# Qualitative interpretation of airborne gravity Data of gboko and environs: Implication of mineral exploration.

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**Abstract**

Enhancement techniques applied to the Bouguer anomaly map produced derivative maps for qualitatively interpretation. These techniques include analytical signal, tilt derivative, vertical and horizontal derivatives and shaded-relief imaging. The first vertical derivative **e**nhanced the shallow sources, suppressed the deeper ones, and gave a better resolution of closely spaced sources. The horizontal accentuated derivative shallow masses and boundaries associated with lateral density variations. Boundaries, edges and anomaly contacts were also revealed. The analytical signal filter revealed the source contact and the highest amplitude of the analytical signal is recorded at the areas that have witnessed by intrusions. Upward continuation have determined the form of regional gravity variation over Gboko area which is related to the rifting within the Benue trough. These Geological structures serve as conduit for mineral formation.

**Keywords: Derivative filters, Bouguer Anomaly, and Southern Benue Trough.**

## INTRODUCTION

Gravitation attraction keeps us on the ground, without our planet's gravitational attraction, we and everything else would fly into space (Lyatsky, 2010). Gravity surveying measures the difference in acceleration due to gravity (Igwe et al., 2018). The variation arises from differences of density between subsurface rocks. The application of potential-field methods such as gravity in geophysical prospecting can allow for the delineation of depth to basement and mapping at local and regional levels of geologic structures such as faults and lithologic contacts that do not appear on the ground surface. It is highly imperative that reconnaissance geophysical survey of rock density cannot be achieved without mentioning the gravity survey method. This is very essential in the oil and gas exploration, mineral prospecting, archaeological finding, crustal imaging, environmental problem solving and geological structures mapping. The mapping of such features is of socio-economic importance such as in identifying mineralization veins, geologic structures of interests both at regional and local scales and possible flow patterns of groundwater and hydrocarbons (Blakely and Simpson, 1986). In this research, qualitative techniques of interpretation involving the following: vertical derivative, horizontal derivative, separation of residual and regional anomalies is employed. Interpretation of data was undertaken by visual inspection of map for patterns and signature. Benue trough has been studied extensively by many scholar because the occurrence of lead-zinc mineralization, salt deposits and bright prospects of finding oil in the area (Ugbor and Okeke, 2010). The purpose of gravity data analysis is to locate and describe subsurface structures of Gboko area from the observed gravity effects caused by their anomalous densities (Telford et al., 1990; Lowrie, 1997).

## Geology of the study area

The geographical coordinate of the study area lie between longitude $8^1.30^0$E to $9^1.00^0$ and latitude $7.00^0$N to $7.30^0$N of 32km with the scale of 1:100000. The Benue Trough is an intracratonic Cretaceous basin about 1,000 kilometers in length and up to 250 km at its widest parts, developed as a purely rift structure in the Pan-African mobile belt (Nwajide, 2013), 50 to 100 kilometers wide in the NE-SW direction (Guidraud *et al.*, 1992). The origin of Benue trough has been discussed extensively in literatures by different scholars who helped to form and define their stratigraphy.

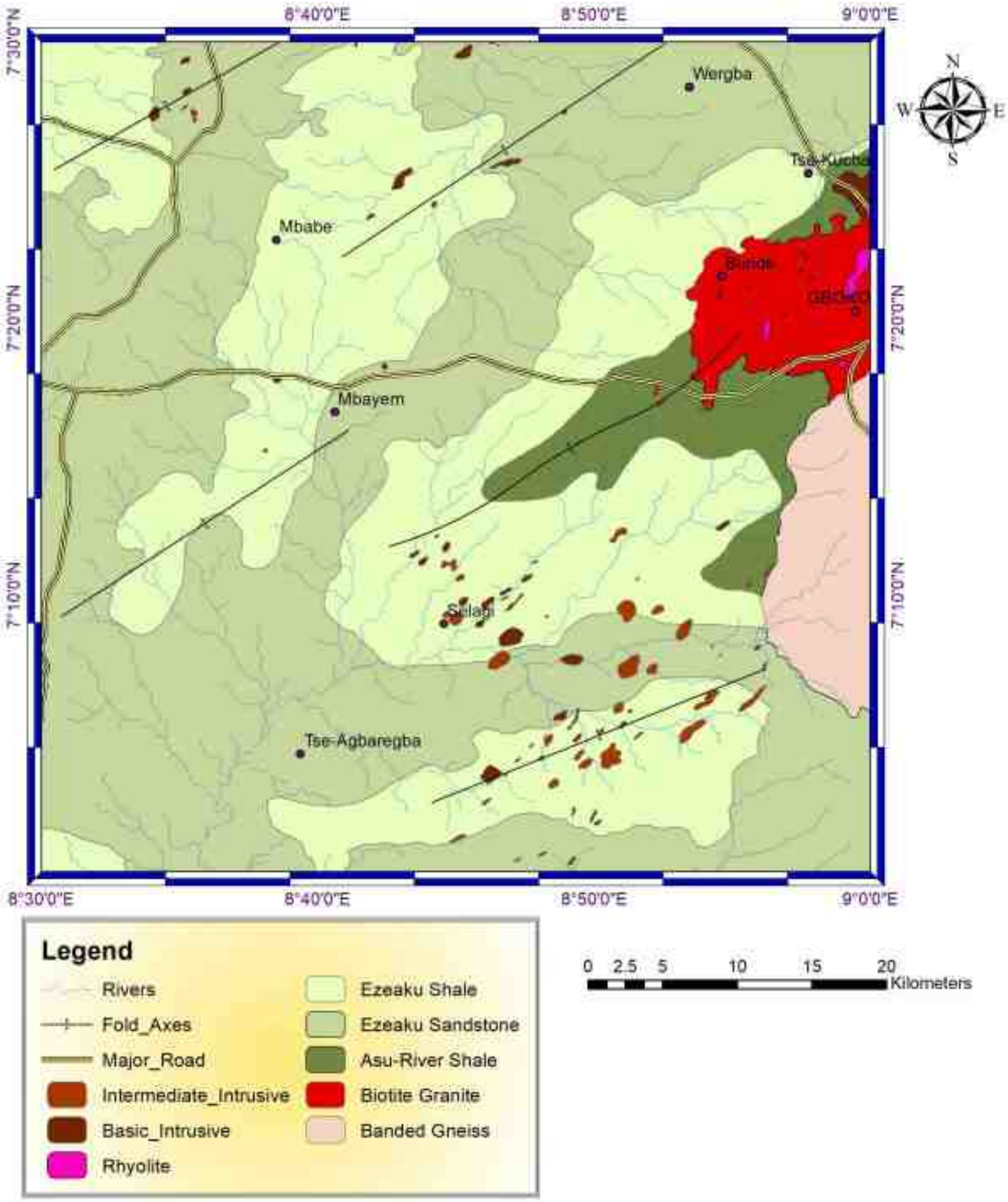


*Fig. 1: The geological map of the area of study.*

The separation of the African continent from the South American continent in the Aptian led to the tectonic evolution of the Benue Trough (Grant, 1971). It is a rift basin system, which trends NNE – SSW of about 800 km length and 150 km width (Olade, 1975). The Trough has a southern limit at the Northern boundary of the Niger Delta Basin, while the Northern limit is at the southern boundary of the Nigerian part of Chad Basin (Obaje, 2009).

The Benue Trough is subdivided into the Southern portion which is also known as the southern Benue Trough, the central Benue Trough and the Northern Benue Trough (Nwajide, 2013).

There is no line that demarcates the individual portions but major localities (towns/settlements) constitute the depocentre of the individual portions (Obaje *et al.*, 1999; Burke *et al.*, 1970). The Trough contains about 6000 m of Cretaceous-Tertiary sediments which predates the Mid-Santonian compressional folded, faulted and uplifted strata in several places. The depocentre of southern Benue Trough comprises of areas around Nkalagu and Abakaliki, Gboko. Sedimentation in the southern Benue Trough commenced with the marine Albian Asu River Group (Ojoh, 1992). The Asu River Group in the southern Benue Trough comprises the shales, limestones and sandstone lenses of the Abakaliki Formation Mfamosing Limestone in the Calabar Flank. The marine Cenomanian – Turonian Nkalagu Formation (black shales, Limestones and siltsones) and the interfingering regressive sandstones of the Agala and Agbani Formations rest on the Asu River Group. Mid-Santonian deformation in the Benue Trough displaced the major depositional axis westward which led to the formation of the Anambra Basin. Post-deformational sedimentation in the sourthern Benue Trough, therefore, constitutes the Anambra Basin

## METHODOLOGY

The aero-gravity dataset used for this study was acquired from Nigerian Geological Survey Agency (NGSA). The agency applied some sorts of reductions/corrections like latitude, elevation, terrain/topography, free air, bouguer and Eotvos. Geosoft's Oasis Montaj ver 6.4.2 and ArcGIS 10.4 soft wares were used in the processing and analysis of the data. Processing of the data begin by production of Bouguer anomaly gridded map of Gboko sheet using grid size of 100m. Upward continuation filter was applied on the Bouguer anomaly grid to enhance the regional components anomalies at the area. Edge enhancement techniques based on gravity signal derivatives such as analytical signal, shaded relief imaging, tilt derivative, vertical and horizontal derivatives were applied to the Bouguer anomalous map.

## RESULTS AND INTERPRETATIONS:

**Bouguer Gravity anomaly map:** This is bouguer gravity map is characterized by both regional anomaly and superimposed by shorter wavelength anomalies from local source (Lowrie, 1997, Kearey and Brooks, 2002). The map shows variations in amplitude which is related to the density contrast between the rocks and it ranged from -5.1 to 16.3mGal (Fig. 2). The anomalies are as a result of inhomogeneous distribution of density in the earth. The map comprises of positive and negative anomalous zones trending N-S, E-W, and NW- SW directions. The density contrast is positive if the intruding body has a higher density than the host rock and negative if the intruding body has a lower density than the host rock. The source for this strong positive gravity is possibly the topography of crystalline Pre-Cambrian basement or basic igneous intrusions. Areas with low Bouguer gravity anomaly are probably areas of intermediate igneous intrusions, deep basement and crustal thinning (Ugbor and Okeke, 2010).

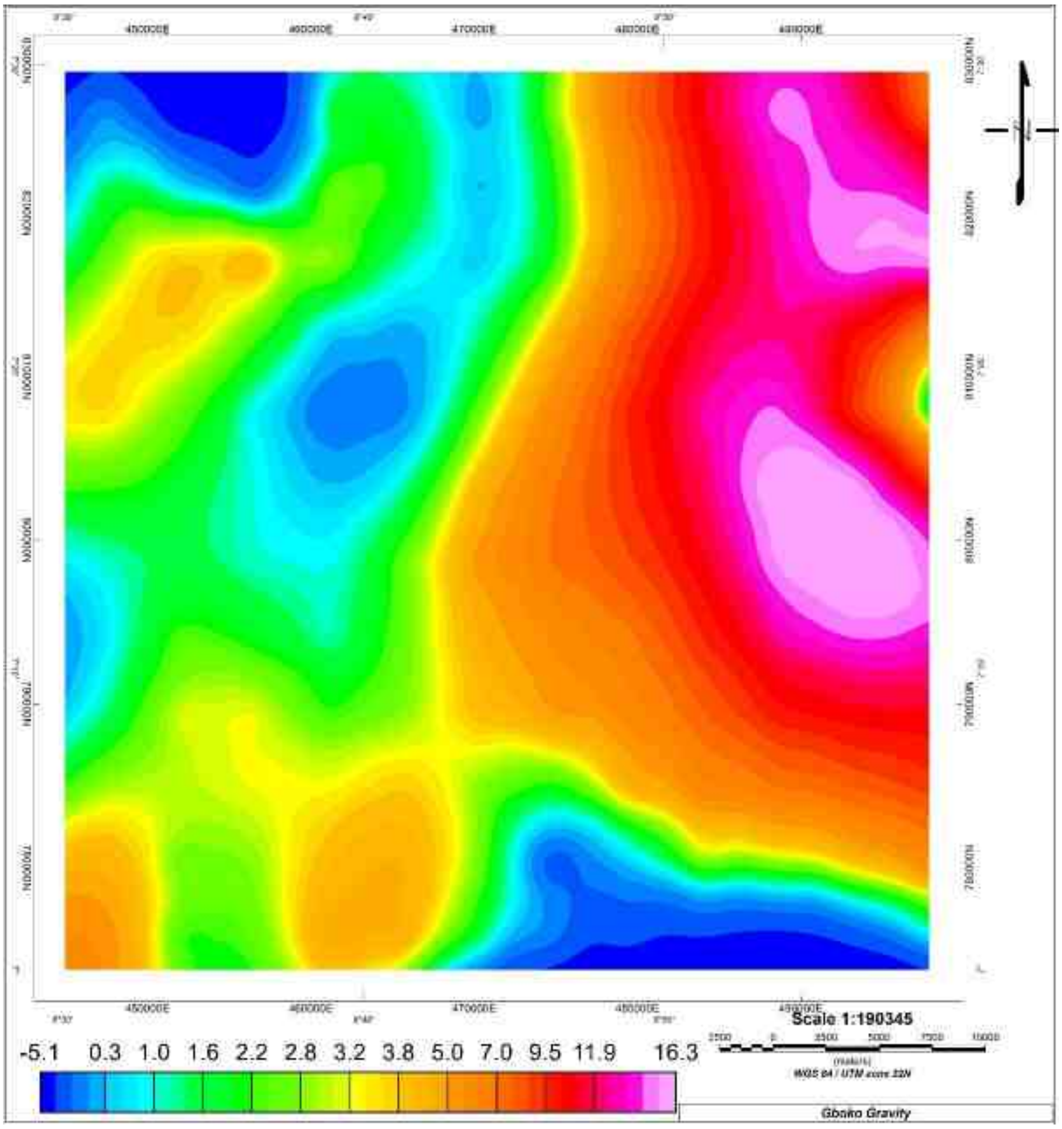


***Fig.2:*** **Bouguer Anomaly map of Gboko**

**Shaded-relief imaging map:**

This is incorporating a sun shading algorithm or artificially illuminating the image from a specific direction. This has the effect of adding spatial resolution to a color image, and highlighting anomalies oriented quasi-perpendicular to the illumination vector. Many interpreters prefer greyscale images to color images because subtle magnetic/gravity features are more obvious in greyscale images (Gunn *et al.*, 1997). (See fig. 3).


***Fig. 3: Grey Scale Imaging***

**Analytical signal map**

Nabighian, 1972, 1974, developed the notion of 2D analytical signal. Roest *et al.*, 1992 showed that the amplitude (absolute value) of the 2D analytical signal at location (X, Y) can be derived from 3 orthogonal gradients of the total magnetic field. The analytical signal provides a means to analyze low latitude magnetic fields without first computing reduction of pole because is not sensitive to the inclination of the geomagnetic fields. The computed analytical signal map is presented in fig. 4. Analytical signal filter technique produced higher resolution results than other edge detection techniques. The amplitude of the analytical gradients is a good tool for analyzing gravity anomalies (Fedi and Florio, 2001). The procedure tends to increase signal amplitudes of short wavelength compared to those of long wavelength. The areas with high amplitudes are areas that have witnessed dolerite and dioritic intrusions in Gboko environs. The high gravity amplitude rocks corresponds to mafic rock with highest average magnetic susceptibility value which reflects the high content of magnetic material in the rock (Eze and Ije, 2019). Ultra mafic (high density) rocks are associated with gravity highs whereas gravity lows are associated with shallow (low density) rocks (Wright, 1981). The analytical signal was calculated to extract the location of gravity sources contacts or edge. The analytical signal showed discontinuities, some of which coincide with the geological boundaries at the area (see fig. 4).

$$|A(x,y)|^2 = \sqrt{\left(\frac{\delta M}{\delta x}\right)^2 + \left(\frac{\delta M}{\delta y}\right)^2 + \left(\frac{\delta M}{\delta z}\right)}^2$$

where M= anomalous magnetic field in horizontal and vertical directions.

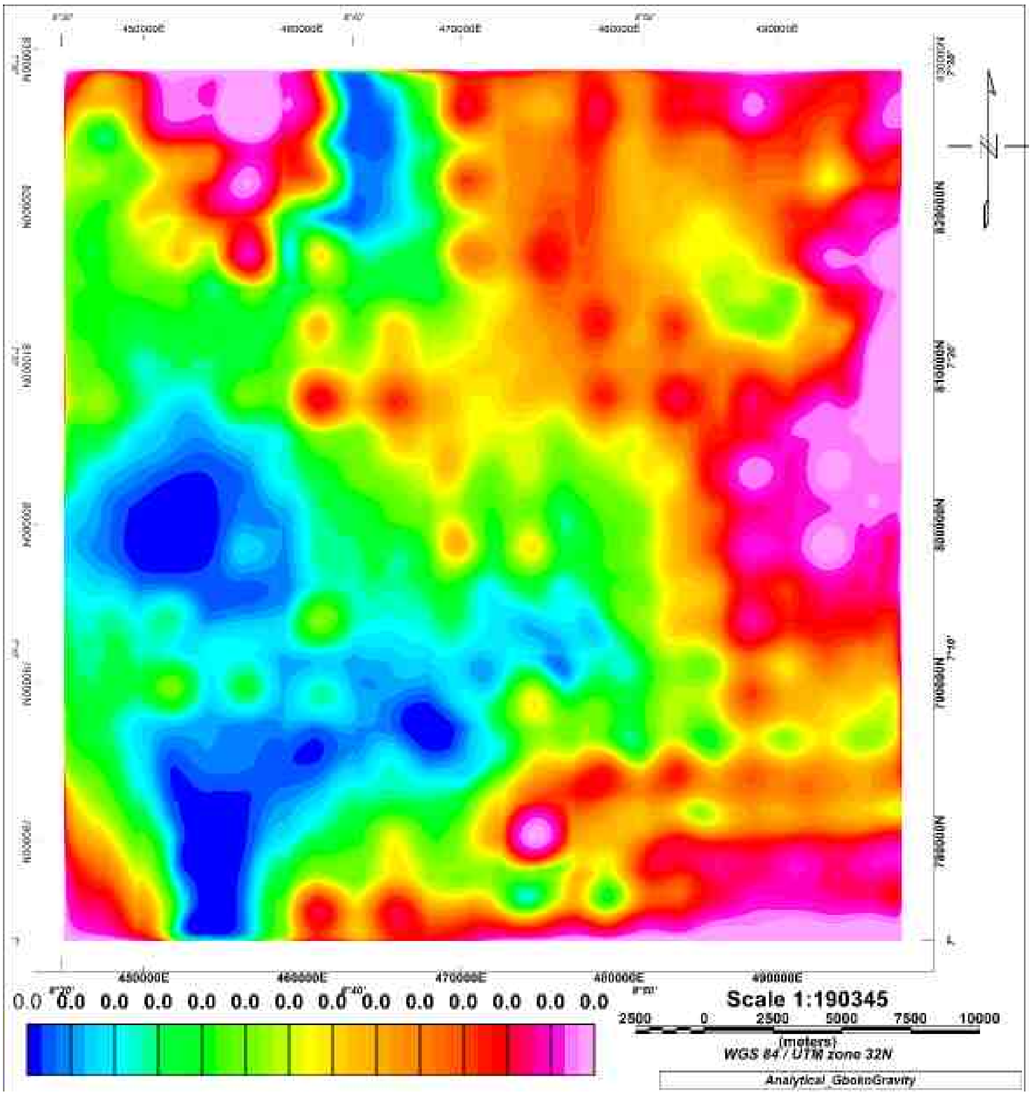


*Fig. 4: Analytical Signal Map*

**First vertical Derivative filter:** Vertical derivative filter has amplifies the high frequency components of the data (Erwin *et al.*, 1995) (see fig. 5). It accentuates gradients along edges of shallow magnetic sources. Hence, it is sometimes used to locate edges of magnetic bodies and to emphasize source at shallow depth (Dobrin and Savit, 1988). Advantages of vertical derivatives are as follows: Enhancing the shallow sources, suppressing deeper ones, and giving a better resolution of closely spaced sources (Reeves, 2005). The equation of the wavenumber domain filter to produce nth derivative is

$$F(\omega) = \omega^n$$

Where

$F(\omega)$ = amplitude at wave number ω in radians/unit (ω = 2Πk; k is in cycles/unit) and n is the order of differentiation. This was computed to accentuate anomalies associated with shallow anomalies (Kearey and Brook, 2002).

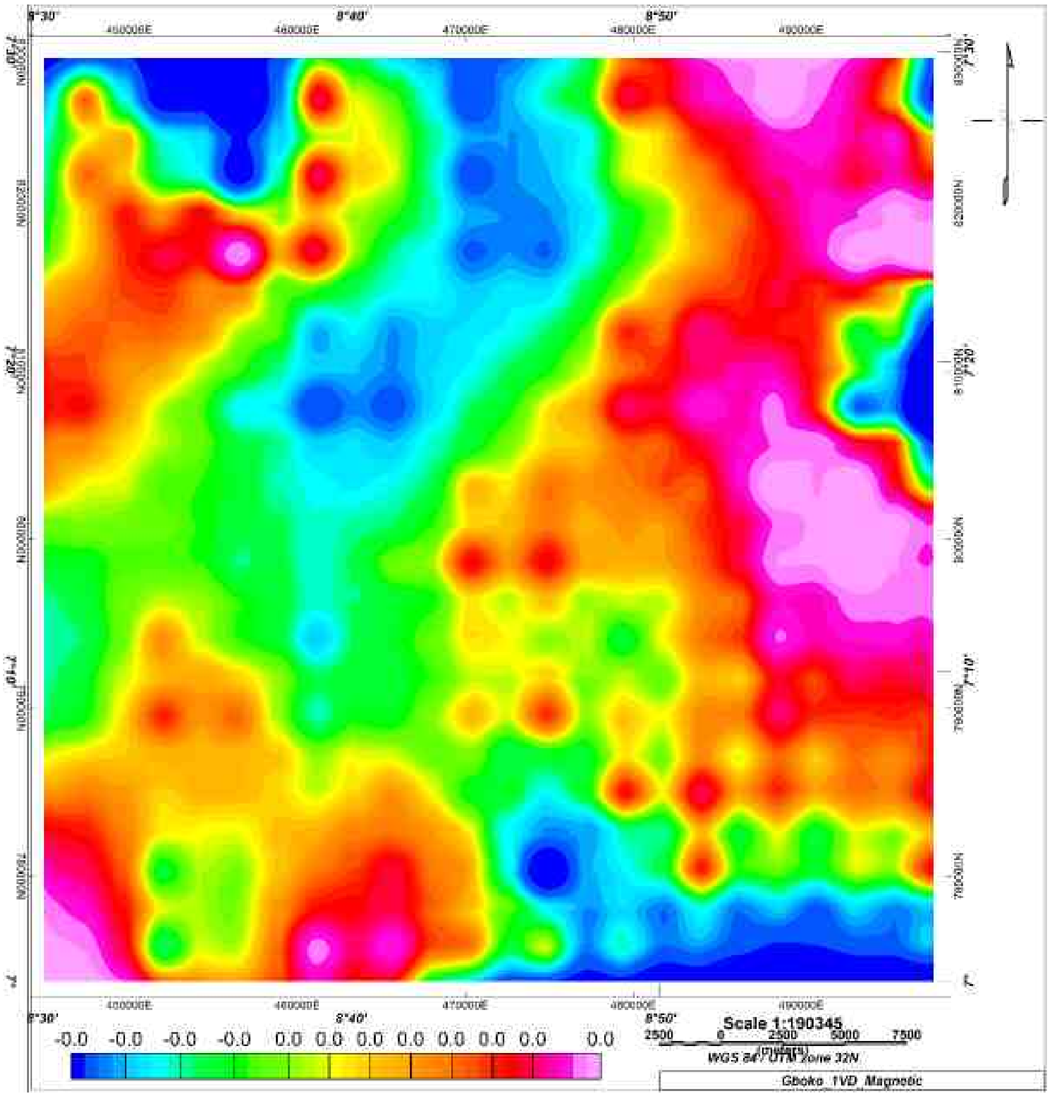


*Fig.5: First Vertical derivative of Gboko*

**Tilt Derivative:** One of the most important edge-detection filter is the Tilt derivative filter which enhances near-surface features and edges of sources in gravity field. The tilt derivative or tilt angle was first proposed by Miller and Singh (1994) as a tool for locating magnetic or gravity sources on magnetic or gravity profile data. The horizontal gradient magnitude (HGM) is given by the square root of the sum of the squares of the horizontal derivatives of the potential field.

$$\text{HGM} = \sqrt{\left(\partial f / \partial x\right)^2 + \left(\partial f / \partial y\right)^2}$$

Where $\partial f / \partial x$ *and* $\partial f / \partial y$ are first derivatives of the field in the X and Y directions. For the gridded data the generalized tilt derivative is

$$\theta = \tan^{-1} \frac{\partial f}{\partial z} \Big/ HGM$$

where $\partial f / \partial z$ is the first vertical derivative of the field f.

The gravity tilt angle is a normalized derivative based on the ratio of the vertical and horizontal derivatives of the gravity field (Salem *et al.*, 2007). The tilt is restricted to value between −π/2 and +π/2 (+90$^0$ and-90$^0$) regardless of the amplitudes of VDR (first vertical derivative) or THDR. This fact makes this relationship function like an automatic gain control (AGC) filter and tends to equalize the amplitude output of Bouguer anomalies across a grid (Verduzco *et al.,* 2004). TDR crosses through zero at or near the edge of a vertical-sided source and is negative outside the source region (Miller and Singh, 1994). The TDR is therefore very effective in allowing anomalies to be traced out along strike. The tilt derivative revealed short and long wavelength and the presence of main gravity trends of NE-SW within the southern Benue Trough (see. Fig. 6).

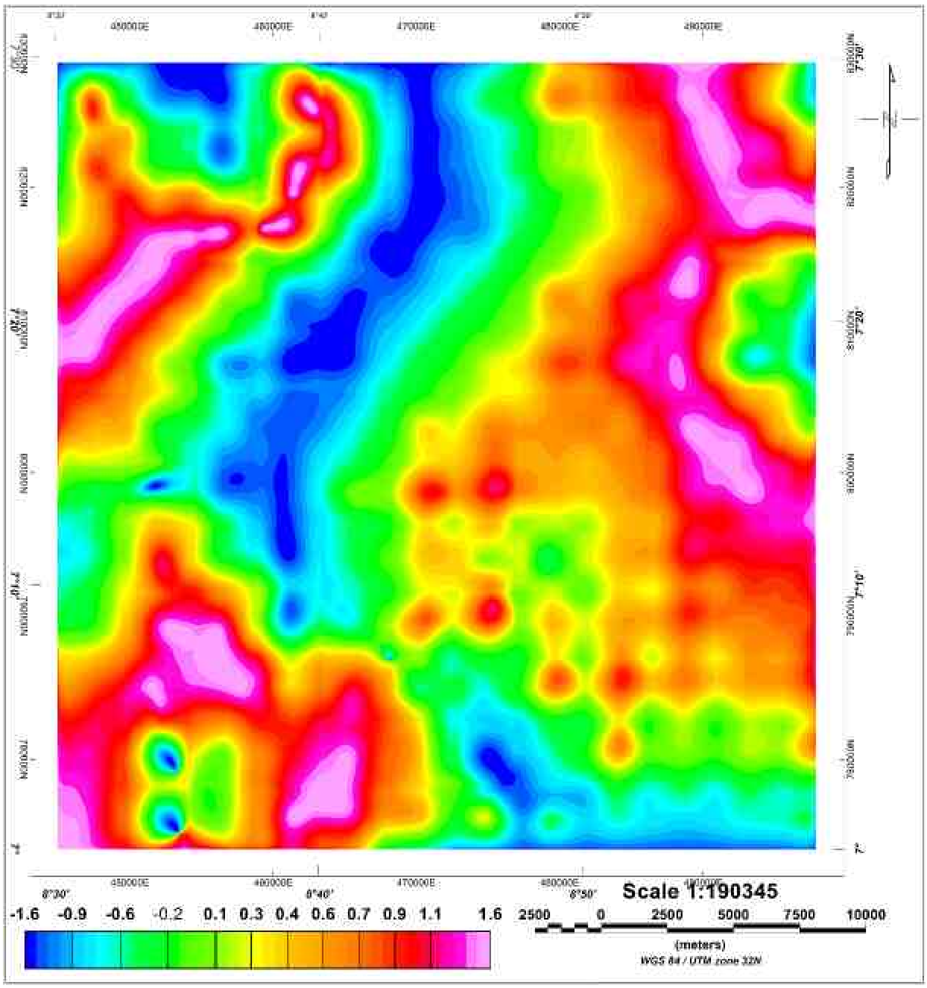


*Fig.6: Tilt-Derivative of the gravity data.*

**Upward continuation:** Gravitational field, a potential field obey Laplace's equation which states that the sum of the rates of change of the field gradient in three orthogonal directions is zero (Kearey and Brook, 2002). The equation of potential field, expressed thus:

$A_k(x,z) = (a\cos kx + b\sin kx)e^{kz}$ shows that a potential field can be represented in terms of sine and co-sine waves whose amplitude is controlled exponentially by the level of observation, where a and b are constants, k is the spatial frequency or wavenumber, $A_k$ is the potential field amplitude corresponding to the wavenumber and z is the level of observation. The above equation enable the general form of the equation to be stated for any value of z.

For a two-dimensional anomaly measure at the surface A(x, o) is a sine wave as follow:

$A(x,z) = (A_0 \sin kx)$ where $A_0$ is a constant and k the wavenumber of the sine wave.

Thus,

$$A(x,z)=(A_0 \sin kx)e^{kz}$$

the field at a height h above the surface can then be determined using

$$A(x,-h)=(A_0 \sin kx)e^{-kh}$$

And the field at depth d below the surface

$$A(x,-d)=(A_0 \sin kx)e^{kd}$$

**Upward and Downward continuation**: The equations show that the field measured at the surface can be used to predict the field any level above or below the plane of observation. This is the basis of upward and downward continuation. Upward continuation was done on the area to determine the form of regional gravity variation over Gboko area (see Fig. 7). The regional gravity represents the deep seated tectonic features which is related to the rifting within the Benue trough (Shemang *et al.*, 2005). The gravitational field is continued upward to an elevation of 100m. Upward continuation filter enhanced the low wavenumber anomalies due to deep sources at the area. On downward continuation, high-wavenumber components are relatively enhanced. It looks as if the anomalies show extreme fluctuations. It seems the field is continued to a depth greater than that of its causative structure (Kearey and Brook, 2002). Thus, this techniques is of more restricted application.

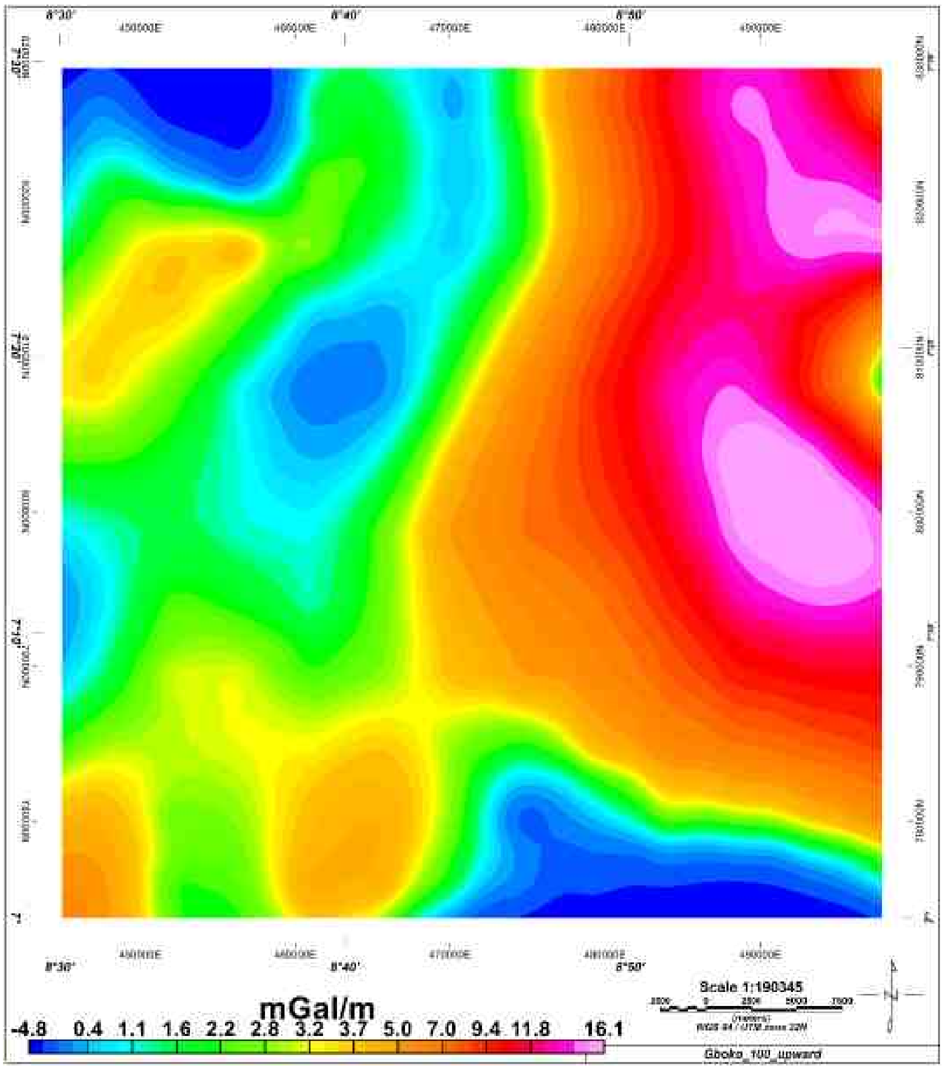


*Fig.7: Gboko Gravity anomalies upward continued to 100m*

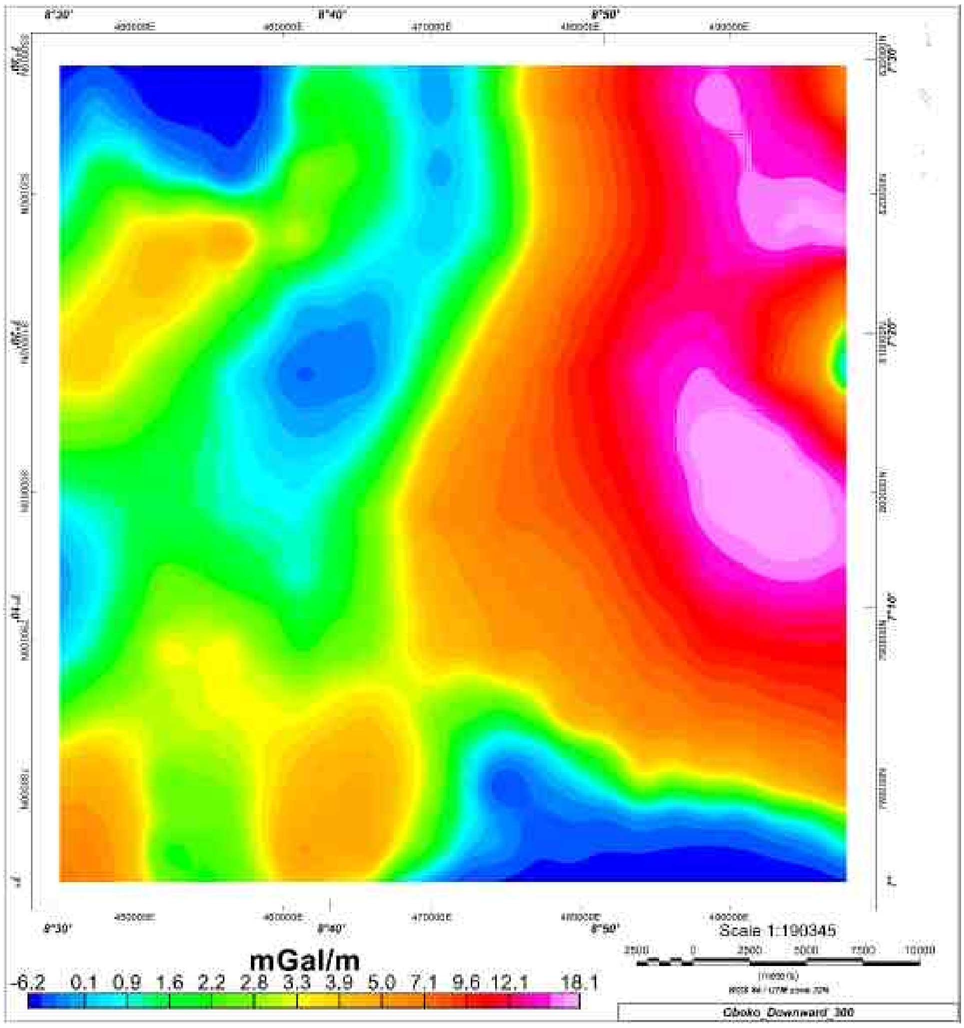


*Fig .8: Gravity Data Downward Continued to 300m.*

**HORIZONTAL DERIVATIVE:** Use of the horizontal gradient for locating the edges of magnetic sources developed as an extension of Cordell's (1978) technique to locate edges of tabular bodies from the steepest gradients of gravity data is also use to accentuate anomalies associated with shallow bodies (see fig. 9). The horizontal derivative produces an "edge" map where the high data values are centred over the edges of the magnetic sources (e.g. highlighting faulting relationships). It is considered the simplest approach to estimate the contact locations (e.g. faults, joints, fractures). The greatest advantage of the horizontal gradient method is that it is least susceptible to noise in the data because it only requires the two first-order horizontal derivatives of the magnetic field $\partial T/\partial x$ *and* $\partial T/\partial y$,

The horizontal gradient HG (x,y) is given by:

$$HD(X,Y) = \sqrt{\partial T/\partial x + \partial T/\partial y}$$

Horizontal derivative map also located better than vertical gradient buried shallow masses and boundaries associated with lateral density variations.

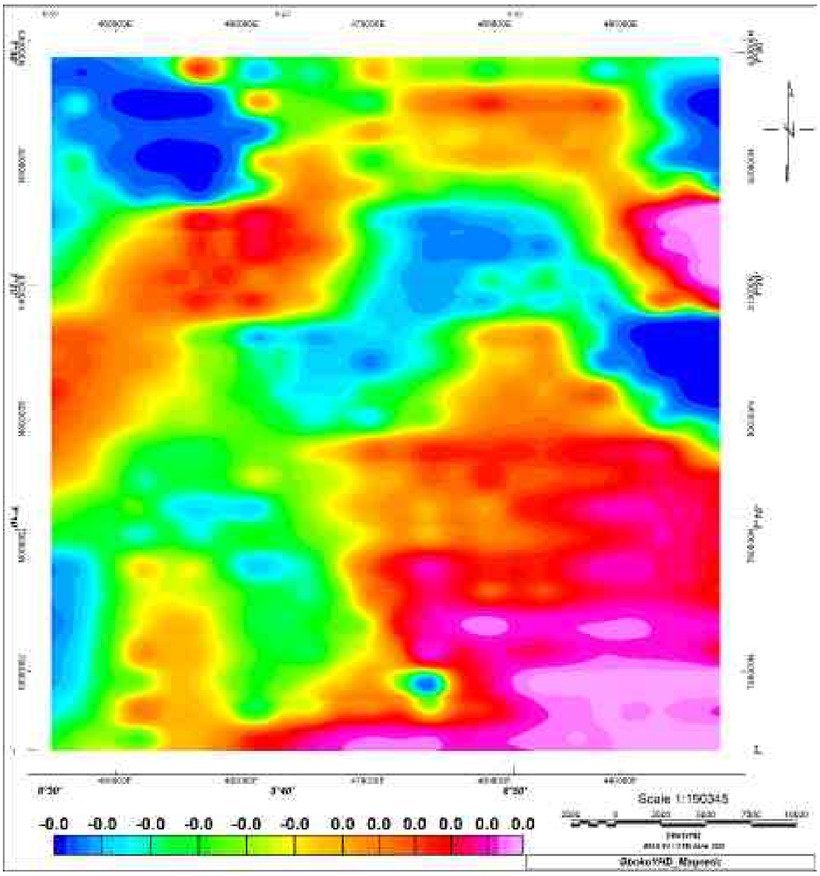

*Fig.9: Horizontal derivative in y- direction.*

## CONCLUSION

Application of various filtering techniques to the bouguer gravity anomalous map have revealed both shallow and deep anomalies. Upward continuation filter has determined the form of regional gravity variation over Gboko area. Data enhancement techniques such as derivative based-filters have been applied in the analysis of the gravity data and the source edges, contact and boundaries have been delineated. These geological structures serve as controls and conduit for mineral formation.

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