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Quantitative Interpretation of Gravity and Magnetic Data in Parts of Sidhi and Shahdol Districts, MP, India

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Abstract

This article is represented to the quantitative interpretation of gravity & magnetic data in parts of Sidhi and Shahdol districts, Madhya Pradesh.Geologically, the area is represented by Vindhyan Super group, Sidhi Gneiss group, Chotanagapur Gneissic complex group, Mahakoshal group, Gondwana Super group and Deccan Trap Super group. The rock samples of 128 Nos. have been collected from different litho-units of the study area for measurement of physical properties (Density and Magnetic susceptibility) which are useful for understanding & evaluating of geological response. Quantitative interpretation of gravity map indicated three sub surface interfaces at depths, viz. 1.8km (shallow), 3.8km (intermediate) and beyond 3.8km (deeper) and magnetic map recorded three sub surface interfaces at depths, viz. 0.6km (shallow), 3.0km (intermediate) and beyond 3.0km (deeper). The average first sub-surface interface recorded up to 1.2km depth while second interface up to 3.4km depth may be correspond to sedimentary rocks of lower Gondwana formation sandstone.

Keywords: Sidhi, Mahakoshal, Gondwana, Shahdol and Chotanagapur Gneissic complex.

Introduction

The study area is bounded by latitude 24º 00'00'' N to 24º 30' 00'' N and longitude 81º 45' 00'' E to 82º 45' 00'' E (Figure-1) and falls in the Survey of India, Toposheet Nos. 63H/15, 16 & 63L/04, 08, 12 parts of Sidhi & Shahdol districts, M.P.

Geology: Geologically, the area is represented by Vindhyan Supergroup, Sidhi gneiss group, Chotanagapur gneissic complex group, Mahakoshal Group, Gondwana Supergroup and Deccan Trap Supergroup (Figure-2). The Vindhyan Supergroup is represented by Semri and Kaimur group of rocks. The Semri Group lies unconformably over the older granite gneiss and Mahakoshal Group of rocks. The Mahakoshal Group of rocks is affected by tectonic disturbances forming the weaker planes, which area later occupied by quartz veins.

The granite belonging to Barambaba granite formation of Palaeoproterozoic age occurs as isolated outcrops and found exposed dominant in northwestern part of the map area. The Chhotanagpur gneissic complex group is represented by quartzite, biotite schist and granite gneiss. The Gondwana Supergroup includes Talchir, Barakar, Barren Measure and Pali formations of Lower Gondwana group and mainly consists of ferruginous sandstone and sandstone.

The rocks of Chhotanagpur gneissic complex group and Lower Gondwana Group have been intruded by basic and Ultra-basic intrusive, syenite, quartz veins and pegmatite[1-8].

Methodology

Gravity and Magnetic (GM) Survey: One thousand, Four Hundred and Eighty (1480) gravity stations have been observed to represent satiation density of 1GM station per 2.5sq km in total 3500sq km area. The elevation from Mean Sea Level (MSL) of each gravity station was connected to triangulation point by DGPS. Gravity and Differential Global Positioning System (DGPS) data were collected by employing Autograv gravimeter CG-5 and DGPS 1200 manufactured by M/s Scintrex Limited Canada and Leica Geosystem AG Switzerland, respectively. The gravity data was corrected for instrument drift and entire data was subjected to free air and Bouguer slab corrections. The gravity data was reduced to mean sea level after applying elevation correction. Bouguer gravity anomaly over the study area was computed for mean crustal density of 2.67gm/cc. For latitude correction, international gravity formula 1980 was used. The magnetic survey was carried out at same stations of the gravity measurements. The total intensity magnetic field measurements was carried out with GSM-19T magnetometer made by GEM System Canada. The magnetic observations (Total field) were corrected for the diurnal variation and reduced to magnetic base. The International Geomagnetic Reference Field (IGRF) correction applied for magnetic data using IGRF coefficients for 2015 epoch using Geo-soft software version 9.1 to evaluate magnetic anomaly at each station. Microsoft Excel, Leica Geo Office, Surfer 9 (Golden software) and Geo-Soft Oasis Montaj software version 9.1 were used for processing and preparing the geophysical maps[1,10,11].

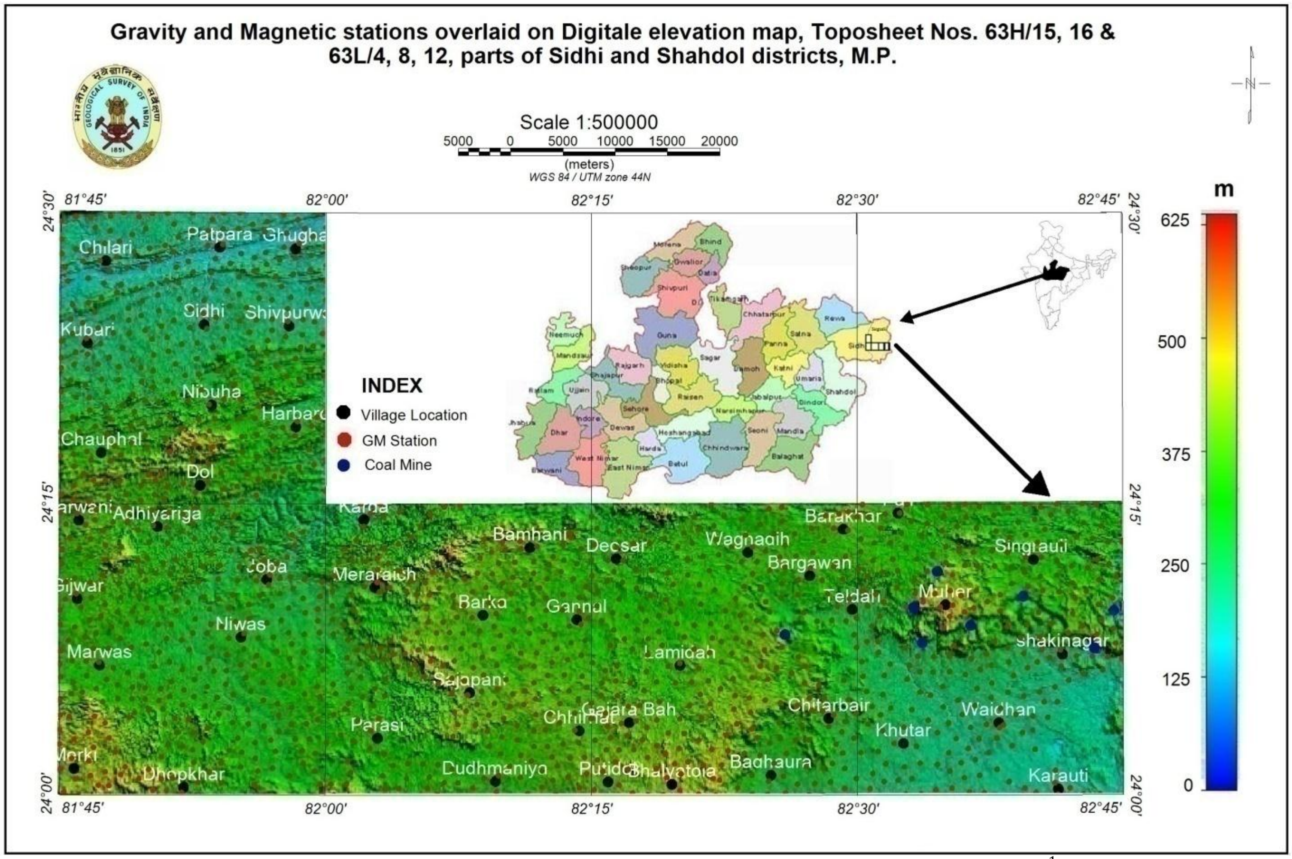

Figure-1: Gravity and magnetic stations overlaid on Digital Elevation Model[1].

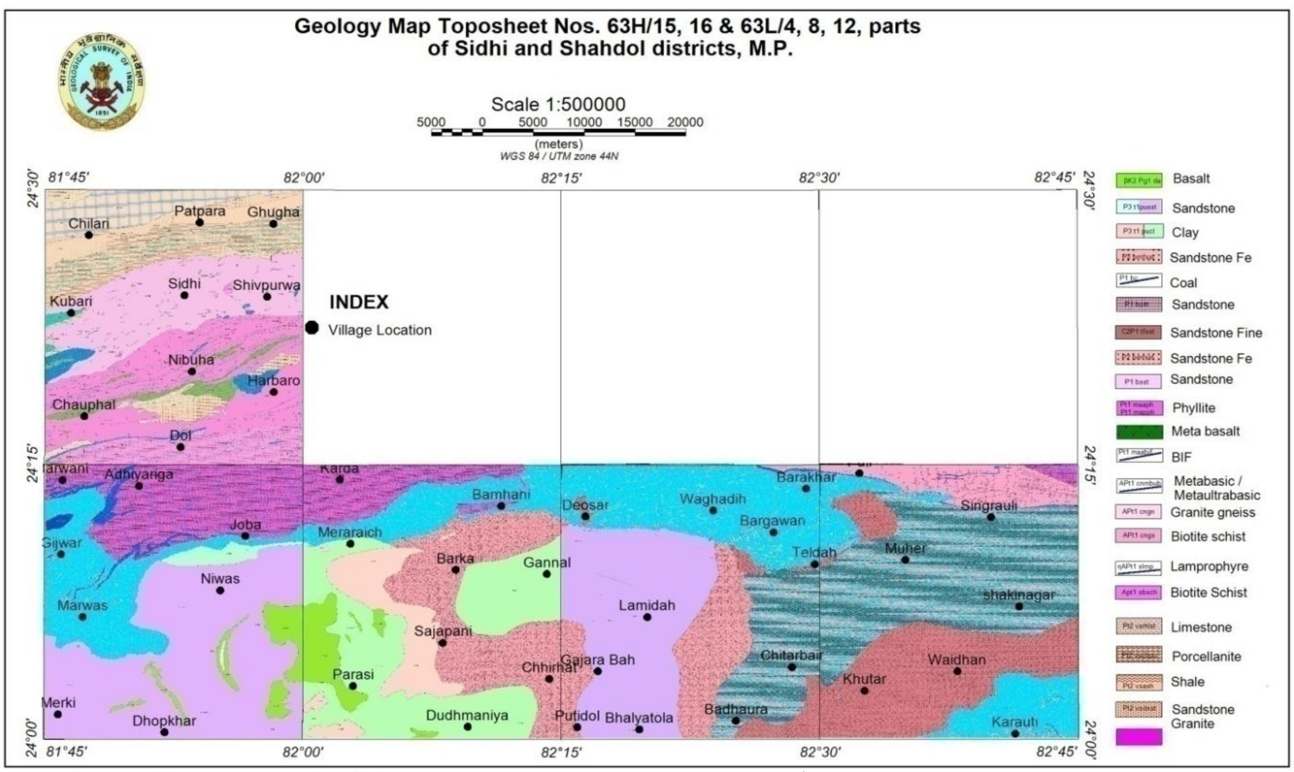

Figure-2: Geology of the area[1].

Results and Discussion

Gravity Anomaly Contours with Density of Rocks Samples overlaid on Geology Map: Bouguer anomaly values have been grided and contoured by using Geosoft programs Oasis Montaj to produce the Bouguer anomaly map, which shows different high and low anomalous values through the surveyed area. The Bouguer gravity anomaly contours (Fig. 3) along with density value of rock samples were overlaid on geological map shown in Fig. 4 for better understanding of geophysical responses with the geological features/ litho contacts/ lineaments. The gravity 'high' (H1) near Karda was clearly recorded over pegmatite, mica schist and ferruginous sandstone of chhotanagpur gneissic complex group (granite gneiss) (F4-F4'). This gravity high may be due to high density rocks. The high Bouguer gravity anomaly (H2) zone around Nibuha, Chauphal, Dol and Harbaro in the northwestern part falls over ferruginous sandstone, ultramafic, chlorite schist, quartzite vein and pegmatite of Mahakoshal Group. This gravity high may be due to high-density rocks/ upliftment of the basement. The low gravity anomaly zones (L1) and (L2) around near Shakinagar, Singrauli & Muher, Gajara Bah and Lamidah fall over sandstone of Gondwana.

Magnetic Anomaly Contours with Magnetic Susceptibility of Rocks Samples overlaid on Geology Map: The magnetic anomaly contours (Figure-5) along with magnetic susceptibility values of rock samples were overlaid on geological map shown in Fig. 6 for better understanding of geophysical response with the geological features/ litho contacts/ lineaments. The low intensity magnetic anomalies around Kubari, Chilari, Patpara, Sidhi, Shivpurwa and Ghugha reflect over sandstone, limestone, shale and porcellanite rocks of Vindhyan Supergroup and also noticed over phyllite, quartzite and dolomite rocks of Mahakoshal group. This low magnetic intensity may be due to low magnetic susceptibility of rocks. The domain 'I' is characterized by high intensity/ high dominant anomalies around Chaupha, Harbaro, Nibuha, Karda and Dol over granite gneiss of Sidhi group, phyllite of Mahakoshal Group and granite gneiss of Chhotanagpur Gneissic Sidhi gneiss group.

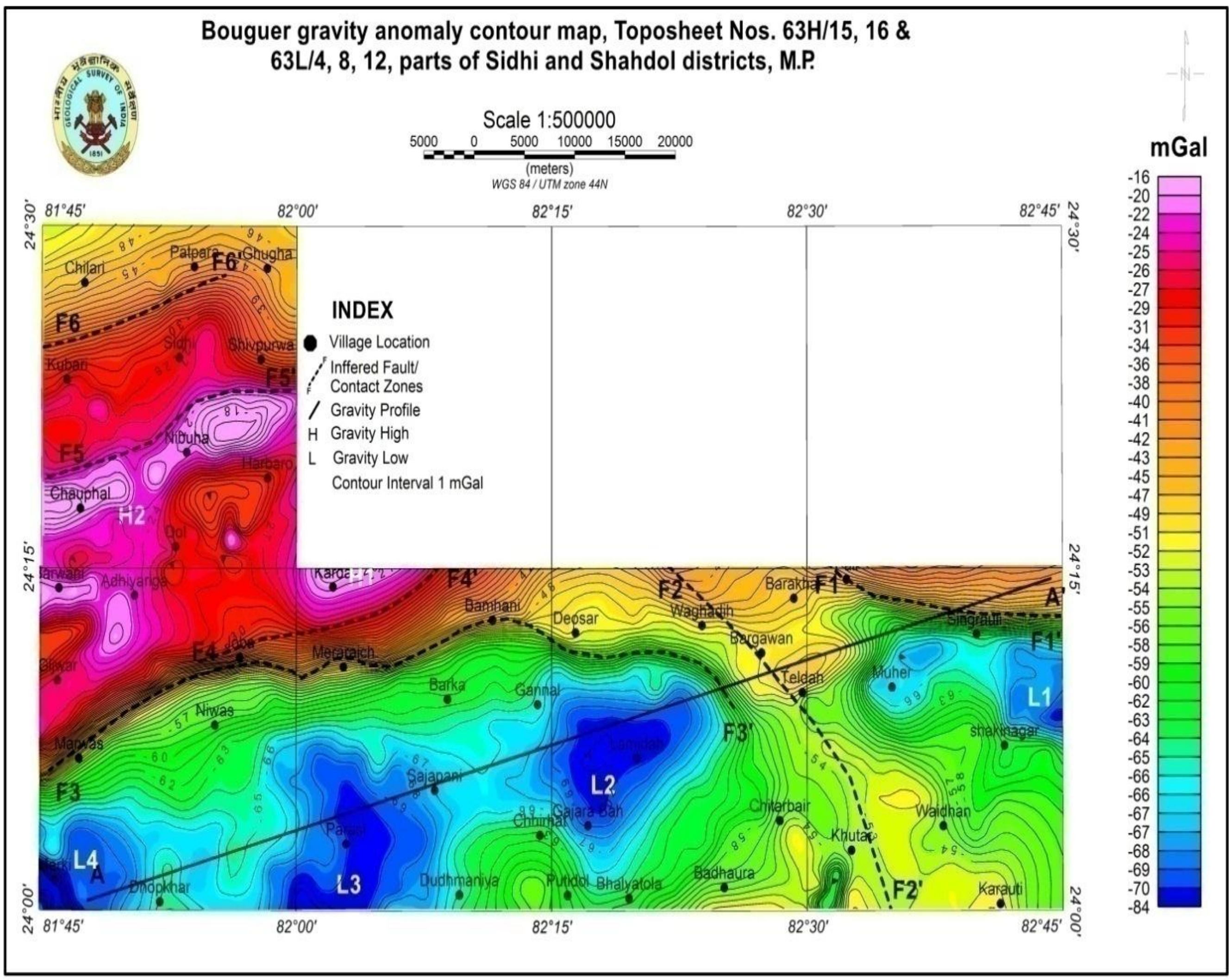

Figure-3: Bouguer gravity anomaly contour map[1].

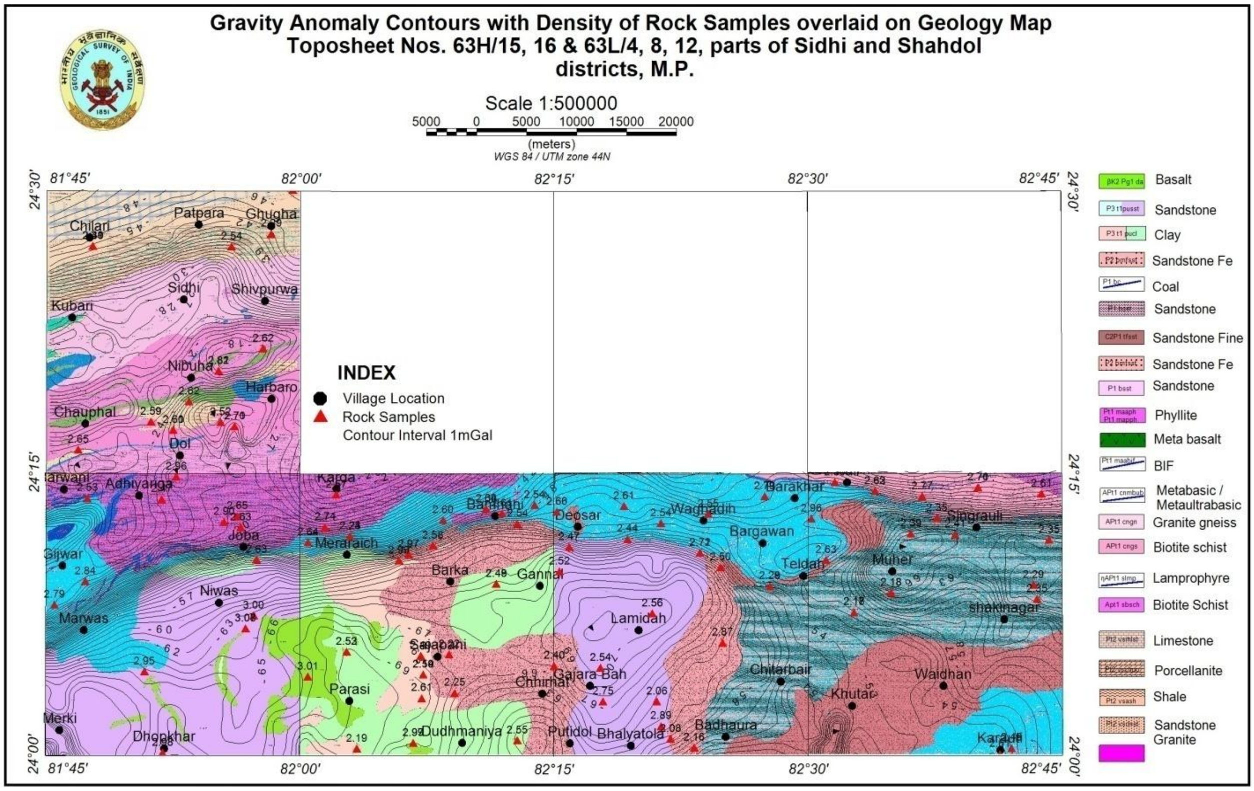

Figure-4: Gravity anomaly contour with density of rocks samples overlaid on geology map.

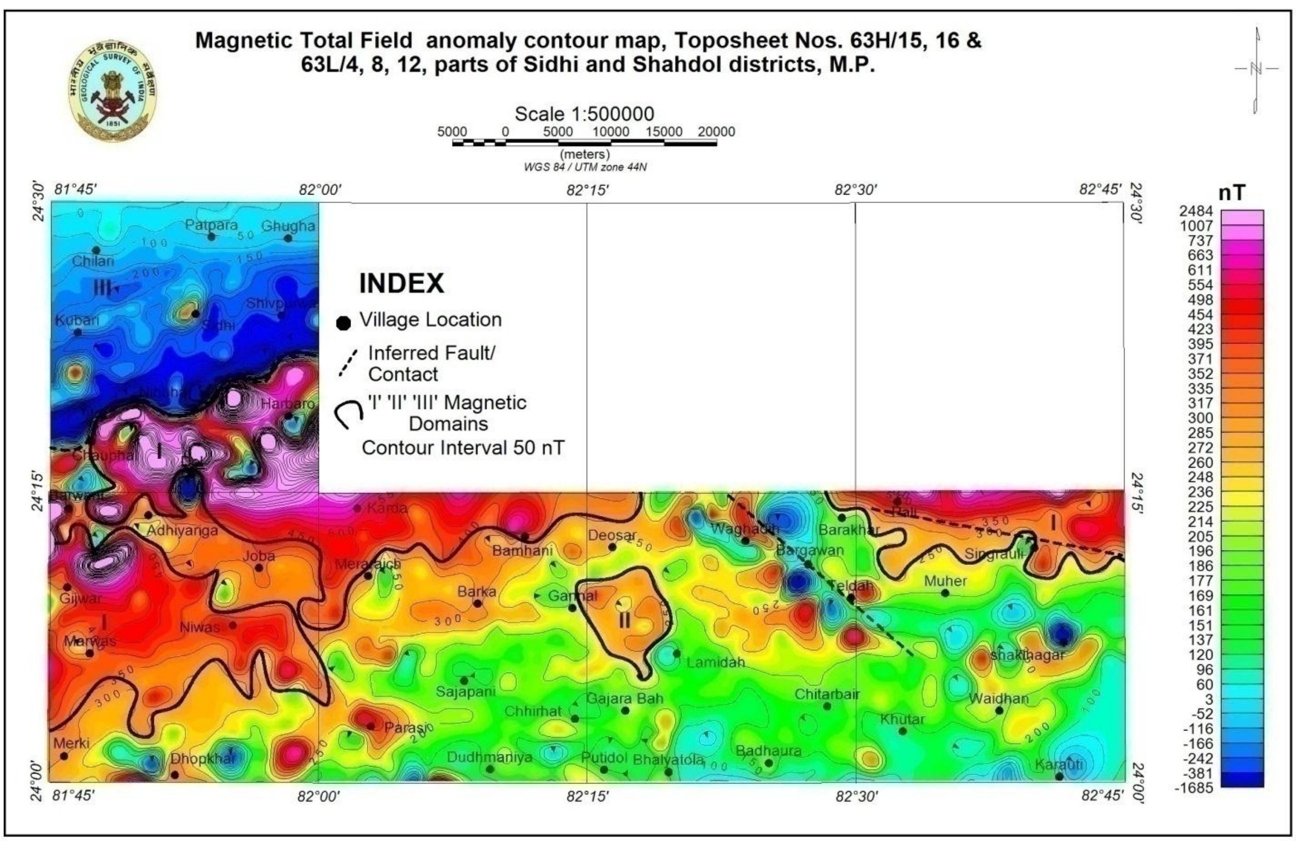

Figure-5: Magnetic anomaly contour map[1].

Radially Average Power Spectrum (RAPS*)* and: The radially averaged power spectrum plot of Bouguer gravity data is a function of wave number and is obtained by averaging energy in all directions for the same wave number. If the grid is large enough to include many sources, the logarithmic spectrum versus the wave number plot can be interpreted to determine the statistical depth to the top of the ensemble of sources. The power spectrum analysis is capable of separation the gravity response from various sources of different depths.

Radially averaged power spectrum of gravity data is presented Figure-7. The power spectrum shows 3 linear segments and depth estimated from the source of interpretation of spectrum at depths, viz. 1.8km (Shallow), 3.8km (Intermediate) and beyond 3.8km (Deeper). The first sub-surface interface recorded up to 1.8km depth computed to while second interface up to 3.8km depth, may be correspond to sedimentary rocks of lower Gondwana formation sandstone.

The radially averaged power spectrum plot of magnetic data has been prepared by using Geosoft software (Version 9.1) is shown in Figure-8. The power spectrum gives up 3 sub-surface layer at depths, viz. 0.6km (shallow), 3.0km (Intermediate) and beyond 3.0km (Deeper). The first sub-surface interface recorded up to 0.6km depth while second interface up to 3.0km depth.

GM-SYS Modelling along the profile AA': An inferred 2D subsurface model along a typically selected profile AA' on Bouguer gravity anomaly (Figure-**3.) has been prepared by using** GM-SYS module of Geosoft Oasis Montaj software **and is presented in Fig**ure-**9.** Total length of the section is 99 km in NE-SW direction extending from Northwest of Dhopkhar to Northeast of Singrauli cutting across Sandstone, Basalt, Sandstone, Clay, Ferruginous sandstone Sandstone, Ferruginous sandstone, Granite Gneiss and Phyllite. Densities of rock samples collected from different litho-units exposed along the profile has been used in the interpretation.

Density and Magnetic Susceptibility Measurements of Rock Samples: The physical properties of rock samples (Density and Magnetic Susceptibility) are very useful for understanding and evaluation of geophysical responses. The density of rock samples helps in interpretation of gravity anomalies and establishes the characteristic ranges of density of major lithological units, whereas magnetic susceptibility measurements are useful to determine the possibility of mineralization associated with magnetite and in mapping various rock units as a function of their susceptibility (Bharti et al. 2016). A total of 128 rock samples are collected from different litho units during field work. The density of rock samples was measured with density meter Mettler Toledo (ME 403). The magnetic susceptibility of rock samples was measured with MS-2 (Dual Frequency) Magnetic Susceptibility meter (MS 2B), of Bartington, UK make. The measured densities and magnetic susceptibilities of different rock samples are presented in Table-1.

It can be inferred that siltstone has low order of density and susceptibility values, whereas granite gneisses, chert, pegmatite, clay and quartzite are showing moderate density and susceptibility. Phyllite is showing moderate density and low susceptibility, whereas granite is showing low density and high susceptibility. The mica schist, grey biotite granite, amphibolite and gabbro have higher order of density and susceptibility. The variations in magnetic susceptibility of sandstone and ferruginous sandstone have high due to alteration/ weathering.

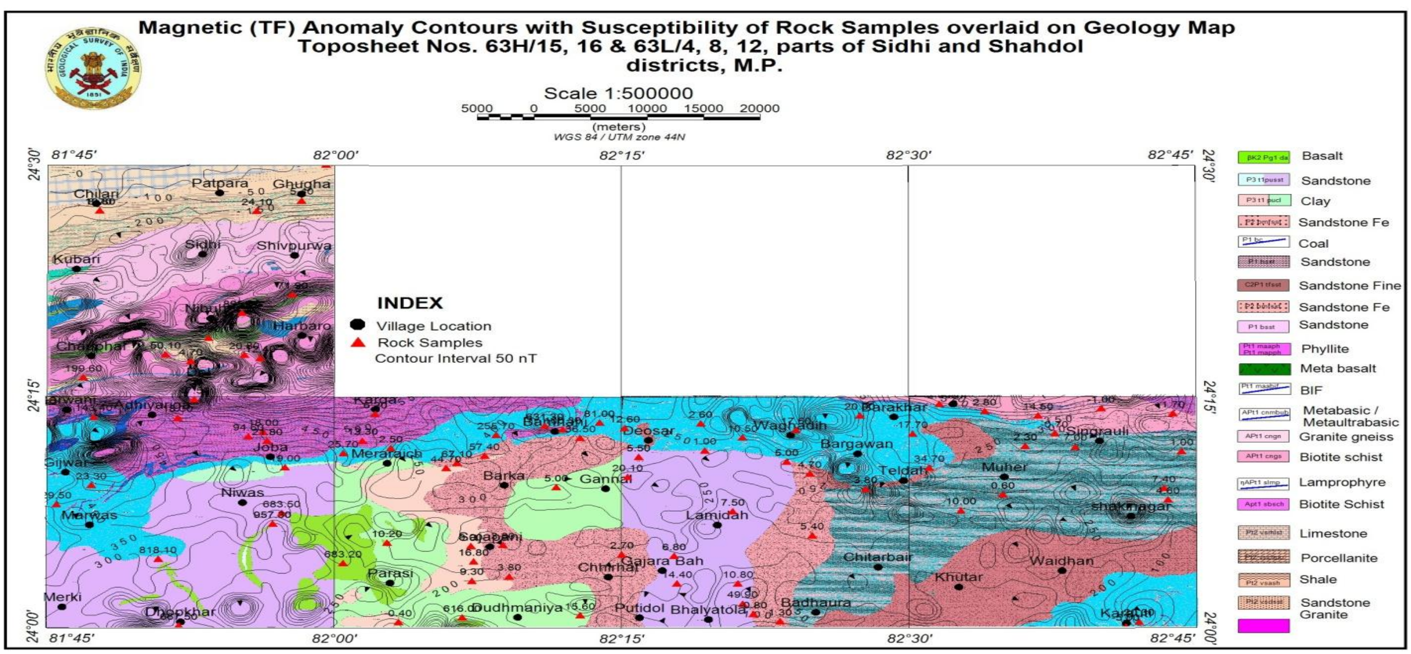

Figure-6: Magnetic anomaly contour with magnetic susceptibility of rocks samples overlaid on geology map.

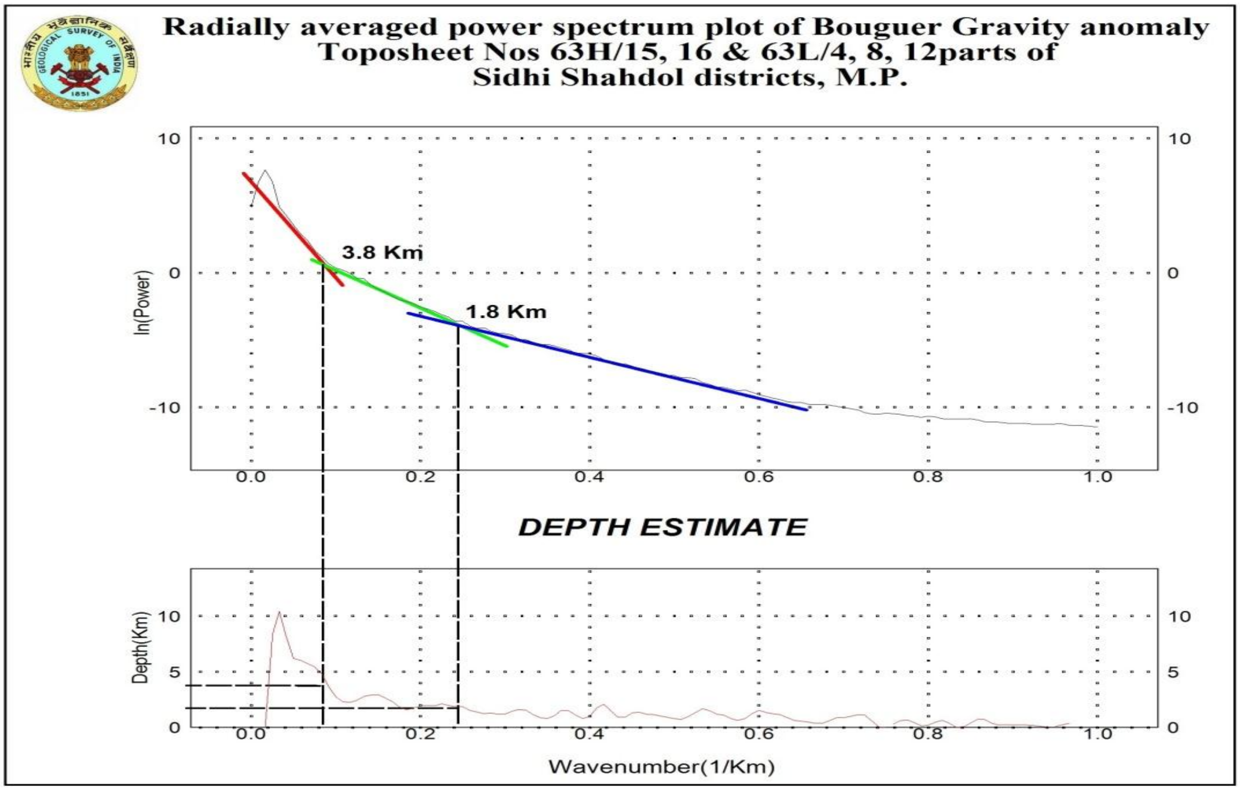

Figure-7: RAPS of Bouguer gravity anomaly.

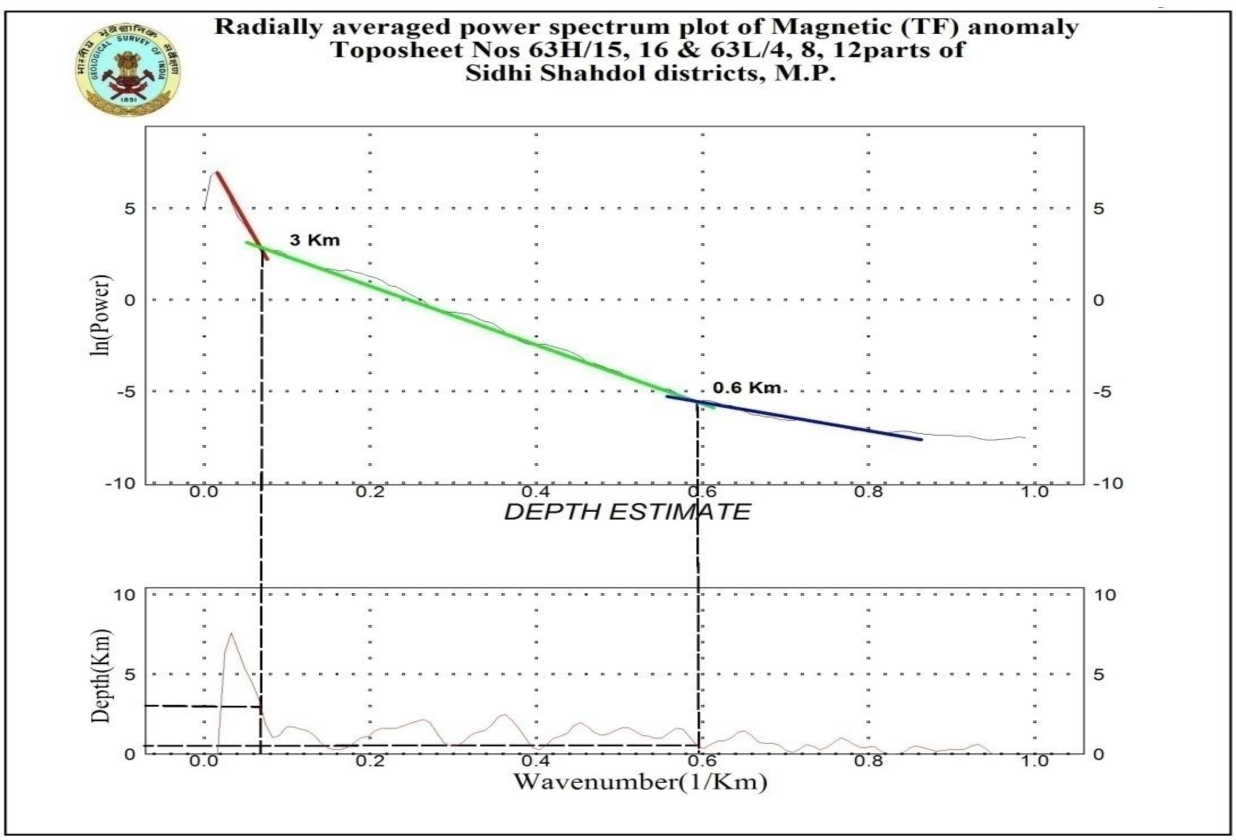

Figure-8: RAPS of magnetic anomaly.

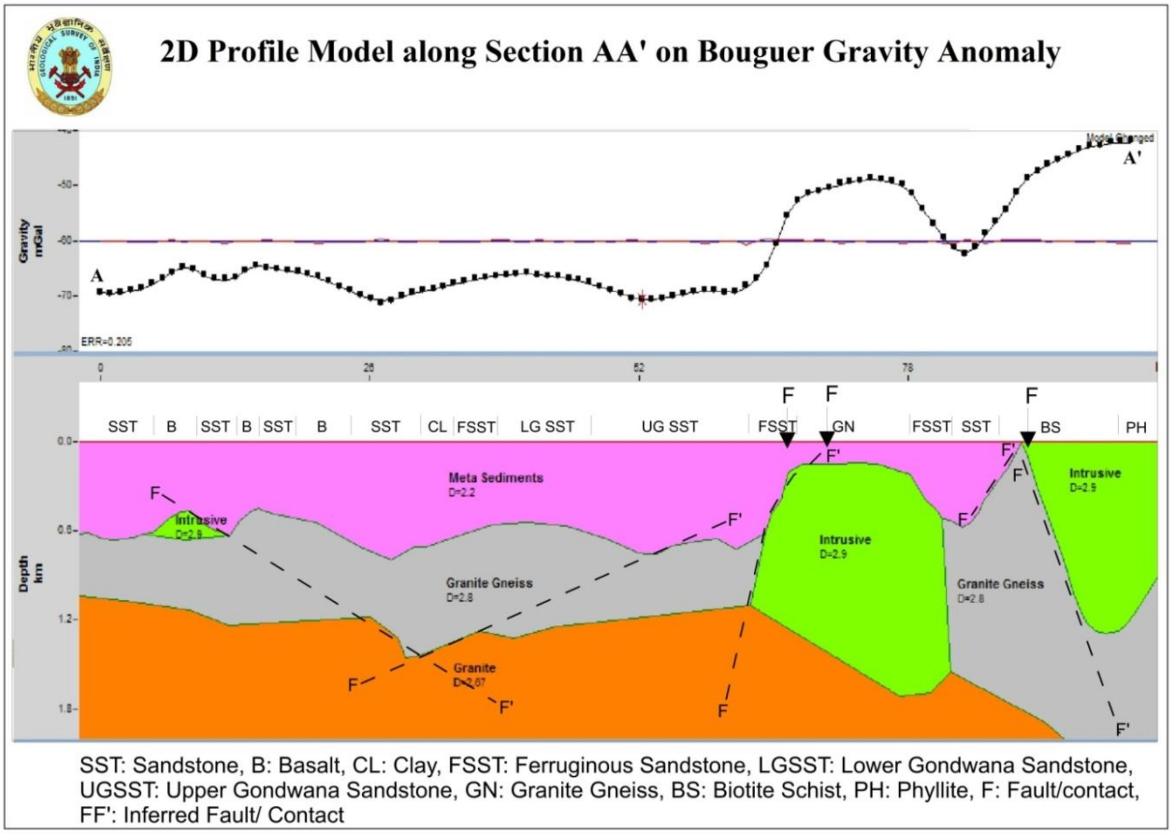

Figure-9: 2-D Modeling of Gravity transect A-A'.

Table-1: Physical properties of rock samples.

Rock Type	No. of Samples	Density gm/cc		Susceptibility X10^{-6} CGS Units	
		Range	Average	Range	Average
Amphibolite	01	2.898	2.898	94.6	94.600
Clay	04	2.232 - 2.398	2.360	19.8-33.8	26.800
Chert	02	2.544 - 2.546	2.545	24.1-23.80	23.950
Ferrugineuse Sandstone	17	2.398 - 2.988	2.687	2.7-71.9	22.954
Gabbro	08	2.947 - 3.076	2.996	603-957	711.443
Granite Gneiss	04	2.461 - 2.612	2.537	2.6-36.5	19.800
Granite	13	2.238 - 2.789	2.367	05-631.3	109.664
Grey Biotite Granite	02	2.978 - 2.980	2.979	667.5-660.2	663.850
Mica schist	05	2.742 - 2.961	2.841	13.3-895	308.600
Phyllite	10	2.466 - 2.775	2.627	-1.0-18.3	8.519
Pegmatite	09	2.521 - 2.600	2.554	6.2-20.8	24.783
Quartzite	09	2.594 - 2.836	2.686	2.8-50.1	27.033
Sandstone	43	2.002 - 2.888	2.383	-0.8-631.3	29.228
Siltstone	01	2.289	2.289	5.4	5.400

Conclusion

Quantitative interpretation of gravity data indicated three sub surface interfaces at depths, viz. 1.8 km (shallow), 3.8 km (intermediate) and beyond 3.8km (deeper) and magnetic data recorded three sub surface interfaces at depths, viz. 0.6 km (shallow), 3.0 km (intermediate) and beyond 3.0 km (deeper). The average first sub-surface interface recorded up to 1.2 km depth while second interface up to 3.4 km depth may be correspond to sedimentary rocks of lower Gondwana formation sandstone.Phyllite is shown moderate density and low susceptibility, whereas granite is showing low density and high susceptibility. The mica schist, grey biotite granite, amphibolite and gabbro have higher order of density and susceptibility. The variations in magnetic susceptibility of sandstone and ferruginous sandstone have high due to alteration/ weathering.

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