

Delineating Deep Basement Faults in Eastern Dharwar Craton through Systematic Methods of Geophysics and Remote Sensing vis-à-vis the Concerns of Moderate Seismicity

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Abstract

The objective of the study was to analyze the subsurface geological structures as well as the litho-contacts of the study area. An effort was made to analyze the Magnetic anomalies (TMI) as well as the Remote Sensing data for the eastern Dharwar craton to understand the setting of geological structures in the region. The analysis was placed according to the methods of Proton precession magnetometer surveys, Data Interpretations and filtering as well as the Remote Sensing skills. The magnetic susceptibility data understandings gave a considerable response towards the subsurface geology thereby indicating the moderate seismicity in Southern India by delineating underground faults. The exploration of the collected field data verified the assumptions of remote sensing towards the seismicity of the area. The study demonstrates the dominance of hornblende-biotite-genesis, charnokite formation, and Epidotite-hornblende-gneiss and small intrusive granitic/gneissic granites in the Tindivanam region of Tamilnadu. The significance of Geophysical ground magnetic surveys and effective processes of De-convolutions, Analytical signals, and Reduction to pole, Hilbert transformations etc. evidenced the efficiency of Ground magnetic and satellite data in structural variations especially for locating faults. The Geophysical ground magnetic surveys have varied its results from interpretations made to satellite magnetic data by a large extent. The study also emphasise the need of incorporated approaches of geophysics and remote sensing for seismic analysis and can be very helpful in the modern science and technology.

Keywords: Eastern Dharwar craton; Moderate seismicity; Geophysics; Remote sensing; Faults

Introduction

The South Indian shield, previously considered as a stable continental region, has become an area of moderate seismicity. The knowledge of seismicity is essential for assessing the seismic hazard. Moderate earthquakes in Kerala (M 5.0, 2000), Karnataka (M 4.3, 2001) and Tamil Nadu (M 5.5, 2001) in the southern peninsular India have created enough concern to understand the temporal and spatial behavior of seismically-active faults and the nature of recurrence. The recent seismicity has been related to the rejuvenation of activity along some of the zones of weakness. The moderate to high seismicity observed in the South Indian Shield is mainly due to the fault reactivation under a SW-NE oriented compressional stress acting on the Indian Plate [1]. The Dharwar Craton (DC) exposes a large section of Archean continental crust. Formation and the growth of different rock suites of DC appear to have taken place in more than one billion years between 3.6 and 2.5 Ga [2]. The Dharwar Craton is divided into two distinct tectonic blocks: the Western Dharwar Craton (WDC) and Eastern Dharwar Craton (EDC) [3,4]. Swaminath et al. [5] marked an arbitrary boundary between both the blocks parallel to the western margin of Closepet granite, which was subsequently modified to coincide with the Chitradurga boundary fault and confirmed by deep seismic sounding [6] and by Landsat imagery [7]. Among the modern instruments employed for magnetic field measurements in surveys, the most widely used equipment for many years was the proton precession magnetometer [8]. Reynold [9] discussed that magnetic method can be used in locating geological boundaries between magnetically contrasting lithologies including faults, and large-scale geological structures. Gunn and Dentith [10] discussed that magnetic data can be used to identify the extent of the favourable host stratigraphy, folds in the stratigraphy, the location of cross-cutting shears that may control the emplacement of the deposits, and the magnetic anomalies caused by magnetite associated with the

economic minerals. Nwankwo et al. [11] carried out a ground magnetic survey using a digital fluxgate magnetometer, and gradient analysis of the residual magnetics. Fasunwon et al. [12] delineate undifferentiated older granite, gneiss and charnockite. Kayode et al. [13] delineated major subsurface structures that include major and minor faults in Ilesa town in Osun State, Nigeria using proton magnetometer. Landsat ETM image and Landsat ETM+PAN were used to map lineaments in the suru villalge to understand the nature of geological structures [14]. Saraf [15,16] used high spatial and better spectral resolution to recognize deformation structures in Himachal Pradesh having tectonic significance in a better and reliable way. Madani [17,18] utilized digital Landsat TM data for automatic lineament extraction in arid regions of East Gabal Nukra region of south eastern Egypt. Mohanty et al. also used Landsat TM and IRS-1D, LISS III data to visualize and provide structural features of North West Himalaya. The GM survey was selected by considering all the ancillary data to produce the best site for Base station data collection. The work started by taking care of all unusual noise by avoiding all the magnetic elements present around the instrument. The GPS was found very supportive in all the proceedings including the traverse direction.

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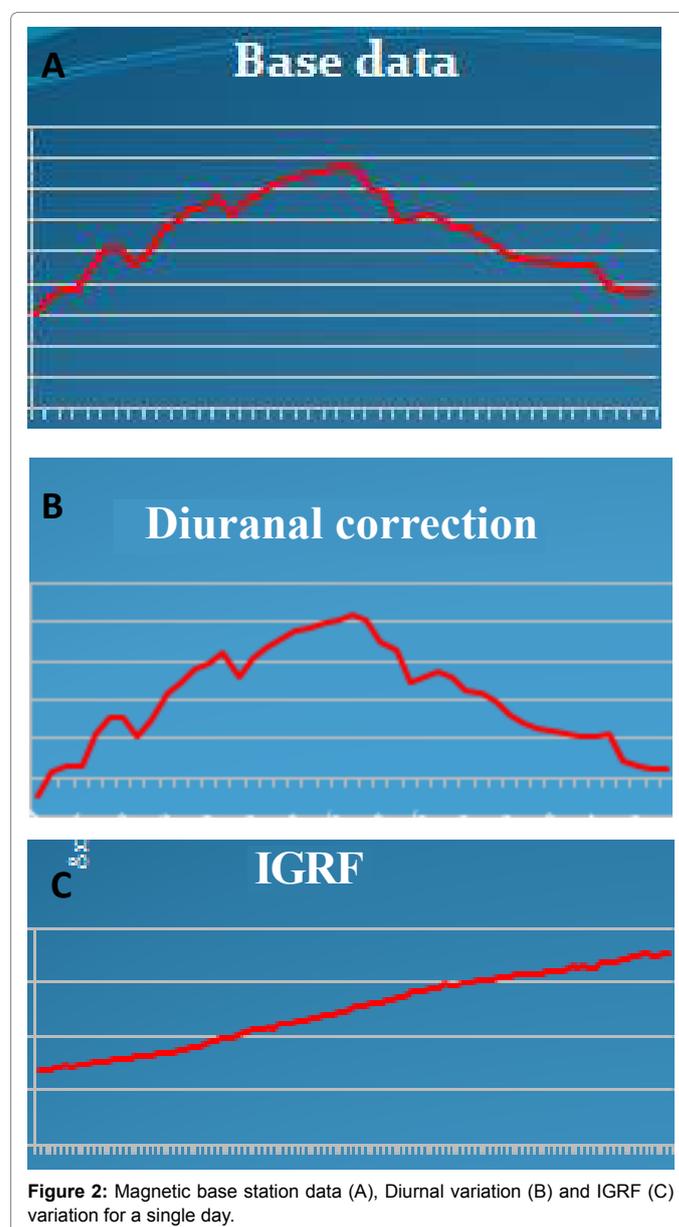
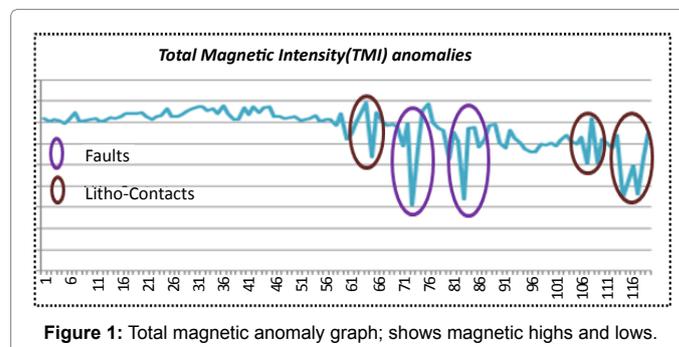
Methods and Objects

The geophysical and remote sensing data techniques and acquisition was performed for the current study. The ground magnetic surveys have been conducted by taking magnetic susceptibility value after every 150 meter interval in a nearly straight traverse. The values derived by magnetometer were considered as total magnetic intensity value (TMI). The base station was set for analyzing the secular variations of the magnetic field. Both the field data and base data given by the instrument were preceded for the underground fault analysis. Further the remote sensing analysis has been brought to satellite imageries to conclude the findings of magnetic anomalies. The presence of fault and other structures are clearly decoded in both the magnetic anomaly as well as the satellite data (ETM, ETM+, LISS III) interpretations to analyze the variation in Total magnetic intensity (TMI) related to structural discrepancy. The ground magnetic data have been collected by two proton procession magnetometers, one at the base station and other for field magnetic measurements. The base station was chosen at a place by taken into consideration the maximum avoidance of noises. The station was placed away from the roads, electrical poles etc., to collect the most actual magnetic values by the magnetometer. The magnetic measurements were taken after every 15 minutes at the base station for the diurnal corrections. The proton precession magnetometer is based on the splitting of nuclear spin states into sub states in the presence of an ambient magnetic field by an amount proportional to the intensity of the field and a proportionality factor (the nuclear gyro magnetic ratio), which depends only on fundamental physical constants. The field survey has been carried by four people as one with sensor of the magnetometer and other carrying rest of the instrument. The third one was carrying a GPS, Brunton compass, camera and a notebook with another one at the base station setup. After the data collection, the Diurnal effect was calculated by plotting the diurnal curves at base stations for each day of data collection. Better results were obtained as the base station was placed close to the survey area. Repeated readings have been taken after about every 15 minutes of the magnetic measurements for the diurnal correction. The international georeferenced fields (IGRF) have been obtained from the satellite data; it removes the strong influence of the main field on the survey data. This is done because the main field is dominantly influenced by the dynamo action in the core and not related to the geology of the upper crust. This is achieved by subtracting a model of the main field from the survey data. The Base station data graph, as well as IGRF graph have been plotted to get the better idea about the regional anomalies. The effective remote sensing techniques were applied for operative interpretations in order to access the visualization of lineaments in the region. ETM, ETM+, LISS III satellite imageries have been interpreted for the lineament extraction for backing the results produced geophysical ground magnetic survey and techniques. The Laplacian and sobel filters were found effective in order to extract the Fault/Lineament map of the Tindivanam town.

Results and Discussion

The magnetic anomaly plotted after fixing diurnal correction and IGRF correction shows interesting results which includes a Fault and other linear features. The Gingee area is dominated by the presence of Epidotite-hornblende-gneiss, which is not showing much variation in the magnetic anomaly that indicates that the magnetic susceptibilities of these two rock types, is almost same. There is a small intrusive granitic body/gneissic granites which are exposed on the surface and the presence fault was evidently visualized in all the graphs generated through effective interpretations (Figure 1) and recommends that these structures have extended to the north.

For the current findings we have mostly operated modern softwares like Geosoft Oasis Montaj and Surfer. The base station data was interpreted and plotted (Figure 2A) and all the unwanted signals have been removed and the Secular variations have been generated for



further interpretations. The data Diurnal variations were plotted in a Grapher to check the variations of each day as shown in Figure 2B. The IGRF (International Geomagnetic reference Field) was extracted from the official site and was plotted in graph for every day to proceed for the findings (Figure 2C).

For effective interpretation of the obtained magnetic data, further enhancements were carried out using various filters and signify De Convolution, vertical derivatives, analytical signal, Reduction to pole etc. Analytical signal filter was applied to the corrected data to emphasize anomalies from shallow sources and an easy detection of the edges of the geological structure in a magnetic anomaly. The processes produced the graph which supported the findings of the survey as shown in Figure 3.

The reduction to the pole (RTP) operation transformed the observed magnetic anomaly in to the anomaly that would have been measured if the magnetization and ambient field were both vertical and was proven momentous in the findings (Figure 4).

The profile plot of analytical signal have been matched with the vertical derivative plots (Figure 5) which is very much correlating with the results thereby indicating the significance of vertical derivate modeling in the current study. The profile shows a trend in the magnetic anomaly and is associated with large magnetic lows paired with small highs, which is indicative of the faulted basement associated with collision tectonics.

EMAG2 was helpful for first order regional geological mapping, as major geologic features can be identified. However, the absence of short to intermediate wavelengths content in the EMAG2 data hinders the interpretation of shallow source anomalies, which requires a high resolution or needs to be spatially well extended (Figure 6). It is evident from the study that the satellite magnetic data was found very inaccurate in terms of detailed fault study.

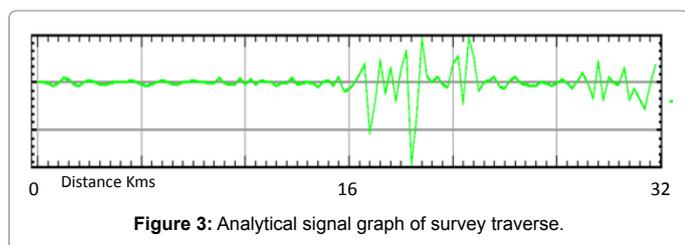


Figure 3: Analytical signal graph of survey traverse.

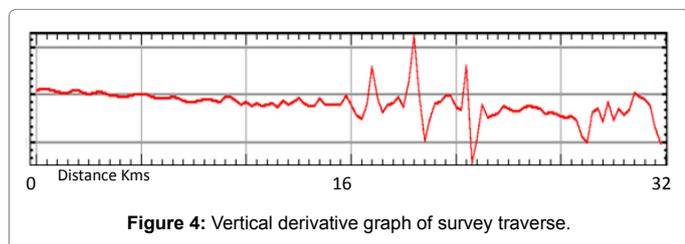


Figure 4: Vertical derivative graph of survey traverse.

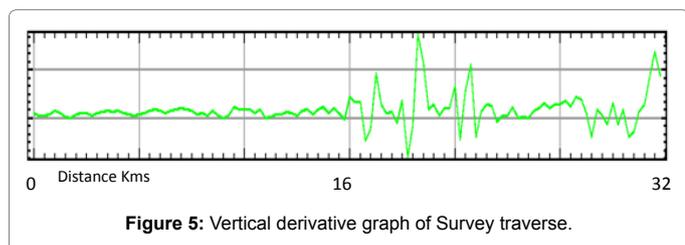


Figure 5: Vertical derivative graph of Survey traverse.

A comparison of topographic, satellite magnetic and Bouguer gravity images maps of south India presented by various satellite data interpretations brings out some interesting results (Figure 7). Shaded relief map of topography clearly shows the regional topography and specific land forms. Dharwar craton, SGT, Eastern Ghat mobile belt and major shear zones, hills and depression in this area are clearly seen. The topographic data has been collected from the available topographic data websites-topex.ucsd.edu and has been gridded to understand the regional topography of south India. The topographic expressions are clearly visible in the map and are self-explanatory. Gravity image necessarily shows the density variations inside the crust and helps in delineating broad geological features and tectonic blocks, but doesn't show very clear indications of major shear zones.

The study further proves the importance of ground magnetic studies which is one of the best geophysical tools to map such variations. This stem from the fact that magnetic observations are obtained relatively easily and cheaply and few corrections only are applied on observations. The analysis to remotely sensed data provides vast information about the different geological features of the area. The ETM data analysis constructed a helpful approach in understanding the results provided through Ground magnetic interpretations. The Visualization extracted faults thereby indicating the presence of structure that has been delineated by magnetic method. The further interpretations to Landsat, LISS III were found significant in identifying the geological structures. The map (Figure 8) generated by remote sensing analysis was coordinated and georeferenced in order to make a future reference of the region.

Conclusion

The knowledge of seismicity is essential for assessing the seismic hazard. The earthquakes in coastal regions of Tamil Nadu and Kerala have invoked special interest to study the coastal seismicity in relation to morphological and tectonic lineaments associated with coastal and near-shore regions of the eastern continental shelf. Understanding the seismicity will throw more light on the neo-tectonic activity within the South Indian shield. The attempt to analyze the seismicity of Tindivanam town by using GM survey and various other geophysical and remote sensing data sets available for south India was to understand how these data sets will bring out valuable information related to structural configuration and density in homogeneities inside the crust. This further proves the importance of ground magnetic studies which is one of the best geophysical tools to map even minor faults/lineaments. The work concludes the significance of integrated approaches for understanding the geological/tectonic setup of any region and also determines its need in modern geosciences. This study proves the efficiency of magnetic data in structural variations especially in locating fault/lineaments and also to identify and establish the

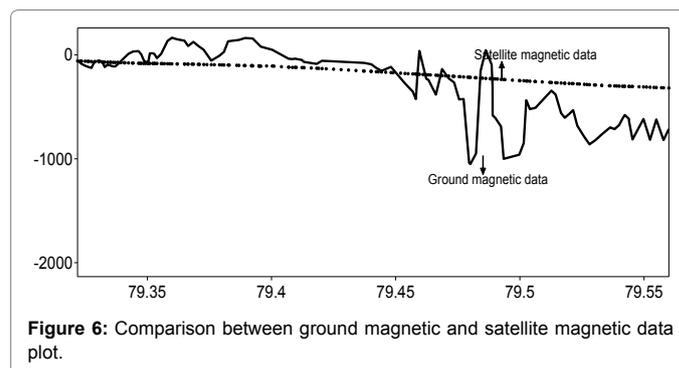
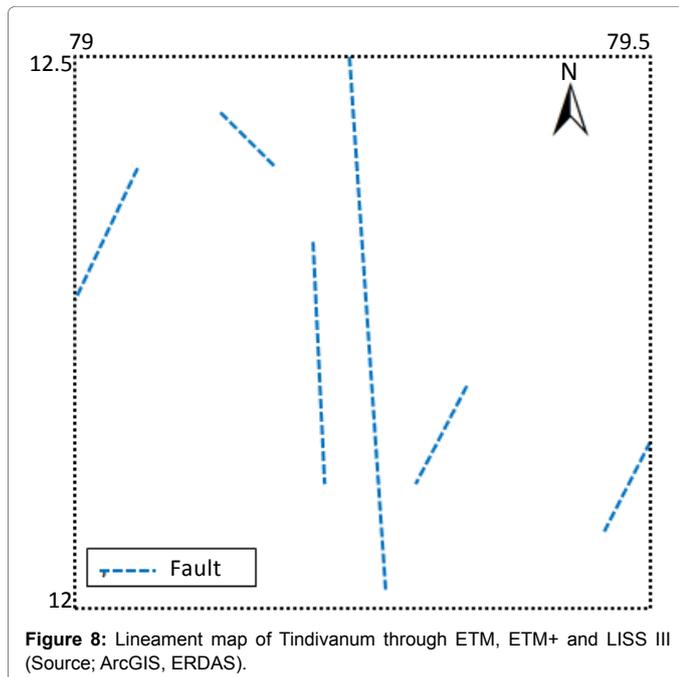
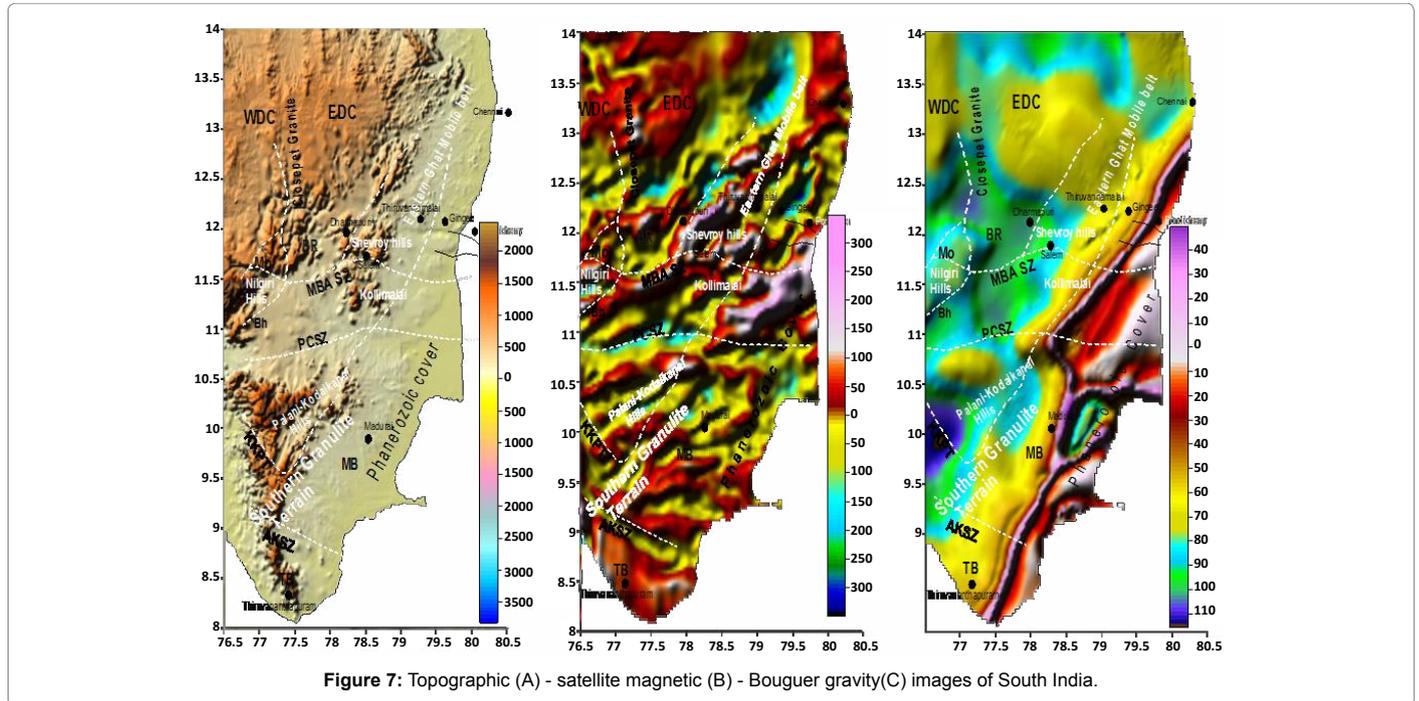


Figure 6: Comparison between ground magnetic and satellite magnetic data plot.



presence of mafic/ultra-mafic dykes. The study also emphasise the need of integrated approaches of geophysics and remote sensing that can be very handful in the modern science and technology.

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