J. Ind. Geophys. Union (September 2018)
v.22, no.5, pp: 478-484

Significance of regional gravity survey in parts of Sidhi and Shahdol districts, M.P.

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ABSTRACT
This article highlights the significance of regional gravity survey in parts of Sidhi and Shahdol districts of Madhya Pradesh. Gravity values vary from a minimum of -84mGal to maximum of -16mGal, with an overall variation of 68mGal. The general trend of Bouguer gravity anomaly contour pattern is E-W and NE-SW direction. The high gravity along with swelling and pinching is recorded near Chauphal, Nibuha, Harbaro, and Dol over Mahakoshal Group. The inferred structural features (Inferred fault/ Lineament/ Contact) are reflected in Bouguer gravity anomaly map, which is corroborated with geological map of the study area. The prominent shallow nature anomalies, recorded in the vertical derivative and residual gravity maps, correlate with the Bouguer gravity anomaly map. The Euler depth solutions provided depths less than 0.5km, 0.5 to 1.5km, 1.5 to 2.5km and beyond 2.5km. The majority of solutions are falling at the contact between two litho-units faults/ contacts, with varying depths from 0.5 to 2.5km. All these depth solutions nearly corroborate with the inferred structural features.

Keywords: Regional gravity studies, Mahakoshal Group, Chotanagapur, Sidhi, Shahdol,

INTRODUCTION

Regional gravity field can be employed effectively to delineate the subsurface structural features, such as faults/ fractures/ shear zones/ altered zones, which are significant loci for the occurrences of mineral resources and emplacement of intrusivesuite of rocks (Dahanayake and Subasinghe 1988; Gorle et al. 2016; Subasinghe 1998). Gravity and Differential Global Positioning System (DGPS) data are collected by employing the Autograv gravimeter CG-5 and DGPS 1200 over the area covered by Latitude 24º 00′00″ N to 24º 30′ 00″ N and Longitude 81º 45′ 00″ E to 82º 45′ 00″ E, which falls in the Survey of India Toposheet Nos. 63H/15, 16 and 63L/04, 08, 12, corresponding parts of Sidhi and Shahdol districts, M.P. (Figure 1). The area exhibits the mixed topography of both plains and rugged hills. The rugged topography consists of a series of roughly parallel to sub-parallel, ENE-WSW trending ridges and intervening narrow valleys. Structure and lithology mainly control the drainage pattern, which varies from sub-dendritic to dendritic and sub-parallel. The study area is mainly drained by Son river and its tributaries Gopad river, Ghiganal Nala and Deonar Nadi, Sehra Nadi, Barchar Nala, Mohan Nadi, Kansad Nadi, Karaundia Nala and Dhunnai Nala (Jha et al., 1980; Jha and Devarajan 2002a; Subramanvam et al., 1972, 1975).

GEOLOGY

Geologically, the area is represented by Vindhyan Supergroup, Sidhi gneisses, Chotanagapur gneissic complex, Mahakoshal Group, Gondwana Supergroup and Deccan Traps. 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. The Chhotanagpur gneissic complex group is represented by quartzite, biotite schist, and granite gneiss. Similarly, the Gondwana Supergroup includes the Talchir, Barakar, Barren Measure and Pali Frmations 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 further intruded by basic and ultra-basic intrusives, syenite, quartz veins and pegmatites (Jha et al., 1980; Jha and Devarajan, 2002b; Majumdar, 1980; Pandhare, 1972; Subramanvam et al., 1972, 1975).

GRAVITY INVESTIGATION

Regional gravity survey is carried out with a station density of 1 GM station per 2.5Sq Km along the available roads, forest tracks, cart tracks and foot tracks and covered 3500Sq Km. Elevations of each gravity stations were connected to the available bench mark and triangulation point by DGPS. The gravity observations are taken with reference to gravity bases established. Gravity data is corrected for instrument drift, and entire data were subjected to free air and Bouguer slab corrections. The gravity data have been reduced to mean sea level (MSL)

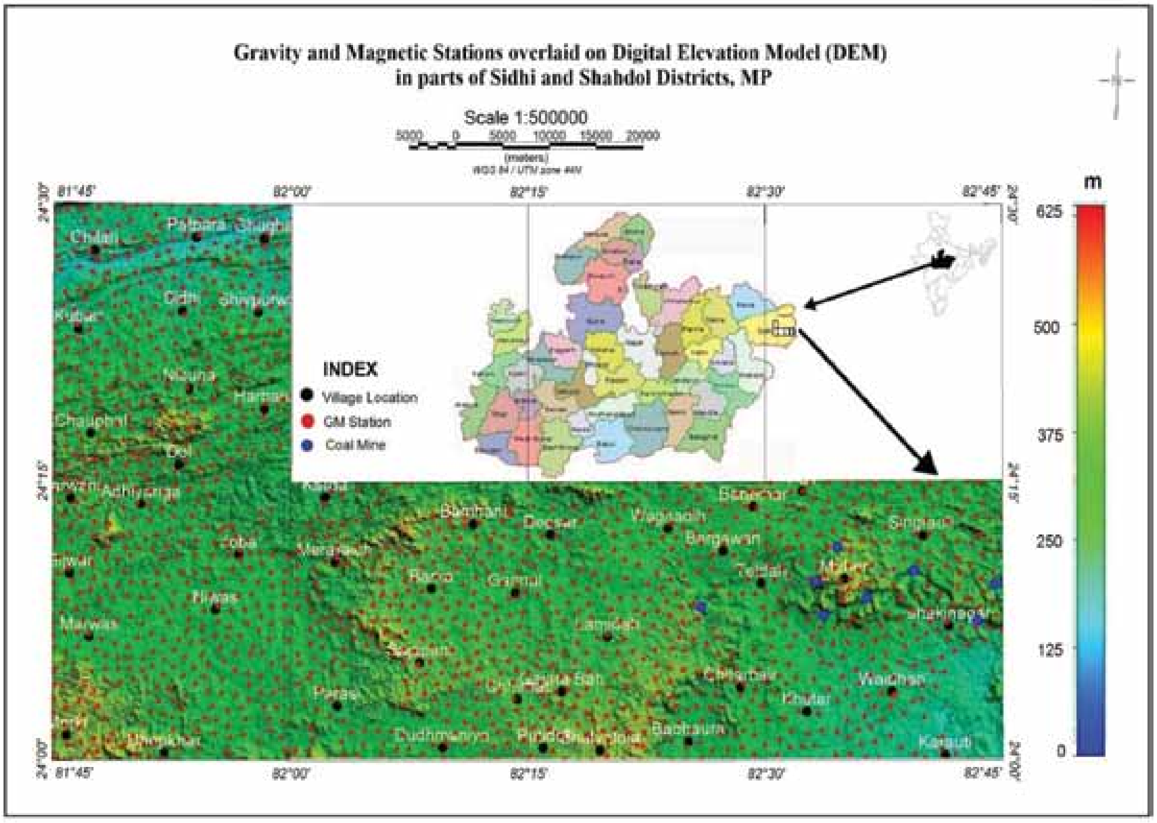

Figure 1. Gravity stations overlaid on Digital Elevation Model of the study area.

after applying elevation correction. Bouguer gravity anomaly over the study area was computed forcrustal density of 2.67 g/cm3. For latitude correction, international gravity formula 1980 was used (Bharati et al., 2016; Gorle et al., 2016).

RESULTS AND DISCUSSION

Bouguer gravity anomaly map

Bouguer gravity anomaly map has been prepared with a contour interval of 1 mGal as shown in Figure 2. The general trend of Bouguer gravity anomaly is E-W and NE-SW directions in southern and northwestern part of the area, respectively. Gravity values vary from -84 mGal to -16 mGal, with an overall variation of 68 mGal. Bouguer gravity anomaly is characterized by broad gravity 'low' in northwestern of Merki, around Parsi, Lmidah and northeastern of Shaktinagar villages and the gravity anomaly 'high' near Chaupal, Nibuha and Karda, south of Larvani and Southwestern of Adhiyariga villages.

The first major gravity gradient (F1-F1′) aligned in NW-SE direction, is observed from Pali to Singrauli in the northeastern part, which is inferred fault in boundary/ tectonic contact between Mahakoshal Group and Lower Gondwana group. The second major gravity gradient (F3-F3′) trend in SW-NE direction is recorded from Marwas to Joba villages and its continued up to Bargawan in approximate E-W direction, which is a inferred fault in boundary tectonic contact between the Chhotanagpur gneissic complex group (Granite gneiss) and Lower Gondwana group. The gravity 'high' (H1)with moderate gradient is recorded near Karda which is basically reflected the contact between the Mahakoshal group (Phyllite) and Chhotanagpur gneissic complex group (Granite gneiss) (F4-F4′). The high gravity (H2) along with negative contour pattern is observed swelling and pinching around Chauphal, Nibuha, Harbaro and Dol over Mahakoshal group which is due to the grading in metamorphism of Mahakoshal Group Formation. Due to the grading of metamorphism, the density variation frequently occurs in Mahakoshal Formation. The first moderate gravity gradient (F2-F2′) aligning approximate NW-SE direction, is observed from Waghadih to Khutar, which may be inferred fault/ contact in between two low gravity anomaly zones (L1 and L2) over coal mines area. The high gravity anomaly is recorded in between these two low gravity anomaly zones (L1 and L2) which may be due to the upliftment of basement. The second moderate gradient (F5-F5′) is observed in NE-SW direction from Chauphal to Shivpurwa, which is inferred fault as the boundary between Sidhi gneiss group (Granite Gneiss) and Mahakoshal group. This fault is also discovered earlier and called Amsi-Jiawan fault. The third

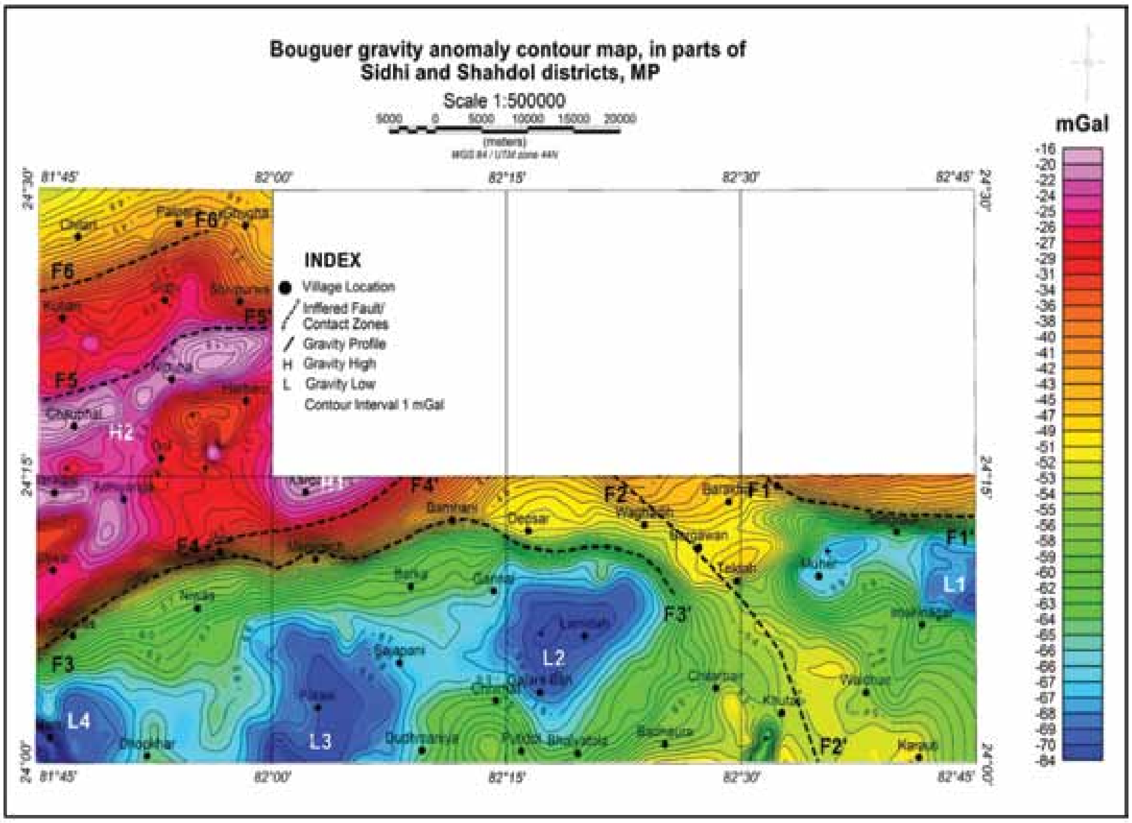

Figure 2. Bouguer gravity anomaly contour map.

major gravity gradient (F6-F6′) aligning in NE-SW direction, is recorded in northwestern part from Kubari to Ghugha, which may be inferred as a fault in the boundary between Semri Group (Sandstone), Vindhyan formation and Sidhi gneiss group (Granite gneiss). This fault is also discovered earlier and called Jamui-Markundi fault.

Regional gravity and residual gravity anomaly map

Regional and residual separations were carried out for better understanding of the sub-surface responses from deeper and shallower causative sources. Various techniques are available to carry out regional-residual separation viz. visual analysis, trend analysis, upward continuation and wave number analysis (Lowrie, 2007; Mallick et al., 2012; Telford et al., 1976, 1988, 1990). Regional gravity anomaly map is prepared by low pass filter using a cutoff wavelength of 12 km and presented in Figure 3. Gravity high, in the northwestern part of the area still exists in the regional map, indicating that causative sources of these anomalies are from a deeper level. The regional gravity map demarcated boundary of Chhotanagapur gneissic complex group (Granite gneiss) and Lower Gondwana group by high gradients.

Residual gravity anomaly map is prepared by regional-residual separation technique, which recorded various residual gravity 'high' (RH) and 'low' (RL) anomaly zones (Figure 4). The residual gravity high near Chauphal to Nibuha (RH-8), in the northwestern part, is due to the presence of meta-basalt which may be reflected from shallow depth. Residual gravity high near Gijwar (RH-9), Joba (RH-6) and Deosar (RH-5) over Granite gneiss is sharpened and clearly demarcated. The residual gravity high (RH-1) is also recorded in northeastern part, near Singrauli over Biotite schist. The residual gravity low near Singrauli (RL-1), in the eastern part is recorded over sandstone, which may be reflected from shallow depth. Residual gravity low near Khutar (RL-2) and Barka (RL-3) may be due to altered sandstone/ low dense material.

Vertical derivative of Bouguer gravity anomaly map

The Derivative maps have been used for many years to delineate edges in gravity and magnetic field data (Evjen, 1936; Hood and Teskey, 1989; Thurston and Smit, 1997). The vertical derivative technique is one of several methods of removing the regional trend. Some gravity anomalies may be distinct on examination of the Bouguer map, while other weak anomalies arising from sources that are shallow and limited in depth and lateral extent, may be obscured by the presence of stronger gravity effects associated with deeper features of larger dimensions. The primary function of the vertical derivative map is to accentuate shallow

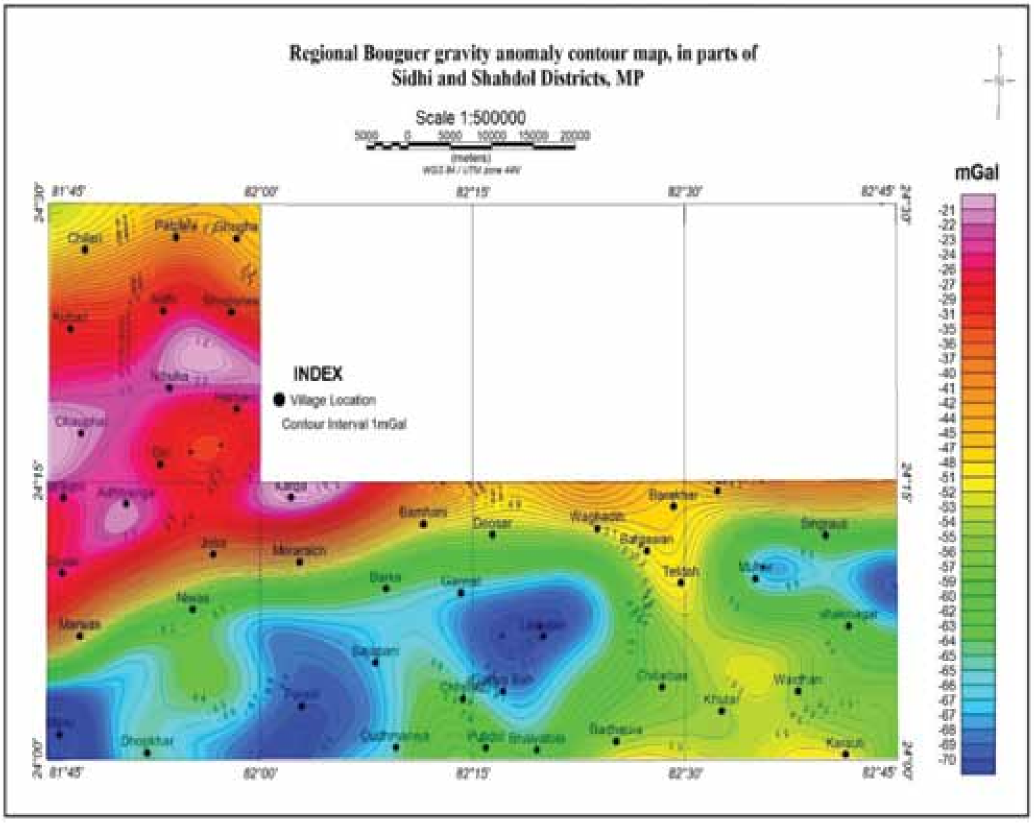

Figure 3. Regional Bouguer gravity anomaly contour map.

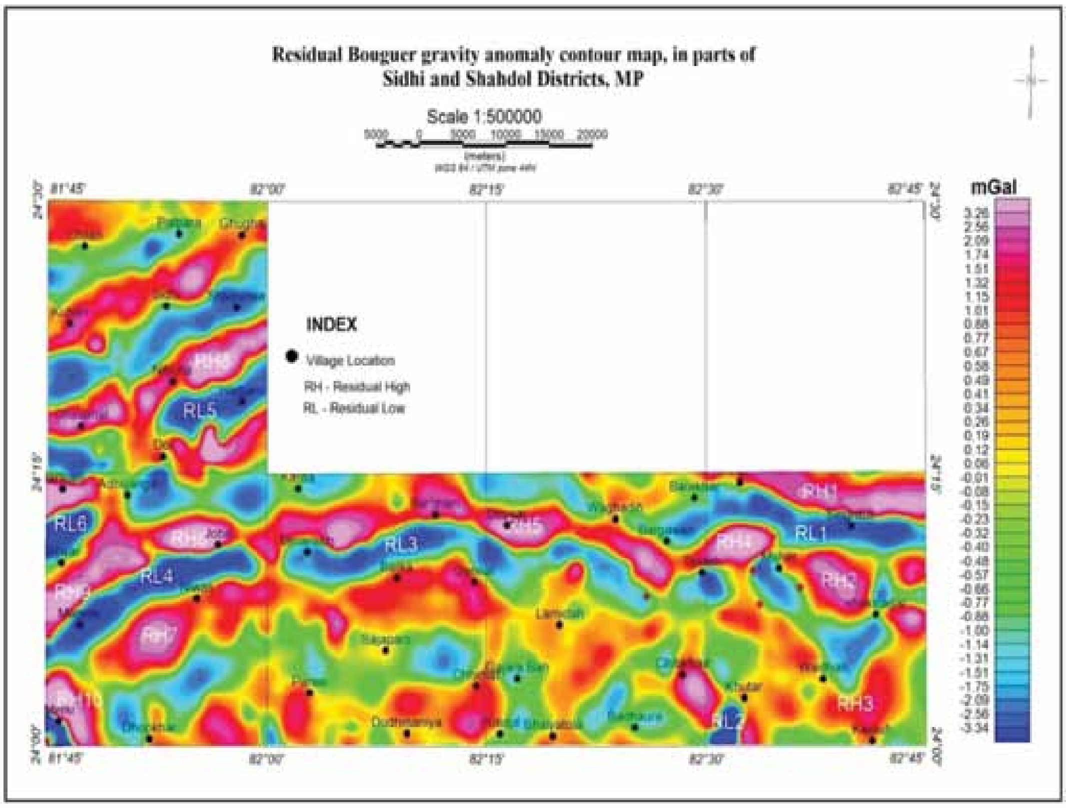

Figure 4. Residual Bouguer gravity anomaly contour map.

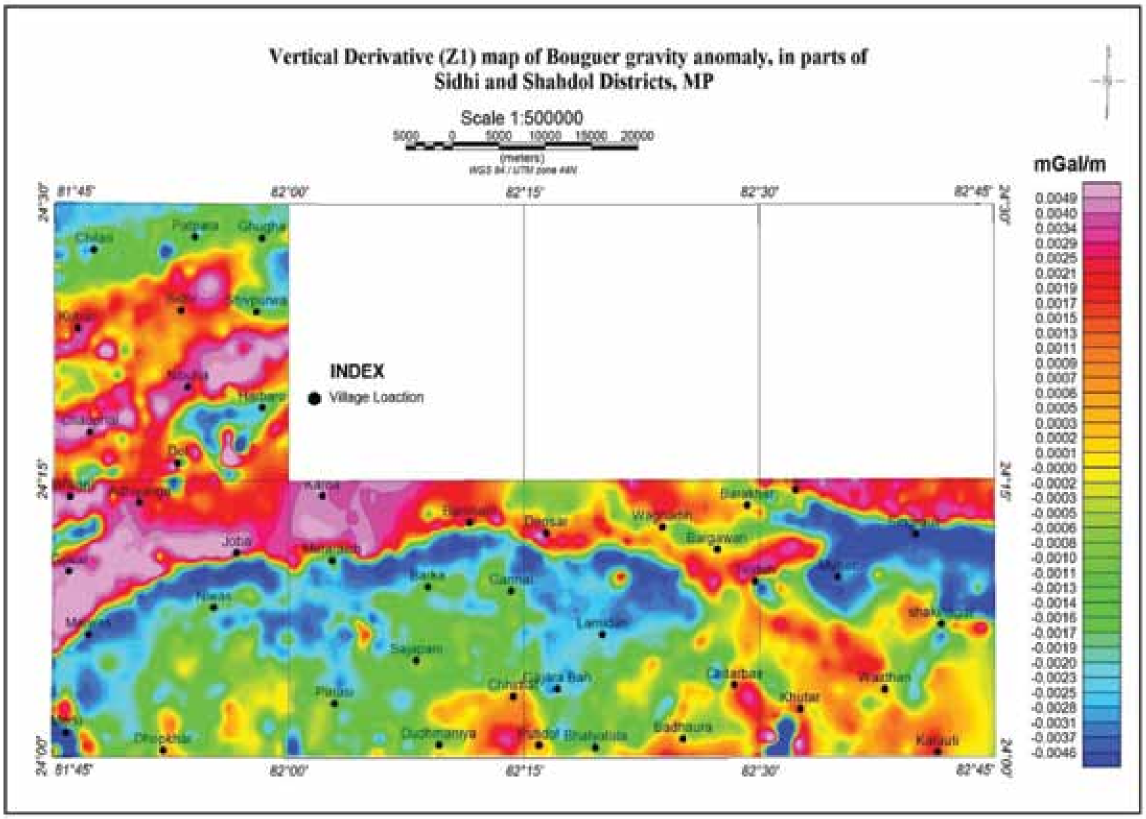

Figure 5. Vertical derivative (Z1) map of Bouguer gravity anomaly.

features at the expense of buried features. The application of the vertical derivative in gravity interpretation to enhance localized small and weak near-surface features (i.e., improving the resolving power of the gravity map) has long been established (Baranov, 1975; Gupta and Ramani, 1982). The prominent shallow nature anomalies, aligned approximately NE-SW direction (Figure 5), are observed near Singrauli, Teldah, Chitarbair, Waghadih, Deosar, Bamhani, Putidol, Karda, Gijwar, Kubari, and Nibuha.

Analytical signal map of Bouguer gravity anomaly

The analytical signal map is shown in Figure 6 which has sharpened the boundaries of the geological features more clearly in northeastern, southwestern, northwestern and central parts of the survey area. Hence, the analytical signal map was utilized in delineating sources and with high intensity gravity gradients observed in the western part near Marwas-Meraraich-Deosar trending in SW-NE and approximate E-W direction, respectively, that has been inferred as a fault in boundary tectonic contact zone between the Chhotanagpur gneissic complex group (Granite gneiss) and Lower Gondwana group which is also corroborated with Bouguer gravity anomaly map. Linear bodies in analytic signal map are recorded over north of Singrauli, north of Waghadih and Bargawan, south of Khutar, south of Merki, east of Chauphal, North-east of Nibuha, east of Dol, north of Chilari, Patpara and Ghugha and also north of Kubari, Sidhi and Shivpurwa.

Euler 3D depth solutions of gravity anomaly

The standard Euler 3D deconvolution method is based on Euler's homogeneity equation that relates to estimate the depth of causative sources obtained from Bouguer gravity anomaly and its first order gradient components in three directions to the location of the sources of the data and gridded data with the degree of homogeneity, which may be interpreted as a structural index (SI). The structural index (SI) is based on the geometry of the gravity anomaly and is a measure of the rate of change of the anomaly with distance from the source (Thompson, 1982).

The Euler 3D depth solutions are obtained by using the Euler 3D module of Geosoft software version 9.1 shown in Figure 7. The window length of 5km and Structural Index = 0, were used to estimate depths of various sub-surface structures. The Euler depth solutions provided depths less than 0.5 km, 0.5 to 1.5 km, 1.5 to 2.5 km and beyond 2.5 km. The majority of solutions are falling at the contact between two litho-units faults/ contacts, with varying depth from 0.5 to 2.5km. All these depth solutions nearly corroborate with the inferred structural features.

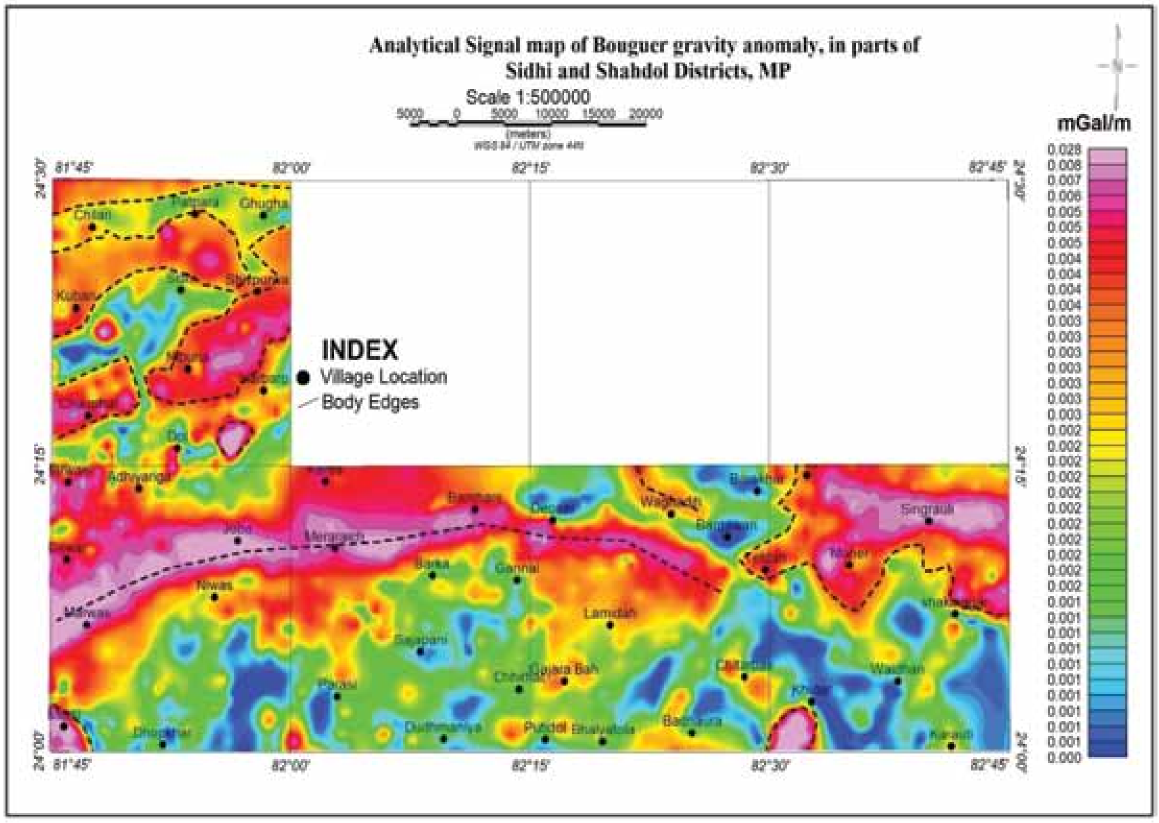

Figure 6. Analytical signal map of Bouguer gravity anomaly.

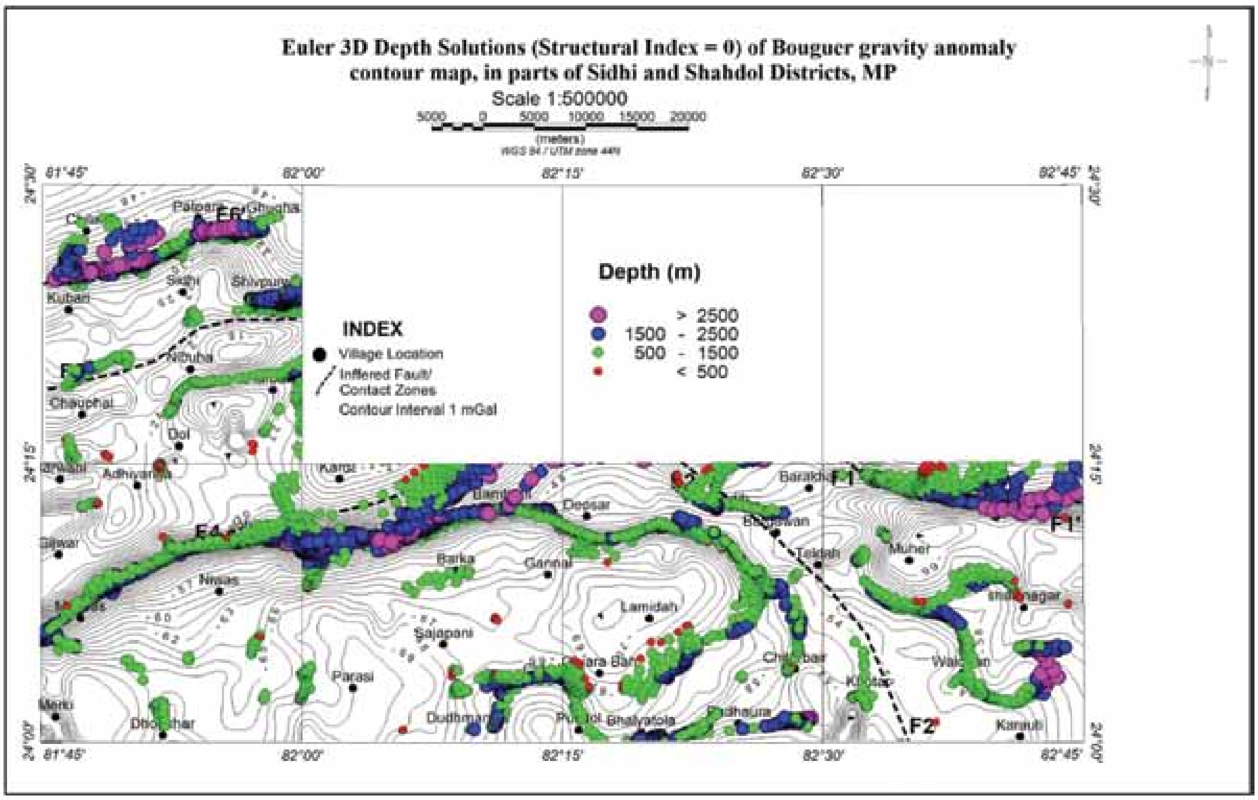

Figure 7. Euler 3D depth solutions (Structural Index = 0).

CONCLUSIONS

The significant gravity gradient (F2-F2′), aligning approximately NW-SE direction and observed from Waghadih to Khutar, may be inferred as fault/ contact, which lies in between two low gravity anomaly zones (L1 and L2) over coal mines area. The high gravity (H2) along with swelling and pinching is recorded near Chauphal, Nibuha, Harbaro, and Dol that lie over Mahakoshal formation. The swelling and pinching of Bouguer gravity anomaly can be considered as characteristic of Mahakoshal group, due to the density contrast caused by metamorphism. The gravity gradient (F5-F5′) is observed in the NE-SW direction from Chauphal to Shivpurwa, which is again inferred as fault/ contact between Sidhi gneiss group (Granite gneiss) and Mahakoshal Group. This fault is called Amsi-Jiawan fault. Another prominent gravity gradient (F6-F6′) is recorded in northwestern part that aligns in NE-SW direction from Kubari to Ghugha, which can be inferred as fault between Semri group (Sandstone), Vindhyan formation and Sidhi gneiss group (Granite gneiss). This fault is known as Jamui-Markundi fault. The majority of Euler solutions are falling at the contact between two litho-units faults/ contacts with varying depth from 0.5 to 2.5km. All these depth solutions are nearly corroborating with the inferred structural features.

ACKNOWLEDGEMENT

The authors express their sincere gratitude to Shri N. Kutumba Rao, Additional Director General and HOD, Geological Survey of India, Central Region, Nagpur for providing all logistics in carrying out the work. We are a great depth of gratitude to D. Hanmanthu for his kind assistance during the geophysical data collection. We are thankful to the reviewers, Publication Division of GSI, CR, and Nagpur who have given critical and thoughtful suggestions.

Compliance with Ethical Standards

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

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Received on: 13.6.18; Revised on: 2.8.18; Accepted on: 4.8.18