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DETERMINATION OF SEDIMENTARY THICKNESS OF ONITSHA AND ITS ENVIRONS, SOUTHEASTERN NIGERIA USING AEROMAGNETIC DATA

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Abstract
Determination of the sedimentary thickness of Onitsha and its environs, southeastern Nigeria using aeromagnetic data was carried out in order to ascertain the sedimentary piles across the area for possible hydrocarbon accumulation. The study area is situated between latitude $6^0 00^l N$ to $6^0 30^l N$ and longitude $6^0 30^l E$ to $7^0 00^l E$. The aeromagnetic data sheet 300 was acquired from the Nigerian Geological Survey Agency (NGSA) for the study and has an area extent of 3025 km2. The acquired data was processed and analyzed using Geo-softwares (Oasis Montaj, Surfer- 32 and GeoRose) for both qualitative and quantitative interpretation in order to produce maps and models. The anomalies identified were analyzed using the half-slope method. The result from the qualitative interpretation shows high magnetic intensity ranging from 8000 nT – 8135 nT). Th result also shows occurrence of sparse and linear contours indicating high sedimentary thickness cover. The analytical map and Rose diagram show magnetic lineaments trending in the Northeast-Southwest direction. The sedimentary thickness deduced ranged from 3.06 km – 12.41 km with an average 6.63km. The sedimentary thickness map reveals that the area has a high sedimentary thickness around the Northern-Eastern regions of the study area and also indicates the areas of uplift and depression. The study concludes that the area has a high sedimentary cover, which may possibly favour hydrocarbon generation.
Keywords: *Magnetic Intensity, Lineament, Rose Diagram, Fault and Half Slope method*

Introduction

The study area is located in Anambra State, southeastern Nigeria. It is known as the gateway of southeastern Nigeria and also the economic nerve center of Nigeria. This is due to the high commercial activities that are ongoing in the area. Onitsha is located in the Niger Delta Basin. The sedimentary rocks of this basin have been characterized to have the potential of bearing hydrocarbon and coal.

Furthermore, geophysical methods have been a viable tool for the characterization and study of the Earth's subsurface features. Our study is focused on the use of magnetic method in characterizing the subsurface features of the earth. Magnetic method is a geophysical technique that is used to characterize the Earth's magnetic field, by identifying and mapping anomalous magnetic field, in order to provide valuable insights about the subsurface geology, mineral resources and the environmental conditions. By employing this method to our studies, it will enable us to analyze magnetic anomalies found within the study area. Also, it will help us to determine the depth to the basement of the study area. According to Telford *et al.,* (1998), subsurface variations of the geomagnetic field is often used to determine the regional structures as well as the mineral structures.

The Earth's magnetic field is known to be generated from the core of the earth, with a percentage of less than 90% of this field generates from the convection that occurred between the upper mantle and the inner core (Usman *et al.,* 2023). Magnetic technique is one of the oldest subsurface probing tool, and it is not only limited to depth to basement determination for the location of mineral resources and hydrocarbon potential. It is effective in engineering studies in a wide range of applications such as the analysis of road failure, groundwater contamination studies, construction of dams and bridges. It is also used in location of buried

objects with magnetic properties in the subsurface.

For a comprehensive and robust geophysical survey, the incorporation of magnetic survey is needed, this is because magnetic technique has a wide range of application and can provide useful subsurface information (Folami 1992; Rajaram, *et al.*, 2017; Nwosu *et al.*, 2015). The preference of magnetic geophysical technique to others is due to its simplicity, speed of operation and cost-effective attribute (Hinze *et al.*, 2013).

Magnetic Surveys can be carried out either as ground magnetic survey or aeromagnetic survey depending on the platform of data acquisition. Aeromagnetic data can be applied in determining the hydrocarbon potential through the mapping of the underlying subsurface structures and determining the sedimentary thickness (Chinwuko *et al.* 2012; Okoro *et al.*, 2021). Anakwuba *et.al.*, (2011) noted that, the aeromagnetic method has been used effectively to map magnetic anomalies of the Earth's magnetic field and correlate them with the subsurface geological structures.

Hence, with the geological complexities of the Niger Delta basin, which our study area falls into, it makes it an ideal location for the geophysical studies using aeromagnetic technique. this will enable us to understand the subsurface structures and mineral deposits that can possibly be found within the study area.

Location of the Study Area

The study area, Onitsha and its environs is located in the southeastern part of Nigeria. It lies between latitude 6°30´N to 6°00´N to longitude 6°30´E to 7°00´E. Onitsha is one of the largest metropolitan cities in Nigeria, and it is an economic hub for commerce, and industry. It hosts one of the biggest markets in West Africa, which is of significant economic importance and growth. This accounts for the dense population and urbanization of the area. Majority of the people living in the area are traders. It has an area extent of about 52km². It can be located and accessed through the East-West road from Lagos through Benin and the North-South route through the Niger Bridge. It is bounded by Odekpe in the South, Nkwelle Ezunaka by the North, River Niger by the West and Ogidi, Oba and Nkpor by the East. Onitsha is made up of nine villages known as Ebo itenani. The Fig. 1 below shows the geographic location of the study area, Onitsha and its environs.

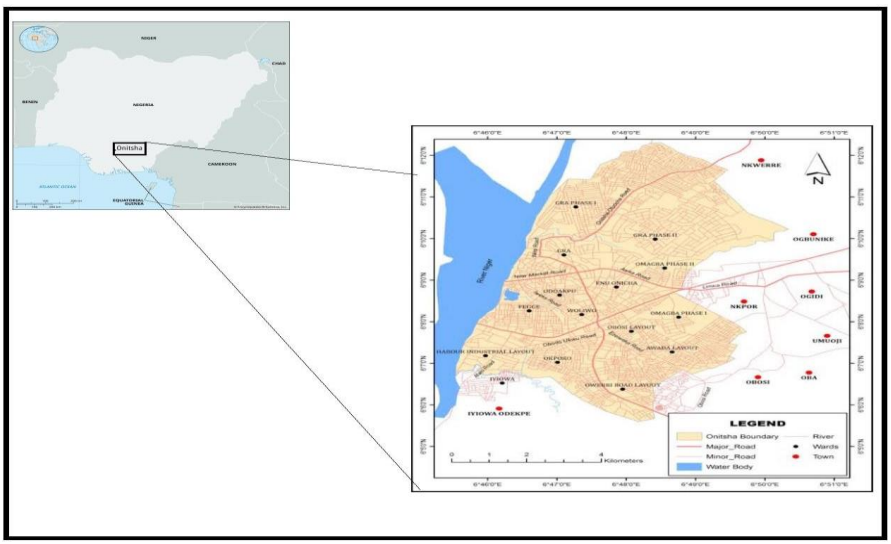


Fig. 1: Location Map of the study area (After Obi-ani and Isiani, 2020)

Methods

The Aeromagnetic data used was obtained from the Nigerian Geological Survey Agency (NGSA), the data was acquired for NGSA by a company named FUGRO in 2007. The aeromagnetic data sheet, named sheet 300 contains the data for the study area and has a difference of 30° and an area of 55km × 55km. The data was given on a soft copy and it contains residual data values with a total of 306195 data points and their corresponding longitude and latitude. To obtain the Total Magnetic Intensity (TMI) values, a regional value of 8000nT were added to the residual data value.

For a detailed interpretation of the study area, a step-by-step procedure would be followed in a sequence to avoid getting poor results that might lead to a misinterpretation of the subsurface. Firstly, QGIS software was used to produce a geology map of the area showing the different geologic formations found within the study area.

Furthermore, using Microsoft Excel the regional data was calculated by adding 8000nT was added to each of residual data points. However, the residual data and the regional data where plotted respectively on the surfer 32 software, to produce a residual map and a regional map of the study area. To interpret these maps, we applied the qualitative and quantitative method of interpretation.

Qualitative interpretation involves careful observations of the magnetic maps to identify the variations in the geologic features in the area, such as lineaments, anomalies, patterns. This will help to infer about subsurface structures like faults, folds, mineral deposits, sediment thickness and rock types. The pattern identified on the maps is due to the magnetic sources and subsurface structures. Other features that can be taken into consideration while carrying out qualitative interpretation includes:

- The presence of sparse contours indicating presence of sedimentary basins.
- Clustered contours on the map shows the closeness of basement complex.
- The changes in the contour gradient indicate structural trends.
- Presence of close anomalies indicates magnetic bodies.
- Lateral shift in position indicates possible fault zones.

Quantitative interpretation involves steps of mathematical analysis, to do this the maps were grided diagonally using a ruler and a pencil. The point where the grided lines intersect with the contour values are picked as profiles. For the residual map I picked about 7 profiles labelled N-N', O-O', P-P', Q-Q', R-R', S-S', T-T'. The values were plotted in a graphical format using Microsoft Excel, it is a graph of magnetic intensity against distance. The graph was analyzed using the Peter's half slope method to calculate the depth to basement of the study area.

Several methods of interpretation have been used for the purpose of depth to basement determination. For the purpose of this study, we employed the Peter's half slope method of interpretation, it was derived for magnetic anomalies over vertical dikes and vertical polarization (Peter, 1949; Rao and Babu 1984). It is to note that, the half slope method and other methods of estimation gives a good estimate of the depth to basement. Peter's half slope method is one of the earliest depths to magnetic source estimation method that was used. It is useful in interpreting magnetic field profiles and map, it estimates the depth by using the magnetic profile's half maximum sloping flank (Telford *et al.,* 1998).

Hence, the Peter's half slope method of depth determination the magnetic bodies are assigned a specific index value which ranges from 1.2*h* to 2*h*. (Adegoke and Layade 2014). 1.6*h* is approximately equal to the half-maximum slope distance (P), given that h is the depth to magnetic sources.

Results and Discussion

Processing and interpretation of the magnetic sheet data 300 was carried out, this is done to obtain information about the subsurface. This entails information about the various structures that can be found in the area, the depth to basement, possible mineral veins and the sedimentary thickness of the region. Additionally, through processing and interpretation of magnetic data patterns and signals becomes clearer and it helps to eliminate unwanted noise from a magnetic data. The extent of a magnetic data interpretation is dependent on the expertise of the interpreter and also the type of softwares that was used for the interpretation process.

Qualitative Interpretation

Total Magnetic Intensity (TMI) Map

The visual examination of the 2D map created from the TMI data certain features were observed on the map. The magnetic intensity ranges from 8000nT being the lowest value to 8120nT being the highest value. However, from the map the contours are linear and the trend in the SW – NE direction. The clustered region is located in the N and NE direction of the map and this is an indicator that the area is closer to the basement. In general, the contours are sparse and it can be inferred that the area has a high sedimentary thickness. The linear contours can also be used to delineate areas of geological features such as faults (Fig. 2). The areas with high magnetic intensity which are indicated by the red colour on the map shows areas possibly containing magnetic minerals. The 3D plot of the TMI (Fig. 3) map gives more details of these features.

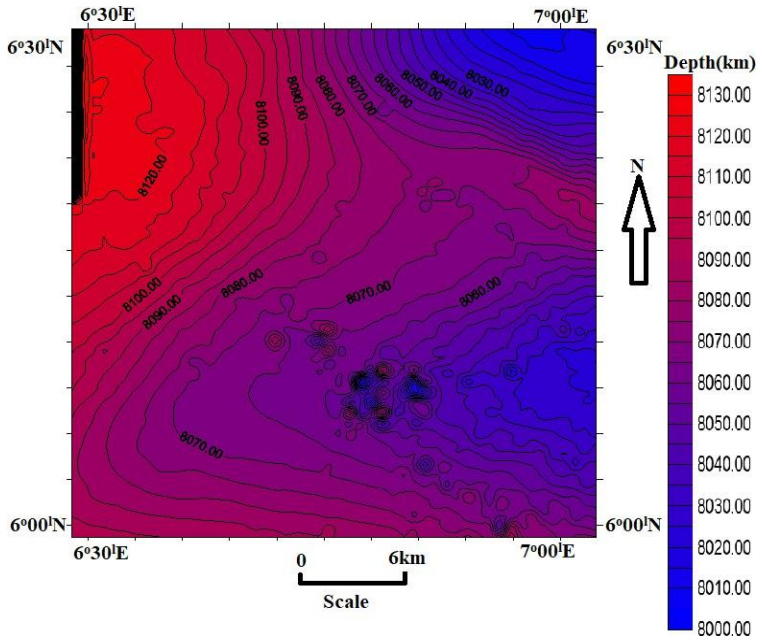


Fig. 2: Total Magnetic Intensity Map of Onitsha and its environs.

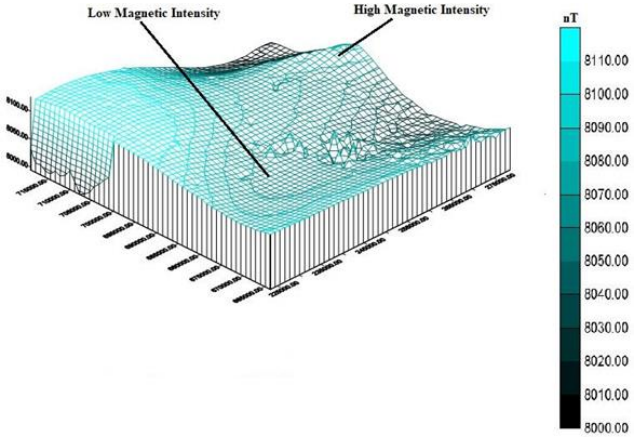


Fig. 3: 3D Surface plot of TMI Map

Residual Anomaly Map

The residual anomaly map (Fig. 4) reveals that the contours are generally linear and sparse, this indicates thick sediments overlying the basement. The magnetic intensity ranges from 20 nT to 140nT and it has a contour interval of 10 nT. However, the positive anomalies show that there is possible occurrence of structural features like faults, hydrocarbon occurrence in the area and high sedimentary cover in the area. The map trends in the N – E and W – S directions and the contours are clustered at N – NE directions of the map. The residual map is digitized and the values obtained are used in calculating for the depth to basement. Fig. 5 shows the 3D representation of the residual anomaly data.

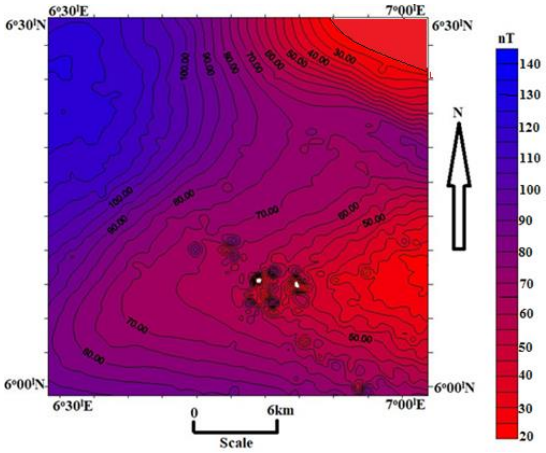


Fig. 4: Residual Anomaly Map of the study area.

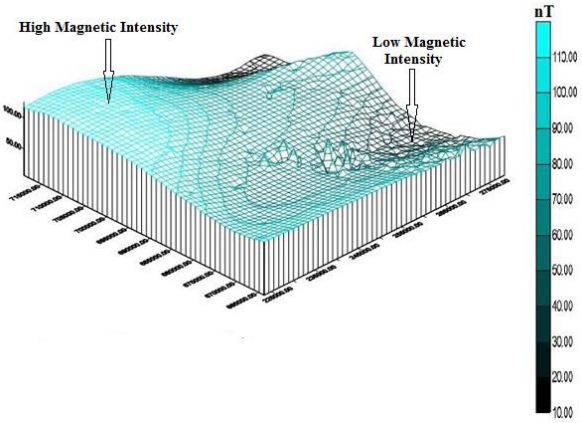


Fig. 5: 3D Residual Anomaly Map of the study area.

Analytical Map

The map below (Fig. 6) is used to show the trends of the magnetic lineaments and location of these anomalous features of the subsurface. It provides a clear visual representation of the geological features and structure, by enhancing the magnetic anomaly signals and suppressing noise. Most of the trend went the NE – SW directions while the others can be located in the NW-SE and E-W directions.

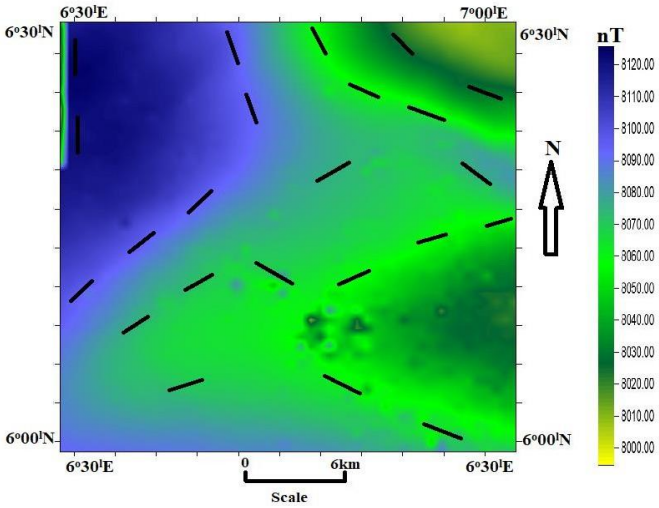


Fig. 6: Analytical Map of the study area, showing the Structural Trends of Magnetic Lineaments.

Rose Diagram

With the aid of the lineament analysis, the rose diagram was generated, and they are based on the azimuth direction and frequency of the structural lineaments. The rose diagram was plotted using a GeoRose Softwares and it is a plot of the lineament and statistical values obtained. The visualization of this diagram (Fig. 7), helped in delineating the structural lineaments trends of our study area. The major trends can be found in the NE- SW azimuths and the minor trends are around the NW-SE azimuths and E-W azimuths.

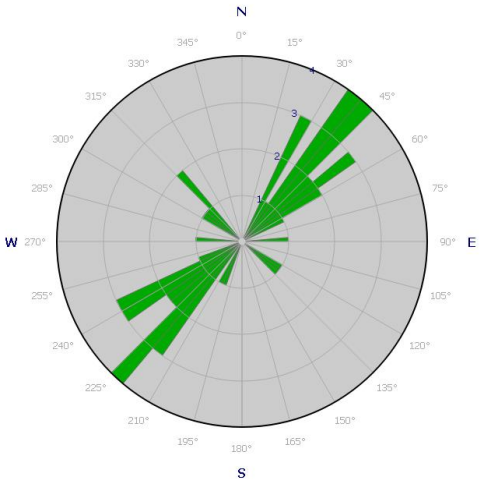


Fig. 7. Rose Diagram of the Structural Lineament Trend of the study area.

Quantitative Interpretation

After the qualitative interpretation of the aeromagnetic data, I then proceeded to carry out a quantitative interpretation of the data. This involves the use of a mathematical graphical method to estimate the sedimentary thickness using the Peter's half slope method of interpretation.

Magnetic Profiles

To create magnetic profiles on the residual anomaly map, lines were drawn perpendicular to the direction of the major contour lines on the map. In total seven profiles (Fig. 8) were taken, labelled M-M^{l}, N-N^{l}, O-O^{l}, P-P^{l}, Q-Q^{l}, R-R^{l}, and S-S^{l} respectively. These profiles are then analyzed to give an estimate of the depth to basement of the study area.

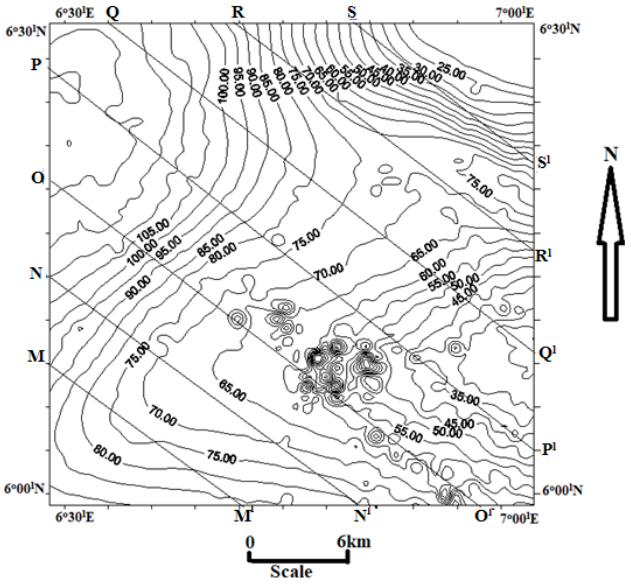


Fig. 8: Profiles lines on a residual anomaly map for depth estimation.

Sedimentary Thickness Estimation using Peter's Half Slope Method

The profiles were digitized and plotted on a graph using Microsoft Excel, from the graphs eighteen anomalous bodies were identified (Fig. 9). This was gotten by picking out the areas the curves deviated from the normal, then using Peter's half-slope method, the sedimentary thickness was determined. The calculated sedimentary thickness ranges from 3.06 km to 12.41 km across the study area.

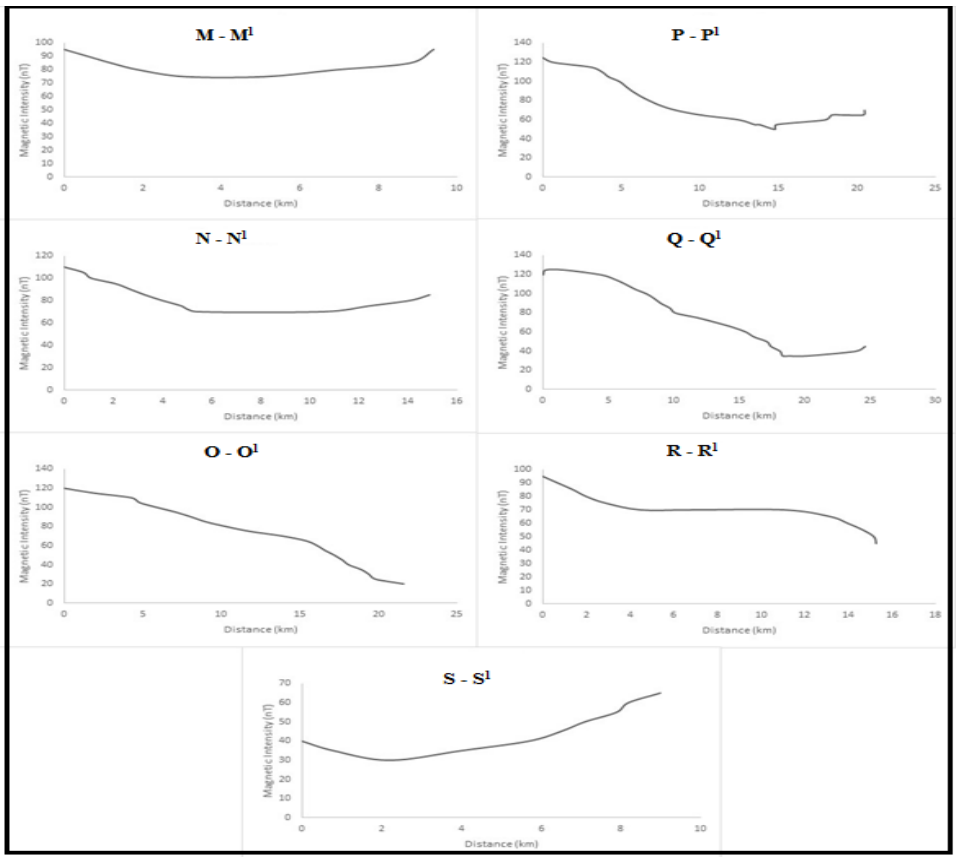


Fig. 9: Graphs of the Profiles within the study area.

The digitization of the profile lines on the residual anomaly map was used to produce the table below as shown in Table 1. From the map, I obtained the value for X and Y, which are the longitude and latitude respectively, the horizontal distance (P) was obtained using the Peter's half slope method. To calculate for the depth (z) it is given by ***h=z=cp***, where (c) is the constant which I assumed to be 1.7. The calculated sedimentary thickness ranges from 3.06 km to 12.41 km across the study area (Table 1) and the values were plotted on a Surfer 32 software, and a map of sedimentary thickness was produced (Fig. 10a).and a 3D surface plot of the study area (Fig. 10b). The plot gives a model of the sediments overlying the basement. Also, from Fig. 10b, the areas of depression and uplift can be visualized.

Table 1: Estimation of Sedimentary Thickness from Slope Method

Anomaly no	Constant (C)	Horizontal distance (P)	Sedimentary Thickness (km) (C×P)
1	1.7	2.0	3.40
2	1.7	4.0	6.80
3	1.7	4.1	6.97
4	1.7	4.9	8.33
5	1.7	2.6	4.42
6	1.7	4.0	6.80
7	1.7	2.9	4.93
8	1.7	3.5	5.95
9	1.7	5.9	10.03
10	1.7	5.1	8.67
11	1.7	4.9	8.33
12	1.7	5.2	8.84
13	1.7	2.9	4.93
14	1.7	2.2	3.74
15	1.7	7.3	12.41
16	1.7	3.7	6.29
17	1.7	1.8	3.06
18	1.7	3.2	5.44

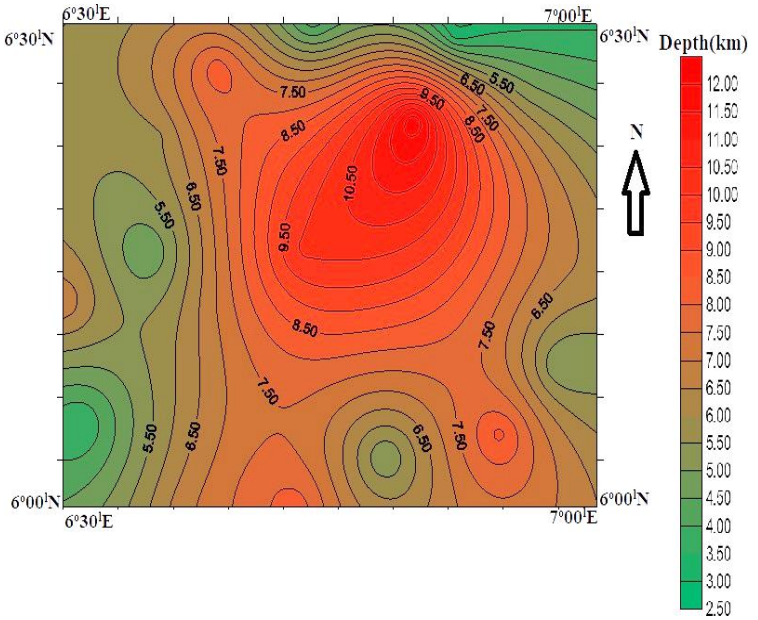


Fig. 10a: Surface Plot of the Depth to Basement.

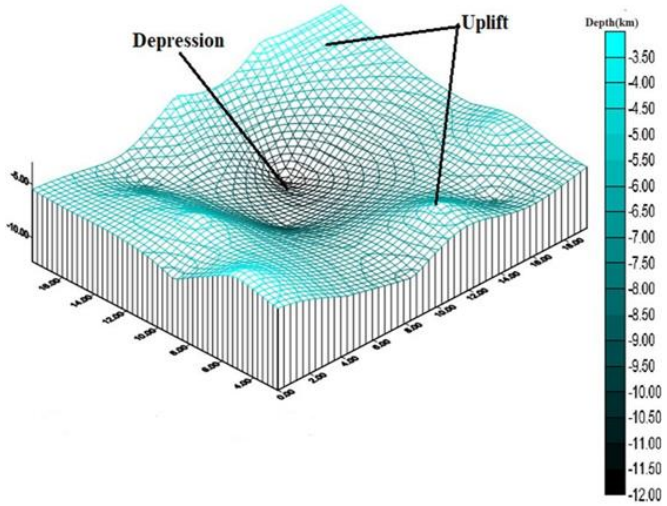


Fig. 10b. 3D Basement Tomography Map of the area.

Implications and Findings

The results of this study suggest that, the area is a sedimentary terrain, this is deduced from the linear and sparse contours from the maps being plotted. Majority of the lineament's trends in the NE to SW directions while others trend in the E-W directions. Subsurface lineaments could act as conduits for fluid flow such as hydrocarbon, brine and water (Chinwuko *et al.*, 2024; Lar *et al.*2023). The area has an average of 6.63km depth to basement thickness and also a huge sedimentary thickness that can possibly favour hydrocarbon accumulation. This is in line with the standards according to Wright *et al.,* (1985) and Chinwuko *et al.,* (2012) which propose that for hydrocarbon accumulation to occur the average sedimentary thickness should be above 2.10km. The study area is located in a hydrocarbon producing basin which possesses the key elements of petroleum play system such as the source rock, reservoir rock and seal.

Conclusions

In conclusion, the aeromagnetic data sheet 300 was analyzed to determine the depth to basement of the Onitsha and its environs. The data set was interpreted qualitatively and quantitatively to map out the subsurface features found within the environs. Through the qualitative interpretation, the zones of lineaments and their trends were mapped, the areas with high magnetic intensity were delineated, and also the possible geologic features that can be found within that region was inferred. The quantitative interpretation was used in determining the thickness of the sedimentary over burden on the basement. Also, the presence of linear and sparse contours can indicate sedimentary basin within the study area.

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