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Evaluation of Aeromagnetic Data Over Some Parts of Lower Benue Trough, Nigeria Using Spectral Analysis

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Abstract

We obtained, processed, and interpreted spectral analyses of aeromagnetic data across a portion of the Lower Benue Trough with the goal of estimating the depth to magnetic basement, modeling a conspicuous magnetic anomaly, identifying the basement topography, and evaluating basin configurations. Qualitative interpretation based on visual examination of the total magnetic intensive anomalies map, residual contour map, and first vertical derivative map reveals major faults trending east-west (E-W) and minor faults trending northeast-southwest (NE-SW), which is consistent with the structure of the lower Benue Trough. The western portion of the research region indicates structural change near the towns of Afikpo and Ishiagu, indicating areas of documented intrusive igneous body activity. According to the quantitative interpretation of the aeromagmatic data, the average sedimentary thickness is between (2.3 and 3.2 kilometers) and Quantitative interpretation utilizing spectral analysis identifies two distinct depth sources in the region: shallower sources ranging from 1.09 to 1.6 kilometers in the southern portion of the research area, and deeper sources ranging from 1.61 to 4.90 kilometers in the northern section. Additionally, the research reveals that the depths to the centroid and magnetic bodies (sedimentary thicknesses) vary between 5.02 and 10.65 kilometers and 0.23 and 3.5 kilometers, respectively. It was recommended that a ground magnetic survey be used in conjunction with this work to provide a more conclusive result.

Introduction

Aeromagnetic mapping is used to characterize the secondary lithology and morphology of rock bodies, as well as the age relationships between them (Abraham, et al 2015; Obaje, et al 2013). It is a contemporary geological mapping technique because it gives a wealth of information that is necessary both during the discovery of new mineral resources and subsequent exploitation. This investigation will seek to offer information about the magnetic bodies' structures and depths, which will aid in redefining basin layouts.

This paper discusses the interpretation of aeromagnetic data across a portion of Nigeria's lower Benue tough. The research region is rich in substantial mineral resources (Galena). This research employed the straight slope approach, which is applicable to both mineral and oil exploration. It specifies the geometry of the structure in mineral prospecting (Abraham, et al, 2014).

The analytical technique utilized in the research, spectral analysis, has shown to be a strong and easy tool for processing and interpreting prospective field geophysical data (Anakwuba & Chinwuko, 2015). It attempts to characterize a signal's frequency content using a limited collection of data. Its benefit is that the spectral domain formulations of anomalies are often simpler than the space domain ones. Additionally, noise associated with potential field data is often of a high frequency, and by limiting interpretation to low frequencies, significant improvement in interpretation is feasible (Ross et al., 2006).

Geology of the Area

The area of study is some parts of Lower Benue Tough, Nigeria. It lies between latitudes 6010IIN to 7010IIN and longitudes 3O40IIE to 40400E (Fig. 1). It covers an area of about 12100 square kilometers. It covers areas like Abakiliki, Afikpo Nkalagu and Ugep.

The Abakaliki trough's geology is similar to that of the Benue trough. The Benue-Abakaliki Trough formed as an arm of the triple junction rift-ridge system that caused the Aptian/Albian split of South America and Africa (Anthony & Obiora 2014; Akande et al, 2012). In the early Albian, the South Atlantic had separated at the Gulf of Guinea and spread north-east to create the Benue-Abakaliki Trough (aulacogen) (Ezepue, 1984). During the Santonian folding, the "Abakaliki Trough" was flexurally inverted into the Abakaliki Anticlinorium. The "trough's" flexural inversion resulted in the formation of the Anambra Basin from the Anambra Platform and the Afikpo Basin from the Ikpe Platform. The stratigraphy of the region reflects the area's transgression and regressive periods (Petters, 1978).

The Abakaliki area's sedimentary infill is composed of Albian-Cenomanian and Turonian-Santonian strata. Overlying the basement in this region is the Asu River Group, the oldest marine sedimentary deposit in the Southern Benue valley. The group is between 1,900 and 3,000 meters thick and is formed of the Abakaliki Formation (Mid-Albian) and the Ebonyi Formation (Late Albian-Cenomanian) (Ayodele & Ukaegbu, 2017 and fig. 2)

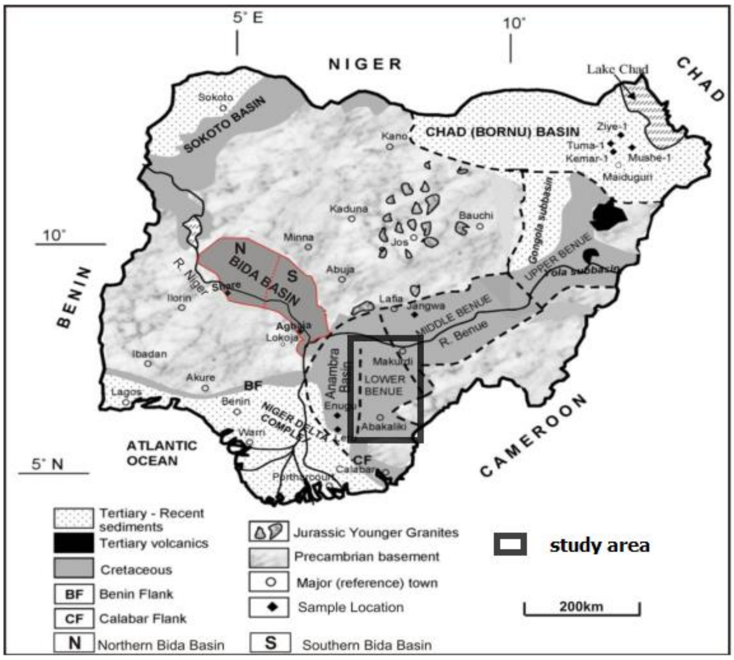

Figure 1. Geological map of Nigeria and locations of the study area (Modify from Usman et al., 2018).

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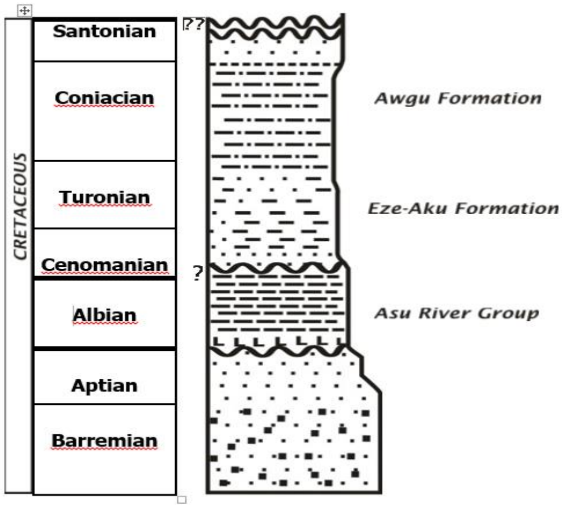

Figure 2. Stratigraphic Section of the Abakaliki Basin through Late Cretaceous. (Modified from Ezepue, 1984)

Methods

Four aeromagnetic data sheets were purchased (Fig. 4), namely 302 (Nkalagu), 303 (Abakalik)i, 313 (Afikpo) and 315 (Afikpo) (Ugap). These sheets have been put together and examined. The aeromagnetic measurements were collected as part of a countrywide study funded by the Nigerian Geological Survey Agency. The data were collected over a set of Northwest–Southeast flight lines with a two-kilometer spacing and an average flight height of around 150 meters, with tie lines at about a twenty-kilometer interval. Using the International Geomagnetic Reference Field, the geomagnetic gradient was eliminated from the data (IGRF). The data was made accessible in the form of digitized contoured maps at a scale of one hundred thousand. Around 1200 square kilometers of land were covered in total.

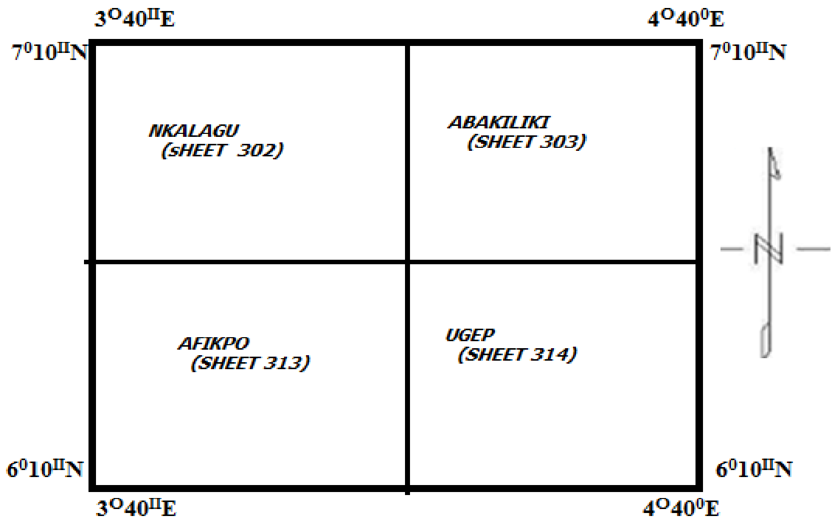

Figure 3. Acquired four sheets of aeromagnetic data

The contoured data, referred to as the research area's total magnetic field intensity (TMI) (Fig. 5), includes both the regional and residual anomaly. After reducing the regional magnetic gradient from the digitized aeromagnetic data, a linear trend surface was created (Eq. 1) and fitted to the digitized aeromagnetic data to get the residual anomaly map (Fig. 6).

$$P(x, y) = 1452.07y - 77.08x - 4658.08 \quad (1)$$

As a result, twenty-two anomalous targets were identified using the seven profiles taken within the residual map (Fig. 7), which were subjected to spectral analysis in accordance with the

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guiding principles established by numerous authors, including Bhattacharyya & Leu (1975), Bhattacharyya, (1966), Spector & Grant (1970), Okubo et al. (1985), Onwuemesi (1997), Kivior and Boyd (1998), Saibi et al (2015) Spectral analysis is a technique for doing quantitative analysis on large amounts of complicated aeromagnetic data. The amplitude's natural logarithm is shown versus the Nyguist frequency (Fig. 8). Each segment's slope indicates the depth to the top of a collection of magnetic or gravity bodies (Kivior and Boyd, 1998). Bhattacharyya & Leu's (1975) method was used to generate the spectral analysis for the curie isotherm. According to Bhattacharyya & Leu (1975), the first step is to determine the depth to the magnetic source's centroid (Z_o) using the slope of the spectrum's longest wavelength, which is shown below:

$$In\left[\frac{\rho(\sqrt{S})}{/S/}\right] = InA - 2\pi/S/Z_o \qquad (2)$$

Where,

P(s) is the radially averaged power spectrum (natural log of amplitude) of the anomaly
/**s**/ is the wave number (Nyguist frequency) and

A is a constant.

The second step is the estimation of the depth to the top boundary (Z_t) of that distribution from the slope of the second longest wavelength spectral segment (Likkason, 2007),

$$In\left[\frac{\rho(\sqrt{S})}{/S/}\right] = InB - 2\pi/S/Z_t \qquad (3)$$

Where,

B is the sum of constants independent of **/s/.**

Then, the basal depth (Z_b) of the magnetic source was calculated from the equation of Tanaka et al., (1999) and Telford et al, (1998) as shown below:

$$Z_b = 2Z_o - Z_t \qquad (4)$$

The obtained basal depth (Z_b) of magnetic sources in the study area is assumed to be the Curie point depth according to Okubo et al. (1985) and Okonkwo, (2012).

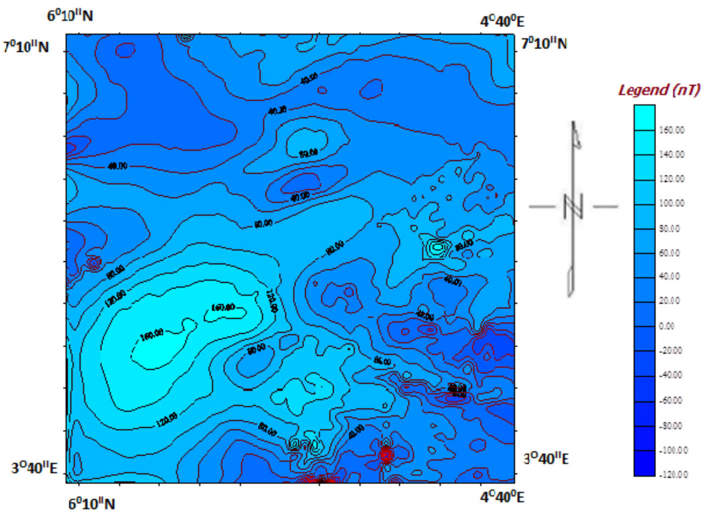

Figure 4. Total Magnetic Intensity (TMI) Map of Part of Lower Benue Tough (Contour Interval~20nT)

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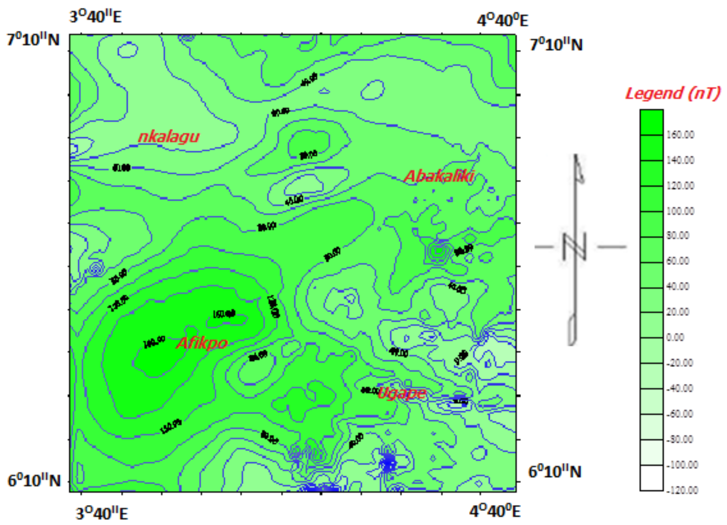

Figure 5. Residual anomaly Map of Part of Lower Benue Tough(Contour Interval~20nT)

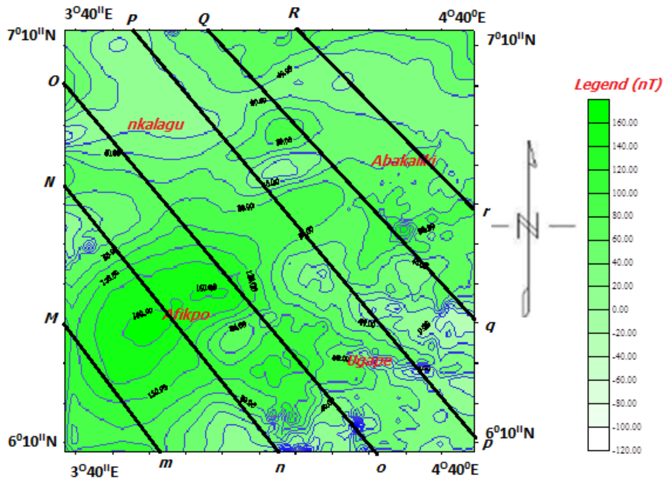

Figure 6. Residual Map with Profile line of Part of Lower Benue Tough(Contour Interval~20nT)

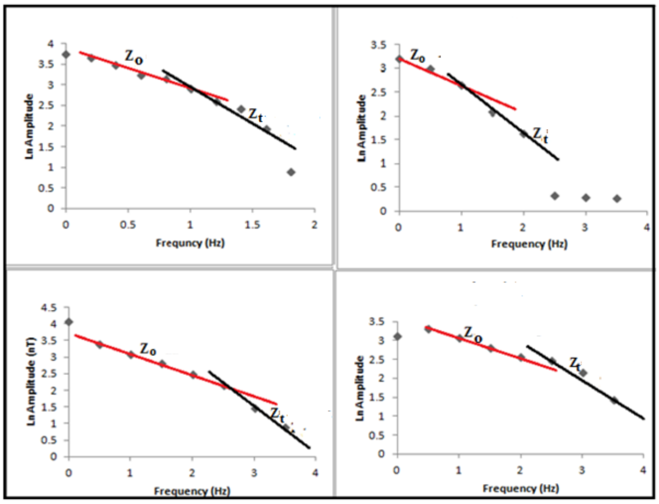

Figure 7. Amplitude spectral for various Magnetic bodies

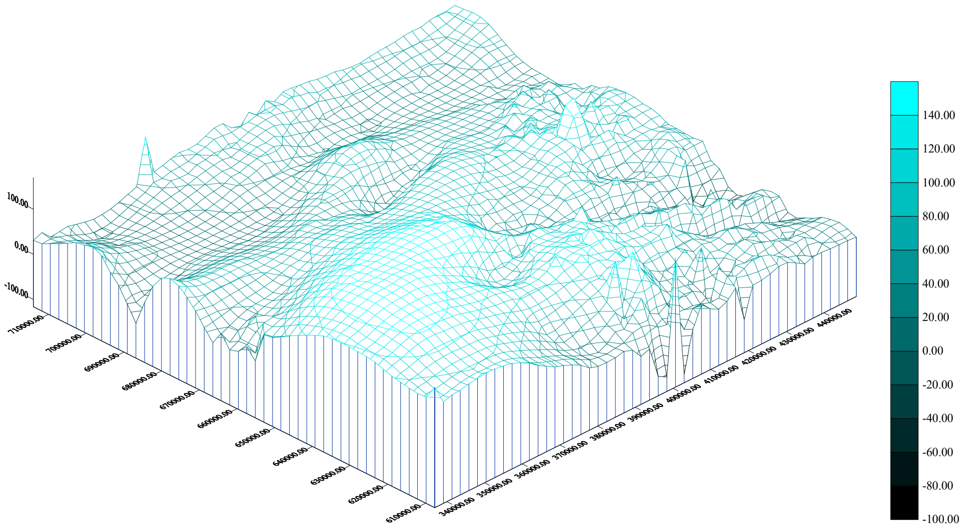

Figure 8. 3D Map of Part of Lower Benue Tough

Lineament extraction was performed using center for exploration targeting (CET) grid analysis, a collection of algorithms that improves (figures 10 and 11), locates, and vectorizes discontinuity structures within prospective field data. By analyzing local data fluctuations, texture analysis filters increase discontinuity zones. Phase analysis identifies structures that are laterally continuous, while structure detection tilts vectorized structures identified by phase analysis (Petters, 1978; Okubo et al 1985).

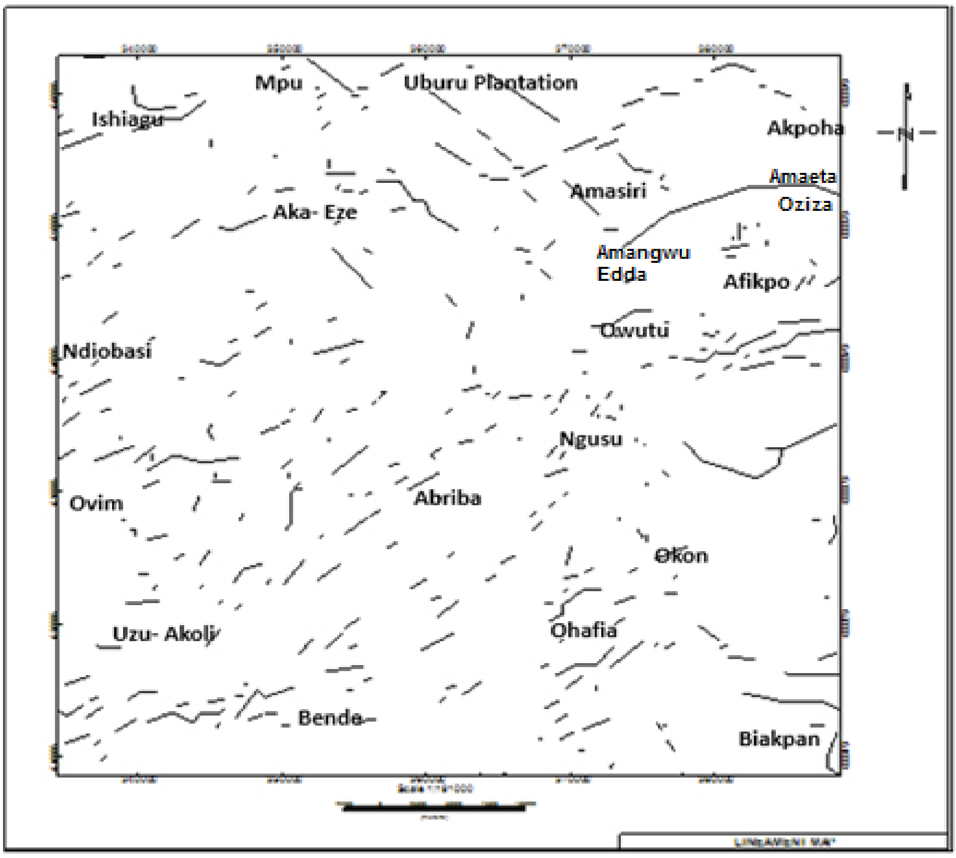

Figure 9. Structural lineament map of the study area

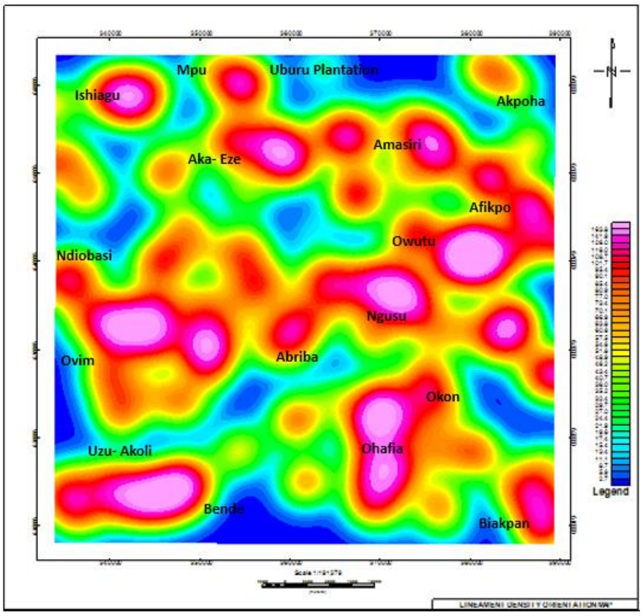

Figure 10. lineament density orientation map

Quantitative Interpretation of the Aeromagnetic data

Seven selected magnetic profiles, namely M-M^1, N-N^1, O-O^1, P-P^1, Q-Q^1 and R-R^1 reveals various magnetic anomalous bodies across the profile lines (Fig. 7). A total of twenty-two (22) anomalies were identified along the profile lines. This revealed anomalous body was subjected to spectral analysis.

Results and Discussion

The magnetic intensity map (Fig. 5) indicates magnetic ranges of around 7600.00nT to approximately 8000.00nT, with a magnetic peak between Umuahia and Ishiagu towns in the research area's northwest corner. The Arochukwu and Uwet regions exhibit a regional magnetic response with a bipolar magnetic signature that coincides with the primary border between the Oban Massif in the east and the sedimentary basin in the west. Additionally, a bipolar magnetic response was detected between the Umuahia and Ikot-Ekpene areas, which may have contributed significantly to the sedimentation pattern seen in the region, as shown in Fig. 6.

The total magnetic intensity of the study area (Fig. 5) was used to generate the first horizontal and first vertical derivatives, which aid in structural modeling (Fig. 10). Using the finite differences approach of (Usman et al., 2018; Anudu et al., 2012), the first vertical and horizontal derivatives reveal points of magnetic source maxima, which enhance the edges of magnetic sources such as lineaments, intrusive, and magnetic basement; and the depth to the magnetic source (2013).

The findings reveal a more accurate sedimentary and basement border, as seen in Table 1, which also depicts the extent of the Oban Massif in the eastern half of the research region, particularly around Ugep, Akpet, and Akamkpa, as well as the structural complexity found in the Akpet area. Fig. 6 illustrates the western sedimentary basin with its structurally altered areas around Afikpo and Ishiagu towns, which revealed areas of reported intrusive activity and are also home to active quarrying activities. The exposed intrusive trend around Afikpo town, as reported by Ayodele & Ukaegbu (2017), is evident in the northeast of the study area; its fissured structural pattern was also observed with NE-SW trends; the north-western part of the study area around Ishiagu indicates portions intruded by intrusive, as Anthony & Obiora (2014). The comparison of the geology map in Figure 8 and the depth to basement map in Figure 9 offers a clearer geologic knowledge of the basement area, sedimentary cover, and structural trends within the sedimentary basin around Afikpo and Ishiagu towns, including the documented intrusive.

Table 1. Calculation of Depth to Basement Spectral Analysis

Profiles	***Anomalies***	***Top of the basement (km)***	***Slope Constant***	***Bottom of the basement (km)***
M-m	a	1.3	1.82	2.366
	b	2	1.82	3.64
	c	0.9	1.82	1.638
N-n	d	1.8	1.82	3.276
	e	2.2	1.82	4.004
	F	0.8	1.82	1.456
O-o	g	1.5	1.82	2.73
	h	1.9	1.82	3.458
	i	0.8	1.82	1.456
P-p	j	1.4	1.82	2.548
	k	1.6	1.82	2.912
	l	0.8	1.82	1.456
Q-q	m	0.9	1.82	1.638
	N	2.7	1.82	4.914
	o	0.6	1.82	1.092
R-r	p	2.2	1.82	4.004

Conclusion

Aeromagnetic measurements over portions of the lower Benue Trough were analyzed using spectrum analysis in order to delineate the research area's magnetic characteristics, and the following results were reached: The total magnetic anomaly map and residual anomaly map both indicated significant evidence of increased magnetic strength, as well as several anomalous bodies and portions of the Afikpo axis. The contour lines are closely spaced in the southeastern parts of the study area, indicating that the depths to basement are relatively shallow in these areas, whereas the contour lines are widely spaced in the northern and north-western parts, indicating that the depths to basement are relatively deep in these areas, namely the Nkalagu and part of Isiagu areas. Additionally, the region is highly faulted, with main faults going east-west (E-W) and smaller faults trending northeast-southwest (NE-SW). Quantitative interpretation utilizing spectral analysis identifies two distinct depth sources in the region: shallower sources ranging from 1.09 to 1.6 kilometers in the southern portion of the research area, and deeper sources ranging from 1.61 to 4.90 kilometers in the northern section. Additionally, the research reveals that the depths to the centroid and magnetic bodies (sedimentary thicknesses) vary between 5.02 and 10.65 kilometers and 0.23 and 3.5 kilometers, respectively.

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