CHAPTER-3

TECTONIC GEOMORPHOLOGY

The Kim river basin is located in a geomorphologically and structurally diverse terrain. As emphasized earlier, the main characteristic of the Kim River is its ability to carve out an independent drainage basin in an area where all the other drainages meet either the Narmada river in the north or the Tapti river in the south. A combination of geological, structural and tectonic factors have contributed in the development of the Kim river basin.

GEOMORPHIC ZONES

Physiographically, the Kim river basin comprises three major divisions. These are - the Upland zone consisting of trappean lava flows, a low hummocky landscape developed over Tertiary rocks and the alluvial plain (Fig. 3.1). Each of these zones

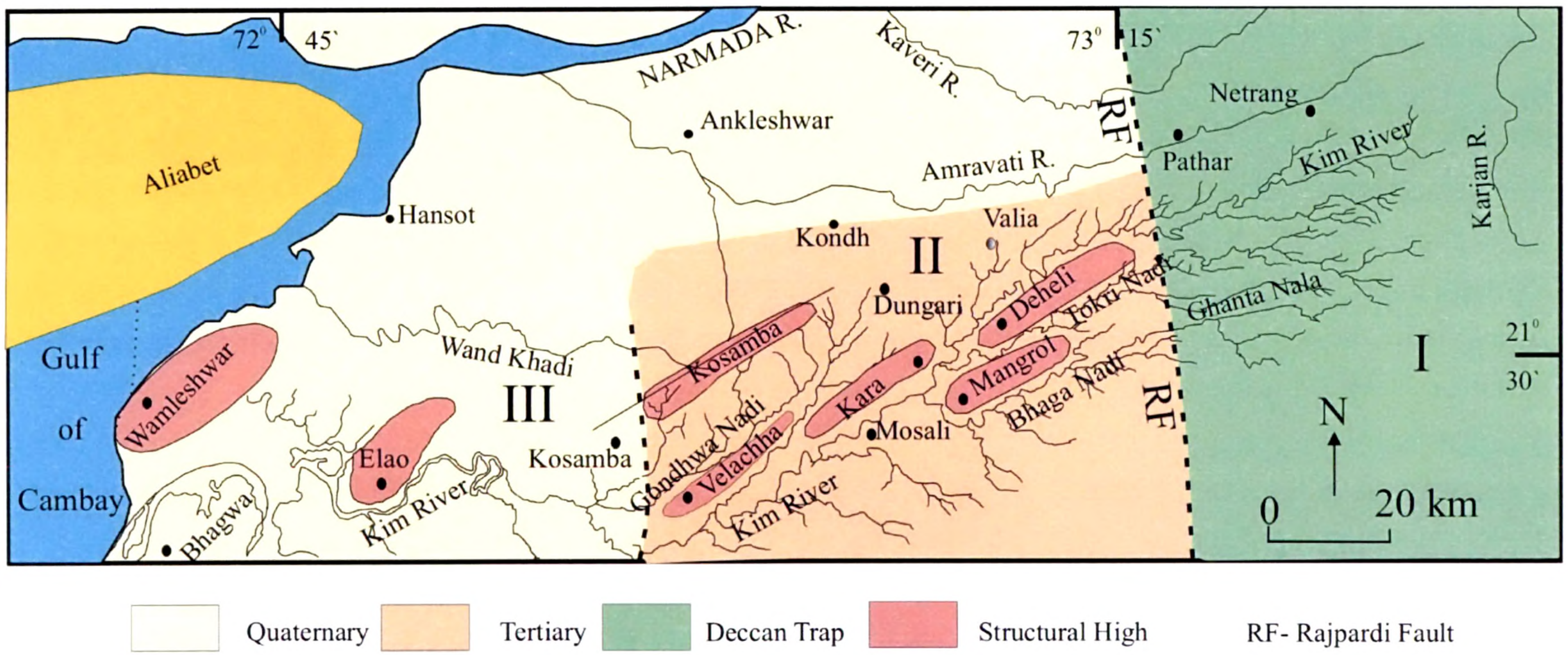

Fig. 3.1 Map of Kim river basin showing structural highs and morphostructural domains.

exhibits its own distinct set of landforms. Considerable diversity of landforms is observed within each of the geomorphic zones.

Upland zone

The upland zone of the Kim river basin comprises exclusively of the basaltic flows of the Deccan Trap Formation (Fig. 3.1). It forms the northwestern extremity of the extensive Deccan Volcanic Province of the peninsular India. The upland zone is characterized by a topography and is similar rugged to typical trappean upland areas (Fig. 3.2). The ENE-WSW trending basaltic ridges are the most conspicuous physiographic features, separated by narrow, linear intramontane valleys filled with sediments. A general youthful aspect to the topography is provided by ENE-WSW trending escarpments of the area.

Fig. 3.2 Panoramic view showing general topography of the upland zone in Kim river basin. In the foreground is an intramontane valley followed by several linear rows of ridges.

Associated with the basaltic flows are the ENE-WSW trending dykes, which also show a pronounced physiographic expression. The dykes vary in thickness from a few tens of meters to over 200 m. Most of these dykes express themselves as features of positive relief in the form of narrow linear ridges forming wall like fronts (Fig. 3.3). A few of these prominent dykes are observed in the source region of Kim river which extend for several kilometers. The trappean rocks and its associated rugged topography terminate against the Rajpardi Fault in the west (Figs. 2.6, 3.1).

Fig. 3.3 Photograph showing general view of an ENE-WSW trending dyke expressed as a linear ridge near Kodvav.

Central low hummocky zone

The central part of the Kim river basin comprises an area of gentle, low, hummocky relief. After crossing the Rajpardi Fault, the Kim river enters in this zone which consists mainly of Tertiary rocks and intervening alluvium. In general, the physiography comprises linear, flat low mounds/highlands forming geomorphic highs separated by areas of low relief. These typical mounds/highlands mark the surface exposures of the various formations of Tertiary age, while the low relief areas are occupied by Quaternary alluvium. This zone shows anomalous slope variations at several places, though the general slope is towards WSW. It has been observed that the topography closely corresponds to the positive structural elements (Fig. 3.1) developed in the Tertiary rocks.

The alluvial plain

In its lower reaches, the Kim River flows through the alluvial plain. It is a gently westward sloping alluvial terrain which is superimposed by coastal geomorphic features further west. Though the area is almost flat the Kim River shows a incised meandering course in this zone. The boundary between the central low hummocky zone and the alluvial plain is not abrupt, but transitional.

MORPHOSTRUCTURAL DOMAINS

As discussed in the previous chapter, the Kim basin exhibits considerable heterogeneity in the structural and geological set up. It is therefore essential to delineate morphostructural domains for a better appreciation of the influence of structural elements on the landscape of the Kim river basin. Taking into account the structural and geologic data, the Kim river basin has been divided into three morphostructural domains (Figs. 3.1, 3.4).

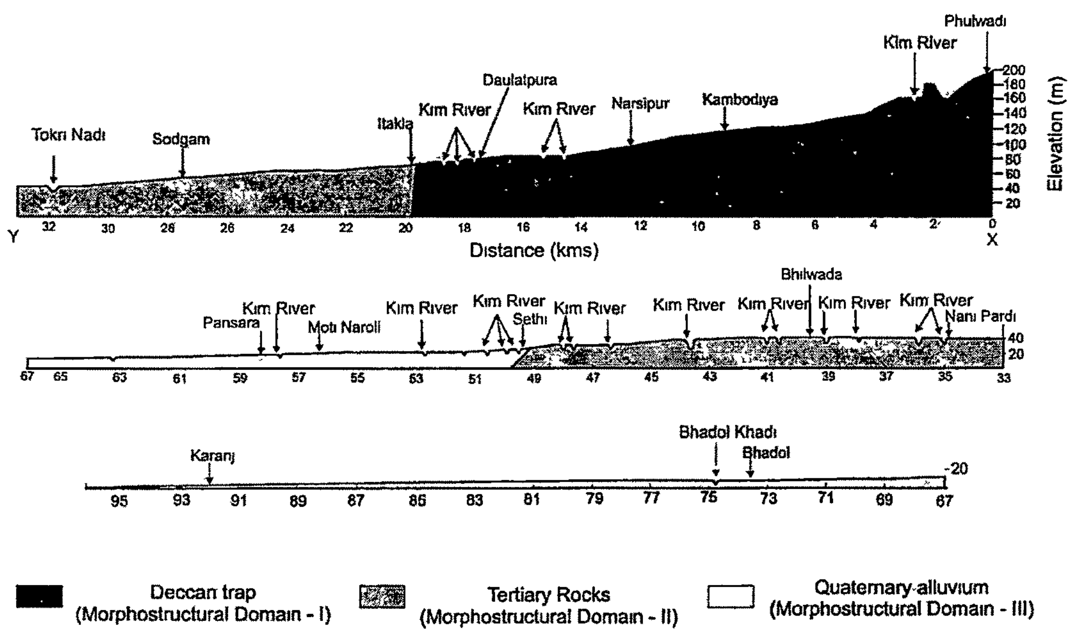

Fig. 3.4 ENE-WSW trending topographic profile along the Kim river basin.

These are as follows.

Morphostructural domain I- comprises the source region (upper part) of the Kim basin which is occupied by the basaltic flows of Deccan Trap and associated dykes.

Morphostructural domain II- comprises the central part of the Kim basin which shows a high degree of structural complexity evidenced in the exposed Tertiary rocks.

Morphostructural domain III- comprises the lower part of the Kim basin which is mainly a gently sloping alluvial plain.

In the following paragraphs the characteristics of the structural elements in each of the above morphostructural domains and their influence on the topographic relief of the Kim river basin are described

Morphostructural domain - I

The morphostructural domain-I shows the highest topographic relief and degree of ruggedness in the Kim river basin. This domain includes the upper part of the Kim basin and is occupied by the basaltic flows belonging to the Deccan Trap Formation of the Late Cretaceous-Eocene age. The basaltic rocks extend further east and northwards and are a part of the extensive Deccan Volcanic Province of the Peninsular India. The Deccan Volcanic Province of India is mainly known for thick and extensive horizontal lava flows of basaltic and associated volcanic derivatives. The largely undeformed nature of the basaltic flows led to the development of a view that the Peninsular India has remained tectonically stable over a long period of time, however, the view was sheltered with the occurrence of several earthquakes in quick succession. Deformation of Deccan trap is known from the west coast and the area around Rajpipla to the south of the Narmada river (Blanford, 1869). Recent studies have demonstrated that the morphology of the Deccan Volcanic Province has developed in response to prolonged phases of uplift in responses to denudational isostatic adjustments (Widdowson, 1997).

The trappean highland provides a very unique landscape in the study area. The highland rises from west to east and show step-like pattern and a progressive rise from north to south and west to east. Striking landscape diversity is observed in the highlands which reveals a combination of factors like tilting and horizontality of lava flows, response of erosional processes on varying lithologies as well as the trend and intensity of large and small scale lineaments and dykes. These flows are intruded by various dykes showing regional structural trend i.e. ENE-WSW.

The trappean highlands are marked by flat-topped hills, steep scarps and slopes of different categories. The angle of slope depend mainly on the rock type and weathering processes. The flat-topped hills and ridges as well as existence of vast flat area of different elevations reflect the horizontality of flows. In the study area, the trappean landscape provides interesting slope features which are mainly related to lithology of the rocks and fracture pattern. The flows show gentle to very gentle slopes which occupy the tablelands or plateaus at various altitudes in the form of roughly horizontal layers. Softer rocks show moderate to gentle slope while harder rocks show very steep to vertical slopes which is indicative of resistant rock and dominance of fracture control (Alavi and Merh, 1991).

The trappean highlands show mainly erosional landforms. Linear ridges of varying dimensions are dominant landforms in the study area (Fig. 3.5). It is controlled by regional fractures trending E-W and N-S directions. The E-W trend is more prominent and their extension is quite variable, ranging from a few hundred meters to several kilometers in the study area. The N-S topographic profile (Fig.3.6) across the Kim river shows a highly rugged topography mainly because of the ENE-WSW trending linear ridges (Fig. 3.3). These dykes stand out as steep linear ridges. The dykes vary in width from a few meters to several hundreds of meters and laterally traceable for several kilometers (Krishnamachary, 1972).

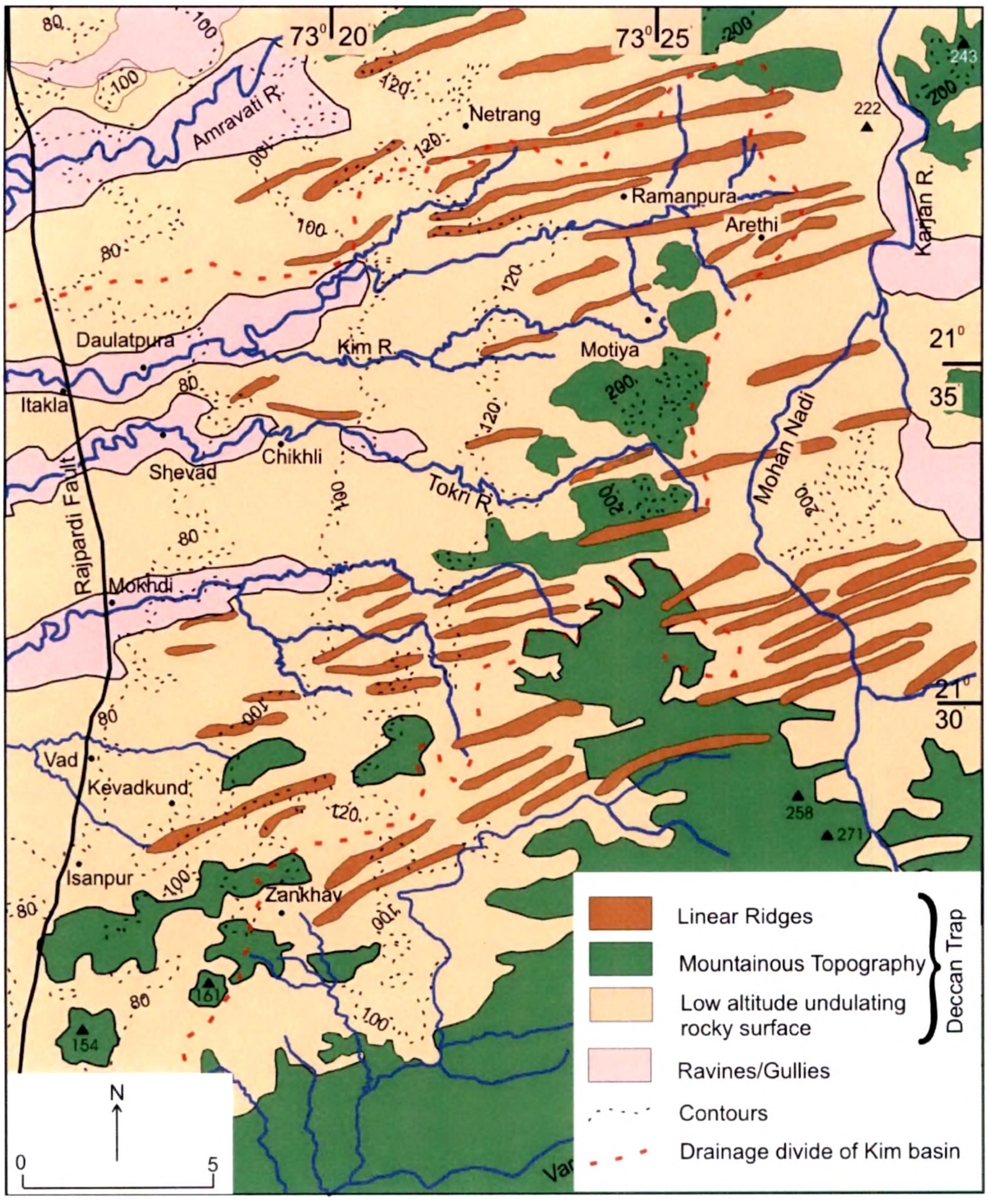

Fig. 3.5 Geomorphic map of the morphostructural domain-I in Kim river basin. Note the presence of ENE-WSW trending linear ridges as the dominant landforms in the Kim river basin.

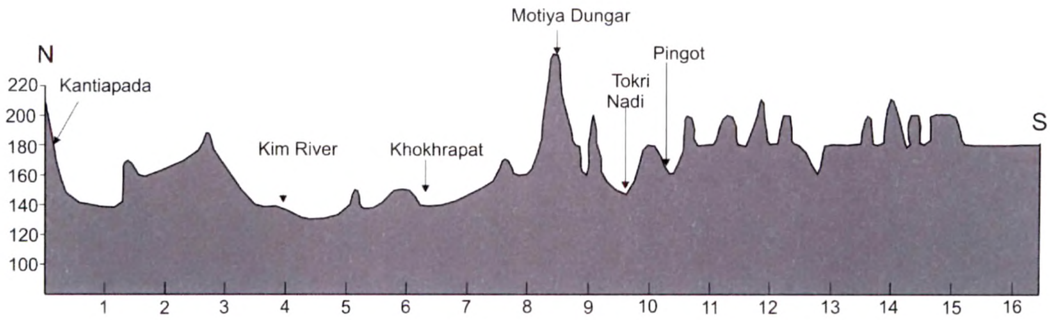

Fig. 3.6 N-S topographic profile across the morphostructural domain –I in the Kim river basin. Note the sharp abruptly rising ridges imparting ruggedness to the topography.

Streams flowing along various lineaments have carved out erosional valleys in the upper reaches while giving rise to depositional landforms along the channel in the form of valley fill deposits and depositional terraces (Fig. 3.7). The drainage pattern shows excellent structural control with the streams flowing almost exclusively along N 70^0 and N 330^0 oriented structural lines (Powar, 1980). The profuse lineaments seen in the

Fig. 3.7 Downstream view of the Kim river incising through the trappean rocks and alluvium at Punjabnagri.

Deccan traps are predominantly the zones of structural weakness along which dykes have been emplaced (Powar, 1980) which developed in response to the stresses generated by the collision of the Indian and Eurasian plates. The locking up of two plates led to cymatogenic uplift and crustal warping in the Deccan Volcanic Province (Powar, 1980).

A major feature of the Deccan Traps occurring to the south of the Narmada Son Fault (NSF) is the large scale deformation which distinguishes it from the undeformed trappean rocks elsewhere in the Peninsular India. The Deccan Traps in this area show series of folds trending in the ENE-WSW direction around Rajpipila (Blandford, 1869; Babu, 1984) further east of the source region of Kim river. The folding of traps is believed to have occurred before the deposition of Tertiary sediments (Blandford, 1869; Auden, 1949). Moreover the area also exhibits a series of minor faults in the same direction (Babu, 1984). However, the overall geomorphic set up is controlled by the tilt blocks formed due to southward tilting of the trappean flows along the E-W trending faults (Rachna et al. 2003).

The oldest movements occurred along the NW-SE trend (Babu, 1984) while, the Late Quaternary tectonic activity took place along the ENE-WSW trend (Rachna et al. 2003). The older phase of tectonic activity along NW-SE trend is evidenced by the similar structural trends in Precambrian rocks in nearby area and the formation of pre-Quaternary basins along this trend. A recent tectonogeomorphic study concentrated in the Karjan river basin has delineated three shallow tilt blocks within a large tilt block formed due to uplift of the trappean rocks along the NSF (Rachna et al. 2003). Continued southward tilting of these blocks due to differential neotectonic uplift along the ENE-WSW trending faults have profoundly influenced the channel morphology and the overall geomorphology of the Karjan basin. One of the faults delineated in this study possibly extends further west into the Kim basin. Though apart from the geomorphic evidence of a linear row of hills trending in the same direction, no other evidence of this fault is found in the upper part of the Kim basin. However, this E-W trending inferred faults and the associated dykes have clearly influenced the E-W trending course of the Kim river, linear ridges and the intramontane valleys in morphostructural domain-I.

Morphostructural domain - II

This domain includes the central part of the Kim river basin. The eastern boundary of the domain is marked by the Rajpardi Fault, which also demarcates the eastern margin of the Tertiary depositional basin. Towards the west the limit of this domain is diffuse as it imperceptibly merges into the alluvial plain. Tectonically the domain shows a high degree of structural complexity as evidenced by the intensely deformed Tertiary rocks (Fig. 2.6). Geomorphologically the domain comprises exposures of Tertiary rocks separated by intervening alluvium. Deep seismic sounding (DSS) studies have delineated the crustal structure of the area along a N-S transect (Kaila et al. 1981). Overall, the crustal section given by Kaila et al. (1981) reveals a horst and graben structure in the area between Narmada and Tapti and further south upto Billimora. This section shows about 1.1 km thick Deccan traps below the Tertiary rocks. The Deccan trap is in turn underlain by 1.2 km thin Mesozoic sediments. Alternating gravity high and lows are seen along the N-S transect between Ankleshwar and Billimora (Babu, 1984), which correspond to the series of horst and graben structures delineated in the DSS studies. The DSS studies have also established a thin crust about 25 km in the area which rapidly reduces towards south and is about 18 km at Billimora. The section (Fig. 3.8) also reveals a deep crustal fault (Fault F4 in the DSS section) which lies to the north of the Kim basin. The southern side in the downfaulted block in which the Kim river flows. This fault corresponds with the Kosamba reverse fault which is located on the southern limb of the Kosamba anticline (Fig. 2.8). The occurrence of alluvium of the Kim river is

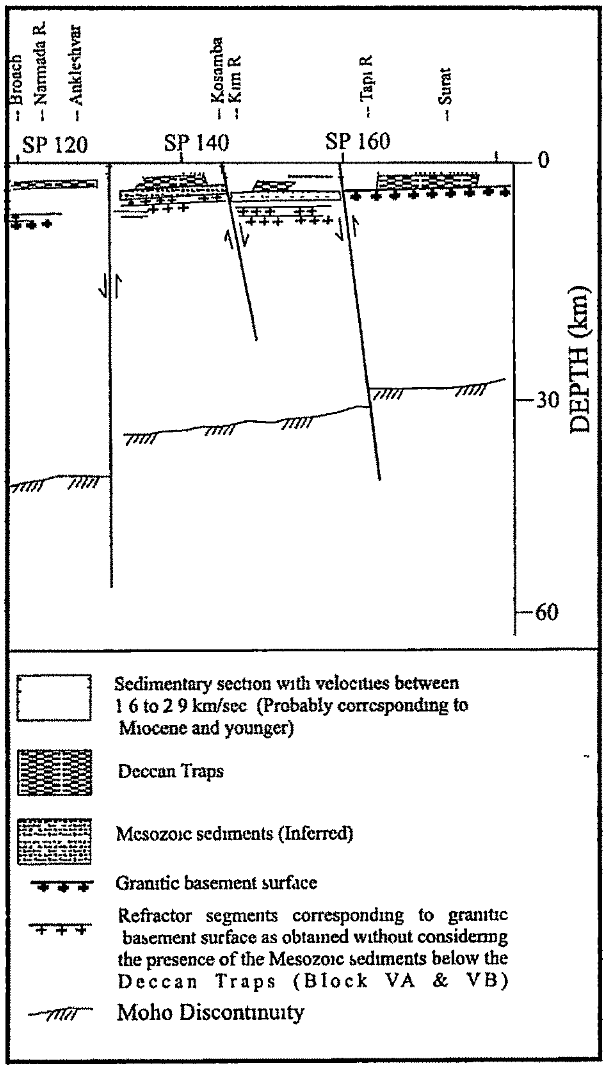

Fig. 3.8 Part of the Mehamadabad to Billimora DSS profile (after Kaila et al., 1981). Note the tectonic blocks delineated by crustal scale faults between Narmada and Tapti Rivers and the shallow depth of the Mohorovicic discontinuity.

also limited to the down faulted block which indicates tectonic activity along this fault in Quaternary times.

In the Morphostructural domain-II, the various geomorphic highs show excellent correlation with the subsurface structural data. The general topography is that of a gently undulating terrain (Fig. 3.9). Two N-S topographic profiles drawn across the morphostructural domain-II typically shows the relation between topographic relief and structural features (Fig. 3.10). The first topographic profile has been taken across NNW

Fig. 3.9 Photograph showing undulating topography over Tertiary rocks in Morphostructural domain-II near Kondh.

to SSE from Limet in the northward and Jhankarda in the south (Fig. 3.10A). In this profile, Dungri Anticline is clearly reflected as a mound like structure. To the NNW direction, a depression occurs through which Amravati River flows along the Limet Reverse Fault. In the central part of the profile, Dungri Reverse Fault passes to the north of the Kim river which delimits the northern limit of the alluvial deposits of Kim river. In second topographic profile (Fig. 3.10B), there are various subsurface structural features

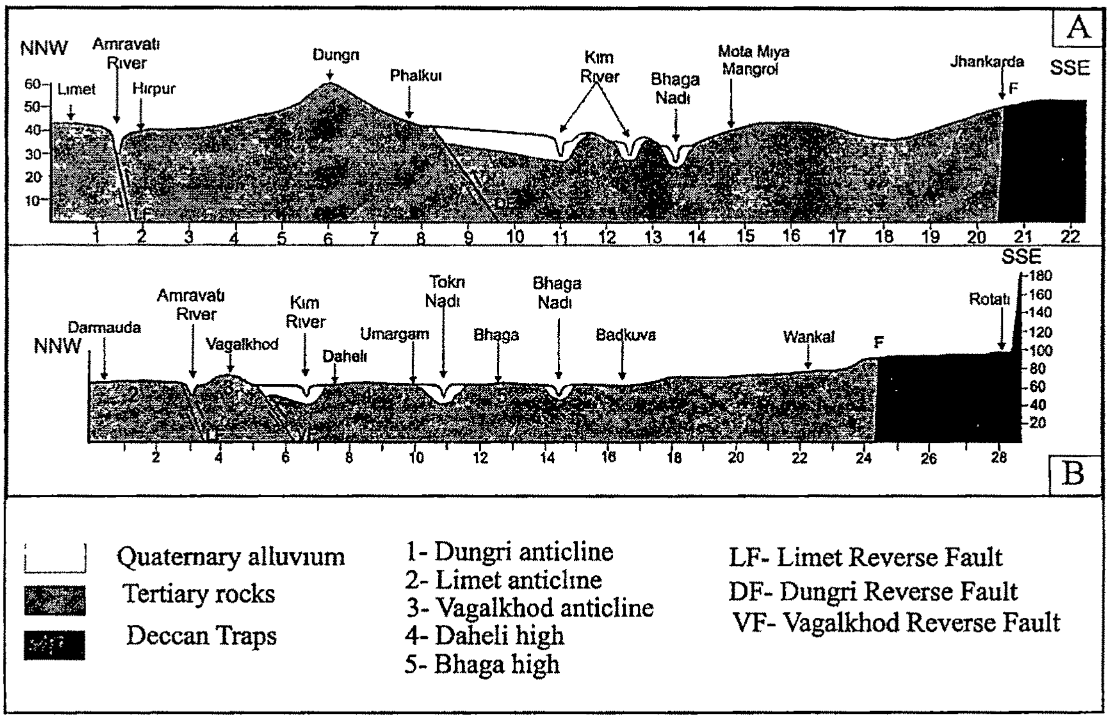

Fig. 3.10 NNW-SSE trending topographic profiles across morphostructural domain-II. Note the excellent correlation between the structural highs and topographic highs and occurrence of Quaternary sediments in structural lows.

which have pronounced geomorphic expression. These are Limet anticline, Vagadkhol anticline, Daheli high and Bhaga high. Here, Vagadkhol anticline is bounded by Vagadkhol Reverse Fault in the south and towards its north, Limet Reverse Fault is present. In the central part of the topographic profile, a small patch of Quaternary alluvium is present in the structural lows.

Morphostructural domain-III

The morphostructural domain-III forms the lower part of the Kim river basin and is occupied exclusively by the alluvial plain. The alluvial plain extends further westward with increasing thickness of the alluvium. The alluvial plain comprises two different depositional environments such as fluvial and tidal-estuarine. The Kim river in domain-III flows mainly through the estuarine sediments (Fig. 3.11). The morphostructural domain – III (Figs. 3.1, 3.4) shows roughly flat topographic relief with a gently sloping alluvial plain.

Fig. 3.11 Downstream view of the sinuous course of the Kim river in morphostructural domain-III at Umrachhi.

In this morphostructural domain-III, the various geomorphic highs are present which correlate with the subsurface structural highs (Fig. 3.1). They are namely Elav high, Bhaga high and Wamleshwar high. The drainage pattern of this domain-III is controlled by these subsurface highs (Fig. 3.1). The N-S topographic profile across the eastern part of the morphostructural domain-III shows a topographic high related to Kosamba anticline which is bounded by Kosamba Reverse Fault (Fig.3.12).

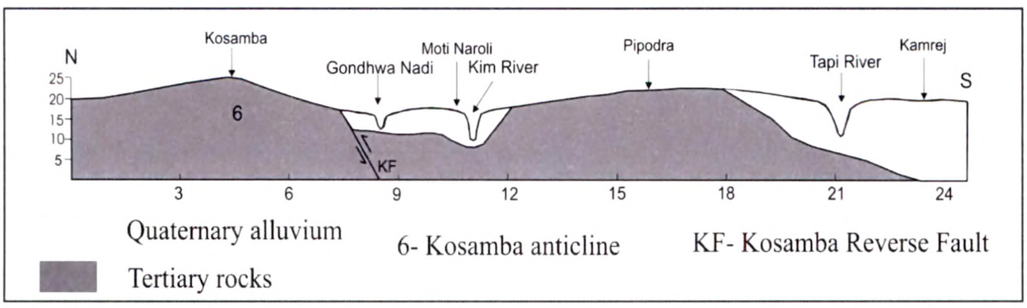

Fig. 3.12 N-S topographic profile across morphostructural domain-III.

STRUCTURAL CONTROL ON DRAINAGE

The Kim river basin is the major and the only independent drainage basin in the highly deformed zone between the Narmada and Tapti rivers. The Kim river follows a general E-W trending course which is in conformity with the dominant structural trend of the area (Fig. 3.1). The basin is narrow and elongate shaped and shows an overall dendritic drainage pattern (Fig. 3.1). On micro scales, the basin show trellis, parallel and radial drainage patterns as well. An important aspect of the Kim drainage basin is its pronounced asymmetry. All the tributaries of the Kim river join it from the south i.e. its left bank, while no drainage line are seen on its right bank (Fig. 3.1). The major streams joining the Kim river on its left bank are the Tokri and Bhaga rivers. The channel of the Kim river lies on the northern periphery of its drainage basin. Another characteristic feature is the highly sinuous incised meandering course of the Kim river in all the three morphostructural domains (Fig. 3.1) described earlier in this chapter. Here, the macro scale drainage architecture and the structural influences in the light of the morphostructural characteristics described earlier in this chapter, are discussed.

The Kim river arises near Phulwadi located in the morphostructural domain I described earlier. The Kim river originates at about 200 m elevation. Initially, the Kim river passes through trappean rocks in the morphostructural domain-I. After crossing the morphostructural domain-I, it enters in the morphostructural domain-II near Itakla which comprises Tertiary rocks and shows mainly a low level hummocky topography. Here, river passes through depressions formed between subsurface highs, whereas in morphostructural domain-III, it passes through Quaternary alluvium. Here, the river course shows good correlation with subsurface structural highs (Fig. 3.1).

The morphostructural domain-I is characterized by the rugged topography developed over deformed trappean basaltic flows (Fig. 3.13). Major structural trends present in the area are the ENE-WSW and NW-SE directions. The course of the Kim river follows E-W trend in this morphostructural domain. The dominating structural influence on the course of the Kim river in this are the ENE-WSW trending dykes which have a prominent geomorphic expression as linear ridges (Fig. 3.5). The river flows across the hard and compact basaltic rocks with patches of alluvial deposits (Fig. 3.7). The river has carved out a incised channel (Fig. 3.14) which shows several entrenched meanders.

Fig. 3.13 Photograph showing deformation in basalts at Pansim.

Fig. 3.14 Photograph showing incision in the trappean rocks near Kambodiya in Morphostructural domain-I.

For detailed study of the river course, the long profile along the Kim river has been drawn (Fig. 3.15). The profiles are markedly uneven especially in morphostructural domain I and II. This is due to the presence of several knickpoints (Fig. 3.16) along the courses of various rivers.

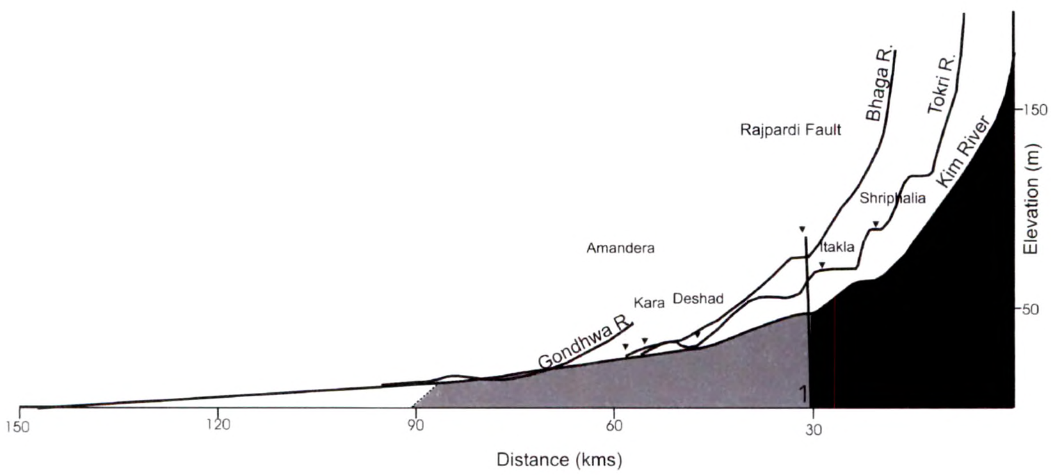

Fig. 3.15 Longitudinal profiles of Kim river and its tributaries.

Fig. 3.16 Photograph showing a knickpoint in the Kim river at Pansim.

The river channels show a high degree of sinuosity (Fig. 3.1) and has incised into the alluvial deposits as well as the trappean rocks (Figs. 3.12, 3.16). The channel exhibits typical characteristics of a confined channel evidenced by the 15-20 m high vertical cliffs along its banks (Fig. 3.16). At Daultapura and Pansim, the Kim river shows an extremely tight meander where it has incised both the alluvium and the bedrock and low terrace surface also (Fig. 3.16). The Kim river all along its course shows several waterfalls and knickpoints which further testify to the rejuvenated nature of the river in this domain.

The river enters into the morphostructural domain-II at Itakla, where the sharp contact of Trappean rocks and Tertiary rocks is exposed within the channel. The contact marks the N-S trending Rajpardi Fault. The contact is overlain by a thin cover of alluvial sediments. In this morphostructural domain the course of the Kim river exhibits a general ENE-WSW trend. Though the depth of incision of 15-20 m is the same as seen in morphostructural domain-I, the channel shows an increase in the degree of sinuosity. This is in conformity with the fact that the morphostructural domain-II is more structurally complex domain than the morphostructural domain-I. The course of the river in this reach shows an excellent contrast of the structural features developed in the Tertiary rocks. Increase in the degree of sinuosity is rather abrupt. The sinuosity sharply increases as soon as the river crosses the Rajpardi Fault at Itakla. Downstream of Itakla, the river shows a sharp meander. Interestingly, the incised cliffs (~20 m) of alluvium overlying the Tertiary occurs as the inside of the meander bend while on the outside band a low terrace is present. The meander of the river is developed along a E-W trending fault exposed within the Tertiary rocks in the channel (Fig.3.17). For few hundred meters the river follows this fault. Further downstream the river shows tight meanders developed within the alluvial deposits (Fig. 3.18). The Limet anticline, Limet Fault, Dinod anticline and the Dinod Fault are located to the north of the Kim river and trend in ENE-WSW direction. These structures are reflected as a series of geomorphic highs (Figs. 3.10, 3.12) which

Fig. 3.17 Photograph showing an ENE-WSW trending fault seen in the Tertiary rocks exposed in the river bed near Itakla.

Fig. 3.18 Downstream view of an entrenched meander in alluvial deposits in morphostructural domain-II at Pithor.

explains the several ENE-WSW trending courses of the rivers and the absence of tributary streams on the northern side, thus creating a marked asymmetry in the drainage configuration. This segment, showing high degree of sinuosity as seen around Velachha which is near to Kosamba antilcline.

In morphostructural domain-III, the Kim river flows westward sloping alluvial plain which consists of unconsolidated Late Quaternary fluvial sediments. The course of the river shows a marked decrease of sinuosity as compared to that seen in the morphostructural domain-II, however, the river continues to show a sinuous channel with entrenched meanders and incision of ~20 m in the alluvial sediments. The available subsurface data shows that the thickness of the alluvium overlying the Tertiary rocks increases westwards. The Quaternary sediments also show deformation which is an indication of upward transmission of the deformation in Tertiary rocks due to tectonic reactivation. Babu (1984) mentions two fold features in the alluvial tract which are surface manifestations of the buried structures. One is recorded near Pakhajan to the north of the Narmada river and the other is near Olpad. Agarwal (1984) has delineated some more subsurface structural features developed in the Tertiary rocks. The Kosamba antcline and Dungri anticline which are bounded by reverse fault at their southern limbs (Kosamba Fault and Dungri Fault) are the major structures which are located in the subsurface to the north of the present course of the Kim river. These structures have significantly influenced the location of the channel of the Kim river (Fig. 3.1). The Kosamba Fault is a crustal scale fault as seen in the DSS profile of Kaila et al. (1981). Other geomorphic highs viz. Elav high and Velcha high are also present to the north of the Kim river which are also the surface expressions of subsurface structural features.

The Elav geomorphic high is situated near the mouth of the Kim River on its right bank. Because this, the Kim river takes an abrupt turn towards south and southwestern direction. The Kosamba geomorphic high forming water divide between the Kim river basin and the lower Narmada basin. This is reflected as a gentle rise in the ground where the highest point of the ground marks the crestal part of the structure. The Dungri geòmorphic high is trends NE-SW direction. This structure forms the water divide of the tributaries of the Amarawati river to the NW and that of Kim river to the SE.

The Velachha geomorphic high is situated between Kim river and its tributary Gondhwa Nadi and controls this courses of three rivers in this part. The course of the Kim river meanders its way around these highs. This indicates that the Kim river in its alluvial reach is also structurally controlled as evidenced by the close correspondence of the subsurface structural features with its course (Fig. 3.1).