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Research Article

A GIS BASED CORRELATION BETWEEN LINEAMENTS AND GOLD OCCURRENCES OF RAMAGIRI- PENAKACHERLASCHIST BELT, EASTERN DHARWAR CRATON, INDIA

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ABSTRACT
Gold mineralization is often found in linear tectonic green-stone belts across the world, which can easily be captured from satellite imagery. The mapping of lineament networks in one of such green-stone belt viz., the Ramagiri-Penakacherla Schist Belt (RPSB) in Eastern Dharwar Craton of Southern India provides the basis for correlation analysis of the lineament network in an area of known gold mineralization. The linear features are classified as Type 1 and Type 2 based on their origin. Type 1 structures are primary penetrative structures whereas Type 2 linears are shallow, brittle disjunctive structures or fractures that control drainage system. The attempt made in this paper to relate both Type 1 & 2 linear features with gold occurrences revealed that lineaments of NE-SW, NW-SE, NNE-SSW and WSW-ENE trends within the green-stone lithology will help in proceeding further for exploration. Lineament density indicated that gold mineralisation is associated with high lineament density areas. Results of the analysis indicate definite structural control for gold mineralization in the study area and makes it possible to delimit prospective areas. Probable areas of exploration and prospecting were demarcated in RPSB using this analysis.

Keywords: *Ramagiri- Penakacherla Schist Belt, Lineaments, Gold Occurrences, GIS, EDC*

INTRODUCTION
The term lineament was coined by Hobbs (1904), to describe any linear feature in the earth's surface. The lineaments may be simple or complex and rectilinear or curvilinear. These lineaments are consequence of underground geological structures. Role of remote sensing &GIS in reconnaissance mineral exploration need not be over emphasised. It is a well-known fact that GIS is a handy tool extensively used in decision making in exploration and was developed since the usage of aerial photographs in geology. The data generated from satellite imagery can be analysed using GIS software and inferences can be made pertaining to prognostication of mineral occurrences, thereby can be used as an exploration tool for similar deposits in the region. Among such techniques, lineament analysis is considered as a well-known tool that has been used by many workers in their routine exploration and prospecting. Landsat imagery have been used by many workers to map lineaments in several areas (Onyedim, 2001; Johnpaul, 2013).
The first detailed report of the gold resources of India wasattempted 35 years ago in 1974 by of the Geological Survey of India (Ziauddin and Narayanaswamy, 1974).In general gold mineralization occurs within linear tectonic zones in which relatively high strain magnitudes and available kinematic indicators attest to shearing in transcurrent or thrust systems. The Ramagiri Penakacherla Schist Belt (RPSB) in the Eastern Dharwar Craton (EDC) is one such linear belt where gold occurrences are known since more than a centuryin Indian Geology. These zones contain faulted rocks and discrete ductile shears as well as relatively unreformed megalithons; they are also marked by transposition of roughly parallel stratigraphy with the deformation zone. Many conduits for fluid flow were generated within theselinear zones, dependent on variable competency response to prevailing strain. These dynamic systems evolved to produce several forms of permeability and styles of mineralization in any one location. Permeability induced by structural deformation provided the main access for the hydrothermal fluids which were derived from a source external to the immediate environment of deposition.
Many workers have attempted to characterise different types of lineaments from TM-Landsat imagery to decipher the structural control of gold-quartz veins (Fablo *et al.,* 1996, Chan *et al.,* 2000).The lineaments

may be man-made or natural; the man-made linear features consist of highways, urban boundaries and agricultural farms, whereas, natural lineaments are developed due to geological processes. The natural lineaments may be positive, as strike ridges and dykes, while, the negative includes joints and faults (Leech *et al.*, 2003; Ranganai *et al.*, 2008;Marghany *et al.*, 2010).In recent years several workers have attempted to study this area in relation to gold mineralization and structural control. In RPSB, economically exploitable mineralization, however, occurs mainly in the greenstone belts of RPSB where gold deposits of the eastern greenstone belts are geologically comparable to those of the younger greenstone belts of Canada, Zimbabwe and Australia where the mineralization is associated with quartz carbonate veins often in iron-rich metabasic lithologies. The gold was localized as hydrothermal fluids, originated from early komatiitic and tholeiitic magmas and later injected into suitable dilatent structures (Devaraju *et al.*, 2009).

In this paper, a study on controls on gold occurrences, by linear intrusions, lineaments and other structures with reference to gold occurrences in the RPSB of the EDC and their spatial relationship has been attempted. The linear features are grouped into two broad categories Type 1 and Type 2 comprising penetrative structures like primary fractures, faults, lithological linears, foliations and dikes and brittle disjunctive structures respectively. Based on this geological association, the study aims and focuses on the relationship of lineaments, faults, intrusions to gold occurrences in identifying prospective zones.

STUDY AREA

The area (8045 Sq.Km.) involved in this study is located in the south central part of the EDCcovering the RPSBand is selected by virtue of its potentialgold occurrences in RPSB(Figure 1) falling Survey of India toposheets 57E, F & G, of 1:250K scale.

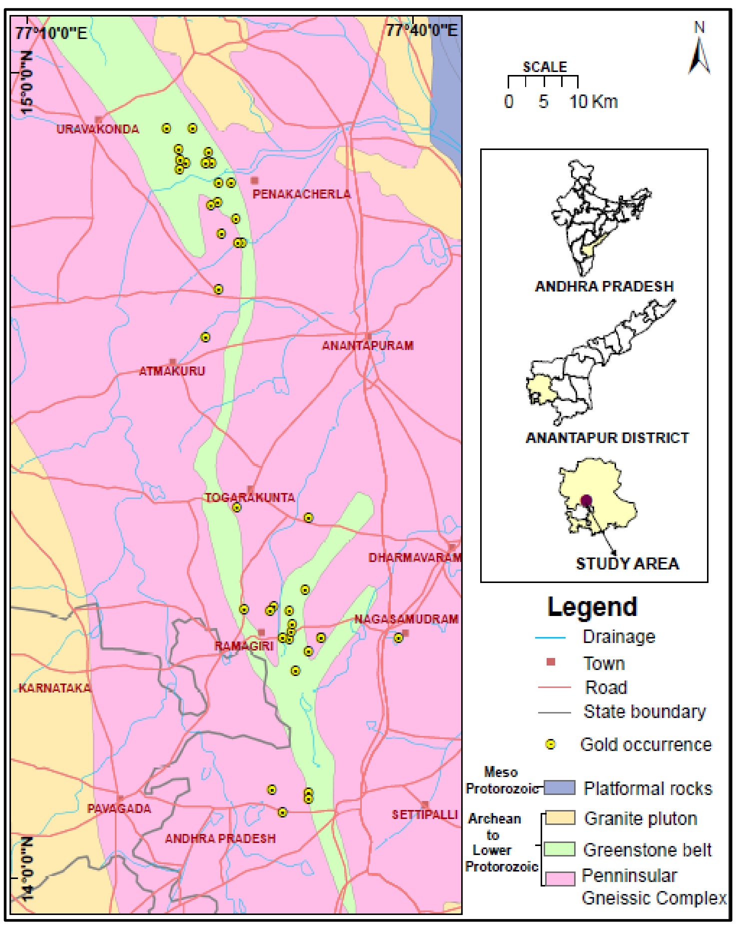

Figure 1: Location of the study area and lithological map

MATERIALS AND METHODS

Geological maps (1:250k) published by the Geological Survey of India (GSI) scale were used to capture various lithological units, lineaments, faults and gold occurrences using ArcGIS 10.1 software.A total of 39 gold locations were captured from GSI maps and used in this study.

Based on the concept of Amaro and Strieder (1994) two types of lineaments are distinguished viz., type 1 and type 2 which are primary and secondary structures respectively. Type 1 group consists of dikes, lineaments faults, foliation and aeromag trends which were interpreted and attributed in the form of different .shp files using Landsat and aeromag (Lakshmi and Babu, 2002)image. Also structural information gathered from available literature was also captured and added to the GIS layers with proper attributes. Type 2 linears were interpreted by using Landsat and SRTM 90 meter DTM imagery. Subsequently the spatial relationship was determined through the selection of the gold locations and its relationship to various structures. Number of gold locations intersect with, their centre within and in defined distances from both Type 1 and 2 lineaments were determined and calculated to percentages. The gold occurrences in majority coincide with the lineaments but some locations exist away from the lineament. Hence a buffer zone of 7 kmwas generated around gold locations, which is assumed to be appropriate. The spatial relationship of gold occurrences toType 1 & 2 linears is determined. Rose diagrams were constructed using open web source tool, GeoRose version 4.0 (*www.yongtechnology.com*). Density maps for Type 1 and Type 2 lineaments with a buffer of 2km were prepared using Global Mapper version 13.2 of *Blue Marble Geographics*.

GEOLOGY AND MINERALIZATION

The RPSB is a part of Ramagiri- Hungund schist belt extending for about 180 km dominantly composed of pillowed basaltic rocks, felsic volcanics, volcanoclastites, BIFs, conglomerates, hornfelsed greywacke and phyllites intruded by ultramafic rocks and younger potassic granites and granodioritestrending NS to NNW-SSE with a varied width of 8 to 200 km (Figure1).On both the sides of this narrow linear belt, mylonite zones mark as margins. Various lithologies of the RPSB comprise pillowed metabasalt, meta-andesite, sheets of gabbro and ultramafics, graphitic phyllites, banded cherty iron formation, felsic volcanics and hornfelsed greywacke. These are intruded by thin sheets of syn to late tectonic potassic granites (Ramakrishnan and Vaidyanathan, 2008). The carbonated and sericitised schistose pillowed metabasalt acts as the favourable host in the Ramagiri Gold Field (Vasudev, 2009).

The Penakacherla sector existing in the northern part of the study area of RPSB shear zone is excellently exposed, enabling a detailed investigation of synorogenic gold mineralisation and its relationship to associated hydrothermal alteration. Metamorphism and deformation under NE–SW compression associated with Archaean subduction processes converted mafic volcanic rocks into amphibolites and intermediate to felsic volcanic rocks into quartz mica schists. Continued compression generated a 50–100-m-wide shear zone complex consisting of mafic phyllonites (Manikyamba, 2004).In RPSB, gold-bearing sulphide occurs in sheared grey to smoky quartz veins (associated with carbonate) emplaced in quartz-chlorite sericite/quartz sericite schist. These are sheared altered products of parent andesitic lava at a late stage of folding where silica was released. The localization of gold is present in the narrow ductile shear zones where sericitization is observed. The first generation quartz fluids which have undergone shearing acted as hosts for gold mineralization. The quartz bodies that formed early and underwent further shearing were favourable to gold emplacement and higher concentration in synclinal portions.The maximum dimensions of ore shoot is in pitch direction which is 45° to 80° N and significant ore-shoots show en-echelon disposition towards dextral side.

In the RPSB, gold mineralisation extends over a length of 15km from Buruju in the north, Ramagiri gold mine in the middle and Jibutil mine in the south. Structurally, the mineralisation iscontrolled by stacked shear zones within phyllites. The total width of the zone comprisingseveral parallel vein systems is 150–200m. The zone comprises quartz veins of three typesviz. (a) White to blue quartz veins, (b) White brecciated quartz veins, and (c) Black brecciated quartz veins, intervened along thin laminae of phyllite. The latter two types are reported to hold much of the gold mineralisation. Individual quartz veins are 30-100m in length and vary in thickness from a few millimeters to 3 metres. About 500m east of the main

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zone, another quartz vein of quartz ankerite association extends for a considerable distance, which is 15–28m wide but no data of gold tenor are known. East of the quartz ankerite zone three bands of gossans occur with a few shallow pits. No details of their gold tenor are known in this zone.

RESULTS AND DISCUSSION

Lineament Capture

Amaro and Strieder (1994) have emphasized that any lineament in imagery have topographic relief and/or associated tonal features which are due to the underground 3D structure in the Earth's crust. In such cases, most of those linear features may be considered as topographic highs or lows when seen in the lightening direction of the image. The patterns and nature of the lineaments are different according to the association of positive, negative or tonal lineaments.In the current study, the lineaments are broadly grouped into two types viz., primary and secondary which are termed as Type 1 & 2 respectively (Figure2A).

The type 1 lineaments are associated to regionally penetrative structures. Such structures develop parallel positive and negative geomorphic features, distributed in linear or curvilinear patterns. Type 1 lineaments can be considered composite lineaments because they are also characterized by a tonal banding related to the lithological component. For the analysis of this kind of lineament, it is important to evaluate parameters such as density, geometric disposition, azimuthal trend and length. The penetrative ductile structures present the best geomorphologic expression of this kind of lineament; however these lineaments can also characterize sedimentary and/or volcanic layers slightly foliated/folded. Lineaments interpreted using aeromagnetic data were also included in this group. As a whole, Type 1 lineaments represent the differential erosion of deep-seated penetrative structural features associated to lithology. These lineaments can model structural forms, faults, folds and shear zones.

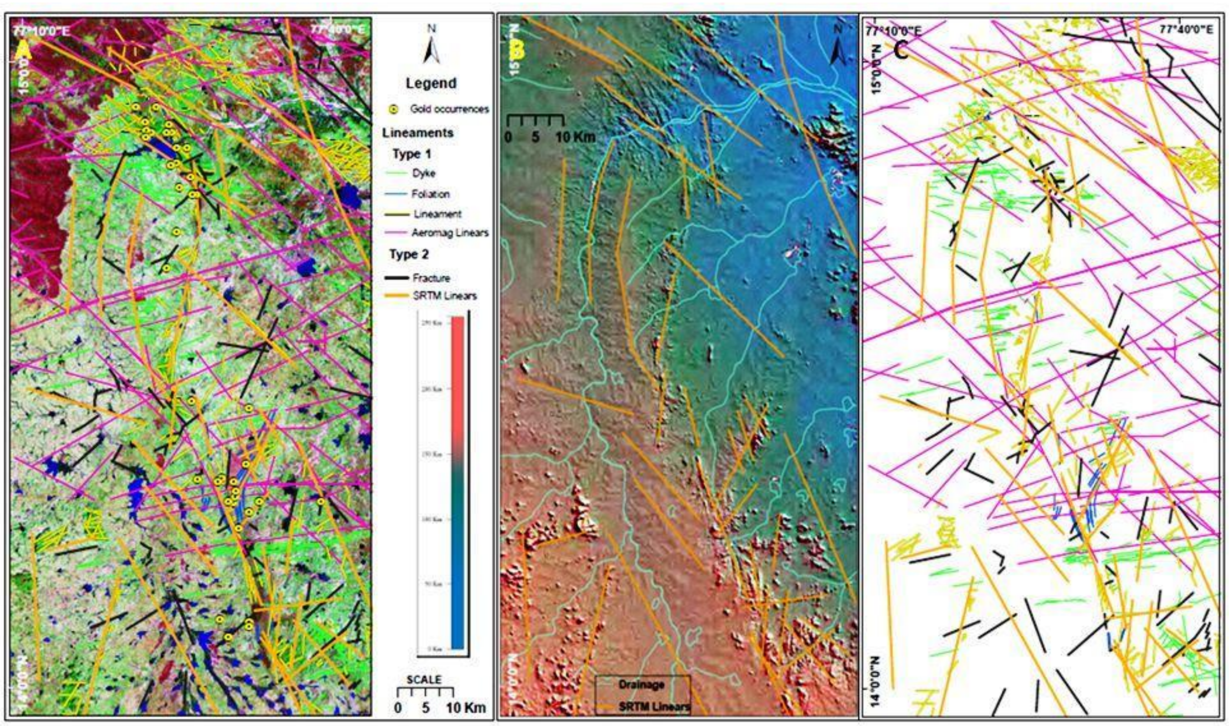

Figure2: (A) Landsat image(A), (B) SRTM 90m DTM and (C) combined map different types of lineaments in the study area

The type 2 lineaments are associated to brittle disjunctive structures which are mainly topographic lows (negative lineaments) which cut across lithological boundaries; this type of lineaments can also develop associated positive and negative features, sometimes with tonal banding, when regarded to brittle-ductile fault zones and represented as fractures. Type2 lineaments are often rectilinear to slightly curvilinear features and control drainage pattern. Type 2 lineaments may be analysed through their spatial distribution pattern, azimuthal trend and length. This group also included lineaments captured using SRTM DEM image as they are attributed to features depicted from differential elevation and linearity (Figure 2A &B).Overall view of all linear features deciphered in this study is shown separately (Figure2C).

A general summary of total number of lineaments with respect to gold occurrence locations is shown in Table 1.The gold occurrence % is high at the intersection of primary lineaments and also in the vicinity of aeromag linears followed by the mafic intrusions.

Table 1: Summary of lineaments vs. gold occurrences in the study area

Feature		Count	Length (m) Min.	Length (m) Max.	Frequency %	Length %	Gold occurrences count (Intersecting & within a 7km buffer)	Gold Occurrence %
Type 1	Lineament	548	0.09	12.61	0.068	0.275	32	82.05
	Fault	49	0.32	56.91	0.006	0.208	3	7.69
	Dike	392	0.07	10.33	0.048	0.212	24	61.54
	Foliation	39	0.43	9.35	0.005	0.033	20	51.28
	Aeromag linear	78	2.33	30.04	0.010	0.024	34	87.18
Type 2	Fracture	132	0.02	16.12	0.016	0.121	30	76.92
	SRTM	21	7.07	49.05	0.003	0.128	34	87.18

Relation between Frequency % and Lineament length

The plots shown in Figure 3(A-E) illustrate the trends of frequency% vs. actual length of Type 1 lineaments. It can be inferred that lineaments of shorter lengths are widely distributed in the study are than the longer lineaments in relation to gold occurrences. However their trends are controlled the major structural trend of the area.

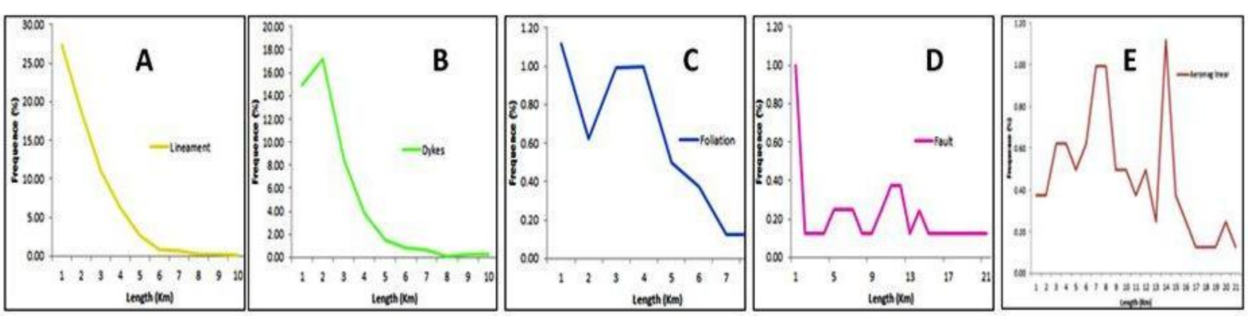

Figure 3:A to E. Relation between actual lineament length and frequency % of Type 1 linears in the study area

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General Trend of Linears

The Type 1 lineaments have a general trend NE-SW, NNE-SSW, NW-SE, EW, ENE-WSW whereas dikes are ENE-WNW, EW, NE-SW trend. The foliation is more or less NS or NNE-SSW, NNW-SSE in majority while NE-SW, NW-SE are also present which follows the trend of major regional structural trend of the area. Faults exhibit NW-SE and ENE-WSW trend whereas aeromag linears exhibit NW-SE and NE-SW and few EW trends (Figure4A-E).

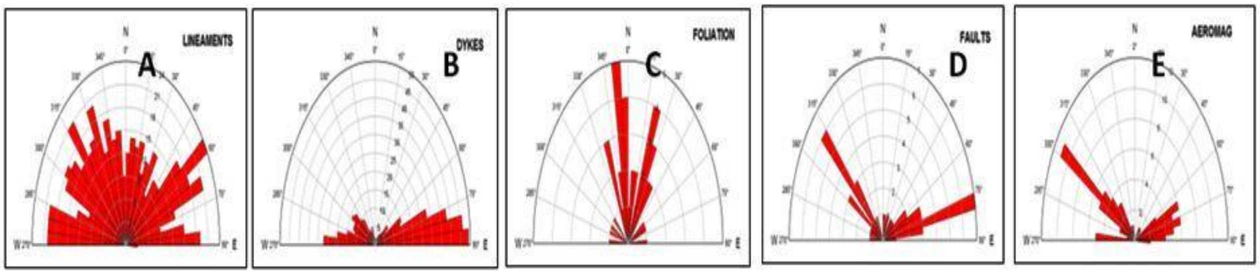

Figure4: Rose diagrams of Type 1 linears (A to E) in the study area

The Type 2 comprises surface fractures and linear features depicted from SRTM image and that are visibly identifiable with a definite course of drainage. The general trend of Type 2 linears is NE-SW to NNE-SSW with minor percentage of NW-SE trend (Figure4). The analysis has shown that drainage follows certain trend and is controlled by structures. It is observed that about 34 gold occurrences coincide with NE-SW and NNE-SSW trend of Type 2 structures(Table 1). Some placer gold occurrences are reported where the Type 2 structural trend mimics the Type 1 linear structure.

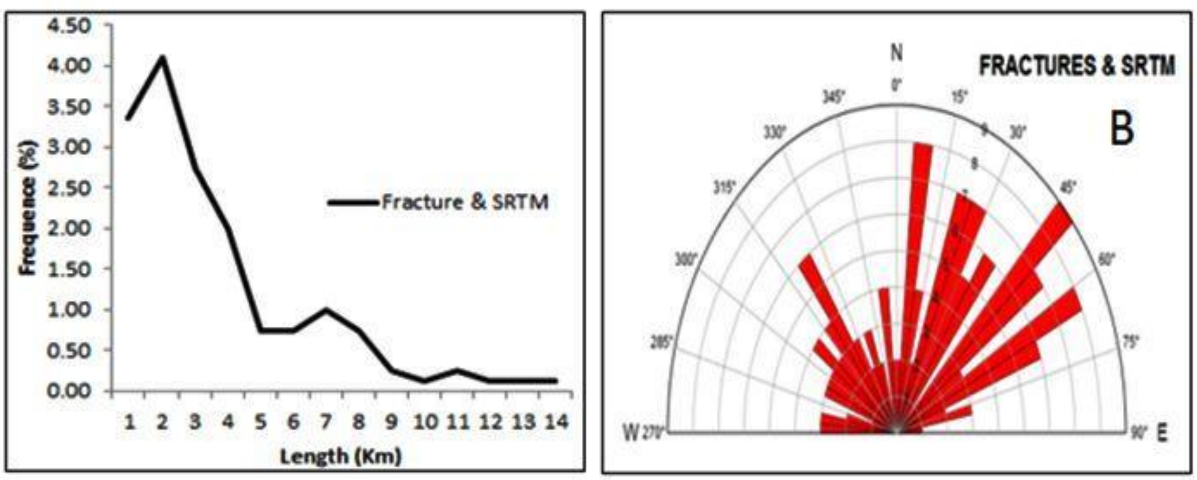

Figure5:A (Left). Relationship between actual lineament length and frequency% B (Right). Rose diagram showing trends of Type 2 linears in the study area

Lithology and Lineaments

All the lineaments captured were counted as per lithological unit also (Figure5). It is observed that lineaments trending NE-SW, NW-SE, NNE-SSW and WSW-ENE directions are prominently distributed. This is well attributed to the general tectonic linear trend in this area. Lithologically, greenstone belt contains moderate number of lineaments however PGC has maximum count due to excessive fracturing and shearing. The foliation trend in greenstone belt shows a roughly NS or more precisely NNE-SSW, NNW-SSE pattern which is attributed to the general trend of schistose rocks in the study area. Younger granitic plutons and platformal rocks in the study area contain minimum number of lineaments.

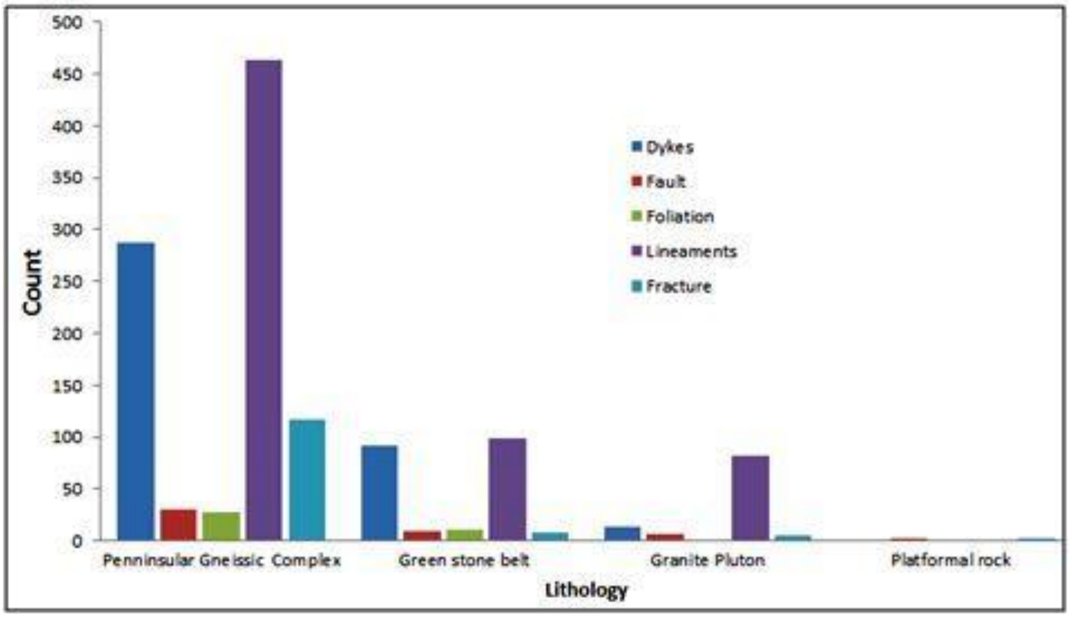

Figure 5: Lineament counts in different lithologies in the study area

Lineaments and their Azimuth

Azimuth of all types of linear features was measured and grouped into eight zones from 0° to 360°. By this comparison, it is observed that Type 1 lineaments of NW-SE, NNW-SSE and NE-SW are very prominent. Mafic intrusions represented by dolerite and amphibolite dikes and faults and aeromag linears trend in NE-SW and NW-SE directions although EW trending dikes are also not uncommon. Trends like ENE-WSW, NNE-SSW are also present.

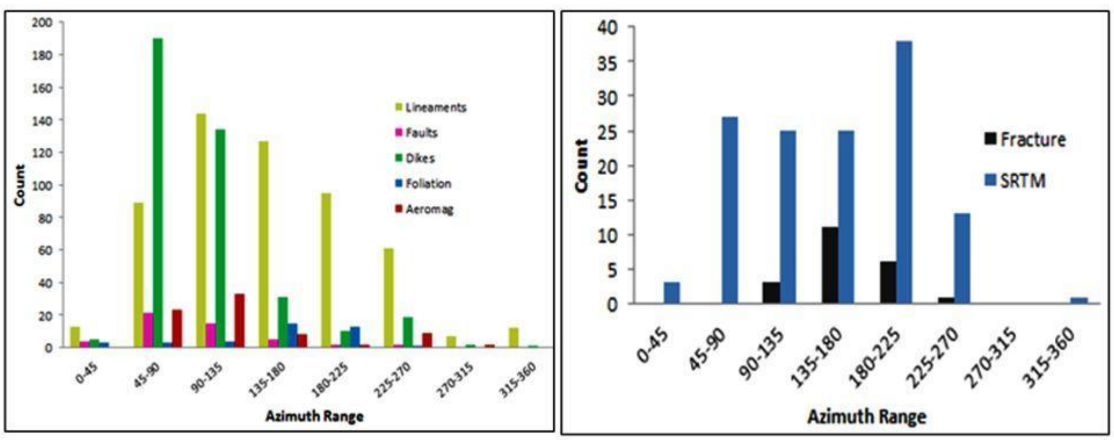

Figure 6: Azimuth ranges for lineaments. Left- Type 1 &Right- Type 2

Lineament Density

This category includes lineaments, faults, foliation trends, dikes, ridges and fractures. From the analysis it is evident that the trends of lineaments have significant control on the gold occurrences. High density areas of Type 1 lineaments are observed to bein close spatial association with the majority of the gold occurrences.In general it is observed that within the schist belt, gold occurrences are present where the lineament density is high. These high lineament areas where no gold occurrences are reported deserve further exploration and hence suggested as prospective areas (Figure7).

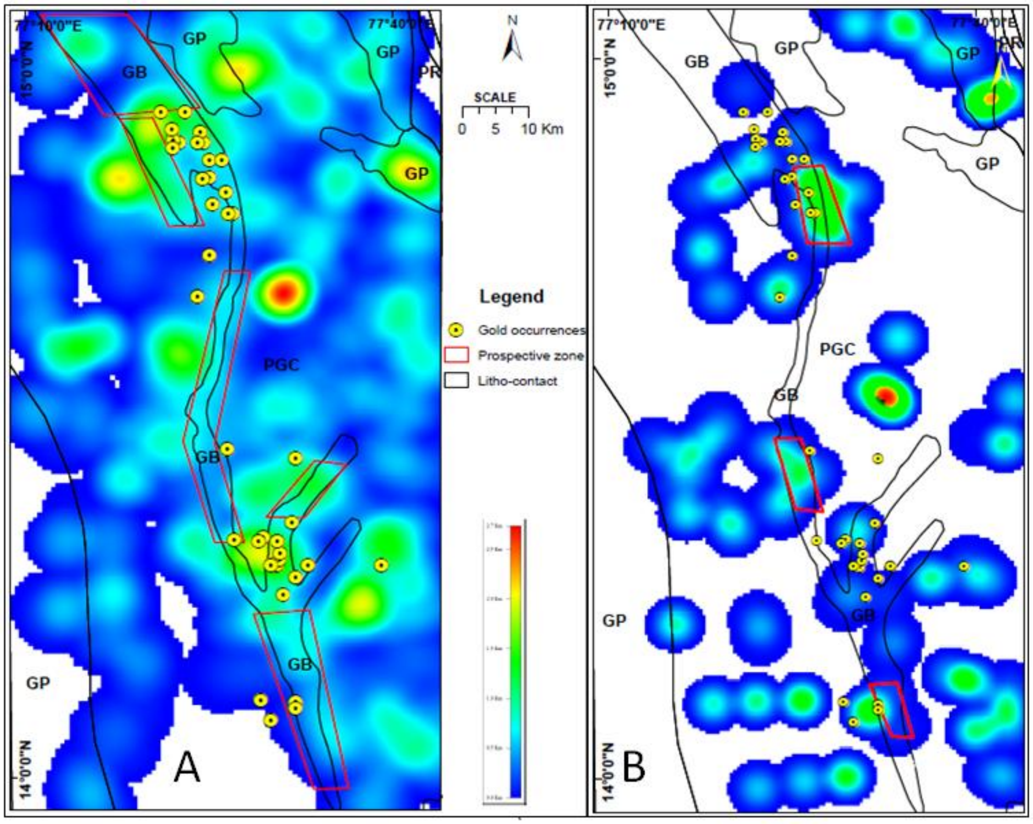

Figure 7: Density plot showing Type 1 & 2 (A & B respectively) lineaments with search radius 2 km.(PGC- Peninsular Gneissic Complex, GB- Greenstone Belt, GP- Granitic Pluton and PR-Platformal Rocks)

Conclusion

An attempt to understand relation between lineaments and gold occurrences in Ramagiri Penakacherla Schist Belt is made in this paper. The knowledge of structural control of greenstone gold mineralization locales initiates with a careful interpretation of lineaments. The discrimination of different lineament types enabled the recognition of regional folds, shear zones and intrusions (Type 1) and also subsidiary fracture zones (Type 2) in the Ramagiri-Penekacherla Schist Belt. Lineament 80% of the 39 gold locations in the study area intersect with or have their centre coinciding with a fault or a lineament. The spatial relationship of intrusions/ dikes with gold occurrences indicated that 60% of gold occurrences exist in the proximity of an intrusion. About 80% of gold occurrences occur in association with Type 2 linears. Also it is observed that within the schist belt, high lineament density zones form locales for gold mineralization. The gold mineralization in the study area can be associated to different trends of Type 1lineaments prominently NE-SW, NS, NW-SE, however a general approximation to locate gold mineralization may not be possible but an analysis in conjunction with other exploration data will lead to successful interpretation.The best way to investigate and to select target are with this kind of technique of exploration is to divide specificstructural domains, with integration of field, advanced statistical tools and geological analysis.

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