

Substructural Mapping Based on Potential Field Data in Part of Vindhyan Fringe Belt in Northern Madhya Pradesh, India

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Abstract: Potential field methods are used to map the substructural features such as faults, fractures, shear zones and altered zones in the part of Vindhyan fringe belt of northern, MP. Geologically, the study area is represented by Vindhyan Supergroup of Meso to Neoproterozoic age. The area is mainly covered by alluvium which is characterized by river gravels, sand and residual soil. Bouguer gravity anomaly contour map brought out a broad gravity variation 'high' in southern part due to upliftment of basement rocks/ presence of denser rock below the Vindhyan formation, whereas gravity 'low' in northern part due to presence of low depression zone (altered/ weathered Sandstone and Limestone). The high dominant anomaly is observed in the southern and northern parts which may be due to effect of basement/ basic dyke of BGC and the presence of Ferruginous Shale and Ferruginous Sandstone, respectively. The 'high' residual gravity anomaly aligned approximately NW-SE is recorded and interpreted as inferred lineament on Bouguer gravity anomaly map in central part of the map which is reflected from shallow feature and not observed on geological map. The residual magnetic map shows clear increase of the numbers of the local magnetic anomalies with different polarities along with various shapes, extensions and orientations. The inferred as lineament in central part are clearly reflected in THDR and TDR map of gravity data, while the THDR of the magnetic data is not represented properly. The map of the TDR of the magnetic data depicts close to zero magnetic values that coincide with edges or boundaries of inferred lineament in central part of the map. The majority of solutions are falling varying depth from 0.5 to 2.5 Km. The solution of gravity data is falling at inferred lineament and contact between two litho-units varying depth from 0.5 to 2.5 Km in central part of the map.

Keywords: Substructural, Potential field, Vindhyan fringe Belt, THDR and TDR.

1. Introduction

The potential field (Gravity and Magnetic) methods are successful to mapping of substructural features such as inferred fault/ tectonic contact, cavity detection, regional & global tectonics and basin boundaries. The area of the investigation is located in part of Vindhyan fringe belt of northern, M.P. is bounded by latitude $25^{\circ} 15' 00''$ N to $26^{\circ} 15' 00''$ N and longitude $77^{\circ} 30' 00''$ E to $77^{\circ} 45' 00''$ E and falls in the Survey of India Toposheet Nos. 54F/12, 54G/09, 10 & 11 shown in figure 1a. The objective is the mapping of substructural features such as inferred fault, tectonic contact and basin boundaries from potential field methods (Gravity and Magnetic anomalies). Gravity, Magnetic and Differential Global Positioning System (DGPS) data were collected by employing the CG-5 Autograv gravimeter, GSM-19T Magnetometer and DGPS 1200, respectively.

2. Geology

Geologically, the study area is represented by Vindhyan Supergroup of Meso to Neoproterozoic age (figure 1b). The area is mainly covered by alluvium which is characterized river gravels, sand and residual soil. The Vindhyan Super Group is exposed in the area besides small patches of unclassified deccan trap and inter-trappean is exposed which is characterized Kaimur, Rewa and Bhandar Groups. The Kaimur is represented by Bijaigarh, Dhandraul and Ghaghar members. Dhandraul Sandstone contains various types of Sandstone but the topmost is Quartzose Sandstone which is white coloured, thickly bedded to massive. Rewa group consists of Jhiri and Govindgarh formations. The Jhiri formation is mainly Calcareous Siltstone, Sandstone and Chert Shale along with Subordiante Siltstone and Ferruginous Sandstone. Bhandar group composed of Limestone and Sandstone of Nagod and Bundi Hills formations¹⁻⁴.

3. Methodology

Gravity, Magnetic and Differential Global Positioning System (DGPS) data were collected by employing the CG-5 Autograv gravimeter, GSM-19T magnetometer and DGPS 1200, respectively. The gravity and magnetic (GM) surveys were carried out with a station interval of 1 GM observation per 2.5 Sq Km in an area of about 2800 Sq Km. The elevation from mean sea level (MSL) of each gravity stations was obtained by tying the DGPS base to triangulation point of Survey of India using DGPS. The gravity data was

reduced following the standard corrections of gravity data and the Bouguer gravity anomaly over the study area was computed for a mean crustal density of 2.67 gm/cc. International gravity formula 1980 was used to account for the latitude correction. The Magnetic observations (Total field) were corrected for the diurnal variation and International Geomagnetic Reference Field (IGRF) correction using IGRF coefficients for 2015 epoch to evaluate the magnetic anomaly at each station. Leica Geo Office, Surfer 9 (Golden software) and Geo-Soft Oasis Montaj software version 9.1 were used for processing and preparing the geophysical maps⁵⁻⁷.

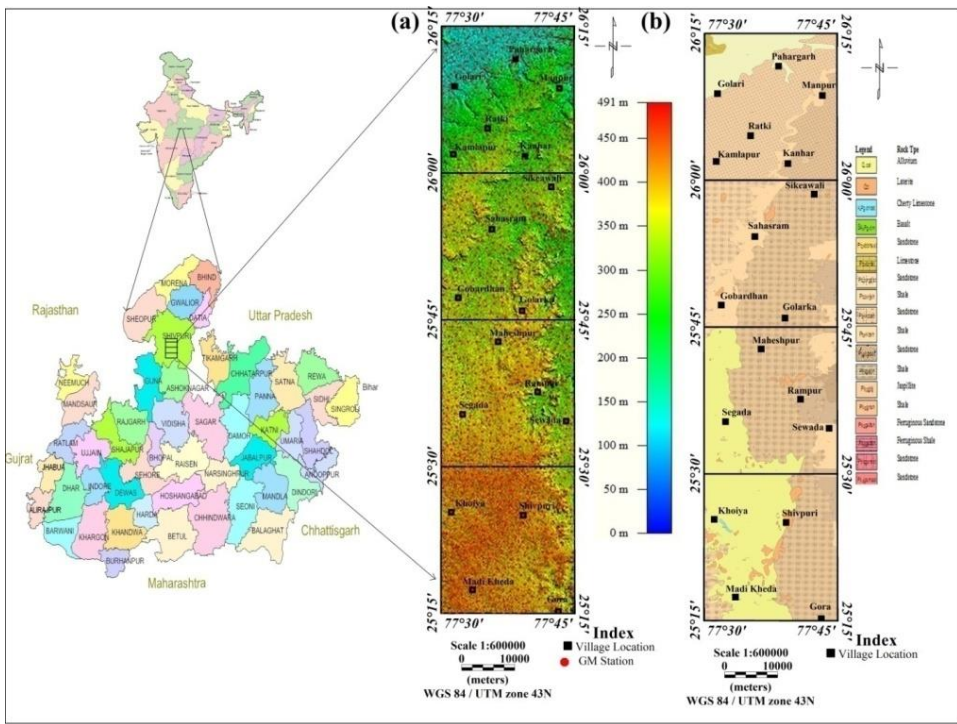


Figure. 1(a) Location map, (b) Geology map of Location map of study area (Source: Geological Survey of India (GSI), India).

4. Result and Discussion

4.1 Bouguer Gravity and Magnetic Anomaly (T.F.) Maps: Bouguer gravity and magnetic anomalies contour maps have been prepared with a contour interval of 1mGal and 50 nT, respectively (figure 2 & figure 3). Bouguer gravity anomaly contour map is characterized by broad gravity variations as it can be observed, ‘high’ in southwestern part around Khoiya, Shivpuri, Madi Kheda and Gora Villages may be due to upliftment of

basement rocks/ presence of denser rock below the Vindhyan formation, whereas ‘low’ around Ratki, Manpur, Golari and Kanhar in northeastern part which may be due to presence of low depression zone (altered/ weathered Sandstone and Limestone).The nosing are aligned approximately NW-SE directionis reflected around Sahasram, Kamlapur, Gobardhan and Golarka Villages in central part which may be interpreted as inferred lineament (figure 2).

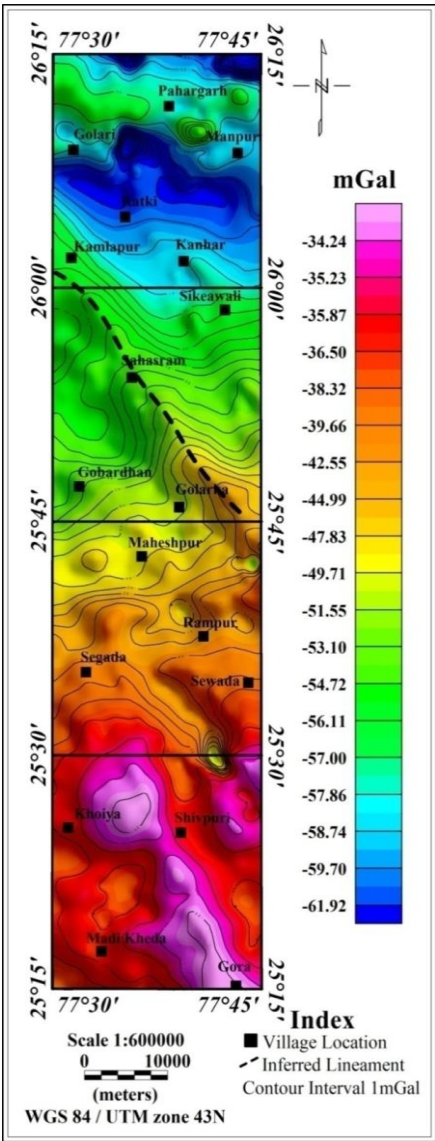


Figure. 2 Bouguer gravity anomaly contour map.

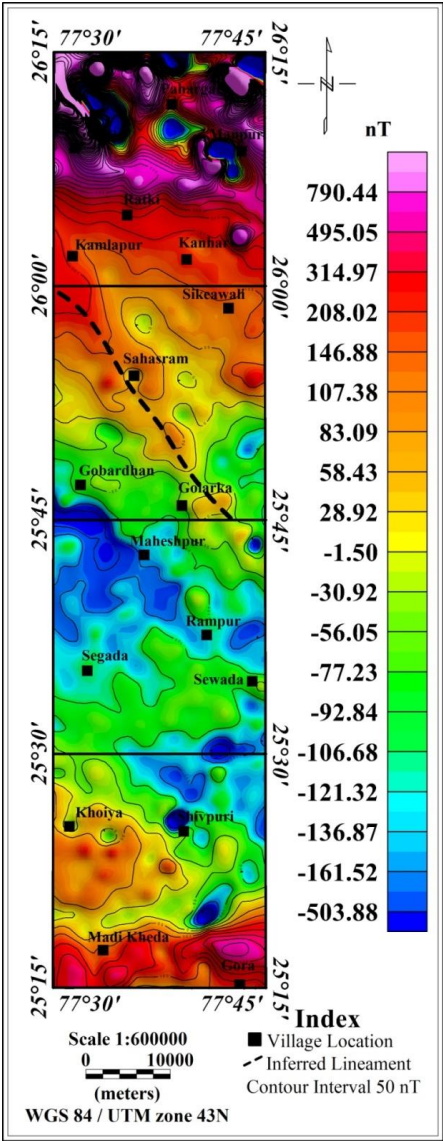


Figure. 3 Magnetic anomaly contour map.

A few bipolar anomalies comprising of lower to higher amplitude is recorded in northeastern of the area over dolerite and medium fine-grained granite, respectively. The high intensity/ high dominant anomaly is observed in the southern part around Madi Kheda and Gora, which may be due to effect of basement/ basic dyke of BGC, whereas, the high intensity is also recorded in northern part around Golari, Manpur, Pahargarh and Kamlapur due to the presence of Ferruginous Shale and Ferruginous Sandstone. The moderate anomaly is observed in the central part, over the Sandstone. The low intensity magnetic (T.F.) anomaly is recorded near central part around Rampur, Ram Khedi, Aichwara and Sankhya over Sandstone and Shale (figure 3).

4.2 Regional & Residual Gravity and Magnetic Anomaly maps: The regional gravity and magnetic anomalies are prepared using upward continuation technique and after analyzing the results of different depth of upward continuation, finally a depth 3Km has been selected with reference to radial average power spectrum of Bouguer gravity and magnetic anomalies (figure 4 & figure 5) while the residual gravity and magnetic anomalies are separated from Bouguer gravity and magnetic anomalies using regional-residual separation technique. Regional and residual separation is carried out for better understanding of the sub-surface responses from deeper and shallower causative sources, respectively.

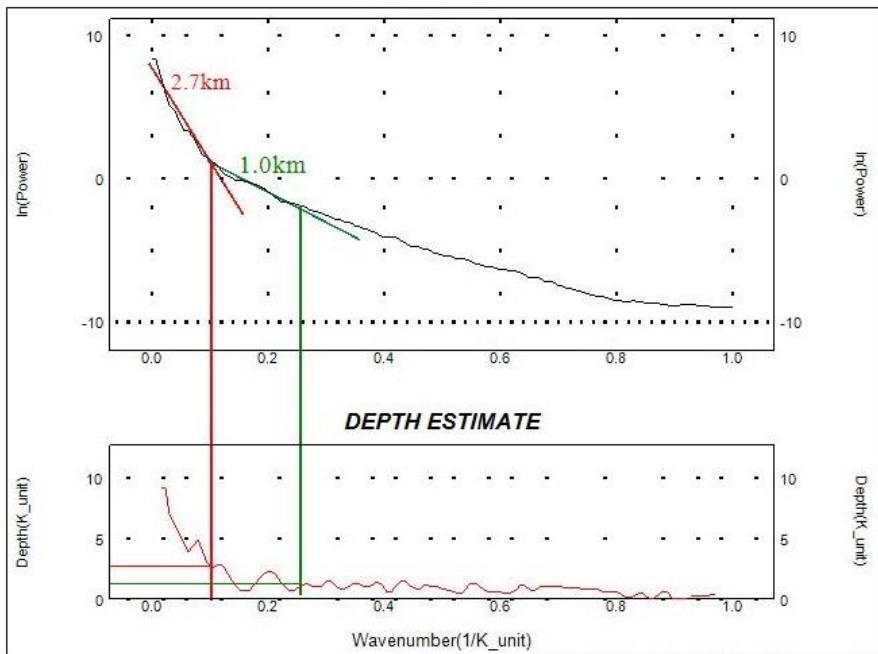


Figure. 4 Radial average power spectrum of Bouguer gravity anomaly.

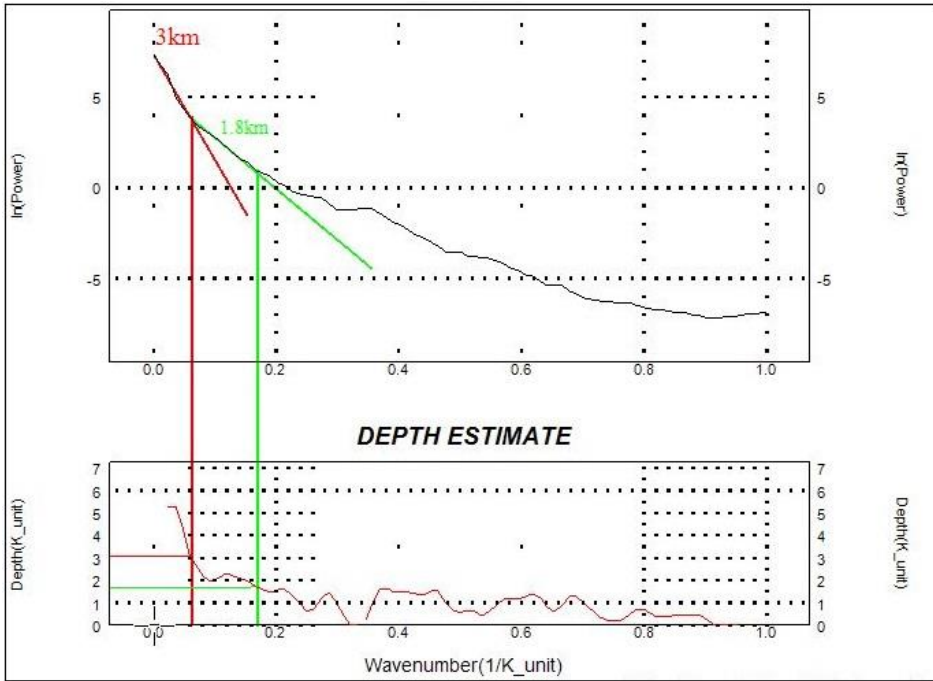


Figure. 5 Radial average power spectrum of magnetic anomaly.

Regional gravity map is observed that near surface noise is suppressed and shows response of deep-seated regional structures such as the nosing is suppressed near Sahasram, Kamlapur, Gobardhan and Golarka Villages, respectively (figure 6).

The regional gravity anomaly is characterized by broad gravity 'high' in southern whereas 'low' in northern part due to depression of basement toward the north. Gravity high, in southern part of the area still exists in the regional map indicating that causative sources of these anomalies are from deeper level. The high regional magnetic anomaly is observed from central to northern part, whereas, the dissipated high magnetic anomaly is recorded in southern part which is reflected smooth trending along E-W (figure 7).

The residual gravity and magnetic anomalies are separated from Bouguer gravity and magnetic anomalies using regional-residual separation technique which are recorded various local gravity & magnetic anomalies along with various amplitude and direction shown in figure 8 & figure 9. The 'high' residual gravity anomaly aligned approximately NW-SE is recorded near Sahasram, Kamlapur, Gobardhan and Golarka Villages which is also interpreted as inferred lineament on Bouguer gravity anomaly map in central part of the map (figure 8). This anomaly is reflected from shallow feature which is not observed on geological map (figure 1b). The residual magnetic

map using regional-residual technique shows clear increase of the numbers of the local magnetic anomalies with different polarities along with various shapes, extensions and orientations (figure 9).

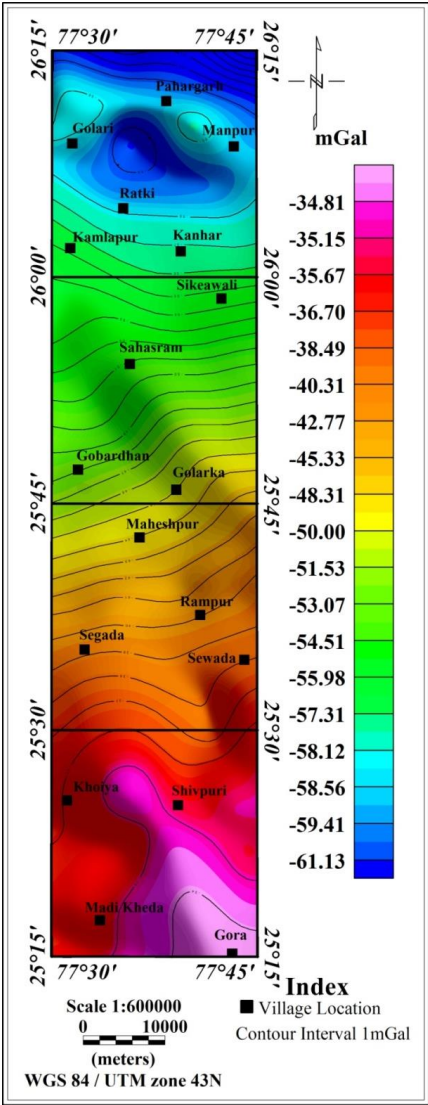


Figure. 6 Regional Bouguer gravity anomaly contour map.

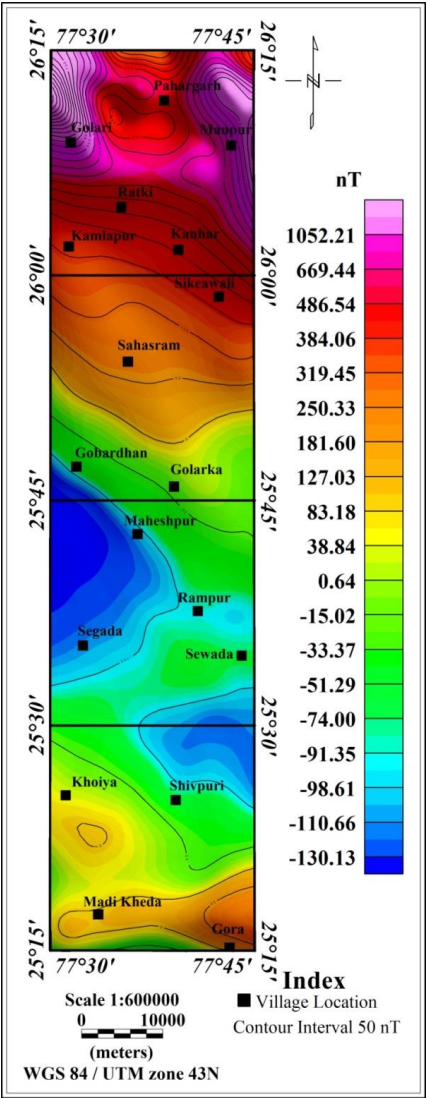


Figure. 7 Regional Magnetic anomaly contour map.

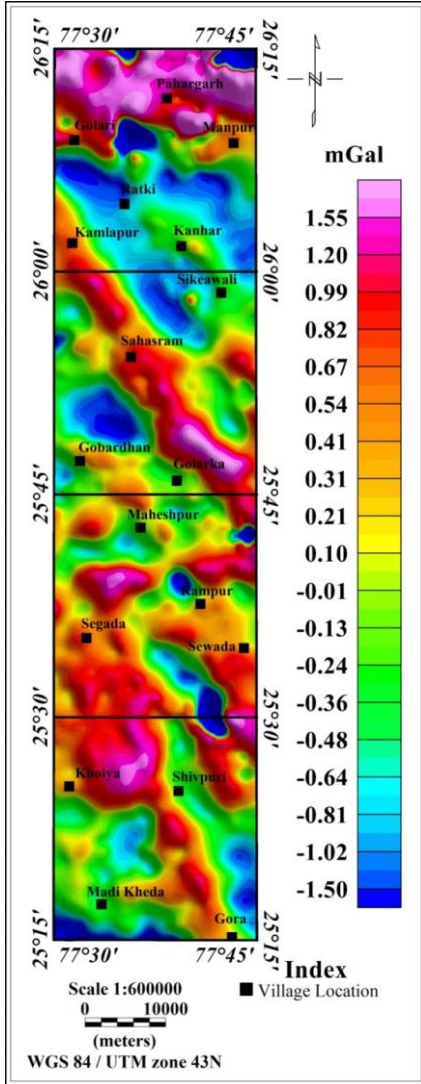


Figure. 8 Residual Bouguer gravity anomaly contour map.

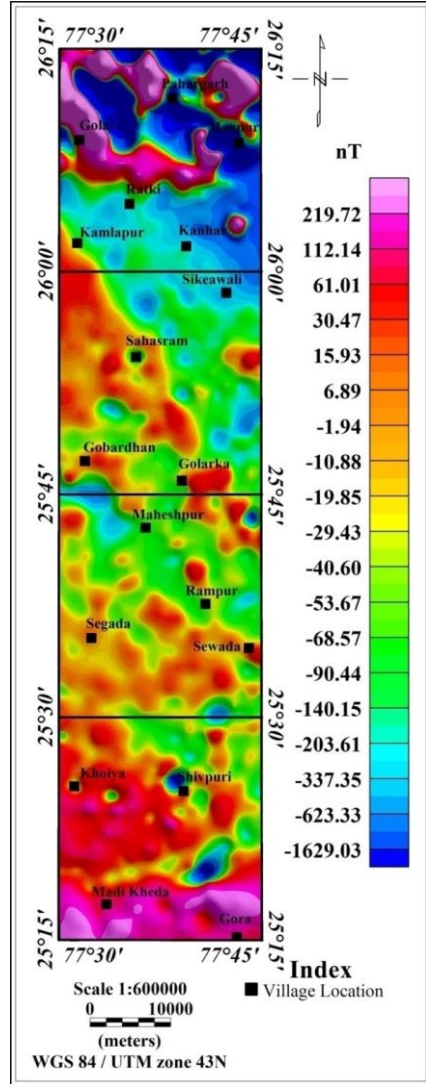


Figure. 9 Residual Magnetic anomaly contour map.

4.3 The Total Horizontal Derivative and Tilt Derivative: The derivative (total horizontal and tilt derivative) of potential field data are powerful tool for identifying as edges or boundary/ contact zone of formations. The total horizontal derivative (THDR) is commonly used to delineate edges of features such as faults or igneous bodies^{8,9}. The THDR peaks over the edges and is zero over the body^{9,10}. The THDR can calculate using the standard formula of Verduzco et al.¹¹ for potential field data:

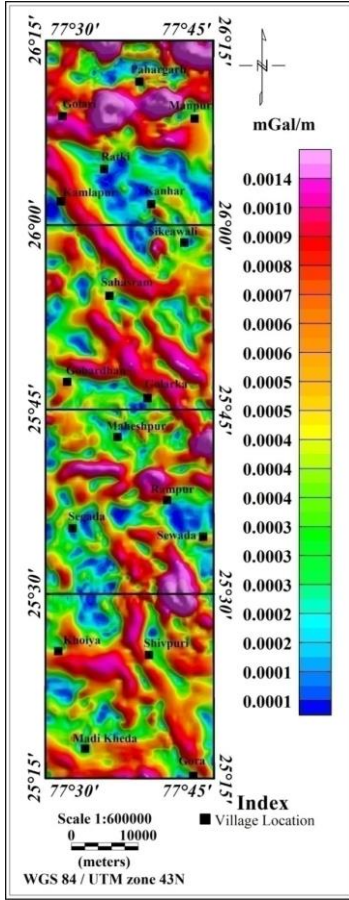


Figure. 10 Total horizontal derivative of gravity data.

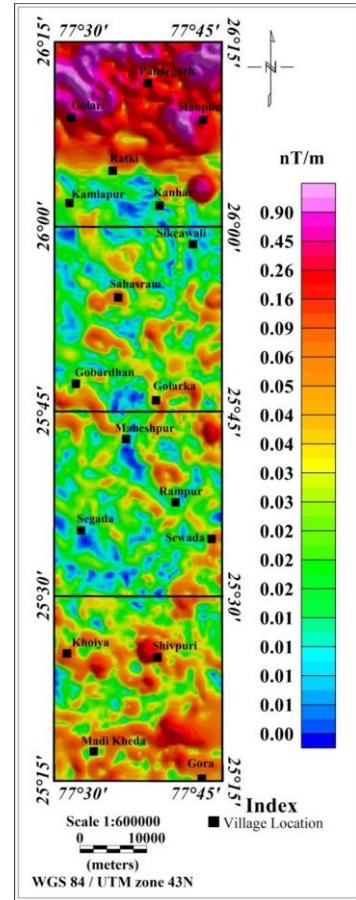


Figure. 11 Total horizontal derivative of magnetic data.

$$(4.1) \quad \text{THDR} = \sqrt{\left(\frac{dT}{dx}\right)^2 + \left(\frac{dT}{dy}\right)^2}$$

where T is the total intensity of the potential field data.

The tilt derivative (TDR) of the potential field is defined as the ratio of the first vertical derivative to the total horizontal derivative of the field. The TDR is positive over the source, close to zero at the edge and it is negative outside the source. The method has a unique advantage over the other edge detectors in that it responds equally to shallow and to deep sources^{9, 10}. The TDR technique was also applied to the gravity and magnetic data using the standard formula of Verduzco et al.¹¹:

$$(4.2) \quad \text{TDR} = \tan^{-1}(\text{VD}/\text{THD})$$

The inferred as lineament around Sahasram, Kamlapur, Gobardhan and Golarka Villages in central part are clearly reflected in THDR and TDR map of gravity data shown in figure 10 & figure 12, while the THDR of the magnetic data (figure 11) is not represented properly. The TDR map of magnetic data depicts close to zero magnetic values that coincide with edges or boundaries of inferred lineament around Sahasram, Kamlapur, Gobardhan and Golarka Villages in central part (figure13).

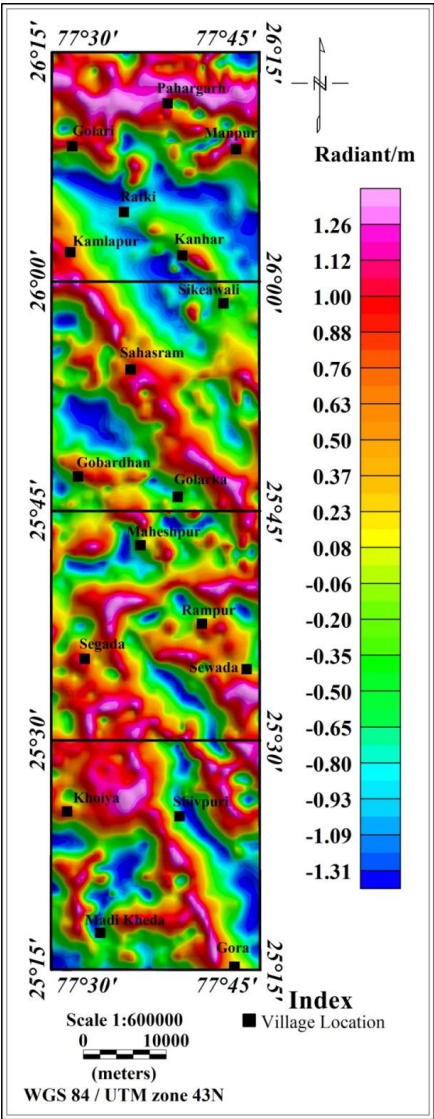


Figure. 12 Tilt derivative of gravity data.

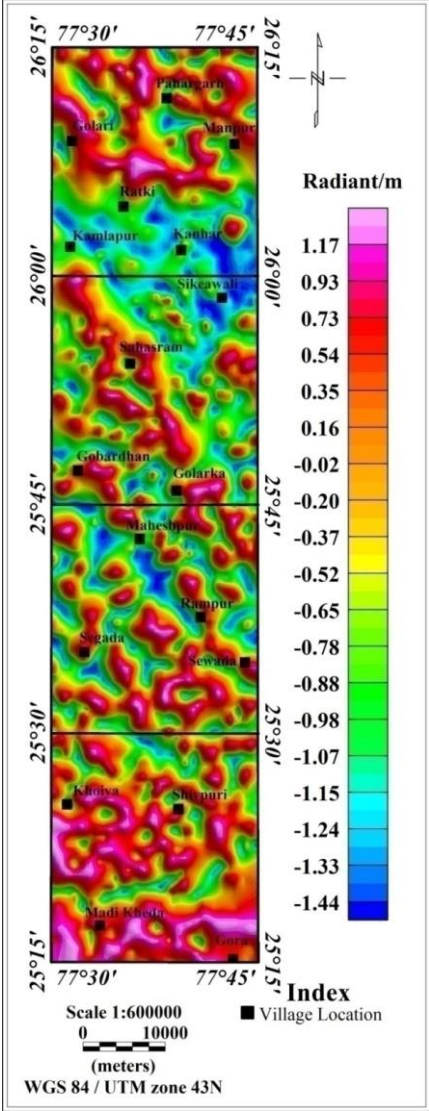


Figure. 13 Tilt derivative of magnetic data.

4.4 Euler 3D Depth Solutions: Euler deconvolution can be used to estimate the depth for wide geological features such as faults, contacts and dykes. The method is best suited for anomalies caused by isolated and multiple anomalous sources¹².

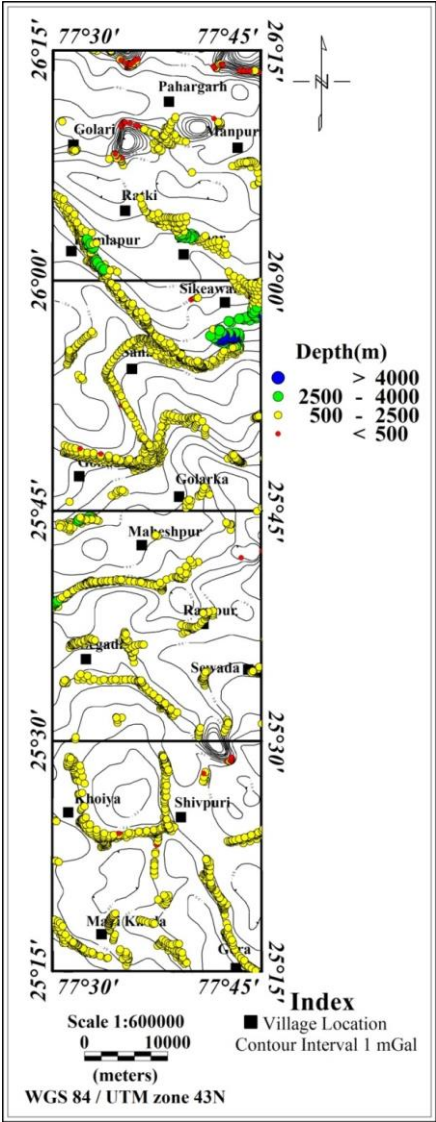


Figure. 14 Euler 3D depth solutions of gravity data for SI = 0.

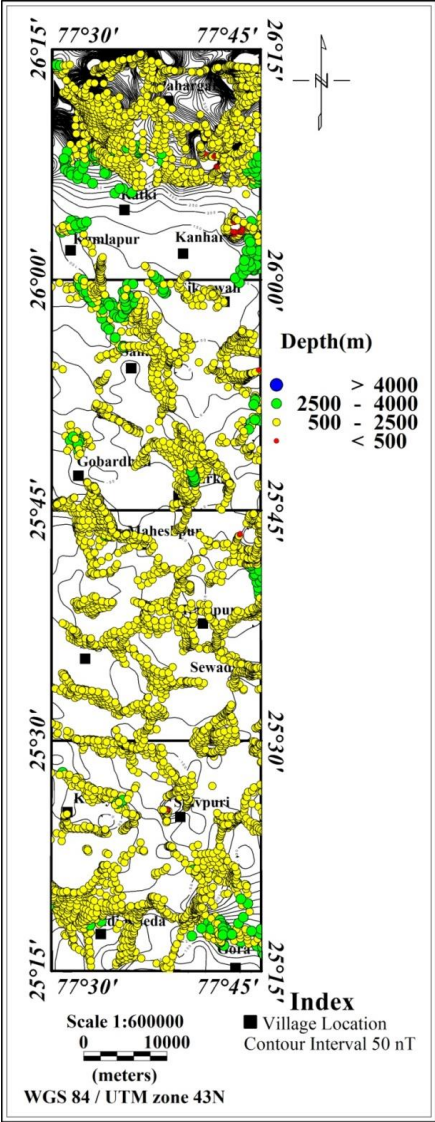


Figure. 15 Euler 3D depth solutions magnetic data for SI = 1.

The standard Euler 3D deconvolution method is based on Euler’s homogeneity equation that relates to estimate the depth of causative sources

obtained from potential field data and its first order gradient components in three directions to the location of sources of the data and gridded data with the degree of homogeneity, which may be interpreted as a structural index (SI). The SI is based on the geometry of the potential field data and is a measure of the rate of change of the anomaly with distance from the source. The cluster of Euler solutions around the perimeter of the bodies in a horizontal plane and provide estimates of the depth of causative sources¹³. Euler solutions were determined using a window length = 5 Km and SI = 0 for gravity & SI = 1 for magnetic data in order to emphasize the contacts and faults. The Euler depth solutions are provided less than 0.5Km, 0.5 to 2.5Km, 2.5 to 4 Km and beyond 4.0 Km of gravity and magnetic data shown in figure 14 & figure 15. The majority of solutions are falling varying depth from 0.5 to 2.5 Km. The solution of gravity data (figure 14) is falling at inferred lineament and contact between two litho-units varying depth from 0.5 to 2.5 Km in central part around Sahasram, Kamlapur, Gobardhan and Golarka Villages.

5. Conclusion

The high intensity/ high dominant anomaly is observed in the southern and northern part which may be due to effect of basement/ basic dyke of BGC and the presence of Ferruginous Shale and Ferruginous Sandstone, respectively. The nosing of Bouguer gravity anomaly contour map are aligned approximately NW-SE direction is reflected in central part which may be interpreted as inferred lineament. The 'high' residual gravity anomaly aligned approximately NW-SE is recorded and interpreted as inferred lineament on Bouguer gravity anomaly map in central part of the map which is reflected from shallow feature and not observed on geological map. The residual magnetic map shows clear increase of the numbers of the local magnetic anomalies with different polarities along with various shapes, extensions and orientations. The inferred as lineament in central part are clearly reflected in THDR and TDR map of gravity data, while the THDR of the magnetic data is not represented properly. The map of the TDR of the magnetic data depicts close to zero magnetic values that coincide with edges or boundaries of inferred lineament in central part of the map. The majority of solutions are falling varying depth from 0.5 to 2.5 Km. The solution of gravity data is falling at inferred lineament and contact between two litho-units varying depth from 0.5 to 2.5 Km in central part of the map.

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