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# Geophysical attributes to evaluate subsurface structural features using ground magnetic data in parts of Karimnagar district, Telangana

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**ABSTRACT**

To decipher both the shallow and deeper features related to Godavari and Kaddam Rivers and the lineaments present in the eastern margin of Deccan Volcanic Province (DVP) in the Indian Precambrian shield, a total field ground magnetic survey was carried out around Jagtial town, Karimnagar district, Telangana. The total field anomaly map based on 653 magnetic observations acquired at 300 m station interval reveals a combination of NE-SW, NNE-SSW and NW-SE trends, which coincide with the trends in the earlier observed aeromagnetic anomaly map of the region. The Reduction-to-pole (RTP) map also reveals lineaments that trend in the NW–SE and NE–SW with varying wavelength and amplitude. From the analysis of magnetic data we have mapped the north-west extension of the Kinnerasani Godavari Fault (KGF). From our observations the Kaddam Lineament Zone (KLZ) has been deciphered to be bounded by the Kaddam Lineament to the north and Kinnerasani Godavari Fault (KGF) to the south forming a small linear basin. Both the Kaddam Lineament and the KGF appear to be deep seated lineaments/faults. Also, the north-west extension of charnockites within the KLZ, which form the basement for the deposition of Proterozoic sediments, have been delineated. Results of the present study detailed in this paper may help to understand better some of the structural features in this region, which had not been ascertained in earlier studies.

**Key words:** Eastern Dharwar Craton, Geophysical attributes, Total Magnetic Field, Ground magnetic data, Kaddam Lineament, Kinnerasani Godavari Fault, Karimnagar Granulite Belt, Deccan Volcanic Province (DVP).

## INTRODUCTION

Peninsular India comprises several cratons surrounded by mobile belts whose geological history dates backs to almost three billion years. The major cratons include the Dharwar and Singhbhum cratons separated from the Bastar craton, respectively by the Godavari and Mahanadi grabens. The NW-SE trending Pranhita-Godavari Gondwana graben marks a zone of recurrent rifting. A belt of high grade granulitic rocks were delineated along the northern and southern shoulders of the Pranhita-Godavari Gondwana graben of which the southern granulitic belt was termed Karimnagar Granulite Belt (KGB) (Rajesham et al., 1993; Acharyya, 1997; Anand and Rajaram, 2003). The Karimnagar Granulite Belt, northern part of the Eastern Dharwar craton, extends for about 150km with an approximate width of 20km. In addition the southern shoulder of the Godavari Graben is also traversed by several NW-SE and NE-SW trending lineaments that may be associated with different tectonic regimes. Among these the ~300km long Kaddam mega lineament (GSI, 2000), which runs NW-SE from Narmada-Tapti up to the Godavari graben is the most prominent. Much of the studies of the KGB and the lineaments, including the Kaddam lineament, are based on surface geology, geochronology and remote sensing data, which provided a fairly good picture of the surface and near surface terrain characterization.

To determine trends, extents, and geometries of structural features magnetic data has successfully been used to interpret the subsurface geology. Earlier studies have attributed various deep crustal anomalies and the asymmetric nature of the geophysical anomalies in the Godavari graben from gravity, magnetic, magnetotelluric and DSS observations (Kaila et al., 1990; Mishra et al., 1987; 1989; Mishra, 2011; Murthy and Babu, 2009; Gokarn et al., 2001; Sarma and Krishna Rao, 2005; Chakravarti et al., 2007; Naganjeneyulu et al., 2010). From the gravity data of the Godavari-Pranahita sub-basin Mishra et al., (1989) opined that the main fault in the northeastern margin of the rift valley stretched up to Bhadrachalam as a sharp gradient has signature in the Bouguer anomaly. From the joint inversion of gravity and magnetic data across the Godavari Basin, Sarma and Kirshna Rao (2005) suggested that the main graben formation is Post-Proterozoic with a maximum thickness of the sediments to be around 7 km. However, the relation of Kaddam fault with the Godavari graben is not ascertained in earlier studies and requires further investigations (Sangode et al., 2013). In the present paper an attempt is made to understand the subsurface continuation and lateral extension of the lineaments in the

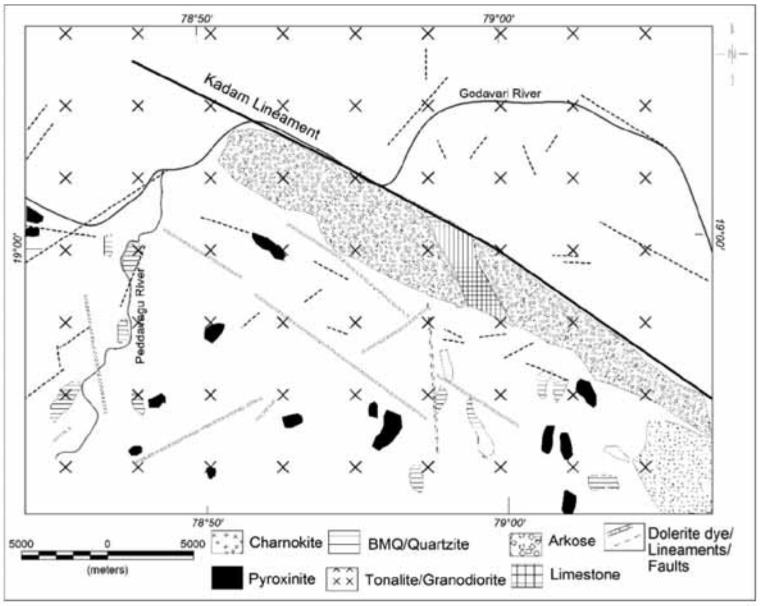



**Figure 1.** Geology and tectonic map in the Godavari Sub-Basin (after Bhuvan, ISRO/NRSC, 2014; http://bhuvan.nrsc.gov.in/gis/thematic/index.php).

region and to extract subsurface lithological information, using magnetic data.

## Geological Set-Up

The area under investigation is located at the boundary of Adilabad and Karimnagar Districts, Telangana State. This area lies in the Eastern Dharwar Craton bordering the Godavari Graben. Figure 1 shows a generalized geologic and tectonic map of the study region (after Som et al., 2010; GSI, 2000; Bhuvan, ISRO/NRSC, 2014). Major part of the region is occupied by Tonalite/Granodiorite suite of acidic rocks belonging to the Proteozoic age. These rocks at places contain enclaves of Archean metasediments represented by Banded Hematite Quartzite (BHQ) (Kameswara Rao, 1989). These metasedimentary enclaves have either a sharp or diffusive boundary with the enveloping granitic (Som et al., 2010) country rock. Arkose and limestones are found along a narrow patch running in a NW-SE direction. The region of study falls under the KGB (Rajesham et al., 1993, Anand and Rajaram, 2003; Rajaram et at, 2000) with the most predominant rock being coarse grained unfoliated charnockites (Santosh et al., 2004).

The KGB rocks are remnants of an Archaean supracrustal granite association, which underwent granulite grade metamorphism around 2.5 Ga. Highly exposed granite-gneisses, charnockites, banded magnetite, quartzite and dolerite dykes, gneisses and basic granulites occupy the eastern sector of the study region (Prakash, 2013). Two major fracture/lineament trends viz. NW-SE and NE-SW are visible in the region. Among these the major NW-SE lineament is the Kaddam Lineament. Sangode et al., (2013) reported that the Kaddam mega-lineament along with its associated structural features caused the Godavari River to change its direction into four sharp bends and finally connecting with the Kaddam River along the Kaddam fault. The Kaddam mega-lineament extending northwest up to the junction of seismically active region of Tapi and Purna faults and to the seismically active region of Bhadrachalam towards the south, is considered to be a neotectonic fault (GSI, 2000). Several NW-SE and NE-SW trending doleritic dykes intrude the area. The area is drained mainly by the Godavari River and its tributaries of which the Peddavagu River flows in the western part of the study region.

## METHODOLOGY

The study area lies between 18°52′ to 19°06′ N latitudes and 78°46′ to 79°06′ E longitudes. The total magnetic field (F) was measured at 653 observation points with an average interval of 300 m (Figure 2) using a Proton Precession Magnetometer of resolution 0.1 nT. Figure 2 is a histogram equalized total intensity (F) crustal anomaly map prepared after removing the main and external fields from the observed magnetic data. IGRF-2015 was utilized to account for the main field at each observation point. For the representation of the external field variations, the magnetograms corresponding to survey period (i.e., date and time) were utilized from the Magnetic Observatory data of IIG, Nagpur.

The analysis of total field magnetic anomalies is complicated as the ambient field direction changes with location and the magnetic anomalies may not directly be placed over the causative bodies (Blakely, 1995). Hence,

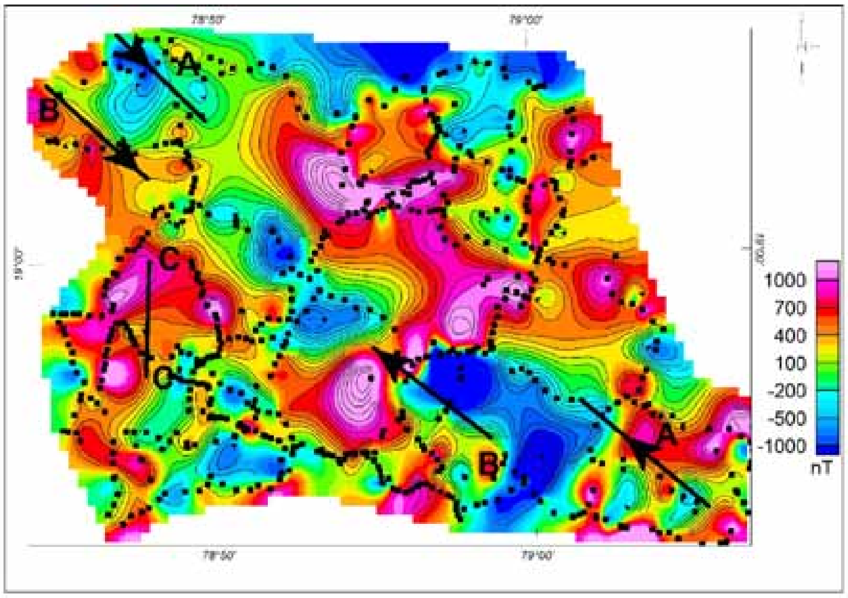



**Figure 2.** Total Magnetic Field Anomaly Map showing the observation locations in the area.

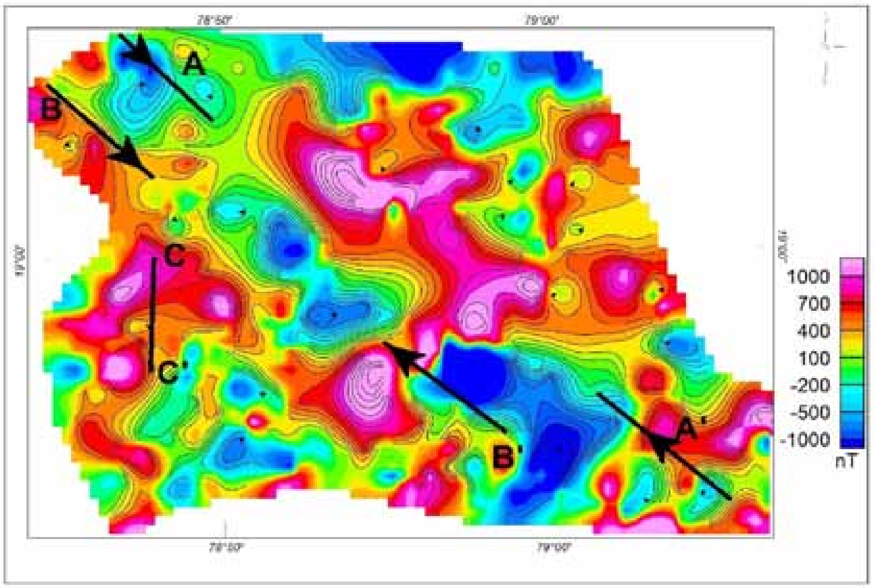



**Figure 3.** Total Magnetic Field Anomaly Map showing the regional attributes in the prominent NW-SE trend and the NS trend.

Reduction-To-Pole (RTP) of the magnetic data was carried out to circumvent the bipolar nature of the anomalies such that the anomalies are placed directly over the source (Silva, 1986). The study area being in low magnetic latitudes, the pseudo-inclination method (MacLeod et. al., 1993; Xiong Li, 2008) has been applied, wherein a pseudo-inclination higher than the actual inclination is specified to suppress the amplitude of the noise along the direction of declination. Since the airborne magnetic data was collected in the entire study region to understand the distribution of magnetic sources in the study region the analytic signal map of airborne data was also utilized.

## RESULTS AND DISCUSSIONS

The magnetic anomaly map shows a combination of varying amplitudes and trends suggesting differing lithologies at varying depths. Based on this different lineaments in NNW-SSE and NW-SE directions with few lineaments trending in NE-SW have been marked in Figure 3. One major lineament (AA′) trending NW-SE, restricting the north-eastern continuation of several minor lineaments, presumably depicts the regional attribute of the Kaddam lineament/fault. Another NW-SE trend BB′ can also be delineated from the anomaly map. A small NS trending

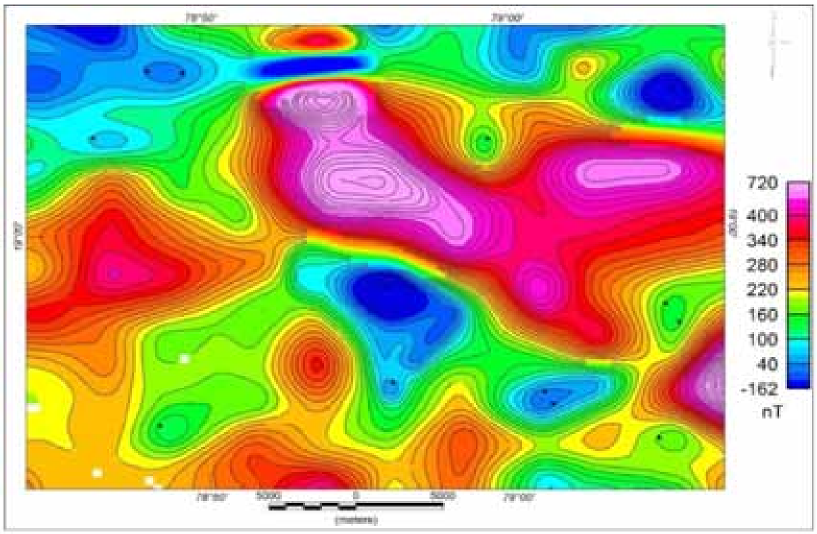



**Figure 4.** Aeromagnetic map of the study area in the Godavari Graben (after GSI, 1995).

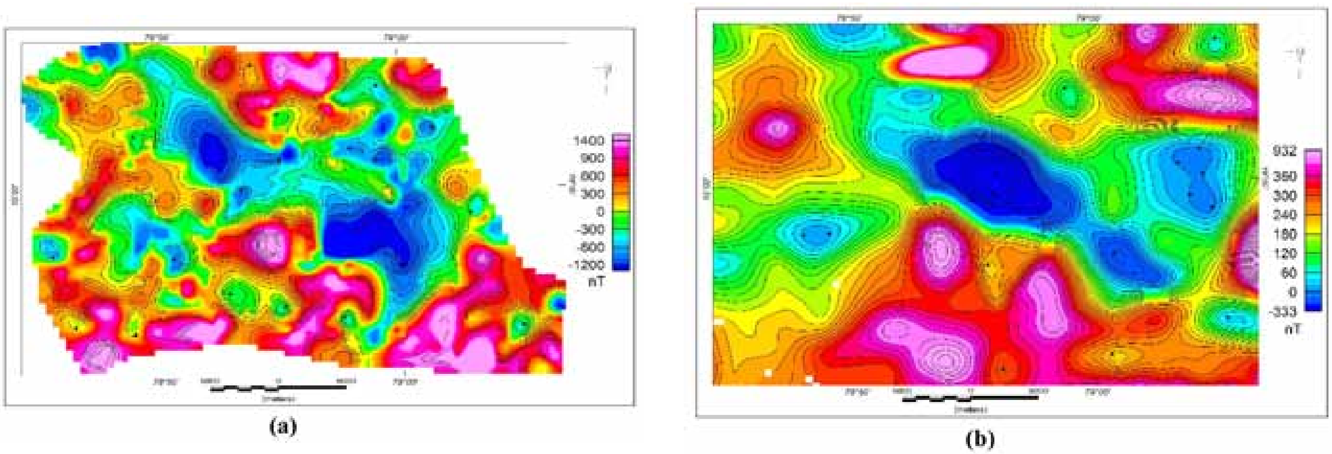



**Figure 5.** RTP Map of (a) ground magnetic data (b) aeromagnetic data.

anomaly (CC′) is observed parallel to River Peddavagu. Several high magnetic closures observed throughout the study area could be due to charnockite/pyroxinite/ sillimanite gneisses.

As the study area is covered by reserved forest, hills and inaccessible terrain, several data gaps of more than few kilometres exist in the ground magnetic coverage. The aeromagnetic data (Figure 4) (GSI, 1995, Rajaram et al., 2006) acquired at 1500 m altitude and with a line spacing of 4km has been utilized to obtain a regional picture of the distribution of the magnetic sources and the lineaments. The total field anomaly map generated after applying necessary corrections is shown in Figure 4 as a histogram equalized colour image. Butterworth low pass filter with cut-off wavelength of 2km is used for removing some high frequency noise in the data. Much of the long wavelength anomalies seen in the ground magnetic anomaly map are reflected in the aeromagnetic data. The lineaments delineated from ground magnetic anomaly map (Figure 3) on aeromagnetic data are also observed. It can be seen that the major lineaments like Kaddam lineament (AA′ and BB′) are well reflected and its continuation from northwest to southeast can be clearly traced in the aeromagnetic map. The ground magnetic data (Figure 3), gives an impression that two NE-SW minor lineaments are restricting the southward extension of the Kaddam lineament. Its extension is visible in the aeromagnetic map suggesting that the minor lineaments are at relatively shallow depth levels. In addition to the lineaments, the aeromagnetic map depicts a high amplitude bipolar anomaly towards the north-central part, which can possibly represent an iron ore body (GSI, 2010).

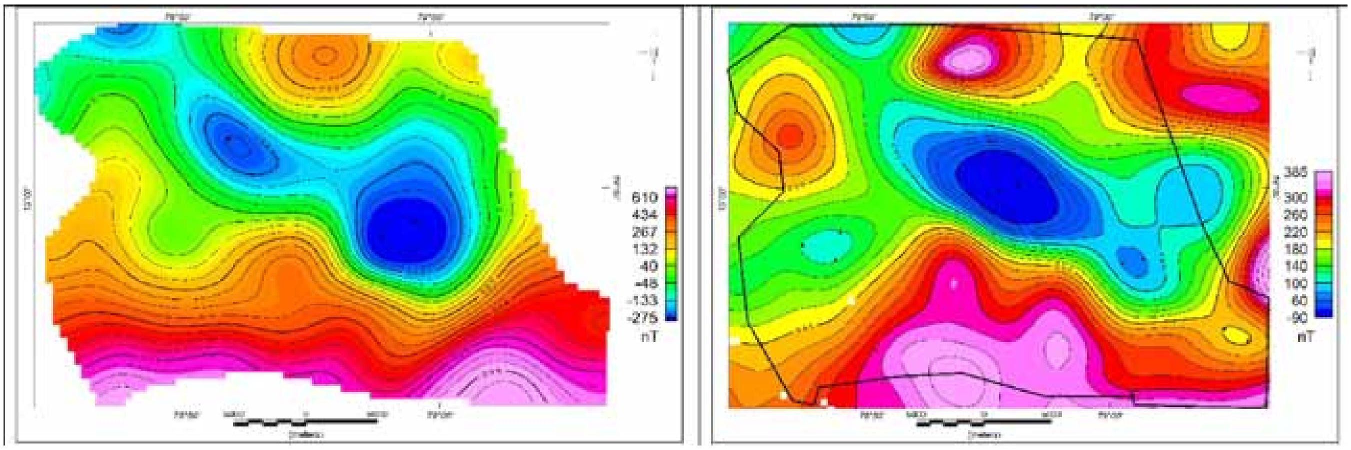
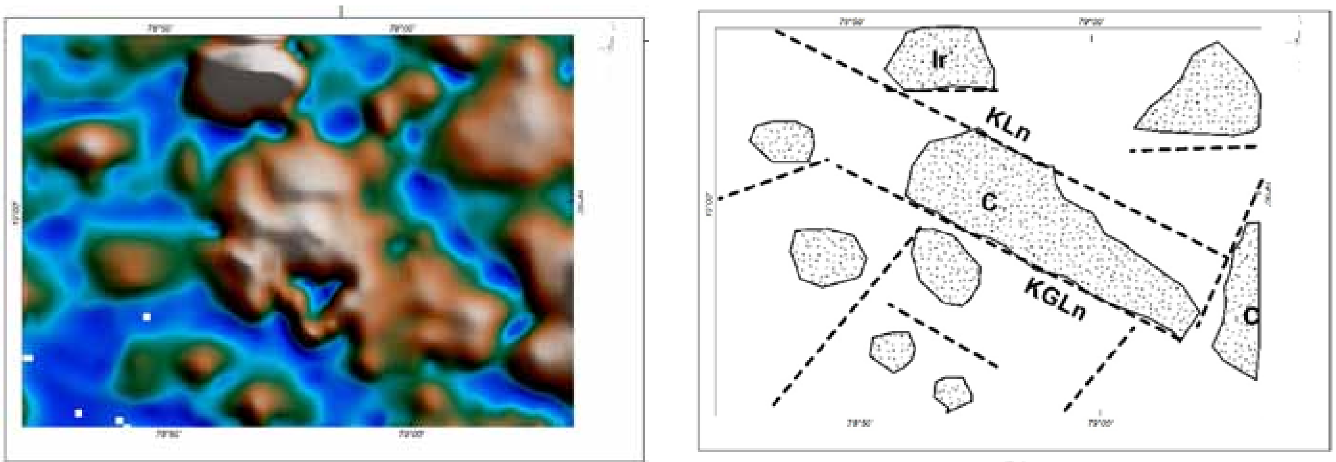



Figure 6. Upward Continued Magnetic Map for 3 km of (a) ground magnetic data (b) aeromagnetic data.




(a) (b)

**Figure 7.** (a) Distribution of (a) magnetic sources (b) major lineaments and rock types.
KLn – Kaddam Lineament; KGLn – Kinnersani Godavari Lineament; C – Charnokites; Ir – Iron ore

The anomalies in the RTP maps (computed from ground magnetic data and aeromagnetic data (Figure 5), using respective inclination and declination of the ambient field depending on the epoch during which data is collected) reveal a combination of NW–SE and NE–SW trends with varying wavelength and amplitude signifying different levels of occurrence of the sources.

A slight shift in the location of anomalies as compared to total field anomaly map can be observed in the RTP map. From Figure 3 the NW-SE trend of Kaddam lineament (AA′) and BB′ is clearly evident as in the RTP map of both ground data and aeromagnetic data. Some of the high frequency closures seen in the ground magnetic RTP map (Figure 5a) may not be visible in the aeromagnetic RTP map (Figure 5b) as the aeromagnetic data was collected at a higher altitude and hence these might have been filtered. The magnetic lows in the RTP map overlie the sedimentary belt of Arkose and Limestone formations. In the RTP map of the ground magnetic data, this low is divided into two distinguished lows but the same appears as single low in the aeromagnetic RTP map. This suggests the possibility of a fault/lithological contact at the shallow level while in the deep it appears as single unit. A bipolar anomaly seen in the central part of the RTP aeromagnetic anomaly map (Figure 5b) depicts the location of mapped magnetite ore (GSI, 2010), as a single magnetic high located over the source.

As the RTP map constitutes anomalies ranging in amplitude as well as wavelength, it is possible to separate out the magnetic anomalies arising from different depth levels. To have an understanding of the deeper sources, the RTP of ground and airborne magnetic data is upward continued to 3km (Figure 6) (Telford et al., 1993). Continuation maps generated can be qualitatively used to construct a structural model of the region. Several high frequency and high amplitude anomalies representing charnockite/pyroxinite/sillimanite gneisses evident in the anomaly map (Figure 3) are absent in this RTP map suggesting they are at shallow depths. As the level of upward continuation increased, the NW-SE trends including the Kaddam lineament, is more prominent suggesting that the basic Precambrian structure in the region under study trends NW-SE representing the regional Dharwar-Bastar-Godavari Graben trends. We have not reproduced the downward continued anomaly maps, as in the study region much of the sources responsible for the magnetic signatures are either exposed or at very shallow levels so that the downward continued maps just reflect high amplitude closures. The analytic signal map of aeromagnetic data (Figure 6a) shows the distribution of magnetic sources in the study region.

It can be seen that most of the sources are either to the south or north of the Kaddam lineament. Higher amplitude maxima suggest strong magnetic carriers in the subsurface.

The NW-SE trend, in accordance with the trend of the Godavari graben and the Dharawar craton, appears to be the dominant trend in the study area as these lineaments are seen at all levels of upward continuation. Minor NE-SW trends can be attributed to faults associated with river (for eg. Peddavagu) and these trends appear to be at shallow levels owing to their absence in the upward continued maps.

From a combination of the anomaly map and its transformation, we have generated an interpreted map showing the delineated lineaments/faults and also the distribution of magnetic sources in the study region (Figure 7), which shows two NW-SE trending lineaments of which the northern one is the Kaddam Fault/Lineament (GSI, 2000). From the present study we have delineated another NW-SE lineament (BB′) south of the mapped Kaddam lineament. The sismo-tectonic map of the Godavari graben and adjoining regions (GSI, 2000) shows a NW-SE fault termed Kinnerasani Godavari Fault (KGF), south of the Kaddam Fault, which lies towards the southeast of the study region. Hence, we conclude that the delineated NW-SE lineament (BB′) is the northwest continuation of the KGF. On comparison with the geology map, it can be seen that all sedimentary rocks including Arkose and limestones are constrained to lie between these two lineaments/faults. We have assigned the nomenclature for this region bounded by Kaddam Lineament and KGF as Kaddam Lineament Zone (KLZ), which probably represents the northward extension of the Pakhal sedimentation. Sangode et al., (2013) extensively studied the Precambrian terrain of Adilabad and Karimnagar districts about the Quaternary reactivation of old fracture system associated with the Kaddam lineament /fault by field studies. Further, the northern and southern extension of the Kaddam lineament is associated with seismically active regions supporting the active tectonic role of the Kaddam Lineament.

From Figure 7b it is clear that the major part of the KLZ is occupied by highly magnetic sources. Charnockite exposures are seen towards the southeast end of the KLF (Figure1). Previous studies including magnetic anomaly interpretation and susceptibility measurements (Ramachandran, 1990, Murthy and Rao, 2001) have shown that Charnockites are highly magnetic. Hence, we infer that the magnetic sources occurring within the Kaddam Lineament Zone is the subsurface continuation of charnockites. It was previously inferred that the linear belt of magnetic sources along the shoulders of the GG, from south of Adilabad to Khammam are exposed and buried charnockites (Anand and Rajaram, 2003) probably forming the basement for the deposition of Proterozoic sediments. From this detailed study, it can be further confirmed and refined that high grade granulitic rocks (Charnockites) occur in patches along the shoulder of Godavari Graben, even though it appears as a continuous belt when the area is looked from a regional perspective. Studies by England and Thompson (1984) have suggested that high-grade metamorphism is related to crustal thickening during a compressive regime. Hence, it appears that a compressive scenario between the Dharwar and Bastar cratons existed in the Precambrain (?) times, which resulted in the exhumation of these high grade granulitic rocks that usually form at high temperature and relatively higher pressure. Laboratory studies (Ramachandran, 1990) revealed that charnockites have undergone retrograde metamorphism and depleted magnetite content. These alterations tend to show low susceptibilities compared to charnockites that have undergone prograde metamorphism. During prograde metamorphism Fe-Ti oxides are produced at the expense of silicate assemblages. Rajaram and Anand (2014) have shown that charnockites that have been affected by intrusives during a later period show up as magnetic sources while those not associated do not show considerable magnetic anomalies. This is due to the fact that magnetic mineralogy (magnetite content) of the protolith that has undergone tectono-thermal alteration due to sporadic younger intrusive tends to increase the magnetite content of the protolith due to prograde metamorphism, thereby increasing the magnetization that can be easily mapped using the aeromagnetic data. There are several intrusives in the form of doleritie dykes, gabbro plutons etc., reported from the study area (Rajesham et al., 1993). Due to these instrusions the high grade metamorphic rocks might have undergone prograde metamorphism in the later periods thereby increasing the magnetite content and susceptibility which are being mapped by the ground and aeromagnetic surveys.

## CONCLUSIONS

Ground magnetic surveys were conducted in the Jagital and Karimnagar Districts, Telangana. These studies have helped to delineate several major and minor faults in the region of which the NW-SE tending Kaddam fault/ lineament is prominent. The north-westward extension of the Kinnerasani Godavari Fault (GSI, 2000) was mapped. From our studies the area bounded by the Kaddam Lineament to the north and Kinnerasani Godavari Fault (KGF) to the south, termed as the Kaddam Lineament Zone (KLZ), is attributed to a small linear basin facilitating deposition of the Proterozoic sediments. The subsurface, north west extension of charnokites within the KLZ forming the basement for the deposition has been marked. Both the Kaddam Lineament and the KGF appear to be deep seated faults. Further, the recent earthquakes in the Bhadrachalam region provide evidence of the seismic activity in this region, suggesting the necessity to monitor the weaker tectonic boundaries in this region.

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## Compliance with Ethical Standards

The authors declare that they have no conflict of interest and adhere to copyright norms.

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"The mineral world is a much more supple and mobile world than could be imagined by the science of the ancients. Vaguely analogous to the metamorphoses of living creatures, there occurs in the most solid rocks, as we now know, perpetual transformation of a mineral species".

*- Pierre Teilhard de Chardin (1881 – 1955) a French idealist philosopher and Jesuit priest*

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"Exploration is really the essence of the human spirit".

*- Frank Borman (1928--) is a retired United States Air Force pilot and NASA astronaut*

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"If you go to work on your goals, your goals will go to work on you. If you go to work on your plan, your plan will go to work on you. Whatever good things we build end up building us".

*- Jim Rohn (1930 – 2009) an American entrepreneur, author and motivational speaker*

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"Exploration is the engine that drives innovation. Innovation drives economic growth. So let's all go exploring".

*Edith Widder (1951--) is an American oceanographer and marine biologist,*

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"I'm a storyteller; that's what exploration really is all about. Going to places where others haven't been and returning to tell a story they haven't heard before".

*- James Cameron (1954--) is a Canadian filmmaker, engineer and philanthropist*

***

"There's a constant tension in climbing, and really all exploration, between pushing yourself into the unknown but trying not to push too far. The best any of us can do is to tread that line carefully".

*- Alex Honnold (1985--) is an American rock climber*