Journal of Geomatics
Vol 9 No. 2 October 2015

Lineament extraction analysis for geotectonic implications around Biligiri-Rangan hill ranges in Southern Karnataka, India using IRS-1D, LISS-III image

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(Received on: Jun 08, 2015; in final form: Aug 13, 2015)

Abstract: Lineaments are linear fracture commonly associated with dislocation and deformation. A lineament is a regional scale linear or curvilinear feature, pattern or change in pattern that can be attributed in analyzing the structural and tectonic aspects of an area. Larger lineaments have larger zone of influence and larger amount of deformation is associated with them. In central parts of the study area represents highly sheared and fissile type of intermixed gneisses with granitoids, migmatitic gneisses with massive retrograde and incipient type of charnockite exposures with mylonites are noticed with basic granulites, younger dolerite dyke rocks are cross cutting all other earlier rock types. Ductile to ductile brittle, dextral and sinistral type of shears are also noticed. The present aim is to study the tectonic activity on Precambrian basement rocks in Southern tip of Karnataka state by lineament extraction through satellite image. Remote sensing images show best enhancement techniques for the linear features like fracture system and lineaments. These are useful in groundwater, mineral exploration and engineering geological applications. Lineaments are derived by Digital Image Processing (DIP) techniques on IRS-1D LISS-III image through GIS softwares. Remote sensing techniques have been further boosted to lineament studies since the identification and mapping of lineaments become relatively easy using high resolution satellite images. The final results show geotectonic implications around Biligirirangan hill ranges of Southern Granulite Terrain (SGT) of Indian subcontinent.

Keywords: Lineament extraction, Geotectonic implications, IRS-1D LISS-III, Biligiri-Rangan hill ranges

1. Introduction

The term lineament was originally used by Hobbs (1904) to describe linear feature that are "significant lines of landscape". The study area implies the geotectonic activities ranging from ten to hundreds of kilometers in length in the form of fracture systems. These represent deep seated faults, master fracture and joint sets through which magmatic and hydrothermal fluids are brought to the surface, act as zones of erosion, house geothermal springs and also act as geotectonic windows through which earthquakes and seismicity take place (Dinakar, 2005). Detection and mapping of large lineaments, faults and fractures can be achieved by visually analysis of satellite images. Lineaments are the linear, lineation, geo-fracture, suture, mega fracture and shear zones formed by several tectonic processes and related parameters (Rakshit et al., 1985). Identification and analysis of underground fractures and concealed lineaments are crucial in hard rock terrains (Srikantappa et al., 2003; Mondal et al., 2008). Fractures, rock cleavages and fault/thrust play a vital role in affecting the surface storage, groundwater recharge and base flow and consequently, the efficiency of structural measures are lineament (Ramakrishna, 1993) that appeared as tonal discontinuities. Lineaments studies have arising as an important step in analyzing the structural and tectonic aspects providing useful information in mineral exploration and in engineering geological applications (Pushpavathi, 2010). Massive to banded charnockites and charno-enderbitic granulites exhibiting regional foliation trending N-S with steep dipping towards East is noticed in Precambrian Bilirigiri-Rangan Hill (BRH) ranges. Granulites show a general sinistral, dextral and ductile brittle shear deformation due to different types of deformational event such as D1, D2 and D3 (Basavarajappa and Srikantappa, 2014). Two types of Charnockitic granulites such as massive to banded and foliated charnockites and incipient charnockites have been recorded (Basavarajappa et al., 2013a & b)

2. Study area

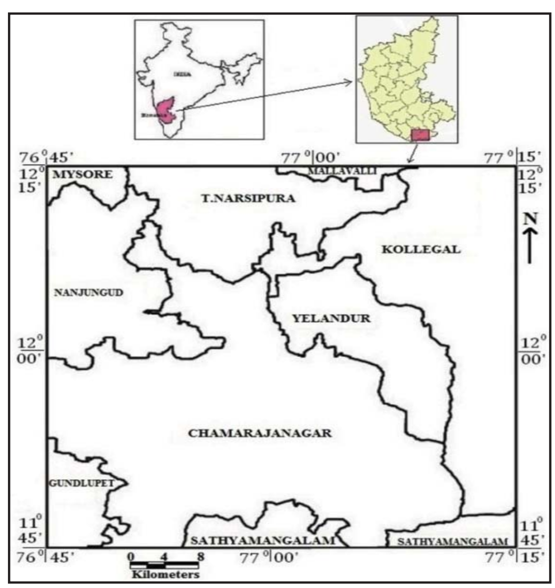

Figure 1: Location map of the study area

The study area lies in between 11°45' to 12°15'N latitude and 76°45' to 77°15'E longitude with total aerial extent of 3,011 km^2 (Fig. 1). The main unit of BRH ranges shows high land granulitic rocks, low land gneissic rocks with metasediments and in between these two units; there exists granulite-gneiss mixed zone with younger granitoids and post-tectonic dykes (Satish, 2002).

3. Methods and materials

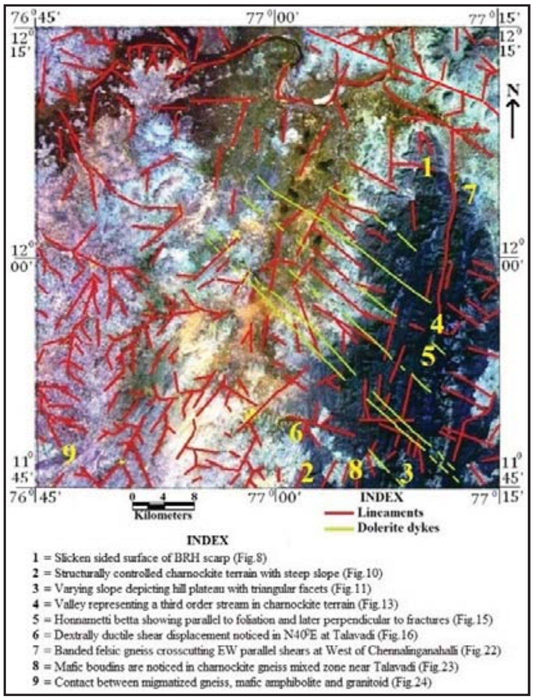

Figure 2: Lineament overlaid on IRS-1D, LISS-III satellite image (Bands: 1, 2 & 4); Date of pass: March 10, 2003

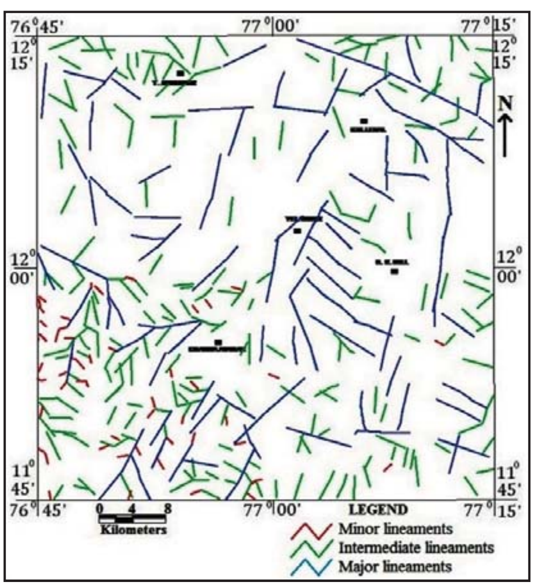

Figure 3: Lineament category map of the study area

Digital image processing (DIP) has been well utilized with various algorithms to enhance the ground/ linear features for better interpretations and analyses. Linear contrast stretching, edge enhancement, spatial filtering, de-correlation techniques and principal component analysis (PCA) techniques are the few methods applied on the present image analysis (Satish, 2002). Linear contrast stretching increased the input of brightness range of the image. Edge enhancement delineated the edges and sharpened the lineaments. Spatial filtering techniques such as sobel directional filters and convolution methods were utilized in sharpening the images with linear features and edges highlighted using high pass filters. Correlation between the spectral channels of multispectral digital image of the study area was analyzed using de-correlation technique to spread the data into 3D axis. PCA was well utilized in the present study to produce the maximum information with respect to the reorientation of the co-ordinate system of the particular band of LISS-III.

Lineaments are extracted using DIP techniques on IRS-1D LISS-III image through Erdas Imagine v8.5 and are shown in Fig. 2. Lineament map is converted into coverage, considering the lineament as a line feature (Fig. 3). Dyke rocks show tectonic implications which have shown N45^0 westerly trending and cross cutting all other lithology and the major Kollegal Shear Zone (KSZ) also (Basavarajappa et al., 2015).

The following data, software and instruments were used in analysis.

a) IRS-1D, LISS-III of 23.5m resolution (March and Nov-2001) and PAN of 5.8m, Date of pass (10-March-2003).
b) GIS software: Erdas Imagine v8.5 and ArcView v3.2.
c) GPS Garmin-12: Carried out GPS survey during field visits to record different observed lineaments.

4. Lineament analysis

Lineaments may vary in magnitude from as small as a cleavage in minerals to as inter plate boundaries. This term is preferentially used to define the unidirectional earth features of larger magnitude (Bhave et al., 1989). Lineament patterns can be directly correlated to the structural, geomorphic events and results of tectonic deformation. Lineament represents fault, fracture, master joints, axial plane fracture, dyke system, long and linear lithologies, straight courses of stream, vegetation alignment or topographic linearity.

4.1 Classification of lineaments

Lineaments of the study area are classified based on their length & directions and are measured using ArcView v3.2. Lineaments are grouped into four categories such as continuous, discontinuous, simple and composite (Ganesh Raj, 1987) with respect to geotectonic activities in the study area. An uninterrupted linear scarp is an example of a continuous lineament. In discontinuous lineaments, the discrete features are aligned along a contact path and are relatively closely spaced such as a linear stream valley or a series of aligned topographic escarpments. A composite lineament consists of more than one type of feature such as a combination of aligned tonal features and stream segments. Kowalik and Gold (1976) suggested a classification of lineaments based on their lengths (Table 1). Lineaments are divided into four major types like fault lineaments, fracture and joint lineaments, contact lineaments and dyke lineaments based on geology of the study area.

Table 1: Lineament classification

Sl No.	Lineament class	Length (km)
1	Short / Minor	1.6 to 10
2	Intermediate	10 to 100
3	Long / Major	100 to 500
4	Mega	>500

4.2 Graphical analysis

Rose diagrams are an effective way of representing structurally oriented geological data. It is the simplest structural representation that can be constructed by drawing a circle with reference to a central point. The cardinal point of azimuth is divided into sections so that each section contains an equal number of degrees. The size of the section is chosen in accordance with the number of observation and intensity of the preferred orientation of the lineament being studied. The length of the line indicates the length of lineament, frequency of the lineament and the number of degree indicates the direction of lineament (Basavarajappa, 1992).

4.3 Lineament Orientation

The lineaments range in length from a few km to tens of km. They appear as rectilinear or curvilinear features depending on the dip of the structural plane. It has been observed that lineaments either intersect each other or meet almost perpendicularly at large lengths. At few places, however, the lineaments occur parallel to each other and form a zone of en-echelon pattern. In the study area, 323 numbers of lineaments are identified (Fig. 3). These lineaments are overlaid on the satellite data product of band combination 1, 2 and 4 (Fig. 2). The maximum length of the lineament encountered is 22.55 km trending towards N15°E and minimum length is 0.40 km trending towards N36°W (Table 2; Fig. 4). Lineament trend analysis is given in table 3.

4.4 Lineament categorization

These lineaments are grouped into three categories according to their length. The study area is divided into four sectors viz., NE, NW, SE and SW based on the lineament trends (Fig. 5).

Table 2: Lineament categories

Length category (km)	No. of lineaments	(%)	Total length (km)	(%)
<1.5 (Minor)	51	15.84	58.32	5.54
1.5 – 4 (Intermediate)	195	60.56	517.78	49.20
>4 (Major)	76	23.60	476.31	45.26

Table 3: Lineament trend analysis

Trend	No. of lineaments	Percentage (%)	Length of lineaments (km)	Percentage (%)
N-N10^{0}E	29	8.98	97.10	9.23
N10^{0}E-N20^{0}E	19	5.88	83.24	7.91
N20^{0}E-N30^{0}E	17	5.26	67.14	6.38
N30^{0}E-N40^{0}E	18	5.57	53.14	5.06
N40^{0}E-N50^{0}E	16	4.95	73.73	7.01
N50^{0}E-N60^{0}E	13	4.03	44.59	4.24
N60^{0}E-N70^{0}E	8	2.48	23.77	2.26
N70^{0}E-N80^{0}E	12	3.72	27.35	2.60
N80^{0}E-N90^{0}E	18	5.57	54.38	5.17
N-N10^{0}W	22	6.81	61.47	584.00
N10^{0}W-N20^{0}W	15	4.64	49.67	4.72
N20^{0}W-N30^{0}W	14	4.33	43.48	4.13
N30^{0}W-N40^{0}W	21	6.50	50.17	4.77
N40^{0}W-N50^{0}W	18	5.57	49.00	4.66
N50^{0}W-N60^{0}W	24	7.43	99.28	9.43
N60^{0}W-N70^{0}W	29	8.98	78.77	7.48
N70^{0}W-N80^{0}W	18	5.57	57.29	5.44
N80^{0}W-N90^{0}W	12	3.72	38.79	3.69
Total	**323**	**100**	**1052.38**	**100**

Out of total population of 323 lineaments, 195 lineaments fall in the dominant group of intermediate lineaments ranging from 1.5 - 4 km covering total length of 517.78 km (49.20%). These contribute maximum percentage of about 60.56% to the total number of lineaments. The second group is dominated by major lineaments ranging more than 4 km covering total length of 476.31 km (45.26%). Seventy six (76) of lineaments fall in this group consisting of 23.60% of the total number of lineaments. The third group consists of minor lineaments (<1.5 km) and 51 lineaments fall under this group covering only total length of 58.32 km (5.54%). These are straight and structurally controlled lineaments represented by foliation trends. The intermediate lineament is abundant in number, parallel to regional strike; few are sinuous and often folded forming a network in the entire study area. The minor lineaments are of smaller magnitude and are abundantly found in southwest parts of BRH ranges (Table 2; Fig. 4).

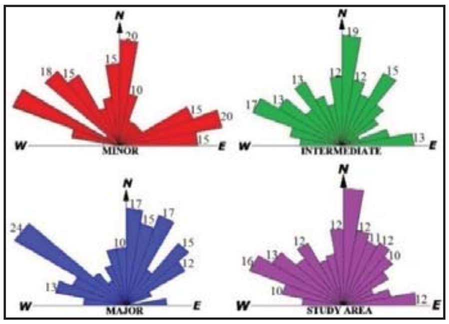

Figure 4: Rose diagram depicting lineament trend analysis of the study area

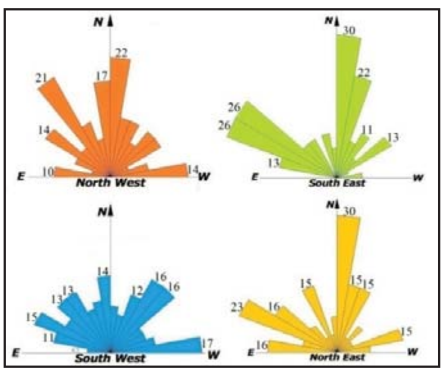

Figure 5: Rose diagram depicting the lineament trend analysis in sector-wise

5. Faults/fracture zones and dykes

Topographic rises or linear hills are in sharp contrast to the soils of surrounding plains with gully erosion in narrow linear tracts along the observed fault zones. Tectonic movements show the utter youthfulness of horst terrain of BRH. Recent movement on northerly extension i.e., NNE-SSW trending faults are noticed in eastern parts of BRH. Late movements along N-S trending regional structures have given rise to linear hills representing the predominant structural features. Numerous late dolerite dykes transect gneiss and BR massif crosscutting rivers and all other lithological units including migmatitic gneiss exhibiting sharp contact with them. It contains plagioclase and clinopyroxene observed in hand specimen. Clinopyroxene (augite) shows two sets of parallel cleavages under thin section. Dykes are observed on IRS-1D, LISS-III in the form of band and discontinued with black signatures (Basavarajappa, 1992; Basavarajappa and Srikantappa, 1998 and 2013; Basavarajappa and Dinakar, 2005).

6. Structural and petrographic evidences

Structural and petrographic studies of foliated charnockites show medium to coarse grained, greasy grey colored rocks with well developed regional foliation. Foliation is defined by orthopyroxene and /or biotite. Quartz shows stretching and parallel to regional foliation in highly deformed zones. Garnet show porphyroblastic growth and defines regional foliation. Foliated charnockites show evidences of at least three deformational events (D1, D2 and D3) (Basavarajappa and Srikantappa, 2000). They represent granulitic, granoblastic to foliated micro-textures and evidences of ductile to brittle deformation. Peak metamorphic minerals in charnockite show the following assemblages:

1. Quartz: plagioclase, orthopyroxene, biotite
2. Quartz: plagioclase, K-feldspar, orthopyroxene, biotite,
3. Quartz: plagioclase, K-feldspar, orthopyroxene, biotite, garnet.

Peak metamorphic minerals of basic granulites show following assemblages:

1. Plagioclase – orthopyroxene – clinopyroxene – hornblende – garnet
2. Plagioclase – clinopyroxene – hornblende – biotite
3. Plagioclase – orthopyroxene – clinopyroxene – hornblende.

Petrographic study shows presence of euhedral orthopyroxene (En_{40-70}) pleochroic from X-colorless. Y-light pinkish yellow and z-light pink constitute about 2-15 modal percent in the rock. In deformed rock orthopyroxene show stretching parallel to foliation and often bent and broken orthopyroxene grains are seen showing wavy extinction due to ductile deformation. Presence of inclusions of biotite and quartz in orthopyroxene grains shows the following metamorphic reaction:

Biotite +quartz-----orthopyroxene+K-feldspar+H_2O (1)
Clinopyroxene + plagioclase = garnet + quartz (2)
(Basavarajappa and Srikantappa, 2014).

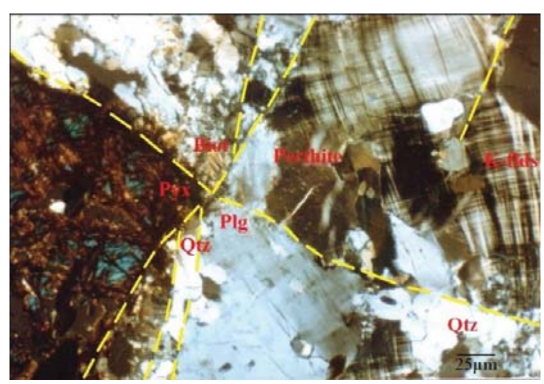

Figure 6: Microphotograph of pyroxene granulite shows different directional shears around BR hills (Biot-biotite; Pyx-pyroxene; Plg-plagioclase; Qtz-quartz; K-flds- Potash feldspars)

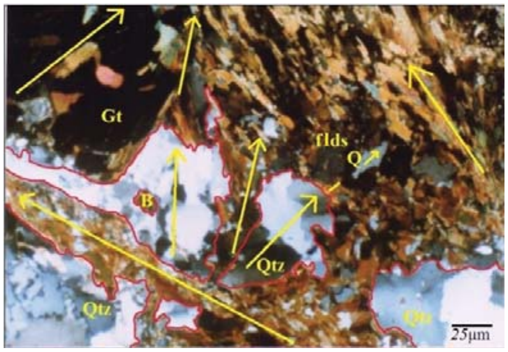

Figure 7: Microphotograph of garnetiferous gneiss rock showing different deformational directions with quartz and biotite fish types around BR hills (Gt- garnet; B-biotite; flds-feldspar; Qtz-quartz)

7. Geochemical signatures

Charno-enderbites show igneous parentage exhibiting tonalitic to trondhjemetic in composition based on geochemical analysis. They reveal depletion of LIL (Large Ion Lithophile) elements with higher K/Rb ratios ranging from 250-500 ppm. Geochemistry of charno-enderbitic granulites and basic granulites indicate that they are not co-genetic and are derived from different magmatic sources (Basavarajappa and Srikantappa, 2014). Basic granulites of BRH are iron rich tholeites to high alumina basalt representing low k-tholeitic geochemistry indicating their magmatic origin. Regional granulite facies metamorphism is estimated at pressure of 6.2 – 8.2 kb and temperature of 700^0-930^0C during M1 metamorphism suggesting the depth of burial at least ~30 km during Precambrian times (Basavarajappa and Srikantappa, 2014).

8. P-T conditions and evidences of metamorphism

Pressure and temperature estimations based on various geothermobarometric models have carried out for the granulite facies rocks of BRH. The mean temperature ranges from 750^0-900^0C and mean pressure ranges from 5.1-7.3 kb suggesting the depth of burial of about 20-25 km during granulite facies metamorphism around 2.5 b.y ago, subsequently, these rocks were sheared and retrogressed during the late Proterozoic times (Basavarajappa and Srikantappa, 2014).

9. Field observations and evidences of geotectonic implications

Detection and mapping of large lineaments, faults and fractures are digitized immensely using the synoptic view of LISS-III image with their varying lengths and directions (Tables 2 & 3; Fig. 4 & 5). The most typical geological, structural and tectonic features and trends are well noticed during field visits and petrographic studies on observed lineaments of the study area around BRH. BRH ranges shows typical structurally complex in hard rock terrain by both dextral and sinistral shearing events and active fault trending N40^0W and N60^0W noticed through field evidences. Structural studies and field investigations as well as geomorphological landforms shows four major types of deformational and folding events in the study area (Basavarajappa et al., 2015). The entire BRH ranges show approximately N-S foliation. The southernmost part of Biligiri-Rangan Granulites (BRG) show E-W foliation in the junction of Nilgiri hill ranges. Slicken sided surface of BRH scarp shows N46^0E fault plane (Fig. 8). Sinistral shears are noticed in high-grade charnockite at Gumballi area (Fig. 9). The southern tip of BRH shows structurally controlled Charnockite terrain with steep slope and streams in the foreground (Fig. 10). Plateau hill complex shows typical triangular facets at southern parts of BRH (Fig. 11). N60^0W fault generated steep scarp, genesis of mantle pediment in the foreground shows thick and densely vegetation (Fig. 12). Regional structural trend enforced the genesis of landform characteristic in southern parts of BRH ranges that surrounded by four major important shear zones such as Kollegal Shear Zone (KSZ) in the West (Basavarajappa, 1992; Meenakshi, 2003; Satish, 2002; Dinakar, 2005; Basavarajappa, 2013; Basavarajappa et al., 2015), Cauvery Shear Zone (CSZ) in the North, Mettur Shear Zone (MSZ) in the East and Moyar Bhavani Shear Zone (MBSZ) in the South (Prakash Narsimha, 1992; Radhakrishna and Vaidyanadhan, 1997; Basavarajappa and Srikantappa, 2000; Wadia, 1999). Charnockite massifs represent the genesis of third order stream in valleys (Fig. 13). Low relief and undulating topography are noticed in background of BRH linear ranges comprising of peninsular gneissic terrain. In the study area, Charnockite representing terrains are characterized by youthful rugged hills; whereas massive charnockite is noticed at the top of BRH ranges. Geomorphic features like uncommon Kastle koppies are noticed in high-land topography (Fig. 14). Massive charnockite exposure and rock pillar are noticed at Honnametti betta showing parallel to foliation and later perpendicular to foliation textures (Fig. 15). Dextral shear shows displacement trend with N40^0E are noticed at Talavadi, Southern parts of BRH (Fig. 16). Mafic boundins show both sinistral and dextral type of shear displacement and graben fault near Kolipalya at Western parts of BRH (Fig. 17). Parallel to foliation fractures in mylonite exposure shows N15^0E trending in the northern parts of BRH (Fig. 18). Typical highly deformed migmatitic gneiss is located at northern parts of the study area (Fig. 19). Mafic boudins of rectangular and fish type; show dextral shear measures at N25^0W displacement near Talavadi, Southern parts of BRH (Fig. 20). Banded gneiss trends N15^0E is observed at Talavadi (Fig. 21). Banded felsic gneiss is observed as crosscutting EW parallel shear at N10^0E at Chennalinganahalli in tip of BRH (Fig. 22). Charnockite exposure shows mafic boundins at Talavadi, southern parts of BRH (Basavarajappa and Srikantappa, 1996 and 1998). Mafic boundins are noticed in Charnockite gneiss mixed zones and contact between migmatized granitoid and mafic amphibolites (Fig. 23 & 24).

Figure 8: Slicken sided surface of BRH scarp showing N46^{0}E fault plane

Figure 9: Charnockite showing sinistral shear at Gumballi of the study area

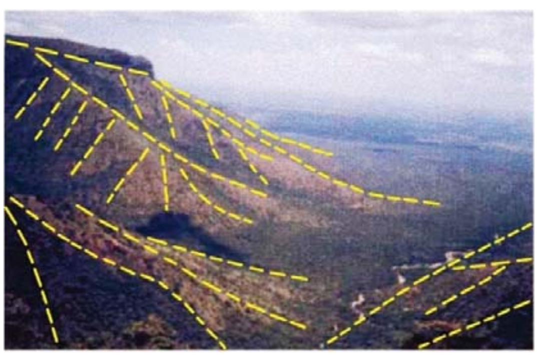

Figure 10: Structurally controlled Charnockite terrain with steep slope in Southern tip of BRH

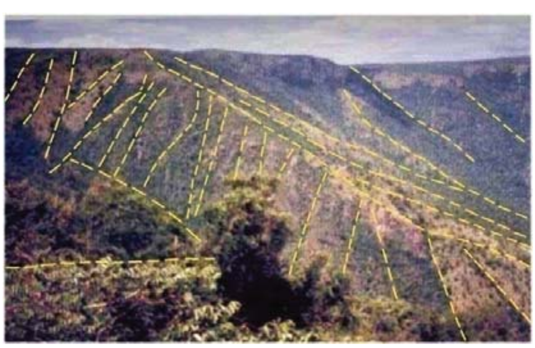

Figure 11: Varying slope depicting the hill plateau complex exhibiting newly formed triangular facets at southern parts of the study area

Figure 12: N60^{0}W fault shows steep scarp

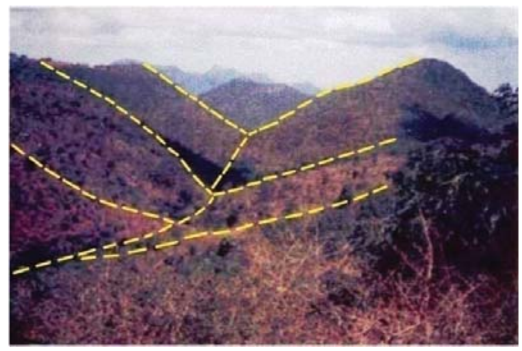

Figure 13: Valley representing a third order stream in Charnockite terrain

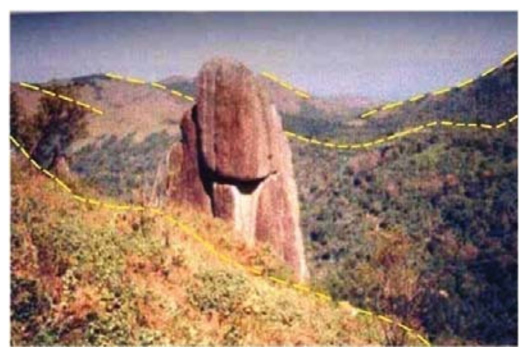

Figure 14: Uncommon Kastle Koppies noticed in high land BRH

Figure 15: Massive Charnockite exposure and rock pillar at Honnametti betta showing parallel to foliation and later perpendicular to foliation fractures

Journal of Geomatics Vol 9 No. 2 October 2015

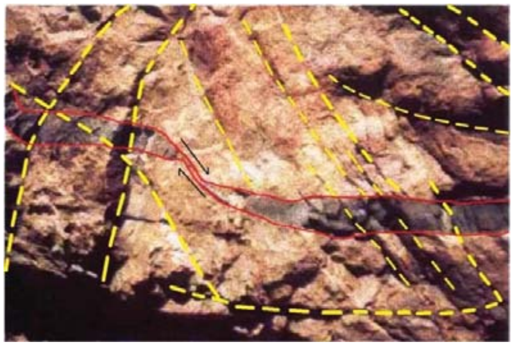

Figure 16: Dextrally ductile shear displacement of N40^{0}E at Talavadi, Southern parts of BRH

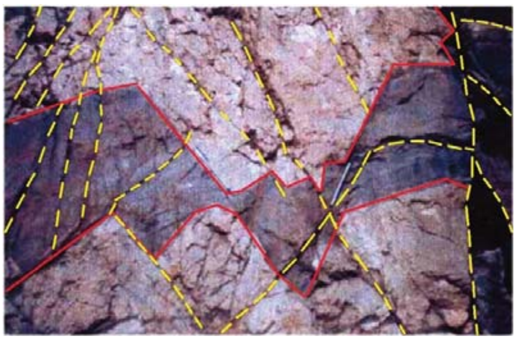

Figure 17: Mafic boundins showing sinistral and dextral type of shears and Graben fault at western parts of BRH

Figure 18: Parallel to foliation fractures in Mylonite exposure trending N15^{0}E

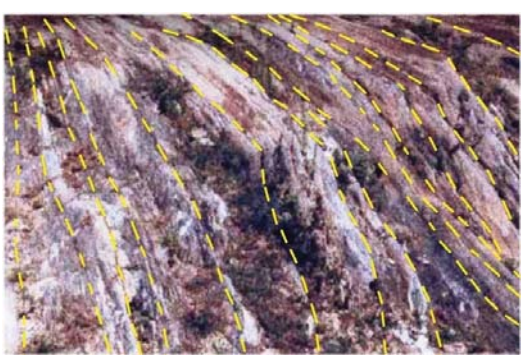

Figure 19: Typical Highly Deformed Migmatitic Gneiss located at Northern parts of the study area

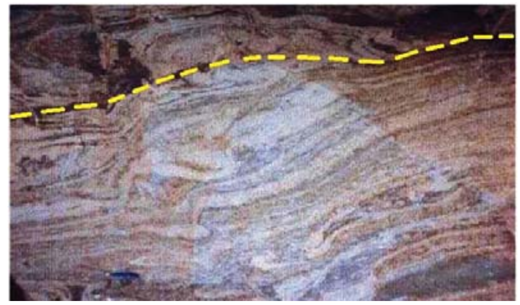

Figure 20: Mafic boundins (a & b) showing dextral shears in Banded Charnockite towards N25^{0}W at southern parts of BRH

Figure 21: Banded gneiss N15^{0}E at Talavadi, Southern part of BRH

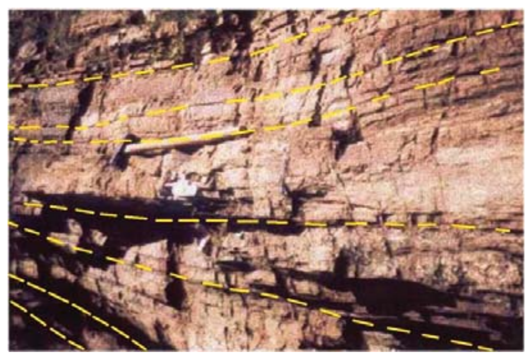

Figure 22: Banded felsic gneiss crosscutting EW parallel shears near Chennalinganahalli N10^{0}E

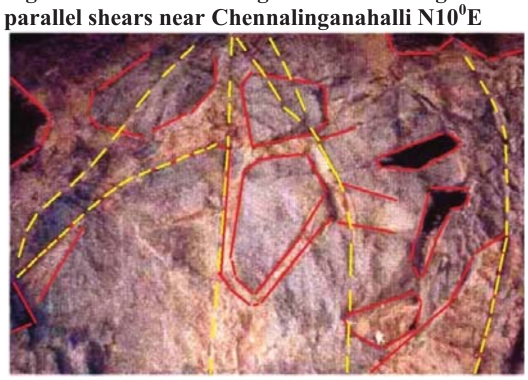

Figure 23: Mafic boundins are noticed in Charnockite gneiss mixed zone near East of Talavadi, southern part of BRH

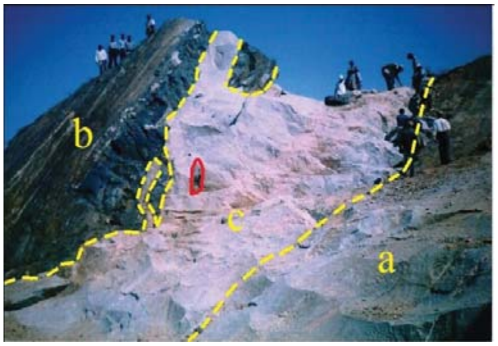

Figure 24: Contact between Migmitised Gneiss-(a), Mafic Amphibolite-(b) and Granitoid-(c)

10. Conclusion

Categorization of lineament, lineament trend and lineament direction are enlightened. Out of total population of 323 lineaments, 195 lineaments fall under dominant group of intermediate lineaments (1.5-4 km); 76 lineaments fall under major lineaments (>4 km) and 52 lineaments occur as minor lineaments (<1.5 km). Maximum number of lineament trending in N-N10°E direction. They are straight, structurally controlled representing the foliation trend falls within weaker plains. DIP and GIS are hi-tech tools that provide ease, accuracy and efficiency for better interpretation of geotectonic movements. Geologically, the terrain confirms to an ancient Archaean terrain. BRH is rised to a height of 800m rather abruptly from the adjacent Mysore plateau. Geomorphologically, BRH are characterized by steep cliffs trending N-S. One can trace the structural trends and even lithology from the Dharwar craton from the amphibolite facies gneissic region to the granulite grade Biligiri-Rangan terrain. Granulite facies rocks of the BR hills are predominantly composed of medium to coarse grained, dark greenish grey colored banded enderbites and charnockites. Numerous basic granulites, banded Mn, Fe-rich quartzites and politic rocks occur as bands, lenses or pods within the charnockites. Structural and petrographic studies indicate that the banded charnockitic granulites are formed during an earlier metamorphic event around 2.9 b.y. during ductile regime. Kollegal Shear Zone (KSZ) metamorphic rocks represent an uplifted landmass with younger granitoids and post-tectonic dykes. Presence of geomorphic features like hilly terrain in the central part is bounded by valleys on all four sides. These valleys are structurally controlled geomorphic features on a regional scale by N-S trending Kollegal Shear Zone (KSZ) along western margins and Dharmapuri-Mettur Shear Zone (DMSZ) in the eastern margins and an E-W trending Moyar Bhavani Shear Zone (MBSZ) towards southern and Cauvery Shear Zone (CSZ) along the northern parts of BR hills clearly represent uplifted granulites of once deeply buried rocks of Precambrian age. Meandering gorges of river Cauvery is generated due to active base level reduction due to tectonic activity. The final upliftment of the deep crustal rock is aided by tectonic activity in the study area. Lineament also shows good inter-relationship among the geomorphic units like denudational hills, residual hill, inselberg, linear ridge, pediplain gullied, alluvium plains, valleys, pediment zones and triangular facets. Geomorphological and structurally controlled faults are reported to be still active with low intensities ranging from 3 to 3.5 magnitude reported at Kollegal taluk. Major, intermediate and minor lineaments and their orientations along with field evidences reveal firm evidences of tectonic scenario especially around BR hill ranges. The general trend of the lineaments (digitized using LISS-III image) implies the regional structural trend and enforcing the genesis of landform characteristics around BRH ranges. The final results of the lineament trend analysis extracted from LISS-III image is apparently correspond well with known regional fold set trends and same local fold set trends.

Acknowledgment

The authors are indepthly acknowledged to Prof. G.S. Gopalkrishna, Chairman; Prof. C. Srikantappa, Emeritus Professor, for thier support in research in this study, DoS in Earth Science, CAS in Precambrian Geology, University of Mysore; Mr. D. Nagesh, MGD, Govt. of Karnataka and UGC-MRP, New Delhi.

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