ASCENDANCY OF S_H COMPRESSIVE AND HALF GRABEN STRUCTURE DERIVED FROM LINEAMENT PATTERN THROUGH DIGITAL ELEVATION MODELING IN THE LANJA REGION FROM SOUTHERN KONKAN COASTAL BELT, MAHARASHTRA, INDIA.

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ABSTRACT

The Digital Elevation Model and field data of Lanja region from southern most Konkan Coastal Belt was studied to recognize various tectonic structures and associated landscape features, which helped to infer structures of strong extensional and a relatively weak horizontal compressive stress. The former is characterized by a group of N-S trending westerly dipping listric normal faults associated with synthetic and antithetic faults which reveal the presence of a half graben structure. This structure is responsible for the development of fault bounded blocks across the Lanja region, exhibiting plateau in west, low land at the centre, and sub-Ghat and the scarp in east. The NW-SE and ENE-WSW oriented conjugate lineaments have cross-cutting relationship to N-S trending half graben structures and are the result of WNW oriented compressive stress which appears to be imposed by intra-plate stress field prevailing in the Central Indian Ocean.

Keywords: Digital Elevation Model, Konkan Coastal Belt, Lineaments, Half graben, Stress field.

1. Introduction

Morphotectonic features of northern section of passive western continental margin of India from west to east are coast line, Konkan Coastal Belt (KCB) and Western Ghat Scrap (WGS) popularly known as Sahyadri (Fig.1a and b) paralleling to each other. The KCB is distinct morphotectonic feature, whose average width is about 50km. Geomorphologically this belt exhibits numerous plateaus and E-W trending ridges at different altitudes up to a width around 40km from coast line and further east it suddenly rises to great heights forming scrap facing towards west and hence the region is traversed by numerous westerly drainage network mainly controlled by structures.

The Konkan plains north of $16^0 30´$ N latitude and the main plateau east of WGS are covered by horizontally disposed basaltic lava flows of Deccan Traps of Upper Cretaceous to Eocene age. The basement of southern traps is composed of heterogeneous stratigraphic formations which mainly include Dharwar Supergroup, Kaladgis and Bhima Groups and spans about 3000 million years of the earth's history. These basement rocks are exposed immediately South of Deccan Traps. Dharwar craton is exposed southwest of Deccan Traps (Rogers and Maudlin, 1994); whereas, Kaladgis and Bhima Group at south and southeast respectively (Radhakrishna and Vaidyanadhan, 1997).

This belt is one of the major belts of tectonic disturbance and it is supported by few numbers of seismic events of moderate magnitude (Chandra, 1977). It is characterized by strong concentration of lineaments in an approximately N-S, NW-SE and NE-SW directions (Powar and Patil, 1980 and Powar, 1981). The NW-SE trending major lineaments in the southern Deccan Traps coincides the structural trends in the basement exposed at its south and hence indicate these are as the results of rejuvenation of weak zones or faults in the basement.

According to Widdowson and Mithchel (1999), there is an absence of major faults (order of > 20m to 100m) in this region which is puzzling and inconsistent with respect to tectonism. They are also in opinion that the major lineaments along which the pattern of modern drainage is controlled are possibly an expression of extensive fracturing or small scale faulting and their details are not clear.

Topographic features on Survey of India topographic maps (47H/5 and 9) on 1:50,000 scale of the Lanja region (Fig.1c) showing curvilinear lineaments and trellis drainage pattern has inspired us to investigate and analyze the lineaments. This paper reinterprets the lineaments in the light of nature of faults and their significance in the evolution of anomalous drainage and landscape and to understand the relationship between lineaments. The main objective of the study is to extract the tectonic features and their characterization by using Digital Elevation Models (DEMs). For this purpose primary and secondary tectonic indicators suggested by (Jordan et.al., 2005) were considered.

2. Data used and methodology

The Shuttle Radar Topographic Mission (SRTM) elevation data has been used to produce DEM for the analysis of lineaments. It is base of the form of digital topographic data. The capture resolution is 3arc second with pixel resolution 90m in World Reference System (WRS-2) and dated Feb. 2000. The source of these data sets is Global Land Cover Facility (GLCF), www.landcover.org. The advantage of SRTM data is to minimize the influence of vegetation and perennial clouds, if any (Asner 2001). In addition to these datasets lineament maps (Powar and Patil, 1980 and Widdowson and Mitchel, 1999) have been used as reference for tectonic features. Similarly, Survey Of India (SOI) topographic map of the study region at scale 1:50,000 have been used for getting geo-information and carrying field visits for ground truths. The ground survey was carried out to collect 108 reference points at random using hand held Global Positioning System (GPS) receiver. This data was used for accuracy assessment, resampling of images, georeferencing and ground truths. SRTM DEM was converted into UTM projection coordinate system with zone number 43N and datum WGS84 ellipsoid using projection tool in ArcGIS 9.2. Using mask operation the required area is extracted from the WRS-2 on ArcGIS platform. The SRTM DEM data is reduced to 30m resolution using resampling method in ArcGIS platform. SRTM DEM was used to enhance lineament at various sun angles. The best suited sun angle for the model is at azimuth 288 and sun elevation at 35^0 and presented in figure 2a. The lineaments were digitized using visual interpretation method in GIS environment. The profiles were extracted across linear features to know the effect of tectonic features on slope and elevation. Demirkesen (2008) has generated digital terrain model of Nevsehir province (Cappadocia), Turkey, using Landsat-7 (ETM+) multispectral image set and a SRTM (DEM) for geological and lineament analysis to prepare land use and land cover pattern.

The idea about half-graben structure of many rifts (Frostic and Reid, 1987) and the geological method of determining contemporary stress directions (Dunne and Hancock, 1994, Angelier, 1994) were applied for the analysis of lineaments.

3. DEM

Although, the study was focused on the part of the KCB region around the Lanja lying between Kajali and Machkundi rivers, the DEM generated represents region up to Rajapur in the south. The DEMs are in the form of shaded relief model (Fig. 2a) and digital profile across the E-W line (Fig.2b). Both of them clearly show three major morphotectonic zones viz., 1. WGS at east, 2. middle low lying area and 3. chain of flat topped hillocks near the west coast. These models also exhibit the perspective view of the lineaments, associated topographic and landform features, such as the general increase in

elevation from west to east, narrow and elongated drainage basins of the westerly flowing Kajali, Kodavali, Machkhandi and Vaghotan rivers, linear straight and curvilinear valleys and ridges, depth of valleys, degree of dissection, change in the local relief, planar surfaces and drainage pattern etc. Thus, these models helped to recognize secondary as well as primary indicators of tectonics. The primary tectonic features include, (i) linear and curvilinear valleys, (ii) linear ridges and (iii) linear slope breaks. The drainage network, drainage density, drainage patterns and modified valley slopes etc. are the secondary morphological indicators which are recognizable in the model. Curvilinear features are considered as complex tectonic features. These features and field characters were helped to recognize the fault bounded blocks and features related to the uplift, subsidence and tilting.

4. Lineaments in KCB

The KCB expresses the dense network and complex pattern of lineaments. These lineaments include major and minor lineaments. All these lineaments and the other major morphotectonic features of western India are intimately related to the series of events of intense intra-plate volcanism, the role of compression resulting from the collision of Indian plate and its subsequent subduction below the Eurasian plate and vigorous post-Deccan Trap history of cymatogenic uplift (Powar and Patil, 1980 and Powar, 1993). The reactivation and superimposition of weak zones in the basement upon the horizontally disposed lava flows of Deccan Traps, has also increased the density and complexity of lineaments in the KCB (Drury and Holt, 1980; Powar, 1981). These lineaments represent preferentially aligned fracture zones, fault zones, dyke swarms (Powar and Patil, 1980; Deshmukh and Sehgal, 1988; Desai and Bertrand, 1995 and Srinivasan, 2002). The lineaments in the images coincides deep and straight valleys, linear scraps and ridges, and linear tonal variations etc. Statistical analysis of lineaments by Powar and Patil (1980); Deshmukh and Sehgal (1988); Widdowson and Mitchel (1999) indicate that the common trends of lineaments are NNW-SSE to NNE-SSW, NW-SE and NE-SW. The cratonic basement rocks exposed south of Deccan Traps show very strong NW-SE lineament trend which is similar to one of the common trend the KCB (Powar and Patil, 1980 and Widdowson and Mitchell, 1999).

The West Coast Fault and Panvel lineament are the major tectonic features in the KCB. According to Powar and Patil, (1980), the N-S trending lineaments are most common and parallel to major structures in KCB and offshore structures are characteristic of vertical uplift. Although there is difference in opinion regarding, the exact position of the west coast fault, it is accepted that it runs parallel to the coast line (NNW-SSW) (Powar, 1981). Thus, it is presumed the west coast of India represents a fault. The Panvel lineament delineates the axis of the monoclinal flexure of Blanford (1867). This lineament has been traced by Auden (1949) for over 120km from Silvasa in Dadra from southern Gujarat to south of Panvel in Maharashtra. According to Das and Ray (1977), this lineament is associated with the line of hot springs and has extension further south along number of hot springs up to Rajapur. The basaltic flows east of the flexure axis are horizontal, while those on the western side are dipping towards west or southwest. The amount of dip is higher ($55^0 – 58^0$) in the Panvel region, and is progressively decreases in the south of Savitri River (Powar, 1981) and Ratnagiri (Widdowson and Mitchell, 1999). Desai and Bartrand (1995) have described three N-S faults at west of Panvel and the Panvel flexure structure akin to a half graben structure. According to Sheth, (1998) it is a reverse drag structure on a east dipping listric master fault with numerous subsidiary antithetic and sympathetic faults. It is interesting to note that although the trend of this lineament has been described as N-S, its trace on the map is curvilinear and concave towards west. Srinivasan (2000) has inferred ten normal faults and the step faulting framework in the northern KCB.

5. Lineaments and associated features in the Lanja region

Lineaments in this region (Fig.3) are recognizable in the forms of deep and straight to curvilinear valleys, linear scarps, ridges and linear tonal variations. These are continuous or discontinuous lineaments for the distance in the range of 5 to 85km and most of them have controlled the drainage pattern mainly in the eastern region in the form of trellis and asymmetrical drainage patterns. Lineaments were described by means of their orientation and shape. Dominating orientation criteria helped to assemble them into three broad groups, viz., (i) N-S trend, (ii) NW-SE trend and iii) ENE – WSW trend, while the shape of trace of lineaments helped to recognise nature of weak zones. This map exhibits the angular relationship between lineaments. The plots of earthquake

epicenters mostly coincide along the N-S lineaments (Fig. 3a), while few of them coincide with other two, indicating recent deformation along their weak planes. The NW-SE and ENE-WSW trending lineaments express acute and obtuse angles pattern. The acute dihedral angle (2θ) measured between these two sets of lineaments is greater than 50^0 which are in the range of 55^0 to 59^0, indicating these lineaments are conjugate shear fracture. Bisecting the acute angle is an axis of maximum stress (σ_1) responsible for the development of such conjugate fractures (Dunne and Hancock, 1994).

5.1. N-S trending lineaments

These are most common and seen all over the region and are apparently parallel to the west coast fault and Panvel lineament. These are continuous, distinct to indistinct lineaments either coincide linear coastal line segments or straight to curvilinear valleys. Curvilinear lineaments are longer than the straight lineaments and hence represent the major. The trend of straight lineaments is about N10^0W, while those of curvilinear lineaments are varying from N40^0W, through N-S to N20^0E. The region east of Lanja exhibits four curvilinear lineaments parallel to each other, out of which L_1 to L_3 are major and distinct lineaments. The concave traces of these lineaments are towards west and transverse to the general slope of the KCB and are controlling the N-S deep and transverse valleys of Palu and Agav tributaries of Kajali River. L_4 lineament locating west of curvilinear lineaments is sinus, has controlled the stream segments and also coincide the line of hot springs extending from Vajreshwari in Thane district in the north and to the Rajapur in the south. N-S trending lineaments exhibit intense steep fracturing (Fig.4a) and slicken sliding down the dip indicating vertical displacement along the fault. These intense fractures represent sub-vertical extension fractures to develop wide shatter zone in the dialational hanging wall. Considering these lineaments parallel to the west coast fault and Panvel flexure, steep intense fracturing along them with slicken sliding down the dip, it tends to infer that L_1 to L_4 lineaments are normal faults. The curvilinear and sinus shape of them is indicative of listric type. Waterfalls, potholes and ´V´ shaped valleys along these lineaments are indicative of rejuvenation during Neogene time. The region west of L_4 lineament displays numerous small scale straight lineaments (L_5). Few of them are straight segments of coast line and others are in the inland which follows N-S streams and valleys. South of L_1 to L_3 lineaments, the L_6 east facing curvilinear lineament exists.

DEM exhibiting lineaments separates the blocks of varying relative relief, landforms and drainage patterns indicate those blocks are bounded by faults. The prominent N-S ridge is bounded by L_1 and L_2 lineaments, while the region between L_2 and L_3 lineaments has E-W trending ridges and valleys. The westerly flowing Salpe stream along one of these valleys exhibit giant potholes at its western end whereas tilting of lava flow contact at 6^0 towards east (Fig.4b) is observed at the eastern end. These features indicate the upliftment as well as rotation of the block lying between L_2 and L_3 lineaments along N-S axis. The E-W artificial vertical section across a ridge, east of L_3 lineament, near Khorninko village also exhibit tilting of lava flows at 6^0 towards east indicate back tilting as a result of rotation along N-S axis. Thus, the curvilinear lineaments and rotation along N-S axis of L_1 to L_3 lineaments is indicative of listric type of normal faults whose eastern block of each is upthrown footwall while western side is downthrown hanging wall. L_4 lineament coincides the line of hot springs indicate the presence of deep seated fault zone. The block west of L_4 lineament has higher relative relief and degree of drainage dissection than relatively featureless eastern side block, as well as sudden increase in sinuosity of westerly flowing Beni River (Fig. 1c and 3a) very close to this lineament also strongly supports presence of fault zone. The dip of flows in west of Lanja is 1:300 towards west (Ravi Shankar, 2001). Thus, it is inferred that the weak zone coinciding L_4 lineament is a normal fault whose western block has uplifted, tilted towards west while the eastern block is downthrown. The L_5 lineaments are parallel to the coast line suggest that they are related to the west coast fault. The region west of L_5 lineament is Arabian Sea and hence represents the downthrown hanging wall while that of east is upthrown footwall.

5.2. NW-SE Trending Lineaments

These lineaments are continuous or discontinuous and expressed as linear valleys, tonal variations and topographic scarps for longer or shorter distances. These are mainly disposed in the eastern region. These are either intersecting or parallel to the escarpment segments in the east, and others have crossed the region diagonally along which they have controlled the few deep valley segments. One of them (L_8) extends from valley of Sukh river from east up to Ratnagiri in northwest. The reversal of Panhale stream from SW to SE is controlled by the (L_7) lineament. Such sharp bends and reversal of streams are characteristics of KCB (Powar and Patil, 1980) and are the areas where NW - SE trending lineaments have been rejuvenated across the westerly flowing streams or rivers. The trend of these lineaments coincide the Dharwarian structural trend in the basement of Deccan Traps. Thus, these represent secondary weak zones and were formed as the result of rejuvenation of weak zones existing in the basement at the time of Post-Deccan tectonic activity.

5.3. ENE – WSW trending lineaments

These lineaments (L_9 to L_{11}) are linear and indistinct which are mainly traceable in the eastern region and few of them are extending in the scarp region. These have controlled southwesterly flowing stream or river channels. As mentioned above the angle between these and NW-SE lineaments make an acute and obtuse angle pattern. The acute angle is more that 50^0 indicate both of these lineaments were controlled by conjugate fracture system.

6. Discussion:

The Lanja Konkan region is the southern most part of the KCB of western passive continental margin of India. The passive continental margins are formed by the sequence of phenomenas as arching and uplift, rifting and continental ruptures. Flood basalts are intimately related to the passage of continents over static hot spots and subsequent continental rifting induced by plume effects (Morgon, 1972 and Campbell and Griffith, 1990).

Seismic investigations and the off-shore drilling data in the Arabian Sea reveal that the Traps occur at the depth of more than 150m below the msl, indicating the down faulting along western margin of India (Desai and Bartrand, 1995) and support a presence of fault along the coast line. The presence of rift structures in the offshore regions (Biswas, 1982; Naini and Talwani, 1983 and Kaila et al., 1981) whereas a half graben structure in the Panvel region (Desai and Bartrand, 1995) have been inferred. The large and small tectonic structures (L_1 to L_6) in the Lanja region are parallel to these rift structures.

The DEM analysis of the study region explains three major lineament trends, viz. 1. N-S, 2. NW-SE and 3. ENE-WSW. The length azimuth rose diagram (Fig.3b) shows the dominance of lineaments. The acute angle between NW-SE and ENE-WSW lineaments is distinctly seen in the lineament map. The N-S lineaments are dominating, seen throughout its width, confirms the continuity in the other regions of KCB and parallel to the major structures (WCF, Panvel flexure and rift structures in the offshore). NW-SE and ENE-WSW sets of lineaments exhibit angular relationship and the dihedral acute angle between them is 55^0 to 59^0, indicating these are conjugate shear fractures. The acute angle between linear N-S and NW-SE lineaments is less than 35^0 and hence these can not be considered as conjugate. The axis bisecting the dihedral angle is used to infer the palaeo-compressive stress direction. Thus the region exhibits two systems of lineaments, A. extensional and B. compressive tectonic structures.

6.1. Extensional structures

The morphotectonic features and flood basalts of western Indian continent are the result of passage of the continent over the Reunion plume, subsequent rifting and down faulting (Radhakrishna, 1993). Thus the interpretation of structures in the KCB is only possible by understanding the rift structures. The seismic data have revealed that the rifts are asymmetric and have half graben structure with most of upthrown occurring along a major boundary listric fault forming a footwall and the opposing downthown crust forming a hanging wall (Summerfield, 1991). According to Frostric and Reid (1987), the fault pattern in the half graben constitute the major faults tends to occur on only one side of the rift, discontinuous, curved in plan and alternate of opposite polarity and separated by transverse faults. The number of major boundary faults, second and third order vertical faults may develop as a result of progressive evolution of rift. The important feature of the half graben structure is the back tilting of the footwalls, which is through combination of doming, rifting and displacement associated with movements along the major listric faults. As the drainage adjust to active tectonics (Doornkamp, 1986), the characteristic drainage network in such a region are as the result of development of major elongate, parallel drainage basins perpendicular to the major faults and axial streams along the major listric faults (Frostric and Reid, 1987) and trellised as well as asymmetrical drainage basin patterns (Stewart and Hancock, 1994).

The lineament patterns in the Lanja region can be analyzed with the help of structures associated with half graben structure. The extensional lineaments of this region can be grouped in to two families, 1. A group of curvilinear (L_1 to L_3) lineaments locating in the eastern region, inferred as listric faults and 2. Linear to sinus (L_4) lineament present in between coast line and curvilinear lineaments. L_3 lineament is major listric fault while remaining two are synthetic faults. Considering these fault lineaments, relief and drainage patterns it is also possible to distinguish the fault bounded blocks in to three groups (Fig.2), viz. 1. The blocks bounded by listric faults, 2. The low relief block bounded by L_1 and L_4 lineaments and 3. The block between L_4 lineament and coast line (L_5).

6.1.1. The Blocks Bounded by Listric Faults

It constitutes three blocks in the eastern region, close and adjacent to the WGS. Listric faults are dipping towards west and hence eastern block of each fault represents upthrown footwall while western blocks are downthrown hanging walls. The gently dipping lava flows towards east in the two easternmost blocks of footwalls are as the result of tilt and rotation along N-S axis. The associated curvilinear axial drainage lines of asymmetrical drainage basins of Agav and Palu as well as the trellis drainage pattern can be explained with the presence of curvilinear listric faults and back tilting along them.

These three blocks in this region from west to east are having progressively and relatively higher and higher relief (Fig. 2a and 2b), indicating the deformation along each listric fault is as the result of asymmetric displacement (Stein at al., 1988). In such deformation the hanging wall is down dropped and footwall is uplifted, which might have responsible for the formation of initial westerly faced scarp in the WGS and steep slope in the sub-Ghats.

6.1.2. The Low Relief Block Bounded by L_1 and L_4 Lineaments

This block in comparison to the blocks on either side has subdued topographic features in the form of low relief, lower drainage density and dissection, leveled to gently sloping planar surface towards west and dendritic to trellised drainage patterns. Similarly the L_4 lineament inferred as fault as it coincide the line of hotsprings. This block represent hanging wall with respect to L_1 and L_4 faults. Thus, the L_4 fault with respect to the major listric fault is antithetic.

6.1.3. The Plateaux Block between L_4 Lineament and Coast Line (L_5)

This block has higher relative relief and highly dissected than the low relief block to its east, and hence this represents the plateaux with higher dissection to yield numerous messas. The low relief block east of L_4 lineament is hanging wall. Thus this block is upthrown footwall with respect to the L_4 fault. The coast line segments are linear and represent the west Coast Fault (Powar, 1980) and the Arabian Sea east of it is hanging wall.

The L_1 to L_3 faults are westerly dipping listric faults and one of them is master fault and remaining two are synthetic to it while L_4 fault is antithetic. Such association along with tilting towards east explains the presence of half graben structure.

6.2 .Horizontal compressive palaeostress structures

The knowledge of neotectonic stress orientation and its relative magnitude are significant for knowing the tectonic forces operated and in seismic hazard reduction. It is possible to infer the orientation of maximum horizontal stress (S_H) and least horizontal stress (S_h). In the areas of thrusting S_H is σ_1 and S_h is σ_2, whereas in the strike slip faulting and normal faulting S_H is σ_1 but S_h is σ_3, and S_H is σ_2 and S_h is σ_3, respectively (Stewart and Hancock, 1987).

Gowd *et.al.* (1992) have recognized four provinces of tectonic stress fields in the Indian subcontinent, viz., northern mid-continent, southern shield, Bengal basin and Assam wedge. According to their palaeostress map, S_H in the KCB regions north and south of Koyna are related to the northern mid-continent and southern shield respectively. The mean orientation of S_H in the mid-continent is N 23^0 E, sub-parallel to the direction of compression which largely determined by the tectonic collision process. The S_H orientation in the southern Indian shield is towards NW and appear to those of the intraplate stress field prevailing in the Central Indian Ocean.

The presence of S_H can be determined with the help of conjugate lineaments. Powar and Patil (1980) have recognized the N 70^0 and N 330^0 trend of lineaments in the Deccan Volcanic Province and interpreted to represent the conjugate shears developed in response to a compression stress oriented N 0^0 to N 15^0 (i.e. nearly N-S). Desai and Bartrand (1995) have recognized NNW- to NNE- oriented fractures cutting the N-S fracture system in the Panvel region is a result of N-S directed compressive stress field. In the Lanja region the conjugate lineaments recognized are NW-SE and ENE-WSW, and the S_H direction determined is N 70^0 W to N 60^0 W i.e. WNW direction. This stress direction does not coincide with S_H determined in the northern mid-continent or in the KCB region north of Mahad – Koyana. But this is nearly sub-parallel to the orientation direction determined in the southern Indian shield by Gowd et.al. (1992). Thus, S_H orientation in the Lanja region confirms the stress field of southern Indian shield which is distinctly different from northern KCB.

7. Diagrammatic cross-sectional model

The relationship between fault bounded blocks across the half graben structure along E-W line is presented in the form of diagrammatic cross-sectional model (Fig.5). For this purpose few number of E-W digital profiles have been studied and one of them is used to present the model. This model has been constructed based on the location of the fault lineaments, type of faults with upthrown and downthrown blocks and tilt of lava flow directions, existing elevation on either side of the lineaments and depth of dissection along lineaments. This model exhibits the major listric fault associated with synthetic and antithetic faults, fault bounded blocks, strike drainage, tilted blocks and Ghat and sub-Ghat segments.

8. Conclusion

The DEM is found useful to recognize and demarcate three distinct trends of lineaments and associated sub-geomorphic zones in the Lanja region from southern KCB. The N-S lineaments are dominating and have controlled sub-geomorphic zones and drainage pattern. The presence of half graben structure is inferred by recognizing westerly dipping listric faults in the eastern region and easterly dipping antithetic listric faults west of it. The region from coast line to WGS has fault bounded blocks of the half graben structure and the deformation along these faults might be responsible for the development of associated geomorphic features as plateaux in west, Ghat and sub-Ghat region in east, and the middle low land between the plateaux and sub-Ghat. The Inferred half graben structure explains formation of various geomorphic features, relief and drainage patterns existing in the Lanja region. The conjugate relationship between NW-SE and ENE-WSW trending lineaments is inferred as the result of WNW oriented compressive stress. This stress field appears to be imposed by intra-plate stress prevailing in the Central Indian Ocean. This stress field is distinctly different from the N-S oriented compressive stress field in the northern Konkan regions imposed by the collision of India with Eurasia. The idea of inferred half graben structure and the compressive stress fields thus can be applicable in other regions of KCB and that will throw light on evolution of KCB and WGS regions as well.

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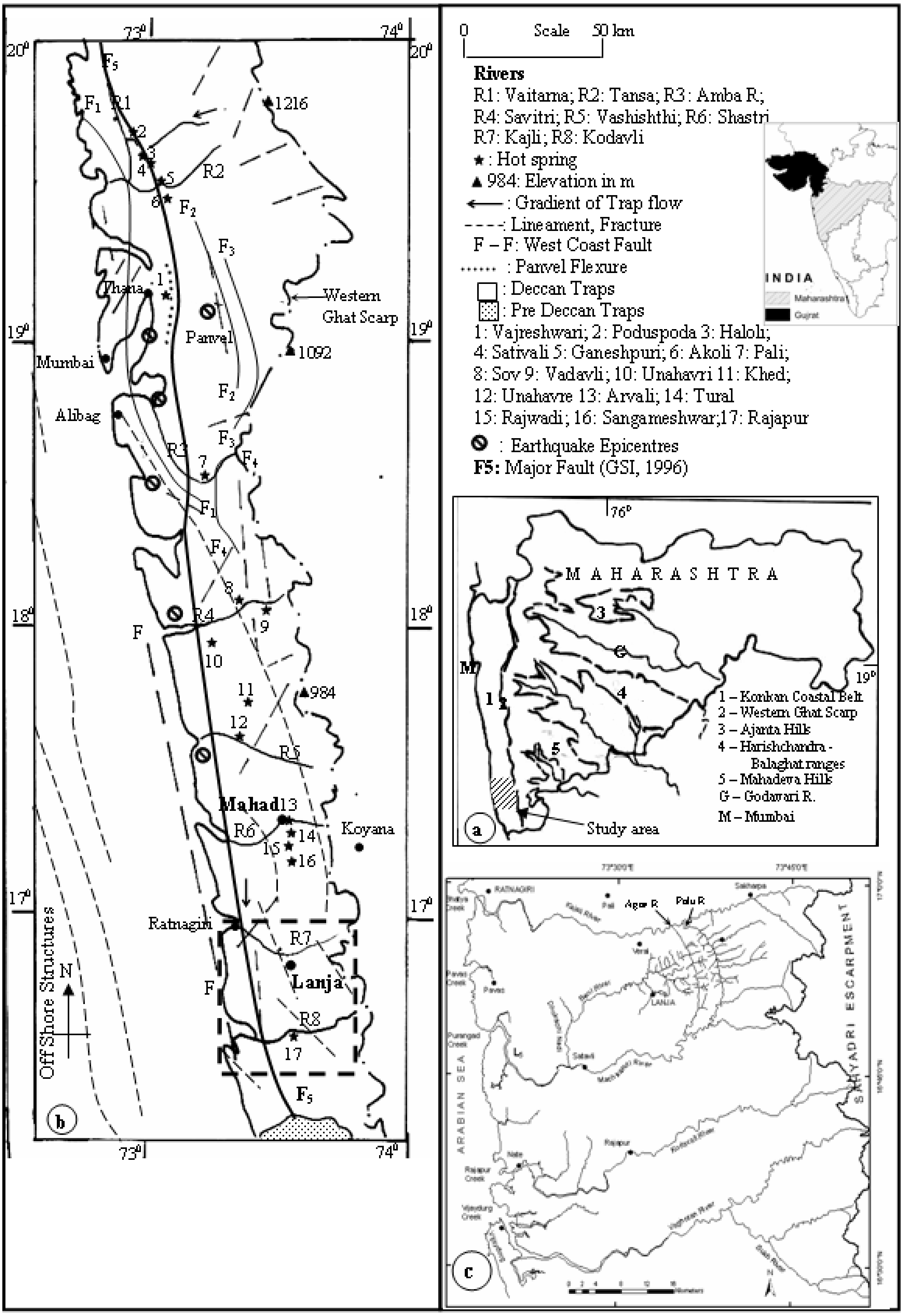

Figure 1: **a**: Location map of the study area., **b**: Geological and Tectonic Map of Konkan Coastal Belt, Maharashtra. (Modified after Deshpande, 1998)., **c**: Major rivers between Ratnagiri and Vijaydurg.

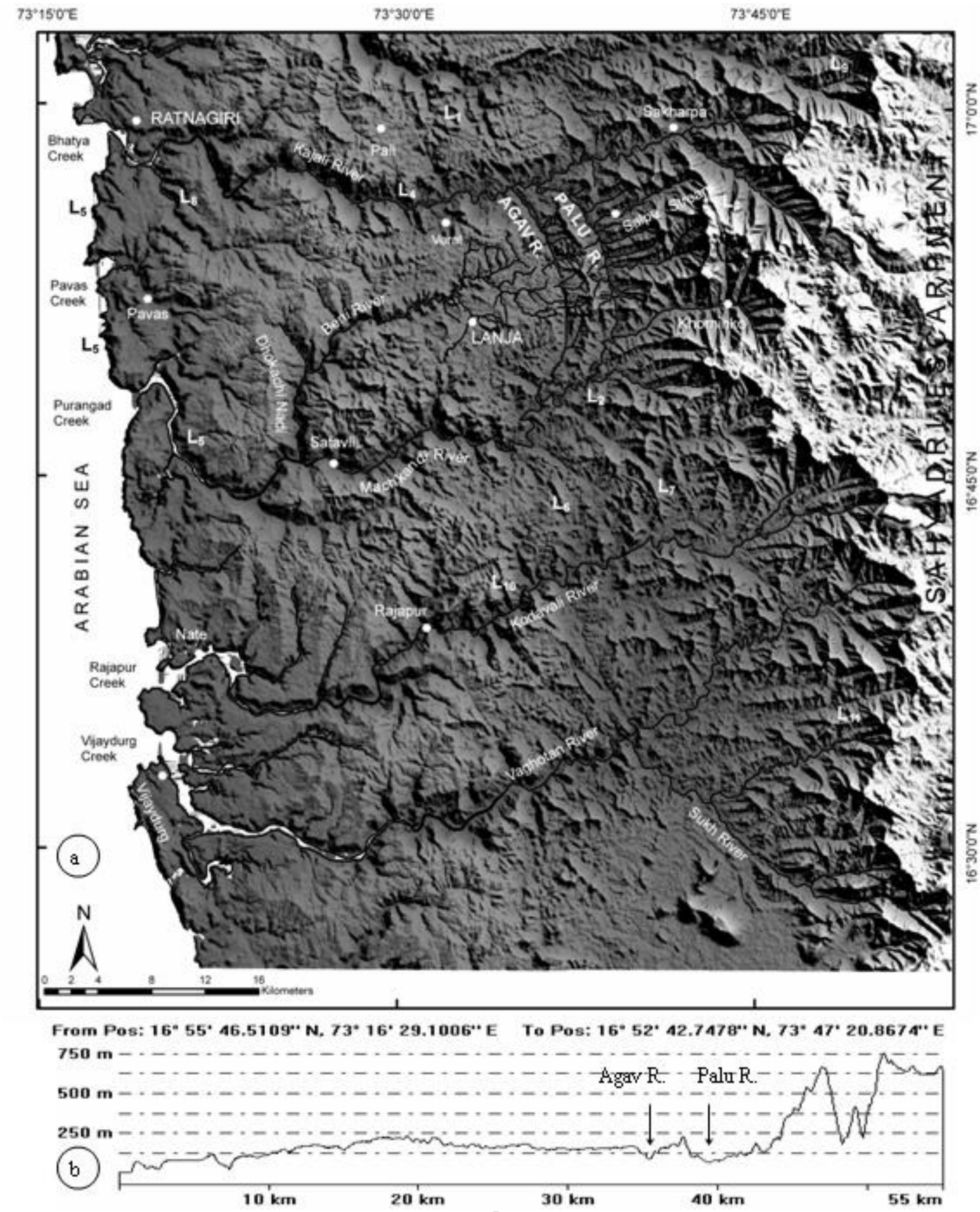

Figure 2: **a:** Digital Elevation Model with Shaded Relief of the study area., **b:**E-W profile.

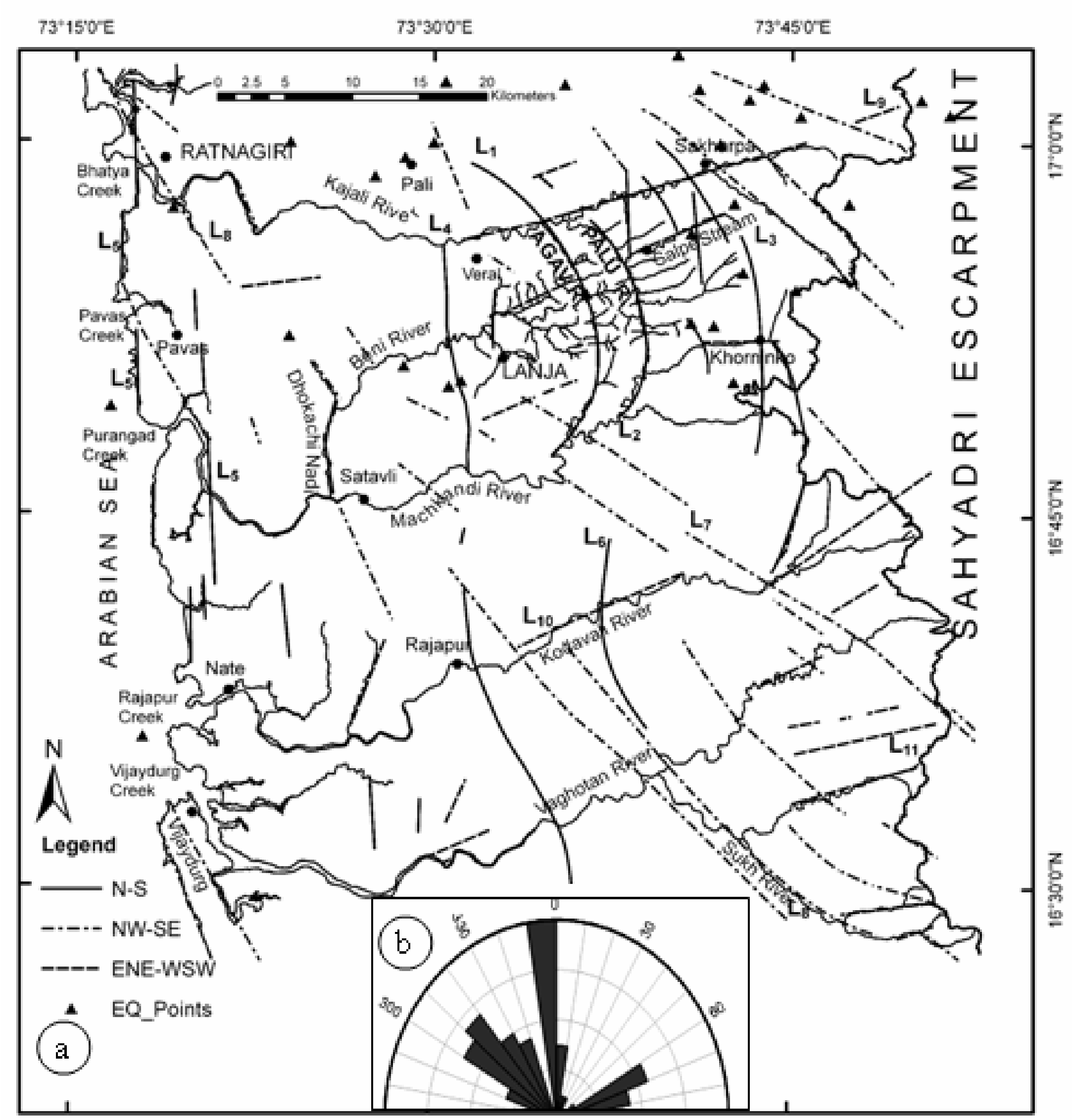

Figure 3: a: Lineament Map of the area. b. Azimuth Rosette.

Figure 4a: Intense steep N-S fracturing with dip >85^0E.
Location: Agrewadi – $73^0$30´31”E; $16^0$40´20”N

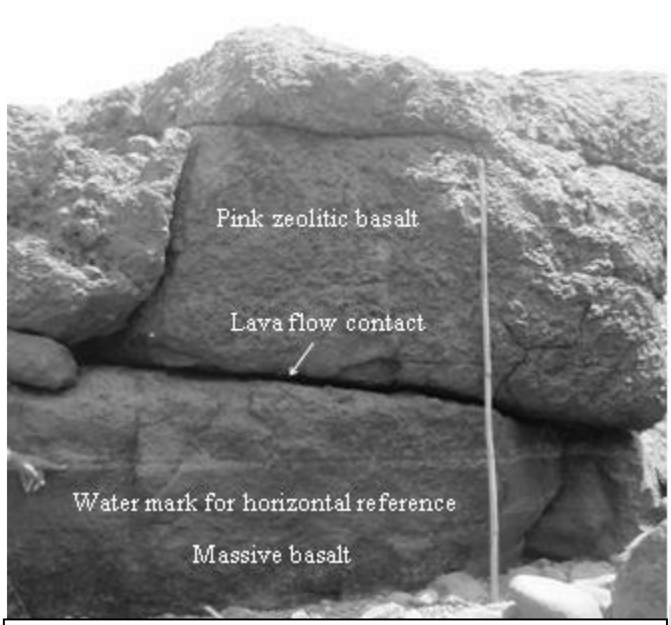

Figure 4b: 6^0 tilt of lava flow contact towards east.
Location Daphlewadi – $73^0 41'36''$E; $16^0 56'56''$N

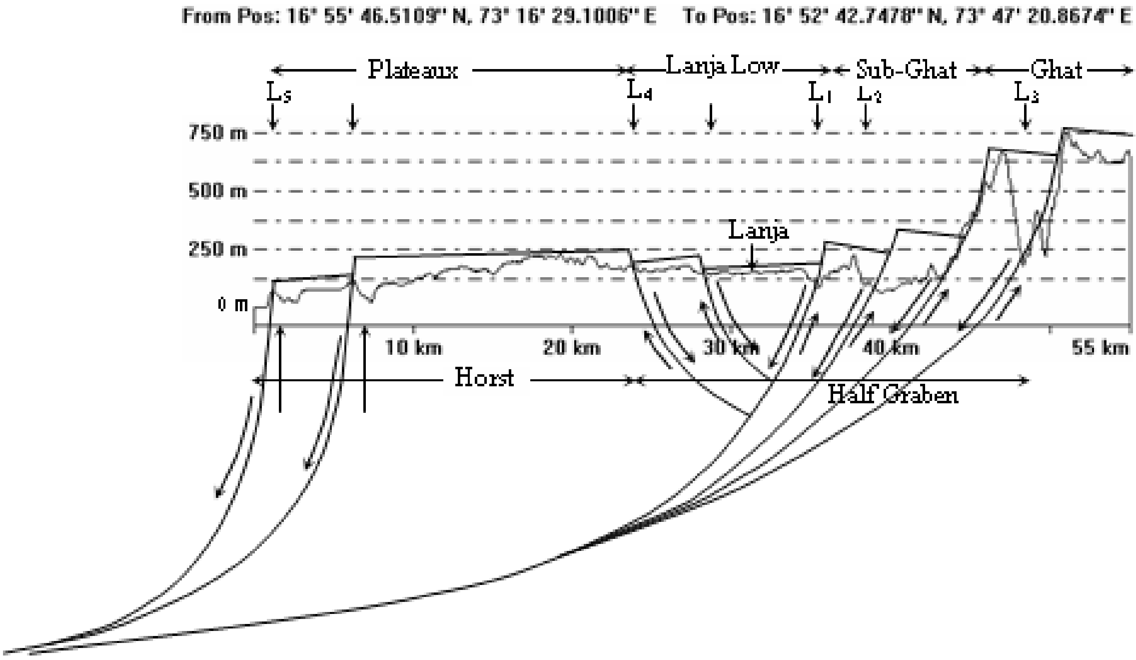

Figure 5: Conceptual model showing half graben structure.