CHAPTER V

FIELD INVESTIGATION
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5.1: INTRODUCTION:

The landscape development is the result of system operation series of changing environment. The evolution of landscape is explained in terms of the Devisian triunity of structure, process and time. In understanding landscape, size and shape of various landforms are most significant. The scale of landforms varies from the mega- through macro- and meso-scales to micro-scales. Mega- to meso-scales features can be analysed by using remote sensing data and topographic maps of varying scales. But detailed micro-scale analysis is possible only in the fields because scale of linear and areal features are less than 0.5 km and 0.25 km respectively. The size of micro-scale varies from small grain size to outcrop scale features. The study of such small scale landforms and geomorphic indicators are only possible with direct observations in the field. Thus field investigations include collection of numerical and qualitative data regarding structural, erosional and depositional features. Such studies are considered as ground truths to confirm remote sensing and morphometric analysis, which add more information about lithology, landforms, structural and tectonic characters.

5.2 APPROACHES:

Lineament and preliminary geomorphological maps prepared by using remote sensing data and basin morphometric data were considered to plan the fieldwork. The traverses and locations of field visits were planned to study lithology, structure and various geomorphic features. In general, traverses and locations were selected on the topographic maps of 1:50,000 scale. Importance was given to study change in the type of lava flow and their nature of contacts, geomorphic features, channel characters,
type of valleys and associated landforms and sediments. Significant characters of rocks and sediments have been observed. Photographs of significant lithological structure and geomorphic features were taken and similarly, sketches have been also drawn for the same. Brunton compass has been used to measure attitude of planar surfaces, such as fractures and any change in the inclination of lava flow contacts. Digital altimeter with 0.5 m least count was used to record difference in elevation for small scale features such as depth of channel and height of terraces. Data collected with respect to lithology, structure and landforms etc. were recorded in the field notebook.

5.3. GEOLOGY:

Lithological and structural characters of the Bori river basin as well as adjacent areas have been studied to understand distribution of rock types, presence of structures and their associated features. The study area is composed of number of basaltic lava flows of Deccan Traps. Lava flows generally found to separated by red bole beds.

5.3.1 TYPES OF BASALTIC LAVA FLOWS:

Basalts in the study area are black to dark gray coloured, fine-grained, vesicular to nonvesicular (massive) and with or without fractures and joints. The contacts of individual lava flows have been recognized with following characters.

1. Red bole beds: Contacts between lava flows have been recognized by the presence of red bole bed. Red bole is dark red in colour, porous, granular and fine grained. Thickness of red bole varies from few centimeters to few meters (Plate 5.1). Red bole and lava flow contacts are horizontal to gently undulatting. Such contact represents base of the upper lava flow.
2. **Vesicular zone**: Top and bottom of lava flows are also recognized by the presence of very thin enriched zone of vesicles. Vesicles at the basal contact are elongated and pipe-like whereas at the top they are spherical to irregular. Some of these vesicles are partially or completely filled with secondary minerals such as quartz (SiO₂), calcite (CaCO₃) and zeolites.

3. **Brecciated or clinker zone**: Top and bottom of the non-vesicular lava flows are recognized by the presence of thin brecciated and clinker zones respectively. Brecciated zone is composed of vesicular to amygdaloidal, fine-grained basalt fragments, which are angular to sub-angular (plate 5.2). Basal clinker zone is chilled zone, which is relatively more massive and of varying thickness.

### 5.3.1.1 VESICULAR TO AMYGDALOIDAL LAVA FLOWS:

These lava flows are highly vesicular and dark gray in colour. Vesicles are spherical to irregular in shape. The size of vesicles varies from less than 1 mm to few mm. Vesicles are abundant in upper most and lower most parts of flow. Top of lava flow are enriched with spherical to irregular vesicles while at the base these are pipe like to elliptical. Vesicles are partially or completely filled with secondary minerals to form amygdales. Some of vesicular or amygdaloidal lava flows constitute one or few thin sheets of lava units to form compound lava flow (plate 5.3 and plate 5.4). This type of lava flow is called as pahoehoe lava flow. Exposed top of these lava flows are very flat and smooth.

### 5.3.1.2 COMPACT OR aa LAVA FLOWS:

These are non-vesicular, massive, black coloured, fine-grained lava flows and forms top of plateau (plate 5.5). Vesicles are absent or minor in
amount. Top of compact lava flows is fragmentary with angular to sub angular brecciated zone. Exposed top surface of compact lava flow is gently undulating. These flows exhibit vertical to steep and horizontal fractures, which are either planar or curved (plate 5.6).

The compact lava flows around Naldurg and eastern margins of middle reach of the basin exhibit columnar joints. Columnar joints are enclosed by 4 to 6 rectangular vertical fractures. Well developed vertical columnar joints are seen along the bank of the incised Bori river near Naldurg town (plate 5.7), whose heights varies from 1 m to 5 m. Crudely developed columnar joints, which are of shorter height, less than 1 m are seen in and around Wagdari. Compact lava flows do not constitute lava units and hence are simple lava flows.

5.3.2 STRUCTURE OF LAVA FLOWS:

The lava flows in the study area are horizontal. In most of the areas, the contact of lava flows are horizontal. In and around Andur lava flow shows very gentle dipping that is less than 2° towards southeast direction (plate 5.4). It is interesting to note that vesicular lava flows exposed across the scarp near constitute thin and compact lava unit of about 35 cm exhibit 4° to 5° tilt in NW direction. (plate 5.3). Fractures which are observed in the compact lava flow shows either vertical to steeply dipping (plate 5.6). Most of the fractures are trending in three directions viz., NE - SW, ENE - WSW and NW - SE. In and around Naldurg town, fractures are trending NE - SW direction. Fractures across northwestern part of the scarp exhibit verticle to steeply dipping fractures, which are trending North 2° to 6° West, N 65° W and N 80° E. In the middle part of the basin around Wagdari fractures are trending mostly N 40° E.
5.3.3 DISTRIBUTION OF LAVA FLOWS:

Field investigations indicate that the area under study constitute tabular alternate sheet of compact and vesicular lava flows. Map (Fig. 5.1) shows distribution of predominating type of lava flow in the study area. NE areas of the basin i.e. plateau and that of extreme eastern hills and ridges around Wagdari and Kamanhalli are composed of compact lava flows. Remaining parts of basin are predominantly composed of vesicular type of lava flows. Thick compact lava flows occur in and around Naldurg, which exhibit excellent vertical columnar joints. These are very well exposed in the cliffs of incised Bori river (Plate 5.7). These columnar joints are of greater height ranging from 1 to 5 m. and 5 to 6 sided. Similarly, compact lava flows around Wagdari and Kamanhalli exhibit crude columnar joints, which are of shorter height and 4 to 5 sided.

Vesicular type of lava flows are mainly of simple type, which constitute single lava flow. Some of vesicular lava flows are compound lava flows, which constitute 1 to 3 thin and uniform non-vesicular lava units. (Plate 5.3 and 5.4)

5.4 LANDSCAPE:

Landscapes are assemblage of regular and irregular surfaces. The part of landscape, which has consistency of form is known as landform. Landscape is composed of landforms and their slopes are components of landforms. The study of landforms is important in understanding landscape evolution.

These are groups of remnants surficial features left out by various processes operating on the surface. Type of landscape and landform depend on structure, processes, time and stage. (Davis 1899). The type of landform development also depends on physical and chemical properties of rocks. The type of rocks and
Fig. 5.1 - PREDOMINANT DISTRIBUTION OF LAVA FLOWS WITHIN THE BORI RIVER BASIN.
discontinuities, such as bedding plane, fracture, fault etc. play important role in the landscape development. Landforms are formed by either constructive or destructive processes acting on structure. Tectonic and climatic changes occur with the passage of time. The processes of landscape change through time are related to stages of alteration and such changes are known as geomorphic cycle. Davis (1899) used terms, such as youth, mature and old age stages for cycle of erosion. The completion of such cycle of erosion depends on tectonic and climatic stability of larger period and is liable to frequent interruptions. Because of interruption, cycle of erosion, is either lengthened or shortened, which is known as base level changes. Lengthening period of cycle of erosion is known as rejuvenation. The landforms related to the normal cycle of erosion and those of rejuvenation can be recognized in the field with various types of topographic and landform features (Spark, 1986). The most common features of rejuvenation are valley in valley topography, hanging valley, uplifted peneplains, incised meanders, knick points, paired terraces etc.

5.4.1. TERRAIN TYPES FROM THE BORI RIVER BASIN:

Field investigations indicate that the area under study is composed of 2nd order to 4th order relief features. 2nd order relief features existing in the study area are plateau, step like topography, hills, large valleys and pediments. 3rd order relief features are gullies, medium size valleys, small hills, interlocked spurs, hanging valley, point bars, water falls and rapids, pools and riffles, river terraces and natural levee etc. 4th order relief features observed are potholes, sediments and related structures.
5.4.1.1 LANDFORMS OF HIGH RELIEF:

Plateau, step like topography, scarp, ridge, mesa and hills are the terrain types seen and studied within the Bori river basin. Plateau, step like topography, scarp, ridge, mesa are associated with each other and mainly found in the extreme north eastern part of the Bori river basin. Remaining areas constitute hills and mesa landforms. Ridges of various sizes occur in between streams.

5.4.1.2 PLATEAU AND SCARP:

Northeastern terrain of the Bori river has extensive tableland with absolute relief ranging from 660 to 700 m. It is capped with compact lava flows and underlain by vesicular lava flows. Southwestern side of this plateau is in the form of linear scarp. (plate 5.5) Scarp is steep to moderately slopping towards southwest direction.

5.4.1.3 STEP LIKE TOPOGRAPHY:

The terrain of plateau constitutes terraces and step like topography, which are characteristic of the Deccan Traps. Such topography is also seen southwest of scarp (Plate 5.4).

5.4.1.4 MESA & BUTTE:

The study area constitutes number of broad and very small flat topped high grounds known as (plate 5.4) mesas and butte (plate 5.8) respectively. The tops of mesas are horizontal (Plate 5.4) or very gently slopping. The amount of sloping is less than 2°. Mesas with gently slopping tops are mainly seen around Andur near Naldurg town. The top of mesas are either composed of compact
lava flow or vesicular lava flows with thin hard brecciated top and underlain by vesicular lava flows. The relief of mesa is between 50 m and 30 m. The slopes of mesas are moderate at the top and gentle at the base.

5.4.1.5 HILLS:

Most of the moderate relief areas exhibit hills with rounded form. Slope forms of these hills are convex which are smooth. The height of these hills varies from 40 m to 20 m. These are composed of either mainly vesicular lava flows or vesicular lava flow with thin remnant cover of compact lava flow.

5.4.2 SLOPES:

Slopes are basic elements of the landscape. The form of landscape depends on slope elements and is indirectly depend on rocks, structure, denudational processes, climatic condition and vegetation cover etc. Classification of hill slopes is based on slope element, their mode of origin and slope angles. Hill slope profile consists of four elements viz., (1) summited convexity, (2) free face, (3) rectilinear element and (4) concave element (King, 1957). Similarly, Darlymple et. al. (1968) have explained diagrammatically nine slope units. Small (1970) has described slope forms into two broad groups, as simple slope and composite slope. According to Small, form of simple slope constitute single element, such as convex or rectilinear, free face or concave etc., where as composite slope consists of more than one slope elements. Composite slopes are of different types, such as convex-concave, convex-rectilinear-concave, free-face-rectilinear-concave, convex-rectilinear-free face-rectilinear-concave etc.

Based on mode of genesis, hill slopes are classified into three types such as, (1) tectonic slope, (2) erosional slope and (3) aggradational slope. Tectonic
slope is due to tensional and compressional forces resulting to form scarp. Such type of scarp may be because of faulting and tilting of rock layers. Erosional slope is due to erosion by river, glacier etc. and shows a stage of cycle of erosion. Differential erosion plays important role in the formation of erosional slope. Predominant convex slope indicates youth stage, rectilinear slope indicates mature stage, while concave slopes are found in old age stage. Free-face and pediment slopes are due to fluvial erosion. Aggradational slopes are due to deposition of sediments. Young (1972) has classified slopes based on slope angles (please see section 3.5.5).

5.4.2.1 METHODOLOGY:

Field observations helped to recognise micro-scale slope elements. Slope profiles of hills across scarp, basin dividers were studied to recognize slope elements and genetic aspects. The type of lava flows i.e. compact and vesicular, have been taken into accounts to study the slope profiles. Landscape with slope elements have been presented in the form of sketches and photographs.

5.4.2.2 SLOPE PROFILES IN THE STUDY AREA:

Figure 5.2 and 5.3 show slope elements in the study area. Slope elements observed, indicate that slope profiles in the area under study are of composite types as mentioned below.

1. Scarp slope:

Slope elements across NW-SE trending scarp shows four elements as explained by King (1957) (Fig. 5.2a and Plate 5.5). It shows summital convexity at the hill top followed by free face and rectilinear elements. Concave element occur at the base of scarp. The change in slope angle related
Fig. 5.2 Slope elements of Hills

a) Convex-Free face-Rectilinear-Concave

b) Convex-Concave

c) Compound slope and step topography- Convex-Rectilinear-Concave-Convex-Concave
Fig. 5.3 Slope elements of hills and divider a) Symmetrical Convex-Concave b) Asymmetrical Convex-Concave c) Combination of Convex-Concave-Rectilinear-Convex d) Combination of Convex-Concave-Rectilinear-Concave
to free face, rectilinear element and concave element represent change in the lava flow. Free face is related to the compact lava flow unit, whereas rectilinear element is related to vesicular lava flow or in some places red bed. Concave element associates with again change in the lava flow representing difference in lithological character of lava flow. At the extreme northwest part of the scarp lineament, Bawi-Kamta scarp section shows tilted character (Plate 5.3) indicating this scarp is possibly of tectonic origin. The amount of tilt measured is about 4° to 5° in the NW direction.

2 Hill Slope of Vesicular Lava Flows:

Vesicular lava flows are either simple or compound type. Compound lava flows constitute thin sheets of lava units of non-vesicular. Flat topped hills composed of vesicular lava flow underlain by another vesicular lava flow shows two to three slope elements, viz., summital convexity, and concave (Fig 5.2b and Plate 5.8) or summital convexity, rectilinear and concave.

The areas with more than one vesicular lava flows exhibit repetition of slope elements along the slope profile. Figure 5.2c show repetition convex-concave-convex-concave elements in the case of hills composed of two simple vesicular lava flows. Small hills consisting vesicular lava and underlain by other lava flow shows symmetrical (Fig. 5.3a) or asymmetrical slope (Fig. 5.3b) with convex-concave slope elements.

3. Slope Along the Basin Dividers:

Eastern basin divider shows various combinations of slope elements (Fig. 5.3c) as convex-rectilinear-concave, convex-concave, convex-rectilinear-
free face-rectilinear-concave, whereas western basin divider exhibits either convex-rectilinear-concave or convex-concave slope elements. (Fig. 5.3d)

5.4.2.3 CHANNEL SLOPES:

Channels slopes in the study area are either erosional or depositional. Channel slopes of 1st to 3rd order streams within the study area exhibit different elements. These are either convex slope, rectilinear slope or concave slope. In general, the streams of Harni river basin northern parts of the 5th order Bori river (Fig. 5.4 a to c, h), eastern parts of middle reaches (fig. 5.4 k and l) and the channel of lower reach (Fig. 5.4 m and n) of the Bori river show convex-concave combination form of slopes indicating mature stage of erosion. Streams around Naldurg and those of Horti, Morta, Khandala, Badole shows convex form of slope indicating youth stage of erosion (Fig. 5.4 d and e and plate 5.9). Incised meander due to Bori river near Naldurg exhibits convex-free face-concave slope elements (Plate 5.10 and Fig. 5.4 f). Channels with river terraces exhibit convex-concave-convex-concave slope elements (Fig. 5.4 g and j and Plate 5.11 and 5.12). The former combination of composite slope element are seen in the middle reaches of the Bori river while the latter that of the lower reaches of the Bori river.

5.5 WEATHERED PRODUCTS:

Weathered Products found on the surface depend on climate, biological variables and topography, lithology and period of weathering (Strakhov, 1967). Starkhov, (1967) and Laughnan, (1969) have mentioned that the chemical weathering depend on precipitation, temperature, intensity of leaching and prevailing pH conditions. Physical weathering is influenced by weak discontinuities in the rocks as
fractures and contacts etc. Most common weathered products observed in areas of tropical and semi arid regions are duricrust, regolith and soil.

Duricrusts are hard layers formed at the surface by weathering in the tropical wet-dry climate condition. The most common duricrusts are fericretes (laterite), alcrites (bauxite), calcretes (calcium carbonate) and silcrete (silica). Laterites and bauxites are associated with deep weathering in humid to sub-humid tropics where prevalent rainfalls were high (minimum annual precipitation greater than 1300 mm.). Calcretes are widespread in arid to semi-arid climatic condition in which calcium carbonates are saturated at or near the land surface. Thus calcretes coincides with annual precipitations from 200 to 600 mm. Regolith is mantle rock waste of varied characters consisting mixture of soil, sediment and broken rock fragments overlying the solid rock of the earth.

Regolith occurs as deposite over the various types of slopes. These are formed by transportation of gravitational force (colluvial deposits), river (fluvial deposits) etc. The type of regolith depends on the type of bed rock, topography and mode of origin. Various types of regolith formed on slopes are talus (composed of relatively rock fragment), colluvium composed predominantly of finer material and taluvium (composed mixture of fine and coarse rock fragments).

Soils are mixture of inorganic and organic, fine grained and unconsolidated material formed by weathering of rocks. These supports growth of vegetation and hence it is man's most vital natural resource for agricultural purpose. The thickness of soil varies from few cm to 10s of m. Soil is characterised by weathered zones known as soil horizons. A simple soil profile consists of three distinct horizons, which are designated as the A, B, and C horizons. Soil profile gradually grade in to parent bedrock. Soil horizons are recognised with their colour, texture, inorganic and organic
material. Soils are either residual or transported. The soil in the river valley belongs to second type, while other areas are mainly covered by residual soil. According to Krishnan, (1982), soil over the Deccan Traps are broadly of four types viz., (1) lateritic, (2) red, (3) black cotton or regur and (3) alluvial soil.

5.5.1 LATERITES:

Within the study area laterites are absent. But laterites are observed east of Naldurg at about 43 km near Turori in the form of cap at the top of mesa landforms. These form northeastern parts of upper reaches of the Benithora river (Plate 5.13). Presence of lateritic duricrust indicates the Benithora river basin and the Bori river basin had low local relief and experienced humid tropical climate.

5.5.2 CALCRETE:

Calcrete type of duricrust are found mainly in the basin Harni stream and middle reaches of Bori river basin. These occur in the form of small, thin sheets below the black soil and along the banks of third and fourth order streams. These are white in colour, granular to nodular form, porous and predominantly composed of CaCO₃. Presence of calcretes along the banks of streams and below the soil indicates these are of recent age. Calcretisation of alluvium is seen from the point bar deposits of incised horseshoe shaped meander around Naldurg fort (Plate 5.14).

5.5.3 SPHEROIDAL WEATHERING:

Outcrops of fractured and jointed compact basaltic lava flows show spheroidal weathering character (Plate 5.6). Compact basalts weathered along fractures to form spheroidal weathering and shows successive onion like
concentric shells around cores of relatively fresh basalt. Such cores are observed in the form of boulders at the top of the compact lava flow and over the slopes of moderate inclination. (Plate 5.15) Compact lava flows with columnar joints are weathered to show spheroidal weathering in and around Naldurg and over the eastern flank of middle reaches of the Bori river basin. Similarly, such large size boulders are also recorded along the contact of lower vesicular lava flow and remnant upper compact lava flow (Plate 5.16). The areas of eastern flank of the Bori river basin are covered with boulders and red soil i.e. regolith. Such regolith is not observed in the western part of the Bori river basin, which are predominantly covered by red soil.

5.5.4 **SOILS:**

Four types of soil covers have been observed in the Bori river basin. The areas of higher elevation and moderate to steep slopes are covered by red soil (Plate 5.8). The areas of low land are covered by regur. These soils are highly porous, black in colour and swells by adding water. The top of the elevated areas having low slope (less than 2°) covered with dark brown coloured soil. In the areas of gently sloping ground red soil grades to black soil through dark brown soil.

The areas close to the Bori river and its tributaries from lower reaches are covered by alluvial soil. These constitute (Plate 5.17) mainly black soil and enclose thin layers of sand and silt sediment indicating residual and transported types of soil.
5.6 FLUVIAL LANDFORMS:

Morphology of any drainage basin depends on three fluvial processes as intensity of channel erosion, transportation of sediments and deposition of sediments. These three processes are correlated with normal cycle of erosion stages as youth, mature and old age respectively. These three processes operate simultaneously but one of them is dominating in one of the stage. In general, from upper reach of river basin erosion i.e. sediments production predominates, whereas deposition of sediments takes place in the lower reach of the river. In the middle reach of the river basin all the three processes roughly occur in balance.

River channels are mainly of three types, viz., (1) bedrock channels, (2) alluvial channels and (3) semi controlled channels. Types of fluvial landforms formed depend on relief, lithology and structure, climatic conditions and tectonics. In general, fluvial landforms are broadly of two types, (1) erosional landforms and (2) depositional landforms. Observed fluvial morphological features have been described under four sub-headings, such as, (1) valley types, (2) erosional features along river, (3) depositional landforms and (4) river terraces.

5.6.1 VALLEY TYPES:

Cross sectional shapes have been observed across the stream channels of various orders within the Bori river basin. Symmetry, depth, shape and stage of stream, channel characters of streams and river have been taken in to account for description. The types of profiles observed are presented in the form of sketches (Fig. 5.4) and photographs.
(I) CHANNEL FORMS FROM PLATEAU AREA AND HARNI BASIN:

Cross sectional profiles of 1st to 3rd order streams are shallow, gently sloping and are exposed with bedrock and intermittently covered with thin mixture of gravel, sand, silts and soil sediments. Most of these profiles are symmetrical except in the areas of bends where they are asymmetrical. Figure 5.4a represents valley profile of 2nd order, while Figure 5.4b and c are valley shapes upstream of Naldurg.

(II) CHANNEL AROUND NALDURG:

The Bori river and its tributaries, Horti, Morta, Ramtirth and Khandala, show five types of channel forms around Naldurg, viz. (a) gorge and incised meander, (b) cut off meanders, (c) ‘V’ shaped valleys, (d) Hanging valleys and (e) disappearing streams. The Bori river around Naldurg shows two types of incised meanders are horseshoe shaped and other cut off meanders.

a) GORGE AND INCISED MEANDERS:

Incised, horseshoe shaped meander and ‘U’ shaped gorge occur along the Bori river down stream of Naldurg. Incised horseshoe shaped meander is very well seen surrounding the Naldurg fort. Channel segments of the incised Bori river are deep, vertical to steep walled with broad and flat base (Fig. 5.4f and Plate 5.10). The depth of gorge and meander valley is about 60 m near Naldurg fort. It goes on decreasing in the down stream direction. Figure 5.4h and Plate 5.18 represent valley shape downstream of Ramtirth at the distance of about 9 km, where potholes are seen. The length of gorge is about 11.5 km. Walls of incised meander and gorge exhibit well developed, elongated
Fig. 5-4 - SHAPES OF VALLEYS ACROSS THE BORI RIVER.
THE INSITE MAP [A] SHOWS THE LOCATION OF CROSS SECTION.
columnar joints in its upper 2/3 levels while compact lava flow is exposed in the lower levels (Plate 5.7). Width of valley floor is more in this segment than upper and middle reach of the Bori river. Valley floor are also more irregular.

b) CUT OFF MEANDER:

Two cut-off meanders of the Bori river, one near Naldurg and other near Ramtirth (Plate 5.19) are of ‘U’ shaped with steeply inclined channel walls are covered with thin soil, grass and shrubs. Topographic map analysis reveal that the depth of cut-off meanders is about 40 to 30 m. The floor of the cut-off meanders is filled with alluvium and is covered by black soil, which are under cultivation.

c) ‘V’ SHAPED VALLEY AND INTERLOCKED SPURS:

Streams of first and second orders of the Bori river and its tributaries around Naldurg and across the scarp are deeply incised and ‘V’ shaped (Fig. 5.4.3 e). Their slopes are steep, dissected by gullies and covered by thin soil, grass and shrubs. These streams are sinuous and exhibit interlocked spurs (Plate 5.9). The floor of these ‘V’ shaped valley are covered by thin mixture of gravel, sand and soil. Slopes of these valleys are convex and cut by gullies.

d) HANGING VALLEYS AND DISAPPEARING STREAMS:

The lower order streams which meet to the incised Bori river and cut-off meanders are of hanging valley type and disappearing stream type (Plate 5.19) respectively. Both of these valleys are ‘V’ shaped in cross section. The relief of these valleys at their confluence points with main channel varies from 1 m. to 3 m.
e) VALLEYS ACROSS SCARP:

These are also 'V' shaped (Fig. 5.4d) but in comparison to valleys around Naldrug, these are broader and exhibit concave slope.

III) VALLEYS ACROSS MIDDLE AND LOWER REACHES OF THE BORI RIVER:

Valleys in these parts of the river are broad, shallow and 'U' shaped. Depth of these valleys is less than incised upstream gorge around Naldrug. These are relatively more smooth and floored by coarse-grained deposits of gravel and sand. Valley walls are composed of alluvium and covered by soil (Plate 5.12).

Figure 5.4 j and k are valleys across middle reach of the basin. Figure 5.4 m and n represents forms of values from lower reaches of the Bori river. Figure 5.4 J (Motyal) and k (Umerge) constitute valley fill deposits (Plate 5.20) and has river terraces. Figure 5.4 n represents cross section near mouth of the Bori river and shows natural levees. The tributaries of the Bori in middle and lower reaches are shallow, broad and flanked by medium slope of alluvium. Figure 5.4 l is section of 3rd order stream of Ibrahimpur Nalla.

5.6.2 WATERFALLS, RAPIDS, POTHOLES:

The Bori river channel between Na'durg and confluence point of Harni Bori river dissect into bed rock. Channels of this segment are deeply incised, floors are irregular and show pools, rapids, waterfalls and pot holes. Pools, rapids near Naldrug (Plate 5.10), water fall near Ramtirth and potholes downstream of Ramtirth (Plate 5.18) are distinct. The height of Ramtirth waterfall is about 5 m and plunge pool exists at the base of waterfall. Potholes are smooth and elliptical in shape and size of potholes are in the range of 15 cm. to 65 cm. The presence of
these features along the segment of Bori river in between Naldurg and Harni-Bori confluence point indicate very steep stream gradient. Waterfall and rapids indicate discontinuities in the longitudinal profiles of bedrock channel and represents nick point. Similarly, potholes along the down stream segment of this irregular channel are due to intense abrasion and corrosion.

5.6.3 DEPOSITIONAL LANDFORMS:

The depositional features have been observed from lower order segments to mouth of the Bori river. Meandering segment of the Bori river around Naldurg and middle, lower reaches of the Bori river exhibit different types of depositional landforms. They show varied type of sedimentary deposits. Based on place of deposition these are described as channel deposits, channel margin deposits and over bank flood deposits. The lower order streams of the upper reach of the Bori river basin cut into basalt rocks. 3rd and 4th order streams are intermediate type that is locally controlled by bedrock or thin mixture of sediments constituting sand and soil. The segment of incised meandering Bori river between Naldurg and Khandala-Bori confluence point is bedrock channel and covered by very large boulder fragments of basalt, which are angular to sub-angular in shape (Fig. 5.4 f and g). The common depositional features and landforms observed are 1) transitory channel deposits, 2) lag deposits, 3) channel fill deposits, 4) point bar and 5) bank deposits. The type of sediment and thickness etc. of these deposits are as given below.

1) Transitory channel and lag deposits:

The Bori and Harni rivers in their upper reaches are floored by thin alluvium. The thickness is between few cm and one m. These constitute thin layers of sand, black soil and brown coloured sediments. The type of bed load
INDEX
BOLDER
COBBLE
PEBBLE
GRANNULE
SAND
CLAY

1. JALMAHAL NALDURG
2. RAMTIRTH
3. KHANDALA
4. MOTYAL
5. UMERGE
6. IBRAHIMPUR
7. JAVARGI

Fig. 5.5 - BED LOAD AND CHANNEL FILL DEPOSITS ALONG THE LONGITUDINAL PROFILE OF THE BORI RIVER.
observed along the Bori river has been plotted on the longitudinal profile in the form of symbol (Fig. 5.5). The type of bed load upstream of nick point is mixture of sand, silt and soil. The convex segment i.e. high gradient channel from Naldurg to Khandala-Bori confluence point is mainly covered by large size, angular to sub angular boulders (>25 cm.). As the channel gradient decreases, the size of the sediment decreases. Down stream of Khandala-Bori confluence point, channel floor is covered by mainly cobble and pebble (5mm. to 25 cm.). The cobble and pebble are flattened to sub-spherical in shape. The deposits of boulders, cobble and pebbles represent lag deposits.

The lower reach of the Hami and middle reach of the Bori river channels are floored by transitory channel deposits. These deposits are mixture of gravel and coarse sand (1 mm to 4 mm, Plate 5.12). The bed load cover within the lower reach of the Bori river is mainly composed of very coarse to coarse grained sand (2mm. to 1 mm.). At the mouth of Bori river, sand is coarse grained (average 0.5 to 1 mm).

2) Channel fill deposits:

These are mainly observed in channel of middle reach of Bori river, between Hami-Bori confluence point and confluence point of Ibrahimpur-Bori. Dug wells driven within these channels show the thickness of channel-fill deposits in the range of 5.50 m near Motyal (Plate 5.20) to 3.50 m near Umerge. Channel-fill deposits are mainly composed of gravel to coarse-grained sand (4mm to 1 mm. size). These deposits occur in the form of cross beddings. These deposits are found good resources of ground water, which is used for agriculture purpose.
3) Point bars:

These are crescent shaped lateral accretion deposits observed on the convex side of the meandering channels. The prominent point bars are observed within the incised horseshoe shaped meanders surrounding the Naldurg fort and along the meander belt of lower reach of Bori river. The alluvium of a point bar is partially lithified and calretised (Plate 5.14), thus indicates older in age than the age of point bar deposits from lower reach of the Bori river. Point bar deposits of latter segments of unconsolidated mixture of sand to gravel sized sediments (1 to 4 mm.) and occur in the form of cross beddings.

4) Bank deposits:

These are lateral accretion deposits along the river banks, which have been observed middle and lower reaches of the Bori river. Bank deposits within the middle reach are coarse to very coarse-grained sediment of gravel and sand. While those along the lower reach are fine-grained sand to silt and clay deposit (plate 5.21). Plate 5.21 shows graded bedding with layers of pebble at the base, followed by gravel, coarse sand, fine sand and silt to soil at the top (clay). Coarse sediment layers of these bank deposits occur in the form of cross bedding.

5.6.4 RIVER TERRACES:

River terraces have been observed along two segments of the Bori river, viz., (1) within the incised channel near Ramtirth (Plate 5.11) and (2) near Motyal (middle reach of the Bori river). These are narrow and flat surface on both side of the Bori river and found nearly at the same level (Fig. 5.4 g and j), representing paired terraces. River terraces near Ramtirth occur at two levels (Fig 5.4 g and Plate 5.11). The lower level paired terraces are of very narrow
than the upper level. The alluvium of these terraces shows graded beddings (Plate 5.22). Both of these levels are covered by alluvium and soil, which are under cultivation. River terraces near Motyal (Fig. 5.4j) exhibit one pair on either side. These pairs of river terraces also support the area around Naldurg has been rejuvenated due to uplift.
Plate 5.1: Red bed contact between lower vesicular lava flow and upper compact lava flow. Location: Tuljapur-Apsinga ghat section.

Plate 5.2: Bracciated top of the vesicular lava flow. Location: Near Chivari village.
Plate 5.3: Tilted lava flow unit within vesicular lava flow. Amount of tilt about $4^\circ-5^\circ$ towards NW. Location: Bawi-Kamata scarp section.

Plate 5.4: Mesa landform composed of compound lava flow showing very gently inclined terrace and step like topography. Location: Near Andur Village.
Plate 5.5: Scarp section showing compact (top) and vesicular (bottom) lava flows. Section shows slope elements. Location: Tuljapur-Apsinga ghat section.

Plate 5.6: Spheroidal weathering and vertical to steeply dipping fractures within compact lava flow. Location: Apsinga ghat section.
Plate 5.7: Well-developed columnar joints exposed in compact lava flows in the Bori river cliff. Location:- Surrounding the Naldurg fort.

Plate 5.8: Butte landform showing convex and concave slope elements. Soil cover is red. Location:- Near Khudawadi.
Plate 5.9: ‘V’ shaped valley and interlocked spur around Naldurg exhibiting convex slope elements and gullies.

Plate 5.10: Incised gorge with ‘U’ shaped channel and rapids of the Bori river near Naldurg fort, cliff shows slope elements (Viewing towards upstream).
Plate 5.11: Bori river channel between Naldurg and Ramtirth showing paired terraces and compound slope elements (viewing toward downstream).

Plate 5.12: Bori river channel across middle reach near Umerge showing carpet of gravel deposits and river terraces (viewing towards downstream).
Plate 5.13: Laterite outcrop near Turori, east of Naldurg at distance of about 35 km from Bori river basin.

Plate 5.14: Calcretised alluvium section of point bar surrounding Naldurg fort.
Plate 5.15: Rocky surface (regolith) due to boulders. Location: Western divide of the Bori river basin.

Plate 5.16: Boulders over vesicular lava flow. Boulders are remnant portions of compact lava flow. Location: Akkalkot-Dudhani road.
Plate 5.17: Alluvium soil along lower reach of the Bori river. Location: Near Bankalga.

Plate 5.18: Pot-holes along the Bori river, downstream of Ramtirth.
Plate 5.19: Part of cut-off meander, view near Ramtirth. Its streams disappear in the alluvium.

Plate 5.20: Valley fill deposits in the Bori river channel near Motyal. Thickness of deposit is about 5m.
Plate 5.21: Bank deposits showing graded bedding. Location: Near Javerji, lower reach of the Bori river.

Plate 5.22: Close view of the river terrace showing graded bedding. Location: Near Ramtirth.