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Research Article

AEROMAGNETIC STUDIES OF SHEET 248, 249,268 AND 269 LOWER BENUE TROUGH, NIGERIA

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ABSTRACT

Aeromagnetic map interpretation of the study area was done qualitatively and quantitatively using four Geological Survey of Nigeria (GSN) maps, namely sheet number 248, 249, 268, 269. From the interpretation two, belts of magnetic highs were identified in the northern and southern parts of the magnetic map bounding a central basement depression (structural low) of width 72km. The trends of the magnetic features are sub-parallel to the basement element of the Benue Trough, which trends in the northeast to southwest direction. Both subtle and linear features were observed cutting across and disrupting the general structural grain of the anomalies on the aeromagnetic map. They are suggestive of some major features like faults, fractures and shear zones. They were displayed in the form of discontinuity, disruption or displacement of anomaly pattern. The central basement depression (structural low) could be a prospect zone based on the depth estimate.

INTRODUCTION

GENERAL OVERVIEW AND LOCATION OF THE STUDY AREA:

The area covered by the Geological Survey of Nigeria (G.S.N.) aeromagnetic maps of sheet numbers 248, 249, 268 and 269, occupies part of the lower Benue Trough (Fig.1). It is located between longitudes $7^0$00'E to $8^0$30'E and latitudes $7^0$00'N to $8^0$00'N with an area extent of approximately 13,128 square kilometers. The Benue Trough is a major tectonic feature of West Africa, trending in the NE-SW direction and resting uncomformably upon the Precambrian basement. It is commonly subdivided into three main regions of upper, middle and lower Benue Trough. The lower Benue Trough which is the area of concentration of this study is about 250km wide and it includes the Anambra Basin, the Abakaliki Anticlinorium and the Afikpo Syncline (Benkhelil, 1988).

OBJECTIVES OF THE RESEARCH WORK

The objectives of this study are:

To have an understanding of the geology of the basin (study area) by calibrating the magnetic data with known geology. To delineate significant structures that may have a relationship to known mineralization or favourable combination of rock types. To delineate and establish depth to the basement which in turn gives a clue to the sedimentary thickness of the study area. To distinguish possible ultra sedimentary volcanic areas. To produce simple geologic maps of the basement rocks containing all the interpreted features above. To recommend possible area of hydrocarbon potential, if any.

STRATIGRAPHY:

From the interpretation of magnetic anomalies of the Benue Trough, Ofoegbu (1984) estimated the thickness of sedimentary rocks in the lower Benue Trough to vary between 0.5km and 7km southwestward. This thickness increases to the south from the north attaining its maximum thickness of 12km in the central Niger Delta. The sedimntary sequences deposited on the Trough belong to seven geologic formations.

The Asu River Group: The Asu River Group comprises of bluish black shales with minor sandstone unit. The shales are typically fractured and weathered to needle shaped bodies at the surface. Sandstone horizons are minor in the extreme south but tend to increase northwards.

This is the oldest sediment overlying Precambrian Basement complex. They are non-fossiliferous intra-continental deposits, that accumulated in basins and old rivers formed on the surface of the crystalline Archean rocks. This shale is associated with intermediate pyroclastic flows and volcanic conglomerates which were interpreted by early workers as products of late Cretaceous volcanism. Around Abakaliki, the shales are associated with pyroclastic rocks (Hoque, 1984). The close association of the Albian Asu River Group with alkaline mafic lavas during the early stage of mantle plume evolution might possibly account for a high magnetic susceptibility of these sediments.

The Eze-Aku Shale: The Eze-aku shales consist of thick flaggy calcareous and non-calcareous shales, sandy or shelly limestones, and calcareous sandstones. It has the Amaseri, Makurdi and Tobi sanstones as major sandstone facies. This formation was deposited unconformably upon the folded Asu River Group, during the late stage of the plume theory.

The Awgu Shale: The Awgu shale which was deposited in the Santonian stage, consists of marine fossiferous grey-blue shales associated with subordinate limestones and calcareous sandstones. It contains the Agbani sandstone facies. No study has been done to establish the magnetic significance of this formation.

The Nkporo Shale: The Nkporo shale consists of blue or dark gray marine shale in the southern part of the sedimentary basin with occasional thin beds of sandy shale and sandstone in south- west part of Benue valley. The Nkporo shale is 340 meters thick (Simpson, 1954), but the Geological Survey of Nigeria (GSN) gave the thickness of 1830 meters. However, Reyment (1965) gave a thickness of 1000 meters. According to the Geological Survey of Nigeria, the Nkporo shale is of Santonian age (upper).

Mamu Formation: The overlying Mamu Formation (Lower Coal Measures) consists mainly of sandstones, carbonaceous shales, sandy shales and some coal seams. It is known to be up to 460 meters thick at Awgu, 610 meters between Awgu and Enugu and 90 meters at Okigwe (Simpson, 1954).

The Mamu Formation is Maestrichian age and it is best exposed at the road cut above the Onyeama Mine in the Iva valley at Enugu and the escarpment at Leru on the Enugu-Port Harcourt expressway.

Ajali Sandstones: The Ajali sandstone consists of friable white crossbedded sandstones with thin beds of white mudstone near the base; also a large scale of cross bedding is common with dips as high as 20^0 (Nwajide and Reijers, 1996). The thickness is highly variable. Simpson (1954) quoted a thickness of 12-15 meters. Between Enugu and Ekana the thickness is 250ft and in the north-west of Enugu, the Ajali sandstone could be over 520 meters (Nwajide and Reijers, 1996). The Ajali sandstone is of Maestrichian age.

Nsukka Formation: The Nsukka Formation is stratigraphically synonymous with the Upper Coal Measure (Murat, 1972; Dessauvagie, 1974). This Formation is marked by the deposition of carbonaceous shales, sandstones and some thin coal seams. The age of this formation ranges from Maestrichtian to Paleocene (Simpson, 1954; Reyment, 1965).

Imo Shale: The Imo shale occurs extensively within the Anambra basin. This sand comprises texturally mature quartz arenites, interbedded within deep water marine shales which suggest that they may represent lowstand erosion turbidites on the basin floor or edge. This turbidites do not have any magnetic significance.

Nanka Formation: Nanka sand consists of mature medium to course-grained quartz arenites underlying an area 1000 square kilometers straddling Imo and Anambra States (Nwajide and Reijers, 1996). It is well over 300 meters of thick sand at the lowermost Eocene as could be seen from palynomorphs.

METHOD OF STUDY

Data: Four Geological Society of Nigeria (GSN) total intensity aeromagnetic map sheets were used in this study figure 1, namely: Ankpa (269), Dekina (248), Loko (249) and Angba (268). The airborne geophysical survey was flown and compiled by Fairey Surveys Ltd. in 1975 on behalf of the Geological Survey of Nigeria (GSN).

Total magnetic field intensity maps were presented on a scale of 1. 100,000 with a normal flying altitude 500 feet above sea level. The flight line direction was $150^0/33^0$ with a tie line direction $60^0/240^0$. A nominal flight and tie line spacing of 2km and 20km, respectively, were used during this operation. Regional correction based on IGRF epoch date of 1/01/74 were used to obtain general correction of 1.66 nT per km to the north and 1.03 nT per km to the east. The average magnetic inclination (magnetic latitude) used in the survey area varied from – 3.24 in the north to – 14.22 in the south.

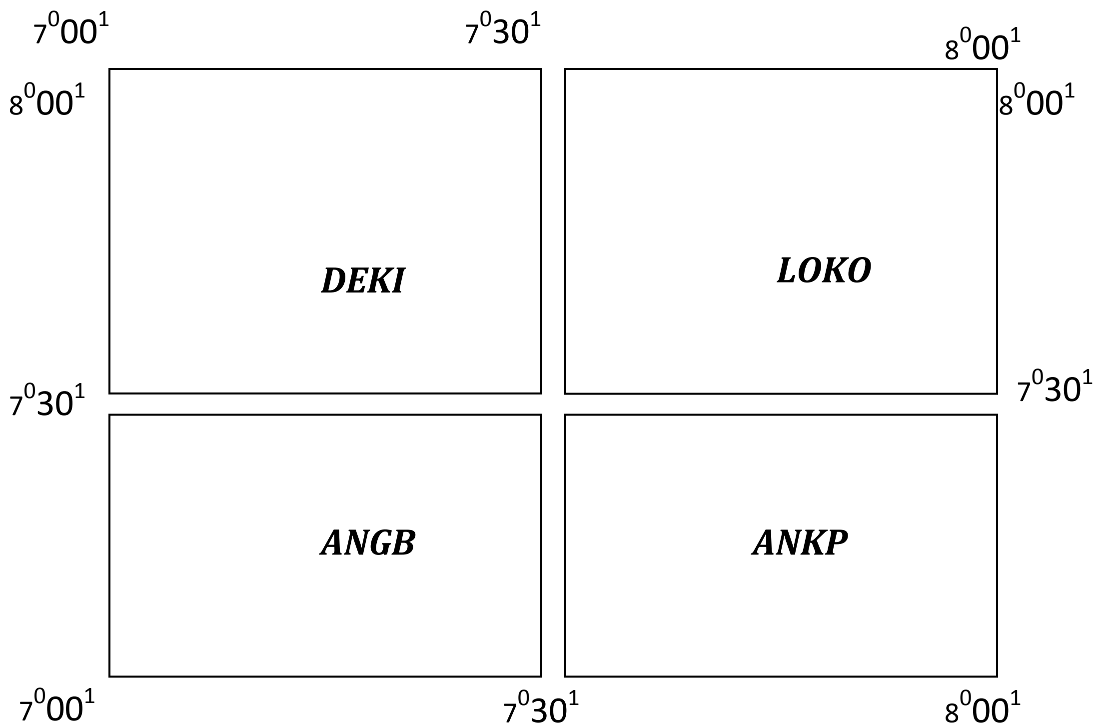


Figure 1: Aeromagnetic Sheet numbers and their coverage towns.

QUALITATIVE INTERPRETATION:

The qualitative interpretations adopted are in three stages:

- **Stage 1:**

Systematic colouring and declination of magnetic zones on the contour map. This is based on the magnetic texture, character and intensity of the anomalies.

- **Stage II:**

The delineated zones are analysed based on the shape and the magnetic character of each body, this is done by studying the shape and amplitude of the magnetic profiles over the bodies. The division of magnetic contour map into a number of zones is done to simplify the handling of the thousands of individual anomalies of which the magnetic contour map is composed. Most anomalies are included within the following five groups of simple sheet, complex zones, dislocations, superficial layers, equidimensional bodies.

QUANTITATIVE INTERPRETATION:

In spite of the qualitative methods employed in the interpretation, a quantitative method of interpretation was also carried out by the use of Horizontal Slope Distance (HSD) and the Half Maximum Width (W) (Vacquier, Steenland Henderson and Zeitz, 1951). These methods gave estimates of Depth, Width, Susceptibility value and the Amplitude of anomaly. In each method, it was assumed that the causative bodies were uniformly magnetized, flat semi-infinite. A thin dyke model was assumed.

RESULTS AND DISCUSSION

DESCRIPTION OF MAGNETIC ZONES:

Zone B:

Zone B occupies the central portion of the study area and encompasses about 45% of the entire study area. It is characterized by magnetic anomalies ranging from 7680 nT to 8020 nT. Within this zone are found major towns like Ejule, Ayangba, Ankpa, Oshigbudu, Bopo, Ofugo, Egume, and Adoka. This zone is generally characterized by smooth contours and low magnetic relief, suggesting greater basement depth. There are two main anomalous bodies (B_1 and B_2) found in the uppermost part, that is, northwest of these zone. These anomalies are elongated, elliptical in symmetry with high relief. Anomaly B1 trends in the E-W direction while anomaly B3 trends NE-SW. These two anomalies were probably in lateral continuity or they are of the same magnetic bed prior to the faulting that separated them. The broadening of the contour intervals toward anomaly B3 indicates that it is the down-thrown block. Beyond these anomalies and towards the east (Ankpa, Adoka, Bopo, Ofugo), the contours are smooth and regular, with low relief and long wavelength. This is indicative of a greater basement depth in this area. This zone is underlain by upper coal measure, falsebedded sandstone, Nkporo shale group, lower coal measure and Awgu Ndeabor shale group. The low relief and broad gradient of the magnetic contours can be explained in terms of basement crystalline rocks. Again, the sedimentary rocks here are not known to have any magnetic significance. Thus, the anomalies in this part of the zone are a reflection of the basement rock.

At the south western corner of zone B is also observed a linear magnetic feature marked B_2. This anomaly is linear and elongated, and trends in the NE-SW direction. The magnetic texture of this anomaly which broadens NW indicates that it is probably caused by deep-seated intrusive feature. This anomaly is located around Idah.

Anomalies B_1 and B_3 which have high magnetic relief and steep gradient are interpreted to be caused by intrusive at shallow depth. These anomalies can be correlated with the outcrop of meta-sediments/volcanics towards Ajaokuta.

Zone C:

Zone C is located in the southern portion of the study area. It covers about 28% of the entire study area. The major towns here are Angba, Ogugu, Obokolo, Ingele, etc. This zone is characterized by regular and smooth magnetic contours with very few linear magnetic anomalies (C_1, C_2, and C_3). The total magnetic intensity ranges from 7670 nT to 7900nT. The trend of the anomalies here is E-W with few subtle structural features trending NE-SW. These long linear magnetic anomalies appear to be connected with the occurrence of dykes along fractured basement. This can be seen from the broad nature of the contours which is suggestive of deep basement.

PATTERN BREAKS:

Both subtle and bold linear features were observed cutting across and disrupting the general structural grain of the anomalies on the aeromagnetic map (fig. 2). They are suggestive of some of the major features like faults, fractures shear zones etc. They are displayed in form of discontinuity, disruption, or displacement of anomaly patterns. These were recognized through a number of phenomena, which include:

(a) Regions of magnetically flat or quiet zones, which exhibit characteristic linear anomalies. This anomalies pattern is conspicuously displayed around Oshigbudu, Adoka, Ankpa, and Ayangba (Mf_{11}, Mf_{13}, Mf_{14}, Mf_1). These pattern breaks may reflect deep weathering of the basement rocks underlying the area.

(b) Changes in wavelength, gradient and relief of the anomalies patterns across each of the zones (Mf_8, Mf_{17}, Mf_{18}). This is suggestive of the varying basement depths in the zones.

(c) Apparent displacement of magnetic horizons along strike. This is seen in Mf_2, Mf_3,Mf_{12}. These are probably due to faulting.

(d) Boundary separating zones with different magnetic character (Mf_4, Mf_7, Mf_{16}). These are the major boundary faults demarcating the entire map into several NE-SW trending magnetic zones. Mf_4 separates zone A into two magnetic belts with different degrees of relief. This is interpreted to be a major basement fault. The area above Mf_4 in the north western part of zone A is characterized by intense magnetization and concentration of magnetic linear anomalies while the zone below it is magnetically smoother. Mf_7 is the boundary fault separating zone A from zone B. It trends in the NE-SW direction and runs across the entire study area.

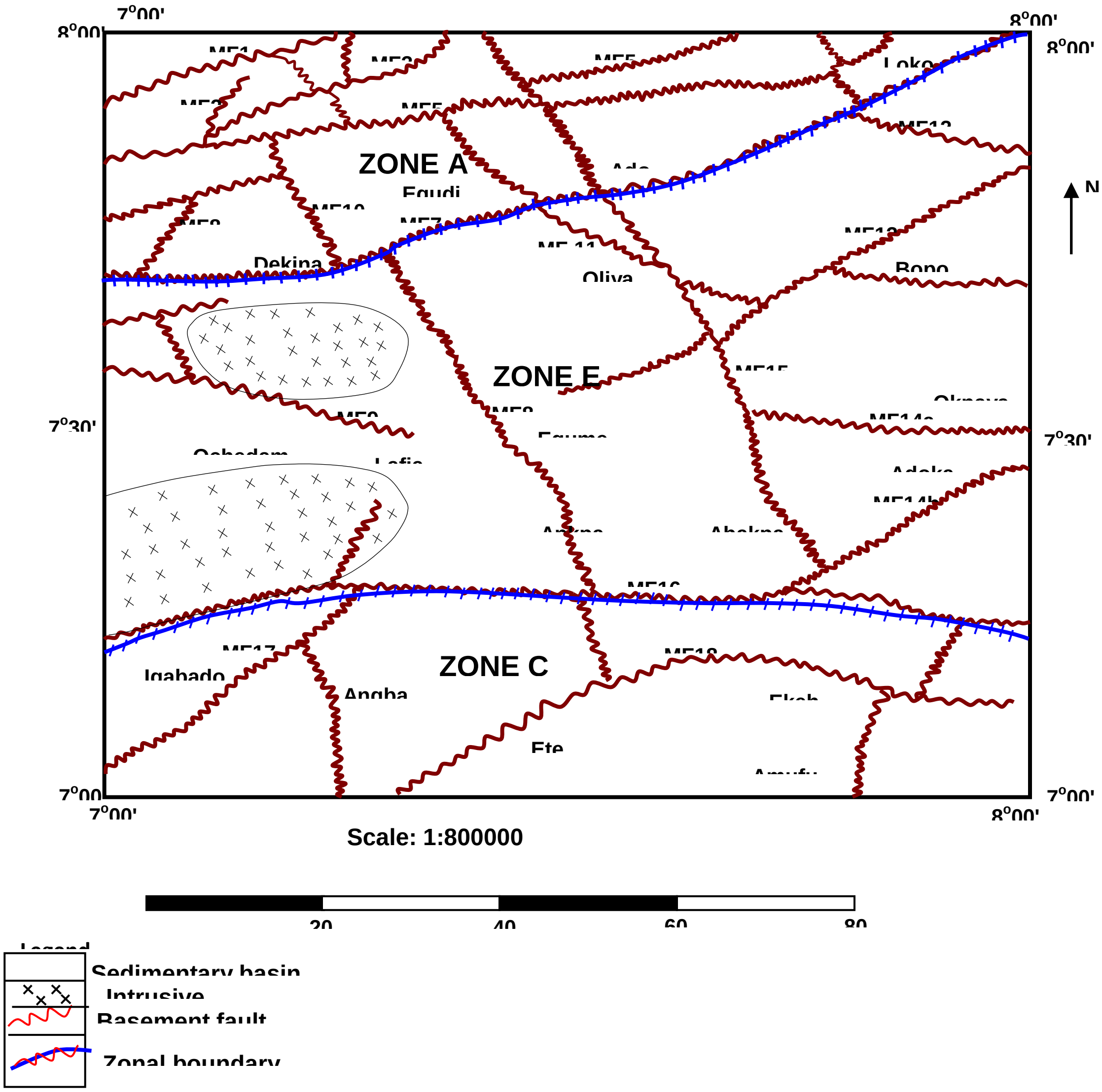
MF_{16} on the other hand, is the boundary fault separating zone B from zone C. It is recognized on the aeromagnetic map as a zone or belt separating zones with different degrees of relief. It separates the broad magnetic gradient observed in zone B from the steeper gradients of zone C. This boundary fault trending NE-SW, the trend of the major anomalies, is interpreted to be induced or controlled by basement tectonics.

Faults which are recognized as apparent displacement or truncation of magnetic beds along strike (Mf_2, Mf_3, Mf_6, Mf_{10}, Mf_{14b}) are also interpreted as faults since they strike in the same direction as the basement features.

There are also other pattern breaks which trend in the NW-SE direction, opposite the trend of basement features. These dislocations or pattern breaks are interpreted to be confined within the sedimentary cover. They may not have been induced by basement tectonics since their direction is different. They are, therefore, interpreted to be due to sedimentation, or changes in sediment type or unconformity. These pattern breaks are represented by Mf_8 and Mf_{15}. Mf_8 is seen as truncation of magnetic horizons. Mf_{15} is recognized as termination or total disappearance of magnetic beds along strike. It coincides with the position of the lower coal measure, and may represent the changes in sedimentation or sediment types across the study areas.

INTRUSIVES:

Intrusives were recognized in the study area (fig. 2). These were recognized by the magnetic pattern of the anomalies. However, these identified intrusives were not mapped geologically but were inferred in this study from the occurrence of meta-sediments/volcanic outcrops in the adjacent areas to the study area. These intrusives are however concealed under sedimentary cover in the study are



The : The Geologic equivalent of the magnetic anomalies

MAGNETIC SUSCEPTIBILITY:

Table 1 shows the results of the calculated apparent susceptibilities which range from 0.0012 to 0.0094 cgs unit. The susceptibilities of different rock types as presented by Sherift (1982). However a relatively simple relation between the rock type and the magnetic property can be formulated. Intermediate to acid rocks are moderately magnetic, while most sedimentary rocks and acid igneous rocks are weakly magnetic (Sherift, 1982).

X-section anomaly	Magnetic amplitude (NT)	Magnetic susceptibility (CGS Unit	Width of anomaly (KM)	H.S.D 1.3X (km)	½ max width (0.5xw)Km	Average depth (km)	Real average depth (km)	Zones
A_1	40	0.0019	0.70	2.08	2.40	2.20	2.24	ZONES A
A_2	140	0.0065	0.70	2.08	2.80	2.44	2.29	
A_3	60	0.0028	6.70	2.08	2.00	2.04	1.89	
A_4	40	0.0012	1.64	3.12	5.60	4.36	4.27	
B_1	120	0.00 56	0.52	1.56	7.20	4.38	4.23	ZONES B
B_2	140	0.00 42	1.64	3.12	7.60	5.36	5.21	
B_3	100	0.00 46	6.35	1.04	4.80	2.92	2.77	
B_4	120	0.0056	139	4.16	6.40	5.28	5.13	
B_5	40	0.0019	8.70	7.0	8.40	7.70	7.55	
B_6	40	0.0019	1.73	5.10	10.00	7.60	7.45	
C_1	140	0.00 65	0.70	2.08	6.80	4.44	4.29	ZONES C
C_2	200	0.0094	1.06	4.60	4.20	4.40	4.25	
C_3	200	0.0094	1.38	3.20	4.20	3.70	3.55	

Table 1: Computation of Anomaly Amplitude Susceptibility, Width and other Parameters for Depth Calculation.

DEPTH TO MAGNETIC BASEMENT MAP:

The purpose of this is to outline the extent and depth to magnetic basement from result of quantitative analysis of magnetic anomaly profiles. All the magnetic depth values obtained from the analysis of profiles were merged to produce the basement depth map (fig. 3). The basement depth map shows depth ranging from 2km within zone A, around Kwianbana and Egudi to over 7km in the western part of zone B, around Adoka, Ankpa, Abakpa and Bopo. Also regions of lows and highs are show in the map. The regions of highs are found in the upper part of study area (zone A) and the southern part (zone C). Zone B is seen to be a zone of structural low. Thus, the basement map shows the presence of basins resulting from differential displacement of fault blocks. The geologic model obtained from this basement depth map indicates that the study area is made of two regions of uplifts bounding a central depression. This depression is found in the central part of the study area covering Dekina, Ayangba, Ejule, Ankpa, Adoka, Abejukolo, Oshigbudu, Bopo, Ofugo and Ejume axis. This result clearly agrees with the structural frame of the Benue Trough. This trough is seen to trend in the northeast-southwest direction. The study area can therefore, be interpreted to be a graben bounded by two horsts in the north and south.

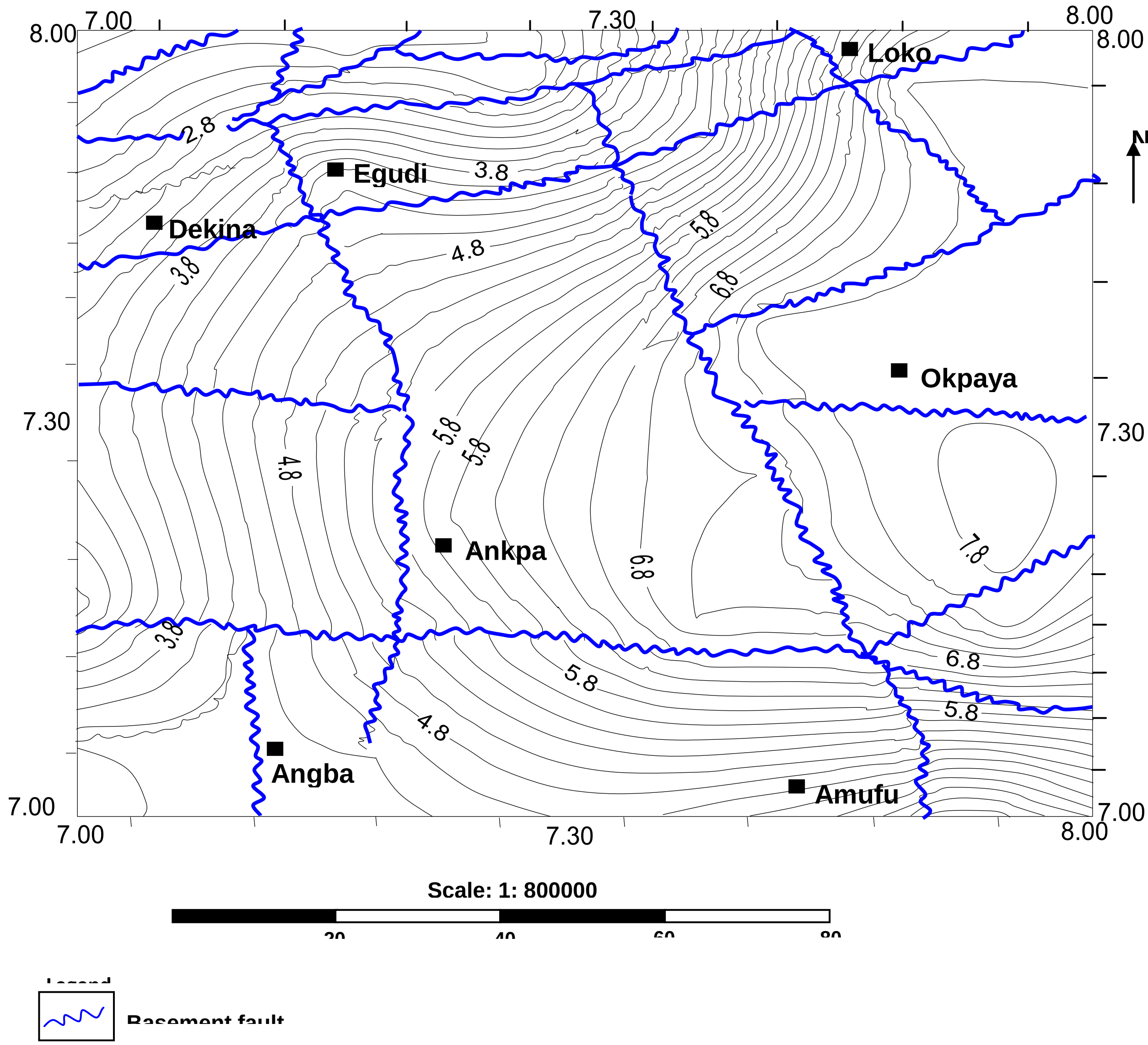


Figure 3: Depth contour map of the basement surface with associated basins

CONCLUSION

The aeromagnetic map of the study area is characterized by belts of magnetic highs and lows which are non-continuous. The trends of the magnetic features are sub-parallel to the trend of the basement elements of the Benue Trough.

From qualitative interpretation, one main sedimentary basin trending from northeast to southwest was identified. The width in this depression is about 7km. This basin is bounded in the north and in the south by two basement highs. Quantitative estimations used to determine depth to basement and amplitude of anomalies also revealed a central basement depression (structural low) bounded by two structural highs in the north and in the south. The trend of the basement magnetic features observed here is generally northeast-southwest. Other structural features were observed which were interpreted to result from changes in sedimentation, or unconformity. The magnetic structural features observed throughout the study area trend in the NE-SW direction. These NE-SW trending structural features or faults are interpreted to be basement induced.

From the analysis above, it is appropriate to conclude that the study area is a trough trending northeast-southwest bounded by two uplifted belts of shallow basement, thus forming a horst-graben-horst structure.

RECOMMENDATION

In view of the growing interest in the economic potential and structural significance of the lower Benue Trough, I recommend that further detailed aeromagnetic survey and interpretation be carried out on the study area, with the integration of gravity and seismic survey to reduce the uncertainties that accompany aeromagnetic survey. This will generate effective basinal assessment of the area.

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