ENVIRONMENTAL AND MORPHOMETRIC STUDIES TO KNOW TECTONIC EVOLUTION OF THE AREA BETWEEN JAIGARH CREEK AND DABHOL CREEK, RATNAGIRI DIST. MAHARASHTRA

A

Final Project Report

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1. Introduction :

The Konkan Coast of Maharashtra has a coastline of about 720 Km as its Western boundary (Lat.15 ^{0} 43'N & 20 ^{0} 10'N and Long. 72 ^{0} 40' E & 73 ^{0} 45'E). It has always attracted the attention of the Geo-scientists due to neo-tectonic activities, environmental and ecological degradation, varied geomorphology, landslide hazards etc. The Konkan coastal belt (KCB) is drained by 18 major and 36 small rivers. Several workers have carried work on different geological aspects.

The geomorphic studies of Konkan Coastal Belt (KCB) of Maharashtra with respect tectonism, erosional and depositional features have been carried by Wynne (1866), Ahmed (1972), Sawant P. T.(1980), Dikshit V. M.(1993). Auden(1975).Sukhtankar et.al. (1989) have investigated Quaternary sediments in relation to geomorphology and tectonics and stated possible neotectonic activity to the south of Ratnagiri Coast in the development of the coastal geomorphology. Morphotectonic evolution of the west coast of Maharashtra under the influence of tectonism has been carried by Powar et.al. (1980), Tiwari (1984), Sukhtankar and Pandian (1990), Kundu (2001), Kale and Shejwalkar (2008) and Valdiya (2011). Sedimentological studies of Tertaries along the coast of Ratnagiri has been carried by Suryavanshi R A (1995). However, the attempts made by many workers were on regional scale. The present investigation has been carried with respect to environmental, morphotectonic studies on Shastri River Basin (SRB) of Ratnagiri dist., Maharashtra.

2. Area of Investigation :

The present research work is concentrated on Shastri River Basin (SRB), which lies between Lat. 17 ^{0} 05' N & 17 ^{0} 30' N and Long. 73 ^{0} 15' E & 73 ^{0} 45'E (Fig.1)

River Shastri originates near Prachitgad, on the crestline of the Western Ghats (17 ^{0} 27' N & 73 ^{0} 45' E) at an elevation of 839 msl. The SRB forms a part of survey of India topographic sheet nos. 47G/3, 4, 7, 8, 11, 12, 47H / 9 (1:50,000). The area falls entirely in the Ratnagiri district, covering three talukas viz. Sangmeshwar, Ratnagiri and Guhagar. The total length of

the Shastri River is about 72 Km, with first 20 Km in the hilly areas forming steep slope. The total basin area is about 2098 Km^2 The Bav, Asavi, Sonvi, Gad and Kapsi are tributeries of Shastri river.

3. Physiography, Climate and Vegetation :

The present area under study is coastal river basin (Shastri River Basin) which lies between Western Ghats to the East and the Arabian sea to its west . The physiography is typical for its irregular landscape, rugged and hilly nature intersected by Jaigad Creek (Shastri river). Number of flat topped hills are striking in N-S as well as E-W directions. The major part of the area is with undulatory topography and prominent plateau tops. Maximum elevation in the area investigated is at Prachigad in the Western Ghat, 839 m above MSL. The area can be divided physiographically in following parts from west to east.

i) A tidal, mud flat zones at the mouth along with plains covered by low altitude laterites.
ii) Steep rocky slopes encircling the plateau.
iii) Undulating hill ranges of Western Ghats.

The area is influenced by humid and tropical climate with heavy rainfall. The area received rainfall of 3549 mm (Average of last 10 years). Humidity ranges maximum up to 90%.

The grasslands atop the laterite hillocks and forest along the slopes are important in the maintenance of local ecological conditions. Mouth of the Shastri river appear to be rich in seaweeds. Mangroves found along the interface of land and water, especially along the inter-tidal zones of seacoast, creeks, estuaries. The climate is suitable for mango and cashew plantation.

4. Geology :

From detailed field studies and available literature, it is observed that the investigated area is characterized by presence of Deccan flood basalt of cretaceous age (65 ma) (Fig 2). Basalt belongs to Ambenali formation of the Wai subgroup (Mitchel and Widowson 1991). The study area shows general dip towards west. The massive horizontal flows of basalt are mainly

exposed along the valleys (Plate 1), valley sides at Prachitgad, Makhjan and along sea clifts near Jaigad. Vesicular and Amygdaloidal basalts are exposed at (Asore, Marleshwar). Highly jointed basalts with N-S, NW-SE trend are also exposed at Nivali, Kondivare(Plate 2). The basaltic formation is capped by laterites of primary and secondary origin. They are of late tertiary age. Laterite covers upto 70% of the total area. Rolled debris of laterites are observed along Jaigarh coast.

General stratigraphic succession observed in the present area can be given as

Alluvium	Quaternary
Consolidated and Unconsolidated sediments	Tertiary
Laterites	Plistocene
Deccan Basalt	Upper cretaceous to Miocene

5. Objectives :

The present investigation has been carried out on environmental, geomorphological and morphometric studies to know the tectonic evolution of the area between Jaigad and Dabhol creek of Ratnagiri dist., Maharashtra, especially on Shastri River Basin (Jaigarh Creek) and its tributaries.

Main Objectives of the proposed research work are –

1. To carry morphometric studies.
2. To identify Geomorphic features.
3. To carry lineament analysis.
4. To understand landscape evolution.

5. To demarcate landslide prone regions and to prepare landslide susceptible zonation map
6. To understand environmental degradation.

6 Methodology and Data Used

In view of above mentioned objectives, following methods have been adopted.

i) **Field Visits** :- Based on literature and preliminary maps, field studies have been carried in two stages –
   a) Preliminary survey and field observations were carried to locate different geomorphic features in the study area and to collect mud samples, rock samples for further studies.
   b) The second stage of field studies was carried out for confirmation of data. Some interesting and supporting facts come out in this work. The joint systems in the Deccan Basalt are located which coincide with the orientation of major lineaments (N-S and NW-SW). Landslide prone zones were also located.

ii) **DEM Data** :- The morphometric analysis of the SRB has been carried out with the help of the SOI topographic sheets (1:50,000) and Digital Elevated Model. The shuttle Rader Topography Mission (SRTM) obtained elevation data on a near global scale to generate high resolution (30m) digital topographic data base (DEM) (Fig 3) of SRB. The SRB was divided into 5 sub basins for morphometric analysis (Fig 4).

iii) **Remote Sensing Data** :- In present investigation the IRS- 1D LISS III Geocoded digital satellite images (path 95, row 60 & 61) were used to prepare thematic maps .

The satellite Images were processed by using ERDAS software. The work includes image processing (Geometric Correction, Enhancement) and Image interpretation.

iv) **GIS Studies**:- The GIS methodology was used (Arc GIS 9.3) for data processing and for preparation of various thematic maps .

7 Drainage Pattern :-

SRB is characterized by presence of mainly dentritic to sub dentritic drainage pattern.. However in sub basins like Kapsi, Gad, Bav parallel, sub parallel and trellis types of drainages observed (Fig.5).

8 Geomorphology and Tectonics :

The study area is dissected by Shastri river and its tributaries viz. Asavi, Bav, Gad, Kapsi and Sonvi. Various Geomorphic features were identified in the field. They can be classified under the fluvial and marine environments. These geomorphic features support tectonic activities in the area .The area is tectonically active represented by lineaments, blind faults (Powar K.B. 1978, Valdiya 2011). Lineament analysis of the entire basin was done with the help of DEM and remote sensing data (FCC bands) (RGB 532) (Fig. 6). The study indicated that the lineaments trending NW-SE and NE-SW are abundant in the area (Fig. 7) (Table 1). These conjugate shears resulted from compression on NS areas (Powar K B 1978). The most prominent lineament follows the trend of Kapsi tributary.

9 Morphometric Analysis :

Shastri River Basin (SRB) was divided into 5 sub basins and morphometric analysis was carried out at sub basin level in Arc view. The total drainage area of SRB is 2098 $Km.^2$ Based on drainage orders, SRB has been classified as 7 th order basin. Linear, relief and areal morphometric parameters were determined. Table 2, 3, 4 and 5.

9.1 Linear Aspects :-

The linear aspects such as stream order, stream numbers for various orders, bifurcation ratio, stream length, mean stream length and length ratio for Shastri river and its 5 tributaries were determined and described below.

9.1 a) Stream Number (Nu) :- It is obvious that the total number of streams decreases with increase in stream order. The number of streams of each order and their total number were computed (Table 2).

9.1 b) Stream Order (u) :- The streams of the Shastri river basin have been ranked according to the Horton's (1945) stream ordering system (Table 2). The stream characteristics confirm Horton's law of stream numbers, which states that the number of streams of different orders in a given drainage basin tends closely to approximate an inverse geometric ratio. It also confirms Hortons (1932) law of stream length i.e. the average stream length of each order in drainage basin tends closely to approximate a direct geometric ratio. The variations in order and size of SRB and tributary basins are due to geology, physiography and structural control of the region. The drainage network of the SRB is of the seventh order. Two sub-basins (1 and 5) are under fifth order; three sub-basins (2, 3 and 4) were identified under sixth order. First and second order streams are dominate in 2, 3 and 4 sub-basins occupied by hillocks.

9.1 c) Stream length (Lu) : The stream length for SRB and sub basins of various orders have been measured and shown in table . The maximum length of the total basin is 8710 Km and that of the five sub-basins are 129, 1359.7, 763.5, 1006.5, 192.5 Km for respectively (Table 2).

9.1. **d) Stream length Ratio (RL)** : The stream length ratio (RL) values are changing haphazardly in SRB as well as at sub-basin levels. The RL values vary from 0.23 to 1.92 for sub-basins while it varies from 0.32 to 0.95 for SRB. The differences in RL values are due to differences in slope; topographic conditions and erosional stage of the basin (Rakesh Kumar et.al. 2001, Sreedevi et.al. 2005) (Table 3).

9.1 e) Bifurcation Ratio (Rb) : It is the fundamental importance in drainage basin analysis as this parameter link the hydro-logical regime of a water shed under lithological and climatic conditions (Rachana et.al.1999) The Rb values for 1^{st} basin vary between 2.00 to 4.80; for 2^{nd} basin 2 to 7.14, for 3^{rd} basin 2.00 to 5.08, for 4^{th} basin 2.00 to 6.00 and for 5^{th} basin Rb values vary between 2.00 to 5.83. For entire Shastri river basin it is between 3.00 to 5.26. The mean bifurcation ratio varies between 3 to 5 indicating that the river flows through mountainous and highly dissected area (Horton 1945). The values of Rb for higher order stream segments are in general less than

those for lower order indicating strong geological control in their development and also suggest nature topography in the area of investigation (Table 3)

9.2 Areal Aspects :-

The basin area was computed by converting the basin map into polygon form. The total basin area of Shastri river is about 2098 Km^2. Following different areal morphometric aspects for SRB and its sub basins are determined (Table 4)

9.2 a) Drainage Density (Dd) :- The ratio of sum of channel length to the basin area gives drainage density (Dd) (Horton 1945). The values of Dd depend mainly on climate, geology (type of rocks), slope, relative relief (Strahter 1964). For entire SRB, the Dd is 4.15, indicating structurally controlled region with low permeable rocks and high humid terrain (Gardiner 1980). Dd values of sub basins are shown in Table 4.

The Dd values for sub basins 1 and 5 are low indicating highly resistant and permeable sub soil with dense vegetation cover and low relief. The Dd values of sub-basins 2, 3 and 4 are moderate indicating moderate relief with moderate vegetation cover.

9.2 b) Drainage Texture (T) :- This aspect (T) also depends upon climate, rainfall, vegetation, rock and soil types, relief and stage of development of channel (Smith, 1950). T is the product of Dd and Fs i.e.stream frequency. Value of T for SRB is 8.84, which comes under fine texture (Smith 1950) suggesting the presence of weak, unprotected rocks by vegetation. Value of T for sub-basin 1 & 5 comes under coarse texture suggesting resistant rocks with dense vegetation cover. The values of T for sub-basin 2, 3, 4 are moderate.

9.2 c) Stream Frequency (Fs) - Fs is defined as the number of streams per unit area (Horton 1945). For SRB, stream frequency is 2.13 Km/Km^2. The Fs values for sub-basin 1 & 5 are low and for sub-basin 2,3,4 are moderate. Fs depends again on litho logy of the basin and the texture of drainage network.

9.2 d) Elongation Ratio (Re) - Re is the ratio of diameter of a circle with same area of the drainage basin (A) and the basin length (L).The Re values for SRB and for sub basin 2, 3 ,4 & 5 are more than 0.5 suggesting moderate to strong relief and steep ground slope (Strahler 1964). Re for sub basin 1 is 1.00, suggests low relief and is susceptible for sediment load. The variations in the values of elongation ratio (Re) for SRB and its sub basins are due to guiding effect of lineaments, joints present in the basin.

9.2 e) Circularity Ratio (Rc) - It is the ratio of stream area and area of circle having same perimeter of the basin (Miller p.c., 1953). The Rc values for SRB and its sub-basins are more than 0.40 indicating dendritic drainage and mature stage of topography.

9.2 f) Form Factor (Rf)- Horton (1945) proposed this parameter to predict flow intensity of a basin. It is the ratio of the basin area to the square of the basin length. The values of Rf for SRB are shown in table 4.

9.2 g) Constant of Channel Maintenance (Ccum) - It is the inverse of the drainage density (Shumm 1956). The values of Ccum are calculated for SRB and its sub-basins.

It follows that sub basin 1 and 5 are 5^{th} order drainage basins having Ccm values nearly same i.e. 0.70. For SRB and other higher order sub basins (2, 3 and 4) the values are lower. It indicates that for lower order sub basins geomorphic evolution is same and degree of dissection of topography is also same. It also indicates that the head ward erosion of high order streams may be guided by structurally weaker zones.

9.2 h) Length of overland flow (Lg) - It is the measure of drainage texture. (Horton 1945). It is calculated by a formula

$$Lg = 1 / D \times 2$$

Where D = drainage density.

The values of Lg for SRB and its sub-basin are shown in Table 3. It follows that the tributaries (Basins 1 & 5) flowing in the alluvial zone have higher values of Lg than those tributaries (Basins 2, 3 & 4) flowing in upland

zone. It indicates that the intricate channel developed in upland zone needed less space to flow over the terrain before it gets concentrated in definite stream channel (Horton 1945)

Relief Aspects – Relief properties are three dimensional characters of any terrain which involve area, volume and attitude of landform. Following aspects of relief with respect of SRB and sub basins are determined (Table 5)

9.3 a) Basin relief (H) – It is an important factor in understanding the denudational characteristics of the basin. Basin relief is the maximum vertical distance between the lowest and the highest points of a basin. The maximum height of the SRB is 839 m and the lowest is 20 m; and hence basin relief is 819 m.

Basin relief for other sub-basins is shown in table 5. .

9.3 b) Relief Ratio (Re) - Relief ratio (Re) is the dimensionless property (schumm 1963), calculated by using formula

$$Re = \frac{\text{Relative relief (H-b)}}{\text{Longest axis (L) of River basin}}$$

The Re value for SRB is 0.011 which suggests that the basin has reached to maturity stage. The Re values for sub basin 1 & 5 are high indicating immature stage of basin and are characteristic of hill regions. The Re values for sub basin 2, 3 and 4 are low, indicatives of valley region or pediplains with mature stage.

9.3 c) Dissection Index (Di) - This morphometric parameter is used for complete Shastri River Basin (SRB) to understand the nature and magnitude of terrain dissection. It is the ratio between the relative relief and absolute relief of the basin. The areal distribution of Di Values show moderate to high dissection index.

9.3 d) Asymmetric Factor (AF) - Asymmetry of drainage basin can be described with reference to basin area on either sides of the stream channel. It is regarded due to river migration indicating structural control. AF is

calculated by using a formula F = 100 x (Ar x At), where Ar is the area of the basin to the right side of the stream channel and At is the total area of the drainage basin . AF values lower or more than 50 suggest tilt. If it is less than 50, it suggests that the tectonic rotation is perpendicular to the main channel and is towards right and vice versa. For SRB and sub basins 4 and 5 the values are more than 50 indicating asymmetry and tectonic rotation towards left. For sub basins 1, 2 and 3 the AF values are less than 50 indicating tectonic rotation towards right.

9.3 e) Slope - It is one of the basic element of the relief and is useful in describing landscape evolution. Slope is controlled by climate, morphogenic process along with rock formations. In the study area slope map is prepared based on SRTM data into slope grid using Arc view method. (Fig 8). In the SRB the slope varies from 0^{0} to > 35^{0}. (Table 6). A high degree of slope is noticed along Eastern part of basin promoting land siding. The SRB is characterized by “Moderate to steep slope”.

10 Sinuosity Index –

The calculation of sinuosity index is of great use in understanding the geomorphic characteristic of a region (schumm 1963). It is the ratio between average channel length and average direct length. The sinuosity index values for SRB and sub-basins are calculated. The values indicate sinuous nature of the streams.

11 Geomorphic features –

The investigated area shows variety of geomorphic features based on detailed field studies. They are useful to understand landscape evolution. Geomorphic features can be classified under two environmental conditions – the fluvial and marine. The identified landforms are presented in table 7.

11.1 A) Features Due to Fluvial Erosion

a) **Planar surfaces** – The presence of five planar surfaces (Plate 3) i.e. prominent plateau tops were observed by constructing topographic profiles on SOI topographic sheets. It is confirmed in the field by

altimetric analysis using GPS. These planer surfaces are recorded at 0-15m, 100-110m, 170-180m, 260-270m, 580-620 m above MSL.

b) Hills and Escarpments – The flat topped hills are oriented in NNW-SSE and NE-SW directions. The valleys are oriented in E-W, NW-SE and NE-SW directions. They are narrow and steep at upper reaches. Valleys are broad and 'U' shaped at the mouth of Shastri River and tributaries.

11.1B) Features Due to Fluvial Deposition

a) Alluvial Plains - They consist of gravel, sand, silt and are developed on either sides of Shastri river.

b) Fluvio-colluvial deposits - These consist of loose boulders of laterites and silt. They are found along the hill ranges near Bomnoli, Jaigarh.

c) River Terraces- This feature is observed along Shastri river and its tributaries at Sangmeshwar, Devrukh. River terraces have height of 2 mts to 6 mts with width upto 25 mts, made up of fine sand, silt.

11.2A Features Formed Due to Marine Erosion

a) Creeks- Shastri is the major creek present in the area trending in E-W direction (Plate 4), which follows the prominent lineament on topographic sheets and satellite imageries. Besides these, Kapsi (NW-SE), Gad (NE-SW), Bav E-W) are minor creeks present in the area. They also follow the lineaments.

b) Tidal Flats - These are extensively developed at Jaigarh constituted by consolidated and unconsolidated sediments and covered with thin veneer of mud.

c) Head land - It is present near Jaigarh along the coast representing resistant, hard, compact rocks.

11.2B Features Formed Due to Marine Deposition

a) Beach - Recent beach is observed near Jaigad ,Tavasal consisting of sand of variable size.

The presence of degradational features such as planar surfaces, hills and escarpments, valleys, creeks, headlands, tidal flats etc are characteristics of youthful submerged terrain reflecting imprints of neo-tectonic activity.

12 . Landslide Hazard Zonation :

The landslide hazard mitigation is concerned directly with landslide Hazard Zonation (LHZ) map. In preparing this map, synthesized and weighted data pertaining to geomorphology, lineaments, slope, lithology, rainfall have been used. The weightings were assigned to each terrain parameter to reflect its importance in the landslide occurrence, while the scores are assigned to the individual classes within each probability due to particular parameter.

The weight and score details are given in table 8.

By integrating the effects of various above said factors and also by considering rainfall, human interfere (tunneling, road excavation etc.), a landslide prone map is prepared (Fig 9). The entire area is delineated according to the landslide vulnerability into three classes i.e. low, Medium and High susceptible.

The map shows that the risk of high land sliding are incident mainly along structural hills, in the vicinity of NW-SE trending lineaments, steeply sloping terrain with lateritic soil (Plate 5).

13 Environmental Degradation :

The present area of investigation i.e. Shastri River Basin (SRB) belongs to Konkan which is bordered with Western Ghat mountain range (Sahyadri) to its East and is blessed with extreme natural beauty and highly biological diversity of both natural and agricultural. Shastri estuary houses two port projects, one Thermal plant and many coushing units. They important of them are -

1) Jindal group's 1200 MW coal based thermal plant.
2) M/s JSW Jaigarh Port Ltd (Jindal Group Company) – expected to handle 20 million tons of cargo / year.
3) M/S Chougule Port & Infrastructure Pvt. Ltd. – expected to handle 5 million tons of cargo / year.

   The dredging destroys the nutrients, mangroves, eggs and young fish and crustaceans. It releases variable pollutants in the water affecting richness of zoo and phytoplankton.

   Currently the Shastri estuary is supposed to be the most productive and bio-diverse part of the riverine system which is being dredged and destroyed (plate 6) and mangroves offering shelter to fishes and other aquatic animals are being uprooted for about 7-8 Kms to a depth of 15 mts in the creek.

   In addition, the TDS from local wells in the Jaigarh & adjoining area is found to reached upto 1450 mg/l after the began of JSW TPP since April 2010.

   It is expected to release about 18.3 tons of fly ash per day through TPP at Jaigarh.

Conclusions :

The present research work was carried mainly on Environmental, geomorphologic, morphometric studies of Shastri River Basin, Ratnagiri dist. Maharashtra.The important observations and conclusions are summarized in following discussion

a) Geologically SRB belongs to Deccan flood basalt of Ambenali formation of Wai subgroup (Cretaceous age - 65 my). The basalt is highly jointed at places having N-S, NW-SE trend. About 70% of the area is covered by lateritic capping.

b) The SRB has been classified as 7th order basin and is characterized by detritic, subdentritic drainage pattern indicating uniform litho logy. The presence of parallel, sub-parallel, treills type of drainages at places suggest structurally controlled basin.

c) Lineament analysis of entire SRB has been carried. It indicates that NW-SE, N-S and NE-SW trending lineaments are dominant. The river Shastri has been controlled by NE-SW lineament. In general it follows that the lineaments in the area follow the regional structural trends.

d) The length of Shastri river is about 72 Km and the area of SRB is 2098 Km^2. It constitutes five sub basins – Asavi, Bav, Gad, Kapsi and Sonvi. The morphometric analysis of entire SRB and all sub basins have been carried. It includes linear, areal and relief aspects. The stream length ratio (RL) values for SRB and sub-basins vary haphazardly, suggesting differences in slope, topographic conditions and erosional stage of basin. For SRB and sub-basins mean bifurcation ratio values vary between 3 to 5 indicating that the river flows through mountainous and highly dissected area. The Rb values for higher order stream segments are less than lower order. It suggests strong geological control and mature topography in the area of investigation.

   The drainage density value for SRB is 4.15, indicating structural controlled region, low permeable rocks and high humid terrain. The drainage texture (T) values for SRB is 8.84 which comes under fine texture depicting the presence of weak, unprotected rocks by vegetation. Elongation ratio (Re) value for SRB is more than 2.57, suggesting moderate to strong relief and steep ground slope. The variations in Re values for SRB and sub basins is due to guiding effect of lineaments and joints. The values of circularity ratio (RL) for SRB is more than 0.40 which indicate dendritic drainage, and mature topography. The values of constant of channel Maintenance (Ccm) for SRB and high order streams are low suggesting headword erosion of these streams may be guided by structurally weaker zones.

   The basin relief (H) for SRB is 819 mts. While relief ratio (Re) is 0.011 suggesting the maturity stage.

e) Slope analysis of SRB was carried using GIS studies. It follows that the values of slopes vary between 0^0 to > 35^0. A high degree slope is noticed along the structural hills promoting land sliding. SRB is characterized by moderate to steep slope.

f) The sinuosity index values for SRB and sub basins show sinuous nature of the stream. At value of the SRB is 52 indicating asymmetric basin with the tectonic rotation is perpendicular to main channel and is towards left side.

g) Various geomorphic features have been identified and located in the field. The presence of degradational features like planar surfaces, hills, valleys, escarpments creeks, headlands, tidal flats etc. are indicative of youthful, submerged terrain reflecting imprints of neo-tectonic activity.

h) The landslide zonation map shows that the risk zones of maximum land sliding are incident mainly along structural hills, in the vicinity of NW-SE trending lineaments, steeply sloping terrain having lateritic soil.

i) During present investigation environmental degradation is also observed in SRB at Jaigarh and nearby areas. It is due to projects like Jindal group's 1200 MW Coal based thermal plant, M/S JSW Jaigarh port Ltd. And M/S Chougule port and Infrastructure Pvt. Ltd.

Finally we can conclude that the present area of investigation of Ratnagiri dist. Maharashtra is structurally controlled basin and shows neo-tectonic imprints.

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