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Forward And Inverse Modelling Of Airborne Gravity Data Of Kaltungo And Guyok , Upper Benue Trough, North Eastern Nigeria

Nwobodo, A.N., Ikeri H. I. and Chikeleze, P. C
Department of Industrial Physics, Enugu State University of Science and Technology, Nigeria
Corresponding Author: ifeanyihenry75@yahoo.com

Abstract – The airborne gravity data of Kaltungo and Guyok, Upper Benue Trough, Nigeria have been successfully interpreted both qualitatively and quantitatively. Regional anomaly was removed from Bouguer gravity to obtain the residual anomaly using polynomial fitting. The bouguer gravity anomaly map identifies regions of gravity high which corresponds to region with high density contrast and gravity lows which correspond to regions of low density contrast. The structural trend map showed the occurrence of subsurface linear structures which could be the presence of faults in the study area. Forward and Inverse modeling was employed in the quantitative interpretation in order to determine the density contrast and type of mineralization prevalent in the area, infer structures and structural trend within the area and determine the plunge, dip and shape of the body causing the anomaly. The result from the forward and inverse modeling analysis of aerogravity data shows that the density values obtained from the modeled profiles 1 – 3 are 2.63, 2.15 and 2.11 gcm^{-3} respectively, with respective depth of 3767, 3801 and 2279m. These density values indicate the presence of minerals like graphite and rock bearing minerals like Granite and Limestone in the study area. The shape of the body causing the anomaly in the area was identified as ellipsoid. The study area significantly demonstrated potentials for mineral deposit, which could serve as raw material(s) for many factories and industries in Nigeria. The presence of granite and limestone will definitely provide raw materials for building industry, mainly for architectural and construction purposes.

Index Terms: Airborne gravity, Bouguer anomaly, gravitational field, density contrast ,basement rock, forward and inverse modeling, .

1 INTRODUCTION

Gravity method has been widely used in different applications involving engineering exploration, regional and large scales study of geological structures, where measurements of earth's gravitational field are used to map subsurface variations in density [1,2,3,4,5,6] The anomalies in the earth's gravitational field results from lateral variations in the density of subsurface rocks and the distance from the measuring point. Factors like grain density, porosity and interstitial fluids within materials affect density contrast.

Gravity measurements are used in determining the earth gravity field at any point on the surface of the earth. This non-destructive technique measures the density difference of the subsurface rock materials for subsurface geological interpretation especially in delineating basement rock underlying the oil-bearing sedimentary deposits in any oil exploration. Not only in determining the basement rock, gravity surveys are also used in detecting fault structures which also related to locating the oil potential zones.

The aerogravity method has found numerous applications in engineering and environmental studies including locating voids and karst features, buried stream valleys, water table and determination of soil layer thickness. The success of the gravity method depends on the different earth materials having different bulk densities (mass) that produce variations in the measured gravitational field. The gravity method has good depth penetration compared to ground penetration radar, high frequency electromagnetic and dc-resistivity techniques and is not affected by high conductivity values of near-surface clay rich soils [7]. Gravity applications are widely used in the mineral Industry as an exploration tool to map sub-surface geology and to estimate ore reserves for some massive sulfide ore deposits. Additionally, the gravity technique is sometimes applied to detect shallow fallots and paleo channels in hydrologic investigation [8].The aim of this study was to determine the density contrast ,the type of mineralization prevalent in the area and the shape of the causative body using gravity method.

2 GEOLOGY OF THE STUDY AREA

This study covers an area of approximately 6050 km^2 in the north-eastern part of Nigeria between latitudes 9°30' and 10°00' North and longitudes 11°00' and 12°00' East covering Kaltingo and Guyok which are located in the Upper Benue Region. The Upper Benue Trough is part of the Benue Trough of Nigeria and is comprised of three basins: the east–west trending Yola Basin (Yola Arm), the north– south trending Gongola Basin (Gongola Arm) and the northeast– southwest trending Lau Basin (Main Arm). The geological map of Nigeria for the Upper Benue is shown in Fig. 1. The earliest Cretaceous sequence is the continental Bima sandstone, which rests unconformably on the undulating PreCambrian Basement. The unit is a thick and widespread series of continental grits, sandstones and clays. In the north, these beds are wholly continental, but in the south, marine shales occur in the lower part of the formation. Overlying the Bima Formation is the paralic Yolde Formation (Early Turonian), comprising alternating sandstones and shales. Thesandstones are fine- to medium-grained and light-brown, with shale and limestone intercalations. Thick marine Turonian shales with limestones at their base overlie the transitional deltaic-to-marine Yolde Formation in many localities. These shales, called the Pindiga Formation in the Upper Benue Trough, are found in the south to be laterally equivalent to the Jessu Formation, consisting of interbeds of shales, sandstones and limestones, the gypsiferous Numanha Formation and the Sukuliye Formation (shales and limestones). The type localities of the Sukuliye and Numanha Formations occur at Sukuliye and Lamja Kasa, respectively [9]. These two units succeed the Jessu Formation.

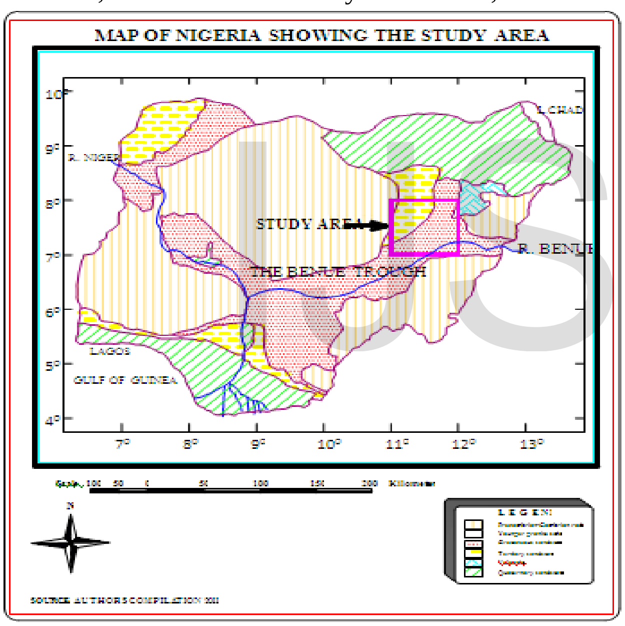


Figure 1. Map of Nigeria showing the study area

3. MATERIALS

The high resolution airborne magnetic data of Kaltungo (sheet 173) and Guyok (sheet 174), used for this study, were obtained from the Nigerian Geological Survey Agency (NGSA). The airborne gravity data were obtained using GRACE GRAVITY MODEL Sensor onboard 2 satellites by National Aeronautics and Space Administration (NASA) and German Aerospace Center in 2013. The airborne gravity Bouguer anomaly data (gravity data) were obtained in XYZ format; X and Y are distance in meters measured along east and north direction respectively. While Z is the Bouguer anomaly values measured in miligal.

4. METHOD

The digitized airborne gravity data of Kaltungo and Guyok were merged together to produce one single sheet which forms the study area. The merged data was gridded in order to produce the Bouguer gravity map of the study area. First order polynomial fitting was used for the regional – residual separation using Oasis Montaj software.

5 FORWARD AND INVERSE MODELLING

Three profiles were taken from the airborne gravity residual grid Fig. 9 of the study area and modeled. Each profile produced a degree of strike, dip and plunge where the observed values matched well with the calculated values. The blue curves in Fig. 10(a - c) represented the observed field values while the red curves represented the calculated field values. The forward modelling being a trial and error method, the shape, position and physical properties of the model were adjusted in order to obtain a good correlation between the calculated field and the observed field data. The field of the model was calculated using Potent Q 3D tool of the Oasis Montaj software. The root mean square (RMS) difference between the observed and calculated field values was minimized by the inversion algorithm. The RMS value was displayed at the end of the inversion. The RMS value decreased as the fit between the observed sand calculated field continues to improve, until a reasonable inversion result as achieved. Less than

5% of root mean square value was set as the error margin.

6 RESULTS AND DISCUSSION

The Bouguer anomaly of the study area varies from -67.4 mGal to -25.8 mGal Fig. 2. The colour legend bar identifies regions of gravity high (red and pinks) which corresponds to region with high density contrast beneath the surface; intermediate values (green and yellow) and gravity lows (blue colour) that correspond to regions of low density contrast.

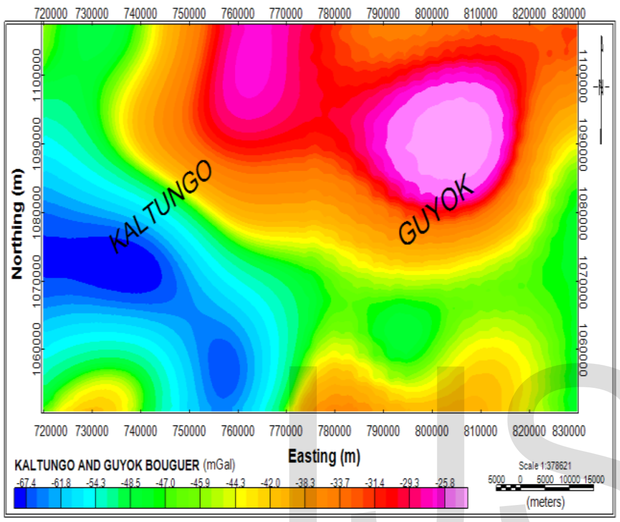


Figure. 2: Bouguer gravity map of the study area.

The residual Bouguer anomaly of the study area varies from -15.4 mGal to 18.3 mGal Fig.3. The colour legend bar identifies regions of gravity high (red and pinks) which corresponds to region with high density contrast beneath the surface; intermediate values (green and yellow) and gravity lows (blue colour) that correspond to regions of low density contrast. Figure 3 is the regional Bouguer anomaly map. The values range from -56.1 mGal to -29.4 mGal.

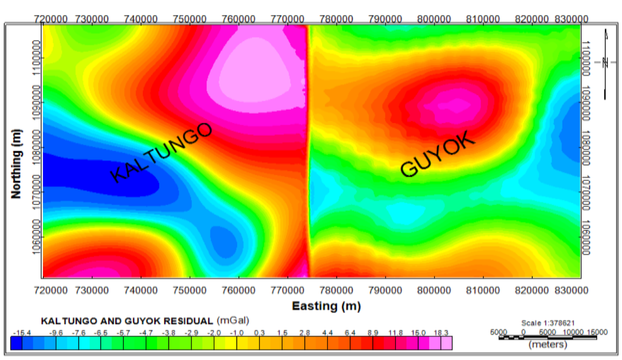


Figure. 3: Residual gravity map of the study area

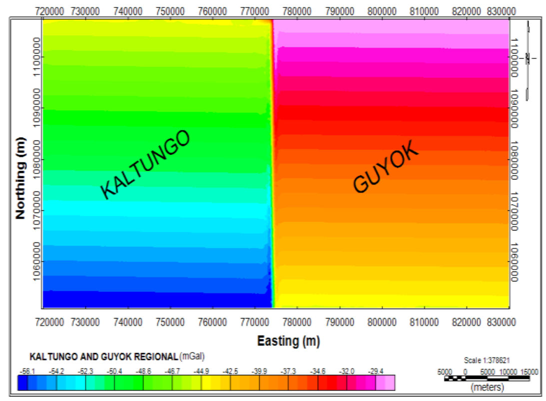
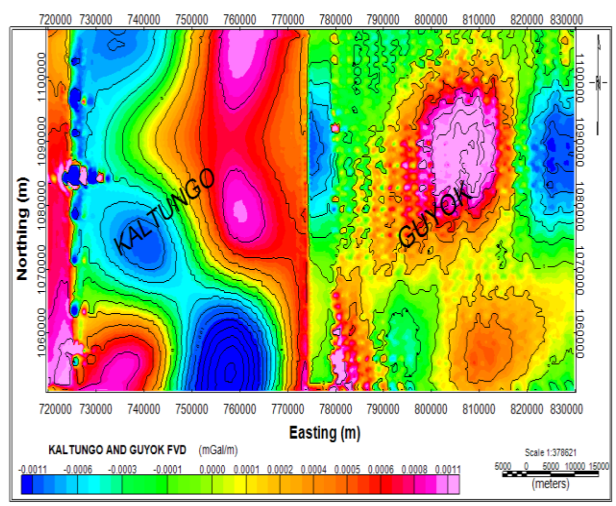


Figure. 4: Regional Gravity Map of the study area

The first vertical derivative computed on the residual data of airborne gravity of the study area enhanced the shallow sources by suppressing the effect of the deeper ones, this helped to reveal near surface intrusions Fig. 5. The second vertical derivative sharpens the effect of the first vertical derivatives and helps to determine the edge of the anomalous body Fig. 6. The horizontal derivative shows more exact location for faults Fig. 7. The Fig. 8 is the structural trend map showing the lines of faults within the study area. The most dominant trend are seen in Kaltungo area. This could be a favorable structure for the control of mineral deposits in the area and it could also serve as reservoir for the suspected minerals in the study



area [10,11]. The structural trend map was obtained from the residual grid using Oasis Montaj software.

Figure. 5: Airborne gravity first vertical derivative map of the study area

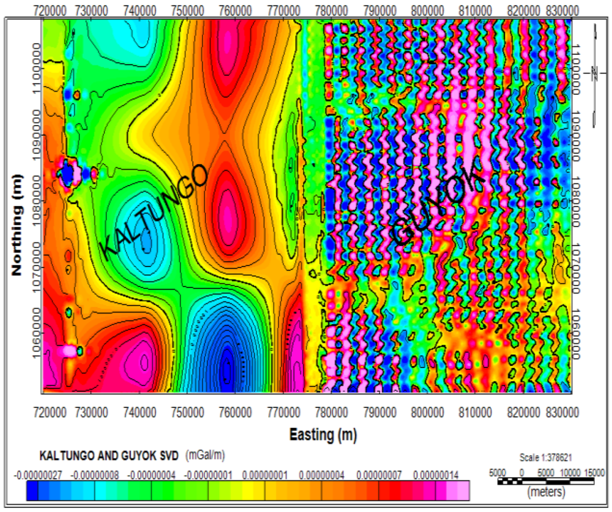


Figure. 6: Airborne gravity second vertical derivative map of the study area.

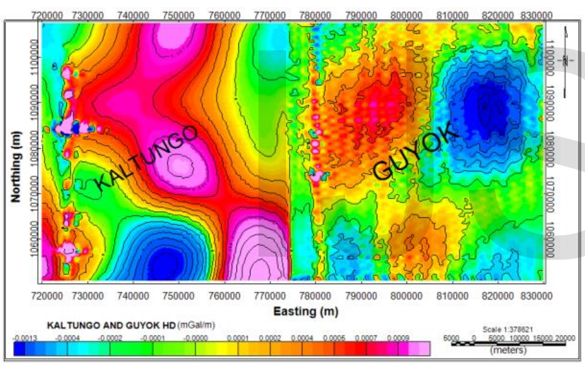


Figure. 7: Airborne gravity horizontal vertical derivative map of the study area.

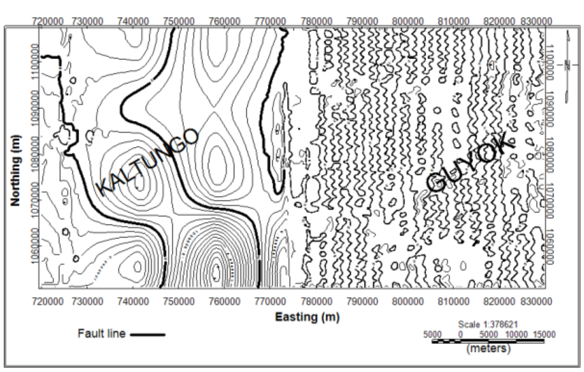
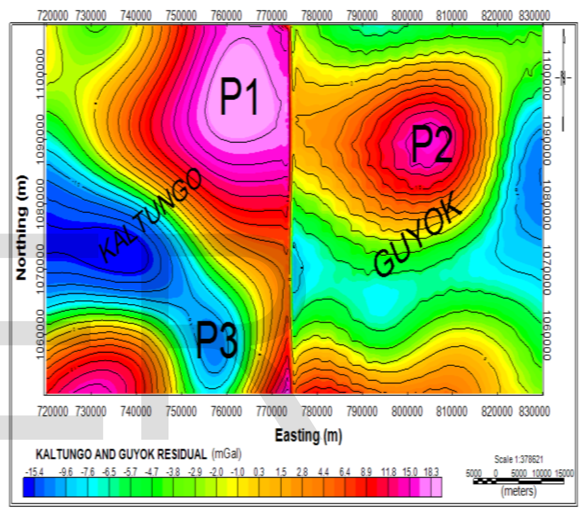


Figure. 8: Structural trend map showing the line of the faults in the study area

The results of the forward and inverse modelling are summarized in Table 4.2. The result from the forward and inverse modelling analysis of airborne gravity data shows that the density values obtained from the modelled profiles 1 - 3 are 2.63, 2.15 and 2.11 g/cm3 respectively, with respective depths of 3767, 3801 and 2279 m. These density values indicate the presence of minerals like graphite and rock bearing minerals like Granite and limestone in the study area. The shape of the body causing the anomaly in the area was identified as ellipsoid. The study area has revealed potentials for mineral deposit, which could serve as raw material(s) for many factories and industries in Nigeria. The



presence of granite and limestone will definitely provide raw materials for building industry, mainly for architectural and construction purposes.

Figure 9: Airborne gravity residual contour map.

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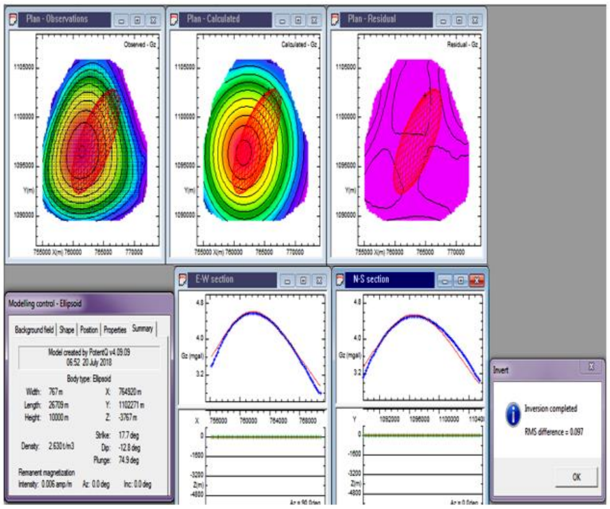

Figure 10(a): Profile 1 (P1) modelled.

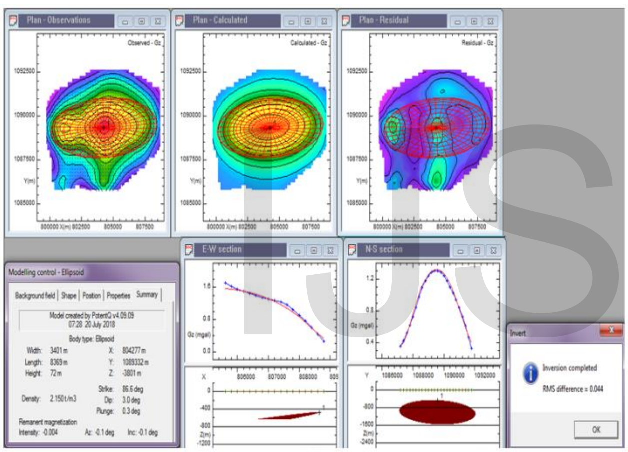

Figure 10(b): Profile 2 (P2) modeled.

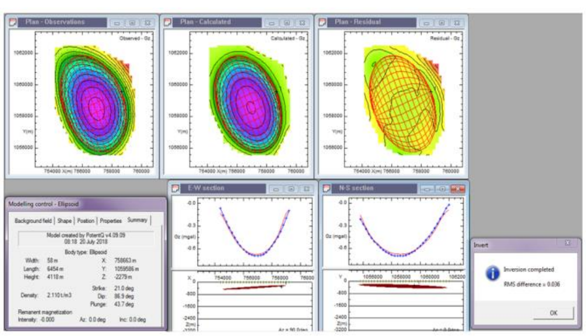

Figure 10(c): Profile 3 (P3) modelled.

Table 4.1: Summary of airborne gravity Forward and Inverse modelling results.

Model	Model shape	X(m)		Depth to anomalous body (m)	Plunge (deg)	Dip (deg)	Strike (deg)	Density value (g/cm3)	Possible cause of anomaly
P1	Ellipsoid	764920	1102271	3767	74.9	-12.8	17.7	2.63	Granite
P2	Ellipsoid	804277	1089332	3801	0.3	3.0	86.6	2.15	Graphite
P3	Ellipsoid	758663	1059586	2279	43.7	86.9	21.0	2.11	Limestone

7 CONCLUSION

The airborne gravity data of Kaltungo and Guyok, Upper Benue Trough, North-Eastern Nigeria have been interpreted qualitatively and quantitatively. The Bouguer gravity anomaly map identifies regions of gravity high which corresponds to region with high density contrast and gravity lows which correspond to regions of low density contrast. The structural trend map showed the occurrence of subsurface linear structures which could be the presence of faults in the study area. The modelling of the residual map revealed some minerals in the study area, which are; graphite and rock bearing minerals like limestone and granite.

The study area has revealed potentials for mineral deposit, which could serve as raw material(s) for many factories and industries in Nigeria.

8 ACKNOWLEDGEMENT

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