Structural Analysis of Airborne Radiometric data for Identification of Kimberlites in Parts of Eastern Dharwar Craton

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Abstract: ***Airborne radiometric data, covering 1933 Sq.km of Mahabubnagar and Gulbarga districts of Telangana and Karnataka states in the Eastern Dharwar craton, India to evaluate the structural configuration of the region. Air-borne radiometric data has been analyzed to identify the surface anomalies pertaining to the lithological characteristics and several lineaments trending in three major directions NE-SW, NW-SE and E-W were well matched with the Aster & Landsat 8 and Airborne magnetic structures, has been integrated and presented in the GIS environment.. The Zones of intersection of these structural trends which could have acted as potential sites for kimberlites emplacement were accordingly delineated at 21 locations (AA1, BB1 to BB5, CC1 to CC2, DD1 to DD2, EE1, FF1, GG1 to GG3, HH1 to HH3 and II1).***

Keywords: Kimberlite emplacement, structural configuration, high-resolution Airborne radiometric survey

1. Introduction

A radiometric survey is the most economical method of understanding a geophysical reconnaissance of any relatively unexplored or inaccessible region. It provides data on a broad scale of structural trends, the occurrence of volcanic rocks within a sedimentary basin. Recent advancements in high-resolution aero-radiometric data acquisition techniques, to identify the earth's surface phenomenon, with the emphasis on mineral exploration, where those minerals show considerable radiometric anomalies.

Radiometric surveys detect and map natural radiometric emanations, called gamma rays, from rocks and soils. At least 20 naturally occurred elements are known to be radioactive [1] (Telford et. al. 1990). All detectable gamma radiation from earth materials come from the natural decay products of only three elements, i.e. uranium, thorium, and potassium. While many naturally occurring elements have radioactive isotopes, only potassium, uranium and thorium decay series, have radioisotopes that produce gamma rays of sufficient energy and intensity to be measured by gamma-ray spectrometry. This is because they are relatively abundant in the natural environment. Average crustal abundances of these elements quoted in the literature are in the range 2-2.5% of K, 2-3 ppm of U and 8-12 ppm of Th. The basic purpose of radiometric surveys is to determine either the absolute or relative amounts of U, Th., and K in the surface rocks and soils. In appropriate areas, when used as a reconnaissance technique for mapping geology and for prospecting, the cost/benefits ratio for airborne radiometric surveying is nearly as good as that for airborne magnetometer surveying.

Recent advancements in high-resolution aero-magnetic and radiometric data acquisition techniques, its data processing and interpretation methods could be able to identify the Earth's subsurface phenomenon, with the emphasis on mineral exploration, where those minerals show considerable magnetic and radiometric anomalies. Correlation and integration of surface expressions of remote sensing spectral behavior along with the airborne radiometric properties of rocks and soil, becoming very promising technique to short-list the area for very high resolution ground surveys as well as for sampling the targeted mineral in reconnaissance stage.

An attempt is made here to obtained Airborne radiometric structures and to find any possible correlation between the kimberlites occurrences and the structural features using the high resolution aeromagnetic and Landsat structural maps of Narayanpet Kimberlite field of the Mahabubnagar district of Telangana state, India.

2. Geology and Tectonics

Geologically, its character is typical falling under Archean – Precambrian Eastern Dharwar craton. The Dharwar craton is considered to consist of two distinct geological sub-cratons, the older western Dharwar craton and the eastern Dharwar craton ([2]Rajamani 1990, [3]Bruce Foote, 1886). The Narayanpet region is characterized by crustal deformation and forms a type area for the eastern sub-craton ([4] Ramadass et al 2006). Where tholeiitic and komatiitic meta- basalts and felsic volcanic formed 2700 million years ago ([5]Balaskirhnan et al 1990, [6]Krogstad et al 1989). The area mainly consists of granite gneiss and granitoid suites of rocks of Archean age associated with older metamorphic/metabolites, namely, pyroxenite, amphibolites, biotite - schists, migmatites and basic dykes of doleritic and gabbroic composition ([7]Ramam and Murthy, 1997). A number of NW-SE, E-W and NE-SW trending intrusive dykes are a geologically distinctive feature of the area.

The geology of Narayanpet area shown in Figure 1 ([8] GSI,2011), north of Krishna River is represented by grey granite and gneiss with minor pink feldspar bands representing the Peninsular Gneissic Complex (PGC). The zone east of Yadgir is marked by metabasis schist's and amphibolites bands within the PGC as basic enclaves Narayanpet Kimberlite Field (NKF) is characterized by two main fracture domains: an E-W trending strike-slip fault associated NE-SW trending fractures in the Maddur-Kotakonda area, and a predominantly E-W trending strike-slip fault set with associated NNW-SSE trending fractures west of Narayanpet. All the known kimberlites of the NKF are located either along the E-W trending faults or at their intersection with the NNW-SSE trending or NE-SW trending fractures ([9] Rao et al. 2001). All the kimberlites of NKF are emplaced into migmatitic gneisses and granitoid.

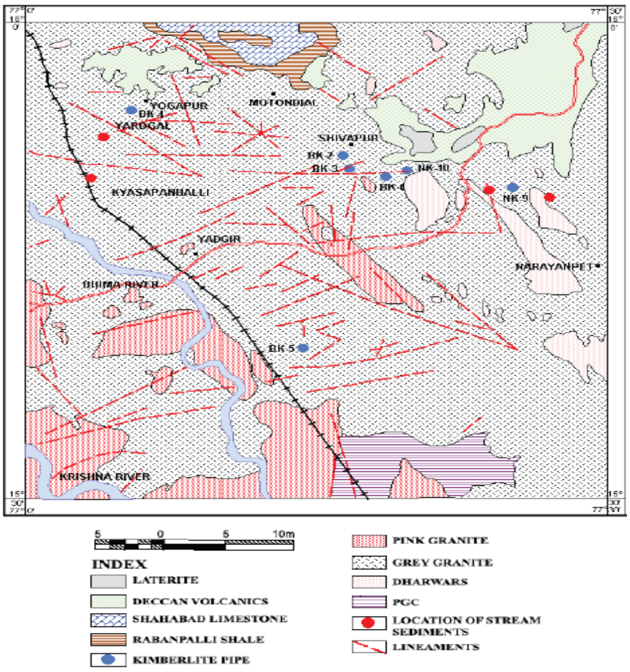

Figure 1: Geological Map showing Narayanpet Kimberlite Field (After GSI 2011)

3. Data Base

Radiometric contour data procured from Airborne Mineral Surveys and Exploration (AMSE) division of Geological Survey of India (GSI). The surveys conducted using Twin Ottar Airborne System (TOASS0 by GSI in 2000-2001 about 12,940 sq.km, the study area lies in-between geographic coordinates of 16o 50' 25"N, 77o 04' 41"E and 16o 29' 39"N, 77o 35' 26"E and falls in parts of the Survey of India (SOI) 1:50,000 scale topo -sheets of 56 H1,2,3,5,6,7,9,10 and 11, collected in the period 2000-2001 with NE-SW oriented flight lines direction and clearance of 120m (AGL), 500m mean flight line spacing. The total area is about 1933 sq km. The Study area covered two towns those are Narayanpet of Telangana and Yadgir of Karnataka (Figure 1), which are well connected with state high-ways to major cities. Spectrometric total count contour interval 250 cps, Potassium data contour interval 0.2 %K, Thorium data contour interval 2 ppm eTh and Uranium data contour interval 2 ppm eU data in the scale of 1:50,000 purchased from Airborne mineral Surveys and Exploration wing (AMSE) of GSI.
Qualitative Analysis

The gamma-ray spectrometry method is widely used in diverse fields. Initially developed as Uranium exploration tool, the application of the method now include geological mapping ([10]Andrson and Nash, 1997, [11]Graham and Bonham-carter, 1993, [12]Jaques et al. 1997,[13]Charbonneau et al. 1997), mineral exploration ([14]Grasty and Shives, 1997, [15]Lo and Pitcher, 1996), soil mapping ([16]Cook et al. 1996), and environmental radiation monitoring. [17]Wilford et al. (1997) demonstrated that airborne gamma-ray spectrometry patterns provided important information for soil, regolith, and geomorphology studies used for land management and mineral exploration decisions. [18]Darnley and Ford (1989) show that, in many situations, gamma-ray spectrometry is probably more useful than any other single airborne geophysical or remote sensing technique in providing information directly interpretable in terms of surface geology.

U, K and Th occur at high concentration in fresh granite soil (white to violet) and in granitic soil where clay layers are close to or exposed at the surface (yellow, pink and white). Highest levels of U and Th (brightest blue/green) denote exposed Ironstone gravel where potassium is low and these colours fade out as the depth of overlying quartz sand increases. However, similarly muted U and Th signaling can emanate from duplex soil developed in highly weathered (K deficient) substrata. Deep sandy duplexes and deep yellow and grey sands of the sand plain show up as brown to black while deep granitic sands (fresh soil) with appreciable quantities of potassium feldspars show up as dark red.

Composite images provide a simultaneous display of up to three parameters on one image and facilitate the correlation and delineation of areas based on subtle differences in numerical values. The following combinations are developed by the USGS [19] (Duval, 1983):

1) The radio element composite image combines the data of K (in red), eTh (in green), and eU (in blue).
2) The potassium composite image combines the data of K (in red), with the ratios K/eTh (in green) and K/eU (in blue).
3) The uranium composite image combines the data of eU (in red) with the ratios eU/eTh (in green) and eU/K (in blue).
4) The thorium composite image combines the data of eTh (in red), with the ratios eTh/eU (in green), and eTh/K (in blue).
5) The radio element ratio composite image combines the data of the three radiometric ratios eU/eTh (in red), eU/K (in green) and eTh/K (in blue).

In the present study granitic rocks with little soil cover could be easily identifiable with high concentrations of K and Th, whereas the same granitic bodies with thick soil cover (derived from Deccan Traps) showing negative anomalies than the granitic terrain. Even greenstone belt (Dharwar schist) is showing moderate anomalies.

All processed radiometric data were analyzed to generate and correlated with geological and spectral interpretation. The radiometric spectral trends are corroborated with magnetic spectral strengths (Figures 2,3 & 4).

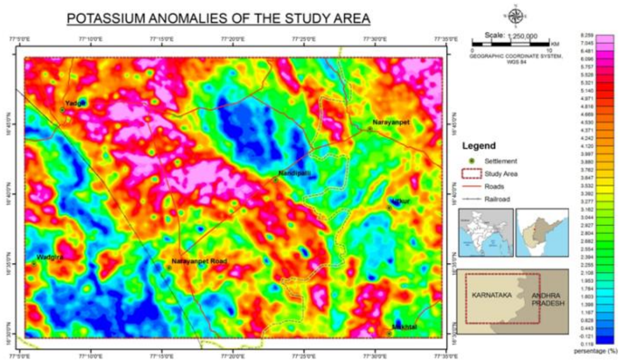

Figure 2: Airborne Radiometric Potassium Anomalies of the Study Area

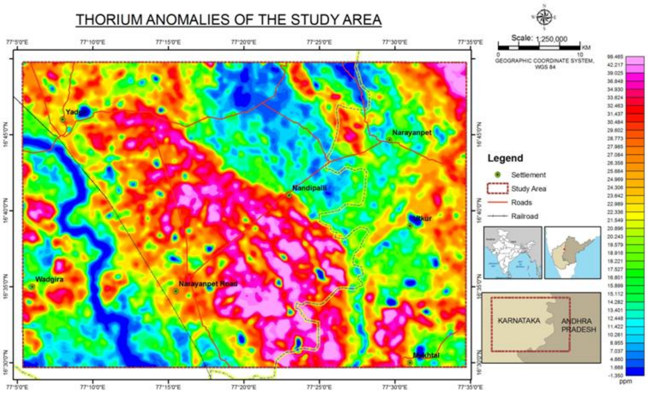

Figure 3: Airborne Radiometric Thorium Anomalies of the Study Area

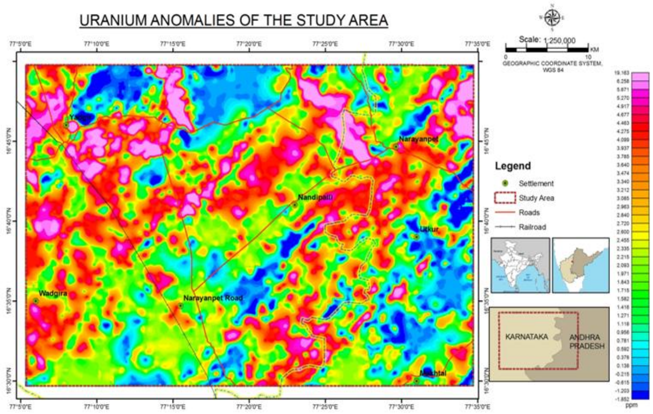

Figure 4: Airborne Radiometric Uranium Anomalies of the Study Area

4. Integration of Radiometric Anomalies

Anomalous radiometric element concentration may be detected by radiometric surveys over the subsurface structures containing radioactive materials. Since a thin cover of soil marks alpha and beta emissions, only gamma radiation is useful in exploration. Most of the gamma rays emanative from the earth's surface originate in the top 30 cm of the earth and it can penetrate appreciable thickness of air without much attenuation and it can be recorded even at 100 m above the ground.

Gamma-rays emitted from the surface will relate to the mineralogy and geochemistry of the bedrock and weathered materials (eg. soils, saprolite, alluvial and colluvial sediments). Weathering modifies the distribution and concentration of radioelements compared to the original bedrock. Understanding the bedrock and regolith responses has proved invaluable for not only mapping regolith materials but also understanding geomorphic processes ([17]Wilford et al. 1997). Fortunately, from a regolith prospective K, Th and U behave quite differently from one another during bedrock weathering and pseudo-genesis. As a general rule, K concentration decreases with increasing weathering. This is because K is highly soluble under most weathering environments and is rapidly leached from a regolith profile. An exception to this is where K is incorporated into potassic clays such as Illite. In contrast, U and Th are associated with resistant minerals and are scavenged by iron oxides in the weathering profile. Therefore, U and Th concentration tends to either stay the same or are preferentially increased in regolith materials or other more soluble minerals area lost in solution.

K, U and Th (Figures 2,3,4) anomalies are correlated with the lithology created using satellite remote sensing methods. Because these two methods are surface expressions. Most of the litho-unit boundaries are matching with the K and Th anomalies with minute deviations. These deviations are common due to K leaching and Th concentration in the soils or regolith. U anomalies are behaving differently and are not aligned with the K and Th anomalies. It might be due to restrictions of GSI, AMSE might have suppressed the U details using high-intensity filters.

[20]Harris (1989) applied a minimum distance-to-mean clustering of gamma ray data. The most informative clusters were derived from 6-dimensional (K, Th, U, U/Th, Th/K and U/K) and 4-demensional (K, Th, U and U/Th) data sets. Spatially continuous clusters with distinct boundaries showed good correlation with the mapped geology. But due to suppression of U anomalies, these clusters are not yielding good results in the study area.

According to [21]Versteeg and Peterson (1997) measurement of the radioelement concentrations from fresh rock samples and drill core clearly showed that the kimberlite could be distinguished from most other igneous rocks (altered and foliated granites, granodiorites, gabbros, rhyolites, lamprophyre dyke, altered mafic dykes) and meta sediments through anomalously high levels of K, U and Th. The unaltered granites show similar levels of those radioelements, but the kimberlite is differentiated through higher Th/K and lower U/K ratios. This phenomenon is unable to correlate in the current studies due to suppression of U anomalies.

In the study area lithology (geology) is matching with the other radiometric data except U anomalies, which are not supportive to correlate (Figures 5,6,7). K and Th anomalies are matching with granitoid (pink and grey granites, migmatites, mixed gneisses) and not showing any significance in Deccan Trap derived soil cover. Moderate in green schist belt. Ratio images are not showing (Figure 8) much significance except K/Th (Figure 9). In general all ratio images are with the combination of U.

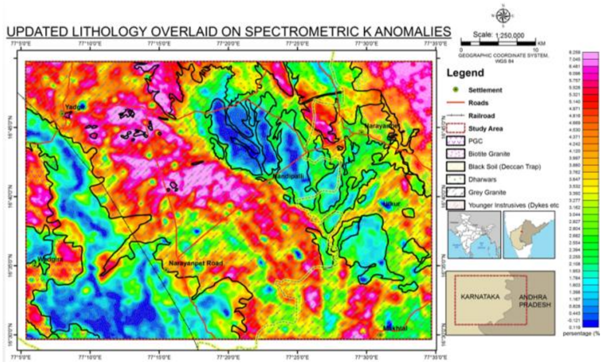

Figure 5: Updated lithology overlaid on spectrometric Potassium Anomalies

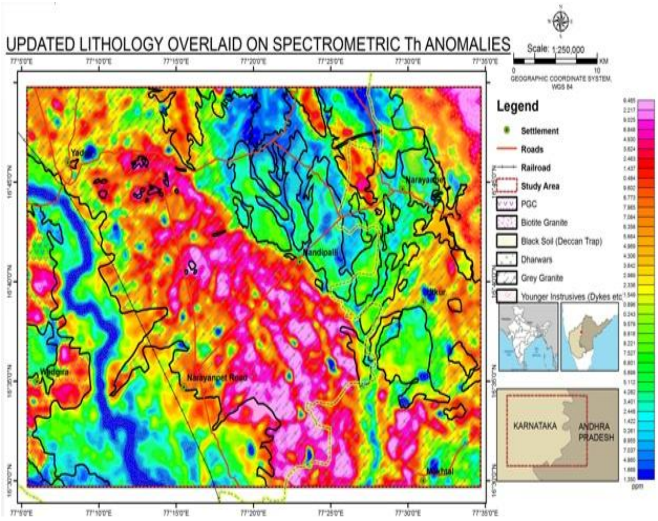

Figure 6: Updated lithology overlaid on spectrometric Thorium Anomalies

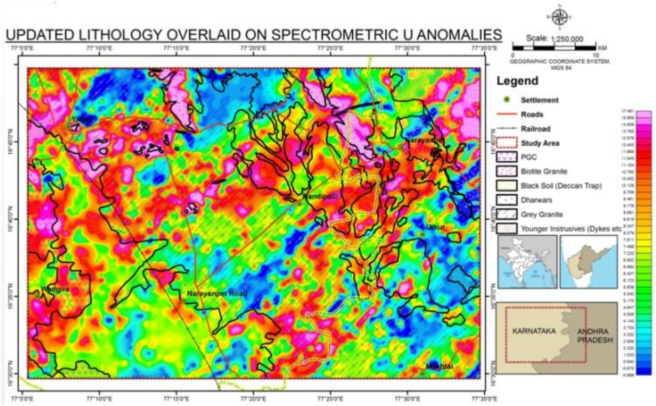

Figure 7: Updated lithology overlaid on spectrometric Uranium Anomalies

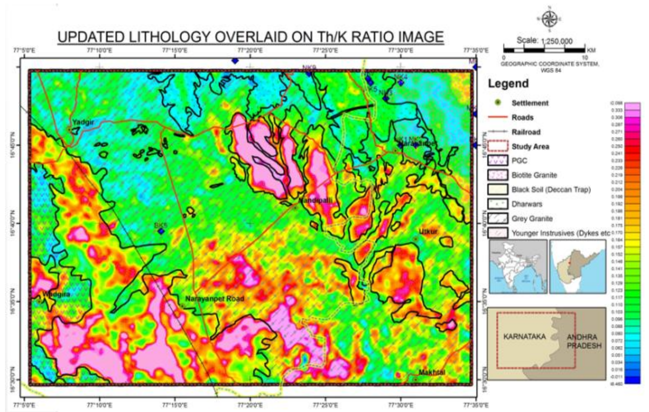

Figure 8: Updated lithology overlaid on Th/ K Ratio Image

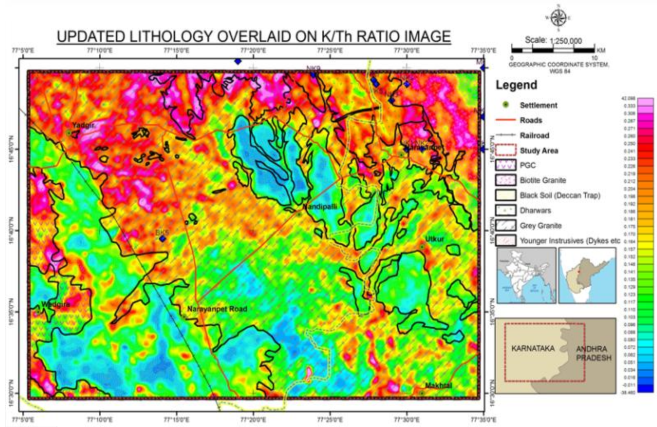

Figure 9: Updated lithology overlaid on K/ Th Ratio Image

5. Ternary Image

Ternary image was prepared using K anomaly image in Red channel, eTh anomaly image in Green channel and eU anomaly in Blue channel. The resultant figure is shown in Figure 10. In this ternary image, dark colors are representing as granites, pink color without any mixed color representing green schist belt and the rest of the dull colored portion representing as soil cover. Based on its depth the color hue is varying throughout the image.

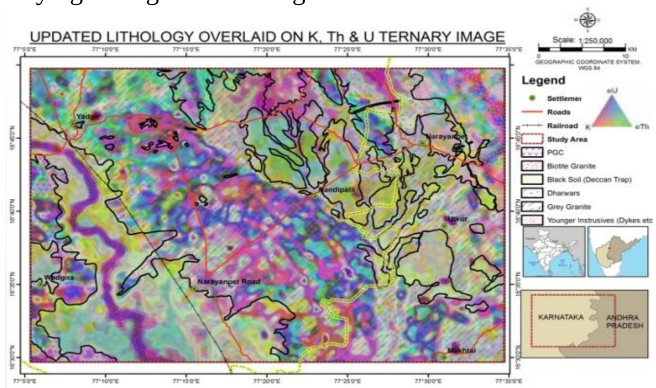

Figure 10: Updated lithology overlaid on K, Th and U in RGB Ternary Image

Measurement of the radioelement concentrations from fresh rock samples and drill core clearly showed that the kimberlite could be distinguished from most other igneous rocks (altered and foliated granites, granodiorites, gabbros, rhyolites

6. Integration in GIS Environment

ASTER and LANDSAT 8 satellite images are used to discriminate the lithological boundaries. Various attempts have been made to do such lithological boundaries using spectral geological methods (is part of satellite remote sensing for geology) like band combinations, band indices/ band ratios, principle component analysis (PCA), minimum noise fraction (MNF), spectral angle mapper (SAM), curve matching etc. in GIS environment. Based on the available geology (Peninsular Gneissic Complex – PGC rocks of Granite Gneisses, Migmatites etc, Dharwar Schists – Amphibolite, Hornblende Schist, Chlorite Schist etc. Pink and Grey Granites as well as younger dykes) all possible attempts have been made to differentiate the litho-units. An attempt has been made for identification of kimberlite indicator minerals like serpentinites, carbonates, phlogopite, saprolite etc as in-situ MgOH rich soil concentrations.

Surface lineaments like joints, fractures, faults etc. also delineated using various spectral geological technics, intersections of these are main source of kimberlite emplacement if those are penetrated into deep-sea.

Qualitative analysis of airborne magnetic data many lineaments have been identified ([22] Subash et al.,2015) in which the probable fault intersections were matching with kimberlite emplacement and shown in prognosticated locations (Figure 11). According to literature, lineaments of the current study area are mainly E-W to WSW-ESE direction strike - slip faults and NW-SE tear faults. Intersections of these faults in the granitic terrain are the focal points for kimberlite emplacement.

More than 30 locations were initially identified and finalized 21 locations, where all these qualitative magnetic analyses have been satisfied along with lithological (spectral geological outputs), surface structures and radiometric data.

Air-borne radiometric data have been matched with the lithology as these radiometric are penetrating only 30 cm on the surface (either in rocks or soil) and it is known as surficial expression. K, Th and Total Radiometric are more or less matching with lithological data derived from satellites, whereas U data could be deformed due to strategic mineral policies of the country.

After intelligent overlay analysis of all the data in GIS environment, prognosticated 21 new kimberlite pipes in the study area. The resultant prognosticated pipe locations are shown in Figure 11. These figure is showing series of overlay analysis and final results.

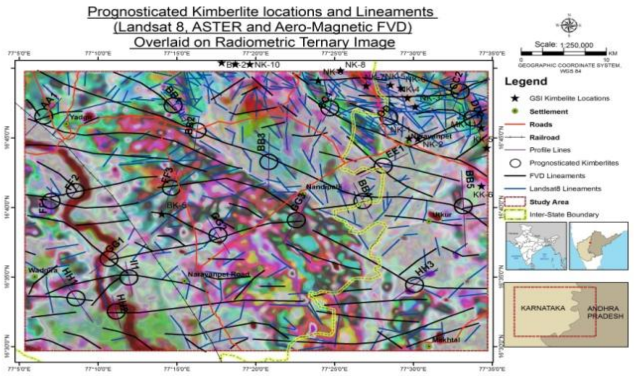

Figure11: Prognosticated Kimberlite locations and lineaments overlaid on Radiometric Ternary image

7. Discussion

A qualitative analysis of airborne radiometric data likes to anticipate the surface structures and rock assemblages, where kimberlites emplacement could be possible. Several magnetic linear features suggesting the presence of various geological lineaments (Figure 2, 3 and 4). Thus lineaments that fall within the migmatite gneisses show a concordant relation with the regional Dharwarian trend, i.e., NW-SE, whereas lineaments that fall over the biotite granites show both parallel as well as transverse relation, i.e., NW-SE, WNW-ESE, E-W, ENE-WSW and N-S trends. Intersecting lineaments from structural locales conducive for emplacement of kimberlites. The region around Maddur, a rich kimberlite field ([23]Nayak et al. 2008, [24]Babu Rao et al. 1992,[25][26] Sreerama Murthy et al. 1997, 1999) is characterized by intersection of a few major and several minor tectonic elements.

Several lineaments criss-crossing and trending in two main directions, NW-SE and E-W are identified. [27]Rao (1996) opines that the regional trend of kimberlite rocks in the Dharwar craton is possibly related to crustal warping and closely related deeply penetrating faults. It is evident that the inferred lineaments are associated with crustal deformation in the region.

The location where the trend changes from NW- SE to NE-SW can be considered as the structural boundary. Another important feature is the absence of NW-SE trends in the region south of Maddur trend is ENE-WSW.

8. Conclusions

Present study of airborne radiometric analysis focuses basically identification and/ or updation of lithological boundaries through various spectral band methods (indicator mineral identification, alteration mapping –like in-situ MgOH soil identification, which are main kimberlite indicator minerals through weathering) using satellite images, where kimberlite assemblages are found. Surficial lineaments (joints, fractures, faults etc) identification and updations through satellite remote sensing is another task to identify twenty-one kimberlites, where these structures and their intersections are the main sources of kimberlitic emplacement.

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