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Upward Continuation and Reduction to Equator Filters on Aeromagnetic Data of parts of Bida Basin, Nigeria

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Abstract

To enhance the aeromagnetic maps covering six data sheets encompassing the Mokwa, Egbako, Bida, Lafiagi, Pategi, and Baro regions of the Bida Basin, Nigeria, this research employs two magnetic filtering techniques. The aim is to refine the maps for a better representation of the study area. The study intends to improve the interpretation of aeromagnetic data by better identifying depth discrepancies and differentiating between shallow and deep-seated magnetic sources within the surveyed region using upward continuation (UC) and reduction to the magnetic equator (RTE) filters. Variations in anomalies observed in both total magnetic intensity and reduction to the equator can be attributed to lithological differences, depth variations, strike angles, magnetic susceptibility variations, or the presence of basement complex rocks with varying concentrations of magnetic materials.

Keywords: Aeromagnetic data, Upward Continuation, Reduction to the Equator and anomalies

1. Introduction

The magnetic technique, an age-old geophysical method, is utilized in the exploration of mineral hydrocarbon and deposits. This method investigates the earth's internal structures by detecting variations in the magnetic field, which arise due to the magnetic characteristics of the underlying minerals/rocks. As Kearey *et al*., (2002) suggested, the magnetic method is effective in probing the geology of a specific area due to differences in the earth's magnetic field. These differences are the result of the magnetic features of subsurface rocks. This technique proves highly useful in estimating the likely depth to the basement beneath sedimentary rocks, as stated by Birch, F. S. (1984). The process of upward continuation is a technique that elevates data above the original height at which it was collected. The effect of this is the smoothing out of short wavelength features as one moves away from the anomaly, as explained by Ganiyu *et al*., (2012).

This technique is also applied in geophysics for oil exploration to determine the strengths of gravitational or magnetic fields. It entails taking low-elevation observations and, assuming continuity, projecting them upward. Upward continuation is useful in magnetic interpretation because it reduces the intensity of high wave number anomalies associated with shallow magnetic sources, which helps interpret or clarify deeper magnetic sources. Additionally, it aids in separating the reported magnetic sources from a regional magnetic anomaly brought on by deep-seated sources. On the other hand, low magnetic latitude regions—that is, those with a geomagnetic

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inclination of less than 15˚—are those where the reduction to the magnetic equator is used. This technique is used to beautifully simplify magnetic interpretation by perfectly centering the peaks of modest magnetic anomalies over their sources or exact placements. Nevertheless, correlations between the sites of sources and the observed aberrant maxima in the decrease to the equator invariably provide difficulties. These obstacles can occasionally be frustrating because solving them calls for cautious navigation and close attention to detail. This is because, as observed by Ganiyu *et al*. (2012), magnetized bodies at low latitudes usually exhibit two extreme magnetic values due to their bipolar nature. Furthermore, Leu (1982) proposed that magnetic data may be efficiently lowered to the equator (RTE), which would result in the horizontal appearance of magnetic bodies at the equatorial plane. To perform reduction to the equator and upward continuation at various levels on the aeromagnetic data of the Mokwa, Egbako, Bida, Lafiagi, Patigi, and Baro regions within the Bida Basin, Nigeria, the goal of this study is to use six magnetic enhancement processes. It is expected that the differences between the shallow and deeper magnetic sources will be visible from specific areas inside the Bida Basin. The aeromagnetic measurements will then show fluctuations that correspond to shifts in the magnetic susceptibility of rocks that are close to the surface.

1.1 Geological setting

According to Kande *et al*. (2005), there is a claim that the Anambra Basin flows into the Bida Basin from the northwest (Figure 1). The sedimentary deposition in the basin comprises an Upper Cretaceous band of sedimentary rock strata trending northwestward, formed due to block faulting, basement disintegration, and subsidence resulting from the Cretaceous opening of the South Atlantic Ocean. The southern portion is termed the Lokoja sub-basin while the northern region is commonly known as the Bida sub-basin. The Bida Formation, which covers the Basement Complex unconformably, is located in the basin's northern part. The basement is also unconformably covered by the Lokoja Formation, just like it is in the southern portion. Both the Bida and Lokoja Formations exhibit juvenile characteristics in terms of texture and mineralogy. They consist of conglomeratic sandstone, medium-grained sandstone, siltstone, and subordinate claystone, forming finely aggregated products of massive conglomerates supported by a matrix and clasts (Ojo and Akande, 2013). Above the Lokoja Formation lies the Patti Formation, comprising shale, sandstone, ironstone, and claystone. In the northern part of the basin, the Enagi Formation, consisting of siltstone, sandstone, and claystone, overlies the Bida Formation (Ojo, 2020). As documented by Adeleye (1974) and Akande *et al*. (2005, the Enagi and Patti Formations are directly covered by the Batati and Agbaja Formations, respectively. In addition to small amounts of ferruginous siltstone, claystone intercalations, and shale beds that have created near-shore shallow marine to freshwater fauna, the Batati Formation comprises argillaceous, oolitic, and goethitic ironstones (Adeleye, 1973). The Agbaja Formation is composed of oolitic and pisolitic ironstones, and its age is estimated to be Late Maastrichtian (Ojo *et al*., 2020). The Bida Basin's structural characteristics are demonstrated by a system of Northwest - Southeast trending faults at its borders that connect to the surrounding crystalline basement topography. This fault system also suggests the basin's rift origin (Kogbe *et al*., 1983; Rahaman *et al*., 2018). There were no noteworthy lineaments, intrusions, or morphological characteristics within the sedimentary basin (Salawu *et al*., 2020). On the other hand, the lateral continuity of the NNE-SSW trending Kalangai-Zungeru-Ifewara shear zones is a noteworthy structural characteristic of the underlying basement. According to Sarawu *et al*. (2020), these shear zones were created during the Pan-African orogeny.

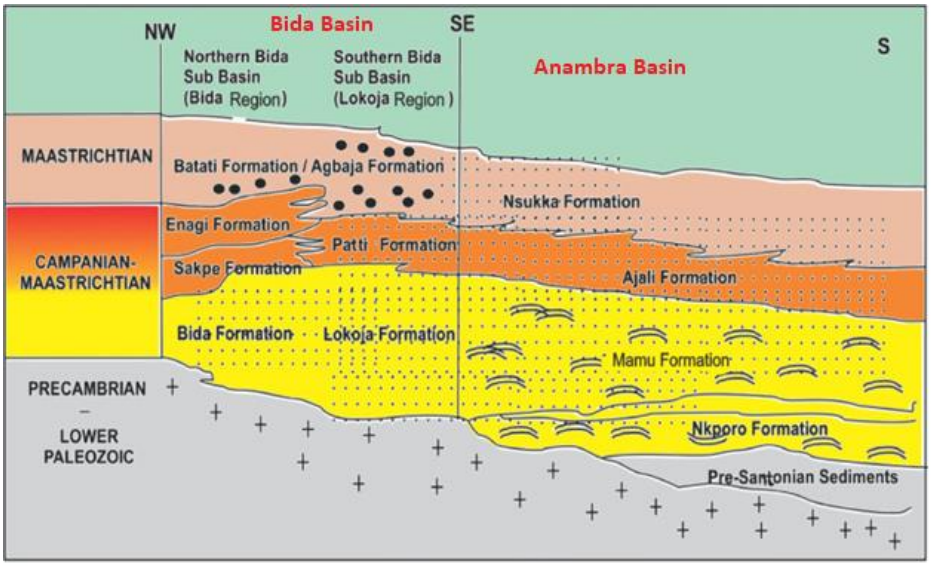

Figure 1: Regional stratigraphic successions in the Bida Basin and NW-SE-S stratigraphic correlations from the Bida Basin to the Anambra Basin (Modified after Akande *et al*., 2005)

2. Materials and Methods

The controlled maps of total magnetic intensity on a 1:100,000 scale that were acquired during the Nigerian Geological Survey Agency's statewide aeromagnetic survey, which took place between 2005 and 2010, were employed in this study. The high-resolution aeromagnetic dataset, comprising sheets 182,183,184,203,204, and 205, consists of these maps. NGSA (2010) states that data were collected and stored in a grid format at 100-meter sample intervals. In the NW-SE and NE-SW orientations, the travers and tie line spacings were 500 and 2000 meters, respectively. The study area is covered by six aeromagnetic maps of total field intensity on ½º by ½º sheets. The initial pre-processing of the data, which involved micro-leveling, removing cultural effects, and filtering for noise elements, was carried out by the Fugro Airborne Survey and Consultant teams. The pre-processed data were examined for anomalies and lone spikes unrelated to the geology. Any probable cultural noise and other absurd noise were removed using Butterworth filtering processing to maximize the signal-to-noise ratio and minimize other noise energy in the data. Maps of the region's total magnetic field intensity were created using the Oasis Montaj software.

2.1 Methodology

2.1.1 Reduction to Magnetic Equator (RTE-TMI)

To create the regional anomaly map, the RTE grid was extended upward to a height of 10 km above the survey plane.

2.1.1.1 Upward Continuation (UC)

To create the regional anomaly map, the RTE grid was elevated to a height of 100 km above the survey plane. The long wavelength (deep-seated) anomalies are amplified by this mathematical technique; by calculating the field at a constant elevation (h) above the measuring plane, it modifies the magnetic data (Miranda and Introcaso, 1999). The upward continuation filter refines the data by reducing noise, thus eliminating the impact of shallow sources and emphasizing long wavelength anomalies associated with deep-seated regional features in the investigated area. At a greater elevation ($z = -h$), the upward continuation (ΔF) of the total field anomaly is stated as follows:

$$\Delta F(x, y, -h) = \frac{h}{2\pi} \iint \frac{\Delta F(x,y,0)dxdy}{((x-x^0)^2 + (y-y^0)^2 + h^2)}$$

Equation (4) provides the field in terms of the average value ΔF at the location (x, y, o) at an elevation (h) above the plane of the observed field (z = 0).

3. Results and Analysis

The contoured maps showed features that resembled a faulted zone in the southeast of the research area after the reduction to the magnetic equator (RTE) filtering method was applied to the aeromagnetic data. This finding aligns with the observations made on the region's total magnetic intensity (TMI) map (see Figure 2a). The faulted zone's existence raises the possibility of structures hosting mineral resources or occurrences. Compared to the total magnetic intensity map (Figure 2a), the RTE map (see Figure 2b) seemed more detailed and distinct, successfully defining the high and low centers. The research area's possible mineralization zones and other geological features can be easier to delineate, hence, improving clarity.

The upward continuation technique was applied to the magnetic data of the study area at various elevations, specifically at 500, 1000, 1500, 2000, 2500, 3000, 3500, 4000, 5000, 6000, 7000, 10000, 20000, 30000, 40000, 50000, 60000, 70000, 80000, 90000, and 100000 meters, resulting in the exposure of the basement at these different levels, as depicted in (Figures 3a and 3b). As elevation above the research region increases, the upward-trending data show a progressive attenuation and widening of the high-frequency anomalies. These upward continuing maps function as efficient low wavenumber pass filters by showing how the anomaly features vary with increasing separation from the magnetic sources. Specifically, the data that extend upward from 10,000 m to 100,000 m (Figures 3a and 3b) provide an integrated and thorough view of the research region that is free from distortion from localized, high-amplitude, high-gradient anomalies that arise from shallow sources within the study region. Roberts *et al*. (1990) have shown that a more lucid and improved visualization of the deeper anomaly sources is produced by the attenuation of shallow source anomalies throughout the upward continuation phase.

Table 1 shows the variability of maximum and minimum values at different levels of upward continued filters. Figures 4a and 4b show the biplot maximum and minimum values against different levels of upward continuation respectively. In Figures 4a and 5a, there is a decrease in values from UC 500 m to 20500 m, and from 20500 UC the values remain constant while Figures 4b and 5b show the increase in values from UC 500 m to 20500 m, and after that, it remains constant. This denotes an important information on upward continuation that is more than 20500 m.

Table 1: Showing the Upward Continuation (UC), Maximum and Minimum values

SN	UC (m)	Maximum(m)	Minimum(m)
1	500	121.62	-29.52
2	1000	116.59	-19.75
3	1500	112.72	-13.07
4	2000	109.38	-07.68
5	2500	106.58	-03.09
6	3000	104.26	0.85
7	3500	102.22	03.95
8	4000	100.35	06.91
9	5000	96.98	12.37
10	6000	94.16	17.04
11	7000	91.79	21.00
12	10000	86.28	29.57
13	20000	78.71	39.28
14	30000	77.13	39.73
15	40000	75.94	39.81
16	50000	75.14	39.86
17	60000	74.63	39.93
18	70000	74.3	40.00
19	80000	74.09	40.08
20	90000	73.96	40.14
21	100000	73.86	40.20

4. Conclusion

The study area's locations and the spherical nature of the sources are better defined by the reduction to equator processing of the magnetic data than by the contour of the unfiltered total intensity magnetic data. The mechanism of upward continuation makes it evident how short-wavelength abnormalities attenuate as the distance from the source to the observation increases. Thus, the reduction to the equator and upward continuation process function as a useful method for improving the quality of the data and supports these analyses of the anomaly sources.

The examination of various maps including the total magnetic intensity map (TMI), regional map, residual map, and upward continuation maps reveals significant insights into the geological structure of the Bida Basin. Upward continuation processing was applied to magnetic data across a range of elevations, from 500 meters to 100,000 meters, uncovering a shallower basin in the northwestern region and a thicker basin in the southeastern area. This trend is particularly notable in the upward continuation from 40,000 meters to 100,000 meters, covering parts of the Mokwa and Baro sheets respectively. The potential discovery and extraction of hydrocarbons in these areas could substantially augment the country's reserves and enhance productivity. Such developments would carry both economic and strategic advantages for Nigeria. Consequently, there is a pressing need to leverage modern geophysical techniques in the exploration of Nigerian inland basins to capitalize on these opportunities.

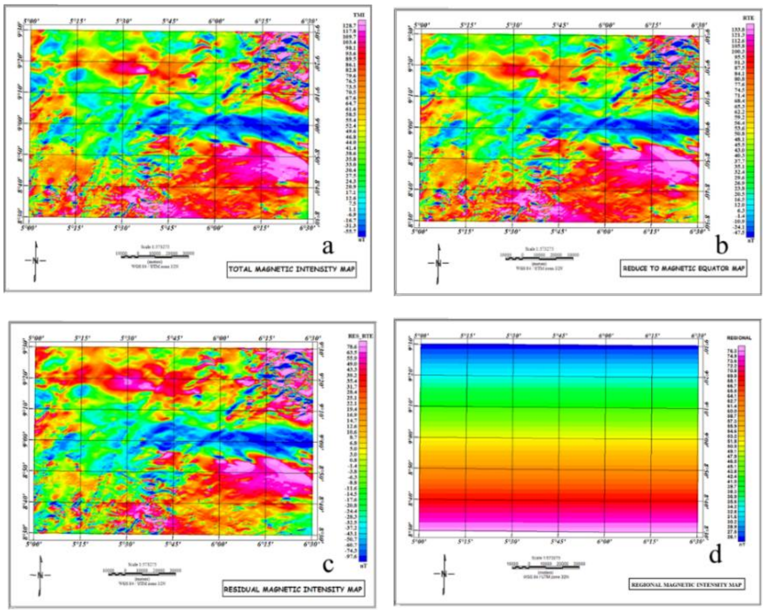

Figure 2: Research Area: a. Total Magnetic Intensity (TMI), b. Reduce to Magnetic Equator (RTE), c. Residual Magnetic Intensity, and d. Regional Magnetic Intensity

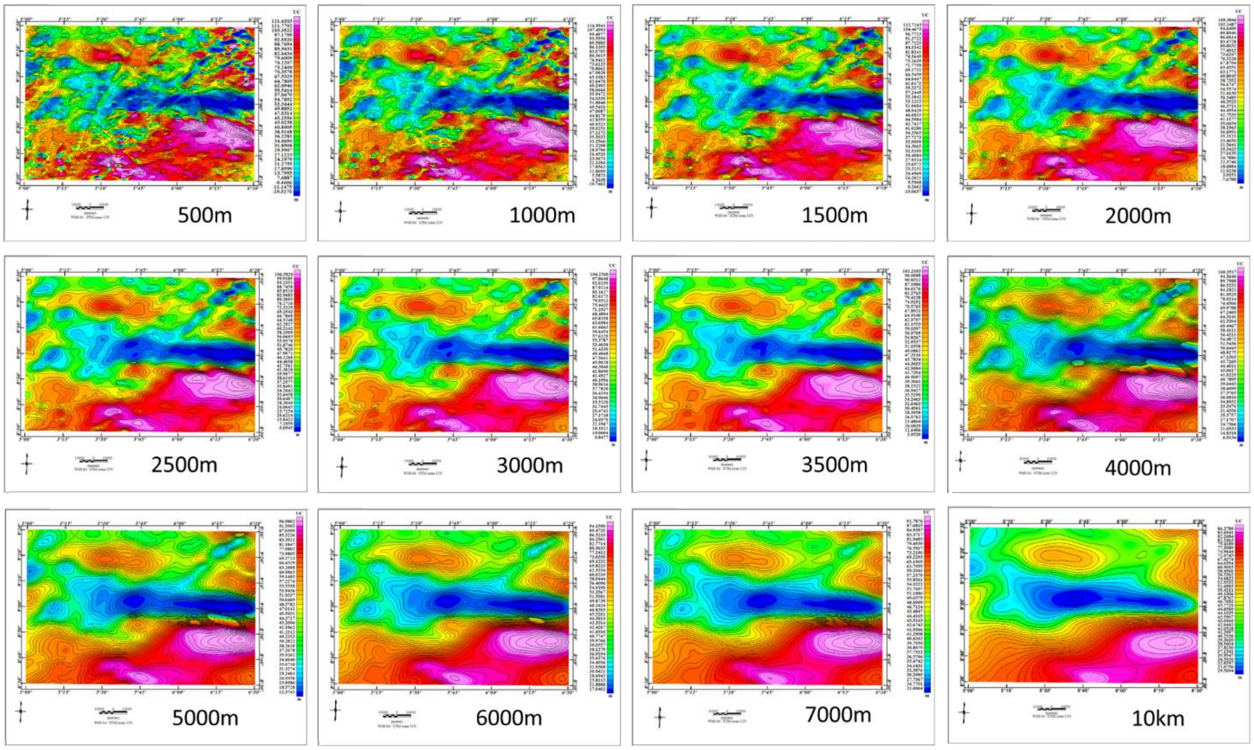

Figure 3a: Upward continuation map of the study area at 500 m to 10 km

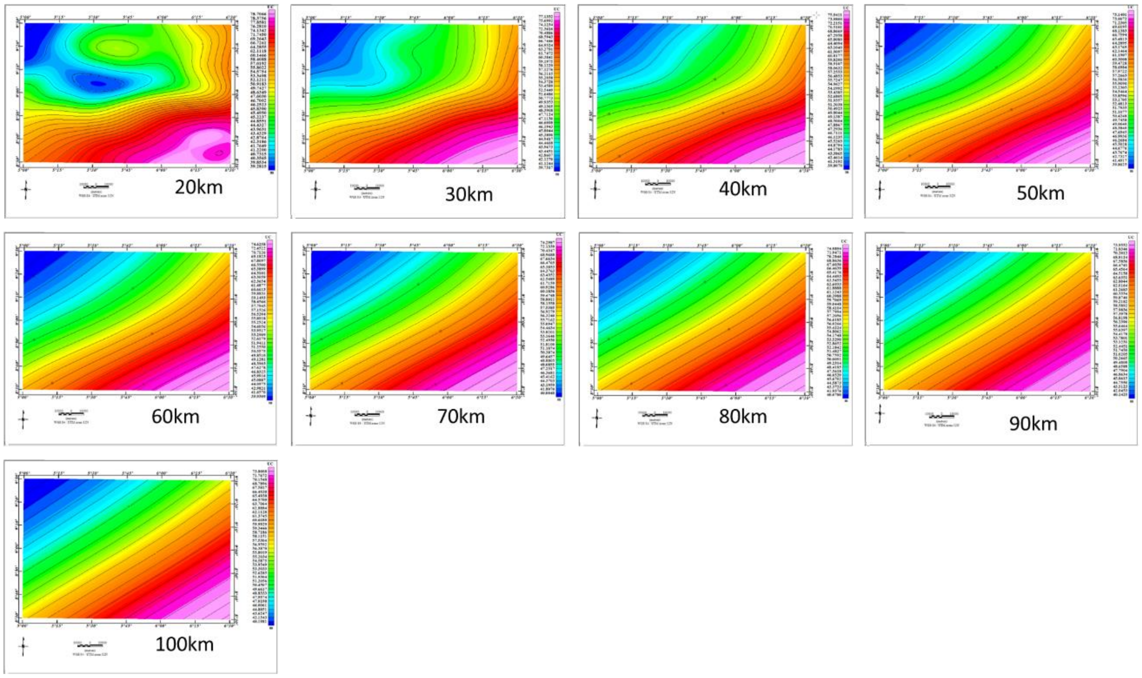

Figure 3b: Upward continuation map of the study area at 20km to 100 km

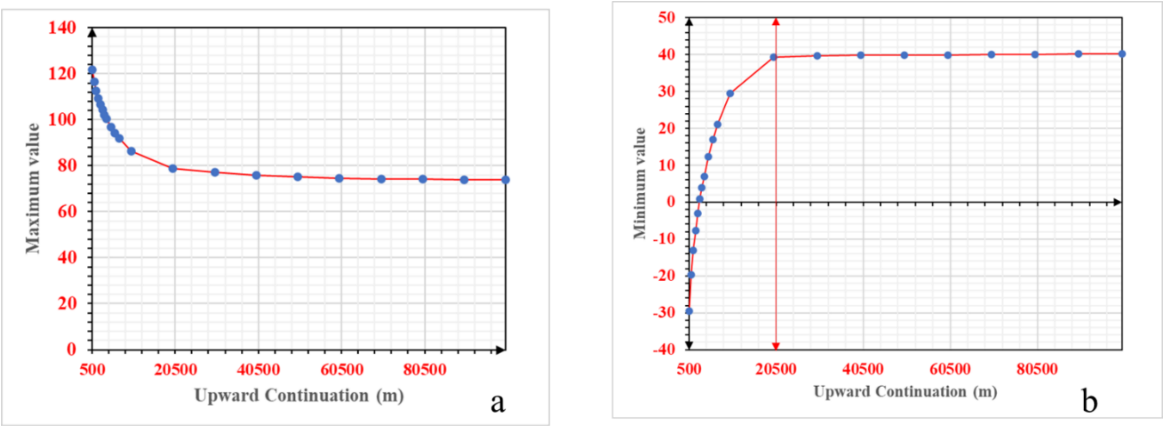

Figure 4: Showing the biplot of Upward continuation with a. maximum value and b. minimum value

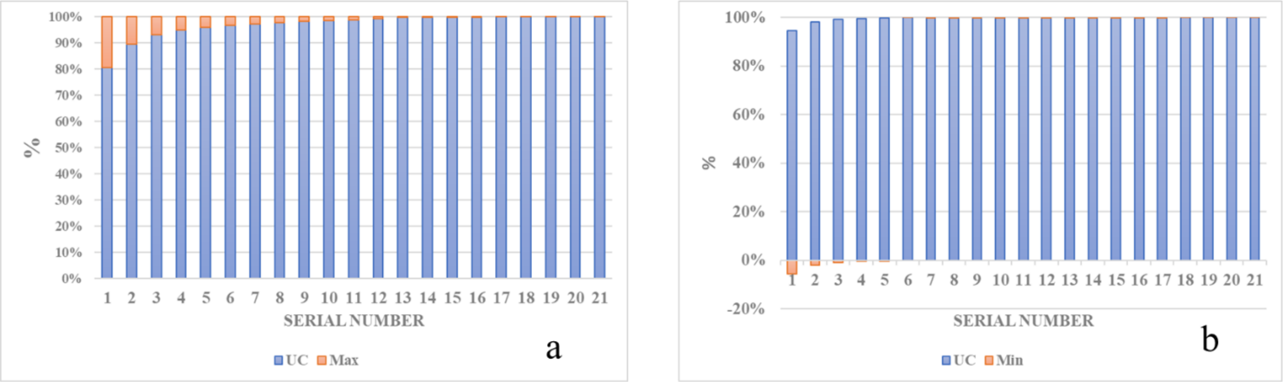

Figure 5: Showing the histogram plot of Upward continuation with a. maximum value and b. minimum value.

References

Akande, S.O., Ojo, O.J., Erdtmann, B.D., Hetenyi, M., (2005). Paleoenvironments, organic petrology, and Rock-Eval studies on source rock facies of the Lower Maastrichtian Patti Formation, Southern Bida Basin, Nigeria. J. Afr. Earth Sci. 41, 394–406.

Birch, F. S. (1984). Bedrock Depth Estimates from Ground Magnetometer Profiles. Groundwater, 22 (4), 427-432. http://dx.doi.org/10.1111/j.1745-6584.1984.tb01413.x

Ganiyu S. A, Badmus B. S, Awoyemi, M. O, Akinyemi O. D and Oluwaseun T. Olurin (2012). Upward continuation and reduction to pole process on aeromagnetic data of Ibadan area southwestern Nigeria. Canadian Center of Science and Education; Vol. 2, No. 1; 2013

Kearey, P., Brooks, M., & Hill, I. (2002). An introduction to geophysical exploration (Vol. 4). John Wiley & Sons.

Kogbe, C. A. (1989). Geology of Nigeria. Rock View (Nigeria) Limited. Jos, Nigeria.

Leu, L. (1982) Use of Reduction-to-the-Equator Process for Magnetic Data Interpretation. Geophysics, 47, 445.

Ojo, O.J., 2012. Depositional environments and petrographic characteristics of Bida Formation around Share-Pategi, northern Bida basin, Nigeria. J. Geogr. Geol. 4 (1), 224–241.

Ojo, O.J., Akande, S.O., 2013. Petrographic facies, provenance, and paleoenvironments of the Lokoja Formation southern Bida basin, Nigeria. J. Min. Geol. 49 (2), 93–109.

Ojo, O.J., Bamidele, T.E., Adepoju, S.A., Akande, S.O., (2020). Genesis and paleoenvironmental analysis of the ironstone facies of the Maastrichtian Patti Formation, Bida basin, Nigeria. J. Afr. Earth Sci. 174.

Rahaman, M.A.O., Fadiya, S.L., Adekola, S.A., Coker, S.J., Bale, R.B., Olawoki, O.A., Omada, I.J., Obaje, N.G., Akinsanpe, O.T., Ojo, G.A., Akande, W.G., (2018). A revised stratigraphy of the Bida Basin, Nigeria. J. Afr. Earth Sci.

Roberts, R. L., Hinze, W. J., & Leap, D. I. (1990). Data enhancement Procedure on magnetic Data from Landfill Investigations. 261-26

Salawu, N.B., Fatoba, J.O., Adebiyi, L.S., Ajadi, J., Saleh, A., Dada, S.S., (2020). Aeromagnetic and remote sensing evidence for the structural framework of the middle Niger and Sokoto basins, Nigeria Phys. Earth Planet. In. 309.