SUBSURFACE CHARACTERIZATION BASED ON DENSITIES AND THICKNESS OF SEDIMENTS OBTAINED FROM FORWARD MODELLING OF GRAVITY DATA

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ABSTRACT

The gravity data over parts of the lower Benue Trough Southeastern Nigeria was acquired from the Nigerian geological survey agency, this six sheets of gravity data covered areas within latitude 6˚00´N to 7˚00´N and longitude 7˚00´E to 8˚30´E. The data was analyzed and interpreted employing forward modelling technique using Glabox and Bloxer software. The model consisted of three profile lines with model bodies emplaced in them in other to match the curve of the observed field to that of the calculated field. The densities that characterized the subsurface materials causing the anomalies ranged from 2.10 to 3.150 g/cm^3. The densities suggested sedimentary rocks such as shale, sand stone, and limestone. Intercalation between sedimentary rocks were observed in profile line 3, Juxtaposition of blocks with similar density range was also observed in profile line 1, these are probably mineralized zones. The area indicates hydrocarbon potential due to densities suggesting source and cap rocks.

Keywords: Gravity Forward Modeling, Subsurface Densities, Depth, Rocks.

INTRODUCTION

Employing gravity data for sub-surface modeling of geological structures may serve as a useful tool in addressing open questions about geological or geophysical processes at the crustal or local scale (Mancinelli, 2020). To address these questions, forward or inverse modelling of gravity data is employed. Forward modelling of gravity involves the Computation of the gravity field of some given mass distribution (Hirt, 2016), it simply denotes the computation of the gravitational field generated by some source mass distribution, and its foundation is based on Newton's law of universal gravitation (equation 1). Gravity Forward Modelling yields the gravitational field of the mass distribution in terms of any functional of the field, e.g., gravitational potential, gravity disturbance (i.e., radial derivative of the potential), and vertical deflections (Nagy *et al*., 2000).

$$F = G\frac{m_1 m_2}{r^2} \qquad (1)$$

F = force, G = gravitational constant, m_1 = mass of object 1, m_2 = mass of object 2, r = distance between center of the masses.

In potential field geophysics, forward modelling of gravity is relevant for the investigation of the Earth's interior structure and other planets (Wieczorek, 2007). Gravity forward modelling delivers the gravity field from mass models, while inversion model seek to estimate the mass distribution from gravity observations, which is inherently non-unique (Oldenburg, 1974).

In this research, we calculate the density distribution of the subsurface bodies causing the anomalies observed on the surface by adjusting the parameters of the model body to fit the observed anomaly curve with the calculated anomaly curve. This represents the application of gravity methods to locate density changes related to variation in subsurface materials.

Materials and Methods

Gravity data over Nsukka area, Igumale area, Ejekwe area, Udi area, Nkalagu area, and Abakaliki, with sheet numbers 287, 288, 289, 301, 302, and 303 respectively were obtained from the Nigerian Geological Survey Agency, NGSA. The agency did several pre-processing on the acquired data (reductions or corrections such as effects of terrain removal). These maps covered areas within latitude 6˚00´N to 7˚00´N and longitude 7˚00´E to 8˚30´E. The six (6) gravity sheets were obtained in Geosoft file format and were merged to produce the complete Total gravity map of the study area depicted in Figure 1.

Grablox 1.6 and Bloxer 1.6 software was used in quantitative analysis to model the Bouguer gravity data which was obtained on performing regional residual separation on the total gravity data, the model generated the density of the subsurface material, their burial depth, as well as the dimensions and the positions of the bodies causing the anomalies.

Forward modelling technique was employed to achieve this and it is a quantitative interpretation process whereby a geometric body or model is chosen to approximate the real geological body to be modelled, the theoretical gravity anomaly of the model is calculated and compared to the measured anomaly. In forward modelling, adjustments are made manually to the parameters that define the model and the anomaly is recalculated until the observed anomaly and calculated anomaly match or fit to the interpreter's satisfaction.

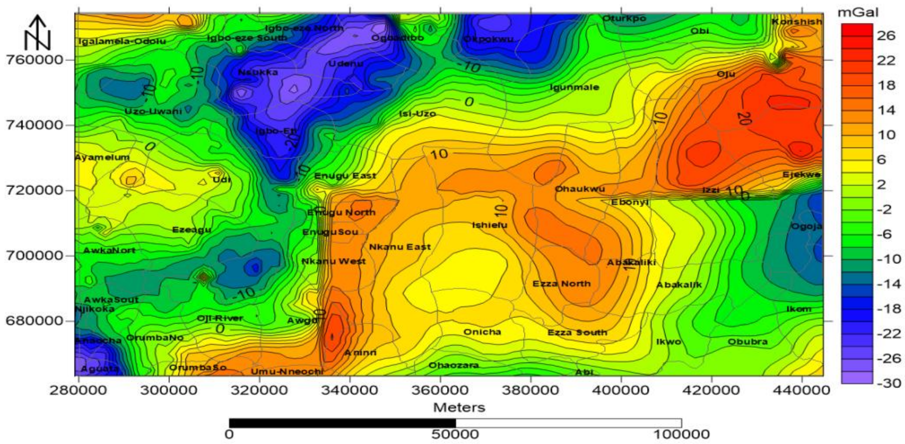

Figure 1: Bouguer gravity map of the Study Area

Geometric bodies such as ellipsoid, plates, rectangular prisms, polygonal prisms and thin sheets can all be calculated. More complex bodies can be built by superposing the effects of several simple bodies. In formulating the forward modelling algorithms, assumptions about the strike length, plunge, dip, azimuth, magnetic susceptibility, density and depth extent are used. Forward modelling is a method that has stood the test of time and is probably the single most useful quantitative technique in use.

RESULTS AND DISCUSSIONS

The Bouguer gravity data (Figure 1) was filtered on application of the regional residual separation, to obtain the residual data which We sliced from the lower point to the highest point in the data, this is also termed as creating profile lines to reduce ambiguity in modelling(Figure 2). There are 3 highest anomalous point in the data as seen in Figure 3. For slice one or profile line one, this consist of % model bodies with varying densities, three of the model bodies are juxtaposed with densities vary slightly (2.52, 2.55, and 2.576 g/cm^3) with the same blue color, a large density (orange model body) value was obtained in the right section which have a 3.0 g/cm^3 and under the structure with this density, a lower density structure within 2.5-2.7 g/cm^3 was found. Also the horizontal density contrast (Figure 4) show that the main rock from left to right has density within 2.5 g/cm^3 and 2.7 g/cm^3. The value 2.5 g/cm^3 suggests sandstone or shale and then to the right 2.7 g/cm^3 suggests granite. The sedimentary thickness in this slice is predominantly greater than 7.5 km, this slice or profile line, has a reservoir potential due to densities suggesting source and cap rocks.

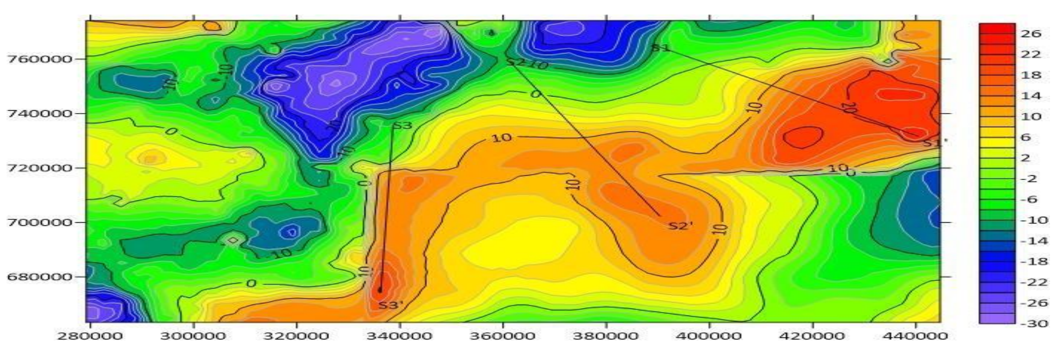

Figure 2: Slicing Line of Study Area

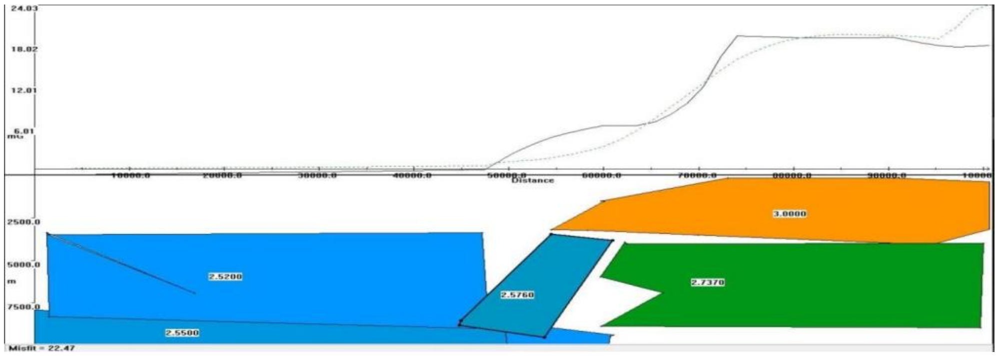

Figure 3: Forward Modelling on Slice 1

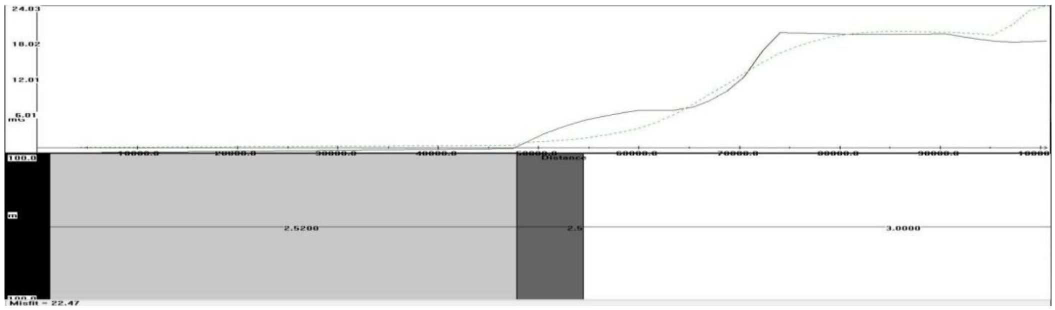

Figure 4: Horizontal Density Contrast on Slice 1

For slice two (profile line 2), this slice consists of 4 model bodies (figure 5), the highest density is observed in the right section which has a density of 3.15 g/cm^3 (light red colored model body), underneath (suggests Meteorites) it lies the lowest density body in the slice (2.6 g/cm^3), which extends from right to left, the other two model bodies towards the left in this profile have densities of 2.756 and 2.8 g/cm^3 respectively. Also, the horizontal density contrast reveals that the main rock from left to right is 2.75 g/cm^3, 2.8 g/cm^3 and 3 g/cm^3 as seen in Figure 6. For this slicing, the density suggests that the main rock in this area is granite, sediments within this slice had thickness less than 6.5 km, this further suggest a probable reservoir that is deep and can be probed using inversion modelling to have a convincing counter view of the slice. This area had thicker sediments and will have more heat flow rate as the density increased from left to right. This more compact sediments will hold the heat from the core or the heat released after radioactivity occurs.

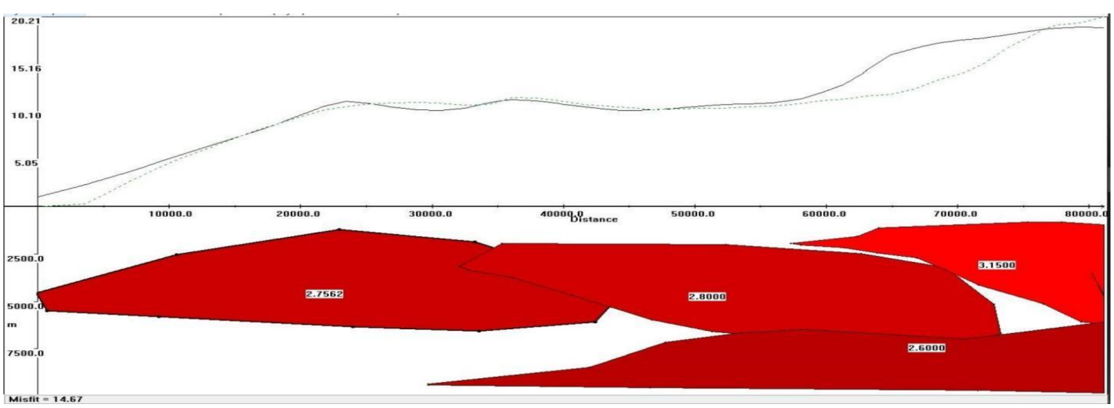

Figure 5: Forward Modelling on Slice 2

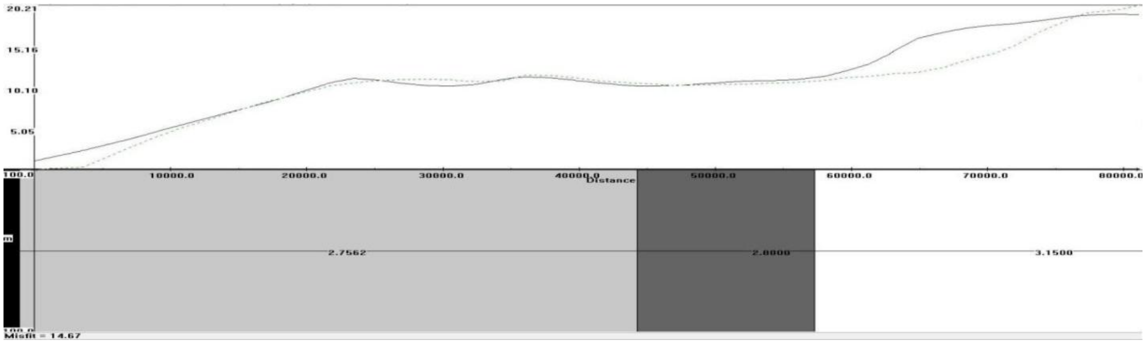

Figure 6: Horizontal Density Contrast on Slice 2

For slice three, 4 model bodies were revealed as seen in figure 7, A long very low density (2.1 g/cm^3) blue colored body which extends from left to right is observed in this profile, this body suggests sedimentary rocks such as shale, limestone or sandstone, on this body rests the high density orange colored body observed in the right section which had a 2.9 g/cm3 high density, an intercalation is observed between two intermediate density model bodies (2.66 and 2.2315 g/cm^3) and the high density model body. The intermediate intercalating model bodies suggested shale interspersed with sandstone. Also, the horizontal density contrast (figure 8) revealed that the main rocks from left to right have densities of 2.6 g/cm^3, 2.2 g/cm^3 and 2.91 g/cm^3. For this slicing the main rock in this area is granite, sediments within this slice had thickness mostly less than 7.0 km, with a wide deeply buried body extending from left to right. The void between the 4 model bodies might be a mineralized zone.

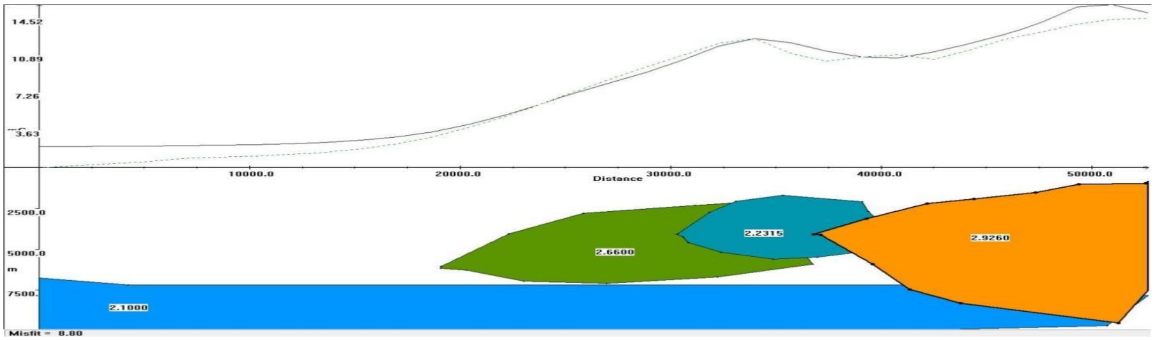

Figure 7: Forward Modelling on Slice 3

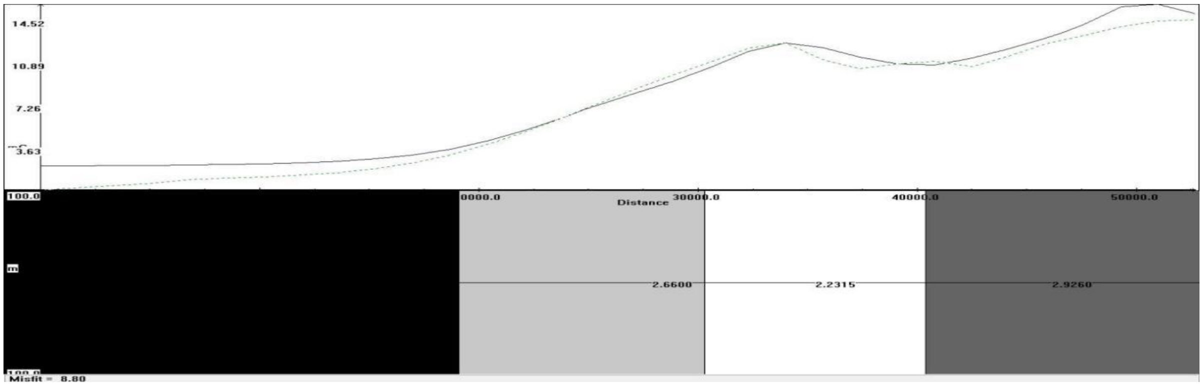

Figure 8: Horizontal Density Contrast on Slice 3

CONCLUSION

The use of Gravity method of Geophysical prospecting in the structural and lithological modelling of the subsurface has proven to be one of the very important tool in understanding the variation and inhomogeneity of the crust, in the area of our Research, the three (3) slices taken along the 3 highest gravity anomalous zone, they show variation in the density of the Earth materials both vertically and laterally which was ascribed to different predominant lithology occurring at various depth, the overall sedimentary thickness was also estimated for each of the profile as described in the discussion section. Lastly there seems to be a drastic change in lithology as we tend towards the heat source, and this was detected by the abrupt density variation.

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