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SPECTRAL ANALYSIS OF AEROMAGNETIC ANOMALIES OF THE NORTHERN NUPE BASIN, WEST CENTRAL NIGERIA

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ABSTRACT

A quantitative interpretation of the aeromagnetic anomalies of the northern part of the Nupe Basin, West of Central Nigeria has been carried out using spectral analysis. In order to minimize aliasing error, the aeromagnetic maps used in the study were digitised at equal spacing of 0.875km, which imposes a nyquist frequency of 0.57km^{-1}. The depths to magnetic basement were found to increase from the edges of the study area to the central portion and vary between 0.52 to 4.38km while a depth range of 0.24 to 1.74km was attributed to shallow sources. Three sedimentary reservoirs were elucidated. One lies to the north-central portion of the study area while the other two lay in the central portion. The reservoirs contain sediments having thickness not less than 3.6km. Sedimentary thickness of this size may be a target for petroleum exploration, hence such areas maybe recommended for further investigation.

KEYWORDS: Spectral Analysis, Aeromagnetic Anomalies Interpretation, Magnetic Basement and Sedimentary Reservoirs

INTRODUCTION

Spectral analysis has proved to be a powerful and convenient tool in the processing and interpretation of potential field geophysical data. It seeks to describe the frequency content of a signal, random process or system, based on a finite set of data. Workers employing spectral applications in the processing and interpretation potential field geophysical data have done, and are still doing, extensive and in-depth studies. This assertion is evidenced by a number of well-known publications in reputable journals and books going back more than 40 years (Bhattacharya, 1966; Spector and Grant, 1970; Clement, 1973; Bath, 1974; Pal et. al., 1978 etc). There are distinctive advantages in working with potential field anomalies in frequency domain. The spectral domain expressions of these anomalies are generally vastly simple as compared to the expressions of the anomalies in space domain. This makes possible the devisal of simpler techniques of interpretation. The noise (observational, instrumental and those due to near surface inhomogenities or irregularities of the structure) associated with potential field data generally has high frequency characteristics and by restricting the interpretation to low frequencies, considerable improvement in interpretation is possible (Hahns et al, 1976; Pal et al, 1978; Khurana, 1981; Olasehinde, 1991). Furthermore, the regionals, which are generally superimposed over anomalies of interest, being expressible as polynomials of certain low order, give rise to no non-zero frequencies in the spectrum (Baranov, 1975). Therefore, by employing only non-zero frequencies of the spectrum in the analysis, one can remove the effect of regionals from the interpretation. An important property of spectral analysis is that features with given direction in spectral domain are transformed into a feature with only one direction in the spectral domain. Moreover, linear features in the power spectrum are perpendicular to the linear space-domain features, which they describe (Thorarinsson et. al., 1988).

The work presented here is a magnetic basement mapping from the aeromagnetic anomalies of the northern part of the sedimentary Nupe Basin of West Central Nigeria using power spectrum analysis. The result will no doubt provide a general basic framework for future detailed survey and contribute tremendously to a better understanding of the geological structures of the sedimentary basin.

LOCATION, CLIMATE, VEGETATION AND GEOLOGY OF THE STUDY AREA

The area of study, which is the northern part of the Nupe Basin, is bounded by latitudes $8^0 30'$ and $10^0 00'$ North and longitudes $4^0 30'$ and $6^0 00'$ East. It is an area of about 27,200 square kilometres situated at the West of Central Nigeria. The Nupe Basin (also known as the Middle Niger Basin or Bida Basin) is an elongated NW-SE trending depression perpendicular to the main axis of the Benue Basin of Nigeria. The entire basin is bounded by latitudes 8°00'N and 10°30'N and longitudes 4°30'E and 7°30'E and covers an area of approximately 90,750km^2 (Figure 1). The area is marked by two distinct climatic conditions. The rainy season lasts usually from May/June to September/October depending on the rainfall pattern for the particular year. The mean annual rainfall is 1560mm. The dry season is usually heralded annually by the dry, cold Harmattan winds and occurs between November and March. After the departure of the Harmattan and in the absence of rain, the hot sunny season with temperatures exceeding 27 °C sets in (Balogun, 2003). The mean annual temperature of the area is 20 °C.

The vegetation, which is predominantly of the Savannah-type, is characterised by giant grasses and few trees. Short feathery grasses form an almost continuous ground cover during the wet season. The Niger River and its tributaries drain the area. The height above sea level is about 100m along areas bordering the River Niger and its tributaries but rises to about 200-300m in other areas. The soil cover in the area is mainly lithosols and alluvial along River Niger areas and its tributaries. The Nupe Basin (Figure 1) is a gentle down-warped shallow trough filled with Campanian-Maestrichtian marine to fluviatile strata. The strata are believed to be more than 300m thick (Jones, 1955; Adeleye, 1971, 1973, 1974, 1976). Murat (1972) reported that the basin might be regarded as

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northwestern extension of the Anambra Basin, which is found in the southeast, both of which were major depocenters during the second major sedimentary cycle of southern Nigeria, in the Upper Cretaceous time

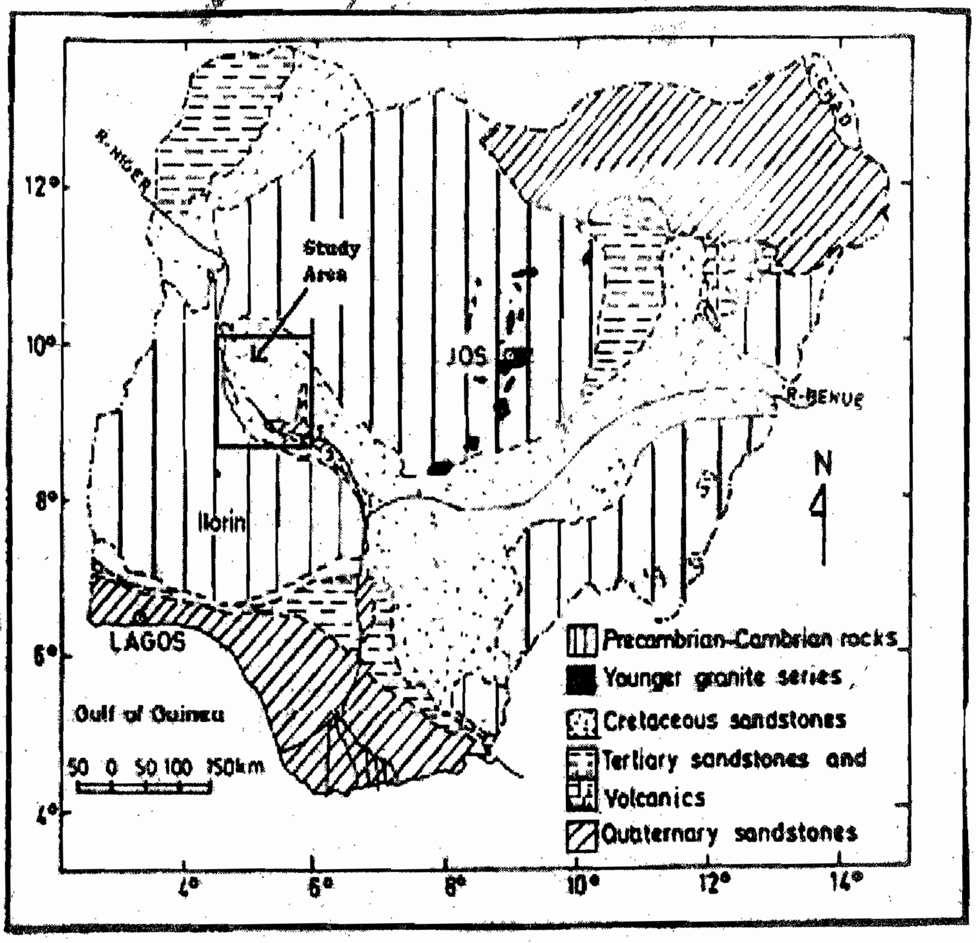


Figure 1: Geological map of Nigeria showing the study area

METHODOLOGY

Airborne magnetometer survey maps of total magnetic field intensity of sheets 160, 161, 162, 181, 182, 183, 202, 203, and 204 published by the Geological Survey of Nigeria Agency, Airborne geophysical series (1976) on a scale of 1:1000,000 were used. The contour interval is variable at 5, 10, 25 and 50 nT. The survey was carried out along a series of north-south lines with a spacing of 2km and an average flight elevation of 152m above the ground level. The average magnetic inclination across the survey area was from 9° in the north to 0° in the south. Since one common problem in automated data interpretation is to select digitisation spacing and minimum length of data profile in order to minimize aliasing error, selecting a digitisation interval of 0.875 km is found to be appropriate (Khurana, 1981). Therefore, the maps were carefully hand digitised at an equal spacing of 0.875km yielding 4096 values per sheet and 36,864 values for the 9 sheets used in this study. Although hand digitisation is the most elementary and least efficient method of digitisation, its accuracy when carefully done, compares favourably with other more sophisticated methods (Bath, 1974). The spacing interval of 0.875 km imposes a nyquist frequency of 0.57 km^{-1}.

In view of the simplicity in the trend of the magnetic field in the survey area, the regional anomaly was removed from the observed data by fitting a plane polynomial surface to the data. The study area does not have complex geology (Olasehinde, 1991) and it has spatial extent, therefore, it seemed adequate and reasonable to assume that the regional field is a first-degree polynomial surface (plane trend) (Olasehinde, 1991; Udensi, 2001). All the regional fields were, therefore, evaluated as a two-dimensional first-degree polynomial surface. The expression for the regional field of the study area is therefore, calculated and given as (Nwankwo, 2006):

$$g(x, y) = 7836.3 + 0.0241x + 0.0872y.$$

Residual data were then obtained as the deviations from the total intensity data from the fitted plane surface. Upward continuation technique was also utilized to suppress short wavelength components of the residual magnetic anomalies in the study area. The continuation was carried out at a height of 0.282 km.

The study area was divided into eighty-one overlapped blocks for the purpose of spectral analysis as shown in Figure 2. Each block covers a square area of 45 Km by 45 Km, which represents a square grid of 24 by 24 upward-continued residual field points. These were cosine-tapered before the radial spectrum was evaluated.

1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	10^0 00'
2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	
3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	
4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	
5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	
6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	
7.1	7.2	7.3	7.4	7.5	7.6	7.7	7.8	7.9	
8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9	
9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.8	9.9	$8^0$30'

4^0 30' 6^0 00'

Figure 2: Diagram showing overlapped blocks of the study area used for power spectral analysis. Gray numbered blocks do not have data.

RESULTS AND DISCUSSION

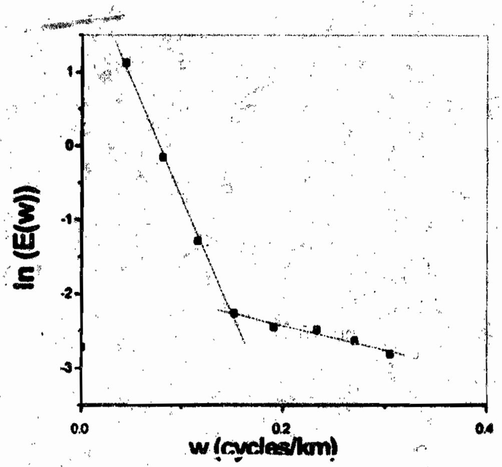
Graphs of the logarithms of the spectral energies against frequencies obtained for the various blocks were obtained. Some of the graphs are shown in Figure 3. Two linear segments could be drawn from each graph. The gradient of each linear segments were evaluated and the equation,

$$h = -\frac{m}{4\pi}$$

(Spector and Grant, 1970; Hahn et al, 1976), was used to calculate the depths to the causative bodies (deep and shallow sources); where h and m are the depth and gradient respectively. The deeper sources depth varies from a thickness of 0.52 to 4.38 km while the shallow sources depth varies from a thickness of 0.24 km to 1.74km. Contour maps of the deeper and shallow depths were drawn and are shown in Figures 4 and 5 respectively.

Two sources account for the first depth derived from the spectral evaluation. The first is magnetic sources on the surface of the basement complex bounding the Nupe basin. The second and more important sources are the magnetic rocks that intrude the sedimentary formation and even sometimes extrude on the surface. The second layer may be attributed to magnetic rocks that intrude on the basement surface. Intra-basement features like fractures and faults are other sources of the second layer. The second layer depth thus represents the depth to basement in the area and this depth has average of 2.16 ± 0.94 km within the study area. This also represents the average thickness of the sedimentary formation overlying the basement complex within the study area. The maximum elucidated depth is 4.38km in the study area. An average depth of 0.71 ± 0.35 km for shallow sources is also obtained.

The spectral average depth of 2.16 ± 0.94 km and maximum depth of 4.38km determined within the study area tend to be in agreement with the results of Adeniyi (1985 and 1986), which suggested that the sedimentary pile in the Nupe Basin, is up to 3.5km thick; and that of Garde and Sunmonu (1999) who elucidated a maximum thickness of 3.0km and an average of 1.81km in the Bida portion of the Basin. Also, Sunmonu et. al. (2000) revealed that the average thickness in the southeastern part of the basin is 2.31km with a maximum depth of 3.40km. The depth estimate also agrees with the results of Kogbe (1989) that the total thickness of Cretaceous sediments in the eastern portion of southern Nigeria is about 3.3km. The sedimentary formation of the Nupe basin is of this age though not in the same tectonic region. Again, Udensi et. al. (2001) revealed that the average thickness is about 3.39Km. However, Ojo and Ajakaiye (1976) stated from interpretation of gravity measurements within the Basin that the maximum possible thickness of the Cretaceous sediment is nowhere considered to exceed 2km. Since spectral depths are mean depths of ensembles of blocks (Spector and Grant, 1970), they are influenced by all the elevations and depressions within the surveyed area, which could therefore exceed 2km. Moreover, the deductions of Ojo and Ajakaiye (1976) emanated from gravity modelling of individual bodies. In this case, there are depressions depicted by reservoirs. Therefore, the difference in depth may thus be appreciated (Udensi, 2001).



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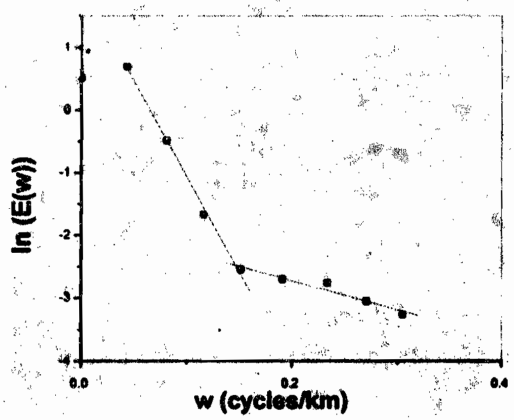

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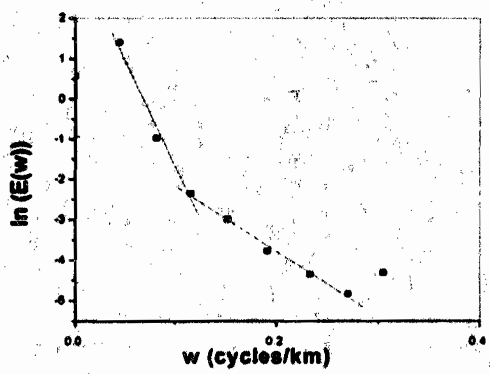

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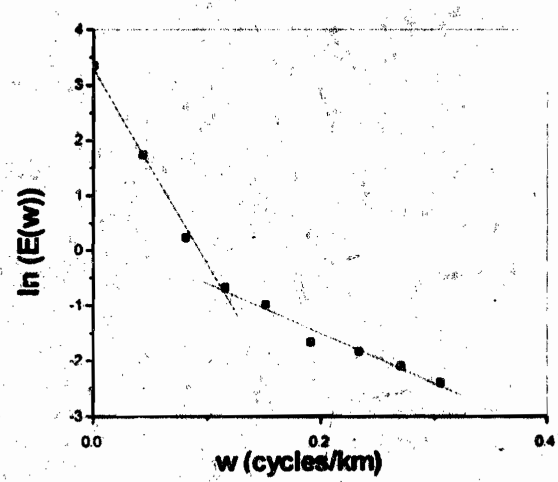

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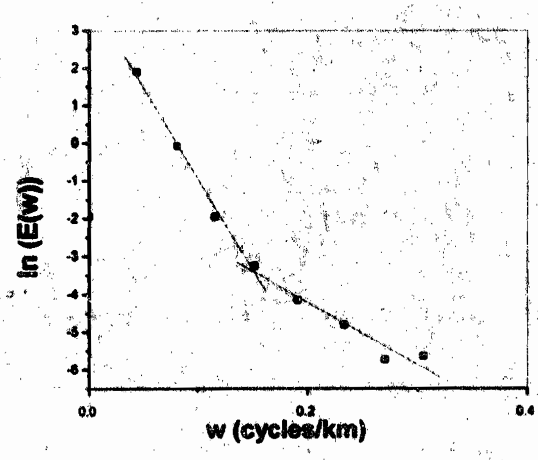

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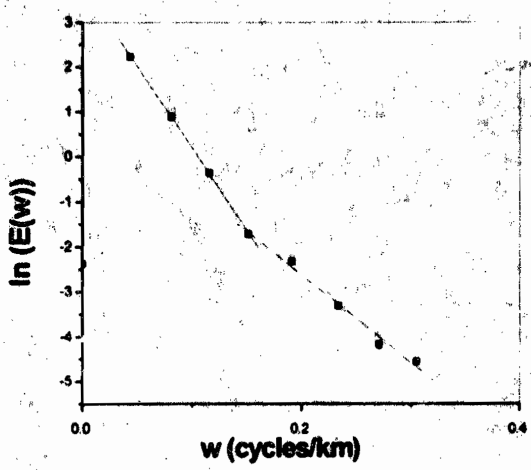

block 6.8

Figure 3: Power spectra for depth estimations of some of the blocks

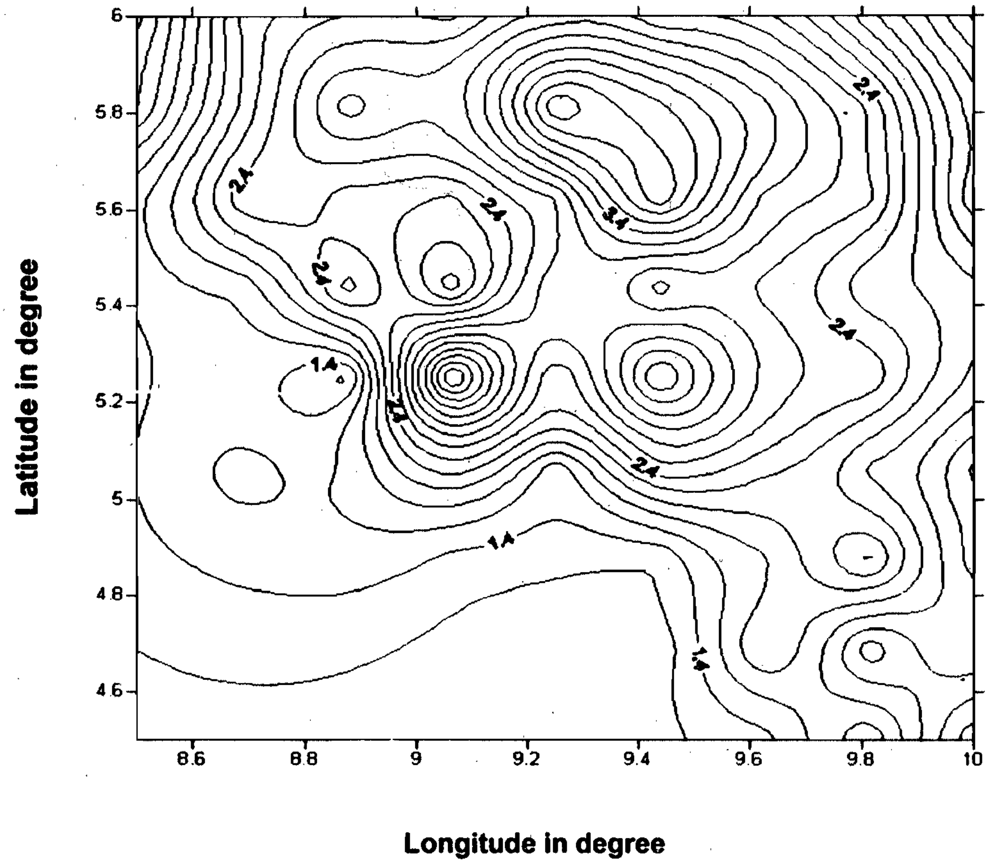

Figure 4: Basement Structure depths contour map of the study area for deeper sources. Contour interval is 0.2 km.

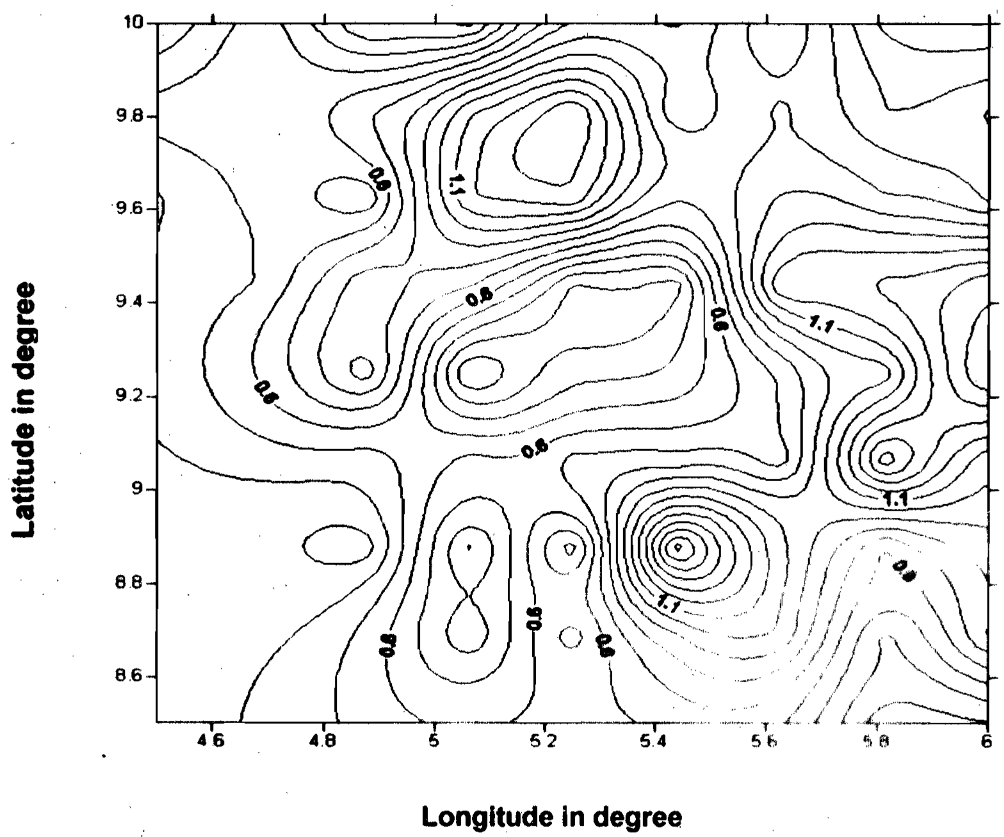

Figure 5: Shallow magnetic source depths contour map of the study area. Contour interval is 0.1 km

The depths to magnetic basement increase from the edges to the central portion of the study area (Figure 5). Areas with not too deep shallow sources depths are found in the central portion of the study area, while south eastern portion houses the deepest shallow sources. Three sedimentary reservoirs are also depicted in Figure 5. One lies to the north-central portion while the other two are in the central portion of the study area. The reservoirs contain sediments having thickness not less than 3.6km. Such sedimentary thickness of this size may be a target for petroleum exploration. Such area in the southern part of the Nupe Basin was identified by Braide (1992) with possible hydrocarbon potential. He stated that the rocks were deposited in a non-marine environment and hydrocarbon detection tested positive, though not strong. Other organic geochemical data indicate that some surface samples, although thermally not very much matured, are close to the oil generation window. It is likely that more deeply buried samples could be thermally matured. Therefore, the areas in the northern Nupe basin with sedimentary thickness of 3.6km and above maybe recommended for further investigation.

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