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Structural Evolution of Kollapur Region in the Northwestern Margin of Cuddapah Basin and, Eastern Dharwar Craton, South India: New Insights from Gravity Anomalies

Linga Swamy Jogu*, Udaya Laxmi Gakka

Centre of Exploration Geophysics, Osmania University, Hyderabad, India
Email: *lingaswamyjogugp@gmail.com, udayalaxmi.g@gmail.com

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Abstract

To decipher both shallow and deeper structural features that may control the emplacement of Kimberlite/Lamproite bodies in basement-exposed and covered areas, a detailed gravity survey was conducted on the northern bank of the Krishna River in the Kollarpur region of the Proterozoic Cuddapah Basin, within the Eastern Dharwar Craton. The study revealed an overall basement disposition dipping from south to north, controlled by a set of parallel E-W and NW-SE trending faults. In the northeastern part of the study area, the high-gravity zone corresponds to high-density source rocks at both shallow and deeper levels within the granite-gneissic basement. The residual gravity map highlights the disposition of high-density shallow source bodies as elliptical highs, located at Narlapur, Kalwakole, and Yelur in the eastern part. These residual gravity highs correspond to enclaves of amphibolite schist and BIF bands within granite-gneissic rocks. In the covered region of the southern part, the overall gravity low zone indicates the distribution of sediments with a thickness of about 1 km. Several NW-SE, N-S, NE-SW, and E-W structural features were delineated from the gravity survey. A major E-W gravity gradient along the northern margin of the Cuddapah and Kurnool groups of sediments is interpreted as a deep-rooted boundary fault. Parallel to this boundary fault, two NW-SE gravity gradients were identified in the northern and central parts within the Archean granite-gneissic basement rocks. Depth extensions of these major structures exceed 1 km. The N-S and NE-SW structures, although shorter in strike length, intersect with the major NW-SE and E-W structures. Some of these intersection zones correspond to known Kimberlite/Lamproite occurrences in both covered and basement-exposed areas. Based on these findings, potential loci for Kimberlite/Lamproite exploration have been delineated along the northern bank of the Krishna River in the Kollarpur region.

Keywords

Amphibolite Schist, Kimberlite and Lamproite, Gravity Anomalies, Euler 3D Depth, Gravity Modelling

1. Introduction

The remarkable history of diamond trading in India is well-documented along the mighty Krishna River, which traverses the stable cratonic regions of central and southern India. The granite-greenstone terrain of the Dharwar Craton (DC), located in Peninsular India, is one of the world's most renowned classical geological regions. It hosts a diverse range of mantle-derived mafic-ultramafic rocks, including pyroxenites, diabase dyke swarms, kimberlites, lamproites, and lamprophyres (Mishra & Prajapati, 2003; Chadwick et al., 2007; Ramakrishnan & Vaidyanadhan, 2008; Chalapathi Rao et al., 2013; Kumar et al., 2013; Sushel et al., 2016; Pandey & Chalapathi Rao, 2019; Giri et al., 2019; Jayananda et al., 2020; Mohan et al., 2020; Singh et al., 2020; Mukherjee et al., 2021b; Sreehari et al., 2021).

Regional geological and geophysical studies indicate a favorable environment for the intrusion of deep-seated mantle-derived magmas, such as kimberlites and lamproites, which are emplaced in the eastern part of the DC in southern India (Chalapathi Rao et al., 2013; Raghuvanshi et al., 2019; Kusham et al., 2021). Similarly, semi-detailed and detailed studies highlight the role of structural features in identifying kimberlite and lamproite bodies in the cratonic regions of the Eastern Dharwar Craton (EDC) (Vasanthi & Mallick, 2005; Chalapathi Rao et al., 2013; Ananda Reddy, 2014; Sushel et al., 2016). Numerous lamprophyre dykes have also been extensively studied along the eastern margin of the Paleo-Mesoproterozoic Cuddapah Basin (CB) (Lakshminarayana & Bhattacharjee, 2000; Lakshminarayana et al., 2001; Shivanna et al., 2002; Anand et al., 2003; Tripathy & Saha, 2013; Pandey et al., 2018; Raghuvanshi et al., 2019; Pankaj et al., 2020). These studies emphasize the importance of detailed investigations along the western and northwestern margins of the CB to demarcate potential target areas for kimberlite and lamproite bodies.

The present study focuses on the Proterozoic sedimentary cover outlier of the Cuddapah Basin (CB), situated on the northern bank of the Krishna River in the Kollapur region, northwest CB (**Figure 1**). This region is surrounded by known kimberlite and lamproite occurrences in the EDC, including the Wajrakarur Kimberlite Field in the southwest; the Raichur and Tungabhadra Kimberlite fields in the west; the Narayanpet Kimberlite Field in the northwest; the Krishna Lamproite Field in the southeast; and the Ramadugu Lamproites in the north (**Figure 1**). Regionally, the Kollapur area comprises granite-gneissic basement rocks of the Peninsular Gneissic Complex-II (PGC-II), which are unconformably overlain by the basal sedimentary units of the Cuddapah and Kurnool formations (**Figure 2**). Furthermore, the northwestern margin of the CB is known for numerous kimberlite and lamproite occurrences (Meshram et al., 2012; Ananda Reddy, 2014; Giri et al., 2019; Nandhagopal et al., 2015). These Kimberlites/lamproites are particularly controlled by E-W to ENE-WSW deep seated fault/fracture zone, their intersection with NW-SE trend linear parallel tectonic fabric and NE-SW to N-S faults (Vasanthi & Mallick, 2005; Veeraiah et al., 2009; Vani et al., 2013; Ananda Reddy, 2014; Jogu et al., 2022).

The Kollapur region, the focus of this study, hosts alkaline and sub-alkaline rocks (lamproites and lamprophyres) within the basement rocks at Thellarlapalle and Ankiraopally, as well as in the cover sediments at Amaragiri and Somsila (**Figure 2**). Some of these occurrences align along the WNW–ESE-trending dykes, which form an important structural domain in the region. This study emphasizes a detailed analysis of structural features derived from gravity data and their potential role in controlling the emplacement of alkaline and sub-alkaline rocks in the basement and covered areas. Detailed investigations are also aimed at identifying potential target areas in the Kollapur region. The structural features were derived from gravity data, which were processed and interpreted using qualitative and quantitative analyses techniques. Additionally, a Two-Dimensional (2D) model was constructed to understand the subsurface structural framework, particularly in the covered areas along the northern bank of the Krishna River.

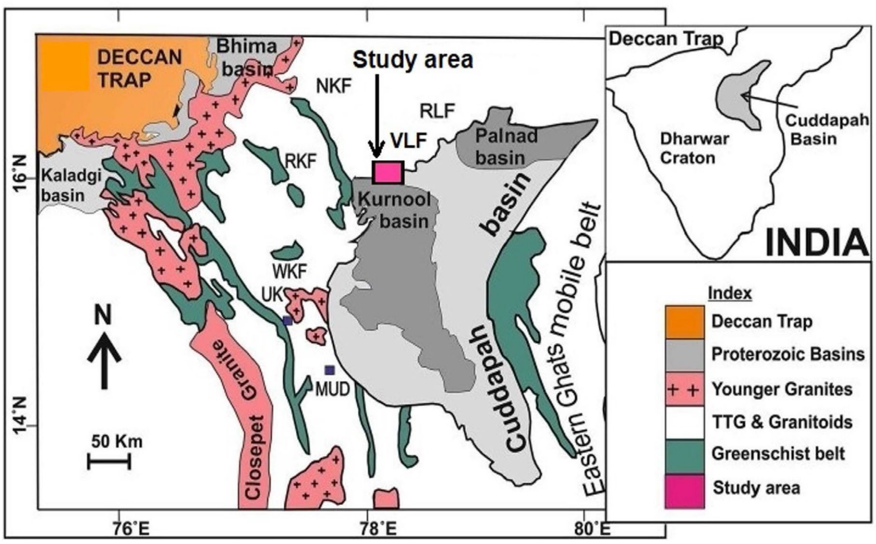


Figure 1. A generalized geological map (MUD: Mudigubba lamprophyre; UK: Udiripikonda lamprophyre; WKF: Wajrakarur Kimberlite field; NKF: Narayanpet Kimberlite field; RKF: Raichur Kimberlite field; VLF: Vattikod Lamproite field; RLF: Ramadugu Lamproite field) (Source: Giri et al., 2019).

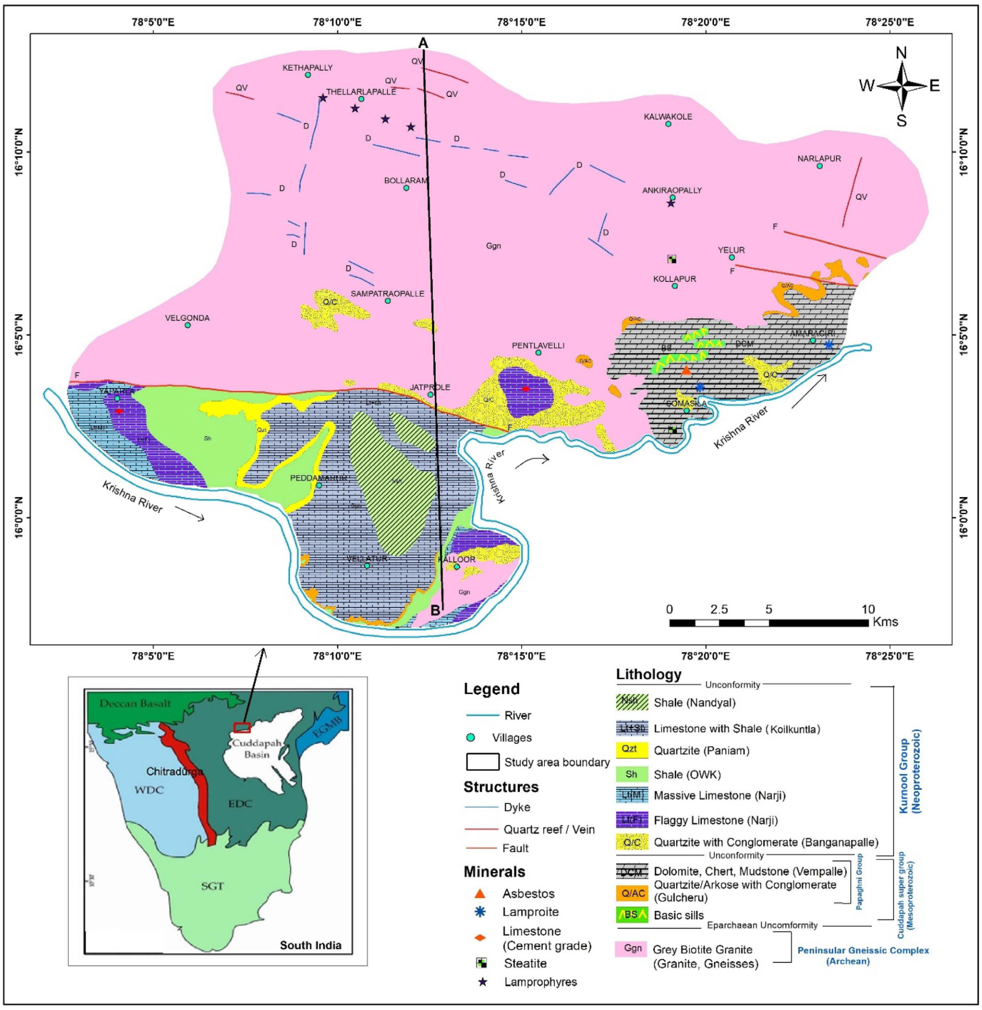
2. Geology Setting

The study area, located in northern bank of Krishna River, exposed with Archaean grey biotite granite basement rocks of PGC-II in northern, central parts, and the Proterozoic cover sediments of Cuddapa and Kurnool groups are occupied in southern and south-western parts (**Figure 2**). The angular and erosional unconformable contact relationship is well in between basement and cover sediments in all along the western margin of CB (Lakshminarayana et al., 2001). The amphibolite schist associated with BIF (Banded Iron Formation) is noticed to the west of Mollachintapally, and in the north of Narlapur and to the eastern margin of Yerragutta quartz reef. According to Sushel et al. (2016) the amphibolite schist may have potential to host gold mineralization and to a strike in length is 10 km and with 500 m width.

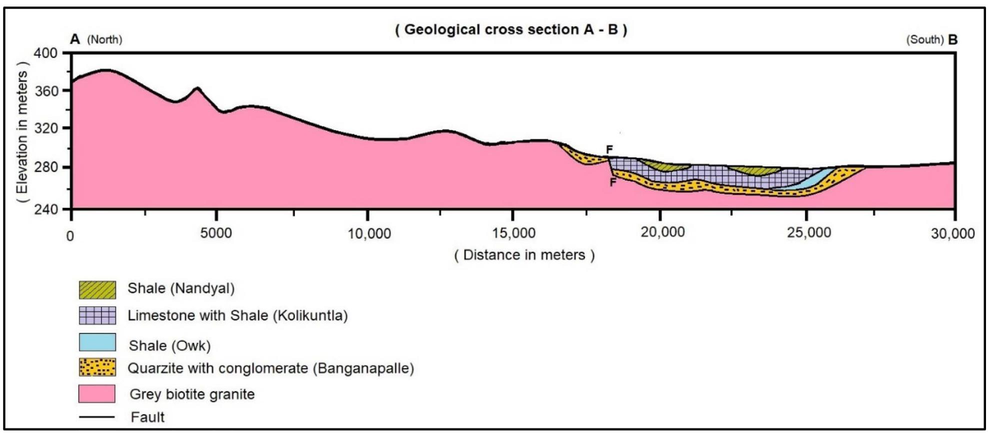
The cover sediments of Cuddapah Supergroup are represented by Gulcheru quartzite and Vempalle formation of Papaghni Group (A-B geological cross-section in **Figure 2(b)**). The Gulcheru group rocks represented with arkose conglomerates and quartzite, along with gritty arkoses, are found on the eastern margin of the study area. The Vempalle formation rests over Gulcheru rocks, represented by dolomites, chert, and mudstone with basic sill and intrusive rocks. The sills are Vempalle formations are low dipping and interstratified with other sediments. The dolomites are exposed along the banks of Krishna River, in the Kollapur, Somasila, and Amargiri areas.

The Kurnool formations are well exposed in the south, and southwestern region along the Krishna River with alternate arenaceous and argillaceous beds. The Banaganapalle quartzite is the basal of Kurnool group unconformably rest over the sediments Cuddapah Supergroup of rocks after a prolonged gap in deposition. It is resting over Vempalle dolomite with a thin conglomerate horizon is known for its distinct diamond bearing. The basal conglomerate has polymictic sediments and consists of a variety of cherts, jasper, and vein quartz pebbles followed by grit and quarzites. The exposures of the Banganapalle quartzite with conglomerate were noticed in the west of Samptraopalle, south of Pentlavalli, and in the southeast of Somasila and Amaragiri villages. Numerous dykes of WNW-ESE, NNW-SSE and NE-SW, NW-SE trends cut-across the basement rocks in the north and northwestern part. The quartz reef/veins occur in the basement rocks along the weak zones and the major quartz reefs/veins are noticed near the Thellarlapalle, Kethapally, and west of Mollachintapally area with an NNW-SSE, NW-SE trend. A major fault from Yaparla to Jatprole, in the E-W direction is a contact of cover sediments and basement rocks (A-B geological cross-section in **Figure 2(b)**).

The lamproite bodies are noticed around Somasila and Amaragiri villages. Somasila is located on the northern bank of Krishna River. During fieldwork, it is observed that, the intrusive-contact relationship is noted for the lamproites bodies within the dolomite rocks of Vempalle formation, at Somasila area. In the contest old working areas were brought to cultivable and the ground is leveled, and still, there are somerelics of old dumps left as paved stone and organized gravel. The village Amaragiri is currently submerged under reservoir, the old workings are visible during summer months as and when reservoir water recedes are traceable as a small mound formed by dumping of sorted gravels, well sorted and rounded, oblate, oval shapes observed during field visits. Further, lamprophyre dykes are seen at the Ankiraopally, Kethapally and Thellarlapalle areas (Meshram et al., 2012; Sushel et al., 2016; Giri et al., 2019). All the lamprophyre dykes are intruded into the granite basement rocks of Peninsular Gneissic Complex.



(a)



(b)

Figure 2. (a) Geological map of the study area (After GSI 2011); (b) Geological cross sections A-B show the interpreted geological-structural (vertical line) distribution of geologic formations.

3. Materials and Methods

The gravity survey was conducted along accessible roads and pathways to maintain consistent station sampling across the study area. However, the uniform station distribution was occasionally disrupted due to the inaccessibility of conserved forests and the challenging hilly terrain. A total of 725 gravity stations were established using a CG-6 Scintrex gravimeter (**Figure 3**). The surveys were designed to maintain a uniform station interval of 300 meters throughout the study area. To minimize cultural noise, gravity data was acquired away from tall buildings, power lines, bridges, pipelines, and other infrastructure. The gravity observation locations were superimposed on the elevation map (**Figure 3**), with white dots indicating station positions. The elevation within the study area varies by 252 meters, ranging from 263 to 515 meters. The overall gradient of elevation decreases toward the south, transitioning from the basement to the covered Proterozoic basin region.

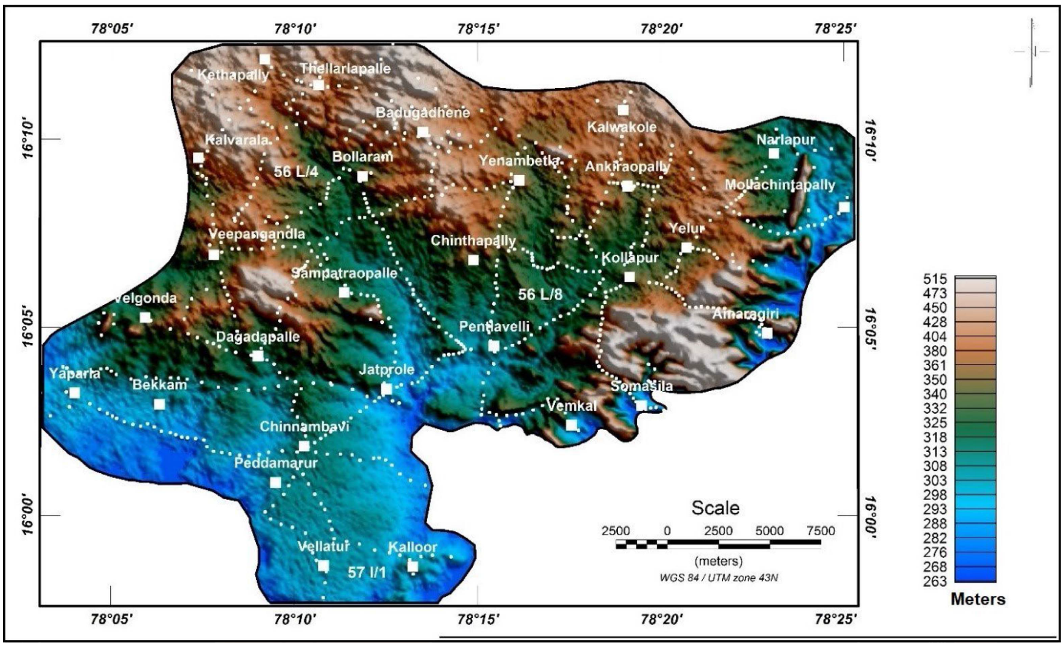


Figure 3. Digital elevation map of the study area.

The International Gravity Statin Network-IGSN 1971 Gravity base was established in the Kollapur RDO office (old R&B Building, 16˚06'26.02''N and 78˚18'47.07''E). It was tied with the known IGSN-1971 gravity base at Gadwal railway station, Gadwal, Telangana, that was established by Ramadass et al. (2001). The CG-6 gravimeter has inbuilt software for taking care of tidal correction. After applying drift correction, the entire data have also been subjected to Free Air and Bouguer corrections. Bouguer correction has been accomplished assuming the standard crustal density of 2.67 gm/cc and International Gravity Formula 1980 has been used for reduction of Latitude correction effect. The differential global positioning system (DGPS-Trimble R8s) was used for station location and the reduced level of the observation point. These observations were made at the same stations to verify the accuracy. The gravity data was processed using Geosoft software and the projection method UTM zone-43N with datum WGS-84 for special distribution of the observed data (**Figure 4**). The gravity and elevation data were gridded with the Minimum Curvature method by keeping a grid size of 250 meters (**Figure 3** and **Figure 4**). The gravity observation points covered all the geological units, to obtain a meaningful interpretation, to generate a data base, and prepare Bouguer anomaly map of study area to understand the density distribution in corroboration with the existing geological and structural inferences.

Density of Rock Samples

In the study area, 40 representative rock samples were collected from various locations to cover various litho-units for density measurements, which were then used to understand and evaluate gravity anomalies (**Figure 4**). The density was measured with Sartorius (PRACTUM612-10IN; made in Germany) instrument. The measured density value of the rock samples has significant implications for the examination of gravity data (Smithson, 1971; Subrahmanyam & Verma, 1982), since density contrast is the causative source of the gravity anomalies. It facilitates the corroboration of gravity response with the exposed geology. The details of density of rock samples collected are tabulated in **Table 1**.

Table 1. Measured physical properties of the representative rock samples.

Rock type	No. of Samples	Density 'D' in g/cc	
		Range	Average
Grey biotite/granite-gneiss	15	2.64 - 2.68	2.66
Dolerite dyke	8	2.72 - 2.89	2.8
Amphibolite	2	2.88 - 2.92	2.9
Quartz vein	1	2.61	2.61
Quartzite with conglomerate	1	2.46	_
Limestone	3	2.42 - 2.46	2.44
Limestone with shale	3	2.42 - 2.47	2.45
Shale	1	2.47	_
Dolomite	3	2.50 - 2.58	2.54
Lamproite	3	2.73 - 2.90	2.83

The analysis of physical properties indicates that the mafic rocks (dolerite dykes, amphibolite etc.) have recorded with higher density values of about 2.85 g/cc with respect to granite-gneissic rocks of 2.66 g/cc. It may be noted that the sedimentary rocks are recorded with low densities (2.5 g/cc). The analysis of density data is used in establishing the characteristic density values over different lithological units, which helps in analysing the interpretation of the corresponding gravity signatures and is also used in construction of Gravity 2D-model with the GM-SYS module of Geosoft software.

4. Qualitative Analysis of Bouguer Anomalies

4.1. Bouguer Anomaly

The Bouguer Anomaly (BA) map of the Kollapur region is prepared in RGB colour shaded image map with overlay of Bouguer gravity contour of 0.5 mGal interval (**Figure 4**). The map shows a total variation of 27 mGal, ranging from −105 to −78 mGal with overall E-W contour pattern paralleling to basin margin of CB in Kollappur region. The intensity Bouguer gravity decreases from basement exposed northeast part to covered area of southwest. Within the predominant E-W trend, the overprint of NW-SE to N-S trend contour patterns, reflecting as nosing, divergent contours, represent the structural tend of basement rocks exposed in northern part. The gravity map displays the disposition of lithological and structural features reflected in the form of gravity high, low and gradient anomalies. Based on the intensity and disposition of BA, the study area is divided into four zones in NE-SW and E-W directions Gravity High (GH), Gravity Moderate High (GMH), Gravity Moderately Low (GML) and Gravity Low (GL) in **Figure 4**. The contact between these zones is differentiated by the NW-SE and E-W steep gravity gradients (Gr1, Gr2, and Gr3) that represent major faults in this area. In addition, a significant steep gravity gradient (Gr4) is delineated in central part of the Somasila-Bollaram.

In the north-eastern part, a prominent gravity high (GH) of −78 to −85 mGal in between Yeloor-Narlapur is associated with a few major gravity highs (Narlapur, Kalwakole and Yelur) and low (between the NW-SE direction of Yelur and Narlapur) anomalies (**Figure 4**). These highs may represent enclaves of amphibolite schist within the granite-gneissic terrain of the Peninsular Genesis Complex (PGC), whereas the elliptical gravity lows indicate intrusive younger granites within PGC (**Figure 4**). Sushel et al. (2016) identified several schist enclaves with a strike length of about 10 km in this area and interpreted them as potential gold mineralization. The moderate gravity high zone (GMH) of −85 to −94 mGal, confined in between two gravity gradients (Gr1 and Gr2) is associated with a cluster of relatively high and low closures at Kollapur, Chinthapally-Yenambetla, Bollaram-Badugadhene and Kathapally-Thellarlapalle areas (**Figure 4**). The NW-SE gravity gradient (Gr4) between Somasila-Bollaram is differentiated as a major fault within this zone. It is interesting to note that, several kimberlites and lamproite bodies delineated at Somasila, Kethapally and Thellarlapalle areas (Sushel et al., 2016; Giri et al., 2019) are confined along this gradient (Gr4). In these areas, the BA is characterized by isolated residual closures. Based on this character, a few such gravity closures are delineated at Kollapur, Chinthapally-Yenambetla and Bollaram-Badugadhene, which represent potential search areas for the kimberlite/lamproite bodies (**Figure 4**). A few orthogonal structural trends, such as the NE-SW gradient (Gr5) and N-S gravity nosing (Gn1) are also delineated at

Veepangandla-Bollaram and east of Sampatraopalle-Thellarlapalle areas in the central part. At Bollaram, the intersection zone of NW-SE, NE-SW, and N-S gradients and nosing is interpreted as a potential zone for kimberlite and lamproite emplacement. Further, a major gravity nosing (Gn2) extending in WNW-ESE directions is delineated at the south of Kethapally, where a few lamprophyres ultramafic and dolerite dykes and quartz veins are emplaced within the PGC (Sushel et al., 2016). A wide zone of WNW-ESE linear gravity contours ranging from −94 to −99 mGal, confined between the Gr2 and Gr3 is differentiated as a gravity moderate low zone (GML) (**Figure 4**).

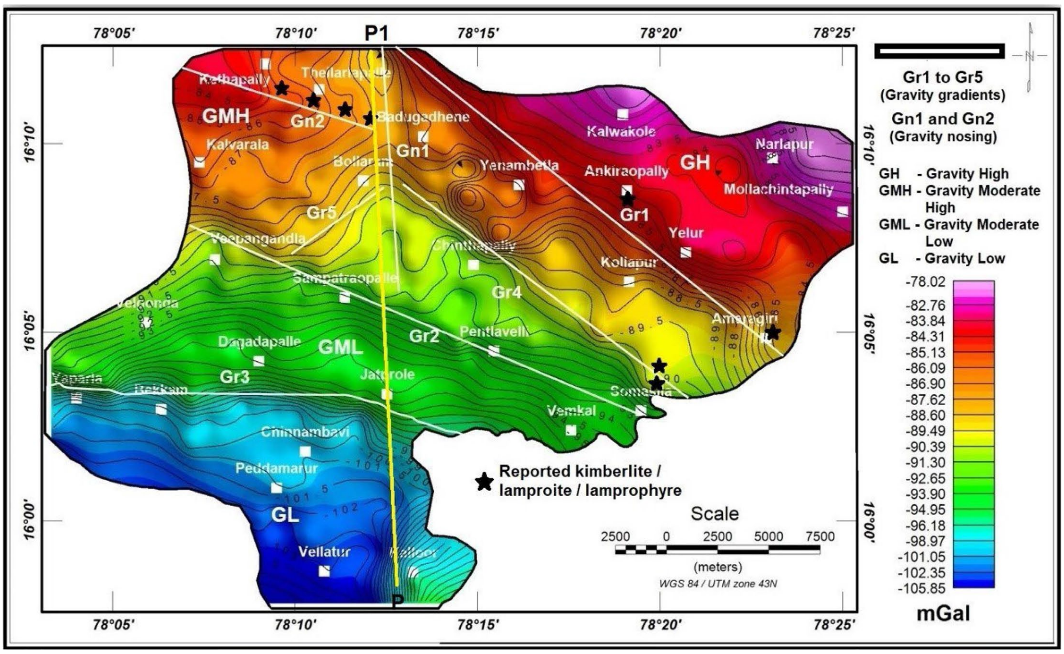


Figure 4. Bouguer gravity anomaly map.

Within this zone, a few sedimentary outliers (Kurnool Group) are unconformably overlaid on the granite-gneissic basement at the southwest of Sampatraopalle and the south of Pentlavelli areas. In the southern part, a major gravity low anomaly (GL) zone varying between −99 to −105 mGal is recorded over the northern part of the Kurnool sub-basin. The E-W steep gravity gradient (Gr3) along the northern contact of this major low represents a boundary fault between the Kurnool sub-basin and granite-gneiss basement. Further, a few residual gravity lows, reflected as divergent contours within the major gravity low zone (GL) at Chinnambavi and east of Vellatur, are possibly due to an uneven basement configuration below the Kurnool sediments. Relative gravity high recorded on the extreme southern part of Kalloor location indicates a shallow basement structure, where the granite-gneiss is partially exposed within the Krishna River section.

4.2. Regional and Residual Gravity Anomalies

The low-pass filtered (10 km) regional gravity map shown in **Figure 5** shows linear gravity contours of NE-SW and E-W trending, north-eastern and south-central parts, respectively; the preceding one represents the regional Dharwar structural trend of the area. In between these two trends, a major N-S gravity nosing delineated at Bollaram area in the central part indicates the disposition of concealed younger intrusive body restricted in upper crustal level. These signatures clearly indicate that the Bollaram area in the central part is formed as a potential zone for the emplacement of younger intrusives such as granite, kimberlite/lamproite bodies etc. Further, the decrease in intensity of the regional BA from the northeast to the southwest is interpreted as possibly due to sub-surface upper-crustal density variations in the southwestern margin of the study area (**Figure 5**).

The high pass filtered (10 km) residual gravity map shows a number of isolated residual high and low anomalies with amplitudes of −3.39 to 4.76 mGal distributed in the entire area (**Figure 6**). The detailed analysis of the residual features indicates that most of the linear residual gravity highs are mainly confined within the linear gravity gradient zones (Gr1, Gr2, Gr3 and Gr4), where several basic dykes are emplaced. A few elliptical residual highs delineated in the north eastern parts of the Kalwakole, Narlapur and Yelur represent high-density units such as amphibolite schist within the granite-gneiss. Similarly, a few isolated lows delineated northwest of Kollapur, Chinthapally, Bollaram and Veepangandla are encircled by the linear gravity highs. These residual lows may represent younger intrusives in this area. In the southwestern part, the residual gravity lows at Bekkam, Chinnambavi and north of Kalloor correspond to thick columns of sedimentary units within the Kurnool sub-basin, whereas the residual highs at Peddamarur, Vellatur and Kalloor possibly due to shallow basement areas within the basin.

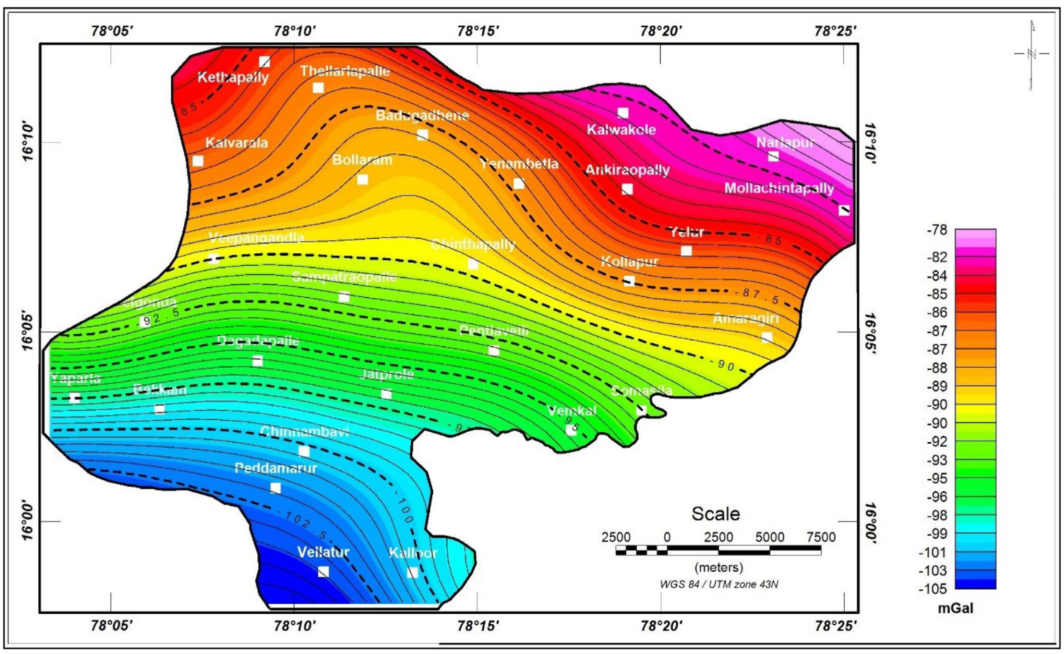


Figure 5. Regional gravity anomaly map.

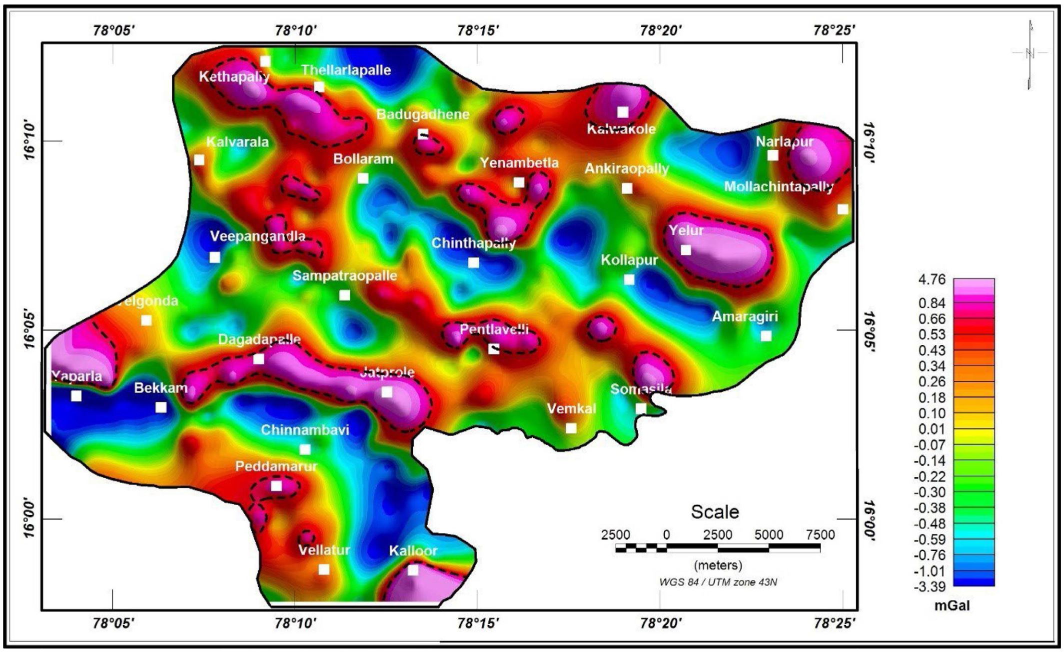


Figure 6. Residual gravity anomaly map.

4.3. Total Horizontal Derivative of Bouguer Anomaly

The total horizontal derivative (THD) of Bouguer anomaly maps is prepared to differentiate several structural features in the northwest margin of CB (Figure 7). In general, THD peak values are recorded across the edges of the anomaly, but minimal values are observed over the centre of the anomaly. The THD map (Figure 7) shows high intensity at the northern margin of the Kurnool sub-basin, indicating a major boundary fault (Gr3). Further, several discontinuous linear highs delineated in central part indicate the disposition of major gravity gradients (Gr1, Gr2 and Gr4 in Figure 4) in this area. In the northeastern part, the boundary of the elliptical gravity highs is delineated by high derivative values in the Yelur, Narlapur area. Similarly, the boundary of major gravity nosing (Gn2) is established from the THD map. Further, a few NE-SW structural trends are highlighted in the derivative map at Kalvara-Kethapally and Bollaram area.

5. Quantitative Analysis of Bouguer Anomaly

5.1. Radially Averaged Power Spectrum (RAPS) of Gravity Data

Spectral analysis is a widely utilized tool in geophysical data processing, and interpretation. The radially averaged power spectrum of potential data provides the depth to the gravity horizons (Spector & Bhattacharyya, 1966; Spector & Grant, 1970; Kivior & Boyd, 1998; Prabhakara et al., 2013; Khalil et al., 2016; Satish Kumar et al., 2018; Ganguli et al., 2020). The radially averaged power spectrum (RAPS) analysis separates gravity responses from various sources at different depths. The power spectrum of gravity data shown in Figure 8 indicates three linear segments with average wavelengths of 10 km, 4 km and 2 km and

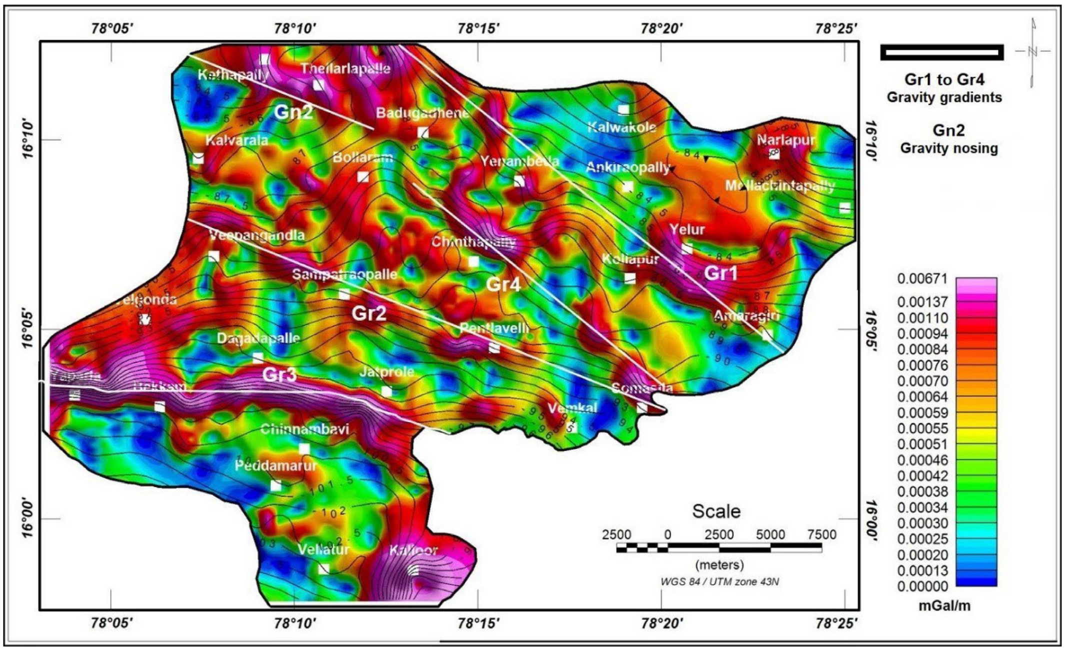


Figure 7. Total horizontal derivative map overlaid on bouguer anomaly contours.

their representative depths estimated from their slopes of interfaces are 3 km, 1.46 km and 0.75 km from the surface. At 3 km, the interface (deeper layer) could be signalling the mean average depth of deeper source zones. The average depth of the bottom and top of the basic body is directed by the interface at 1.46 km (intermediate layer) and 0.75 km (shallow layer). The qualitative analysis further confirms the depth persistence of GH, GMH, GL and gravity steep gradients/gravity nosing (lineaments/faults) in Bouguer anomaly map (Figure 4).

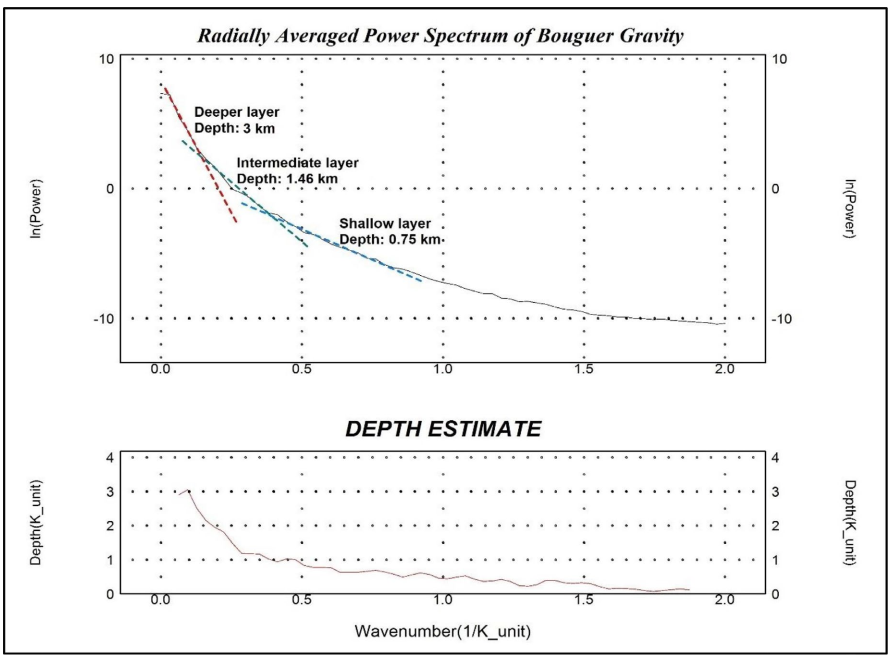


Figure 8. Radially averaged power spectrum of gravity data.

5.2. Euler 3D Depth Solutions of Bouguer Anomalies

The Euler 3D depth deconvolution method is an effective tool for estimating apparent causative source depths of various anomalies distributed in the entire area of study (Reid et al., 1990; Reid & Thurston, 2014; Kumar et al., 2018; Yadav et al., 2018; Ganguli et al., 2019). The Euler 3D technique is applied to gravity data to estimate the causative source depth of various anomalies distributed in the entire area (**Figure 9**). As such, the majority of the study area is occupied by granitic basement rocks associated with amphibolite enclaves, which are partly covered by the sediments of the Kurnool and Papaghni groups in the southern part. The structural index (SI) of gravity data (0.5), the window size of 10 km × 10 km and the depth tolerance of 15% are selected for estimating the apparent source depths.

The Euler 3D depth solutions of gravity anomalies are in the range from <1000 to >3000 m and distributed over the entire area. These depth ranges are well corroborated with the depth inference obtained from the spectral analysis of gravity data (**Figure 8**). The depth solutions are plotted on the BA map in three depth ranges for easy understanding and interpretation: shallow (1000 m as red dots), intermediate (1000 to 3000 m as yellow dots), and deeper source depth solutions (>3000 m as green dots). It is interesting to note that the majority of depth solutions are mainly confined along the major structural features (Gr1, Gr2, and Gr3) trending towards NW-SE and E-W directions (**Figure 9**). The distribution of shallow to intermediate depth range (red and yellow dots) along Gr2 and Gr3 represents the limited depth extension of these structural features up to 3000 m.

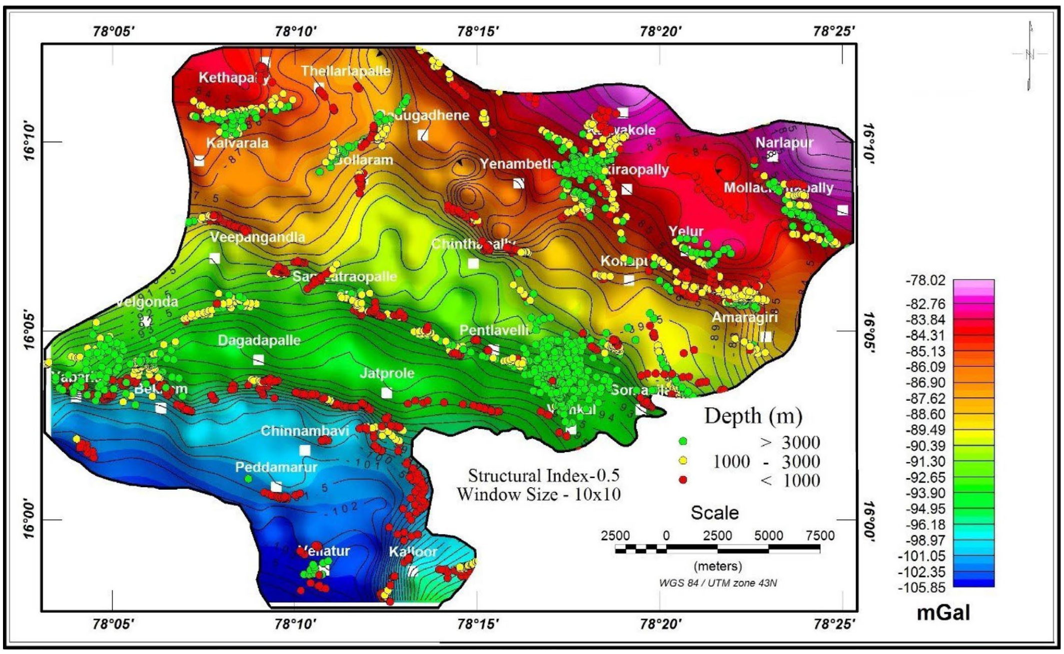


Figure 9. Euler solutions (SI = 0.5) overlaid on a bouguer anomaly contour map.

The deeply rooted fault is represented by the Gr3 recorded with intermediate-to-deeper depth solutions. A cluster of deeper depth range solutions (>3000 m) recorded at Somsila, Yaparla, and Amaragiri areas are confined within major faults along the Kurnool and Papaghni groups, with the latter two areas occupied by basic dykes associated with lamproite bodies. A few clusters of intermediate to deeper depth range solutions (yellow and green dots), confined at the intersection of NW-SE, N-S and NE-SW structures within granite-gneiss terrain, are noticeable at Kethapally, Bollaram, Chinthapally, Ankiraopally and Yelur areas. As such, a few kimberlites and lamproite bodies are delineated in the Kethapally and Ankiraopally areas; hence, these intersection areas are noticeable as potential zones for kimberlite searches. In the northeastern part, a cluster of deeper (>3000 m) forming as a NW-SE trend is recorded at the eastern margin of the gravity elliptical high in the Narlapur area. These gravity highs may be related to amphibolite schist that are favourable zones for gold mineralization in this area.

5.3. N-S 2D Gravity Model of P-P1 Profile

The 2-D modelling of Bouguer gravity anomalies results a plausible geological model that fairly corresponds to the observed anomalies and the computed ones. For estimating basement depths, a gravity model ensures always minimal ambiguity and is more reliable (Vasanthi & Mallick, 2005; Ramadass et al., 2006; Veeraiah et al., 2009; Radhakrishna et al., 2012; Vani et al., 2013; Singh et al., 2014; Rao et al., 2018; Ganguli et al., 2020; Satish Kumar et al., 2021). The results of spectral analysis of gravity data and the measured density values of the rock samples substantiate the study. The depths derived from modelling are almost identical with the depths determined by Euler deconvolution in the case of faults and dykes. The 2-D gravity profile modelling reveals the structural disturbance as well as depth and shape of the subsurface configuration. The model based on the gravity anomaly is shown in **Figure 4**.

The N-S Profile-1 (P-P1), which extends from Kallor to the east of Thellarlapalle and cuts-across the Kurool sub-basin in the south, and the granite-gneiss in the north has a total length of 26 km (**Figure 4**). Along this profile, the Bouguer anomaly varies from −102 to −85 mGal from south to north. The gravity profile data is used to prepare a 2-D model with a satisfactory fit of observed and calculated fields with a minimum RMS error of 0.154. The quantitative inferences obtained from the spectral analysis and Euler 3D depth are considered in the 2D gravity model. The 2D model (**Figure 10**) reveals a granite-gneissic basement (2.66 g/cc) at a depth of ~1.5 km below the sedimentary cover (2.44 g/cc) in the southern part of the area. It is interesting to note that the basement rock samples (granite/migmatite gneiss) collected in this area show a uniform density of 2.66 g/cc. Further, the gravity model reveals a basement fault (Gr3) along the northern margin of the covered sediments, that is characterized by a steep gravity gradient (gravity profile in **Figure 4**) between 12 to 15 km. The gravity profile shows high anomalies within the basement rocks, which are classified as dolerite dykes with a density of 2.8 g/cc and extending to a depth of about 1 km. Most of the kimberlite/lamproite/lamprophyre bodies delineated in this area are mainly confined to the margins of the dyke. The mid crust density about is 2.78 g/cc approximately.

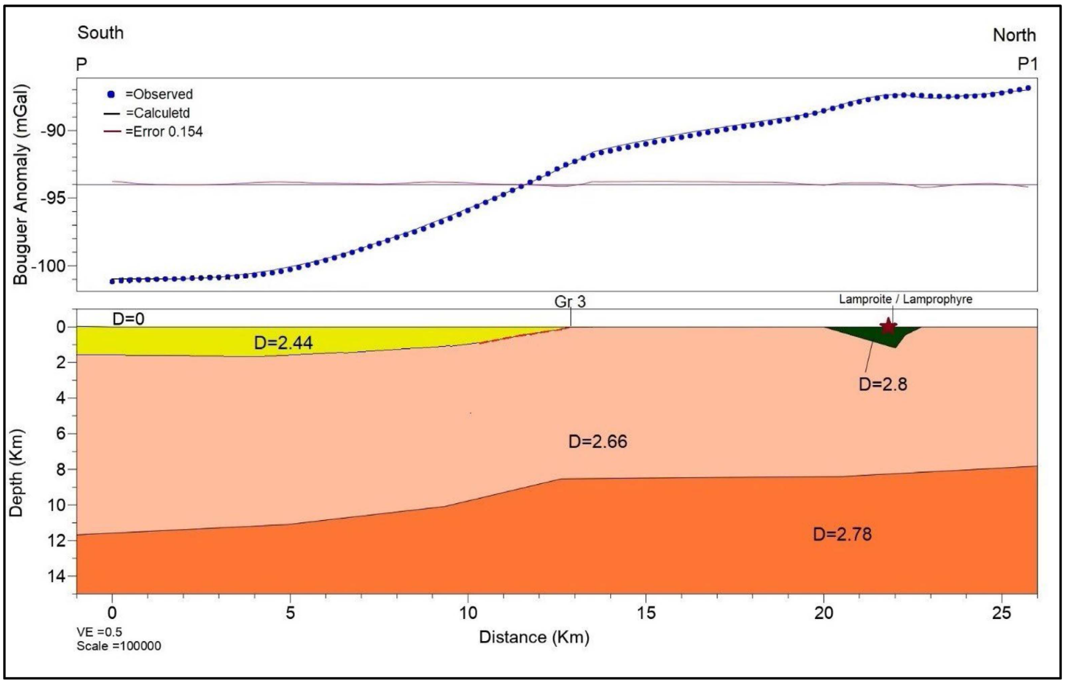


Figure 10. 2-D gravity model along the profile (P-P1).

6. Integration of Gravity Data with the Geological Inferences

The present study focuses on delineating the structural features of the basement, both exposed and covered, along the northern bank of the Krishna River at the northwestern margin of the Cuddapah Basin (CB). The Bouguer gravity map highlights the density distribution across the area (**Figure 4**). The density distribution (BA) has a direct relationship with density property lithological units; hence, a correlation can be established to integrate gravity data with geological inferences (**Table 1**). The overall gravity intensity decreasing towards south (regional trend in **Figure 5**), indicates the overall basement disposition dipping from north to south direction (**Figure 5**). In the northeastern part, the high-gravity zone compared to the southern part is resulted due to high-density source rocks at shallow and deeper levels in the granite-gneissic rocks and as well as the basement fault running along the basin in the Kollapur region (**Figure 4**). It is further corroborating with causative source depth inferences derived from Euler 3D depth showing deeper causative source depth of >3 km in the northeastern part of the area (**Figure 9**). The near-surface density distribution map (Residual gravity in **Figure 6**) shows residual high anomalies, located at Narlapur, Kalwakole and Yelur in northern part, indicate the disposition of amphibolite schist enclaves within the overall granite-gneissic terrain of PGC-II. Sushel et al. (2016) have opined that these enclaves have potential trap for the gold mineralization in the north-western margin of CB. Similarly, the wide low-gravity zone (GL) in the southern and southwestern parts, around the Peddamaru-Vellatur area, is recorded over the sedimentary cover of the Cuddapah Basin (CB), where the thickness of the cover sediments is relatively higher compared to the covered areas in the southeastern part at Somasila and Amaragiri areas. In low-gravity zone (GL), shallow causative source depths of about 1 km have been derived using the Euler 3D convolution technique (**Figure 9**).

It is interesting to note that majority of estimated depths are mainly confined along the major structural features (Gr1, Gr2, and Gr3) trending in NW-SE and E-W directions (**Figure 9**). The distribution of shallow to intermediate depth range (red and yellow dots) along Gr2 and Gr3 represents the limited depth extension of these structural features up to 3000 m. In the central part (Bollaram), a major gravity low (nosing) anomaly differentiated as a concealed younger granite pluton within the granite-gneiss. The presence of a concealed body in a nosing anomaly is clearly indicated by the regional gravity anomaly map (**Figure 6**). In the Bollaram area, intersection of NW-SE, N-S and ENE-WSW gravity anomalies forms a potential zone for the emplacement of younger intrusives such as kimberlite/lamproite etc. The NW-SE and E-W gravity gradients (Gr1, Gr2 and Gr3) are delineated as major structural features correlate well with total horizontal derivative map (**Figure 7**). The E-W steep gravity gradients in the southern part define a major boundary fault (Gr3) along the northern contact of the Kurnool sub-basin is clearly demarcated from Bouguer anomaly map (**Figure 4**) and 2D gravity model (**Figure 10**). It is interesting to note that, the NW-SE, E-W and ENE-WSW lineament intersections and circular features of the Bouguer anomaly contours are noticeable as potential zones for emplacement of kimberlite/lamproite bodies in Bollaram, Chinthapally and Kollapur in this area along the structural features of Gr1 and Gr4. It is further observed that, the most of known kimberlite occurrences in and around the study area are mainly confined to these intersection zone (Rao et al., 1999; Vasanthi & Mallick, 2005; Nayak et al., 2005; Ramadass et al., 2006; Veeraiah et al., 2009; Vani et al., 2013; Smith et al., 2017; Pal & Kumar, 2019; Mukherjee et al., 2021a; Kumar et al., 2022). The residual gravity high and low anomalies within the sedimentary basin represent an undulating basement configuration.

The 2D gravity model depicts an unconformably overlain sedimentary layer (upper Kurnool and lower Cuddapah sediments) (1.5 km average thickness) on the granite-gneissic basement and provided new understandings on the nature and geometry of sedimentary rocks in south part of the area. Based on the 2D gravity modelling, a maximum basement depth of ~1.5 km is estimated in the southern part. The previous geophysical model derived from gravity and seismic data across CB revealed homogeneous nature of Cuddapah sediments (Singh & Mishra, 2002; Chandrakala et al., 2015) in terms of density and seismic velocity. The modelling of gravity data in combination with seismic velocity shows a density of Cuddapah sediments to vary from 2.43 to 2.58 g/cc (Pandey et al., 2018). The seismic study by Chandrakala et al. (2015) indicates a maximum thickness of the Cuddapah sediments as ~4.0 km. The present study with gravity modelling reveals that the nature of Cuddapah sediments varies in terms of density as well as shows considerably low thickness in particularly, northwestern margin of the CB. The basement depth considerably from ~1.5 km.

7. Conclusion

Based on the detailed gravity study in northern bank of Krishna River at Kollapur region, the litho-structural and features are derived in basement exposed and covered area. The highlights of detailed gravity work summarised below.

1) The detailed gravity study in Kollapur region brought out several anomalies, characterized as steep gradients, highs, lows, and nosing reflect deposition lithological and structural features in basement exposed and covered region in the northwestern part of CB.

2) A Prominent high-gravity zone (GH) in the northeastern is resulted due to due to high-density causative source units at shallow and deeper depth levels, where the high-density rocks of amphibolite schist and BIF bands are occurred as enclaves within the granite-gneissic rocks.

3) A low-gravity low (GL) in south and southwestern parts corresponds to cover sedimentary rocks having thickness of about 1 km.

4) A gravity low at Bollaram is interpreted as a concealed younger granite pluton within the granite-gneissic terrain.

5) An E-W steep gravity gradient (Gr3) along the northern margin of Cuddapah and Kurnool group of sediments marks a deep-rooted fault (~2 km depth), with similar faults near Somasila along the Papaghni Group.

6) The gravity gradients and nosing (Gr1, Gr2, Gr4, Gr5 and Gn1, Gn2) of NW-SE, NE-SW, and N-S trends are interpreted as major structural features, which are corroborated with geological inferences.

7) The two N-S 2D gravity models across the cover sediments show an overall thickness of ~1.5 km bounded by the fault contact.

8) The gravity gradient intersections at Bollaram, Chinthapally and Kollapur are interpreted as loci for kimberlite/lamprophyre bodies emplacement, supported by associated lamprophyre bodies. The known lamprophyre bodies reported in this area are mainly confined to such intersection zones.

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Authors Statement

Linga Swamy Jogu: Carried out the geophysical field work and collected rock samples, data interpretation and final draft preparation. **Udaya Laxmi Gakka:** Guided the entire work, contributed to the write-up of the final version, and overall supervised the work.

Conflicts of Interest

The authors declared that they have no conflicts of interest to this work.

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