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Morphotectonic and Lineament analysis from Bhatia and Jaigarh Creek, Ratnagiri, MS, India: Neotectonic Implication

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Abstract

In the present study landscape information viz. lineament, drainage, altimetric and hypsometric analysis has been worked out. The study area is a coastal tract which lies between Jaigarh Creek in the North to Pavas Creek in the South from Maharashtra State, India. The area covered during present investigation is drained by the streams which originate in the Sahyadri ranges of the Western Ghats and follow short tumultuous courses. Majority of streams follow East - West course, some follow NW - SE and NE - SW courses. Most of the streams are characterised by straight segments with acute angle turns, indicative of structural control. This structural control has given rise to drainage anomalies. Most of the streams in their upper reaches exhibit the presence of rapids, which occur, generally at elevations of 60 - 70m amsl. Their height ranges from 1m to 15m. From topographic sheets and LANDSAT - I imageries inferred that the majority of the streams have been controlled by lineaments. Satellite imagery reveals that major streams like Kajavi have been controlled by NW - SE lineament, while river Shastri has been controlled by NE - SW lineament. From the hypsometric values it is inferred that the higher order streams show Monadnock phase, whereas, the hypsometric values indicate maturity stage. It can be said that the area under investigation indicates Monadnock phase of aeration which represents the residual hills.

Keywords: lineament, drainage morphometry, hypsometric and altimetric analysis, Neotectonic Implication.

Introduction

Lineament analysis based on LANDSAT imageries, aerial photographs and topographic maps are useful to give structural history and tectonic set up of the area. However, the accuracy of analysis and the preparation of maps are dependent on the scale, lithology and structural characteristics of the terrain under study. The lineament map is useful in evaluating the tectonic history of the continental area[1]. The presence of geomorphic features and lineament pattern along the West Coast of India are formed mainly due to the changes in the sea level, caused by the tectonic activities[2]. The features are helpful in predicting the evidences of submergence and emergence of the land along the coast. They have investigated the Quaternary sediments in relation to geomorphology and tectonics, South of Ratnagiri and have stated about the possible role of neo-tectonic activity in the development of coastal geomorphology.

Various morphometric parameters are useful to understand the drainage characteristics of any area. It helps to know the terrain texture. The evolutionary changes which are taking place throughout the geological past in a particular area can be interpreted by computing dimensionless parameters. With this view, various drainage parameters have been calculated for the area under investigation.

However, the attempts made by the various investigators were on a regional scale. Therefore, present investigations are visualize to make the assessment of tectonic activity, if any, by carrying out the systematic studies of LANDSAT - I imageries and topographic maps along with geomorphological studies of the Ratnagiri coast. These studies have been substantiated by the intensive field work. These studies have been carried out, as follows: i. To enlarge a part of the topographic maps of the area to the scale of 10 cm = 1 Km, ii. To carry out the lineament analysis with the help of topographic maps and LANDSAT imageries, iii. To study the terrain characteristics, viz., drainage morphometry, hypsometric analysis and altimetric analysis.

Study area: The study area is a coastal tract which lies between Jaigarh Creek in the North (Latitude 17°20' N and Longitude 73°10' E) to Pavas Creek in the South (Latitude 16°50' N and Longitude 73° 16' E) from Maharashtra State, India. Location map of the study area has depicted in figure-1. The area is hilly and intersected by major and minor Creeks. Number of flat topped hillocks is on the east and sea coast is on the west. The area covered by the present investigation is drained by the streams which flow westwards. However, some of the streams flow in NW-SE and NE-SW directions. Many streams are characterised by straight segments with sharp angled turns. The drainage pattern is mainly dendritic to sub-parallel (figure-2). Such features indicate structural control causing the drainage anomalies. It is observed that the rapids, found at Madaliwadi, Tulsankarwadi and Dhamanse villages largely occur at about 100m amsl.

Geology: Study area is mainly composed of Deccan basalts, which are invariably capped by laterite and in subordinate amount of bauxite[3]. The Tertiary sediments are found to be sandwiched between the laterite, while in some sections, they overly directly on the basaltic lava flows. Modified stratigraphic succession of the study area after Anon has depicted in table-1[4].

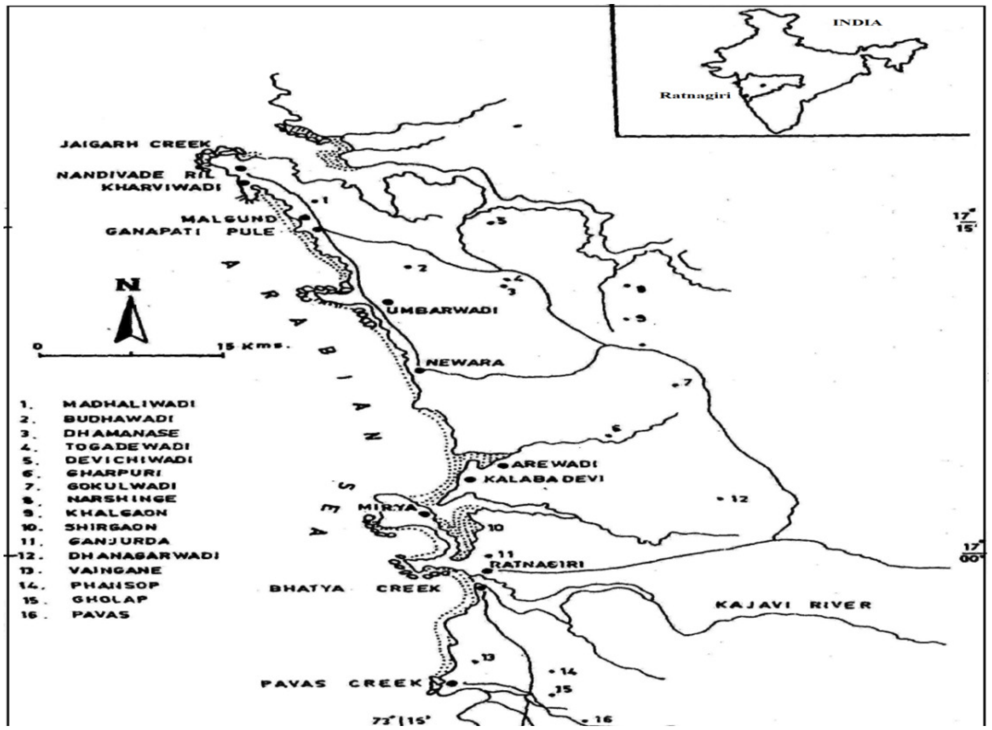

Figure-1
Location map of the study area

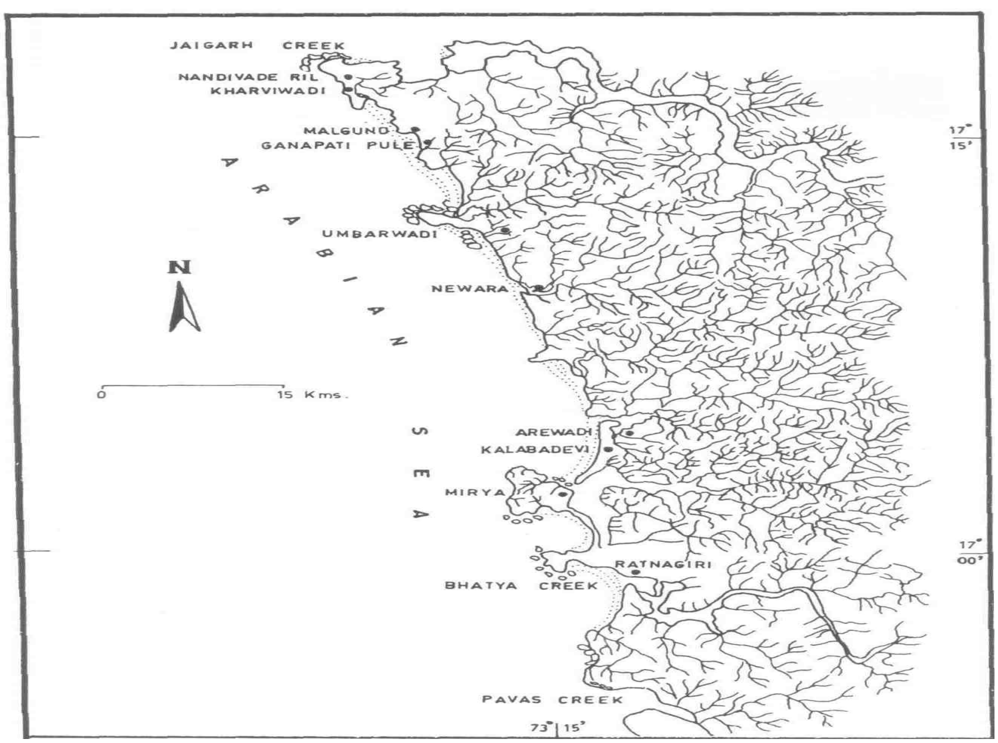

Figure-2
Drainage map of the study area between Pavas creek to Jaigarh creek

Table-1
Stratigraphic succession of the study area (Modified after Anon, 1976)

Lithology	Period
Alluvium	Quaternary
Unconsolidated and Consolidated Sediments	Pleistocene
Laterite	
Grey Shale	Tertiary
Carbonaceous Shale	
Lignite	
Carbonaceous Shale	
Grey Shale	
Gravelly Sand	
Deccan Basalts	Upper Cretaceous to Lower Eocene

Methodology

Topographic maps and LANDSAT - I imageries on a scale 1:50,000 and 1:2,50,000 respectively, have been used. In the present analysis, definition of lineament, proposed by O'Leary, et. al. has been used[5]. Accordingly, lineament analysis of the area has been carried out and the results obtained there from have been discussed in the following subsection. For the purpose of the statistical studies, the Survey of India topographic maps Nos. 47 G/3, 47 G/7, 47 G/8 and 47 H/5 and LANDSAT - I imageries Nos. 89-A~N-D-2L and 189 - 0550 Gl - N - D - 2L were studied in band Nos. 4, 5 and 7.

In case of topographic maps, the lineaments have been plotted by considering the strike of the hills, which have a linear and curvilinear pattern, the direction of the gentle slopes of the hillocks, alignment of the discontinuous hillocks, a straight or nearly straight course of a stream or a river, an alignment of unidirectional pattern of such courses of streams and acute bands of streams followed by a linear courses. In case of LANDSAT - I imageries, lineaments have been studied by considering continuous ridges and alignment of discontinuous hills and hillocks, linear continuous depressions or discontinuous segments of streams, arranged in an alignment; continuous or discontinuous linear resulting from dark tone which are due to vegetation or inherent colour of lithology and moisture content along the fractured zones.

The lineament map prepared with the help of topographic maps, LANDSAT - I imageries and by noting azimuth of each lineament, azimuth frequency diagrams so prepared and are depicted in Fig 3 and 4. The lineament data from the topographic maps and LANDSAT - I imageries are given in Table 2, 3 and 4. It is seen from the azimuth length frequency diagram that lineaments do not show any pronounced concentration in any direction. However, there is a tendency of concentration both in terms of number and length in the azimuth range N 10^0 -20^0 and N 40^0 to 50^0.

The rose diagram constructed from the topographic maps show close correspondence with the one obtained for the lineaments, observed on LANDSAT - I imageries. Maxima of lineaments have azimuth range in N 40^0 and N 50^0 direction. This substantiates, the contention made from the drainage pattern that, courses of many streams are structurally controlled. The importance of these studies was pointed out by Horton and Strahler[6,7].

In the present, study, an analysis of the stream ordering has been carried out by the methods suggested by Horton[6]. This method has an advantage over other methods because it bears close relationship with the structural elements of the area. Following drainage parameters have been worked out for the area under investigation to understand the terrain texture. i. Bifurcation ratio ii. Stream length iii. Drainage density iv. Constant of channel maintenance. v. Hypsometric analysis and, vi. Altimetric analysis.

Results and Discussion

Lineament analysis: It can be observed from the rose diagram that the maxima lies in N 40^0-50^0 E direction, with 14.71 and 15.69 in terms of number and length percentages, whereas, sub-maxima lies between N 30^0-40^0 with number 16.18 and length 16.66 percentages.

It is seen from the azimuth length frequency diagram that lineaments are NW-SE and NE-SW oriented fractures of shear origin, developed due to compression on N - S axis. The trend also suggests the combined action of vertical uplift.

Analysis of lineament from the topographic maps and LANDSAT - I imageries yield significant information regarding the nature of tectonic movement which has affected the area under investigation.

From the number length azimuth frequency diagrams, it is seen that the lineament data obtained from satellite imageries and topographic maps, though comparable, are not identical. The data from topographic maps is rather diffused. This is because; the lineaments marked on topographic maps include straight segments corresponding to second and third order streams which are not necessarily structurally controlled. For structural interpretation, therefore, the lineament pattern obtained on LANDSAT - I imageries is found to be more reliable.

From the analysis of topographic maps and satellite imageries suggesting two major directions, viz., N 10^0 E and N 50^0 E appear to be major directions of structural weaknesses and therefore, represent the conjugate pair of shear fractures. Both of them rather closely coincide, with the Precambrian trends in the South Indian Peninsula. Thus the lineament analysis of the area under investigation matches closely with the major regional structural trends of India. It is interesting to note that the directions of the lineaments are the directions of major rivers and streams of the area under investigation. These tectonic activities might have influenced the subsurface Tertiary sediments by major tectonic disturbances along the West Coast. Therefore, detailed investigations of these Tertiary sediments have been carried out to know the effect of any such activities.

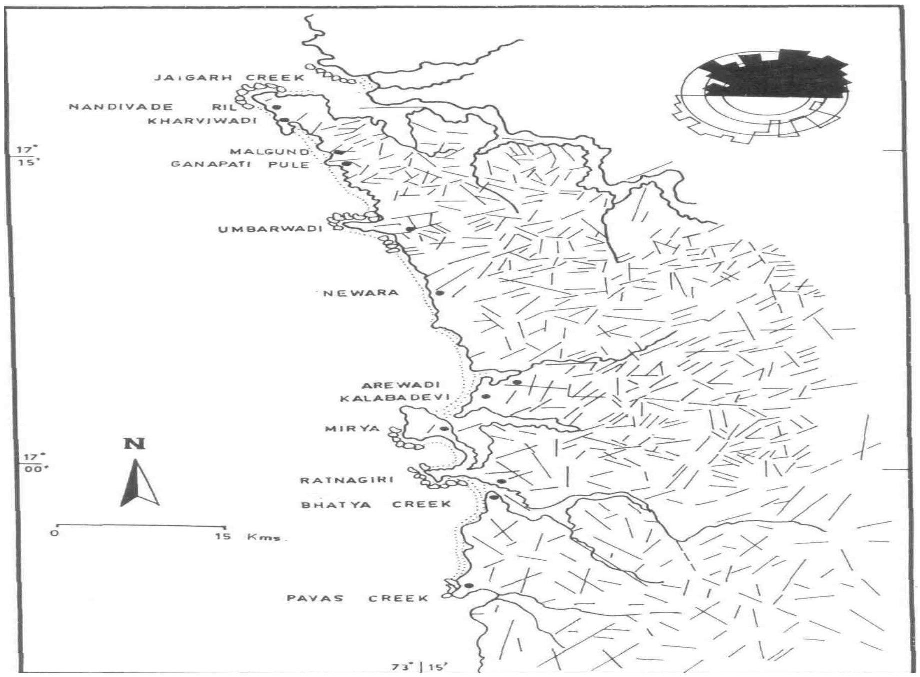

Figure-3
Lineament map based on topographic maps of the area between Pavas and Jaigarh creek

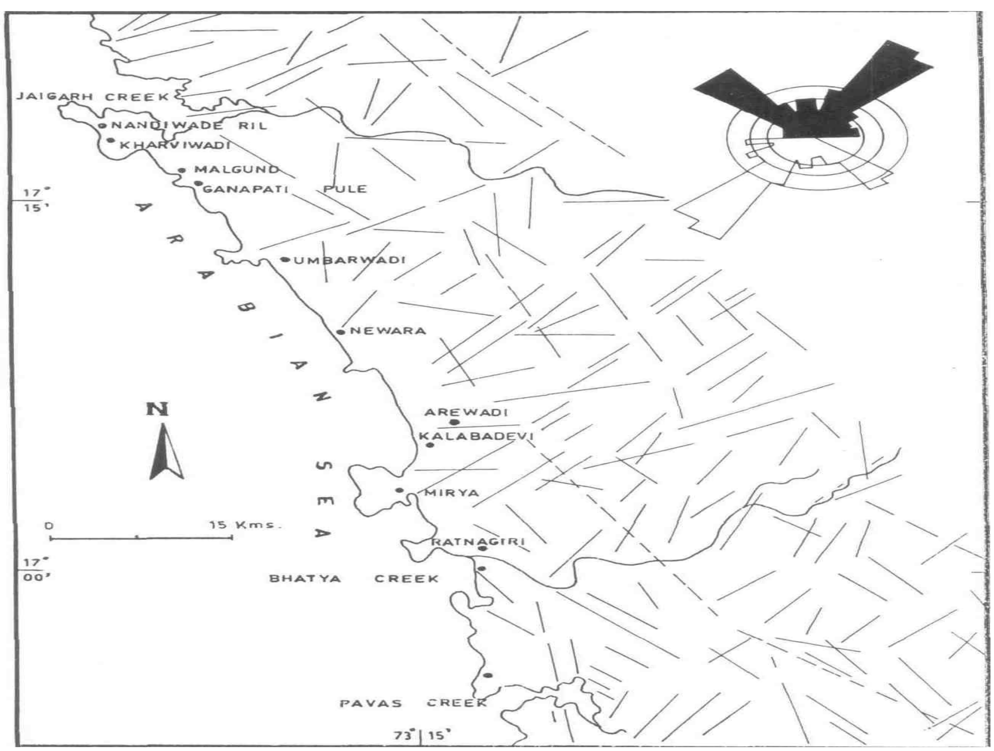

Figure-4
Lineament map based on Landsat 1 imageries of the area between Pavas and Jaigarh creek

Table-2
Data for lineaments observed on the topographic maps

Azimuth Range	N	N %	L	L %
0- 10	58	5.41	41.98	5.03
11-20	72	6.71	57.64	6.91
21- 30	75	6.99	58.57	7.02
31- 40	75	6.99	58.91	7.06
41- 50	79	7.36	62.72	7.51
51- 60	71	6.62	56.88	6.81
61- 70	71	6.62	60.35	7.23
71- 80	65	6.06	50.79	6.08
81- 90	63	5.87	51.46	6.17
271-280	42	3.91	35.89	4.3
281-290	38	3.54	28.86	3.46
291-300	29	2.7	23.19	2.78
301-310	60	5.59	48.25	5.78
311-320	68	6.34	51.04	6.11
321-330	55	5.13	36.39	4.36
331-340	44	4.1	30.89	3.7
341-350	64	5.96	49.18	5.89
351-360	44	4.1	31.65	3.79
Total	1073	100	834.64	99.99

Where, N: Number L; Length in kms

Table-3
Data for lineaments observed on the satellite imagery

Azimuth Range	N	N %	L	L %
0-10	7	5.15	5.58	4.56
11-20	5	3.68	4.31	3.52
21-30	10	7.35	8.8	7.19
31-40	22	16.18	20.4	16.66
41-50	20	14.71	19.21	15.69
51-60	6	4.41	6.01	4.91
61-70	5	3.68	6.94	5.67
71-80	3	2.21	4.06	3.32
81-90	6	4.41	5.92	4.84
271-280	1	0.74	0.93	0.76
281-290	2	1.47	1.94	1.59
291-300	1	0.74	0.93	0.76
301-310	2	1.47	1.6	1.37
311-320	16	11.76	11.25	9.19
321-330	16	11.76	11.25	9.61
331-340	6	4.41	5.24	4.28
341-350	4	2.94	3.2.1	2.63
351-360	4	2.94	4.31	3.52
Total	136	100.01	122.48	100.07

Where, N: Number L; Length in kms

Table-4
Data for lineaments observed on the satellite Imagery and topographic maps

Azimuth Range	N	N %	L	L %
0-10	65	5.28	47.56	4.79
11-20	77	5.19	61.95	5.21
21-30	85	7.17	67.37	7.1
31-40	97	11.58	79.31	11.88
41-50	99	11.03	81.93	11.6
51-60	77	5.51	62.89	5.86
61-70	76	5.15	67.29	6.45
71-80	69	4.13	54.85	4.7
81-90	69	5.14	57.38	5.5
271-280	43	2.32	36.82	2.53
281-290	40	2.5	30.8	2.52
291-300	30	1.72	24.12	1.77
301-310	62	3.53	49.85	3.57
311-320	84	9.05	62.29	7.65
321-330	71	8.44	47.64	6.98
331-340	50	4.25	36.13	3.99
341-350	68	4.45	52.39	4.26
351-360	48	3.52	35.96	3.65
Total	1210	99.96	956.53	100.01

Where, N: Number; L: Length in kms.

Drainage Analysis: In order to know the drainage characteristics and to have a set of systematic measures, various parameters have been considered and computed for the area under studies. These parameters have been used to know the terrain texture of the area.

Major rivers present in the area are Kajavi and Shastri along with few tributaries. These are originated in the eastern part of the area and flow in the western direction. River Kajavi takes a turn at 73^0 25' from NE - SW direction and takes a 'U' turn and bends at 73^0 22' from SE to NW direction ultimately joining the sea. Nearly similar trend has been followed by Shastri river, which takes 'U' turn at 73^0 20' and 17^0 14' and flow towards north and then turns to west and then joining the sea. It is observed that the drainage pattern in the eastern part is dendritic, which gradually gives way to sub-parallel type in the western part of the area. It has also been observed that in the western part of the area, Stream network decreases gradually from East to West. The sub-parallel drainage pattern of many streams having their sharp and active meanders at places might be due to the deep seated lineaments. The rivers/streams in the area predominantly reflect two slope zones i.e. from NE to SW and SE to NW directions. As stated earlier in the lineament analysis, the river courses have been controlled by the trends of the lineament.

On the basis of the stream flow characters, the drainage basins are classified in to exorheic, endorheic and archeic types. The area studied reveals the drainage basins to be of exorheic type because many basins debouch directly in to the sea. The river valleys from the area are generally short and are ranging from 6 to 30 Km. in length. These rivers have generally steep valleys and are narrow in their upper- reaches. The dissection of the area is carried out by the streams. Study of the stream pattern therefore, in terms of the drainage reveals the extent to which dissection of the topography has taken place.

Bifurcation Ratio: The bifurcation ratio explains branching probability in a particular region. It depends mainly on different geological and environmental factors. It is the common observation that unless there is a strong geological control prevalent in the region, bifurcation ratio does not show any significant variation. Bifurcation ratio is the ratio of number of steams of any given order to the number of streams in the next lower order[6].

Bifurcation ratio for the basin of the fifth order within the area has been determined and is presented in table-5. It can be seen that first and second order basins show the identical values whereas; third and fourth order basins show more or less similar value of bifurcation ratio. In the basin first, the values of bifurcation ratio is 4.68 whereas, in the second order basin bifurcation value is 4 .53, which shows that there is slight decrease in the values. The bifurcation ratio is decreased in basin No III, it is 3.06 and again there is a slight increase in the ratio i.e. 3.20. As regards to the basin No. IV, there is a decrease in the value of bifurcation ratio from first to third order and again there is slight increase in the values of the bifurcation ratio for the higher order basin.

The value of the bifurcation ratio for the higher order stream segments are less than those for the lower order stream segments, indicating that branching probability is less for the higher order stream segments. The ratio for the higher order basins is low, indicating strong geological control in their development. The value of the bifurcation ratio lies between 3 and 5, indicate the homogeneity in geological characters of the area. Decrease in the values of the bifurcation ratio for higher order stream segments appear to be due to the development of drainage on the Quaternary sediments i.e. on the tidal flat region.

Stream Length: Study of the stream length with respect to the stream order is of significant importance. Stream length for the basin of the given order is inversely proportional to the stream order[7]. Plot on the double log paper of total stream length of each order Vs the stream order results in a straight line indicate that the relation between the two is a power function.

In the present studies, plots of the logarithm of total stream length for each order against logarithm of the stream order have been made for the basins of the total area. The stream length analysis of these basins has been carried out by following the method suggested by Horton [6.] Accordingly separate graph has been prepared and depicted in Fig. 5. The plots yield a regression which is not a straight line but curved line convex upwards. Increase in the slope of the line with increase in the stream order suggests that the length of higher order streams are greater than what should normally be expected. This could be due to the head-ward erosion of higher order streams which has been guided by the structurally weaker zones.

Drainage Density: It is a linear scale measurement of a basin. With the help of the drainage density, texture of topography can be explained; frequency of the change in the ups and downs of the landscape can also be expressed. Texture can be expressed by the relative closeness of the drainage network.

Ratio of sum of the channel length to the basin area gives the drainage density[8]. Drainage density has been calculated for second and higher order basins. It has been presented in table-6. It can be seen that the values of the higher order basins are low compared to the lower order basins. The lower values of the drainage density for the higher order basins might be due to the streams flowing in more or less low elevated area. Average values of the drainage density for fourth order basin is slightly higher; it is probably because of the basins originating relatively at higher elevations, ultimately joining the sea.

Constant of Channel Maintenance: It is the inverse of the drainage density[9]. The constant of channel maintenance has been calculated from the values of the drainage density. The values obtained are presented in table-6. It can be seen from this table that the constant of channel maintenance is same for second and third order basin, it is 0-05 and for fourth order basin, it is 0.24, while 0.18 for fifth order basin. From the observations made earlier regarding second and third order basins, it appears that the geomorphological evolution of these two basins is more or less identical and therefore the degree of dissection of topography is also same.

It has been observed that, there appears to be no strong geological control in the geomorphic evolution of these basins. Study of the stream length with respect to the stream order indicates that the head-ward erosion of the higher order streams have probably been guided by the structurally weaker zones.

Hypsometric Analysis: In order to evaluate the amount of dissection brought about by the fluvial processes, the area-altitude analysis i.e. hypsometric analysis has been carried out by following the method suggested by Strahler[8]. It is the study of the distribution of the horizontal cross-sectional area of the landmass with respect to elevation. This is represented graphically with respect to elevation, by plotting cross sectional area of the basin under investigation the respective elevation. This plot results in the form of a smooth curve. The percentage hypsometric method has been used to estimate the amount of dissection that the individual drainage basin has undergone[8]. In the hypsometric analysis two ratios are involved, viz., a. Ratio of the area between a contour and the upper perimeter to total drainage basin area and b. Ratio of the highest contour above the base to the total height of the basin.

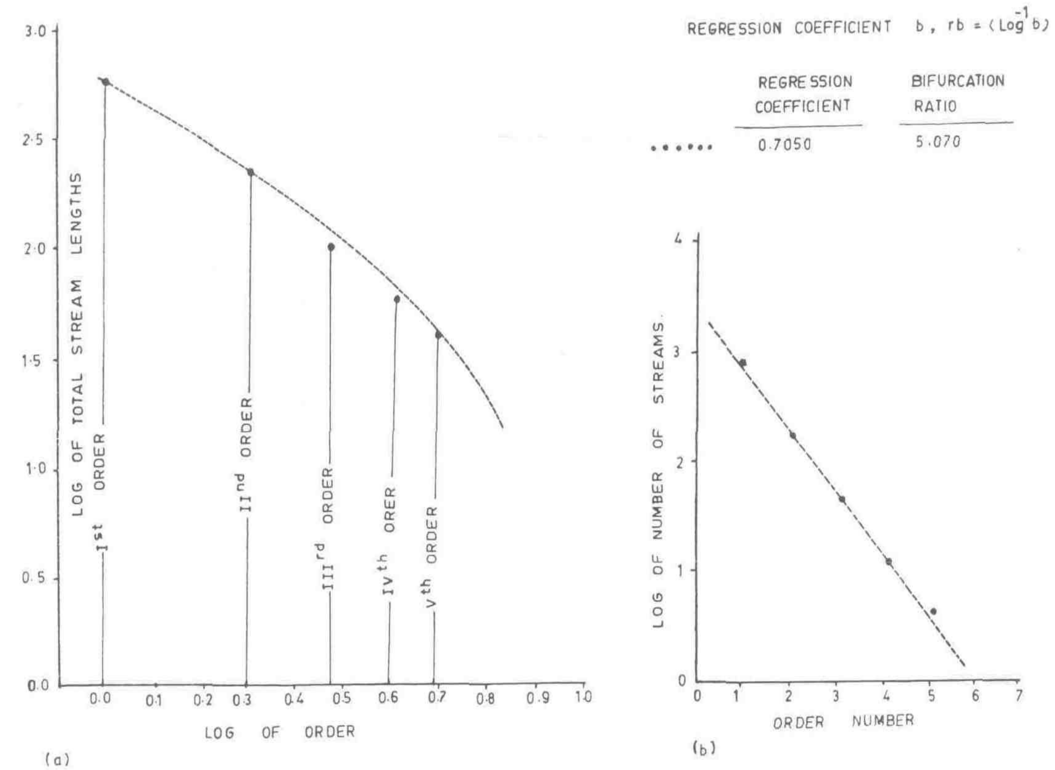

Figure 5
a) Regression of total stream length to stream order of the area b) Regression of total stream segment to stream order of the area

Table-5
Bifurcation ratios and length ratios for streams of the area

Order	Number of Streams	Bifurcation ratios	Length of stream	Length ratio (Ln / Ln+1)
1	1038	4.65	939.86	2.4
2	222	4.44	390.1	2.4
3	49	2.88	161.64	1.56
4	16	2.67	102.91	1.31
5	5		77.72	
Total/Average	1330	3.66	1672.23	1.92

Table-6
Drainage density and constant of channel maintenance for basins of second to fifth orders of the area

Order of basin	Total area (Km2)	Total length (kms)	Drainage density	Constant channel
Second order	78.76	940.95	20.22	0.05
Third order	54.83	604.07	18.61	0.05
Fourth order	265.41	655.68	20.23	0.24
Fifth order	270.28	901.06	6.64	0.18
Total/ Average	669.28	3101.76	16.425	0.52

Hypsometric Analysis: In order to evaluate the amount of dissection brought about by the fluvial processes, the area-altitude

While plotting, the first ratio is represented on an abscissa and second on an ordinate. The resulting curve is termed as the percentage hypsometric curve. The curves for the basin of second, third, fourth and fifth orders have been prepared and presented in figure-6.

The basins near Golap and Ratnagiri were selected for the hypsometric analysis. The curves are drawn for these basins to obtain their hypsometric integrals. It is seen that the values, which are below 0.35 for higher order basin indicate Monadnock stage of their development. The values above 0.35 for the third and fourth order basin indicate a youth stage of development of these streams.

Altimetric Analysis: The preliminary investigations carried out in the field indicate few planar surfaces present in the area (figure-7). In order to prove their presence, altimetric analysis has been carried out following the procedure suggested by Vaidyanadhan [10]. From these studies it is evident that the lower most planar surface is at 15m amsl, coincides with the mud-flats consolidated and unconsolidated Quaternary sediments over which the coconut, causurina and mangrove swamp are observed.

The second planar surface is at 80-100m amsl coinciding with the laterite and in subordinate amounts of bauxite, within which the Tertiary sediments are sandwiched. At places, they are below laterites with basalt at the base.

The altimetric analysis of the area under investigation reveals that there are five planar surfaces recorded at 0-15, 80 -100, 170-180, 260-265m and over 265m amsl figure-7.

The altimetric analysis of the area under investigation reveals that the area generally slopes from NE to SW, NW to SE and SE to NW directions.

Conclusion

Lineament analysis with the help of topographic sheets and satellite imageries can bring out a comprehensive picture of the area. It is observed that rose from topographic maps do not reveal any clear picture about the structural characters possibly due to the inclusion of linear stream segments of the lower order, which are not necessarily structurally controlled.

The rose of lineament pattern from satellite imageries more or less correspond with the maxima and sub maxima, obtained from topographic maps, thereby suggesting the direction of major structural weakness. Satellite imagery reveals that major streams like Kajavi have been controlled by NW - SE lineament, while river Shastri has been controlled by NE - SW lineament. The fracture pattern N 50^0 E direction can be said to represent the conjugate pair of shear fractures. Thus, the lineament analysis of the area matches closely with the regional structural trends of the area studied.

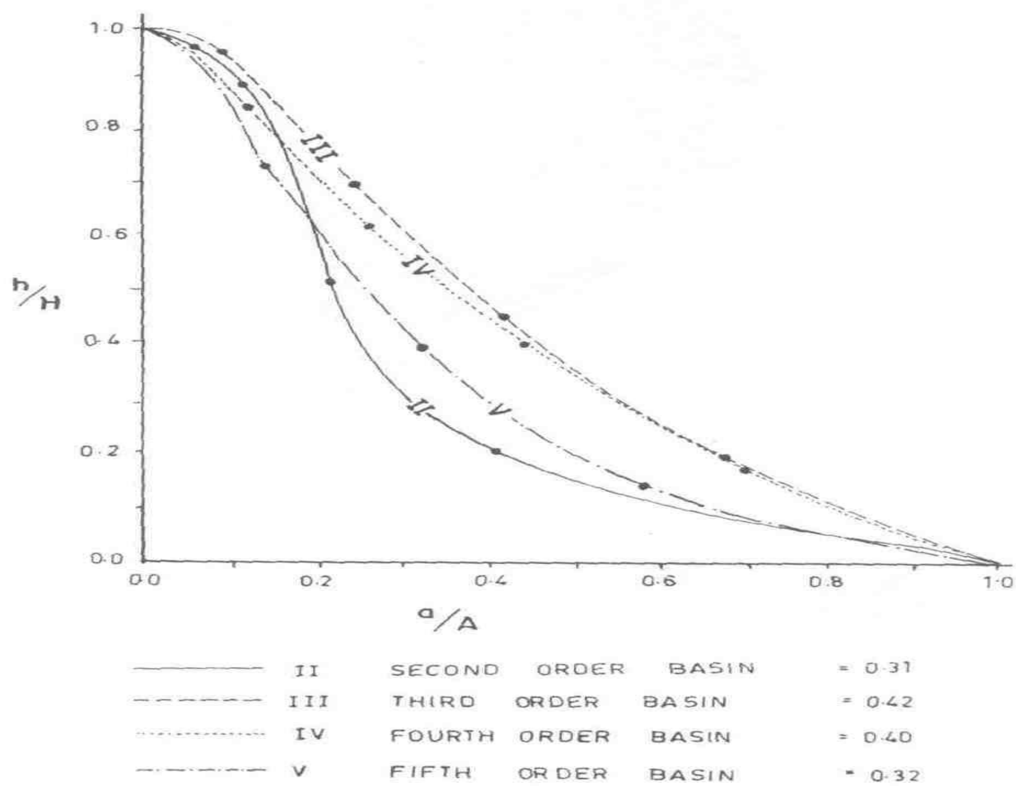

Figure-6
Hypsometric curves for representative basin of the study area

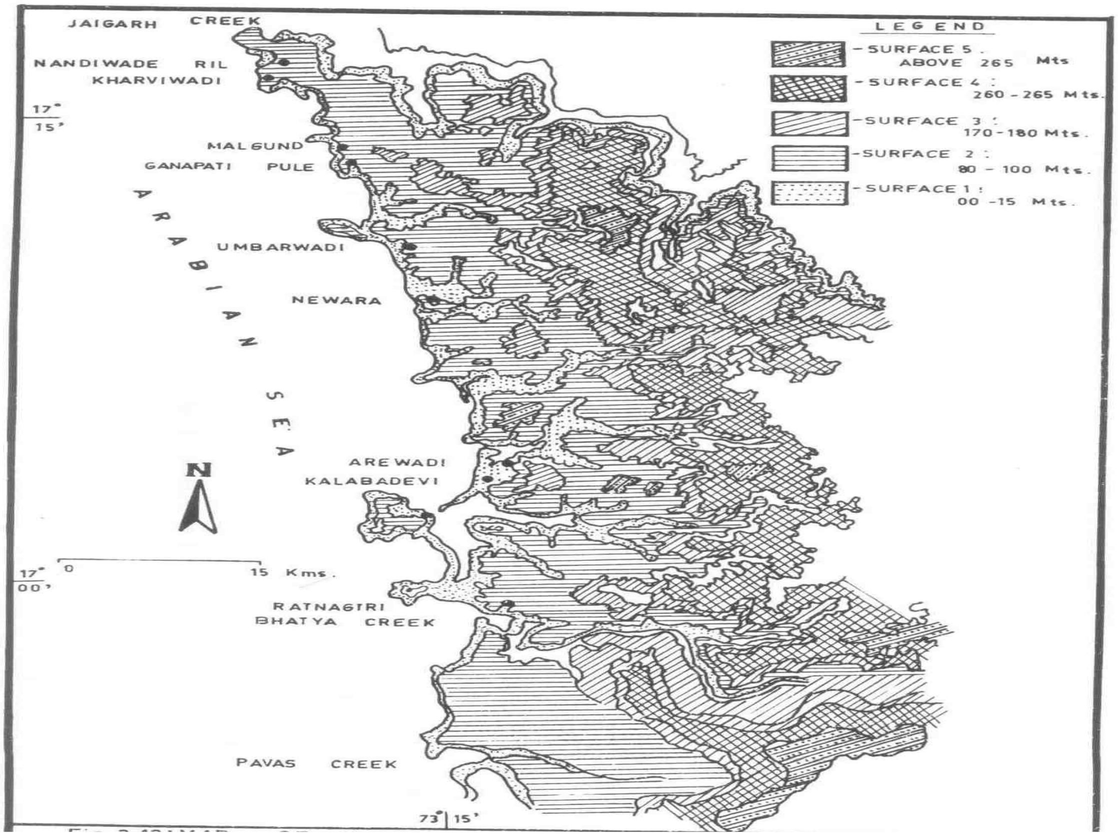

Figure-7
Showing planer surface of the area under study

To understand the drainage characteristics and to get the systematic measures for the drainage basin, different morphometric parameters have been calculated. These parameters help to know the terrain texture. The different dimensionless parameters from the drainage analysis also suggest the evolutionary changes which have taken place because of the various geological agents in a particular area.

From the values of the bifurcation ratio, it is evident that there appears to be no strong geologic control in the development of the drainage, but more or less similar values of the bifurcation ratio suggest that this could be mainly due to the homogeneous nature of the lithology of the area under study. It has been observed that, wherever the drainage is developed on the low lying areas, constituting the Quaternary sediments there is a decrease in the values of the bifurcation ratio, particularly for the higher order streams. The graph of logarithm of stream order indicates that the head-ward erosion of higher order streams has been guided by structurally weaker zones. Stream length analysis of the basins shows that the length of the higher order stream is greater than what should normally be expected, suggesting there by that it is due to the head-ward erosion of the higher order streams. The lower values of the drainage density indicate that the stream has reached more or less elevated area, while slightly higher values of the drainage density are due to higher elevation of the basin.

Considering the values of the constant of channel maintenance it is inferred that second and third order basin has identical values, having similar topography and effect of the degree of dissection. From these values, it can be concluded that there is no strong geological control in the geomorphic evolution. However, the stream lengths values indicate that the head-ward erosion of the higher order streams probably have been guided by structurally weaker zones.

From the hypsometric values it is inferred that the higher order streams show Monadnock phase, whereas, the hypsometric values indicate maturity stage. It can be said that the area under investigation indicates Monadnock phase of aeration which represents the residual hills. From the altimetric analysis, it is observed that in general, the area slopes from NE to SW, NW to SE and SE to NW directions. From the altitude percent frequency, the entire area falls under the category of moderately high relief.

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