River capture/piracy investigations of Panhale and Indavati tributaries of Machkundi River.

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ABSTRACT

River piracy is the diversion of headwaters of one stream to another one. The instance of river piracy causes changes in water routes and sediments and effects on landscape evolution. Stream piracy occurs for several reasons. Two of such reasons in the tectonically active regions are 1) fault induced tectonic movement and 2) Active headward erosion in the upstream direction to capture another higher stream. In this study, the Panhale stream has captured the water of the Indavati stream is documented. The Digital Elevation Model of the study region is used to extract the drainages. The occurrence of river piracy was due to the fore tilting of the hanging wall of the listric fault system and subsequent headward erosion of the stream.

KEYWORDS: River piracy; lineaments; morphotectonic; Konkan Coastal Belt (KCB)

1. INTRODUCTION:

The river piracy, frequently found in the tectonically disturbed areas, diversion of headwaters of one stream (diverter of predatory) into another (captor) with higher kinetic energy and gradient. This phenomenon has capacity to rearrange the drainage network and change in the topography. The footprints of river capture remain on drainage network and topography till it attain equilibrium between rate of erosion and tectonism. Tectonic Geomorphologists often view streams as the transient response of tectonic activities. However, streams are susceptible to tectonic disturbances, which reflect in their structural, fluvial and morphotectonic parameters. Analysis of active tectonics depends upon morphometric parameters, which are sensitive to rock resistance, climatic change, and tectonic processes resulting in landscape evolution. The quantification of morphotectonic parameters gave first-hand information on the tectonic history of the area of drainage evolution. Digital Terrain Modelling and Geographic Information System (GIS) have become essential tools for various surface and sub-surface studies in earth sciences. The GIS platform helps to morphotectonic parameters for terrain analysis. The DEM and GIS-based hydrological modelling are helpful to delineate drainage networks and watersheds to understand the tectonic setting of the study area.

The continental scale geomorphic features occurs along the passive western margin of the India are, 1) low lying Konkan Coastal belt (KCB), 2) The Western Ghat scarp (Sahyadri mountain) and 3) the Deccan Plateau at east. At present, The Western Ghat scarp (WGS) acts as a drainage divide between western flowing rivers through KCB and Eastern flowing rivers overs Deccan Plateau. During the retreat of Western Ghat Scarp (WGS) many easterly flowing rivers were caprured at the drainage divide by the westerly flowing rivers as a adjustment in tectonic setting. In this paper, the phenomenon of river capture occurred in the low lying KCB region is documented to prove the region is still actively engaged in the tectonic activities.

1.1 The study area:

The watershed of Machkundi River is selected from the KCB around Lanja town, District Ratnagiri, in the State of Maharashtra for drainage analysis studies. The study area exposes Poladpur and Ambenali formations. (68+0.6, 65+0.7 Ma respectively) South-western part of the Deccan Volcanic Province (DVP) is represented by massive and amygdaloidal basaltic flows. At some places these basaltic flows are overlain by laterite capping (duricrust).

The KCB is coastal low-land forming narrow and elongated strip of land whose average width is about 40 km. The KCB is bounded by coastline to its west and Ghat escarpment to its east. The E-W offsets have become the site of confluence of major rivers flowing down from the Western Ghats. (Fig. 1) The KCB exhibits different drainage characteristics and landforms as a result of episodic cymatogenic uplift particularly during the quaternary. (Powar, 1981) Drainage pattern is dendritic, angular, trellis and barbed type suggesting structural control. The area is traversed by several east-west trending ridges and west flowing rivers and their tributaries with steep to moderate gradients. The most common geomorphic features recognized are raised beaches, stabilized dunes, mud flats, drowned valleys, estuaries, laterite platforms, weathered hills, hilly interfluves, cliffs, etc. Studies also indicate the presence of submergent and emergent coast formed due to sea level changes and tectonic movements. (Dikshit and Patil 2012) Summer and rainy are two major seasons and hence weather is hot and humid. It receives 2000 to 3000 mm rainfall per year. Most of this belt is under forest and soil cover of varying density and thickness respectively. The study area is enclosed between long $73^0 15'$E and $73^0 50'$E and lat $16^0 40'$N and $17^0 00'$N

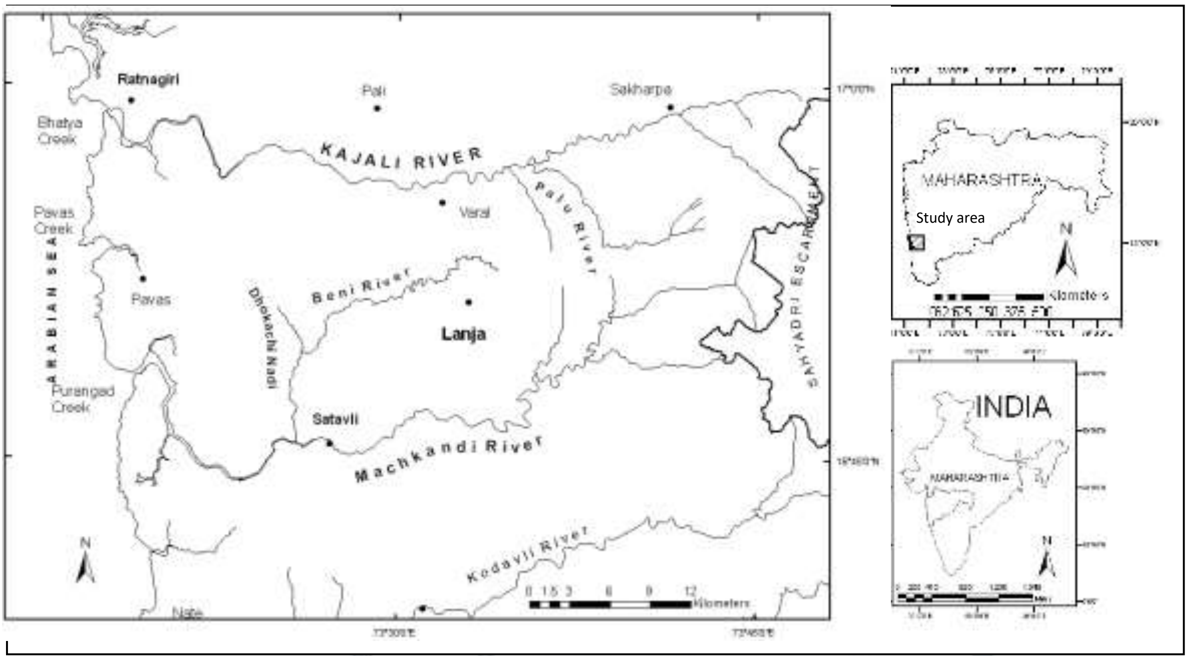

Figure1: Location map of the study area.

1.2 Data Used:

The Space Shuttle Radar Topography Mission (SRTM) gap filled data of the world at 90m horizontal resolution and made available through the Consortium for Spatial Information (CSI) web portal (http://srtm.csi.cgiar.org/).

The Survey of India (SOI) toposheets (Nos. 17H/5, 6, 9 and 10) of 1:50,000 scale were also used for digitization to check accuracy of extracted drainage network from DEMs.

Ground Control Points (GCPs) are mapped with the help of GPS points taken in the field and used for pre-processing of DEM. Extensive fieldwork was carried out to selective localities showing morphologic signatures of tectonic activities.

2. METHODOLOGY

The SRTM DEM (Version 2.1) was downloaded through the Seamless Data Distribution System (SDDS) at 90m resolutions for the study areas. Version 2.1 is a recalculation of the SRTM3 (nominal 90m sample spacing) version made by 3x3 averaging of the full resolution edited data.

2.1 DEM pre-processing:

The downloaded SRTM DEMs was mosaiced in the ARC GIS 9.2 environment.

During the data finishing process (Keeratikasikorn and Trisirisatayawong, 2008) the following tasks were implemented:

a. Spikes and wells in the data were detected and voided out if they exceeded 100 meters compared to surrounding elevations.
b. Small voids (16 contiguous posts or less) were filled by interpolation of surrounding elevations. Large voids were left in the data.
c. Water bodies were edited. The ocean elevation was set to 0 meter and were flattened and set to a constant height.

The original data set of 90m resolution was then converted into 30m resolution using bicubic polynomial interpolation technique. (Keeratikasikorn and Trisirisatayawong, 2008) The resolution conversion was achieved by using ARC GIS 9.2. The higher resolution SRTM DEM helped to delineate micro topographic features and to extract lowest order streams correctly. The SRTM DEM was further orthorectified with the help of resampling technique using ERDAS imagine. The GPS points plotted in the field were mapped and overlayed on SRTM DEM in ARC GIS software. The mapped GPS points were used as GCP (Ground Control Points) for resampling. The orthorectification of the DEM was achieved by using polynomial method in ERDAS software. This process improves correctness in spatial correlation of each pixel in DEM.

Digital drainage network extraction and analysis has been carried out using DEM. Digital data (SRTM DEM) and non-digital data (1:50,000 scale topographic maps) were used to extract channel networks. An extraction of the channel network from digital data was carried out in the ArcGIS 9.3 environment using TauDEM (Terrain Analysis Using Digital Elevation Model) module. Freely available on website -http://www.engineering.usu.edu/dtarb/taudem/. TauDEM module incorporates the DEM analysis tools and functions developed by Tarboton (1997), for hydrologic digital model analysis and drainage basin delineation. An automated delineation using TauDEM is more sophisticated, convenient, and can circumvent the efforts on digitizing to incorporate with other GIS data. It extracts the highest resolution channel network statistically consistent with geomorphological laws by using the smallest weighted support area threshold calculated from the constant drop analysis (Dikshit and Patil, 2012). In the TauDEM, grid digital elevation model data have been used. Grid DEM is distinct from other DEM representations such as Triangular Irregular Network (TIN) and contour-based data storage structures (Tarboton and Ames, 2001). Figure 2. represents the flow chart of the processing of DEM and automated extraction of the drainage network. The extracted drainage network and watersheds of Kajali, Machkundi, Kodavli and Vaghotan Rivers were overlayed on geocoded and orthorectified scanned toposheets for comparison. The drainage network (Fig. 3) derived using TauDEM shows good agreement with the drainage network and basins in toposheets.

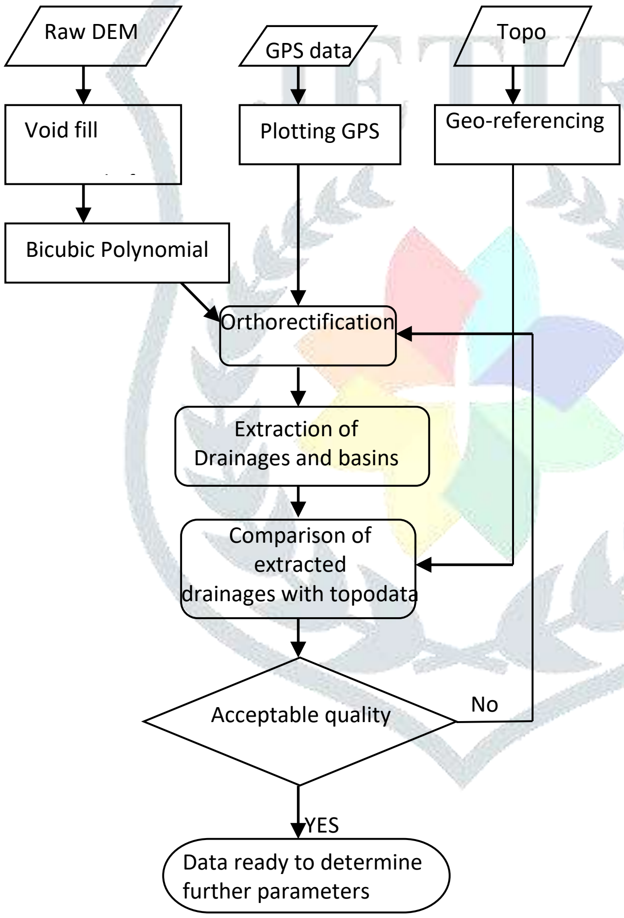

Fig. 2: Flow chart of DEM quality improvement and automated drainage extraction

3. RESULTS AND DISCUSSION

The digital drainage map (Fig. 3) exhibits, major rivers flowing to the west. Their watershed boundaries (ridges) are also oriented in E-W direction. The rose diagram reveals flow directions of drainages of all orders. The other flow directions of streams are N.E. ↔S.W., S.W. ↔N.E. and N↔S. The common drainage pattern in the study area is dendritic to sub-dendritic. The area also exhibits local abnormal drainage characters such as; sharp bends, straight channels, asymmetrical as well as trellis drainage patterns and stream reversal in the inter-basin areas of Kajali and Machkundi rivers indicating structural control. Channels of Palu, Agav-Mandavkar streams are controlled by N-S curvilinear lineaments indicating complex structure. Upstream segment of Kajali, Salpe and Aruna are controlled by ENE-WSW lineaments. Sakharpa segment of Kajali river, Panhale and Vilavade stream tributaries of Machkundi river and Sukh tributary of Vaghotan river are controlled by NW-SE trending lineaments. Although, all major rivers are westerly flowing (WSW), their channels in the coastal plateaux gradually reoriented from WSW to north before they join the Arabian Sea indicate structural control. Similarly, Kajali river, Panhale and Vilavade streams have sharp bends indicating structural control. Similarly, the 1st and

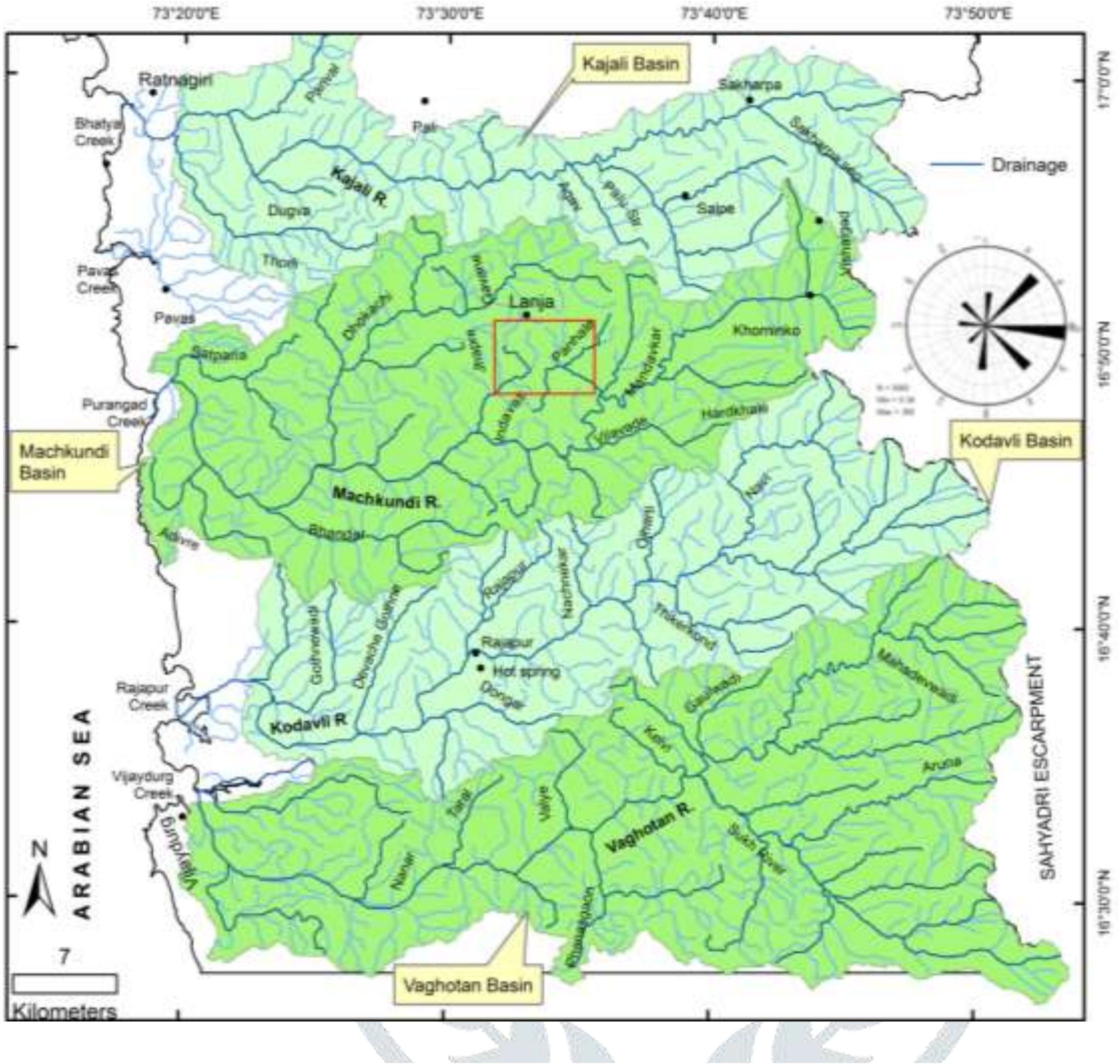

Fig. 3: Major river basins and their watershed boundaries and drainage network for the study area defined by digital drainage extraction using TauDEM module. To reduce ramification, streams of 1st and 2nd order are not shown. Inset shows rose diagram for azimuth of all vectorized channel segments. The area within red square shows streams piracy by Panhale and Indavati streams shown in Figure 4.

2nd order tributary streams and upper reaches of Adivre stream, near coast between Purangad and Rajapur Creeks, flows from west to east and are resequent. These resequent streams are the result of uplift and eastward tilt of the coastal plateau region. The drainage networks of Panhale and Indavati streams are suggestive of river capture (Fig. 3 and 4). Panhale and Indavati are the tributaries of the Machkundi River. The location of the confluence point of Panhale and Machkundi river is on L1 (Agav) lineament. The other tributary streams those have joined the segment of Mandavkar stream controlled by lineament, are very smaller in the basin area, length and order than the Panhale stream. These characters reveal the abnormality of Panhale stream. Similarly, its tributaries have 90^0 sharp bends. Thus the tributary segments of Panhale show abnormal relationship and unfit character, which otherwise, should show concordant relationship to Indavati stream with respect to orientation, length, basin area etc. Thus, the abnormal stream characters of Panhale indicate that its tributary segments were once part of Indavati and its water has been diverted by pirating Indavati's stream segment.

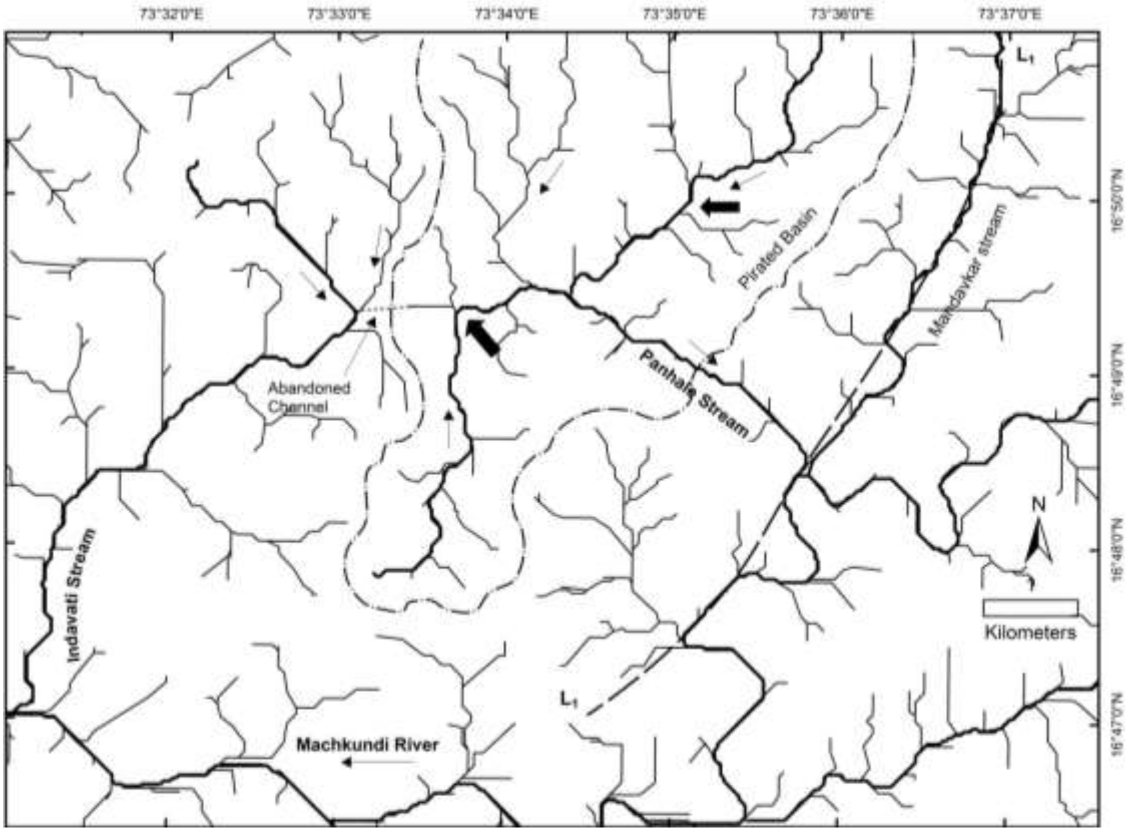

Fig. 4: The drainage of upper reach of Indavati stream has been captured and diverted by Panhale stream. Black solid arrows show sharp elbows in Panhale stream. L-L_1: Lineament controlling Agav-Mandavkar streams.

The major rivers are meandering mostly in their upper reaches (Fig. 3). A segment of Machkundi river between Mandavkar and Vilavde streams exhibits meandering because of their control revealing weak zone. This tectonic control, diversion of Indavati stream described earlier and meandering are the result of westward tilting along major lineaments. According to Adam, 1980 and Reid, 1992, river is highly sensitive to changes in gradient and it is reflected in Phuphere stream. Rivers may respond to changes in gradient by adjusting their channels form, evolving from straight to meandering. This is reflected in the meandering channels of Kodavli and northern Vaghotan rivers when they are crossing lineaments and debouches from high to low relief. This difference in channel morphology suggests lineament control.

4. CONCLUSION

The fore tilting in the hanging wall of fault is responsible for drainage reversals and drainage capture by Panhale stream. According to Doornkamp (1986), the drainage network is mimicking the tectonic framework and the streams are adjusted to tilting as a result of the active tectonic of normal fault. The abnormal drainage network recognized in this study are sharp bends, trellis, asymmetrical, parallel drainage patterns and diversion of upstream segments of Indavati by Panhale as a result of fore tilting due to listric normal fault (Dikshit, 2014). According to Morisawa and Hack (1985) back tilting is responsible for drainage reversals. Thus the present landscape is the result of interplay between tectonic activity and fluvial response to it.

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