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A MATLAB Based Code for gravity data Corrections

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ABSTRACT
An interactive MATLAB based code, designed for processing of relative ground gravity data. This interactive code is robust to compute Bouguer anomalies from relative land gravity data, acquired with reference to single standard absolute gravity base. The processed data will be viewed in the form of excel spreadsheet and graphical window. The efficacy of the code is tested on the real data set near Umred Coal field, Maharashtra and found to be feasible for handling gravity data sets for precise interpretation of the results. 1D spectral analysis of the Bouguer anomaly data shows that the depth to the basement varies from 0.5 km to 1.3 km over which Gondwana group of rocks are emplaced. Similarly, thickness of the trap is found to vary from 0.25 km to 0.6 km. The obtained results are in good agreement with the previous gravity and Magnetotelluric studies.

Keywords: MATLAB; Gravity; Bouguer anomalies; Gondwana; 1D Spectral Analysis.

INTRODUCTION

Gravity method has been invariably used in various geophysical investigations like mapping of sedimentary basins, structural features (faults, folds and lineaments), subsurface cavities, mineralised zones (Sulphide, Chromite, Iron ore, silver, gold, coal etc) and potential ground water resources. CSIR-National Geophysical Research Institute has been collecting relative gravity data sets, to address various geological problems related to mineral, oil and ground water applications (Seshunarayana et al., 2011; Pandey et al., 2014; Satish Kumar et al., 2018; Swarnapriya et al., 2017; Tirupathi et al., 2017 etc.). The acquired field gravity data provides point to point variations due to causative sources, due to earth's topography, and departure of earth shape from the sphere, atmospheric and Tidal changes. Hence, it is required to reduce these responses to obtain actual causative anomalies of the gravity sources concealed beneath the subsurface. Reduction of gravity data may play a crucial role to nullify the other responses, apart from the causative anomaly sources. Reduction of land gravity data involves drift of the gravimeter, conversion of relative gravity to absolute gravity, latitude correction, Free-air correction, Bouguer correction and terrain correction.
Depending on the objective of the survey, huge gravity data sets are needed to be collected in the field. Reduction of such huge data sets is a tedious task and, in fact, need commercial softwares for processing precise Bouguer anomalies. Several researchers developed their own codes, which are available to process the gravity data e.g. CgxTool (Gabalda et al., 2003); Gravnet (Hwang et al., 2002); MCGravi (Beilin, 2006); GravProcess (Cattin et al., 2015) and pyGrav (Hector and Hinderer, 2016). In the present study, we have developed a user friendly interactive MATLAB based application "code" that can handle relative gravity data and can generate the Bouguer anomaly output along with aforesaid corrections. Particularly, user can input raw gravity data with time, latitude, longitude, elevation for a particular base gravity in the form of worksheet. User can view the output in the form of work sheet that contains the raw gravity data with latitude, longitude, elevation, drift corrected, latitude corrected, free-air corrected, Bouguer corrected and Bouguer anomaly. We tested this procedure using real field data, which is collected over the Deccan trap region of central India near Nagpur, Maharashtra. However, we have not attempted the tidal and terrain corrections in this module which can involve the input of external data sets like Digital Elevation Model (DEM). Depth to the basement and thickness of the Deccan trap are estimated through spectral analysis in aid to coal exploration using the processed data set.

BASIC STEPS FOR "CODING"

Basically, code works for land relative gravity data with reference to the single base station. For data with multiple base stations, user can subdivide the whole data set depending on occupied base stations and import the data for a single base at a time. The flow chart for this code is presented in Figure 1. To work with large datasets of any extents, a particular data format is required as the input in the form of excel spreadsheet (Table 1). User has to take care while importing the base station number i.e any alphanumeric or simple alphabetical name to mark the base station number. Otherwise, that will be considered as another station location and flow will end up with error and avoid data gap between any two rows. Further, for a particular profile, starting station number must start with zero.

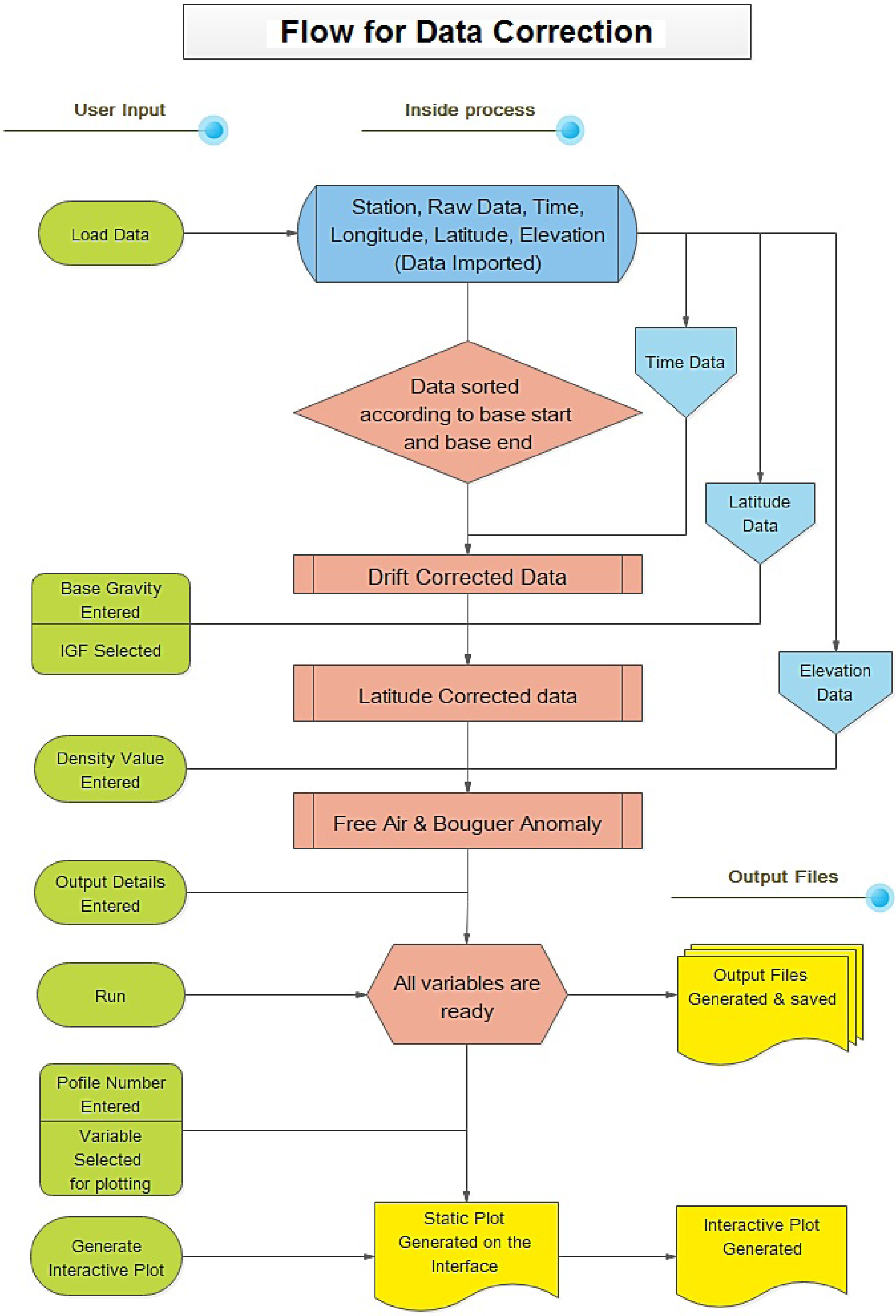

Figure 1. Flow chart for workflow for corrections.

Figure 2 shows the interactive tool panel to process the gravity data, sequential steps from 1 to 10 will be provided to execute the raw data set to calculate the Bouguer anomaly. User is required to input the density in C.G.S units.

REAL DATA ANALYSIS

To test the efficacy of code, field data of three Profile P1, P2 and P3 are considered (Figure 3) near Umred, Nagpur region, Central India which is one of the coal basins of

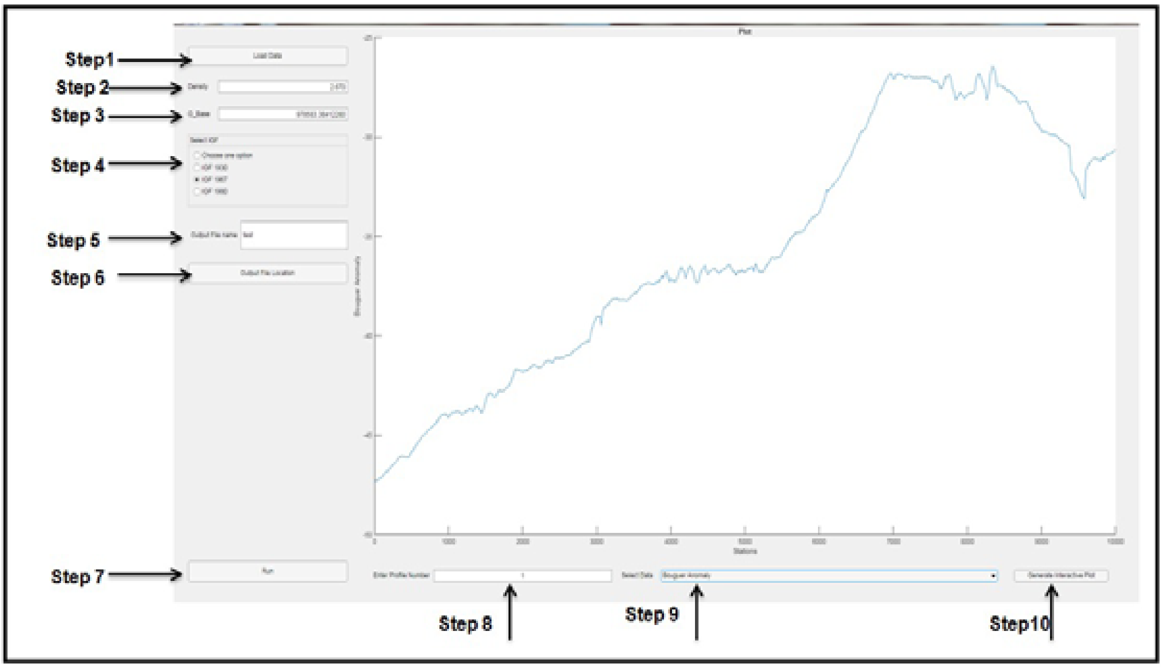

Figure 2. Interactive Window.

Table 1. Input data format for corrections.

Profile No	Station No	Raw data (mGal)	Time (HH)	Time (MM)	Time (SS. SS)	Longitude (Degree)	Latitude (Degree)	Elevation (Meter)
1	**Base 1**	**Base value**	**Hour**	**Min**	**Sec**	**Longitude**	**Latitude**	**Elevation**
1	0	Data	Hour	Min	Sec	Longitude	Latitude	Elevation
1	1	Data	Hour	Min	Sec	Longitude	Latitude	Elevation
1	**Base 1**	**Base value**	**Hour**	**Min**	**Sec**	**Longitude**	**Latitude**	**Elevation**
1	**Base 1**	**Base value**	**Hour**	**Min**	**Sec**	**Longitude**	**Latitude**	**Elevation**
1	3	Data	Hour	Min	Sec	Longitude	Latitude	Elevation
1	4	Data	Hour	Min	Sec	Longitude	Latitude	Elevation
1	**Base 1**	**Base value**	**Hour**	**Min**	**Sec**	**Longitude**	**Latitude**	**Elevation**
2	**Base 1**	**Base value**	**Hour**	**Min**	**Sec**	**Longitude**	**Latitude**	**Elevation**
2	0	Data	Hour	Min	Sec	Longitude	Latitude	Elevation
2	1	Data	Hour	Min	Sec	Longitude	Latitude	Elevation
2	2	Data	Hour	Min	Sec	Longitude	Latitude	Elevation
2	**Base 1**	**Base value**	**Hour**	**Min**	**Sec**	**Longitude**	**Latitude**	**Elevation**

India (De et al., 1982; Rama Krishna et al., 1999a, 1999b). The study area is capped by alluvium and some patches of exposed Deccan basaltic rocks, which are underlain by a Gondwana group of rocks (Naskar and Saha, 2015). Gravity data has been collected along three profiles P1, P2, and P3 with lengths of 10 km, 2.6 km and 9.5 km respectively across the regional strike of the study area (Figure 3). Gravity data was collected with a sample interval of 20 m. The data have been acquired using CG-5 gravimeter with an accuracy of ± 1μGal. Coordinates (longitude and latitude) and elevation of the station is recorded using Trimble Geo XT handheld model global positioning system (GPS) receiver. Differential correction was also applied to the coordinate data using the base station data.

Bouguer anomalies are computed using present code for the profiles P1, P2, and P3 and discussed in the following sections and also demonstrated output of applied corrections (drift, latitude, free air, Bouguer and Bouguer anomaly) to the field relative gravity data. Hence, user can easily find the errors in each stage of processing. Further, 1D spectral analysis has been carried out for the Bouguer anomalies of P1 to P3 to understand the depth to the basement and thickness of Deccan trap.

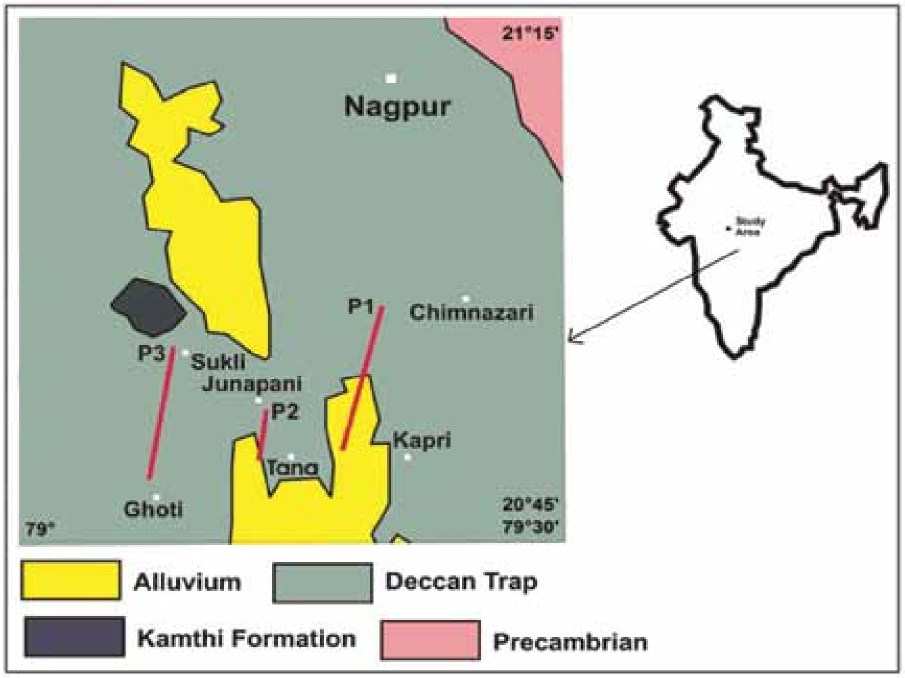

Figure 3. Location of Profile P1, P2, and P3 (after Naskar and Saha, 2015; Satish Kumar et. al., 2018)

Profile P1

The SSW-NNE trending Profile- P1 starts from west of Kapri village and ends near Chimnazari village with a length of 10 Km (Figure 3). Alluvium, basalts are occupied in SSW and NNE part respectively.The Bouguer gravity anomaly varies from -39 mGal to -18 mGal from SSW and NNE of the profile (Figure 4a). The nature of the gravity anomaly which is increasing from SSW to NNE of the profile may represent increasing thickness of the basaltic layer from Kapri to Chimanzari village. Further, a sharp gravity gradient is also observed between 0.6 km and 0.7 km, which might be a contact zone. 1D spectral analysis (Spector and Bhattacharyya, 1966; Bhattacharyya, 1966; Spector and Grant, 1970; Naidu, 1970; Hahn et al., 1976; Mishra and Tiwar,1966; Prabhakara Prasad et.al., 2013; Satish Kumar et al., 2014; Satish Kumar et al., 2015; Tirupathi et al., 2017; Satish Kumar et al., 2018; Pandey et al., 2018) was performed for Bouguer anomaly profile P1 (Figure 4b) and also P2 and P3, to estimate depth to the basement and thickness of the trap. The 1D amplitude spectra of Bouguer anomaly shows two discernible segments with different slopes (Figure 4b). The depth is computed from slope of each segment by using the formula:

$$\text{Depth} = 1/4\pi \times (\Delta E/\Delta N)$$

Where $\Delta E/\Delta N$ is the slope of each segment, ΔE is the log energy and ΔN is the wave number increment. The depth computed from slopes of two straight line segments are 1.25 Km and 0.25 Km, which may represents depth to the basement and thickness of the Deccan trap respectively.

Profile P2

Gravity data along Profile P2 is collected from Tana to Junapani villages, covering a length of about 2.6 km (Figure 3). The Bouguer anomalies vary from -37 mGal to -44 mGal from SSW to NNE. The nature of the Bouguer anomaly, increasing from SSW to NNE, might represent the increase in basaltic thickness from Tana village to Junapani (Figure 5a). 1D amplitude spectrum of Bouguer anomaly shows one straight line segment (Figure 5b). The estimated depth from the slope of the segment is 0.5 km and it is attributed to thickness of the basaltic layer, underlain by Gondwana group of rocks. Due to limited extended of profile length, depth to the basement could not be resolved from the amplitude spectrum.

Profile P3

Profile P3 is starts from Ghoti village and ends at Sukli village and has a length of about 9.5 Km (Figure 3). The entire profile is covered by basaltic layer. The gravity anomaly varies from -67 mGal to -57mGal from SSW to NNE, with amplitude of 10 mGals (Figure 6a). The nature of the Bouguer anomaly increase from SSW to NNE, might represent the increase in basaltic thickness from Ghoti village to Sukli village. 1D amplitude spectrum of Bouguer anomaly shows two straight line segments (Figure 6b). The estimated depths from the slope of the segments are 1.2 km and 0.6 km and it is attributed to depth to the thickness of the basaltic layer underlain by Gondwana group of rocks respectively.

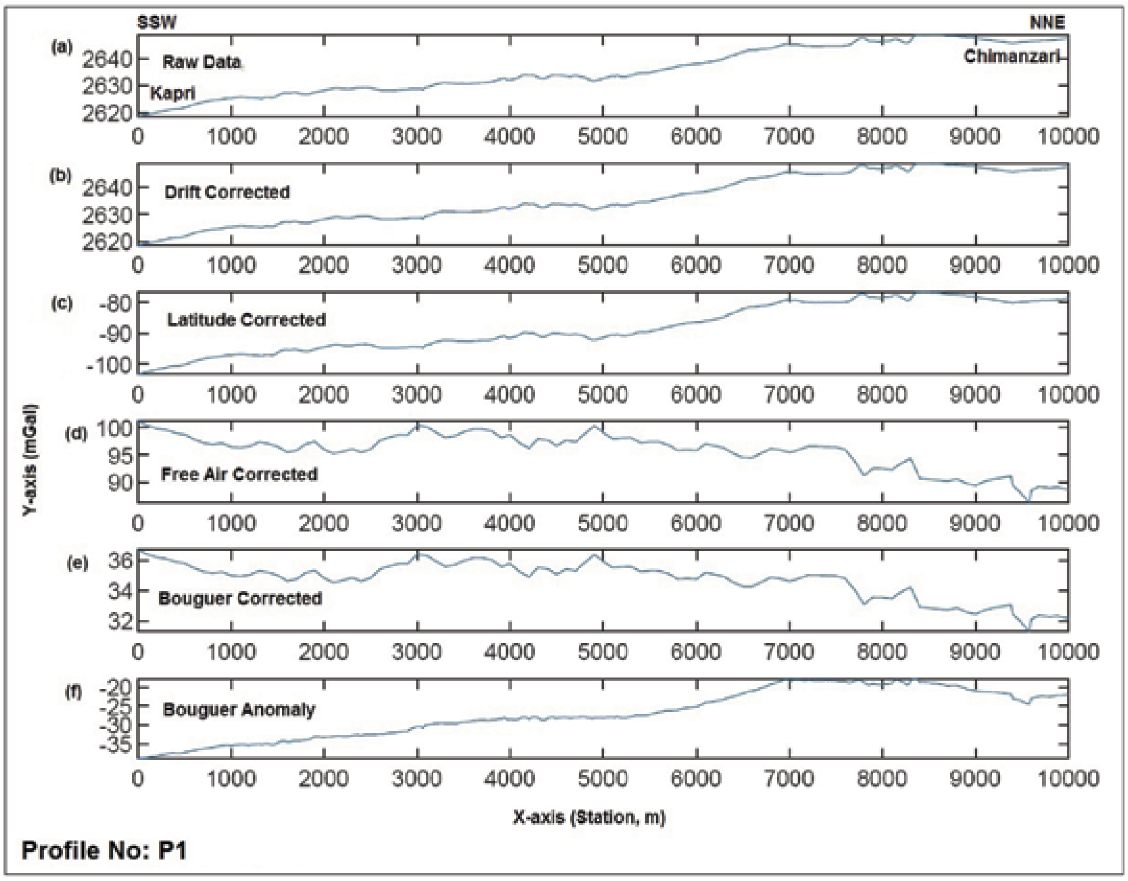

Figure 4a. Plot of (a) raw gravity data, (b) drift corrected, (c) Latitude corrected, (d) Free-air corrected, (e) Bouguer corrected and (f) Bouguer anomaly along profile P1

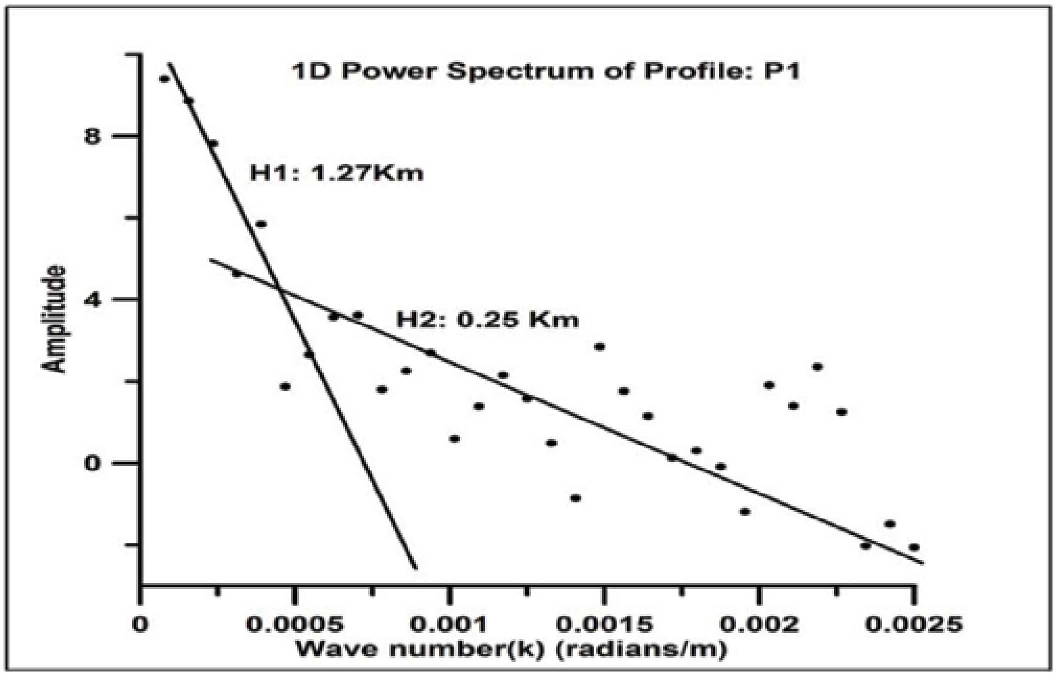

Figure 4b. Amplitude Spectrum of Profile P1

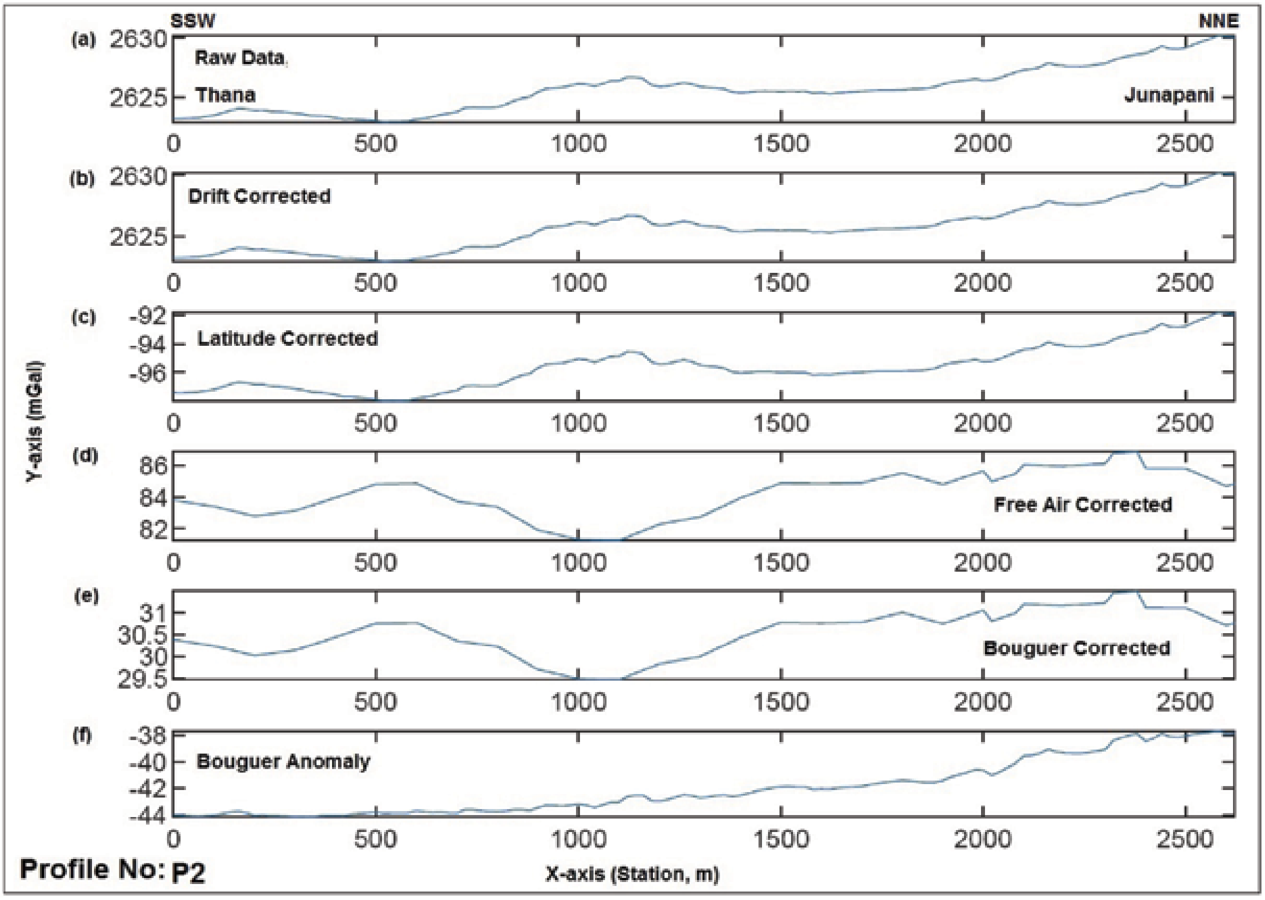

Figure 5a. Plot of a) raw gravity data, b) drift corrected, c) Latitude corrected, d) Free-air corrected, e) Bouguer corrected and f) Bouguer anomaly of profile P2

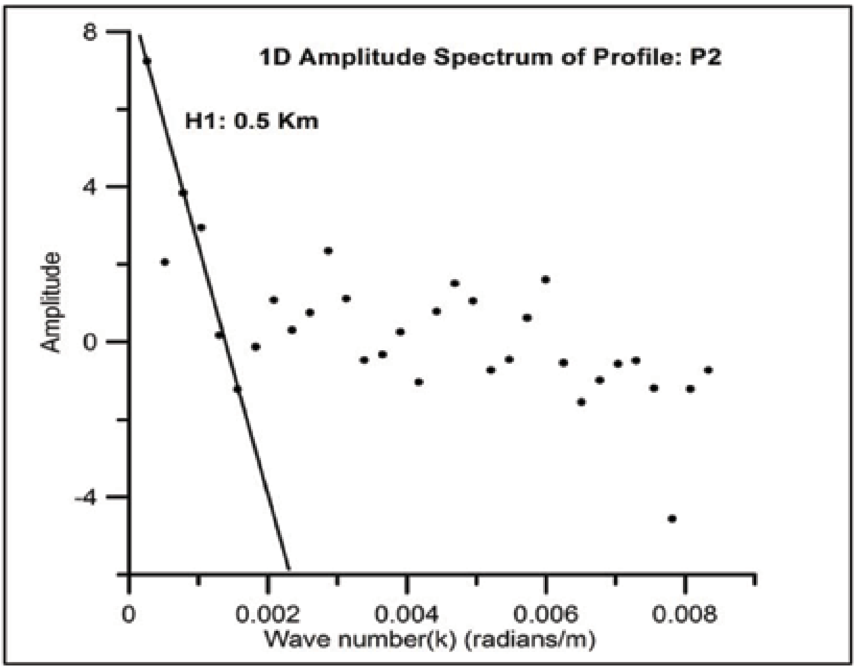

Figure 5b. Amplitude Spectrum of Profile P2

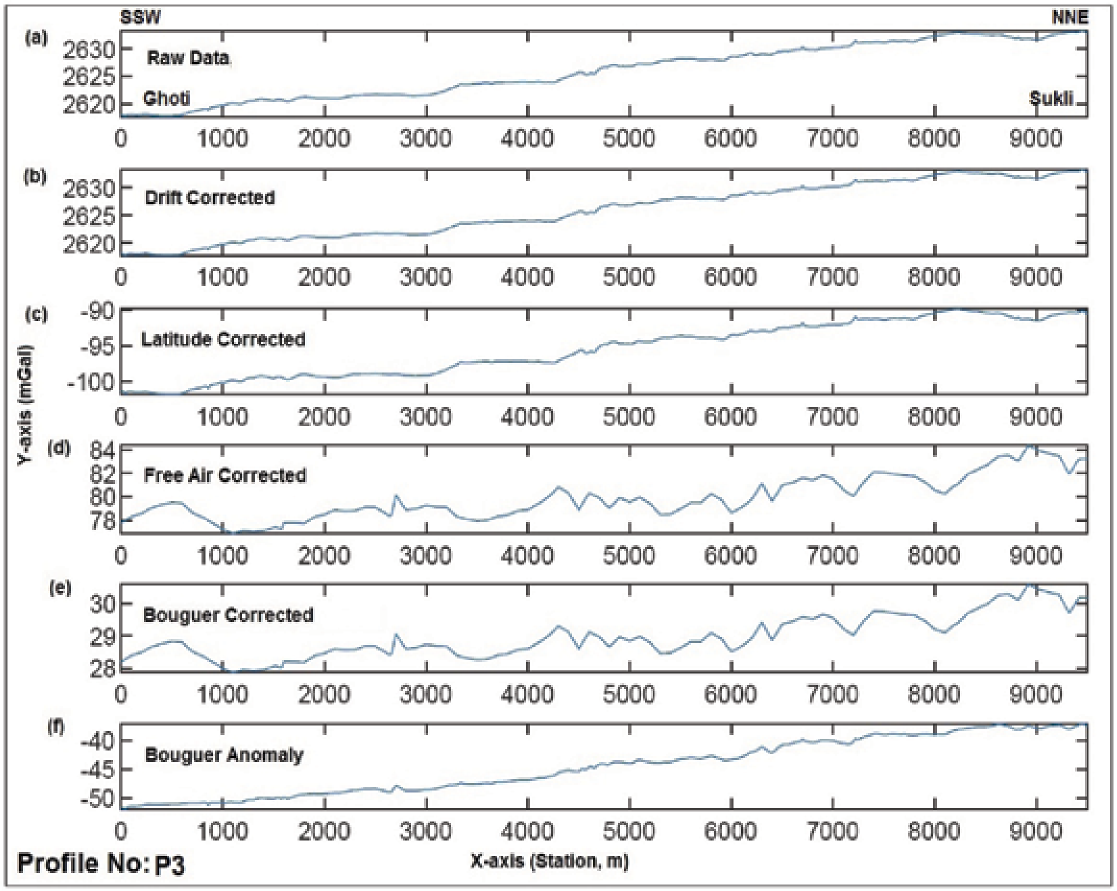

Figure 6a. Plot of (a) raw gravity data, (b) drift corrected, (c) Latitude corrected, (d) Free-air corrected, (e) Bouguer corrected and (f) Bouguer anomaly along profile P3

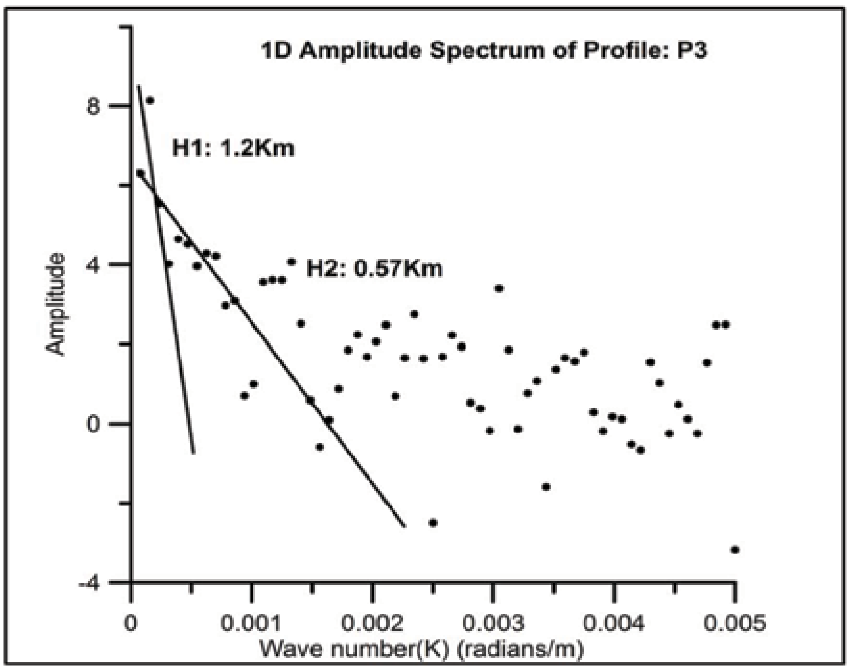

Figure 6b. Amplitude Spectrum of Profile P3

It is inferred from the spectral analysis that the depth to the basement varies from 0.5 Km to 1.3 in the study area. The shallowest basement is observed at profile P2, where as deepest part is observed at P1 and P3. The obtained results are good agreement with the results of lithological (Raja Rao, 1982), Magnetotelluric (Jitendra Kumar et al., 2004) and Gravity (Satish Kumar et al., 2018) studies.

CONCLUSIONS

The developed code is useful for processing of land relative gravity data. The efficacy of the code is tested on the real data set near Umred Coal field, Maharashtra and found to be feasible for handling gravity data sets for precise interpretation of the results.

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CODE AVAILABILITY

The "code" and user guide is available on request from the author. To get the file for installing within MATLAB® environment, go to the following link:
https://drive.google.com/open?id=1TL8fXJdv1eyandsa5crRSYEnRgWiAYKO
or
https://drive.google.com/drive/folders/1TL8fXJdv1eyandsa5crRSYEnRgWiAYKO?usp=sharing

Compliance with Ethical Standards

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

REFERENCES

Beilin, J., 2006. Apport de la gravimétrie absolue à la réalisation de la composante gravimétrique du Réseau Géodésique Français. Inst. Géogr. Natl., Paris, France.

Bhattacharya, B.K., 1966. Continuous spectrum of the total magnetic field anomaly due to rectangular prismatic body. Geophysics, 31, 97-121.

Cattin, R., Mazzotti, S. and Baratin, L.M., 2015. GravProcess: an easy to use MATLAB software to process campaign gravity data and evaluate the associated un- certainties. Comput. Geosci., 81, 20–27. http://dx.doi.org/10.1016/j.cageo.2015.04.005.

De, S., Ghosh, D. and Rao, K.J., 1982, Report on geophysical investigations for delineating Gondwana below traps in Umred trough inNWextension for Wardha valley coal field, Nagpur district, Maharashtra: Unpublished Report, Geological Survey of India.

Gabalda, G., Bonvalot, S. and Hipkin, R., 2003. CG3TOOL: an interactive computer program to process Scintrex CG-3/3 Mgravity data for high-resolution applications. Comput. Geosci., 29(2), 155–171. http://dx.doi.org/10.1016/S0098-3004 (02)00114-0.

Hahn, A., Kind, F.G. and Mishra, D.C., 1976. Depth estimation of magnetic sources by means of Fourier amplitude spectra. Geophys. Prosp., 24, 287–308

Hwang, C., Wang, C.G. and Lee, L.H., 2002. Adjustment of relative gravity measurements using weighted and datum free constraints. Comput. Geosci., 28(9), 1005–1015. http://dx.doi.org/10.1016/S0098-3004 (02)00005-5.

Jitendra Kumar., Singh, P., Dutta, D., 2004. Infra Trapean modelling of deccan syneclise. 5th Conference and Exposition on Petroleum Geophysics, Hyderabad-2004, India, 65-68.

Mishra, D.C. and Tiwari, R.K., 1981. Spectral study of the Bouguer anomaly map of a Rift Valley and adjacent areas in Central India. PAGEOPH, 119, 1051-1062.

Naidu, P.S., 1970. Statistical structure of aeromagnetic field. Geophysics, 35(2), 279- 292.

Naskar, D. C. and Saha, D. K., 2015. Geophysical investigations for delineation of Gondwana sediments below Deccan trap beyond the western limit of Wardha Valley coalfields, Yeotmal and Wardha districts, Maharashtra: a comprehensive analysis of case studies: J. Indian Geophys. Union, 19, 433–446.

Pandey, O.P., Chandrakala, K., Vasanthi, A. and Satish Kumar, K., 2018. Seismically imaged shallow and deep crustal structure and potential field anomalies across the Eastern Dharwar Craton, south Indian shield: Possible geodynamical implications. J. Asian Earth Sci., 157, 302–316.

Pandey, O.P., Srivastava, R.P., Vedanti,N., Dutta, S. and Dimri, V.P., 2014. Anomalous crustal and lithospheric mantle structure of southern part of the Vindhyan basin and its geodynamic implications. J. Asian Earth Sci., 91, 316–328. http://dx.doi.org/10.1016/j.jseaes.2013.11.015.

Prabhakara Prasad, P., Satish Kumar, K., Seshunarayana, T. and Rama Rao, Ch., 2013. New approach for interpretation of scattered ground magnetic data in a part of Delhi Fold Belt-NW Indian shield. Arab. J. Geosci. DOI 10.1007/s12517-013-0926-1.

Rama Krishna, T.S., Ramarao, M.S.V., Bhaskar Rao, K.V.S. and Punekar, D.V., 1999a.Geophysics of the Mahrashtra Gondwana: GSI special publication, 47.

Rama Krishna, T.S., Ramarao, M.S.V., Bhaskar Rao, K.V.S. and Punekar, D.V., 1999b. Geophysics of the Mahrashtra Gondwana: GSI special publication, 49.

Raja Rao, C., 1982. Coalfields of India: Geol. Survey of India, Bulletin Series A, no. 45.

Satish Kumar, K., Kishore, R.K., Parveen Begum., Seshu, D. and Rama Rao, Ch., 2014. Estimation of depth extent of Gangam-Peruru complex of Eastern Dharwar Craton (EDC) from aeromagnetic data. Arab. J. Geosci., DOI 10.1007/s12517-014-1383-1.

Satish Kumar, K., Kishore, R.K., Raj Kumar, R., Seshu, D., Pradeep Kumar, V. and Parveen Begum., 2015. Aeromagnetic Analysis to Locate Potential Ground Water Zone - A Case Study from South Indian Shield. J. Ind. Geophys. Un., 19(2), 160-166.

Satish Kumar, K., Rajesh, R. and Tiwari, R.K., 2018. Regional and residual gravity anomaly separation using the singular spectrum analysis-based low pass filtering: a case study from Nagpur, Maharashtra, India. Exploration Geophys., 49, 398-408. http://dx.doi.org/10.1071/EG16115.

Satish Kumar, K., Srinivas, K.N.S.S.S., Pradeep Kumar, V., Prabhakara Prasad, P. and Seshunarayana, T., 2018. Magnetic mapping of banded iron formation of Sandur Schist belt, Dharwar Craton, India. J. Geo. Soc. India, 91, 174-180.

Seshunarayana, T., Rajendra Prasad, B, Prasad, A.S.S.S.R.S. and Mysaiah, D., 2011. Subsurface Structure Derived from Detailed Gravity and Magnetic Investigations along the Pala-Maneri Traverse of the Main Central Thrust, NW Himalaya. J. Geol. Soc. India, 77, 213-218.

Spector, A. and Bhattacharyya, B.K., 1966. Energy density spectrum and auto correction function of anomalies due to simple magnetic models. Geophys. Prosp., 14, 242–272.

Spector, A. and Grant, F.S., 1970. Statistical models for interpreting aeromagnetic data. Geophysics, 35(2), 293–302.

Swarnpriya Chowdaria., Bijendra Singha., Nageswara Rao, B., Niraj Kumara., Singh, A.P. and Chandrasekhara, D.V., 2017. Structural Mapping Based on Potential Field and Remote Sensing Data, South Rewa Gondwana Basin, India. J. Earth Syst. Sci, 126(84). Indian Acad. Sci., DOI 10.1007/s12040-017-0857-4.

Tirupathi, M., Satish Kumar, K., Laxmaiah, B., Bansal, A.R. and Tiwari, R.K., 2017. Gravity and magnetic investigation along Rewa - Shahdol Basin Central India: Spectral Analysis Results. Socity of Exploration Geophysicsts, 12th Biennial International Conference Exhibition 17thto 19th November 2017.

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