CHAPTER 3

GEOMORPHOLOGY

FLUVIAL SYSTEM OF LOWER NARMADA BASIN

The Narmada River has a long course of over 1300 km and the total basin area is about 99,000 km^2 (Fig 1.1). The basin is known for high magnitude floods, high flow during the monsoon and seismic activity (Gupta et al. 1999). The Narmada River emerges in Gujarat from the trappean uplands near Garudeshwar and flows through the southern part of Gujarat alluvial plains. It follows a NW oriented fault controlled course upto Tilakwada. Further, the river follows a general WSW oriented course. The geomorphic set up of the Narmada River in its lower reaches is at a considerable variance with that in the middle and upper reaches described by Rajaguru et al. (1995) and Gupta et al. (1999). The river in this reach shows large meanders with wavelengths of 5-8 km. The Orsang, Aswan, Men and Bhuki are the major rivers joining the Narmada from the north, The Karjan River, which drains a major part of the trappean uplands in the lower Narmada valley, meets the Narmada from the south. The other tributary, the Madhumati River drains the western fringe of the trappean upland. Between the Karjan and Madhumati Rivers there flows Kaveri and Amrawati and several other north flowing small streams meeting the Narmada (Fig 3.1). These streams drain the low highlands consisting of Tertiary rocks before meeting the Narmada River in the estuarine part. They follow courses that are in conformity with the structural features seen in the Tertiary rocks (Fig 2.5).

The Karjan River basin is one of the largest tributary basins of the Lower Narmada valley, which joins it from the south. The Karjan River arises from the trappean Mandvi hills of Wankal Dungar near Bilwan. It flows northward from its origin and for the most of its 90 km length it traverses through trappean highlands and enters the alluvial plain near Jitnagar before meeting the Narmada River at Mota Bhilwada. The larger part of the river is restricted to the hilly terrain of Mosda-Sagbara hills and Dediyapada uplands. The Tarav and Daman Khadi are the main tributaries that meet Karjan River in the trappean highland on its right bank whereas Mohan

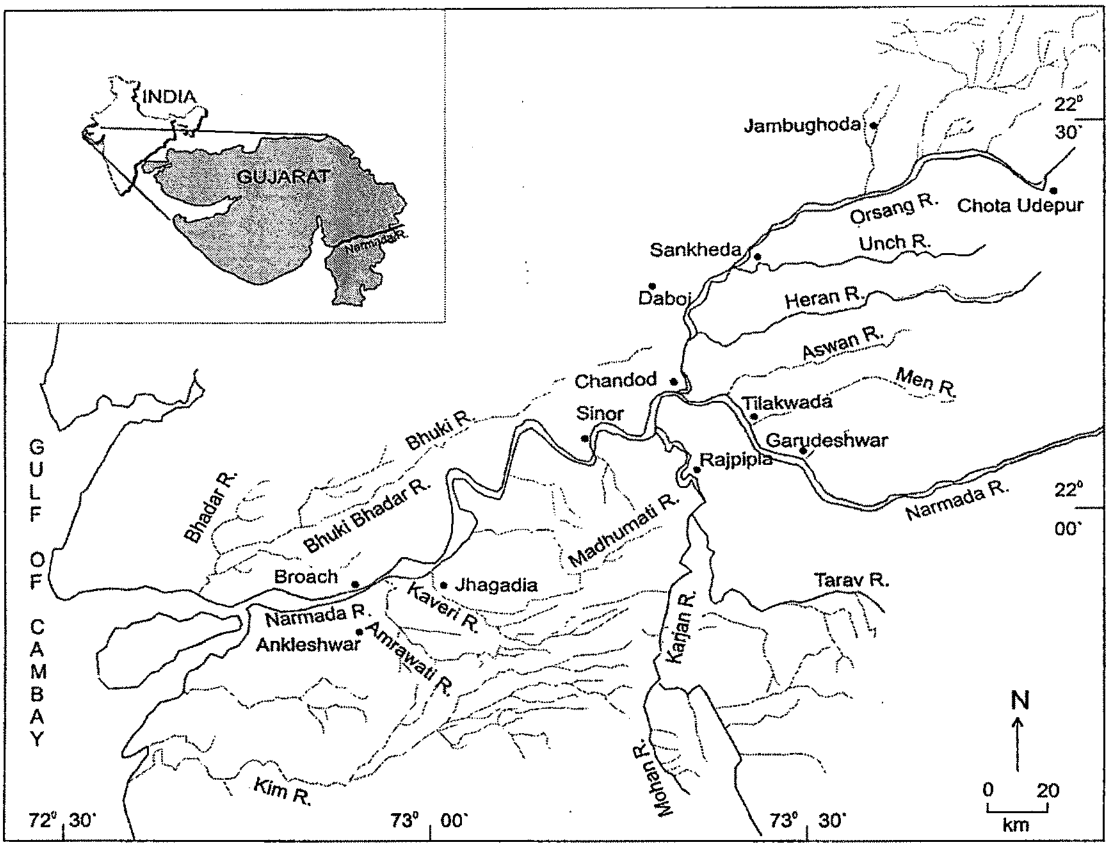

Fig 3.1. Drainage map of lower Narmada basin

Nadi is the only major tributary meeting on its left bank. The dominant part of the Karjan basin is occupied by basaltic trappean rocks.

Another important tributary basin of the Narmada River in Gujarat is the Orsang River which, arises near Umrath Jhabua district of Madhya Pradesh and enters in Gujarat near Bhorda in the Chota Udepur taluka. For most of its part the river flows in the trappean uplands. It flows for a distance of ~20 km in the vast alluvial plain before meeting the Narmada River at Chandod. The Heran River which arises at Jamla, Madhya Pradesh at an altitude of 340 amsl is a major tributary of the Orsang River. It meets the Osrang River near Ghantoli. Another major tributary of the Orsang River is the Unch River. It flows through the trappean uplands and meets the Orsang River near Sankheda. The Orsang River has a vast alluvial plain and its course in its lower parts appears to be fault controlled. The Aswan and Men Rivers are some of the other major tributaries which join the Narmada River from north. These rivers mostly drain through the trappean uplands and a few outcrops of Cretaceous Bagh beds and before meeting the Narmada River at Tilakwada.

The present drainage of the lower Narmada basin is incisive as evidenced by 30-40 m high alluvial cliffs and deeply entrenched meanders. Even the smallest streams, particularly those joining from the south, are found to have incised by 20-25 m. Presence of deep gullies (ravines), uplifted terraces, entrenched meanders and palaeobanks, abandoned alluvial cliffs 15-30 m high away from the present channel are suggestive of neotectonic activity in the area. The Narmada River exhibits characteristics of underfit streams which are characterised by narrow channel inside a wide belt of terraces (Dury, 1970). Even the largest seasonal floods do not overtop the cliffy banks (Gupta et al. 1999). Presently, the Narmada River has a tendency to shift towards north (Agarwal, 1986). The meanders continue to grow towards north conforming to the northward shift of the river.

GEOMORPHIC UNITS

The lower Narmada basin is divisible into four broad geomorphic zones (Fig. 3.2) - the upland zone consists dominantly of basaltic flows and patches of Cretaceous sandstones of Bagh Formation, a low highland consisting of Tertiary rocks, vast expanse of alluvial zone, which correspond with the basin part and a narrow coastal zone comprising mud flats (Fig 3.3).

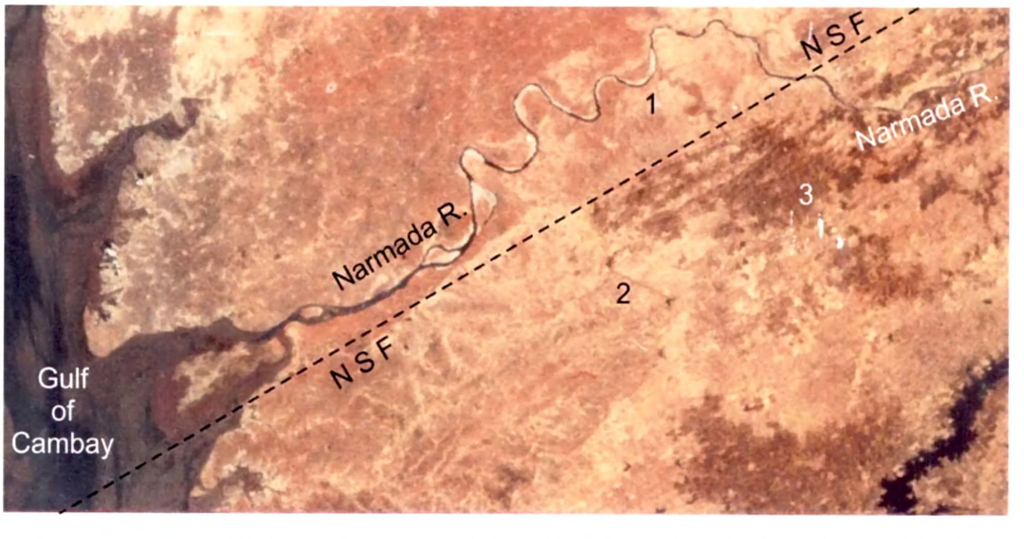

Fig 3.2. IRS FCC image of the lower Narmada valley. 1. Alluvial Zone, 2. Tertiary Upland, 3. Trappean Upland

Field studies in the upland area reveal a highly rugged topography evidenced by steep escarpments bounding the mesa tops and deep narrow gorges along the course of various streams (Fig. 3.4). Since the area consists mostly of southerly dipping basaltic flows, the ridges and the associated intramontane valleys trend in ENE-WSW direction (Fig. 3.4). The low highland to the west of the basaltic uplands comprising Tertiary rocks (Fig. 3.3) exhibit a hummocky topography in conformity with the anticlinal folds and faults (Fig. 2.5). The straight ENE-WSW trending mountain front scarps (Fig.3.4) along the northern edge of the basaltic uplands and the low Tertiary highland mark the NSF beyond which lies the alluvial basin fill.

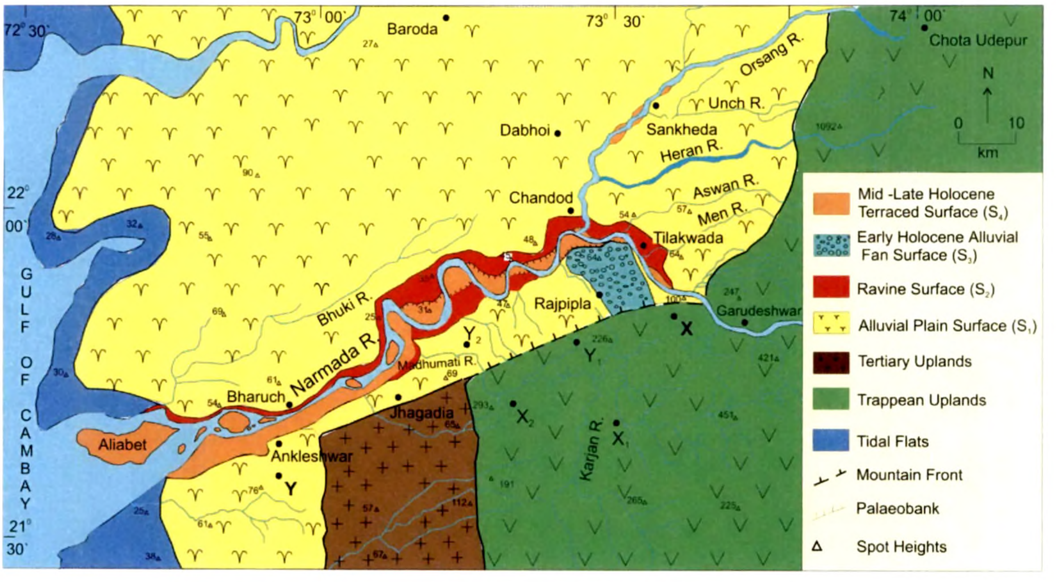

Fig. 3.3. Geomorphic map of the lower Narmada basin (after Chamyal et al. 2002). X-Y, X_1-Y_1 and X_2-Y_2 are the section lines of Fig. 3.4

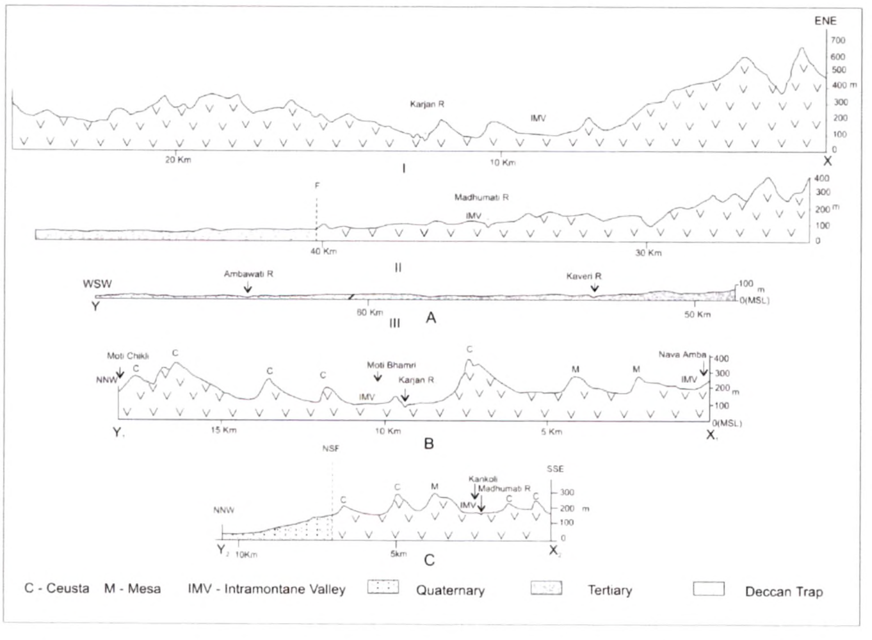

Fig. 3.4. Topographic profiles showing the general physiography of the lower Narmada basin. Section lines are shown in Fig. 3.3

Trappean Upland Zone

The trappean upland of the lower Narmada basin reveals a highly rugged topography evidenced by steep escarpments bounding the mesa tops and deep narrow gorges along the course of various streams. Since the area consists mostly of southerly dipping basaltic flows, the ridges and the associated intramontane valleys trend in ENE-WSW direction. This is in conformity with the dominant lineament trend which parallels the ENE-WSW trending NSF.

The upland zone consists of basaltic flows and associated dykes, exhibiting a landscape

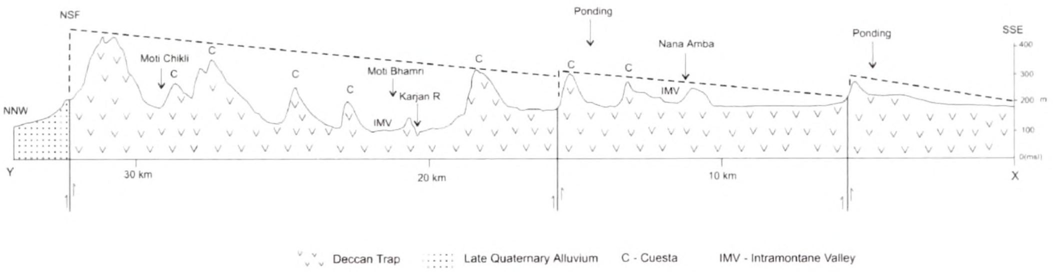

Fig. 3.5. Topographic profile along Karjan river basin showing the tilt blocks. Note the rugged topography and the subdued topography in the northern and southern parts respectively of each tilt blocks. Dashed line indicate the original position of the tilt block

that is at variance with the typical trappean landscape dominated by flat uplifted lateritised palaeosurfaces (Widdowson, 1997) elsewhere in the Deccan Volcanic Province. The main reason for this is that the basaltic flows are tilted southwards all over the Karjan basin which have resulted in the consistently southward directed dip slopes of the ridges (Fig. 3.5 and 3.6). This is attributed to the uplift along the Narmada-Son Fault, which suggests that the trappean flows between the Narmada and Tapi Rivers form a tilt block created by faulting (Fig. 3.5). Presence of highest summits very close to

Fig. 3.6. Field photograph showing southward tilting of trappean rocks at Khuta Amba

the Narmada-Son Fault and the gradual reduction of summit heights towards south together with the southward dips confirm the tilted nature of this block (Raj et al. 2003). This tilting is responsible for the formation of ENE-WSW trending ridges with north facing escarpments (Fig.3.8) and narrow, linear intramontane valleys. The topographic evidences for the tilt block is also corroborated by the drainage that flows northward with a relatively subdued topography and low fluvial incision in the south compared to gorges and highly rugged topography in the north (Fig. 3.5). This clearly indicates the antecedent nature of the drainage of the area. However, most of the lower order streams originate and flow southward incising into the dip slopes before meeting the trunk streams suggesting that only the higher order streams are antecedent while the lower order channels form the consequent drainage. Such coexistence of drainages is seen in Peninsular India where the eastward draining systems (eg. Godavari and Krishna) are antecedent while the shorter westward drainage is consequent to the coastal upwarping of the Western Ghats (Widdowson, 1997).

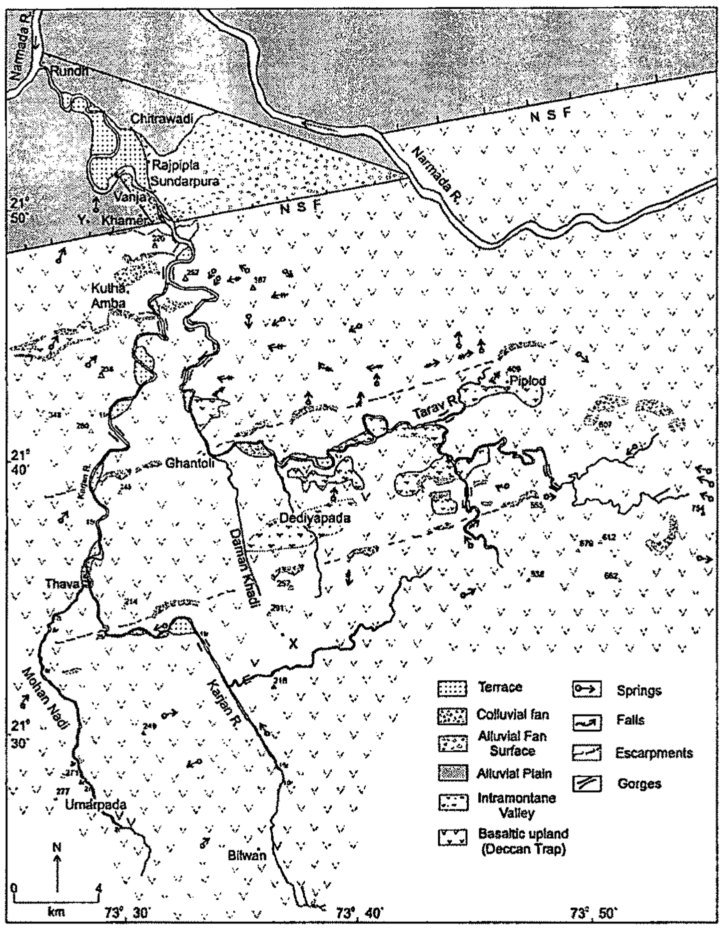

Fig.3.7. Geomorphic map of the Karjan River basin showing the various tectonic landforms. X-Y is the section line of Fig.3.1

Field studies in the trappean uplands were concentrated in the Karjan River basin and the various landforms have been recognized. Geomorphic maps (Fig. 3.7) and topographic profile (Fig. 3.5) of the upland reveals the high degree of ruggedness in topography of the trappean uplands. The various landforms mapped include; escarpments, colluvial fans, intramontane valleys, terraces, cuestas, mesas, gorges, knickpoints, springs and waterfalls and river ponding. These are discussed below:

Escarpments: Scarps are prominent features of the trappean upland and have been well documented (Fig. 3.7). The southward tilting of the trappean rocks is responsible for the formation of ENE-WSW trending ridges with north facing escarpments (Fig. 3.5 and 3.8). These are seen extending for several kilometers occurring as straight wall like features. The scarps are unaffected by gullies cutting across different rocks pointing towards absence of any lithologic control. The fresh nature of escarpments (Raj et al. 2003) together with a youthful topography

Fig.3.8. Photomosaic of ENE-WSW trending ridge with intramontane valley in the foreground. At the base small colluvial fans have developed (1 km South of Ghantoli)

indicates vertical neotectonic movements in the area. The steep, abrupt slopes of the escarpments may be interpreted as a direct expression of vertical uplift (Bloom, 2002).

Colluvial Fans: These have developed along the base of the escarpments and fault lines (Raj et al. 2003). They are found occurring along the escarpments marking the Tarav fault, near Ghantoli (Fig. 3.8) and along the fault lines in the uplands. The colluvial material is comprised of angular trappean fragments of all shapes and sizes placed in a fine sandy matrix (Fig 3.9). Colluvial fans are important indicators of young tectonic movements in the area.

Fig.3.9. Colluvial Fan deposits of irregular shape and size (2 km north of Khamer)

Intramontane Valleys: These are low lying areas filled with fluvial deposits in the uplands. In the Karjan River basin narrow and linear intramontane valleys have developed between parallel ridges (Figs. 3.4, 3.5, 3.10). The valley is deposited by the sediments drained down by the streams originating from the ridges on either side. These consist of a thin layer of silt with occasional pebbles on the top followed by coarse pebbles and cobbles at the bottom. These gravels are highly irregular in shape and size and do not show any stratigraphic correlation that can be compared with the neighbouring valley fills (Fig. 3.8). These are mainly deposited due to torrential action of streams washing down the slopes of the ridges.

Fig. 3.10. Intramontane valley developed at the base of parallel ridges near Ghantoli

Terraces: In the upland zone, the Karjan River has cut through its own deposits and formed a terrace above the new level of the river due to rejuvenation. These terraces are now seen all along the valley side. The Karjan River basin, as well as its tributaries show one level of terrace (Fig 3.11). These are flat uplifted surfaces terminating against the basaltic ridges. The terraces are traceable both in upstream and downstream of the river. At few places the rivers cut through the basement rocks besides the overlying terraces (Fig. 3.12). The terrace material mainly comprises of gravels and silty sand to fine sand.

Fig. 3.11. Photograph of a fluvial terrace in the proximal part of the Karjan river basin (Loc. Thava)

Fig. 3.12. Photograph of the Mohan Nadi cutting the basement rock besides the overlying terrace (Loc. Thava)

Mesas, Cuestas and Gorges: Field studies and topographic profiles have revealed a highly rugged topography in the uplands of lower Narmada basin evidenced by Mesas and Cuestas (Figs. 3.4, 3.5, 3.13). The topographic profiles and field studies have revealed a few Mesa tops occurring as nearly horizontal broad flat top hills. Mesas are found to occur near Nava Amba and Kankoli at a height of 250 and 300 amsl. Asymmetrical cuestas have been documented with a steep escarpment on one side and a gentle dip slope on the other. The cross profile from Moti Chikli to beyond Nana Amba (Figs. 3.4, 3.5) have revealed lot of Cuestas indicating tilting in the southern side of the Karjan River basin (Raj et al. 2003). Deep narrow gorges (Fig. 3.13) have also been observed along the course of various

Fig. 3.13. Photograph showing cuestas in the background (Loc. Rajpipla)

Fig. 3.14. Upstream view of a deep gorge along a tributary stream of Karjan river in uplands (Loc. Near Moti Chikli)

streams in the uplands where the country rock has been cut deep inside. All these features are indicative of recent tectonic activity.

River Ponding: The stagnation of water over long stretches of swift flowing streams and rivers result because of uplift in the downstream block along the faults that cross or follow them. The Karjan River and its tributaries, Tarav River and Mohan Nadi show several discrete segments affected by ponding (Fig. 3.15). The Karjan River (Fig.3.16) is ponded over long distances upstream of the ENE-WSW trending fault cutting across the channel. Uplift along ENE-WSW trending fault also caused ponding in Mohan Nadi near Mandala and Garda (Fig. 3.15 A). Further upstream Karjan River flowing in a straight path following NW-SE trend turns suddenly to WSW direction under the influence of another fault trending ENE-WSW and upstream of this, near

Guldacham and Mulkapada this river shows ponding in its NW-SE stretch (Fig. 3.15 B). Tarav flowing in ENE-WSW direction suddenly takes NW-SE turn near Ghantoli due to the presence of a NNW-SSE lineament and shows ponding in the upstream of this near Bogaj.

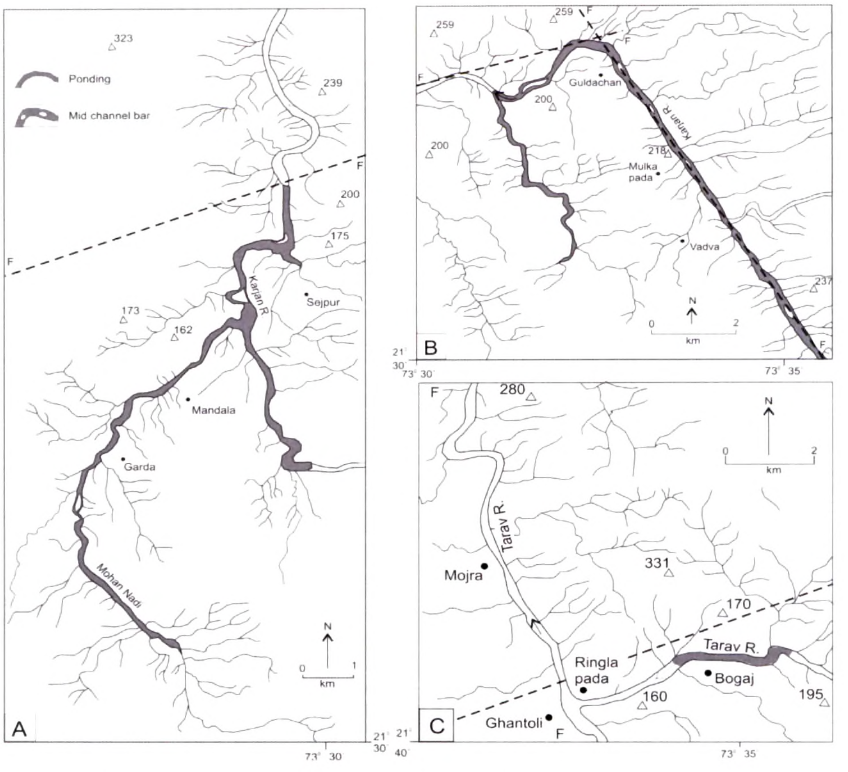

Fig. 3.15. Maps showing ponding due to differential movements along faults (Raj et al. 2003) as seen in A- Karjan and Mohan Nadi, B- Karjan river and C- Tarav river

According to Valdiya (2001) the ponding of rivers and streams provides convincing testimony to very recent, rather continuing movements on faults that traverse their channels.

Fig. 3.16. Ponding in Karjan River at Thava. Note the ponding of the river and the flat topped incised terrace

Incised valleys and gorges have developed at various places as an attempt by the river to re-establish its gradient after uplift. The reduction in the gradient of the river is manifested in the form of mid channel bars in the upstream blocks (Figs. 3.15 A, B, C and 3.16).

Knick Points and Waterfalls: A youthful river is characterised by an irregular profile due to the occurrence of several breaks or knickpoints. Knickpoints have been observed in the Narmada River (Fig. 3.17), Karjan River, as well as its tributaries at Ambadi, Panuda, Moti Daberi and Bej and at Nimbapati, Mathvali, Kundadi and Ghantoli in the Tarav River. The waterfalls are the most spectacular landforms of the area and have been documented in the Karjan River basin near Ghantoli, Piplod (Fig 3.18) and other places. The presence of knickpoints, waterfalls, rapids along the river channel and the deep entrenchment of the various river courses with uplifted terraces are all indicative of tectonic activity in the recent past.

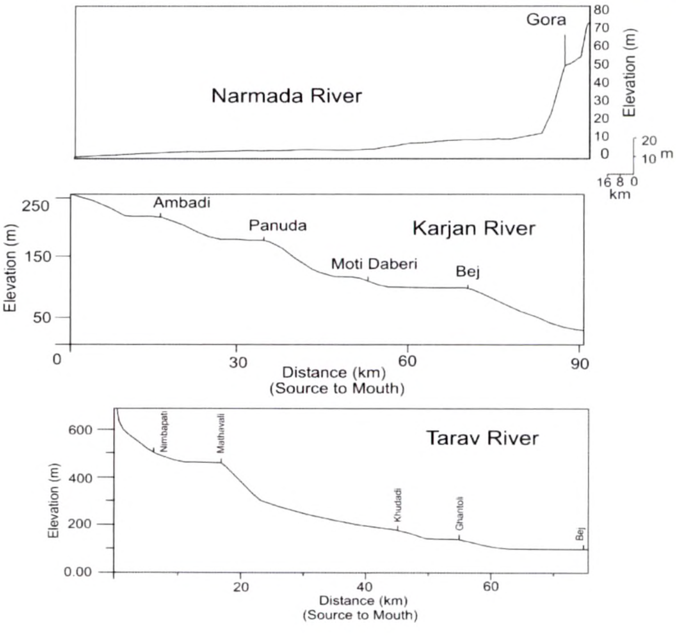

Fig 3.17. Logitudinal profile of the Narmada, Karjan and Tarav Rivers. The places marked on the profile are the points of break or knickpoint

Fig. 3.18. Photograph of Waterfall in a tributary stream of Dhamankhadi (Loc. Rakaskundi)

Alluvial zone

In the alluvial zone, the various geomorphic features were delineated and mapped using Indian Remote sensing Satellite (IRS) FCC images (Fig. 3.2), Survey of India topographical maps on 1: 50,000 scale and detailed field studies. The area shows a large variety of geomorphic features like alluvial plain, deep ravines, uplifted terraces, abandoned cliffs (palaeobanks), incised cliffy banks and entrenched meanders (Figs. 3.2 and 3.3). The alluvial plain between the ENE-WSW- trending mountain front scarps and the Narmada River exhibit a gentle slope towards north while the alluvial plain to the north of Narmada River shows a gentle WSW slope.

Four major geomorphic surfaces (Figs. 3.2 and 3.3) have been mapped in the lower Narmada valley - the alluvial plain (S_1), the extremely dissected ravine surface (S_2), a gravelly fan surface (S_3) and the flat-topped valley fill terrace (S_4). The almost flat but gently sloping alluvial plain, which occupies a major part of the area, has been designated as the S_1 surface. This surface is extremely dissected in the vicinity of the river valley and exhibits gullies as deep as 20-30 m. This extensively gullied ravine surface is termed as S_2 Surface to distinguish it from the undissected alluvial plain and the fundamental importance of the extensive dissection in the geomorphic evolution of the area. The S_1 and S_2 surfaces exposed along the lower Narmada River and are characterized by geomorphic features like deep ravines (Fig. 3.19), uplifted terraces (Fig. 3.20), and incised cliffy banks and entrenched meanders (Fig. 3.21) and abandoned cliffs (palaeobanks) (Fig. 3.19). The S_3 surface is a gravelly surface comprising a series of alluvial fans deposited along the mountain front scarps of the NSF near Rajpipla. This fan surface is bounded by a NW-SE trending fault passing through the river Narmada on its eastern side and by a NNW-SSE trending fault passing through the Karjan River, a tributary of the Narmada on its western side. The S_4 surface is a wide flat topped terrace surface of 5-12 m height, which occupy a deeply incised fluvial valley. The terraces show no evidence of ravine erosion and abut against the abandoned cliffs (palaeobank) of S_1 and S_2 surfaces (Fig. 3.19). These valley fill terraces of 4-10 m height form a discontinuously elevated surface which are confined by the present channel on

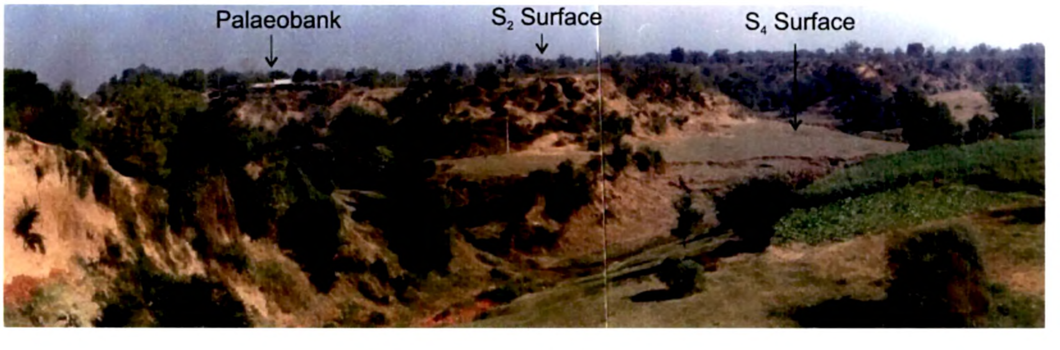

Fig. 3.19. Ravine surface at Ranapur with Holocene terrace separated by palaeobank

Fig. 3.20. Photograph of the uplifted terrace at Gora. The upliftment is about 35 m

one side and the abandoned cliffs (palaeobanks) (Fig. 3.19) of S_1 and S_2 surfaces on the other side (Maurya et al. 2000). These are flat topped surfaces and do not show ravine erosion. The sediments of the terraces comprises of two distinct sedimentary deposits – estuarine-tidal deposits

Fig. 3.21. Upstream view of the large entrenched meander in the alluvial zone near NSF (Loc. Tejpur)

along the river mouth (Fig.3.22) and fluvial deposits (Fig. 3.23) in the upper reaches (Maurya et al. 2000).

Fig. 3.22. Flat topped Holocene estuarine terrace at Tavra

Fig. 3.23. Incised fluvial terrace exposing the S_4 sediments (Loc. near Rajpardi)

Estuarine Zone

The coastline is straight and is marked by a broad funnel shaped mouth of the Narmada River (Figs. 3.2 and 3.3). The width of the estuary at its mouth is more than 20 km. Holocene terrace as high as 8 m is seen on the convex banks of the estuarine zone (Fig 3.24). The estuarine succession is composed of tidal estuarine facies. A island called Aliabet which is about 15 km long and about 5 km in width occurs near the mouth of the estuary (Figs. 3.2 and 3.3). The

Fig. 3.24. Estuarine terrace exposed near Bharuch

Aliabet is coeval with the terrace surface (S_4) and is well above the present day tidal range.