Remote Sensing and GIS Studies in Evolution of Shastri River Basin, Ratnagiri District, Maharashtra: A Geomorphic Approach

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Abstract: ***Geomorphologically the coastal part of Maharashtra seems to be controlled by tectonic and erosional processes. The tectonism along the West Coast of India is represented by faulting and upliftment of blocks in certain areas. Geomorphologically, the Deccan Volcanic Province (DVP) in the western part of Maharashtra has been divided into two major geomorphic units, viz. the low land Konkan plain and the Sahyadri upland region. Eighteen major and thirty-six minor west flowing perennial rivers originating in Western Ghats traverse the Konkan Coastal Belt (KCB).***

Shastri River Basin (SRB) is the seventh order coastal river basin of Maharashtra. In order to understand the tectonic evolution, the underlying structures like faults, fractures, joints, lineaments, the drainage pattern and geomorphic features of the Shastri basin have been determined. The drainage pattern is dendritic to sub-dendritic while, trellis and sub-parallel drainages have been observed at some places. Various geomorphic features of fluvial and marine origin have been identified in the area, based on the study of topographic sheets, satellite data and DEM, which have been supported by intensive field investigations. The presence of the constructional and pro-gradational features towards western part suggests emergence of the land whereas the presence of degradational features towards eastern side of the basin depict the submergence activities in the area. The presence of abnormal drainage patterns and various geomorphic features, hot springs in linear array indicates the imprint of tectonic activity.

Keywords : DEM, River basin, drainage pattern, fluvial

INTRODUCTION

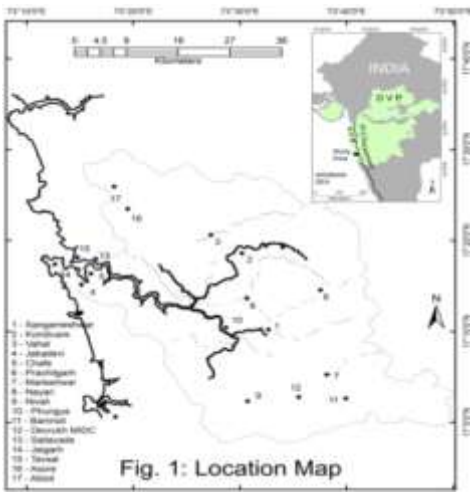
Coastal environment is most active, dynamic and transitional in nature. It is characterized by the interplay of continental and marine environments, recorded in the form of various geomorphic features. These features indicate the evolutionary history of region. The West Coast of India (WCI) has attracted the attention of many geo-scientists, due to its neo-tectonic set up, continuing seismic activities, sea-level changes and environmental degradation. The tectonism along the West Coast of India in certain areas is represented by faulting and upliftment of blocks. The geomorphic expression of the coastal part of Maharashtra seems to be controlled by the tectonism and erosional processes (Wynne, 1866). Geo-morphologically, the Deccan Volcanic Province (DVP) in the western part of Maharashtra has been divided into two major geomorphic units, viz. the low land Konkan plain and the Sahyadri Upland region (Kale, 2000).

Dikshit, K. R., (1976) studied Maharashtra & Goa coast and pointed out that the courses of some of the coastal streams of Maharashtra controlled by tectonic lineaments. Kale and Shejwalkar (2008) determined geo-morphic indices of thirty selected river basins of both sides of Western Ghats on a regional scale. In addition number of scientists have worked on tectonic aspects of western coastal part of Maharashtra (Devey and Lightfoot, 1986; Sukhtankar, 1989; Seth, 1998; Widdowson and Mitchell, 1999; Kundu and Matan, 2000; Erram and Gupta, 2009; and Valdiya 2001). Very few attempts made in connection with the coastal river basins of India on local scale to understand the geo-environmental and tectonic aspects as well as to evaluate the geomorphic set up and geological history of the area.

Shastri River Basin (SRB) is the seventh order coastal river basin of Maharashtra. The drainage pattern is dendritic to sub-dendritic while, trellis and sub-parallel drainages have been observed at some places. Various geomorphic features of fluvial and marine origin have been identified and thematic maps have been prepared based on the study of topographic sheets, satellite data, DEM and using GIS techniques, which have been supported by intensive field investigations. The most prominent planar surface lies at 200 – 220 mts. asl. The depth of incision by the Shastri river reached up to sea level in the southern and towards western part of the basin, suggest the most promising tectonic activity. The flat-topped hill ranges found to be oriented in NNW-SSE, NE-SW and E-W directions and show a decrease in the altitude towards west. They represent lineaments and correspond to the zone of structural weakness. River valleys are narrow and steep in the upper reaches, extended up to 5 -6 km. in length and become broad and graded near the mouth. The fluvial depositional features observed at different places. The alluvial plains developed at the interface of marine and fluvial environments. Various geomorphic features of active incision, viz. waterfalls, cascades, potholes, natural ponds have been observed in eastern part of the area. The presence of the constructional and pro-gradational features towards western part suggest emergence of the land whereas the presence of degradational features towards eastern side of the basin depict the submergence activities in the area. The presence of abnormal drainage patterns, prominent lineaments, hot springs in linear array and various geomorphic features indicate the imprint of tectonic activity in the area of investigation.

AREA

The Shastri River Basin (SRB), lies in the West Coast of Maharashtra, (lat. 16^0, 57' N; long. 73^0, 15' E and lat. 17^0, 30' N; long. 73^0, 50' E) (Fig. 1). It covers an area of about 2098 Km^2. River originates on western scarp near Prachitgarh (17^0 13^1 N, 73^0 42^1 E) at 836 mts asl., joins the Arabian sea towards west after journey of 72 Kms.



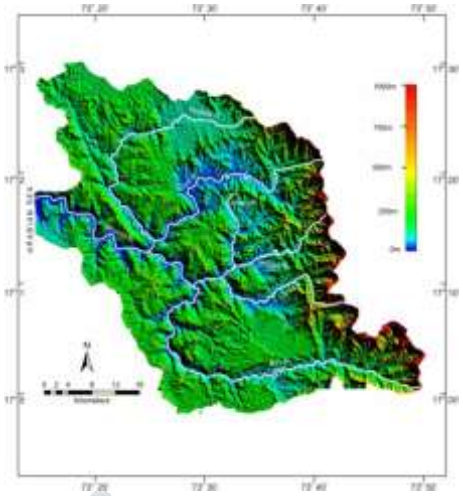


Fig. 1: Location Map of Study Area **Fig.2:** DEM of SRB

MATERIALS AND METHODS

Tectonic set up and geo-morphic aspects of the SRB have been determined by using following data

1. Survey of India topographic sheet Nos. 47 G/3, G/4, G/7, G/8, G/11, G/12, 47 H/9 (scale 1: 50,000)
2. Satellite data - IRS-RS2, LISS- III (Path/Row – 95/60 and 95/61 dated 02nd March 2013)
3. color coded DEM (30 m. resolution)
4. Arc GIS 10.1 software

In addition, detailed field investigations carried by using GPS to identify and locate various lithological units, landforms. Various thematic maps viz. lineament, geological, geo-morphological etc. have been prepared.

PHYSIOGRAPHY

The area shows geo-morphologically diverse topography. It is hilly, rugged terrain, intercepted by westerly flowing Shastri River and its tributaries viz. Kapsi, Gad, Sonvi, Asavi and Bav. Physiographically, the area can be divided into three parts from West to East (Fig.2)

1. A narrow fringe of Quaternary sediments near the coast-line
2. Steep rocky slopes encircling the plateau at the center and
3. Undulating region rising above 100 mts. asl. in the vicinity of the Western Ghats

GEOLOGY

Deccan basaltic lava flows belonging to Diveghat and Purandargarh formations are present throughout SRB (GSI, 2001). These flows exposed along river valleys, valley sides and near shore. Most of them are capped with laterite. The Quaternary sediments are exposed along the banks of Shastri river and its tributaries. The detailed geological map of the area is compiled (Fig. 4) through field mapping using GPS and remote sensing data (FCC 124 bands) (Fig. 3)

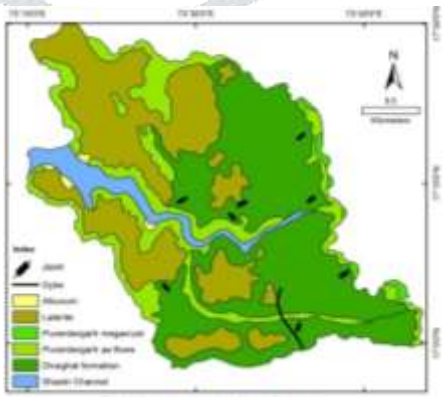


Fig. 3 FCC (124 bands) of SRB **Fig. 4** Geological Map of SRB

GEOMORPHOLOGY

Based on the study of topographic sheets, FCC satellite data (432 bands) (Fig. 5) and DEM supported by intensive field investigations using GPS, variety of landforms present in SRB have been identified (Fig. 6) and given in Table 1. There is decrease in elevation from Escarpment to West Coast. These landforms are the result of erosional and depositional processes related to both fluvial and marine activities.

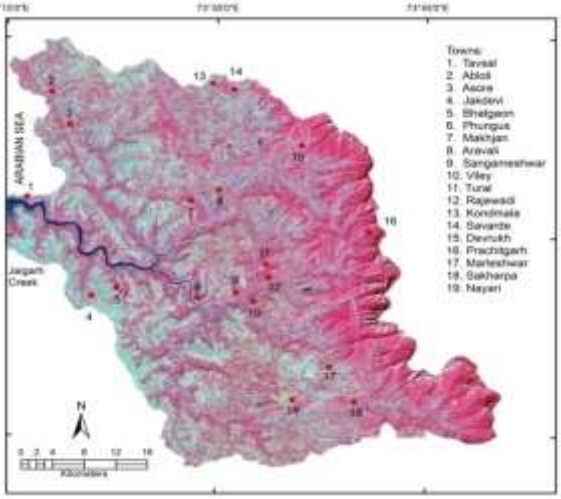


Fig. 5: FCC (432 bands)of SRB

Fig. 6: Geo-morphological Map of SRB

Following different features identified.

A) Features Due to Fluvial Processes:

It is evident that in SRB, the fluvial processes play an important role in geomorphic evolution. During the intense fieldwork, the number of erosional and depositional fluvial geomorphic features have been identified and classified;

I) Erosional Features:

a) Planar Surfaces: The presence of a geologically young planation surface at high elevation suggests rapid and recent uplift (Ollier and Pain, 1997).

SRB indicated the presence of five planar surfaces at 0-20 m., 120-130 m., 160-180 m., 200-220 m. and at 860-880 m. asl (Fig. 7) (Plate 1). The lower most planar surface (0-20 m. above asl.) coincides with mud-flats, consolidated and unconsolidated Quaternary sediments. The second planar surface (120-130 m. above asl.) coincides the low-level laterites. The most prominent planar surface lies at 200- 220 m. asl., which accounts for about 50 % of the total area. The higher planar surfaces lie at / near the western scarp.

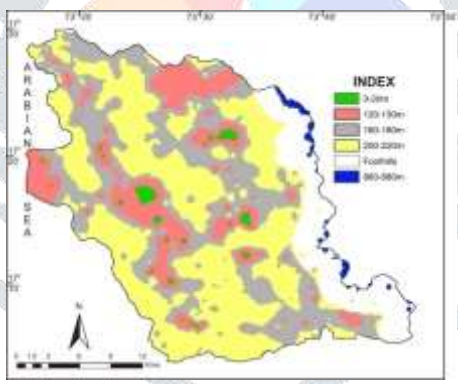


Fig. 7: Map Showing Planar Surfaces of SRB

b) Hill ranges and Escarpments: Western Ghat escarpment trending in N-S, situated towards the eastern part of the area. The maximum elevation reaches up to 886 m. asl., mainly in the north and decreases gradually towards the south. The flat-topped hill ranges occur mostly in the eastern part of the basin (Plate 2), oriented in NNW-SSE, NE-SW, E-W directions. These ridges extended towards west with gradual decrease in height and are identified as lineaments on imageries, which correspond with the zone of structural weakness. The hill ranges are due to the dissection brought about mainly by fluvial processes.

c) Mesa and Butte: These have been observed near Manjre (170 m.) (17^0 11' N & 73^0 25' E) (Plate 3). As the area consists of different basaltic lava flows of variable resistance, a typical trappean topography is evident along the slopes of the mesa and butte.

d) River valleys: Deep 'V' shaped valleys observed near the escarpment. Most of the valleys present in the Shastri River and tributary basins are with steep slopes and extended up to 5-6 km. in length. They are oriented in E-W, NW-SE and NE-SW directions. In the upper reaches, the valleys are narrow with steep slopes and contain rapids (Plate 4).

II) Depositional Features:

a) **Alluvial Plains:** These are developed on either sides of Shastri River or its tributaries especially near the meandering part (Plate 5). They are consisting of sand, silt and clay.

b) **Fluvio-colluvial deposits:** These are sedimentary materials consisting of loose boulders and gravels, which have been transported (eluvium) and deposited at the base of hill slopes. These are developed towards eastern part of the basin (Plate 6).

c) c) River Terraces: The paired and unpaired terraces are observed at different locations. The river terraces near the eastern foothills of the basin are narrow. In the western part, the terraces are broad. (plate 7).

In addition to these fluvial features, the active incision channels are also present in the area, represented by waterfalls, cascades, potholes, natural ponds etc.

B) Features Due to Marine Processes

Various types of erosional and depositional geomorphic features formed by marine processes have been identified.

I) Erosional Features:

a) Creeks: The region shows presence of one major i.e. Jaigarh creek and five minor creeks are viz. Kapsi, Gad, Asavi, Sonvi and Bav. All are controlled by the lineaments (Plate 8).

b) Wave cut platform: Gently sloping (1^0-5^0) Wave cut platform in the compact basalt has been observed at northern part of Jaigarh beach.

c) Head Land: The prominent headland in hard, resistant and compact basalt has been observed at northern part of Jaigarh beach (Plate 9).

II) Depositional Features:

a) Recent beaches: A prominent beach is present at the mouth of Shastri river near Jaigarh. It consists of medium to fine grained sand with gentle gradient (Plate 10).

b) Island: A small island is present on the opposite side of Shastri estuary at Kond.

LINEAMENT ANALYSIS

Studies of lineaments provide the valuable information about the orientation of stresses, which are responsible for the deformation, and about the controls, exerted by structural elements in the development of landforms. In general, lineaments depict lines of weakness and lineament map reflects the structural fabric of the area. Lineament analysis based on topographic sheets, satellite imageries, and Digital Elevated Model (DEM) is useful in determining the structural history and tectonic set up of the area.

A) Based on Topographic sheets:

The length and orientations of individual lineaments have been determined (Table1). It is seen that there is a tendency of concentration of lineaments in terms of number and length in the azimuth range N 331^0- 340^0 and N 51^0- 60^0 directions. This orientation pattern suggests that these lineaments constitute a conjugate pair of shear fractures trending in NNW-SSE and NE-SW directions, which are developed due to the stress oriented in N 10^o direction (Powar, K. B. 1993),

B) Based on satellite imageries:

FCC (RGB 532) is more helpful for the delineation of lineaments (Kundu, 2001). The binary data was converted in to images with the help of Idrisi 2 software (Fig. 8). The lineaments for basin have been marked, analyzed along with azimuth frequency and is given in Fig. 9. The individual length and orientation of all these lineaments recorded (Table 2).

Table 1 Data for Lineaments For SRB (Topographic Sheets)

Azimuth Range	N	N%	L	L%
0^0 - 10^0	173	5.29	141.20	5.49
11^0 - 20^0	187	5.72	135.00	5.25
21^0 - 30^0	151	4.62	125.60	4.88
31^0 - 40^0	194	5.93	136.95	5.33
41^0 - 50^0	191	5.84	146.05	5.68
51^0 - 60^0	221	6.76	193.75	7.53
61^0 - 70^0	173	5.29	147.95	5.75
71^0 - 80^0	177	5.41	129.65	5.04
81^0 - 90^0	170	5.20	120.90	4.70
271^0 - 280^0	153	4.68	116.65	4.54
281^0 - 290^0	169	5.17	123.20	4.79
291^0 - 300^0	171	5.23	126.55	4.92
301^0 - 310^0	140	4.28	96.80	3.76
311^0 - 320^0	176	5.38	126.50	4.91
321^0 - 330^0	161	4.92	131.80	5.12
331^0 - 340^0	212	6.48	186.35	7.25
341^0 - 350^0	198	6.06	181.10	7.04
351^0 - 360^0	253	7.74	205.50	7.99
	3270		2571.50	

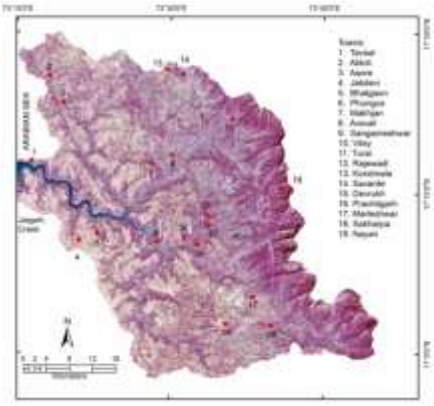


Fig. 8: FCC (RGB 532) of SRB

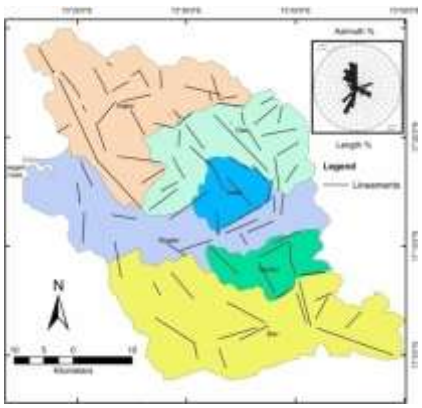


Fig. 9: Lineament Map of SRB (Satellite Imagery)

It has been observed that maxima of the lineaments for the basin lies in N 331^0 - 340^0 W direction whereas, sub-maxima of lineaments is in N 41°- 60° E direction. These lineaments are mainly fracture lineaments and show two dominant directions viz. NNW–SSE and ENE-WSW.

Table 2: Data for Lineaments For SRB (Satellite Imagery).

Azimuth Range	N	N%	L	L%
0^0 - 10^0	7	8.64	12.40	8.15
11^0 - 20^0	3	3.70	4.90	3.22
21^0 - 30^0	3	3.70	3.60	2.36
31^0 - 40^0	1	1.23	1.80	1.18
41^0 - 50^0	7	9.26	14.40	9.46
51^0 - 60^0	9	11.11	19.60	12.88
61^0 - 70^0	5	6.17	11.45	7.52
71^0 - 80^0	2	3.09	4.15	2.73
81^0 - 90^0	8	9.88	16.05	10.54
271^0 - 280^0	1	1.85	2.20	1.44
281^0 - 290^0	4	4.94	8.55	5.62
291^0 - 300^0	5	6.17	7.50	4.93
301^0 - 310^0	4	4.94	4.90	3.22
311^0 - 320^0	7	8.64	13.05	8.57
321^0 - 330^0	1	1.23	2.25	1.48
331^0 - 340^0	9	11.11	18.55	12.19
341^0 - 350^0	3	3.70	5.95	3.91
351^0 - 360^0	1	0.62	0.90	0.59
	81		152.20	

C) Based on DEM:

Based on linear scarps and ridges, straight and curvilinear drainage segments, deep valleys and linear tonal contrast, the lineaments for the entire basin have been marked from DEM and shown in fig. 10 along with azimuth diagram. The individual length and orientation of all the lineaments measured and presented in Table 3. The maxima of the lineaments for the basin lies in N 321^0 - 340^0 W direction, whereas, sub maxima in N 51°- 60° E direction.

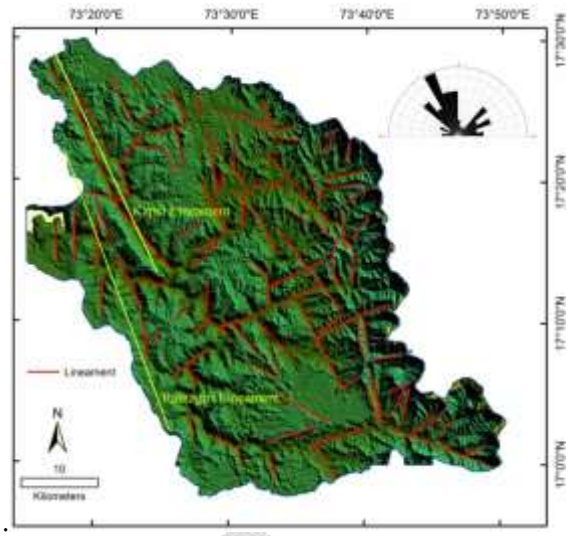


Fig. 10: Lineament Map of SRB (DEM)

Table 3: Data for Lineaments For SRB (DEM).

Azimuth Range	N	N%	L	L%
0^0 - 10^0	04	4.44	16.10	3.93
11^0 - 20^0	-	-	-	-
21^0 - 30^0	-	-	-	-
31^0 - 40^0	01	1.11	4.60	1.12
41^0 - 50^0	01	1.11	20.00	4.88
51^0 - 60^0	07	7.78	14.80	3.61
61^0 - 70^0	05	5.56	24.80	6.05
71^0 - 80^0	03	3.33	16.60	4.05
81^0 - 90^0	01	1.11	17.60	4.29
271^0 - 280^0	05	5.56	12.20	2.98
281^0 - 290^0	03	3.33	10.70	2.61
291^0 - 300^0	05	5.56	17.90	4.36
301^0 - 310^0	02	2.22	36.50	8.90
311^0 - 320^0	08	8.89	50.80	12.39
321^0 - 330^0	13	14.44	56.30	13.73
331^0 - 340^0	11	12.22	38.80	9.46
341^0 - 350^0	12	11.33	16.70	4.07
351^0 - 360^0	10	11.11	55.60	13.56
	90		410.00	

CONCLUSIONS

From above discussion, it is followed that the fluvial processes play dominant role in the geomorphic evolution of the study area. There is a general decrease in the elevation from Escarpment to West Coast and from north to south direction. The studies of topographic profiles, altimetric analysis, followed by field observations show the presence of five planar surfaces in the area. The most prominent planar surface lies at 200 – 220 mts. asl. The depth of incision towards southern and western parts of the basin reaching up to sea level, suggests the most promising tectonic activity in this part of the coastal region. The flat-topped hill ranges found to be oriented in NNW-SSE, NE-SW and E-W directions and show decrease in the altitude towards west. They represent lineaments and correspond to the zone of structural weakness. The fluvial depositional features observed in the field at different places in the eastern part. The various geomorphic features of active incision are viz. waterfalls, cascades, potholes, natural ponds etc. also observed in eastern part of the area. Marine erosional geomorphic features observed mainly in the western part of the area. The presence of the constructional and pro-gradational features like alluvial plains, river terraces, recent beach, fluvio-colluvial deposits, tombolo etc. towards western part suggest emergence of the land whereas the presence of degradational features like hills and escarpment, valleys, creeks, planar surfaces etc. towards eastern side of the basin depict the submergence activities in the area.

Lineaments delineated from topographic sheets show tendency of concentration both in terms of number and length in the azimuth range of N331^0- 340^0 and N 51^0- 60^0 directions. These orientation patterns suggest that the lineaments constitute a conjugate pair of shear fractures in NNW-SSE and NE-SW directions, developed due to the stress oriented in N 10^o direction. The data of lineaments from imageries and DEM show two dominant directions viz. NNW–SSE and ENE-WSW. It has been observed that NNW-SSE trending lineaments collinear

with NNW–SSE segments of the coastline and coincide with West Coast Fault. Three major lineaments on a regional scale along the coastal tract, viz. NW-SE trending Kapsi lineament (about 30 km in length), NNW-SSE trending Guhagar lineament (about 70 km in length) and Ratnagiri lineament (about 25 km in length) are responsible for the development of major tectonic set up of SRB. These lineaments represent the positive signature in the form of shear zones, which are observed in the field as highly crushed and fractured zones. It is confirmed by the presence of hot springs at Tural, Aravali, Rajewadi villages, which are aligned parallel to the West Coast (Shankar, 1991). These hot springs indicate the existence of hidden fault. According to Valdiya, K. S. (2011), the multiplicity of hot springs along NW-SE trending lineaments, occur in linear arrays in the Western Coastal Belt. It clearly shows that the coastal terrain is cut by deep faults. All these activities, demonstrate unequivocally that the so-called lineaments are the faults rather than they are active faults related to the bulging- up of the western part of Peninsular India, developed due to faulting and play important role in the tectonic evolution.

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Plate 1: Planar Surface (Location – Devrukh)

Plate 2 : Hill Range (Location – Prachitgarh)

Plate 3: Mesa and Butte (Location – Manjre)

Plate 4: 'V' Shaped Valley (Location – Nivali)

Plate 5 Alluvial Plains (Shastri River)

Plate 6: Fluvio-colluvial Deposits (Gad River)

Plate 7: River Terraces (Location–Sangmeshwar)

Plate 8 : Creek (Location - Phungus

Plate 9 : Headland (Location - Jaigarh)

Plate 10: Recent Beach (Location – Jaigarh)