanti basin have yielded a calibrated age range of 18980 – 18210 ya B.P. while those from Naira basin and Rukmawati (west) River provided a calibrated age range of 22,210 – 21,320 ya B.P. and a ^{14}C age of 24,300 ±640 ya B.P. (Maurya et al., 2003).

Further north in the Kachchh Mainland the alluvial deposits occur in patches within the various stream channels incised through pre-Quaternary rocks. They occupy the valleys bounded by cliffs of Miliolitic limestone in the Katrol Hill Range and represent deposits of post-miliolite depositional phase. Patches of Quaternary deposits are also found in rugged terrain of pre-Quaternary rocks. These deposits occur in the form of alluvial and colluvial fans and valley fill sheets of miliolitic limestone of fluvio-aeolian origin.

Alluvial fans develop under a distinct set of geological conditions. An abrupt physiographic break marked by a fault leading to the unconfinement of the channel is essential requirement for the development of an alluvial fan. The mountain front scarps of the Katrol Hill Fault and Kachchh Mainland Fault provide the absolute geomorphic conditions for the development of alluvial fans as a result alluvial fans are associated with the KHF and KMF and these are related to neotectonic activities. In general, the alluvial fans formed in the vicinity of the Kachchh Mainland Fault have rounded fragments and flat to gentle conical morphology while those associated with Katrol Hill Fault have less rounded shape (Thakkar et al., 1999).

6. The Great Rann

The gulf filled with accumulation of estuarine sediments during Late Holocene to the north of Kachchh Mainland is referred to as Great Rann. The Great Rann is a unique feature which occupies more than half of the aerial extent of the Kachchh. It comprises a flat geomorphic terrain rising hardly up to 2 to 3 m above mean sea level and is divisible into two parts, viz. the Great Rann occupying the northern part and the Little Rann forming

the eastern and southeastern parts of the Kachchh. The Rann area remains mostly dry except in the rainy season when it is covered by saline water. During summer and winter seasons the lower parts of the Rann surface are salt encrusted while in rainy season salt playas are formed (Merh, 1995). The deeper portion of the playa lakes are made up of bluish grey and yellowish brown oxidized silty gypseous clay.

7. Mud Flats

The tidal waters, during the monsoon season, carry with them a lot of sediments brought from the Indus delta region. The coarse sediments are deposited in the inlet channels at their heads while the finer sediments are carried further and spread over the flooded areas and get deposited as mud flats (Merh, 1995).

The distribution of land and sea around the Kachchh Peninsula with the rise of the sea level illustrates the subtle physiography of the area. An exercise was carried out with the GLCF 90m, radar data with the help of 3dDEM with 1 m interval to depict the configuration of the sea and land. Historical records indicate that during the invasion of Alexander the Great Rann area was navigable with boats. This exercise indicates relative regression of the sea from the area. The configuration pattern at the 2 m and 3 m rise of the sea demarcate the Banni Plain very effectively.

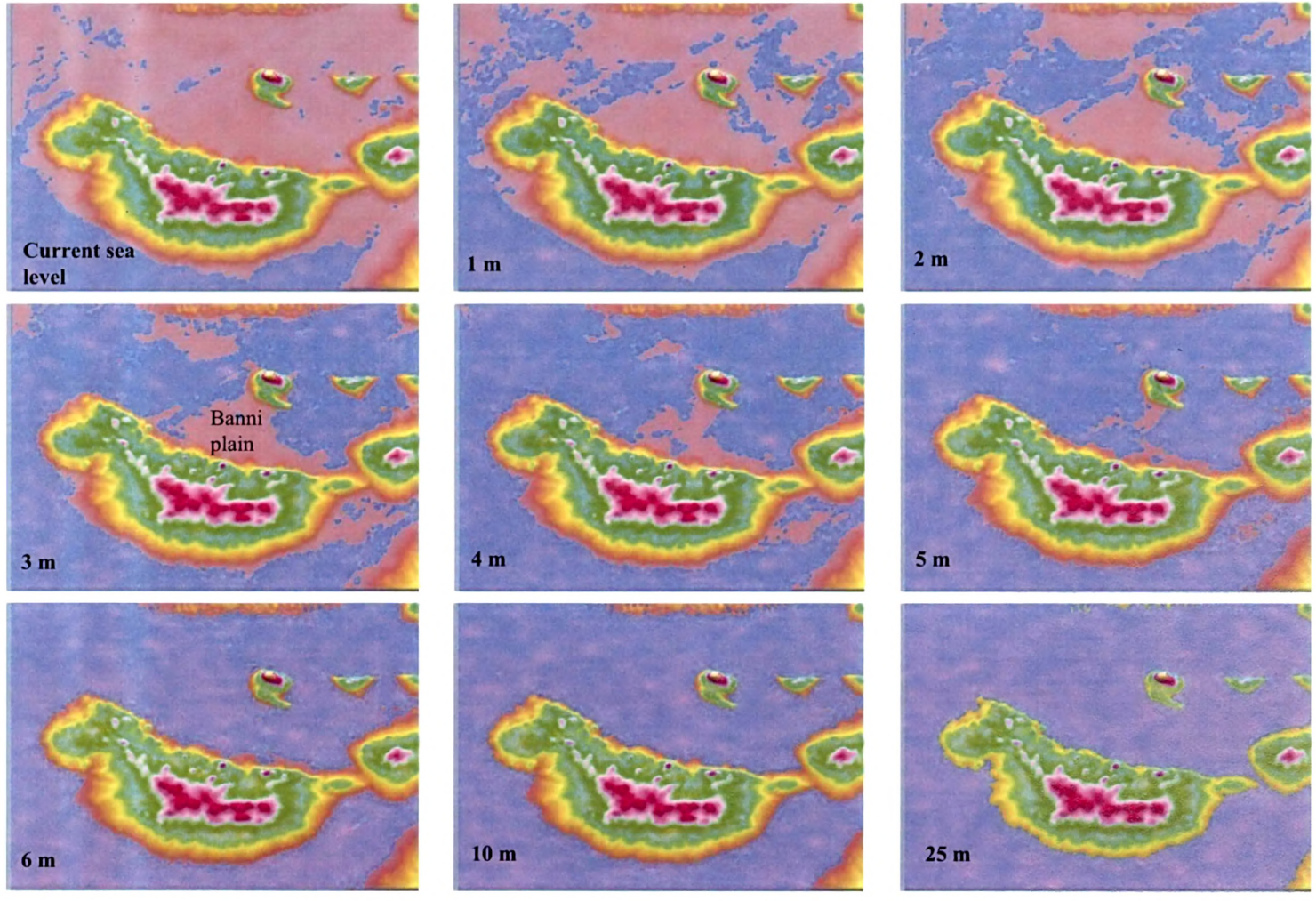

Fig. 3.4: Distribution of land and water with increase in the sea level, showing general topographic model of the Kachchh Peninsula. The rise in sea level is indicated in the each figure in m.

Drainage

The drainage of Kachchh is largely governed by the combination of lithology and tectonics however, the influence of sea level fluctuations during Quaternary Period is also obvious. The central part of the mainland forms the main water divide separating the basins with numerous consequent streams draining the slopes with a radial pattern and debouch into the Arabian Sea, the Gulf of Kachchh and the plain of Banni / the Rann in west, south and north respectively (Fig.3.5). The southward flowing streams include Barwali, Naira, Kankawati, Chok, Sai, Vengdi, Kharod, Rukmawati, Khari, Nagavanti, Phot, Bhuki, Mitti, Sakra, Lerakh and Song meeting the Gulf of Kachchh and the Arabian Sea. The north flowing streams, originating from the northern slopes of the Central highland, join the streams originated from the Northern Hill Range and pour their water into the Chhari, Bhukhi, Nirona (Trambo), Kaila, Pur (Khari) and Kaswali streams and these streams debouch into the Rann making conspicuous alluvial fans. The streams of the Kachchh region are ephemeral and carry water only during monsoon. Many streams like Kankawati, Kaswali, Kharod, Rukmawati and Bhukhi etc. show very broad channels and vertical cliffy banks in their lower reaches.

The relatively well carved valleys which now have very little water, is the characteristics of the drainage of Kachchh Mainland which indicates that the area had experienced a more wet climatic phase in the past during which the streams carried more water and sediment load and the stream dissection was more effective.

Generally, the drainage pattern of the area is dendritic in nature which typically develops in areas with homogenous lithologies in terms of weathering that provide no preferred direction to the development of stream channels. At several places, which are marked by the domes and plug like features, radial pattern has also developed.

The drainage systems developed in the area around KMF and passing through the fault zone have been chosen for detailed analysis to evaluate the effect of tectonism in the area during the recent past.

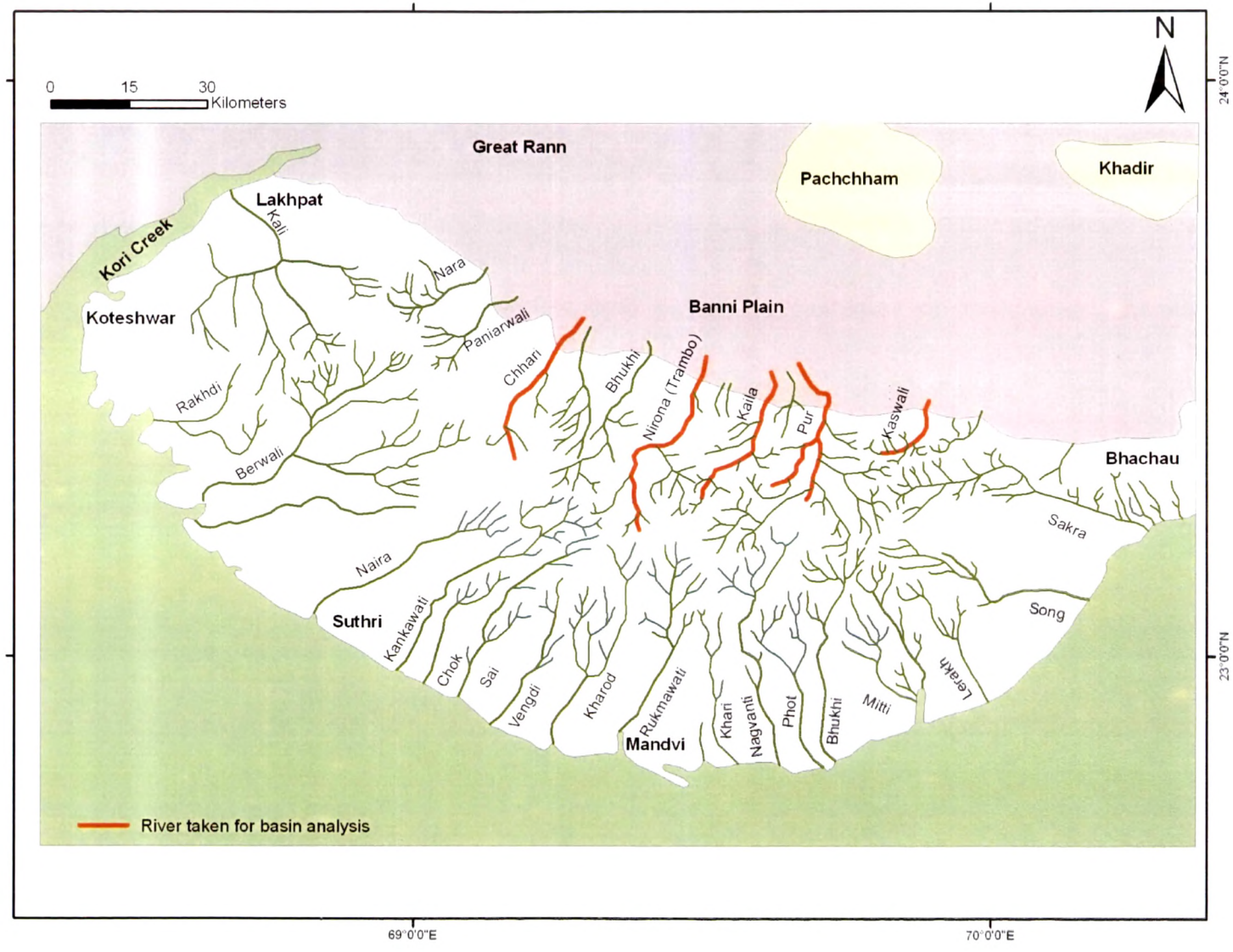

Fig. 3.5: Drainage map of the Mainland Kachchh.

Geomorphology, drainage pattern and nature of streams in the area along KMF:

The variety of geomorphic units of the Kachchh Peninsula reveals a complex interplay of tectonism, sea level changes, lithology and the Cenozoic processes of erosion and deposition. Interestingly, within the limits of the Kachchh Peninsula, one comes across conspicuously high hills and extensive low plains. The uplands comprise rugged hilly terrains exposing Mesozoic rocks bordered by thin strips of gently dipping Cenozoic rocks (Palaeocene to Pleistocene). The highlands are the areas of uplift whereas the plains of low lands represent structural basins between the uplifts and are made up of alluvium, mud and Rann clays.

The landscape comprises rocky highlands standing out amidst the vast plains of Kachchh (Fig.3.6). Whereas the Rann and Banni are the depositional plains of Recent times, the highland areas bear evidences of multiple erosional cycles (Biswas, 1987).

The study area exhibits an array of elongated domes / anticlines with roughly East-West trending axes, forming the uplands in the central part of the area, bounded by pediplain to the south. This hill range forms a chain of domes of Jurassic and Cretaceous rocks and its northern flank is marked by E-W trending Kachchh Mainland Fault. From east to west, it is marked by a series of domes like Devisar dome, Khirsara dome, Habo dome, Jhura dome, Jumara dome, Nara dome and Kira dome. The KMF has significantly controlled the physiography of this part of the terrain. On account of this fault, the northern slopes are steeper whereas the southern slopes coinciding with the dip of the strata are gentler.

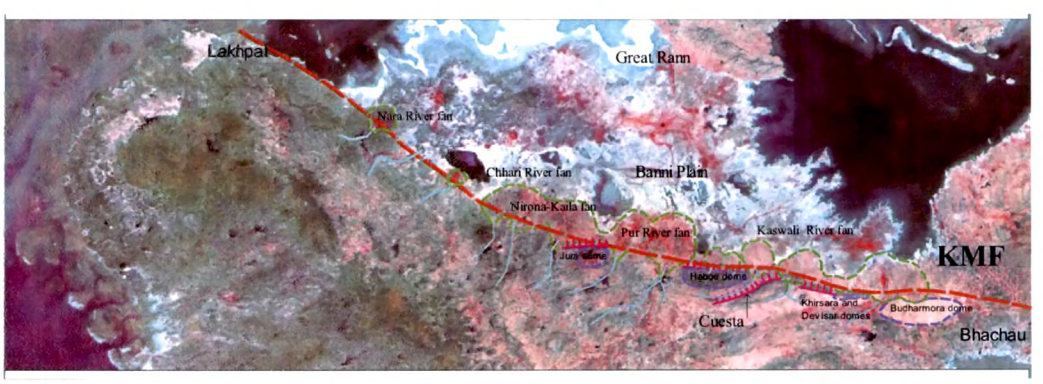

Fig.3.6: ETM FCC image of the Mainland Kachchh showing major geomorphic units and drainage around Kachchh Mainland Fault.

The highlands have been turned into denuded hills in the eastern part, especially near Vondh, Bhachau, Dudhai, and Devisar; giving rise to a few inselbergs standing in the pediplains. Typical cuestas are developed in the area between Jawaharnagar and Lodai (Fig.3.6). This is because of the elongated anticlinal structure with older softer lithounits. The beds dip northerly in the north and southerly in the south of these elongated domes. High plateau like structures are observed at places where harder rocks occur as capping over the thick softer units.

The general elevation of the area varies from 20 m to 80 m above mean sea level. The Dhinodhar Dongar is 388 m high while the Jhura dome touches 324 m height. The Rann, popularly known as Great Rann of Kachchh lying north of Kachchh Mainland Fault, is roughly 2 to 5 m above MSL.

The axial zone of domal anticline roughly forms the water divide, which extends in East-West direction. The streams south of the hill range drain southerly while streams in north make alluvial fans and ultimately pour in the Great Rann of Kachchh. Most of the streams flowing towards north in the mainland are fault controlled. The transverse faults have been followed by streams which show strike slip movement in the area.

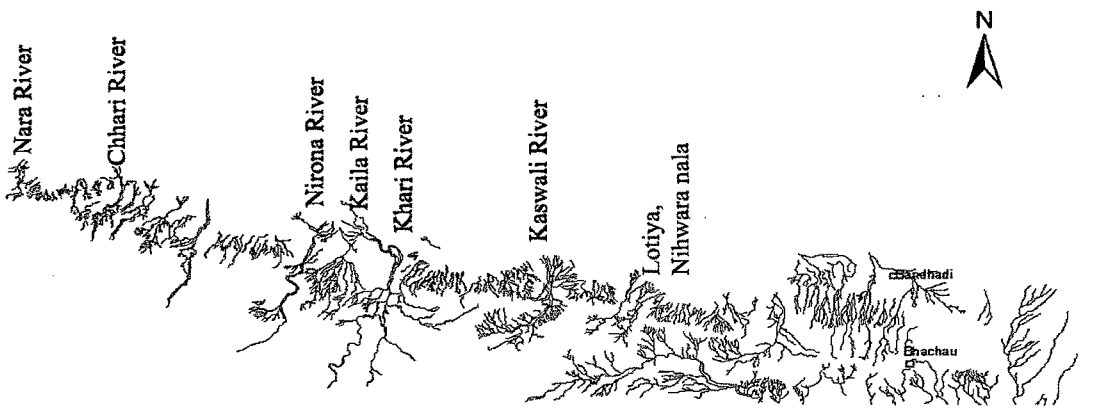

Fig. 3.7: Detailed drainage map of the area along Kachchh Mainland Fault.

The drainage pattern is mainly dendritic which is controlled by homogeneity in lithology and structure but in the alluvial fans radial drainage pattern has been observed. Around the Jhura dome, the drainage is radial. The streams show meandering and braided nature at places. Sharp turns in the streams, flowing towards north, are observed at number of places, which may be correlated with the reactivation of the pre existing faults / weak zones. Rejuvenation of streams flowing north is also recorded with formation of knick

points characterized by head-ward erosion to the northwest of Devisar village. There is a significant down cutting (≥10m) in the channels of the Kaila and Pur Rivers.

The Kaswali River, Lotia nala and Nihwara nala, Dhrung River, the Khari / Pur River, the Kaila River, Nirona River, Jabri Nadi, Gumar Nadi, Bukhi Nadi and Chhari River are the main streams flowing northward (Fig.3.5, 3.7). The Kaswali River near Lodai village makes a typical alluvial fan with a semi circular plan which indicates that stream gradient is not very steep. The converging streams in the pediplain region now diverge into radially distributing pattern, which is typical of an alluvial fan. The Lotia and Nihwara nalas together make a bigger alluvial fan to the north of Jawaharnagar. The Pur River to the north of Rudramata makes another important alluvial fan which is cut by an active fault in its northwestern part. The long profile of the Kaswali, Pur, Kaila and Nirona are prepared to show the nature of gradient of the streams which have been studied in detail (Fig. 3.8, 3.15, 3.16 and 3.17). Fluvial terraces of the river sections and their lithologs are shown in Fig. 3.9, 3.10, 3.11, 3.12 and 3.13. The foot hills along the northern side of the elongated range form a narrow pediment zone covered with thin alluvium. At places bare rocks denuded up to ground level can be seen. This pediment is broader in southern side because of gentle dip of the lithounits and presence of comparatively softer felspathic sandstone of the upper Bhuj Formation. The Upper Bhuj sandstone makes a good aquifer in the area and provides potable fresh water for domestic and agricultural use. All the rivers flowing in the area are rain fed and remain dry almost throughout the year but in rainy seasons.

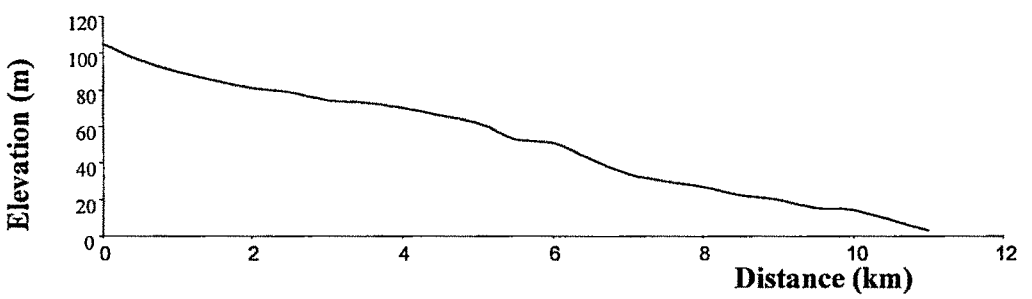

Fig.3.8: Longitudinal profile of the Kaswali River

Fig.3.9: Fluvial terrace sequence exposed along the Dhrung River.

Fig.3.10: Fluvial terrace sequence exposed along the Kaswali River, near Lodai village.

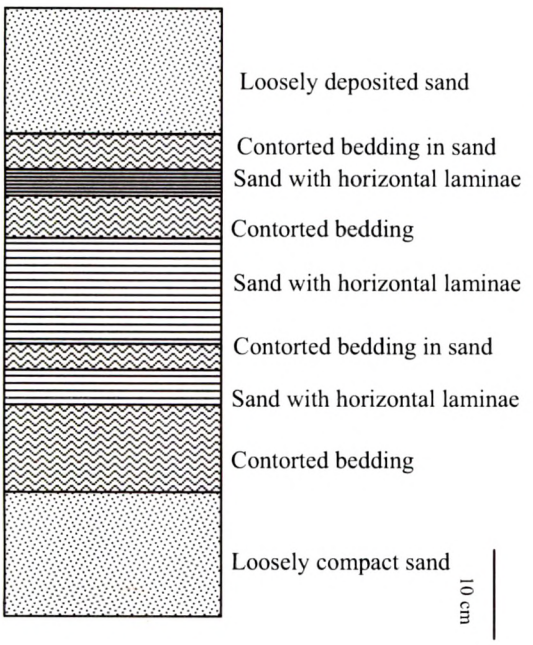

Fig.3.11: Litholog of a trench in the Recent alluvial deposit north of Khirsara village.

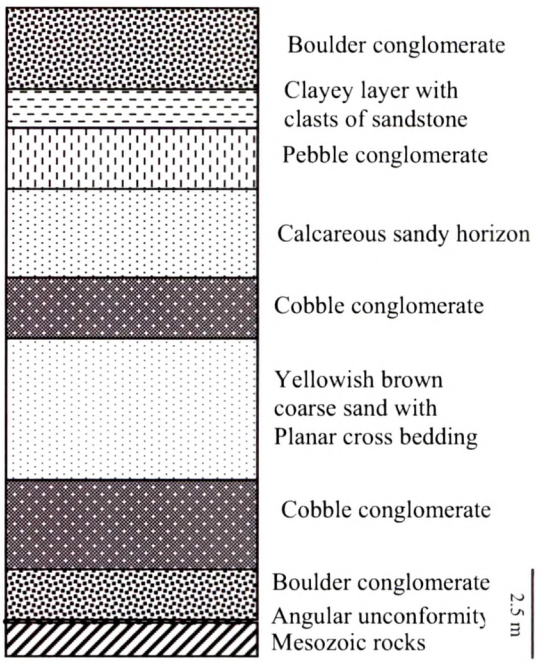

Fig.3.12: Litholog of the Dhrung River Section, Near Dhrung Dam.

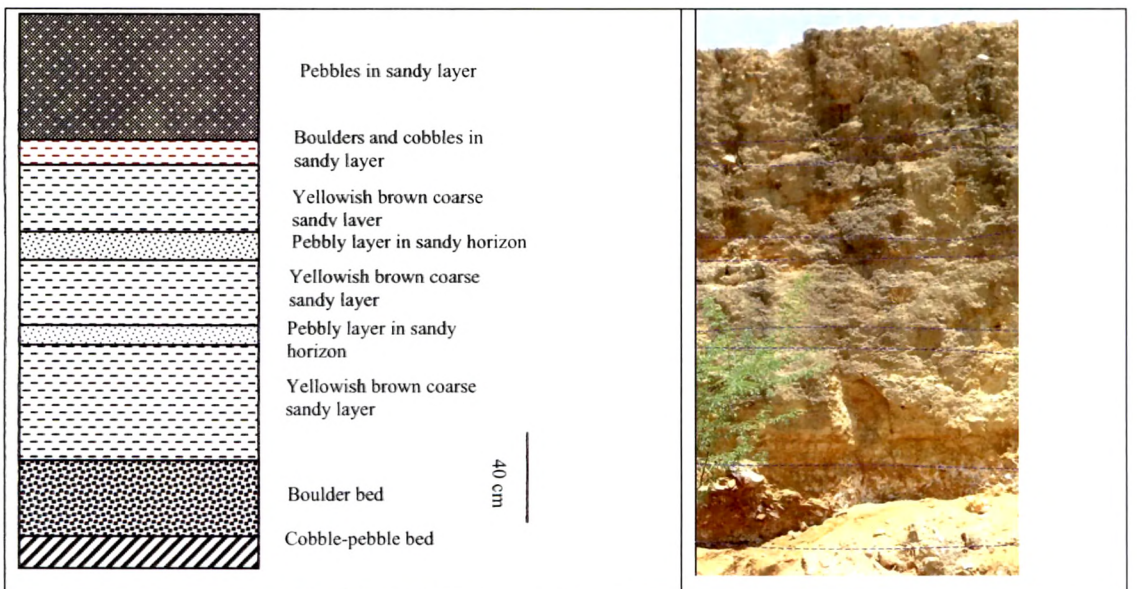

Fig.3.13: Litholog of the Dhrung River Section, Near Dhrung Dam with corresponding section in photograph.

Fig.3.14: Upstream view of the Dhrung River, near Dhrung Dam.

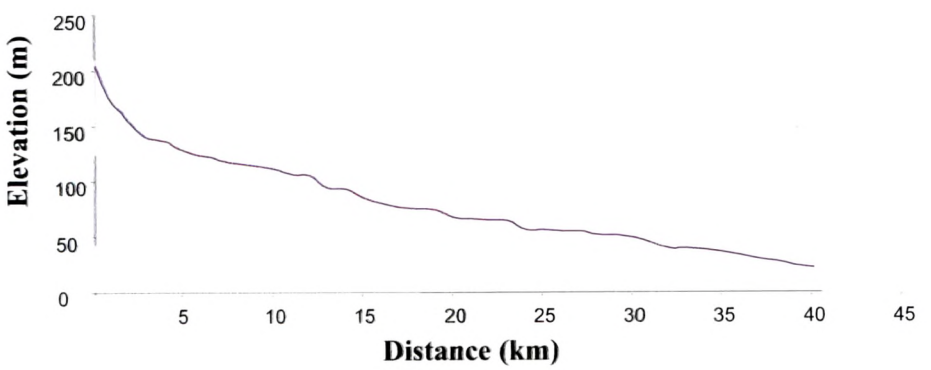

Fig.3.15 Longitudinal profile of the Pur River

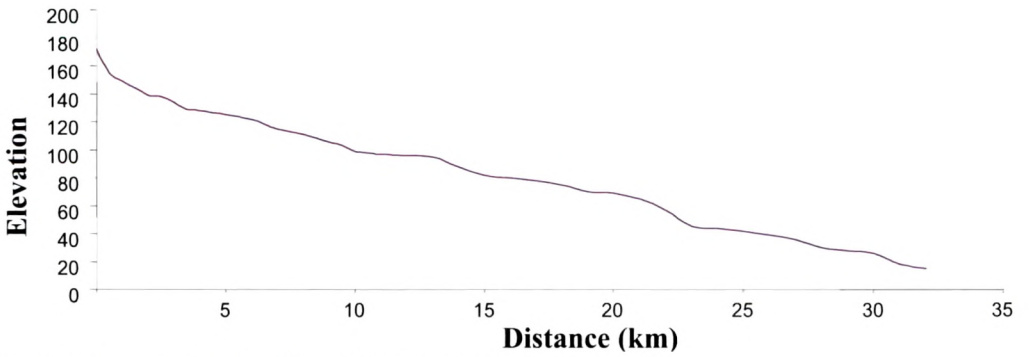

Fig.3.16: Longitudinal profile of the Kaila River

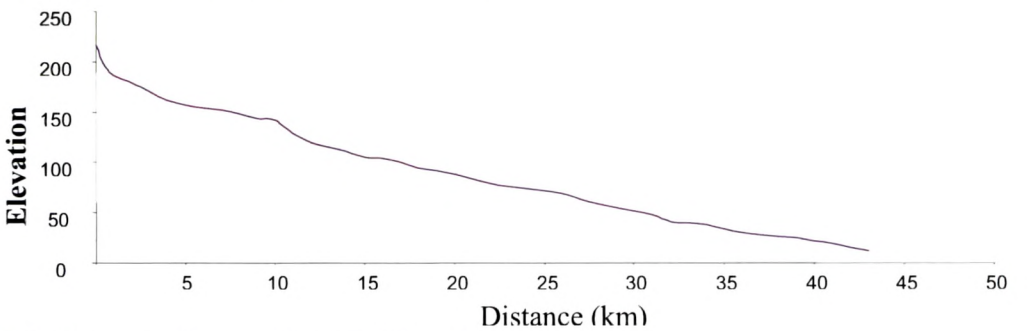

Fig.3.17: Longitudinal profile of the Nirona River

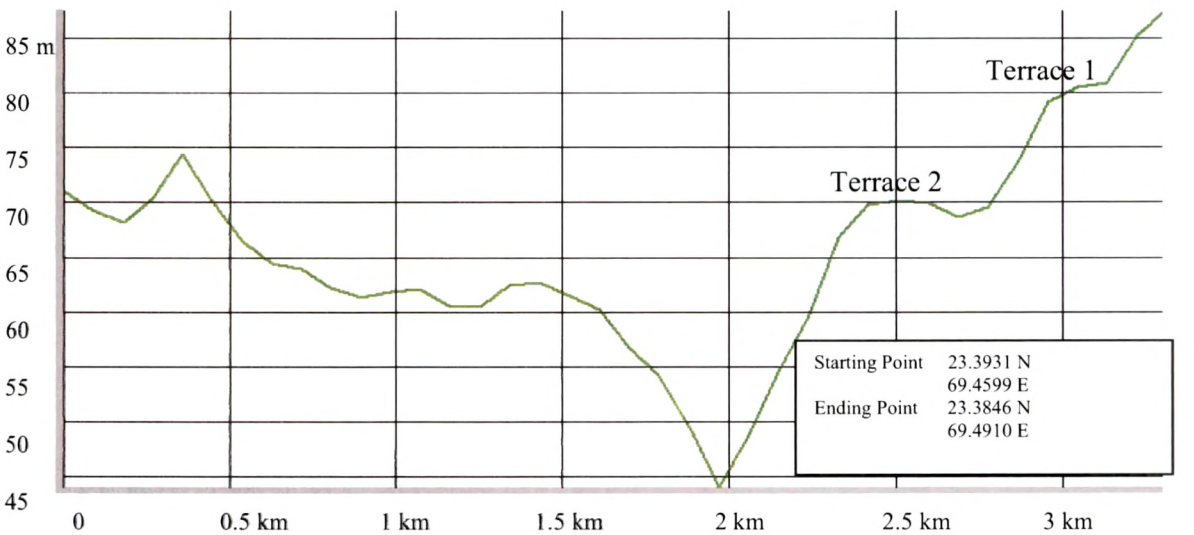

Fig. 3.18: Valley cross section of the Nirona River, away from mouth showing terraces.

The terraces formed by the rivers indicate the tectonic influence in their course of development. These aspects have been described in the next chapter in detail. Typical V-shaped cross section of a stream of the Nirona River, away from the mouth of the river (Fig.3.18) indicates rejuvenation of the stream.