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Application of Geophysical Ground Magnetic Method for the Delineation of Geological Structures: A Study in Parts of Villupuram District, Tamilnadu

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Abstract

The study involves the application and analysis of geophysical ground magnetic method for the detection of geological structures through total magnetic intensity (TMI) and to explain the magnetic anomaly in the parts of Villupuram district of Tamilnadu. Total intensity magnetic data were collected along two parallel traverses using two proton procession magnetometers with sensitivity of 1nT as one for base station and other for traverse. The observations are made at regular intervals and the data are corrected for diurnal variation as well as for the main field using IGRF. Qualitative interpretations of the TMI map, residual magnetic map, vertical derivative map and analytical signal revealed fracture/fault lineaments on the study area trending N-S. The analysis of first profile shows anomalies associated with dyke, fault and litho-contacts. The second profile which is at distance of 6 km from the first profile also shows consistent results and suggesting that the fault/lineaments is extending northwards. The results are highly correlating with the geological information available for the area. The study clearly suggests that magnetic studies can be very well applied to identify and map structural contacts.

Keywords: Total magnetic intensity; Anomaly; Geological structures; Qualitative interpretation

Introduction

The south Indian shield is a composite continental segment, formed by the accretion of the various crustal blocks during the mid-Archean to Neoproterozoic [1,2]. However a unitary model of one continent dissected by steep faults has also been proposed which is consistent with earlier concepts of Fermor. It comprises of Archean granite-greenstone terrain of dharwar craton in the north and the high grade southern granulite terrain in the south. The south Indian shield was considered stable for many million years and is composed of the oldest rocks of the world called Archean rocks and many dyke swarms are recognized in the Archean craton of the Indian. Mafic dykes constitute an important component of any large igneous provinces which can be interpreted as an evidence of continental breakup and remnants of mantle plume related magmatism [3]. Numerous dykes are well exposed in the northern and central part of SGT, but very limited geophysical information is available. The present study aims to provide some geophysical, especially total magnetic intensity data for the parts of Villupuram district in the northern parts of Tamilnadu which falls in Southern granulite terrain. The SGT covers approximately $2{*}10^5$ km^2, which constitute Kerala, Tamilnadu and south parts of Karnataka. Granulite rocks are well exposed throughout SGT, except along the east coast where they are overlain by Mesozoic and tertiary sediments [4].

Study area

The study area lies between latitude Location: 12°00′-12°34′-79°15′-79°45′Longitude (Figure 1.1). From less than 20 meters from M.S.L elevation in the eastern extremity of Top sheet 57 P/12, the topography gradually rises to a maximum of 566 meters in the Pakkam malai reserve forest on the western extremity of top sheet 57 P/8. The study area is dominant of charnockites and gneissic granites which are intersected by faults and mafic dykes, commonly known as black granites. Mafic dykes are intruded in the charnockites and feldspathic gneissic rocks. The general trend of dykes is found to be NW-SE. The nature of the dyke bodies found in around Gingee region also trend NW-SE. The study location falls in the parts of Villupuram district where the morphology changes to pediplain in the central parts and to a hilly terrain in the western side. In the pediplain area, the presences of dykes are marked by boulders, scattered in a linear fashion. In the pediplain and the hilly regions, dykes occur in distinct outcrop and bands respectively. Most parts of the District are covered by a flat plain sloping gently from north to south and from west to east towards the sea. The only hills are the Kalrayan on the southwest bottom, the Gingee hills to the southwest of Gingee. The rivers of the District flow towards the east into the Bay of Bengal. The Gingee River originates in the Gingee taluk, flow past Gingee in the southerly course into the Villupuram taluk [5].

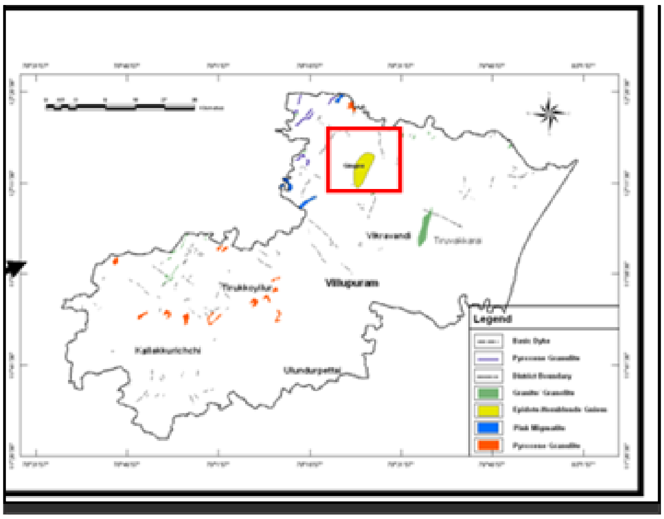

Figure 1.1: Study area.

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Tectonic setting

The southern Indian shield, characterized by several prominent geological and geophysical features, can be divided into three distinct tectonic segments: Western Dharwar craton (WDC), Eastern Dharwar craton (EDC) and Southern Granulite terrain (SGT). With the exception of WDC, the entire crust beneath EDC and SGT has been remobilized several times since their formation during the mid- to late Archeans (3.0–2.5 Ga). In order to understand the evolutionary history of these segments, a multiparametric geological and geophysical study has been made which indicates that the south Indian shield, characterized by a reduced heat flow of 23–38 mW/m^2 has a much thinner (88–163 km) lithosphere compared to 200- 450 km found in other global shields. In the EDC-SGT terrain, high velocity upper crust is underlain by considerably low mantle velocity with a thick high conductive/low velocity zone sandwiched at mid crustal level [4]. The study reveals that the entire EDC region is underlain by granulite facies rocks with a density of about 2.85 to 3.16 g/cm3 at a shallow depth of about 8 km in the southern part and at even shallower depth of about 1 to 2 km below the Hyderabad granitic region in the north. Cratonic mantle lithosphere beneath EDC may contain a highly conductive, anisotropic and hydrous metasomatic zone between the depth of 90 and 105 km where estimated temperatures are in the range of 850–975°C. It is likely that before the early Proterozoic, the entire south Indian shield was a coherent crustal block which subsequently got segmented due to persistent plume-induced episodic thermal reactivations during the last 2.7 Ga. These reactivations led to self-destruction of cratonic roots giving rise to negative buoyancy at deeper levels which may have been responsible for crustal remobilisations, followed by regional uplifting and erosion of once substantially thick greenstone belts. Consequently, the crustal column beneath the EDC has become highly evolved and now corresponds closely to SGT at depth [6].

Methodology

We have used various data sets and different software's for the critical analysis of the structural variations of southeast India. The work was based on the intense ground magnetic survey, collection of all available geophysical data such as Bouguer gravity data and satellite magnetic data and available geological information as well as the appropriate software and other digital work. The various data used for the present were:

•Satellite magnetic data

•Bouguer anomaly data

•Ground magnetic data

The much supportive information has been collected by the existing geological maps of the study area zone. The maps were georefrenced and digitized to get the proper geological information's and locations of lithology variations , structure and other related study so as to approach the most accurate results from the study. Various software's such as Oasis montaj, surfer, Grapher and excel has been used to accomplish the work.

Results and Discussion

The satellite magnetic image map prepared brings out some regional characteristics of the Peninsular India. The region between the line of change of facies and the Palghat - Cauvery shear zone exhibits east- west trending alternate highs and lows. This striking contrast in gradients across the Moyar - Bhavani shear system is indicative of a change in the magnetic sources. The Bhavali lineament, the Moyar fault and the Salem-Attur fault appear as a single system as evidenced from the anomalies. South of the Palghat Cauvery shear again there is a change in trend of the anomalies and south west of the Achankovil shear, there is a magnetic anomaly high over the Khondalite belts. To the east of the Attur fault, is the large magnetic high also associated with the Ariyalur gravity high. The major faults in the region are more or less evident in the map implying that these mark the contact of different lithologic units, intrusives etc. Also evident is the Closepet granite that separates the eastern and western blocks of Dharwar craton. It appears that the susceptibility contrast between granites and gneisses of Dharwar are not very large. The Cauvery basin is marked by a broad wavelength magnetic low.

The Bouguer anomaly map of south India also brings out some regional features. The coastal sedimentary basin areas and the Eastern Ghat mobile belts depict gravity high values suggesting high density material in the sub-surface. Dharwar Craton shows predominantly gravity low. The low density Closepet granite is can be seen in between the WDC and EDC, which shows a comparatively higher anomaly. Gravity lows are generally due to Granitic intrusions and thickening of crust. The gravity anomalies over the southern granulite terrain shows the anomaly shows considerable variation over the charnockites themselves. There was a broad gravity low to the west of Kodaikanal. The gravity field over the eastern Ghat mobile belt is markingly positive, which suggest a basic difference in the nature of crust between two regions. The steep gradient of Bouguer anomaly in the eastern part suggest a faulted contact between crystalline in the east and basin on the west.

Total intensity magnetic data were collected along two parallel traverses of 32 Km and 10 Km each. The 10 km long E-W trending profile has been selected parallel and 6 Km away from the first profile to visualize the extension of the fault as passing through both the profiles and the presence of dyke in the area. Almost 130 readings have been taken for more than 32 kms long profile 1 which starts from Katteri village to Mallandi area in the Villupuram district of Tamilnadu. The collected data has been interpreted and analyzed using various software's such as Oasis Montaj and surfer and results have been matched with the different interpretations of satellite data and geological maps. For the qualitative interpretation and to bring out structural variation and contacts, various data enhancement techniques/filters have been used. The anomalies have been plotted in graphs for the better understanding of results.

The graphic image (Figure 1.2) shows five places which are highlighted along the 32 km profile were we see much anomaly variations. The anomaly graph was correlated with geology maps and other published research. The highlighted part marked with (a) shows the presence of dyke across the profile followed by the fault which is marked as (b) in the image, which can be observed in the geological map of the area also. The highlighted part marked as (c) shows a similar variation as that of the fault, which indicates that it represent a lineament. The geographic locations of the anomaly is then well correlated with the published maps and research which gives the clear indication of dyke(a) and a fault(b). From the literature, the anomaly varies at the litho contact between Charnokite and hornblende-biotite-gneiss (d). The (e) refers to the anomaly related to the presence of granulites/granite intrusions near to the katteri village in Villupuram area. The anomaly variation (c) can be a lineament which is proved by field observations.

All the anomaly graphs from different supportive filters has been plotted in a single graph by the help of Geosoft software which shows very dense areas in the image shown as Figure 1.3 which in turn is very much supportive to the results discussed above.

Another profile, which is 10 kms long has been taken parallel to the profile 1 in order compare the anomalies observed on the profile and also to find out the whether the source of these anomalies of fault and dykes are extending northwards. The data have been carried out through different filtering and other processes and the anomalies are shown by generating different profile plots as shown below (Figure 1.4).

The profile 2 anomaly graph has been correlated with the geological maps and other geological information, which gives the indication that the dyke and fault that observed in profile 1 is extending northwards that is clearly seen in the anomaly profile. To the east of (b), (c) also indicates the presence of a lineament, which is observed on profile 1 also, which shows that this lineament also has structural extension, which is further proved by field observations.

The 10 km long distance from both the profiles which are nearly parallel to each with 6 km distance from between two is shown below Figure 1.5, which has been brought into comparison to visualize the trend of linear structures and their extension. The figure shows extension of the structures towards north and south which includes a dyke, Fault and the lineament.

Apart from this, we have generated the study map based on the ground truth along with the magnetic anomalies associated with the profiles and from digitization from all supportive geological maps and known maps from the geological survey of India published in 1995 as the geological and mineral map of Tamil nadu and Pondicherry and is shown below as Figure 1.6. The study part is dominant by hornblende-biotite-genesis followed by the charnokite formation. The P1 and P2 mark the location of the two parallel profiles of 32 Km and 10 Km long trending East- West. From the map we can see the lithology variations along the profile 1, hornblende- granite- gneiss in the west to charnockites in the east.

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 towards the end of profile 1. The presence of dyke, fault and another lineament is clearly seen in both the graphs suggest that these structures have extended to the north [7-14].

Conclusion

The present study has been accomplished by the usage of different software's such as Geosoft Oasis Montaj and Surfer. For effective interpretation of the obtained magnetic data, different enhancements were carried out using various filters which include vertical derivatives, analytical signal, Reduction to pole, Hilbert transform etc with the help of Oasis Montaj software. Analytical signal filter is used to emphasize anomalies from shallow sources and an easy detection of the edges of the geological structure in a magnetic anomaly.

The study proves the efficiency of magnetic data in structural variations especially in locating fault/ lineaments and also to identify and establish the presence of mafic/ ultra-mafic dykes. In general, the profiles show a negative trend in the magnetic anomaly. It is associated with large magnetic lows paired with small highs, which can be indicative of the faulted basement associated with collision tectonics. The general trend of magnetic low is due to the presence of Phanerozoic sediment

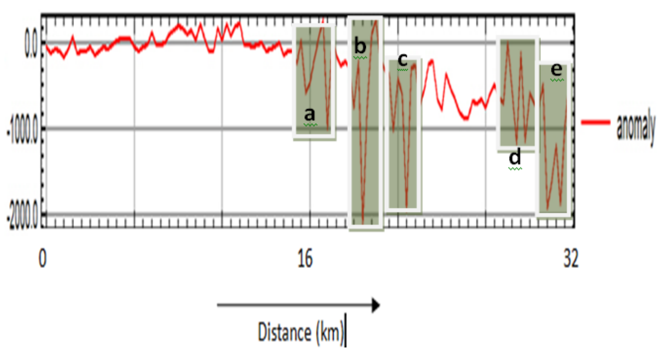

Figure 1.2: Magnetic anomaly of first profile.

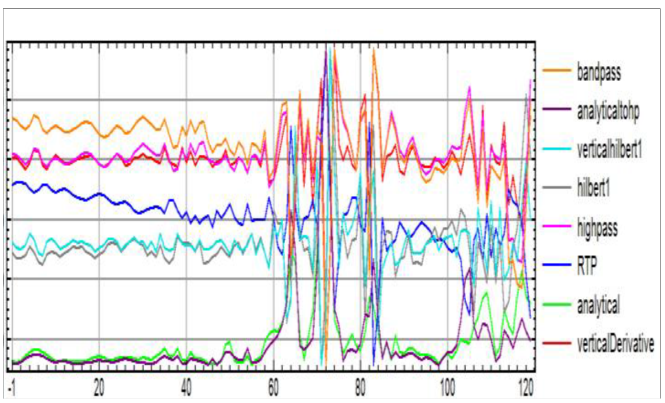

Figure 1.3: Single graph by the help of Geosoft software.

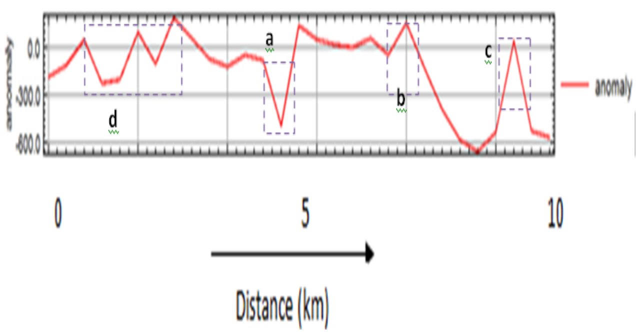

Figure 1.4: Anomalies are shown by generating different profile plots.

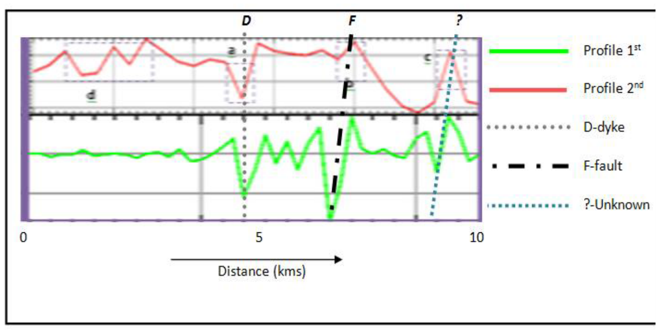

Figure 1.5: Equidistant profile graphs of Profile 1 and 2.

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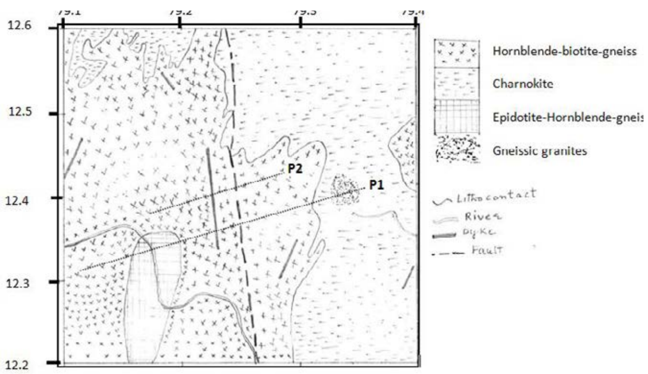

Figure 1.6: Geological and mineral map of Tamil Nadu and Pondicherry.

cover over the granitic basement. Faults and dykes are easily identified in the magnetic anomaly plot. Sharp highs/lows can be interpreted as dykes, which are intruded into the continental crust.

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