An analysis of lineaments and mineral occurrences of Veligallu Schist Belt and surroundings, Eastern Dharwar Craton, India using Remote Sensing & GIS.

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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. Veligallu Schist Belt of the Eastern Dharwar Craton is one such belt which is reported to host gold and tungsten mineralization. The mapping of lineament networks in this green-stone belt in Eastern Dharwar Craton of Southern India provided the basis for correlation analysis of the lineament network in relation to 25 gold and 4 tungsten mineral occurrences. 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 here 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 detailed exploration. Lineament density indicated that mineralization is associated with high density areas. Results of the analysis indicate definite structural control for gold mineralization in the study area and make it possible to delimit prospective areas. Probable areas of exploration and prospecting were demarcated in the study area using this analysis.**

***Keywords*— Veligallu Schist Belt, Lineaments, Gold and Tungsten, GIS, EDC.**

I. Introduction

Remote Sensing & GIS interpretations are significantly cost-effective techniques in mineral exploration programmes. The data interpreted from the satellite imagery is analysed in GIS software environment and an analysis can be made in relation to prognostication of mineral occurrences. It can further be used as a guide for similar deposits in the region by identifying prospective zones. Among such techniques, lineament analysis is a significant tool in mineral exploration that has been used by many workers in the execution of an exploration programme.

The first usage of the term lineament in geology is probably by Hobbs (1904) who defined that lineaments are significant lines of landscape caused by fractures and faults revealing the configuration of the basement rocks [1]. Type and composition of minerals determine the spectral response of the rock type [2], [3]. Satellite imagery exhibit tonal variations and linear features in general show a definite contrast within a background of country rock. Interpretation of lineaments will provide understanding about the structural set-up of the area.

World's greenstone belts like Abitibi, Kolar, Hutti and Kambala host important mineral deposits like Au, PGE, Ni, Cu and hence generated considerable interest among geologists to know the relationship between structural control and occurrence of the ore deposits. The Dharwar Craton of South India is composed largely of plutonic gneisses and several supracrustal belts, commonly referred to as greenstone belts. In general gold deposits occur in these linear tectonic zones in which relatively high strain magnitudes and available kinematic indicators attest to shearing in transcurrent or thrust systems. The Dharwar Craton has been divided into the Western block and the Eastern block differentiated by the zone of steeply dipping Mylonite zone traced along the Chitradurga greenstone belt [4], [5]. Many of the greenstone belts in South India contain gold mineralization and its gold mining history goes back to pre-historic times. The eastern part of Dharwar Craton is dominated by a Neoarchean calc-alkaline complex of juvenile and anatectic granites, granodiorites, monzonites and diorites that are interspersed with greenstone belts formed 2.7 to 2.5 Ga ago [6], [7], [8], [9], [10].These zones contain fault rocks and discrete ductile shears as well as relatively unreformed megalithons; they are also marked by transposition of stratigraphy into rough parallelism with the deformation zone. Within the linear zones, many conduits for fluid flow were generated, dependent on variable competency response to prevailing strain. The systems dynamically evolved and produced permeability forming mineralization loci. Structurally induced permeability provided the main access for the hydrothermal fluids which were derived from a source external to the immediate environment of deposition.

There are several linear greenstone belts occurring to east of Kolar and Hutti in the Eastern Dharwar craton, such as, Gadwal, Kushtagi, Veligallu, and Peddavura greenstone belts. Out of these schist belts, the Veligallu Schist Belt (VSB) of the Eastern Dharwar Craton (EDC) is one such belt where gold occurrences along with scheelite (tungsten ore) occur. Geological Survey of India (GSI) has carried out extensive mapping in this area and identified target areas for gold and polymetallic sulphide mineralisation associated with several shear zones in Banded Iron Formation(BIF) [11]. In this paper, a study on controls by linear intrusions, lineaments and other structures with reference to gold and tungsten occurrences in VSB of the EDC and their spatial relationship has been attempted.

II. STUDY AREA

The study area of 4690 Sq.Km. is selected by virtue of its gold and scheelite occurrence potential in around Veligallu Schist Belt bounded between 14°36'9.57"N 78°14'59.78"E and 13°39'54.36"N 78°41'7.53"E falling in 57J & K SOI 1:250K Toposheets. The VSB lies about 105 km SSW of Ramagiri and 115 km NNE of Kolar (Fig. 1).

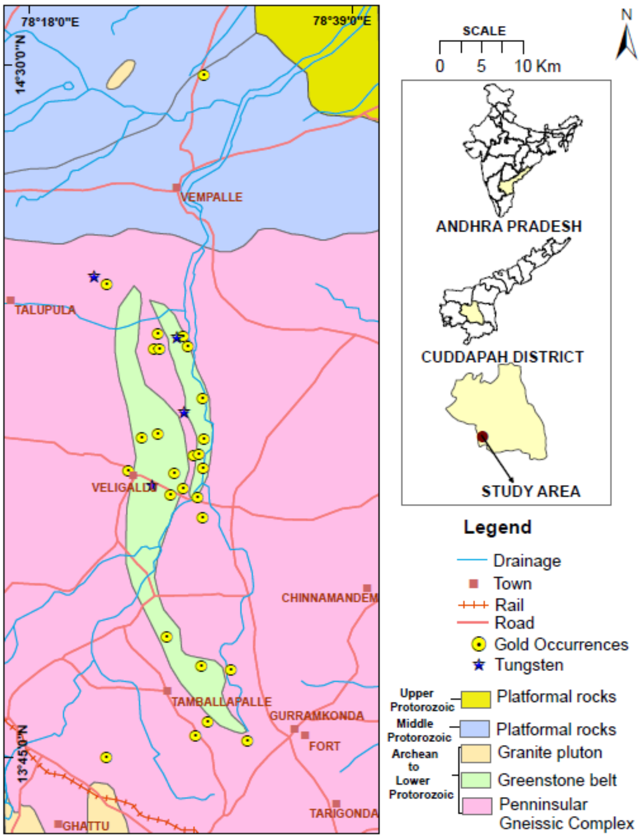

Fig.1 Geological map showing location of the study area. [11], [12], and [13].

III. GEOLOGY AND MINERALIZATION

The VSB is an Achaean greenstone belt on the southern side of the Mesoproterozoic-Neoproterozoic Cuddapah basin extending for a length of 60 km with a width ranging from 6-13 km. The VSB has an approximately NS trend and is exposed over about 60 km in the districts of Chittoor, Anantapur and Kadapa. It consists of a group of volcano-sedimentary rocks with sheared/faulted margins flanked by tonalite-granodiorite-monzodiorite and granite-syenogranite intrusive suites either side. The generalised geological set-up of VSB with rocks classified into three groups viz., the lower Tamballapalli Formation, the Sivapuram Formation and the Mallayakonda Formation is shown in Table 1.

Veligallu Group	Quartz veins	
	Mafic dykes	
	Younger granites	
	-------------- Intrusive contact --------------	
	Mallayyakonda formation	Banded Iron Formation
	Sivapuram Formation	Banded tuff, meta rhyolite, quartzo-felspathic gneiss unit, dacite & volcanic conglomerate
	Tamballapalli Formation	Meta basalt, metapyroxenite, meta ultramafics & metagabbros

Table 1. General geology of the Veligallu Schist Belt [14]

Gold anomalies are reported from Mallayakonda, Tsadukonda, Sivapuram, Tumukunta, Gandimadugu, Merugumulakonda, Erakonda, Gandlapalle, Indukurivaripalle, Marrikommadinne, Kedarekonda. The mineralized zone in VSB is identified by wall rock alterations represented by retrogression of minerals and occurrence of potash in wall rock known as chloritisation and sericitisation. These zones are invariably associated with sulphide minerals like pyrite, pyrrhotite, chalcopyrite, galena and arsenoprite along with carbonatization. Extensive mapping using multidisciplinary studies GSI has identified gold and polymetallic sulphides primarily associated with BIF [11]. In addition to gold occurrences, interestingly the VSB hosts tungsten along with antimony and bismuth which are also indicative of Au mineralization [12]. Of late GSI has reported ~1.29 gm/t of gold in and around Tellakonda, NW part of VSB [15]. Au% ranges from 0.127 to 1.07 g/t. Some private agencies have also recorded alluvial gold and tungsten anomalies in the stream sediment samples (Fig. 2) in this area.

Fig. 2. A. Green-quartz in altered mafic schist where alluvial gold/tungsten anomalies are reported. B. Banded Iron Formation exhibiting surficial gossan [13].

IV. 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 and scheelite occurrences using ArcGIS 10.1 software [12]. A total of 25 gold and 4 tungsten locations in the VSB were captured from GSI maps and used in this study.

Structural interpretation in the present work has been limited to lineament mapping and analysis. Based on the concept of Amaro and Strieder two types of lineaments are distinguished viz., type 1 and type 2 which are primary and secondary structures respectively [16]. Type 1 group consists of dikes, lineaments faults, foliation and aeromag trends which were interpreted and attributed using Landsat image. The magnetic linears are interpreted from aeromagnetic image [17]. Type 2 linears were interpreted by using drainage maps, 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 km was generated around gold locations, which is assumed to be appropriate. Azimuth of linear features was determined using *DefineAngle*, a tool built in-house and rose diagrams were constructed using open web source tool, GeoRose version 4.0. 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.

V. Results and Discussion

A. Lineament extraction

From the analysis it is evident that the trends of lineaments have significant control on the gold occurrences. A preliminary examination of the image reveals several instances of tonal variation along a linear feature suggesting the presence of various lineaments (Fig. 3). 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. Especially NS, NE-SW, EW are major structural trends that are coinciding with the majority of the occurrences. The geometry of contacts depends upon the processes of evolution of the corresponding rocks. Some of the lineaments can be attributed to geological contacts also. Metamorphism at contacts has resulted in alteration of the rocks as can be seen in the deepening of tone at the edges. Observations made from SRTM image also conform to this trend.

Type 1 lineament category includes primary 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. Especially NS, NE-SW, EW, NW-SE are major structural trends that are coinciding with the majority of the gold occurrences.

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 (Fig. 3A & B). Overall view of all linear features deciphered in this study is shown separately (Fig. 3C).

A summary of total number of lineaments with respect to gold occurrences along with length and frequency %, is shown in Table 2. The gold occurrence % is high at the intersection of primary lineaments and also in the vicinity of aeromag linears followed by the mafic intrusions.

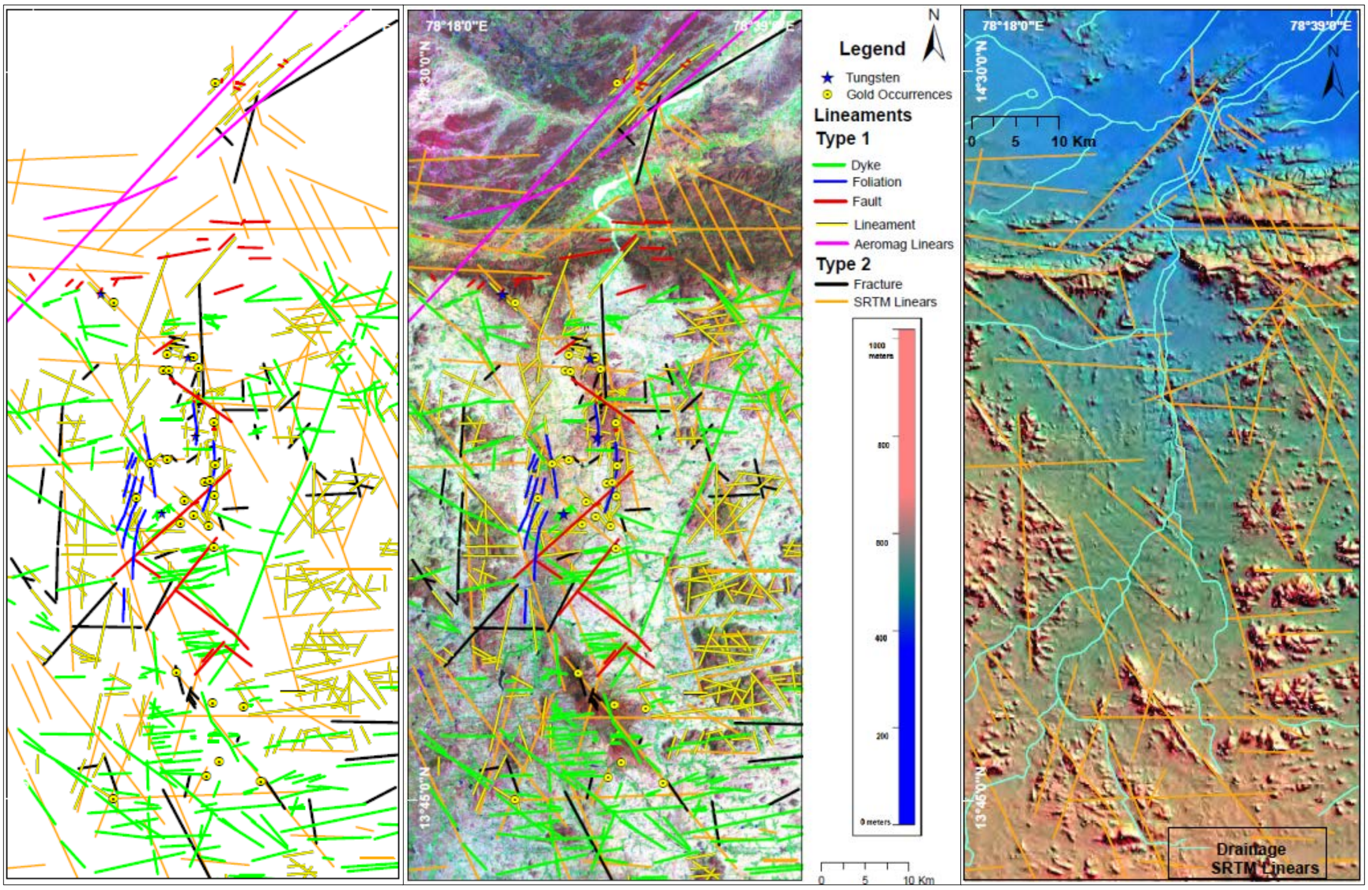

Fig. 3. Lineaments of various types on Landsat image and DTM (SRTM) image in the study area.

TABLE 2: **Summary of lineaments vs. gold and tungsten occurrences in the study area.**

Feature		Count	Length (m)		Frequency%	Length%	Gold occurrences (Intersecting & within a buffer of 7km)	Occurrence %
			Min.	Max.				
Type 1	Lineament	255	0.2	11.3	0.054	0.3	23	85.18
	Fault	44	0.0	35.9	0.009	0.1	4	23.52
	Dike	265	0.3	13.2	0.056	0.3	11	51.85
	Foliation	10	1.2	3.8	0.002	0.0	9	40.74
	Aeromag linear	3	7.1	25.5	0.001	0.0	0	0.02
Type 2	Fracture	68	0.2	19.8	0.014	0.1	18	66.66
	SRTM	50	2.0	27.2	0.011	0.2	21	82.00

B. General trend of linears

The lineaments in the area as inferred from tonal variation are seen to trend in NE-SW, NNE-SSW, NS, ENEWSW, E-W, NW-SE and WNW-ESE directions. Lineaments that fall within the greenstone belt show a concordant relation with the regional Dharwarian trend, i.e., NW-SE, whereas lineaments that fall over the granitoids and biotite granites show both parallel as well as transverse relation, i.e., NW-SE, WNW-ESE, E-W, ENE-WSW and N-S trends. The intrusive bodies i.e., dike have a major trend EW, ENE-WSW and some NW-SE directions. The foliation trend follows the predominant NE-SW trend as in the case of general lineaments. The faults in majority have a NE-SW trend with some trending in EW and NW-SE directions. The aeromag linears show a major NE-SW trend conforming to general Dharwarian trend (Fig. 4 A-E).

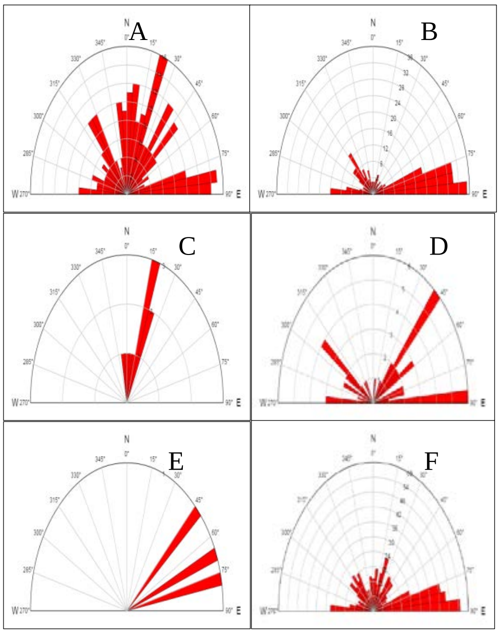

Fig. 4. Type 1 linears, A. Lineaments B. Dykes C. Foliation D. Faults E. Aeromag linears in the study area.

The fractures are widely spread in the strike directions of NS, NW-SE, WNW-ESE, NE-SW and also EW trends. Lineaments captured from SRTM DTM image show a major NW-SE trend. The Type 2 linears in general show a dominant NW-SE trend with a minor NS, EW, NNE-SSW directions (Fig. 5 A-C).

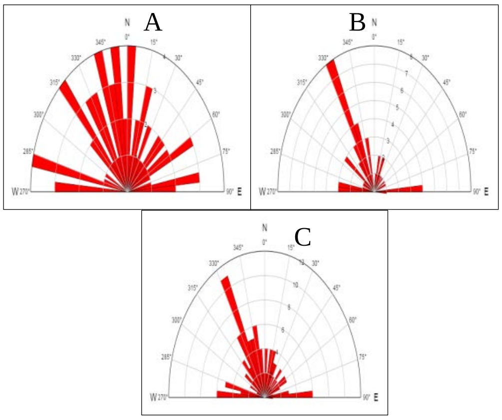

Fig. 5. Trends of Type 2 lineaments A. Fractures B. SRTM and C. both SRTM and Fractures combined)

C. Lithology and lineament distribution

All the lineaments captured were counted as per lithological unit also. Lithologically, greenstone belt contains moderate number of lineaments however PGC has maximum count due to excessive fracturing and shearing. The greenstone belt also has considerably good count of lineaments. No lineaments were captured from upper platformal rocks. The middle platformal rocks have lowest count of lineaments. (Fig. 6).

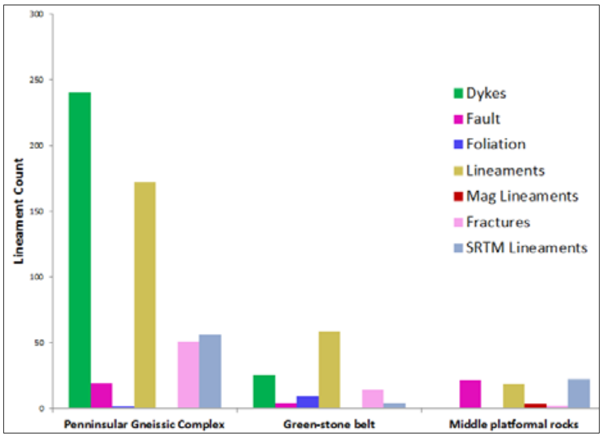

Fig. 6 Lineament counts in different lithologies in the study area.

D. Lineaments and their azimuth

The two types of lineaments were seggregated into different azimuth ranges. It is observed that the major azimuthal trend of Type 1 lineaments is 45o-90o whereas the Type 2 linears range between 135o-180o. The primary Type 1 lineaments conform with the genral Dharwarian trend. The Type 2 linears appear to be structurally influenced by primary lineaments, which is evidenced from sudden deviation of stream courses, abrupt geological contacts and other geological parameters (Fig. 7).

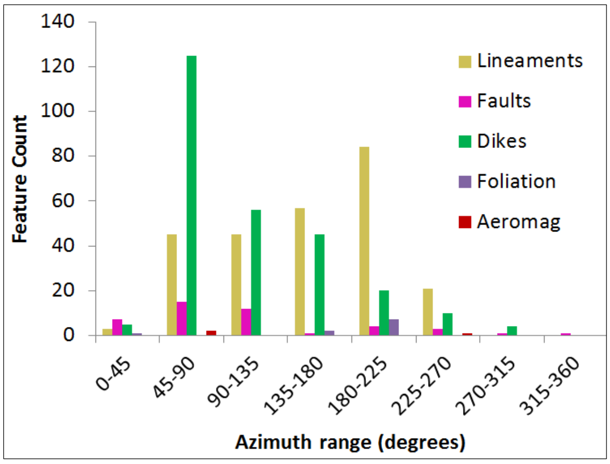

Fig. 7: Azimuth ranges for Type 1 lineaments.

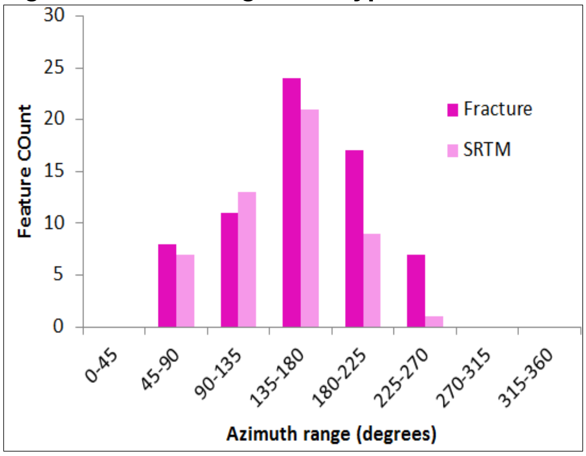

Fig. 7B Azimuth ranges for Type 2 lineaments.

E. Rlation between Frequency% and Lineaments length

The plots shown in Fig.8 (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. General structural lineaments follow the trend of dykes. In other words, the intrusive bodies in the area have influence on general lineament trend in the study area. A similar trend is observed with the fault and Type 2 features (Fig.8F). However their trends are controlled the major structural trend of the area.

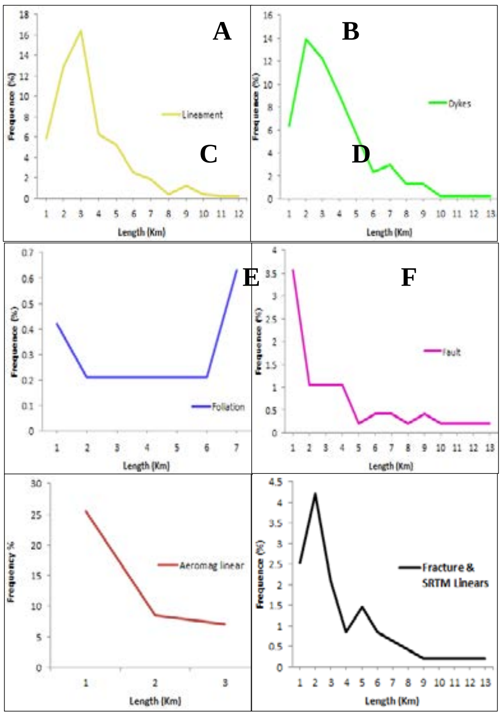

Fig. 8: A to F. Relation between actual lineament length and frequency % of Type 1 & 2 linears in the study area.

F. Lineament density

Lineament density maps based on lineament length and intersections show that schist belt area forms the highly dense area both in terms of Type 1 and 2 linear features.

The lineament density in adjoining granitoids is also high by virtue of intense fracturing and shearing. The highly dense areas where no mineral occurrence was reported were selected as prospective zones.

It is observed that mineralization is more conspicuous in areas where lineament density is high. Also the lineament density is high in the schistose lithology where mineral localization is ubiquitous (Fig. 9).

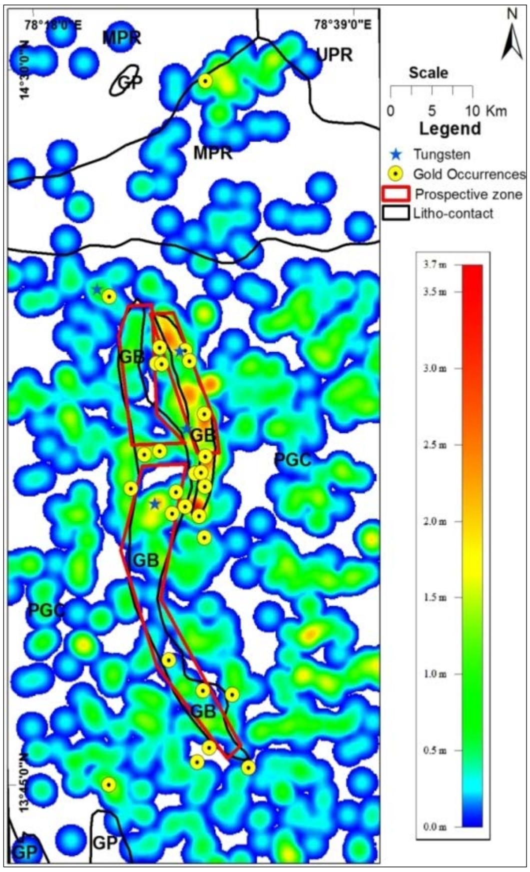

Fig. 9. Lineament density (Type 1 & 2) image showing prospective zones in the study area. MPR- Meso Proeterozoic Platformal Rocks**, UPR-** Upper Proeterozoic Platformal Rocks **GB-** Greenstone Belt **GP-** Granite Pluton**, PGC-** Peninsular Gneissic Complex.

As it is evident, lineament density is high in the schistose lithology which is contributed by regional geological structure and also by natural schistosity, lineations, foliations and other primary structures.

VI. CONCLUSIONS

An attempt is made in this paper, to understand relation between lineaments and gold occurrences in Veligallu Schist Belt where gold and tungsten occurrences are reported. 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 Veligallu Schist Belt. About 85% of the 25 gold and 4 tungsten locations in the study area intersect with or have their centre coinciding with either Type 1 or Type 2 lineaments. The spatial relationship of intrusions/ dikes with gold occurrences indicated that 51% of gold occurrences exist in the proximity of an intrusion. About 74% 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 which are prospective. The gold and tungsten mineralization in the study area can be associated to different trends of Type 1 lineaments 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 more detailed interpretation.

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