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550.311 (540.49)

# Delineation of subsurface features by gravity technique in parts of Shivpuri District, M.P.

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**सार** – यह शोध पत्र मध्य प्रदेश के शिवपुरी जिले में खनिज के सुनिश्चित क्षेत्रों का पता लगाने के लिए भ्रंशों / विभंजनों / ढलान क्षेत्रों / परिवर्तित क्षेत्रों की खोज की जानकारी प्रस्तुत करता है। भौगोलिक रूप से,इस अध्ययन में विंध्यन सुपरग्रुप द्वारा मध्य युग से नव प्राजीव युग (नियोप्रोटेरोज़ोइक एज) तक की स्थिति को दर्शाया गया है। यह क्षेत्र मु ख्य रूप से जलोढ़ मिट्टी से भरा है जो नदी के कंकड़ों,रेत और अवशिष्ट मिट्टी की विशेषता है। 2.5 वर्ग किलोमीटर के घनत्व के 1 गुरुत्व स्टेशन के लिए गुरुत्व सर्वेक्षण किया गया, साथ ही प्रत्येक गुरुत्व स्टेशनों की ऊंचाई 2800 वर्ग किलोमीटर ली गई। भौतिक गुण (घनत्व) के मापन के लिए अध्ययन क्षेत्र की विभिन्न लिथो-इकाइयों से चट्टान के नमूने एकत्र किए गए जो भूवैज्ञानिक प्रतिक्रिया को समझने और मूल्यांकन करने के लिए उपयोगी हैं। Bouguer गुरुत्व के समोच्च पैटर्न की सामान्य प्रवृत्ति उत्तर पश्चिम- दक्षिण पूर्व दिशाएँ हैं। Bouguer गुरुत्व विसंगति समोच्च मानचित्र दक्षिणी भाग में व्यापक गुरुत्व की 'उच्च' जबकि उत्तरी भाग में 'निम्न' विशिष्टता को दर्शाता है जिससे उत्तर की ओर बेसमेंट के अवदाब का अनुमान लगता है। लगभग उत्तर पश्चिम- दक्षिण पूर्व दिशा में संरेखित नोज़िंग को मध्य भाग में दर्ज किया गया है जिसे अनुमानित लिनिआमेंट के रूप में बताया जा सकता है और यह अवशिष्ट गुरुत्व मानचित्र पर स्पष्ट रूप से परिलक्षित होता है। उ.प.- द.पू. में संरेखित क्षेत्रीय गुरुत्व विसंगति दक्षिणी भाग में व्यापक गुरुत्व की 'उच्च' जबकि उत्तरी भाग में 'निम्न' विशिष्टता को दर्शाता है जिससे उत्तर की ओर बेसमेंट की गहराई का पता चलता है। अधिकतर यूलर 3 डी समाधान की संख्या रैखिक निकायों (अनुमानित रेखा) में 2.5 किमी तक गहराई कम हो रही हैं।

**ABSTRACT.** This research paper represents the search of faults/ fractures/ shear zones/ altered zones, to find out mineral target zones in part of Shivpuri district, M.P. Geologically, the study area is represented by Vindhyan Supergroup of Meso to Neoproterozoic age. The area is mainly covered by alluvium which is characterized river gravels, sand and residual soil. The gravity survey was carried out with a station density of 1 gravity station per 2.5 sq km along with elevations of each gravity stations covered 2800 sq km. The rock samples have been collected from different litho-units of the study area for measurement of physical property (Density) which are useful for understanding & evaluating of geological response. The general trend of contour pattern of Bouguer gravity is NW-SE directions. Bouguer gravity anomaly contour map is characterized by broad gravity 'high' in southern part whereas 'low' in northern part which inferred depression of basement toward the north. The nosing in aligned approximately NW-SE direction is recorded in central part which may be interpreted as inferred lineament and it is clearly reflected on residual gravity map. The regional gravity anomaly aligned in NW-SE is characterized by broad gravity 'high' in southern part whereas 'low' in northern part which reflects basement deepening towards north. The majority of Euler 3D solutions are falling on linear bodies (inferred lineament) with varying depths from 0.5 to 2.5 km.

**Key words** – Shivpuri, Gravity, Magnetic, Vindhyan, Euler.

## 1. Introduction

Gravity method is recognised as indispensable search tool for delineation of subsurface features, such as faults/ fractures / shear zones / altered zones, in which mineral resources / emplacement of an intrusive suite of rocks can be occurred (Dahanayake and Subasinghe, 1988; Gorle *et al.*, 2016; Subasinghe, 1998; Kumar and Punekar, 2018). Gravity and Differential Global Positioning System (DGPS) data are collected by employing the Autograv gravimeter CG-5 and DGPS 1200 in the study area. The area is covered by latitude 25° 15′00″ N to 26° 15′ 00″ N and longitude 77° 30′ 00″ E to 77°45′ 00″ E and falls in the Survey of India Toposheet Nos. 54F/12, 54G/09, 10 &11, parts of Shivpuri district Madhya Pradesh (Fig. 1).

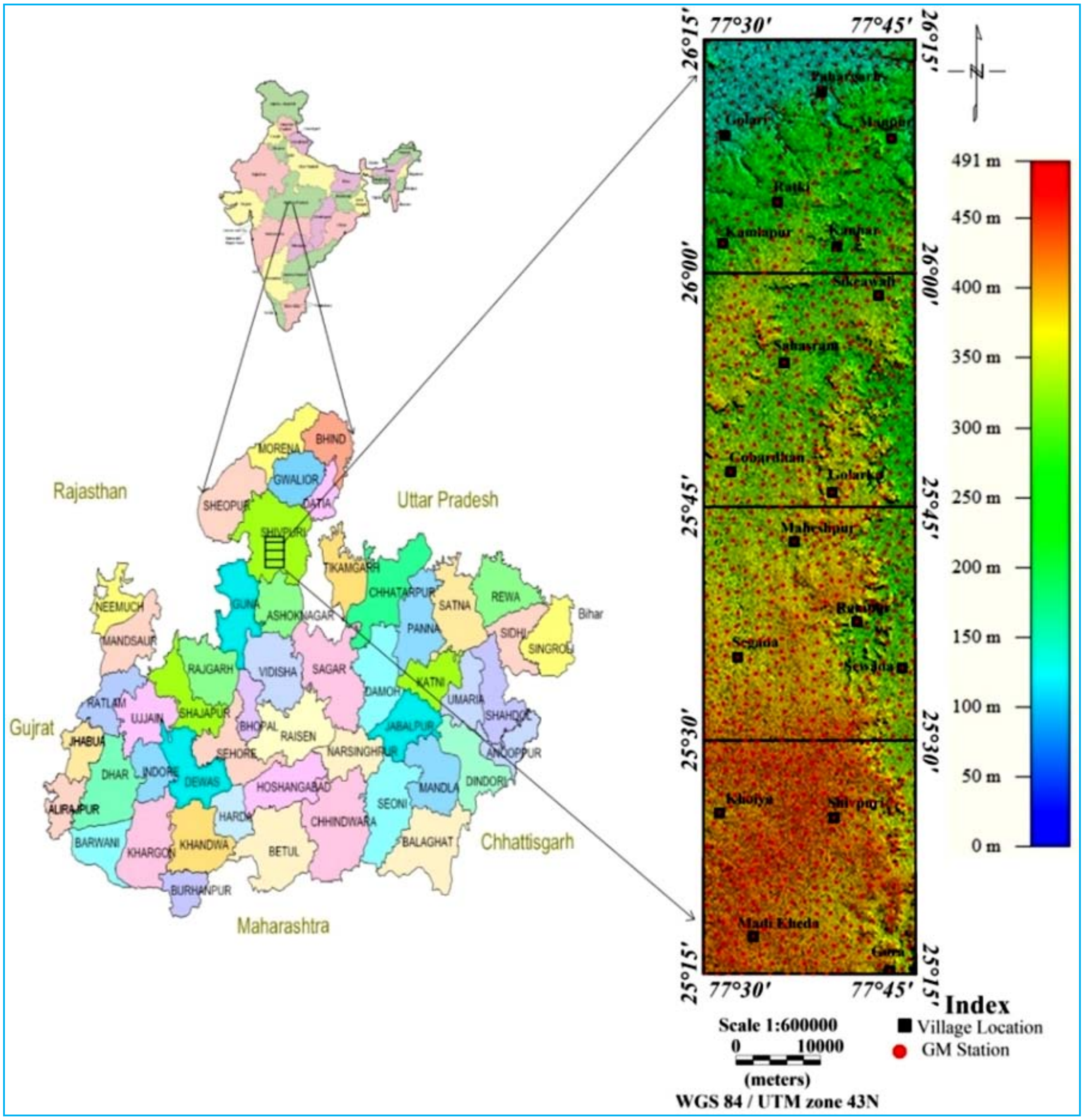


**Fig. 1.** Location & elevation map of study area (Kumar *et al*., 2018).

## 2. Geology

Geologically, the study area is represented by Vindhyan Supergroup of Meso to Neoproterozoic age (Fig. 2). 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 Bhander Groups. The Kaimur is represented by Bijaigarh, Dhandraul and Ghagharmembers. 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. Bhander group composed of Limestone and Sandstone of Nagod and Bundi Hills formations (Shrivastava and Melhotra, 1990; Chatterji and Tripathi, 1989; Jain and Dhar, 1987; Tomar *et al*., 1981).

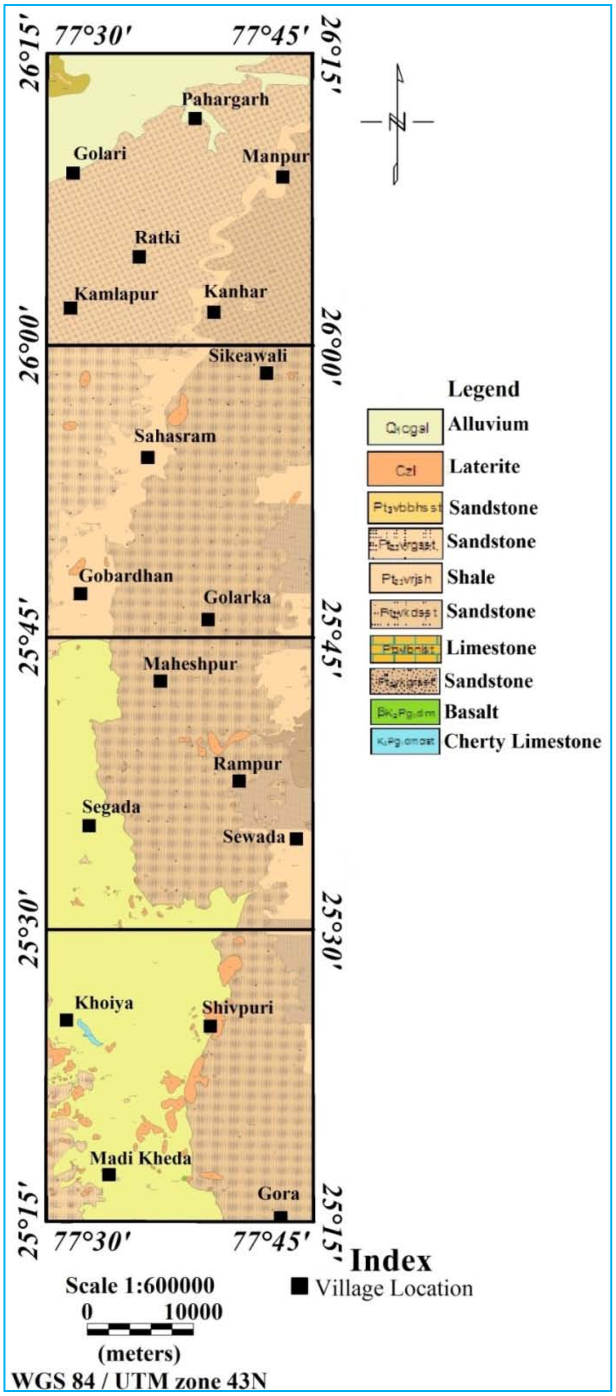


**Fig. 2.** Geology of the area [*Source*: Geological Survey of India (GSI), India]

## 3. Methodology

### 3.1. *Gravity method*

Regional gravity survey was carried out with a station density of 1 gravity station per 2.5 sq km along the available roads, forest tracks, cart tracks and foot tracks and covered 2800 sq km area. Elevations of each gravity stations were connected to the available bench mark and triangulation point by DGPS. Gravity data was 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) after applying elevation correction. Bouguer gravity anomaly over the study area was computed for crustal density of 2.67 g/cm$^3$. For latitude correction, international gravity formula 1980 was used (Bharati *et al*., 2016; Gorle *et al*., 2016; Kumar and Punekar, 2018). The rock samples of 117 Nos. have been collected from different litho-units of the study area for measurement of physical property (Density).

## 4. Results and discussion

### 4.1. *Bouguer gravity anomaly map*

Bouguer gravity anomaly contour map has been prepared with a contour interval of 1 mGal shown in Fig. 3. The general trend of gravity contours are in NW-SE directions. Gravity values vary from a minimum of -61.92 mGal to a maximum of -34.24 mGal, with an overall variation of 27.68 mGal. Bouguer gravity anomaly contour map is characterized by broad gravity ‘high’ in southern part whereas ‘low’ in northern part which inferred depression of basement toward the north. The gravity ‘high’ align NW-SE direction is recorded near Khoiya, Shivpuri, Madi Kheda and Gora villages in southern part which is due to the upliftment of basement rocks / presence of denser rock below the Vindhyan formation. In central part, the nosing aligned approximately NW-SE direction is observed near Sahasram, Kamlapur, Gobardhan & Golarka villages, which may be interpreted as inferred lineament. The gravity ‘low’ is observed near Ratki, Golari, Kanhar, Sikeawali and Manpur villages in northern part, which indicates presence of low depression zone (basin filled with altered / weathered sandstone and limestone).

### 4.2. *Regional gravity and residual gravity anomaly map*

Regional and residual separation was carried out for better understanding of the subsurface responses from deeper and shallower causative sources, respectively. Various techniques are available to prepare regional gravity anomaly *viz*., visual analysis, trend analysis, upward continuation and wave number analysis (Lowrie, 2007; Mallicket *et al*., 2012; Telford *et al*., 1976a; 1988b; 1990c). Regional gravity anomaly map is prepared using upward continuation technique and after analyzing the results of different depth of upward continuation. Finally,

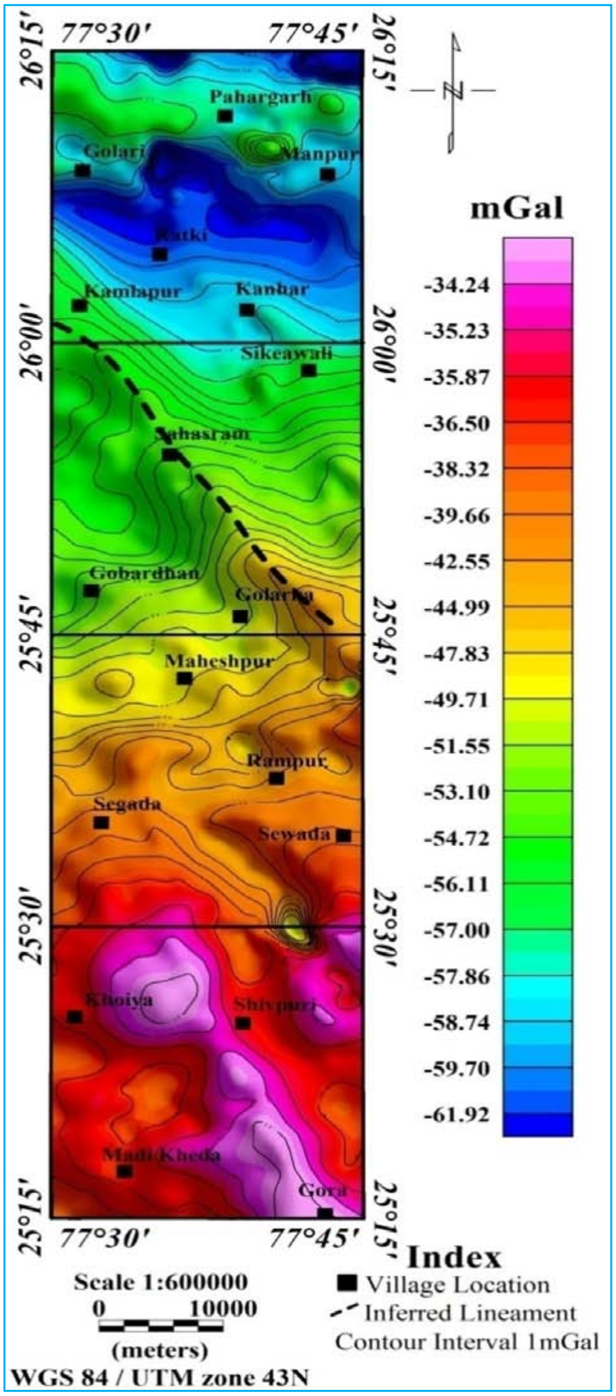


**Fig. 3.** Bouguer gravity anomaly contour map

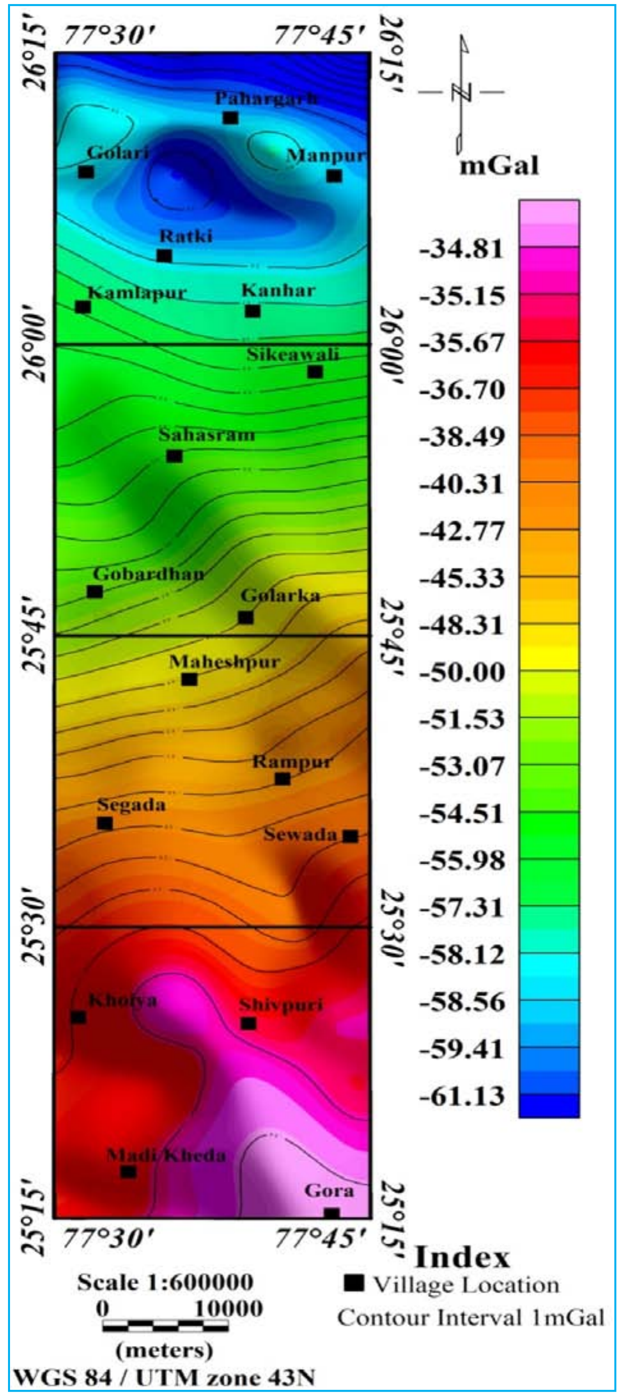


**Fig. 4.** Regional Bouguer gravity anomaly contour map

a depth 3 km has been selected after analyzing the Radial Average Power Spectrum (RAPS) of gravity anomaly. Regional gravity map is observed that near surface noise is suppressed and reflects the deep-seated responses. The regional gravity anomaly align NW-SE is characterized by broad gravity 'high' in southern part, whereas 'low' in northern part shows the depression of basement toward the north shown in Fig. 4. 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, which is due to presence of basement rock at shallower depth.

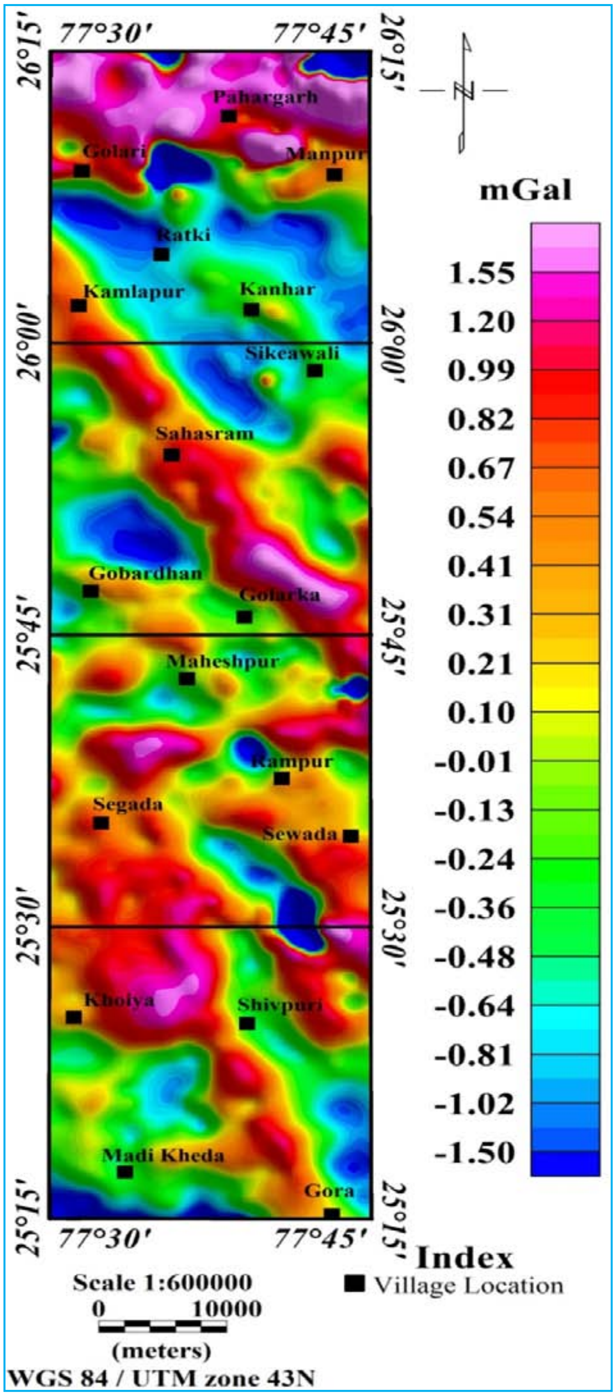


**Fig. 5.** Residual Bouguer gravity anomaly contour map

The residual gravity anomaly is separated from Bouguer gravity anomaly using regional-residual separation technique, which is recorded various local gravity anomalies residual gravity 'high' and 'low' along with various amplitude and trend shown in Fig. 5. The residual gravity high is observed near Sahasram, Kamlapur, Gobardhan & Golarka villages in central part due to presence of as inferred lineament, which may be due to shallow feature anomaly and correlated with Bouguer gravity anomaly.

### 4.3. *Vertical derivative of Bouguer gravity anomaly map*

The derivative has 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 gravity 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 application of vertical derivative in gravity interpretation is to enhance localized small and weak near-surface features (*i.e.*, improving the resolving power of the gravity map) which has been established (Baranov, 1957a, 1975b; Gupta and Ramani, 1982). The prominent shallow nature anomalies (Fig. 6) aligned approximately NW-SE direction is observed near Sahasram, Kamlapur, Gobardhan & Golarka villages in central part due to presence of as inferred lineament and also near Shivpuri may be due to upliftment of basement rock which is correlated with residual gravity and Bouguer gravity anomaly map.

### 4.4. *Euler 3D depth solutions of gravity anomalies*

The standard Euler 3D deconvolution method is based on Euler's homogeneity equation which relates to estimate the depth of causative sources obtained from Bouguer gravity anomaly data and its first order gradient components in three directions to the location of the causative sources (Thompson, 1982) 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 gravity anomaly 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 estimate depth of causative sources.

The Euler 3D depth solutions are obtained by using Euler 3D module of Geosoft software version 9.1 which is shown in Fig. 7. The window length of 5 km and SI = 0 were used to estimate the depths of various sub-surface structures. The Euler depth solutions provides less than 0.5 km, 0.5 to 2.5 km, 2.5 km to 4.0 km and beyond 4.0 km. The majority of solutions are falling on linear bodies (inferred lineament) with varying depths from 0.5 to 2.5 km.

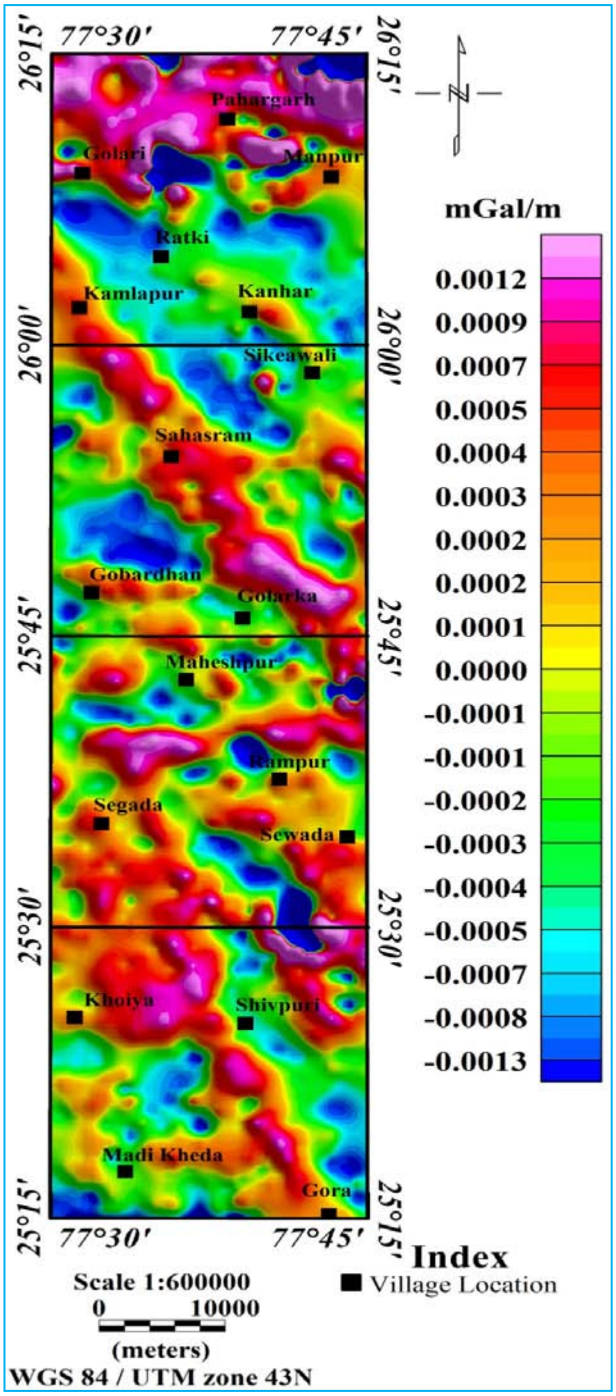


**Fig. 6.** Vertical derivative (Z1) map of Bouguer gravity anomaly

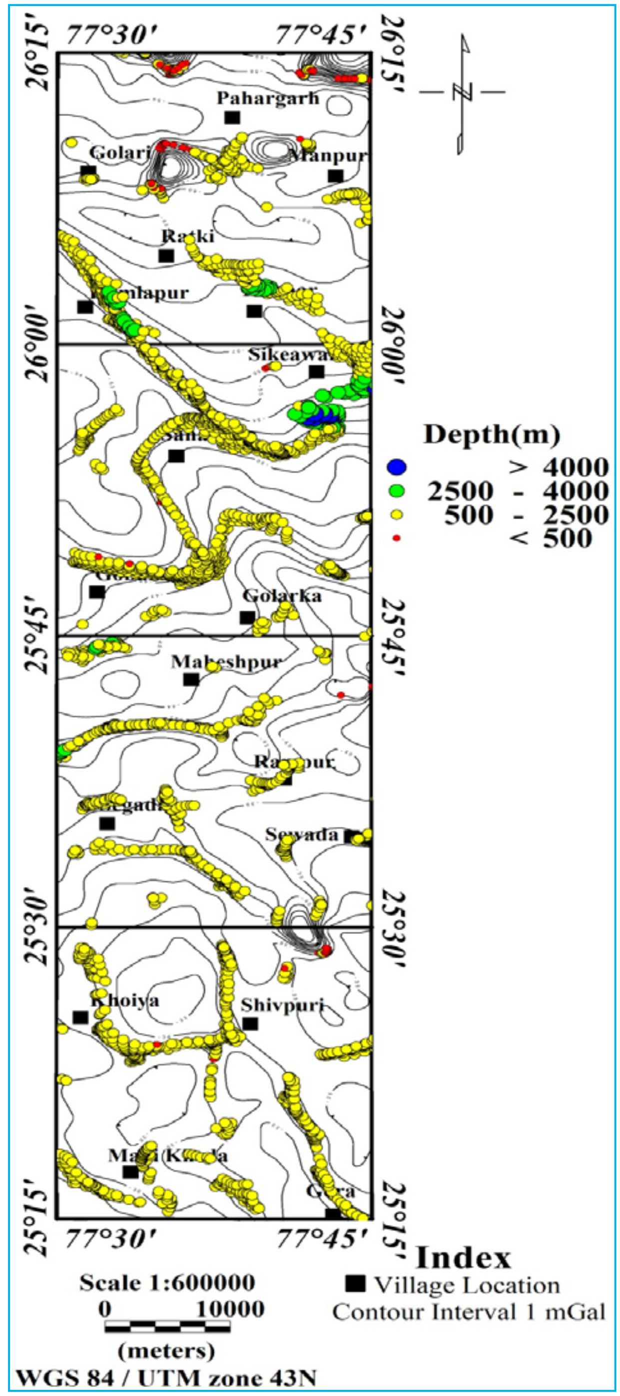


**Fig. 7.** Euler 3D depth solutions gravity data (Structural Index = 0)

## 5. Density measurements of rock samples

The physical properties of rock samples (Density and) 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 (Bharti *et al*., 2016). A total of 117 rock samples are collected from different litho units during field work. The density of rock samples were measured with density meter Mettler Toledo (ME 403). The measured densities of different rock samples are presented in Table 1. It can be

**TABLE 1**

**Physical properties of rock samples**

| Rock Type | No. of Samples | Density gm/cc | |
|---|---|---|---|
| | | Range | Average |
| Fe. Quartzite | 03 | 2.42-2.53 | 2.49 |
| Fe. Sandstone | 25 | 2.30-2.70 | 2.51 |
| Fe. Siltstone | 01 | 2.66 | 2.66 |
| Fine grained Sandstone | 09 | 2.40-2.60 | 2.49 |
| Quartzite | 21 | 2.40-2.62 | 2.52 |
| Sandstone | 43 | 2.35-2.61 | 2.51 |
| Siltstone | 15 | 2.38-2.58 | 2.45 |

inferred that sandstone/siltstone has low order of density values, whereas Quartzite, Ferruginous Quartzite & Ferruginous Siltstone are showing high density. The variations of density of sandstone, fine grain sandstone and ferruginous sandstone may be due to alteration and weathering.

## 5. Conclusions

Bouguer gravity anomaly contour map is inferred by broad gravity 'high' in southern part whereas 'low' in northern part due to depression of basement toward the north. The gravity 'high' align NW-SE direction is recorded in southern part may be due to upliftment of basement rocks/presence of denser rock below the Vindhyan formation. In central part, the nosing aligned approximately NW-SE direction is reflected on Bouguer gravity map which interpreted as inferred lineament. The regional gravity anomaly aligned in NW-SE is characterized by broad gravity 'high' in southern part whereas 'low' in northern part which reflects basement deepening towards north. All the prominent shallow nature anomalies are brought out in residual and vertical derivative gravity map which is correlated with Bouguer anomaly map. The majority of Euler 3D solutions are falling on linear bodies (inferred lineament) with varying depths from 0.5 to 2.5 km. All these depth solutions are nearly corroborating with the inferred structural features.

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*Disclaimer*

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