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GEOPHYSICAL INVESTIGATIONS INFERRED FROM AIRBORNE POTENTIAL FIELD DATA OF PARTS OF THE LOWER BENUE TROUGH IN NIGERIA

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ABSTRACT: *The aeromagnetic data of Nkalagu and Abakaliki areas were interpreted using spectral analysis and modeling to estimate depth to the sedimentary thickness, nature of intrusive, susceptibility values and types of minerals associated with them. The total magnetic intensity was processed to produce the residual magnetic map which was divided into 21 overlapping blocks. Each block was subjected to a spectral program plot (SPP) developed with MATLAB to obtain depths to the top boundary* Z_t *and depth to the centroid* Z_0*. The spectral analysis revealed depths to the top boundary* Z_t*, which is the depth to magnetic basement ranging from 0.77 to 2.34 km with an average value of 1.72 km and the centroid depth ranging between 2.22 and 5.93 km, with an average depth of 3.55 km. The modeling estimated depths of profile 1, 2, 3, and 4 at 5 km, 1 km, 1.68 km and 1.32 km respectively with an average depth of 2.3 km and respective susceptibility values of 0.002, 0.003, 0.003 and 0.003 respectively, indicating the presence of igneous intrusions of gabbro, diabase and metamorphosed sedimentary rocks of quartzite and schist, with iron rich minerals like pyrite, limonite, cassiterite and arsenopyrite. The maximum depth values of 2.34 km and 5 km obtained from the two depth estimation methods confirm feasibility depths for hydrocarbon accumulations. In view of the above results, it is evident that the presence of intrusions delineated from the modeling results accounts for the mineralization in the area and can also destroy any hydrocarbon present since the presence of numerous intrusions are an indication of exceedingly high temperature history.*

KEYWORDS: Aeromagnetic Data, Intrusions, Sedimentary Thickness and Hydrocarbon Potentiality.

INTRODUCTION

Airborne geophysics is a method adopted by earth scientists in the early stage of exploration, to study the physical properties of the earth (composition and structure) from an airborne platform. This airborne geophysical surveying helps geologists and geophysicists to rapidly survey very large unexplored, accessible and inaccessible regions of interest quickly (Reconnaissance survey), in order to help achieve targets for more time-consuming and costly exploration activities such as seismic and drilling, etc. This method is employed to investigate the subsurface structures of the earth from an airborne platform usually with a flying airplane or helicopter. Compared with the ground-based techniques, very large areas and difficult terrain can be accessed or investigated within a short period of time, thereby making it relatively cheaper and faster.

This airborne geophysical surveying detects the earth subsurface through the determination of considerable source anomalies, and it is achieved when measurements are taken close to the surface or on the surface of the earth to obtain data that will be analyzed to provide information about the subsurface minerals and rocks. There are many airborne geophysical methods like magnetic, radiometric, and gravity whose operations are based on different physical principles, methods and physical properties (e.g., magnetic susceptibility, radioactivity, density contrast) of the earth (Kearey et al., 2002). Thus, since geophysics seeks to look for contrasts in rock properties associated with uncommon specific structures, which can contain the minerals being sought for (Telford et al., 1990), any combination of these geophysical methods can be adopted to investigate various geological problems, structural configuration, geothermal energy, hydrocarbon prospecting and mineral exploration of any area of interest. However, magnetic method has been of great use in geophysical investigations as a result of the relatively high magnetic susceptibility contrasts between basement rocks and sedimentary rocks, which usually play a clear role on the magnetic signals emerging from the underlying rocks (Dobrin & Savit, 1988; Kearey et al., 2002; Osinowo et al., 2014). Several geophysical studies have been published based on aeromagnetic data interpretations which adopted different methods within the lower Benue trough to investigate hydrocarbon potentials. This was done on the basis of depths to basements/magnetic source bodies over the lower Benue trough and Anambra Basin in which the study area falls. Obi et al. (2010) investigated the lower Benue trough in Nigeria and identified the presence of twelve (12) intrusive bodies with a sedimentary thickness of 1.0 to 4.0 km from the modeling power spectrum and horizontal gradient. They further opined that areas like Ikot Ekpene, Nkalagu, Uwet and Abakaliki are having enough sediments thickness of (greater than 2km) for hydrocarbon generation but the presence of many intrusives with large lateral extents is an indication of over mature source rocks which could make the areas less favorable for hydrocarbon exploration.

Ugwu and Ezema (2012) interpreted aeromagnetic data of Abakaliki and Nkalagu areas of the lower Benue trough, adopting forward and inverse modeling method and obtained a depth range of 10 to 22 km for some anomalies within the basement and 3.2 to 3.9 km within cretaceous sediments with igneous intrusion of granite, dolerite, basalt and rhyolite which could be favorable sites for the accumulation of hydrocarbons. But a great number of igneous intrusions present indicates an exceptionally high temperature history capable of destroying any hydrocarbon that might have been formed in the area, and these igneous intrusions are what account for mineralization in the area.

Ugwu et al. (2013) in their study interpreted aeromagnetic data over Okigwe and Afikpo areas of the lower Benue trough of Nigeria using forward and inverse modeling techniques. The anomalies over the study area modeled by spherical or dyke-like bodies emplaced at various depths, ranging from 3.0 km to 12.7 km. They found out that the magnetic susceptibilities of most of these bodies indicated that there are igneous intrusions. These intrusions, with large lateral extents occurring more at Afikpo area than the Okigwe area, account for more mineralization at the former than the later. They inferred that the exceedingly high temperature that prevailed at the time of formation of these minerals suggests that the area might not hold any significant hydrocarbon potentials. Igwesi and Umego (2013) employed spectral analysis method to estimate the average depth of magnetic sources covering some parts of lower Benue trough and obtained a depth for deeper magnetic sources ranging from 1.16 km to 6.13 km, with an average depth of 3.03 km while the depths to the shallower magnetic sources range from 0.06 km to 0.37 km, with an average depth of 0.22 km showing the presence of magnetic intrusive bodies within the sediments. Abdullahi et al. (2014) interpreted aeromagnetic data over Afikpo and Nkalagu areas of the lower Benue trough for metallic deposits and hydrocarbons using 2D/3D modeling and spectral analysis techniques. The spectral analysis shows maximum depths of 5.90 km, 6.5 km and 7.5 km which corroborate modeled profiles at 5 km depths. The 2D/3D modeling showed depths between 3 km and 5 km which are suitable for hydrocarbon generation.

Obiora et al. (2018) investigated the magnetic anomalies of Abakaliki area, lower Benue trough, Nigeria. Adopting qualitative and quantitative interpretation methods, they obtained basic intrusive bodies and fault zones which trends in the southeastern part of the study area. Their modeling and SPI showed depth ranges between 50 m to 6366 m and 99.50 to 5930.78 m respectively. They suggested the area is good for hydrocarbon accumulation, but the intrusive bodies that dominate the area at variable depths make the chance of hydrocarbon generation and accumulation rare.

Osinowo and Taiwo (2020) carried out an analysis of high-resolution aeromagnetic (HRAM) data of the lower Benue southeastern Nigeria for hydrocarbon potential evaluation. They delineated the dominantly structural trend of NE-SW and depth values of sedimentary thickness in excess of 3 km around Abakaliki, Afikpo and Ikot Ekpene axis, which are candidates for further hydrocarbon prospect evaluation using more detailed and gas prospecting techniques. The present study tends to compare the results from previous studies in terms of depths to sedimentary thickness, intrusive bodies occupying the area and types of minerals associated with them. This will be helpful in explaining possible hydrocarbon potentiality and types of minerals deposited in the area for further exploratory investigations.

Location and Geology of the Study Area

The study area is located within latitudes of $6^{o}00^{/}$ and $6^{o}30^{/}$ North and longitude $7^{o}30'$and $8^{o}30^{/}$ East. It has a coverage area of approximately 6050 km^2 within the lower Benue trough. The lower Benue trough is underlain by a thick sedimentary sequence, traced from the tectonic processes that accompanied the division of Africa and South America plates in the early cretaceous (Burke, 1996). The major component units of the lower Benue trough include the Anambra Basin, the Abakaliki Anticlinorium and the Afikpo Syncline. The oldest sediment of the sequence belongs to the Asu River Group which unconformably overlies the Precambrian basement complex that is made up of granitic and magmatic rocks (Ofoegbu & Onuoha, 1991). The Asu River Group whose type outcrops in Abakaliki has an estimated thickness of about 2 km (Ofoegbu, 1985) and is of Albian age. It comprises argillaceous sandy shales, laminated sandstone units and minor limestones with an interfingering of magnetic volcanics (Nwachukwu, 1972). Figure 1 shows the geological map of the study area.

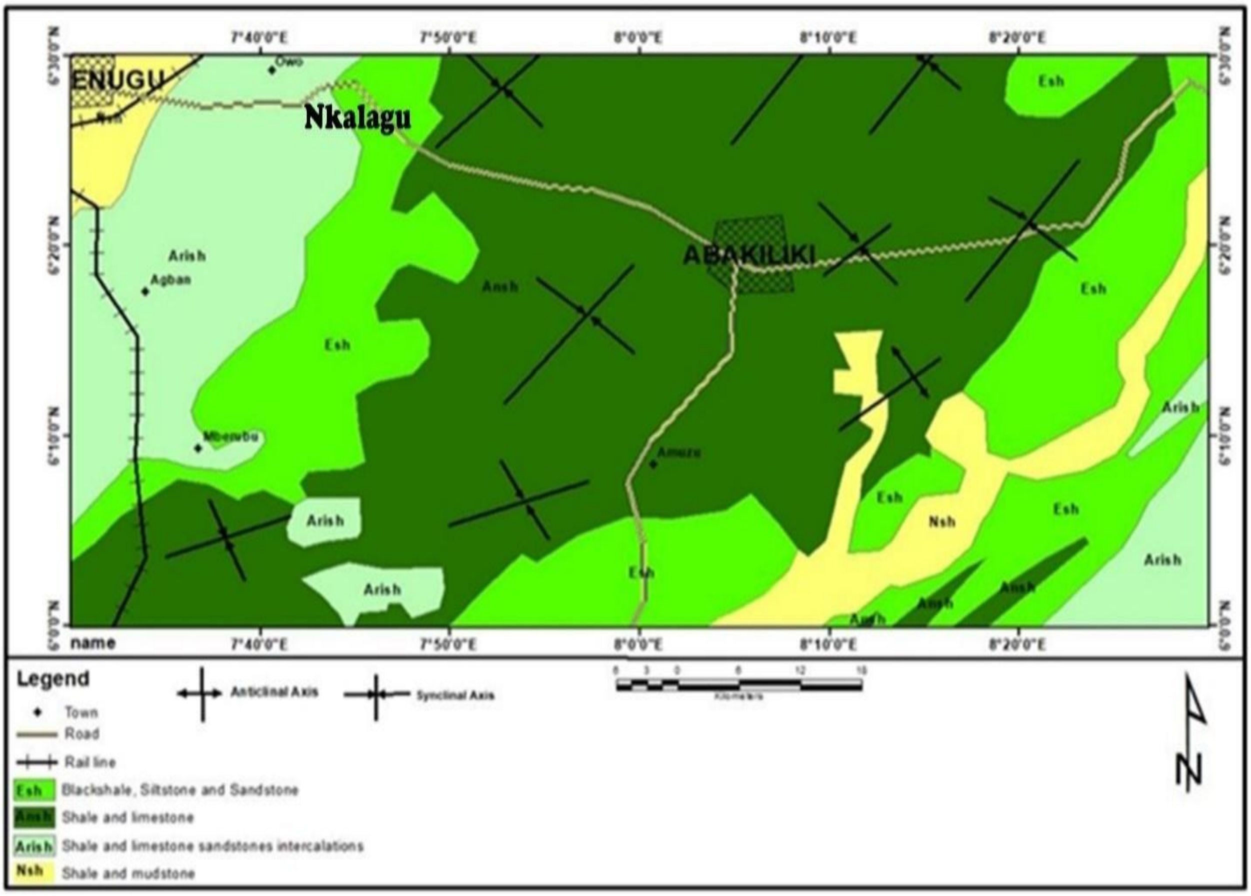

Fig. 1: Geological Map of the Study Area.

MATERIALS AND METHODS OF DATA ANALYSIS

Materials

The materials adopted in the current study are two sheets of soft-copy digitized aeromagnetic data of Nkalagu (302) and Abakaliki (303) obtained from Nigeria Geological Survey Agency (NGSA), which was carried out in Nigeria between the years 2005 and 2009. The data was acquired at a flight altitude of 80 m above the ground surface at a tie line spacing of 2 km. The flight line spacing is 0.5 km and the digital data was made available on a scale of 1:50000, then, two shuttle radar topography mission (SRTM) data sheets for modeling (Softcopy). The software applications employed for the study are the Oasis Montaj 8.4, ArcGis and surfer 16.

Method of Data Analysis

This process started with employing the Oasis Montaj software to grid the data using Bi-directional line gridding method to produce the Total Magnetic Intensity (TMI) map. Thereafter, the regional anomaly was separated from the TMI to produce the residual magnetic field using the polynomial fitting of the second order least squares method. The spectral analysis, which entails calculating and interpreting the spectrum of the potential field data (Rabeh, 2009), started with the division of the residual data into twenty-one overlapping blocks as thus: block A-U of spectral probe of 27.5 km by 27.5 km in order to accommodate longer wavelength and give room for the depth analysis of the area. Thereafter, each of the 21 blocks was subjected to a spectral program plot (SPP) developed with MATLAB, where the results obtained were plotted on a logarithmic scale against the radial wave number. On such a plot, if a group of sources has the same depth, they will fall onto a line of constant slope (tangent of the line fitted to the power spectra). But, if there are sources at different depths (such as a shallow plutonic formation over a deep basement), the plot will be separated into two sections with different slopes. The reciprocal of the angle of slope is a measure of the depth to the source. The first phase estimated the depth to the centroid (Z_o) of the magnetic source from the slope of the first longest wavelength part of the spectrum calculated mathematically as:

$$\ln\left[\frac{\sqrt{P_{(s)}}}{|s|}\right] = \ln A - 2\pi |s| Z_o \tag{1}$$

where $P_{(s)}$ is the radially averaged power spectrum of the anomaly, $|s|$ is the wave number, and A is constant.

The second phase estimated the depth to the top boundary Z_t from the slope of the second longest wavelength part of the spectrum as suggested by Okubo et al. (1985) expressed mathematically as:

$$\ln\left[\sqrt{P_{(S)}}\right] = \ln B - 2\pi |s| Z_t \tag{2}$$

where B is the sum of constant independent of $|s|$.

Modeling involves estimating the depth to buried magnetic anomalies (sedimentary thickness or basement), magnetic susceptibilities of the areas or formations encountered to identify the minerals or rocks beneath the subsurface. This is achieved by making numerical estimates of depths and dimensions of the sources of anomalies, where it often takes the form of modeling of sources which could theoretically replicate the anomalies recorded during the survey. The forward modeling technique which was adopted for the study was performed using the GM-SYS profile modeling extension of the Oasis Montaj 8.4 that permits forward modeling of magnetic data to obtain the optimal fit of the generated source model to the observed data. The profile L1 was chosen and drawn as seen in (Fig. 7). This profile was drawn with a WSW-NNE orientation traversing through the suspected area on the map. L1 (first profile) covers a length of 110 km being the longest profile modeled in the study area. L2 (second profile) covers a length of about 55 km drawn with a WNW-SSW direction, while L3 and L4 (profiles 3 and 4) cover a length of 86 km and 78 km drawn with NW-SSE and N-SE orientations respectively. A close examination of these profiles shows an excellent fit between the observed and calculated anomalies with an error margin set below 3% (Fig.7a-d).

RESULTS AND DISCUSSION

Results

The total magnetic map of the study area (Fig. 2) is characterized by intensities ranging between 33010 and 33091nT which are high, moderate and low in magnitude (magnetically heterogeneous). This is clearly represented by the colour variations, aiding the visibility of a wide range of anomalies and their intensities. The variations inherent in the study area may be attributed to differences in subsurface materials and its depths. It also revealed a dislocation zone noticed at the southeastern (SE) portion of the study area, depicting faults or fractures. The residual map (Fig. 3) revealed magnetic field intensity ranges between -30.30nT (minimum) and 27.90nT (maximum), indicating that the study area is characterized with very low (blue colour), moderate (red shaded with yellow colour) and high (pink colour) magnetic signatures. The positive and negative residual anomalies observed indicate a series of magnetic highs and lows. The variations noticed may be related to the differences in magnetic susceptibility, depth, lithology, degree of strike and others. The positive anomalies may be attributed to a combined effect of zones of basic intrusive bodies, which occurs mainly in sills which could be belocalithics, batholiths or dyke (Ofoebgu, 1985b; Mamah et al., 2000) within the sedimentary basin or basement resulting from magmatism, while the negative anomalies are observed around areas where the observed field showed definite magnetic lows. The residual map which was divided into 21 overlapping blocks A-U (Fig. 4) showed the anomaly source of depth to the top boundary $Z_{t,}$(Fig. 5) which is the depth to magnetic basement ranging from 0.77 to 2.34 km with an average value of 1.72 km, and the centroid depth Z_0 ranging between 2.22 and 5.93 km with an average depth of 3.55 km as detailed in (Table 1). The graphs of the spectral energy against frequency obtained from block A-D as seen in (Fig. 6a-d) are samples of the 21 spectral energy against frequency graphs obtained from block A-U.

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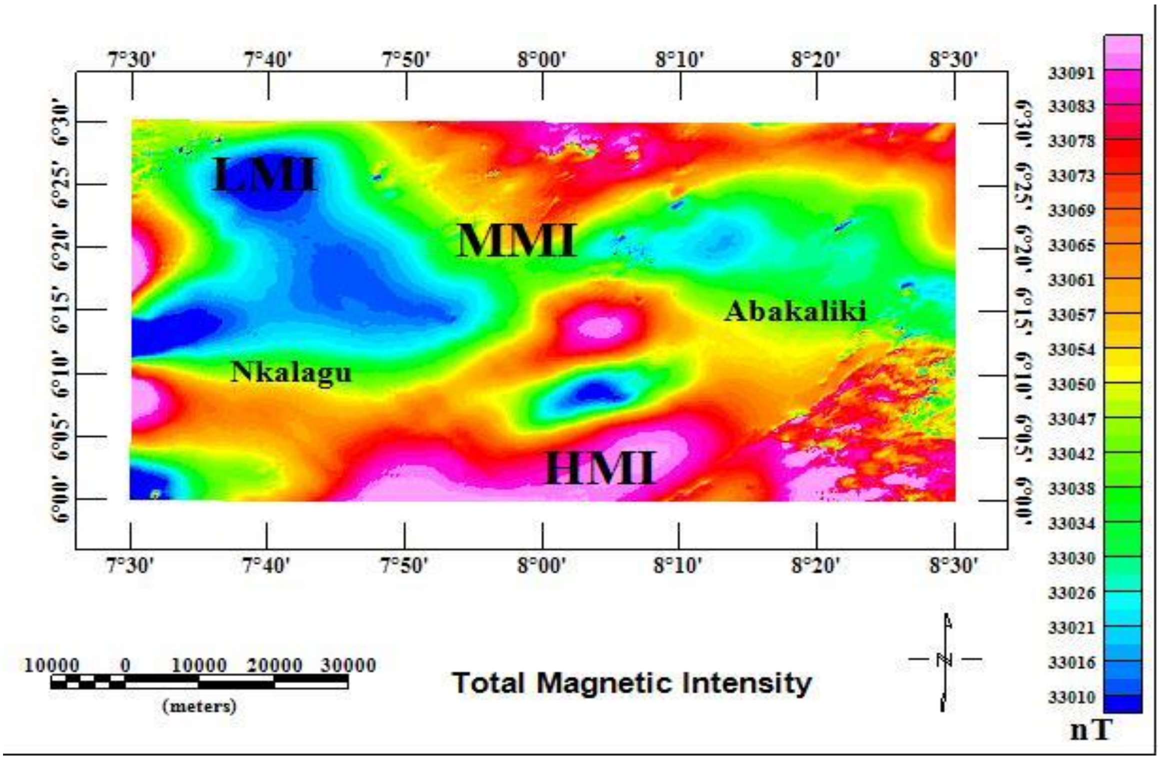

Fig. 2: Total Magnetic Intensity Map of the Study Area

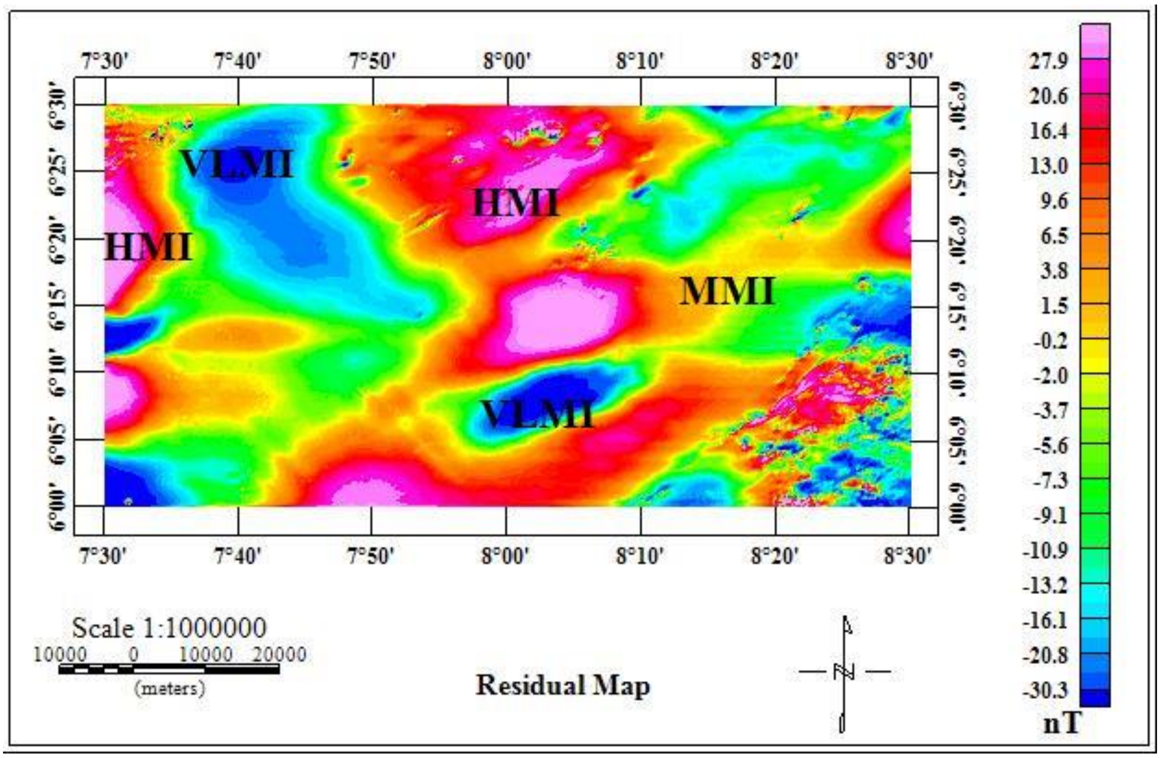

Fig. 3: Residual Map of the Study Area

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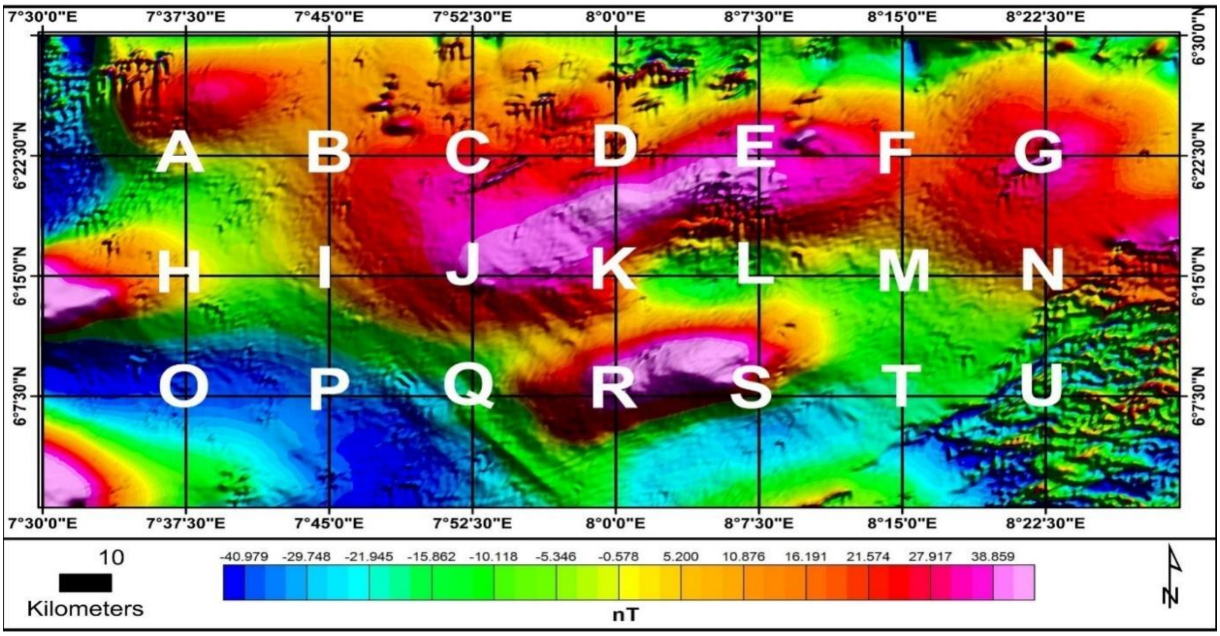

Fig. 4: Grid Map Showing the Division of the 21 Spectral Blocks

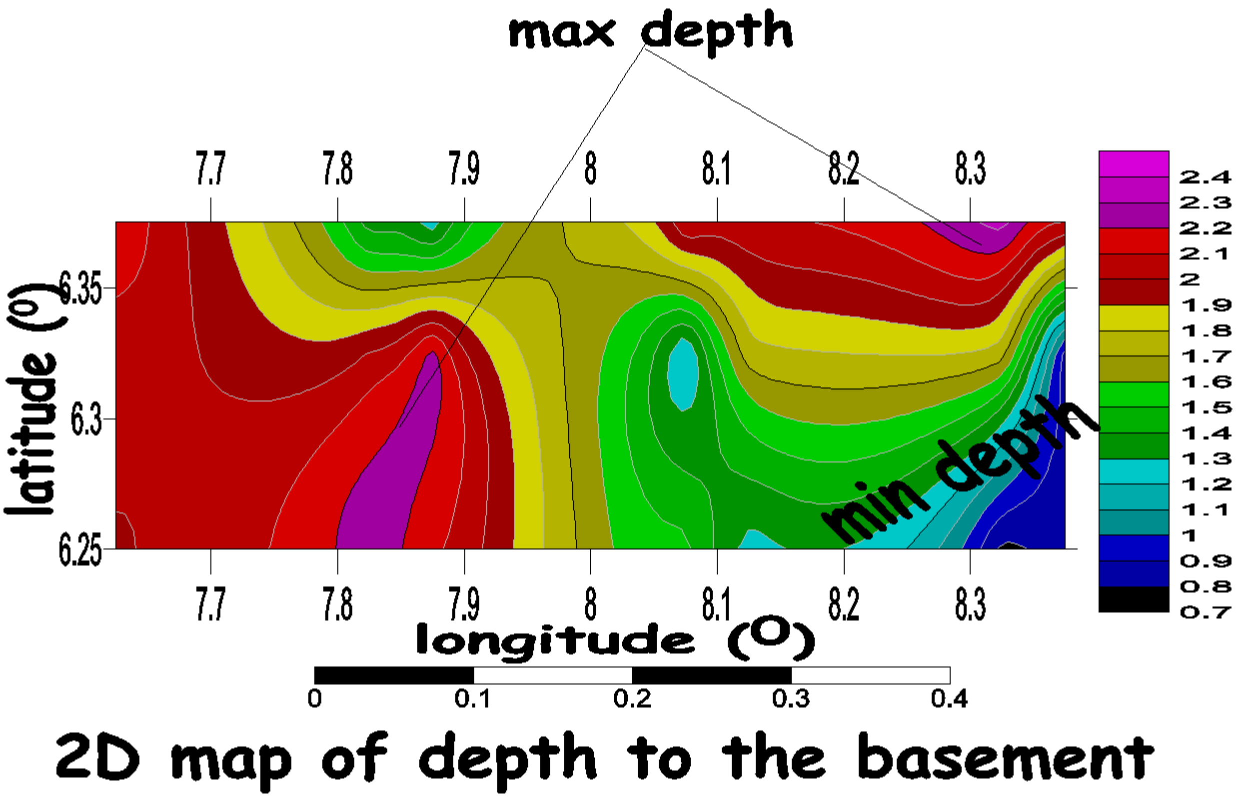

Fig. 5: 2D Contour Map of the Depth to the Basement

Table 1: Summary of the Results of Z_t and Z_0 from the 21 Overlapping Spectral Blocks

Blocks	Longitude (^{0})	Latitude(^{O})	Depth to the Top Boundary (Z_t) in Km	Depth to Centroid (Z_0) in Km
A	7.625	6.375	2.20	3.07
B	7.825	6.375	1.35	3.70
C	7.875	6.375	1.24	2.89
D	8.075	6.375	2.10	3.71
E	8.125	6.375	2.08	4.17
F	8.325	6.375	2.34	5.93
G	8.375	6.375	2.10	5.32
H	7.625	6.325	2.03	3.05
I	7.825	6.325	2.01	5.36
J	7.875	6.325	2.24	3.02
K	8.075	6.325	1.18	3.39
L	8.125	6.325	1.76	2.85
M	8.325	6.325	1.75	2.69
N	8.375	6.325	0.84	2.87
O	7.625	6.250	1.99	3.89
P	7.825	6.250	2.26	4.54
Q	7.875	6.250	2.12	2.86
R	8.075	6.250	1.53	3.13
S	8.125	6.250	1.26	3.24
T	8.325	6.250	0.77	2.73
U	8.375	6.250	0.85	2.22

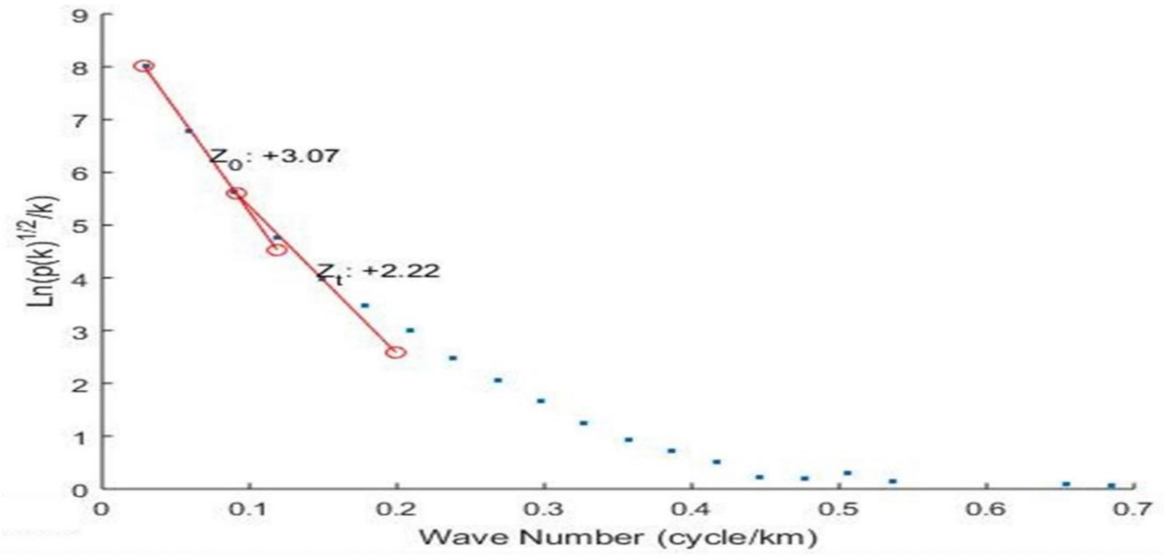

Fig. 6a: BLOCK A

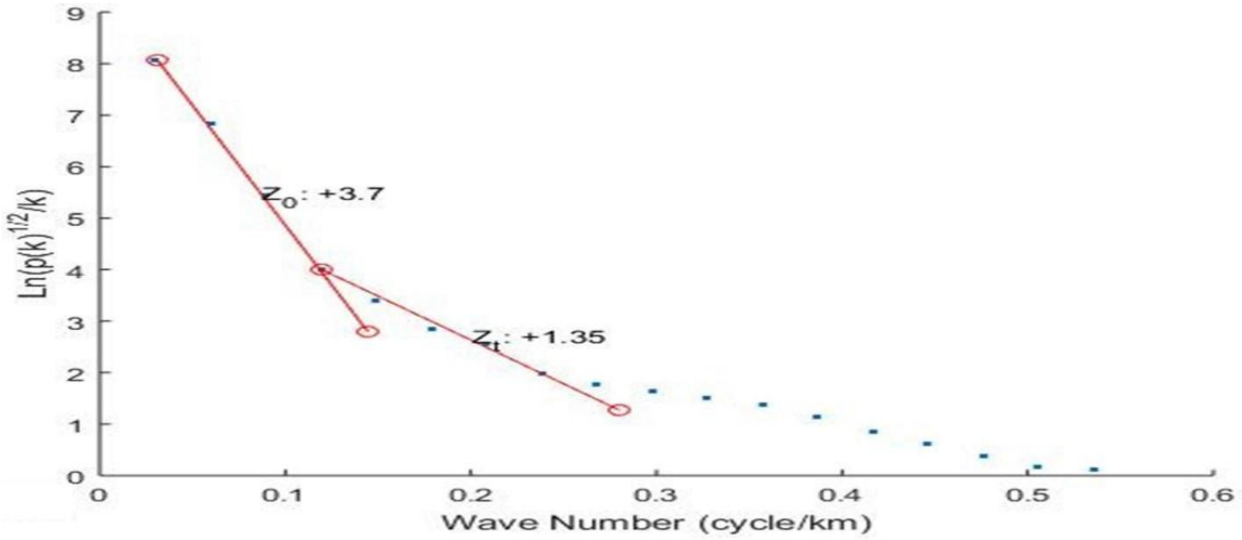

Fig. 6b: BLOCK B

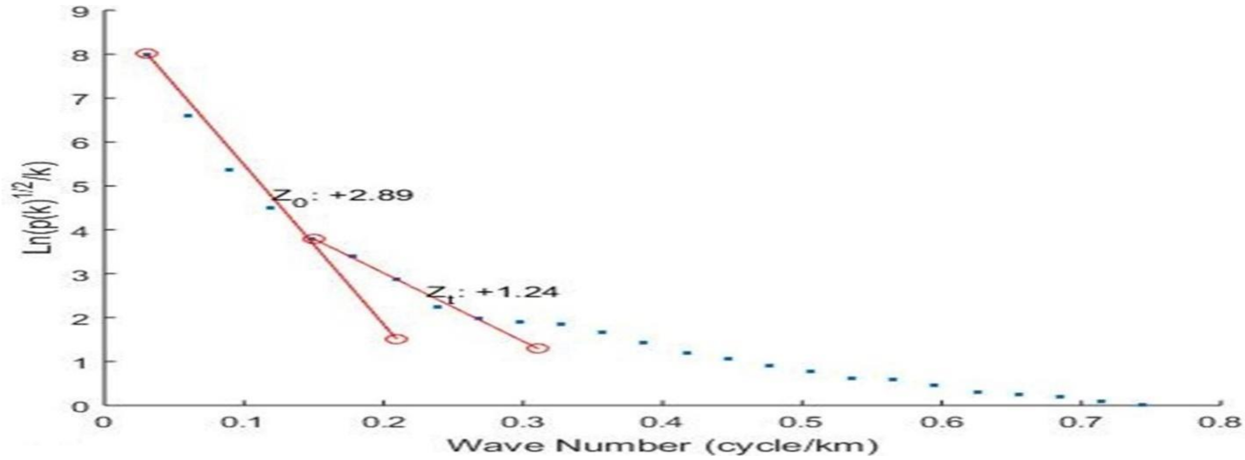

Fig. 6c: BLOCK C

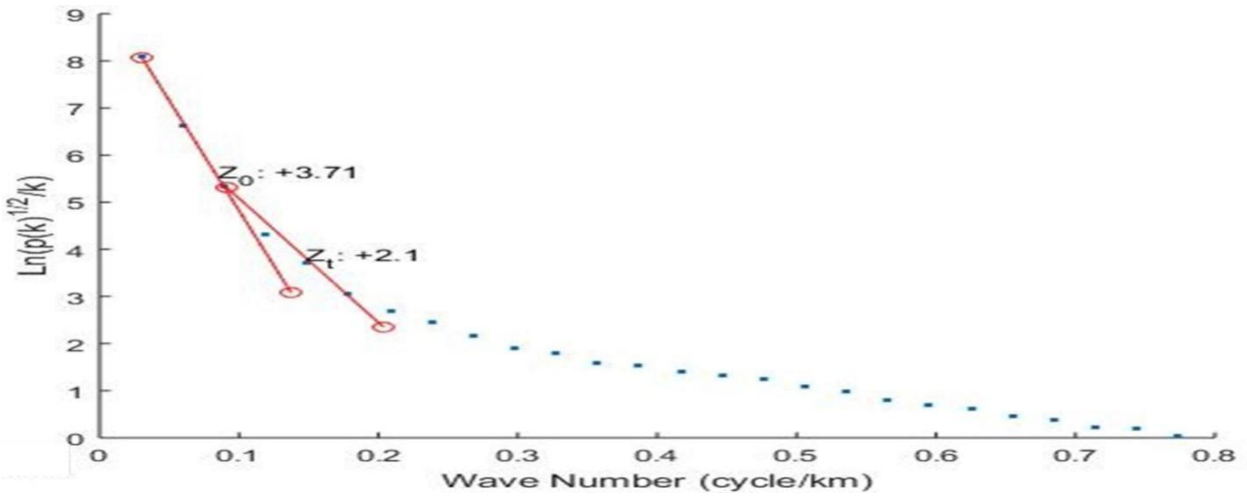

Fig. 6d: BLOCK D

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In modeling, four profiles (L1, L2, L3, and L4) were taken at different locations (Fig. 7). The results from the first profile (L1) (Fig. 7a) taken at WSW-NNE direction estimated a sedimentary thickness of 0.40 km (min.) to 5 km (max.) with a susceptibility value of 0.002 depicting that the possible bodies causing the anomalies are gabbro, diabase, cassiterite and pyrite. The second, third and fourth profiles (Fig. 7b-d) drawn at WNW-SSW, NW-SSE and N-SE orientations estimated depths of 0.6 km (min.) to 1 km (max.), 0.3 km (min.) to 1.68 km (max.), and 0.84 km (min.) to 1.32 km (max.) respectively with all having susceptibility values of 0.003 each, suggesting that the possible bodies causing the anomalies are schist, quartzite, limonite and arsenopyrite (Thompson & Oldfield, 1986; Telford *et al*. 1990; Hunt *et al*. 1995) with an average sedimentary thickness of 2.3 km. Table 2 shows the summary of the modeling results.

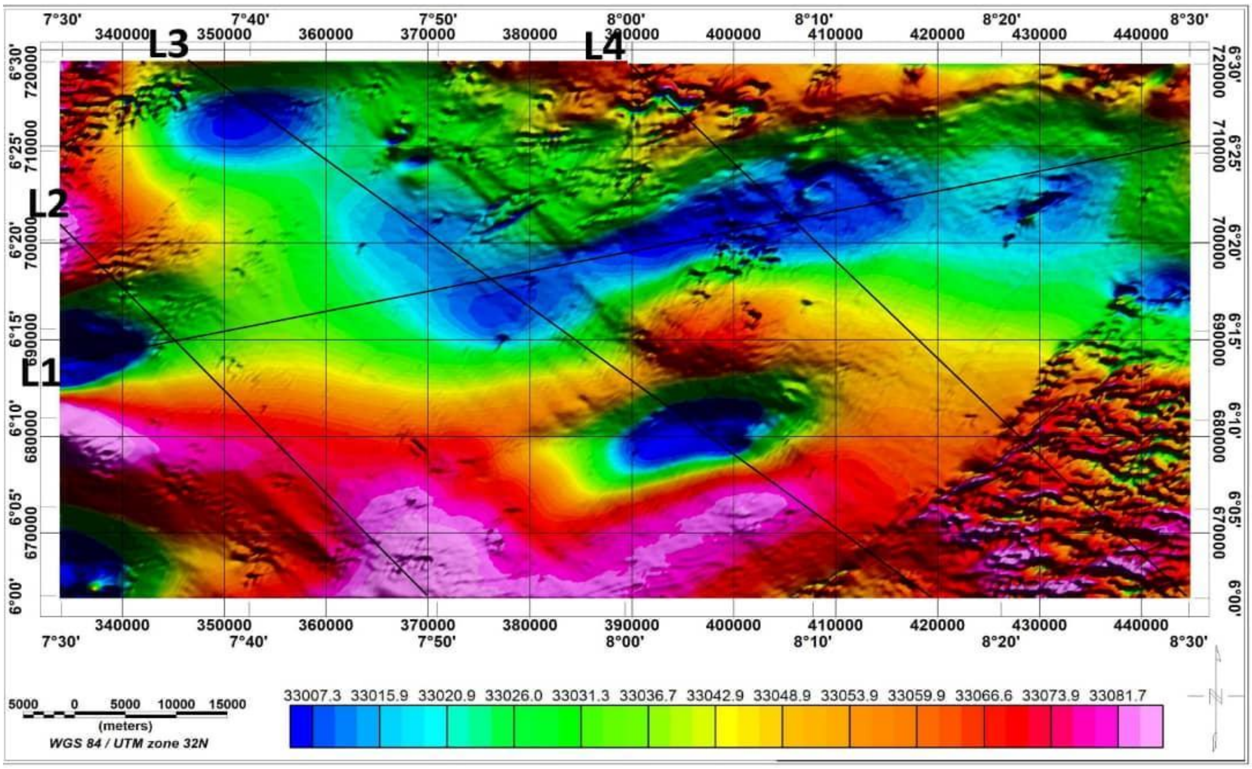

Fig. 7: Grid map showing the modeled areas (L implies line which is profile)

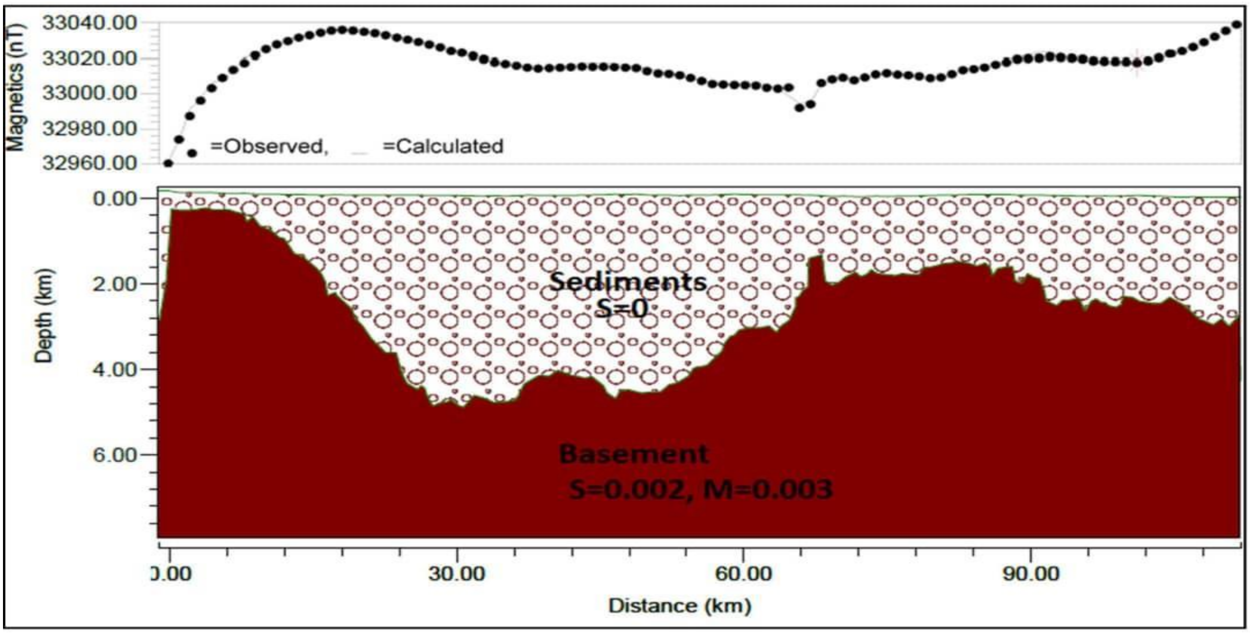

Fig 7a: Profile 1

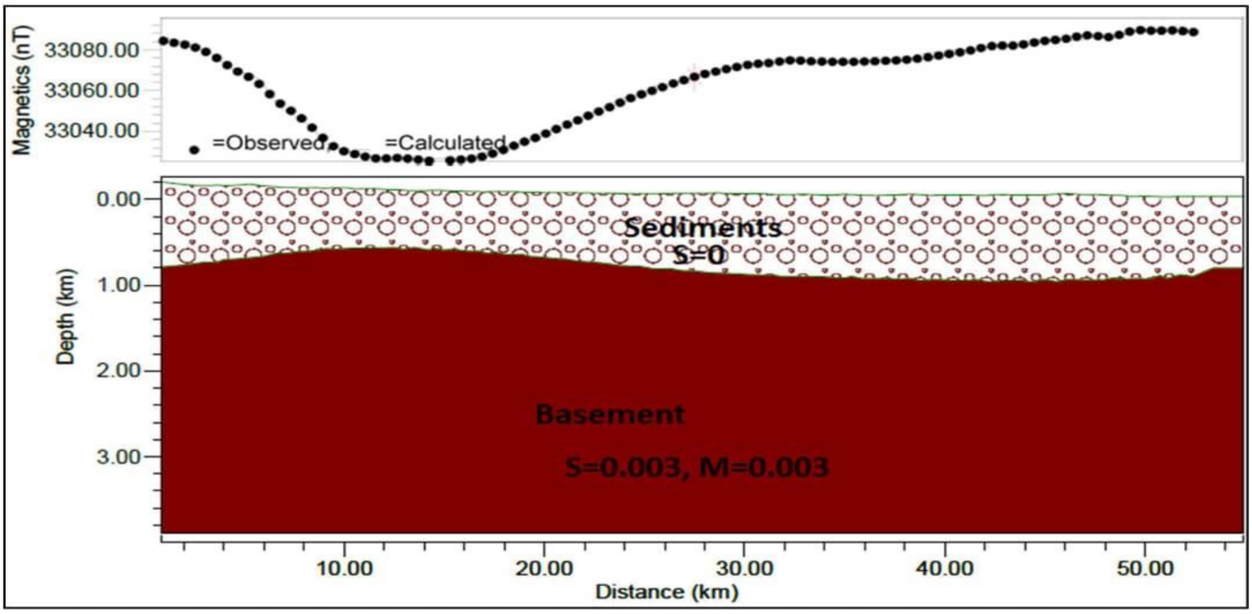

Fig. 7b: Profile 2

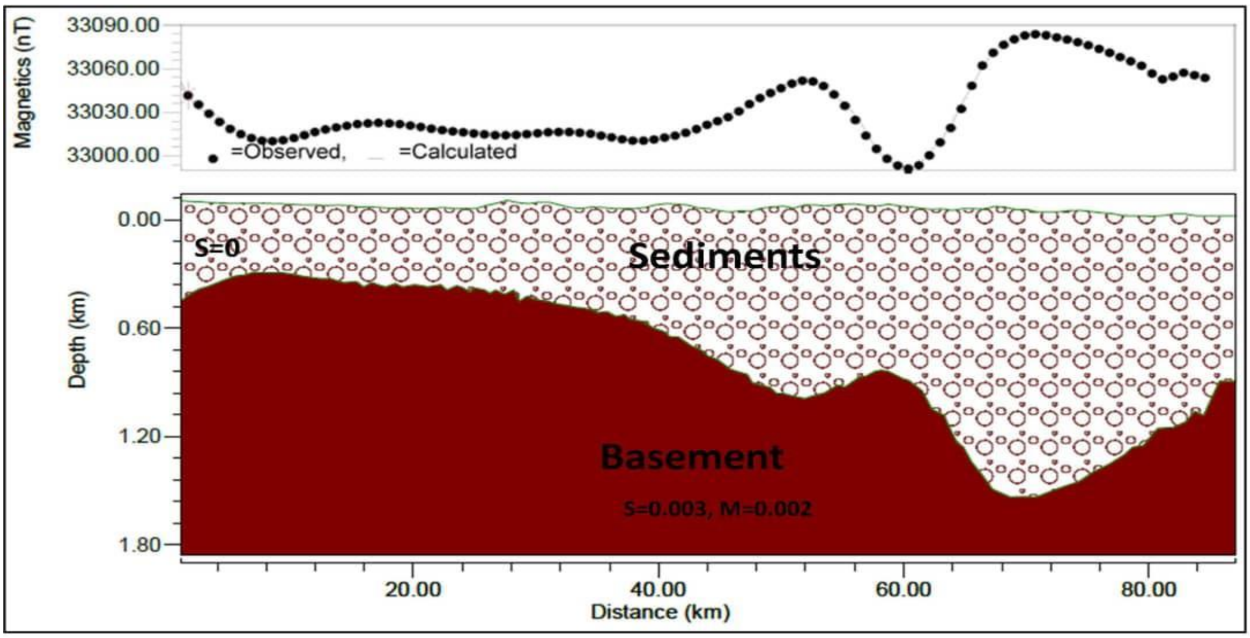

Fig. 7c: Profile 3

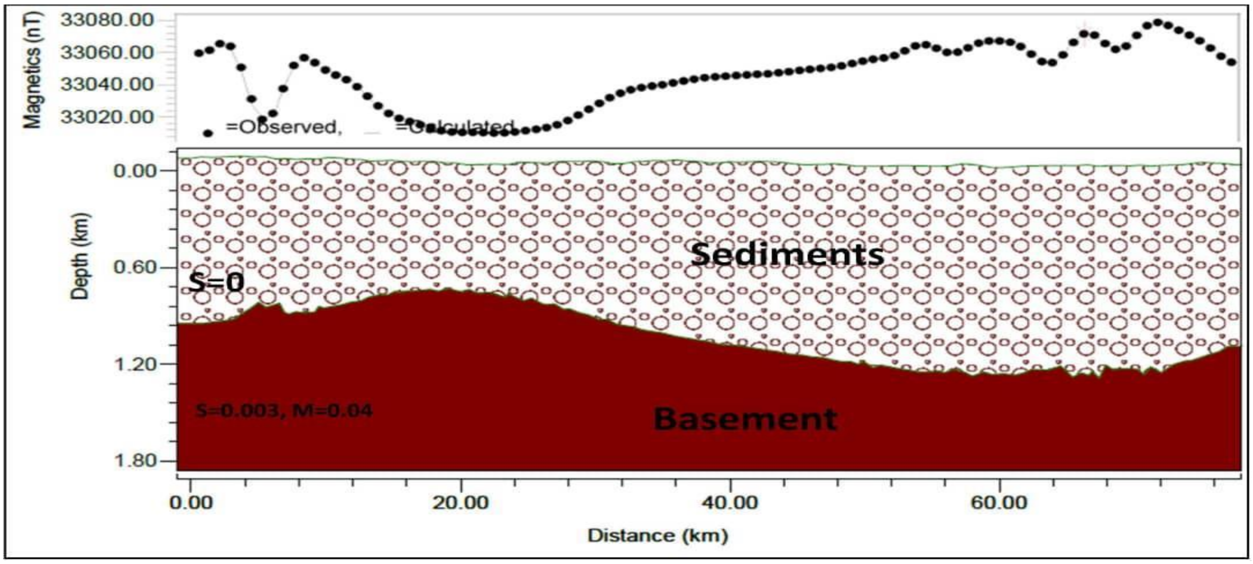

Fig. 7d: Profile 4

Table 2: Summary of the Modeling Results

Model	Min Depth value (km)	Max. Depth values (km)	Susceptibility K-value (SI)	Possible cause of anomaly
LI	0.40	5.00	0.002	Gabbro, diabase, cassiterite, pyrite
L2	0.60	1.00	0.003	Schist, quartzite, limonite Arsenopyrite
L3	0.30	1.68	0.003	Schist, quartzite, limonite Arsenopyrite
L4	0.84	1.32	0.003	Schist, quartzite, limonite Arsenopyrite

DISCUSSION

The shallow basements depths and dislocation zone depicting faults or fractures noticed at the southeastern (SE) portion of the study area as reflected in the contour map of the depth to magnetic sources (Fig. 5), total magnetic intensity and residual map (Fig. 2 and 3) will serve as conduits and conducive depths for solid minerals exploration. A good correlation was noticed from the modeling and spectral analysis in terms of minimum depths of 0.30 and 0.77 km. The areas where the maximum sedimentary thickness was obtained from the modeling traversing along WSW-NNE also correlate with areas where the maximum depth was obtained from the spectral analysis at WSW and NNE parts. The depth results of the present study compares favorably with the depth results obtained by earlier researchers who have worked within the lower Benue trough (Obi et al., 2010; Ugwu & Ezema, 2012; Igwesi & Umego 2013; Abdulahi et al. 2014; Obiora *et al.* 2018; Osinowo & Taiwo 2020). The igneous intrusions of gabbro and diabase delineated from the current study closely agrees with the results of Ugwu and Ezema (2012) who also delineated igneous intrusions of granite, dolerite, basalt and rhyolite from their modeling results. These intrusions are what account for mineralization in the study area.

CONCLUSION AND RECOMMENDATION

The aeromagnetic data proved very useful in estimating the depth of sedimentary thickness, types of intrusive bodies, hydrocarbon potential and types of minerals present in the area. The spectral analysis revealed depths to the magnetic basement ranging from 0.77 km to 2.34 km with an average value of 1.72 km. The modeling estimated depths of profiles 1, 2, 3, and 4 at 5 km, 1 km, 1.68 km and 1.32 km respectively with respective susceptibility values of 0.002, 0.003, 0.003 and 0.003 which indicate the presence of igneous intrusions of gabbro, diabase, metamorphosed sedimentary rocks of quartzite, and schist and iron rich minerals like pyrite, limonite, cassiterite and arsenopyrite. More so, the maximum sedimentary thickness obtained from both methods theoretically favour hydrocarbon accumulation, but evident of a number of intrusions delineated at various depths, which indicates that an exceedingly high temperature history will thermally degrade the kerogen that will yield hydrocarbons, and by implication, the area will not generate any significant hydrocarbon. The solid mineral deposits of pyrite, limonite, cassiterite and arsenopyrite will serve as raw materials for industries in the country and other parts of the world. Based on the results obtained, we recommend that efforts should be channeled for the investigation of other solid mineral resources since the area cannot hold any significant hydrocarbon.

Competing interests:

The authors hereby declare that no competing interest exists.

REFERENCES

Abdullahi, U. A., Ugwu, G.Z. and Ezema P.O. (2014). Magnetic Exploration of the Upper and Lower Benue Trough for Metallic Deposits and Hydrocarbons using 2D/3D. Journal of Natural Sciences Research www.iiste.org ISSN 2224-3186 (paper) ISSN 2225-0921(online) Vol.4, No.20, 41-46.

Burke K.C (1996) the African plate. South African Journal of Geology, 99:341-409.

Dobrin, M. B., and C. H. Savit (1988). An Introduction to Geophysical Prospecting. McGraw Hill, 650p.

Hunt, C. P., Moskowitz, B. M., and Banerjee, S. K., (1995). Magnetic properties of rocks and minerals, in Ahrens, T.J., ed., Rock Physics and Phase Relations: A Handbook of Physical Constants: American Geophysical Union, 3: 189–204.

Igwesi, I. David. and Umego, N. Marius. (2013**).** Interpretation of Aeromagnetic anomalies over some parts of the Lower Benue Trough using spectral analysis Technique. International Journal of Scientific and Technology Research Vol. 2, Issue 8.

Kearey P, Brooks M, Hill I (2002). An introduction to geophysical Exploration third Edition.TJ international. pp. 2-160.

Mamah, L.I., Ezepue, M.C. and Ezeigbo, H.I. (2000). Investigation of Geology and Geophysics in Mineral Exploration in the Benue Trough, Nigeria, the Onuahia Lead–Zinc Deposit. A case study Global Journal Pure Appl. Sci. Vol. 6. No. 2 PP. 255 – 262.

Nwachukwu S.O (1972). The tectonic evolution of the southern portion of the Benue Trough, Nigeria. Jour. Min. and Geol. 11, 45-55.

Obi, D.A., Okereke, O.S., Obei, B.C. and George, A.M. (2010). Aeromagnetic Modeling of subsurface intrusives and its implication on hydrocarbon evaluation of the Lower Benue Trough Nigeria. European Journal of Scientific Research vol. 47/3, PP. 347-361.

Obiora et al (2018) investigation of magnetic anomalies of Abakaliki area, southeastern Nigeria, using high resolution aeromagnetic data. Journal of geology and mining research 10:57-71.

Obiora, D. N., Ossai, M. N. and Okwoli, E. (2015). A case study of aeromagnetic data interpretation of Nsukka area, Enugu state, Nigeria, for hydrocarbon exploration. *International Journal of Physical Sciences*, 10(17): 503-519.

Ofoegbu CO and Onuoha KM (1991). Analysis of magnetic data over the Abakaliki Anticlinorium of the Lower Benue Trough, Nigeria. Marine and Petr. Geol., 8, 174-183.

Ofoegbu, C.O. (1985b). Interpretation of an Aeromagnetic Profile across the Benue Trough of Nigeria. Journal of African Earth Sci. Vol. 3, PP. 293 – 296.

Okubo, Y.J., Graf, R., Hansen, R.O., Ogawa, K. and Tsu, H. (1985).Curie point depth of the Island of Kyushu and surrounding areas, *Japan Geophysic*, 53: 481-491.

Article DOI: 10.52589/AJENSR-ETIJTXAH
DOI URL: https://doi.org/10.52589/AJENSR-ETIJTXAH

Osinowo O.O and Taiwo T.O. (2020) analysis of high- resolution aeromagnetic (HRAM) data of lower benue trough, southeastern Nigeria, for hydrocarbon potential evaluation, NRIAG journal of astronomy and Geophysics, 9:1,350-361, DOI: 10.1080/20909977.2020.1746890.

Osinowo, O. O., O. A. Akanji, and A. I. Olayinka (2014). Application of high-resolution aeromagnetic data for basement topography mapping of Siluko and environs, southwestern Nigeria, Journal of African Earth Sciences, 99, 637–651.

Rabeh, T. (2009).Prospecting for the ferromagnetic mineral accumulations using the magnetic method at the Eastern Desert, Egypt. *Journal of Geophysics and Engineering,* 6(4): 401-411.

Telford W.M., Geldart, L.P., and sheriff, R.E (1990). Applied geophysics. Cambridge university press, second edition.

Thompson, R. and Oldfield, F. (1986).Environmental Magnetism: London, Allen and Unwin, 227.

Ugwu GZ, Ezema PO (2012). Forward and inverse modeling of aeromagnetic anomalies over Abakaliki and Nkalagu areas of theLower Benue Trough, Nigeria. International Research Journal of Geology and Mining 2:222-229.

Ugwu, G.Z., Ezema, P.O. and Ezeh, C.C. (2013). Interpretation of Aeromagnetic data over Okigwe and Afikpo Areas of the Lower Benue Trough, Nigeria. International Research Journal of Geology and Mining (IRJGM) Vol. 3(1), PP. 1-8.

Wright, J. B., Hastings, D., Jones, W. B. and Williams, H. R. (1985). Geology and Mineral Resources of West Africa. George Allen and Unwind publ. London.