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INTERPRETATION OF PSEUDO-GRAVIMETRIC DATA OVER THE MIDDLE BENUE TROUGH, NIGERIA.

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ABSTRACT

Two-dimensional spectral analysis of pseudo-gravimetric data has been carried out to determine the average sediment thickness in the Middle Benue Trough. The analysis show a two-depth model, with the depth to the deeper bodies varies between 1345 and 6530 meter while the shallower depth model varies between 444 and 1000 meters. The deeper source bodies represent the basement complex while the shallower bodies are indicative of the presence of denser intrusive. Two sub-basins were also identified from the analyses. From the Hilbert transformation, fracture zones trending NE-SW, NW-SE and E-W were identified. The results obtained compare well with those previously estimated from gravity and magnetic analyses in the study area.

Keywords: Middle Benue Trough, Pseudo-gravity, sediment thickness, structural trend

INTRODUCTION

The Benue Trough is a deep rift system whose development was closely associated with the separation of Africa from South America and the opening of the South Atlantic Ocean. The trough extends from the Niger Delta toward the northeast to join the Chad basin (Fig 1). The trough is about 250 km wide in the south and between 80 km and 150 km in the north while its overall length is about 800 km.

The area of study lies within latitudes 7° [illegible] 9° north and longitudes 8° 30′ E - 9° 38′ East and covers an area of about 16,400 sq.km in the Middle Benue Trough (Fig.1). The determination of sediment thickness above the basement, and delineation of major faults and structures from pseudo-gravimetric data and Hilbert transformation is expected to contribute to the better understanding of the Middle Benue Trough in particular and the Benue Trough in general.

TECTONIC SETTING

The structure of the Benue Trough is now fairly well known through numerous geophysical and geological investigations (e.g. Ajakaiye, 1981; Peters and Ekweozor 1982; Hoque and Nwajide, 1984; Ofoegbu, 1984; Fairhead and Okereke 1987; Nwajide, 1990; Ofoegbu and Onuoha, 1990; Nur et al., 1994). The main feature of the Benue Trough is an axial zone of basement uplift flanked by deep basins containing sediments (Fig. 1), while a detailed Geological map of the study area is shown is figure 2. Nwajide (1990) summarized the stratigraphic succession of the Benue Trough and is shown in Table 1.

According to Hoque and Nwajide (1984) the sediments in the trough consist mainly of mudrocks and sandstones with occurrences of

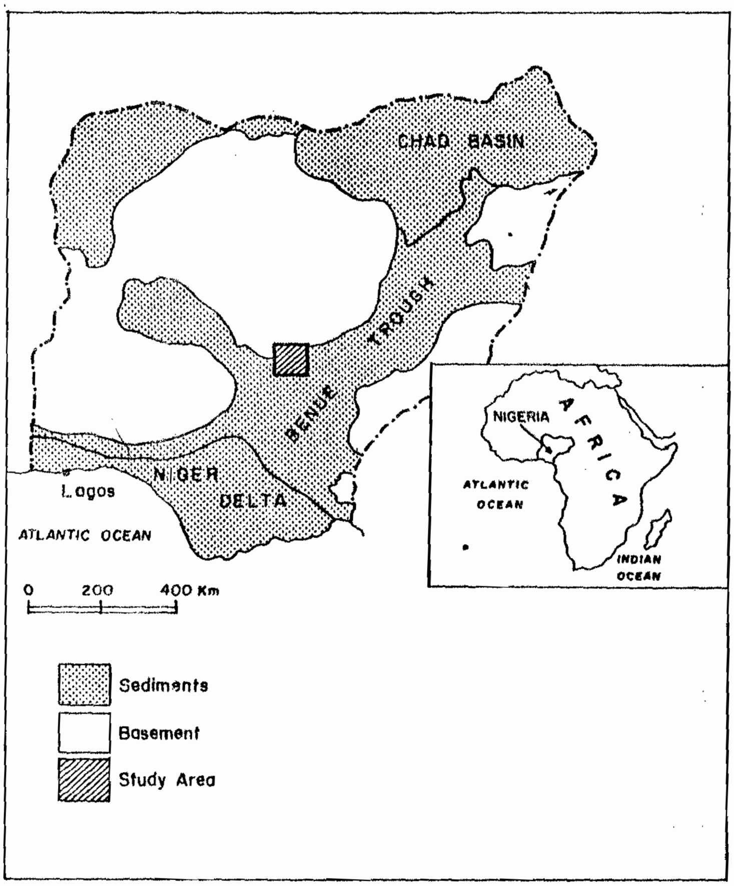

Fig. I: Map of Nigeria showing location of the study area

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carbonate and coal, and in several places there are intrusions of igneous rocks of intermediate to basic composition. The sediment thickness varies between 0.4 km to over 7 km (Ofoegbu, 1984 and Nur et el., 1994).

Ofoegbu and Onuoha (1990) in a review of geophysical studies in the Benue Trough reported that the crustal extension that took place during the formation of the trough ranges from 95-130 km for the Middle Benue and 65-78 km for the Yola arm of the Upper Benue. Artsybashev and Kogbe (1974) estimated crustal thickness between 22 and 37 km while Osazuwa et al. (1981) obtained estimates between 25 and 28 km.

DATA ANALYSIS

The aeromagnetic data for this work were originally acquired as controlled maps of total magnetic intensity on the scale of 1:100,000 complied by the Geological Surveys of Nigeria. The survey was conducted along a series of E-W profiles with a spacing of 2 km, and a nominal tie-line spacing of 20 km. The geomagnetic gradient was removed from the data utilizing the International Geomagnetic Reference Field (IGRF) formula epoch of 1st January 1974. The magnetic maps were digitized at 2 km and regional magnetic field was removed utilizing a multi-regression least squares analysis and the expression for the regional obtained was:-

$$T(x,y) = 7899.599 + 0.005x - 0.443y \quad (1)$$

where x & y are units of spacing.

The regional field values were subtracted from the observed data, and the obtained residual field over the study area is shown on Figure 3.

Pseudo-gravimetric anomalies

The use of pseudo-gravimetric transformation is regarded as a filtering process for short wave-length anomalies and helps to simplify the complicated magnetic anomalies. The transformed magnetic data into the corresponding pseudo-gravimetric anomaly provides an elegant means of comparing pseudo-gravity and magnetic anomalies over the same area and sometimes permits information to be derived about their causative bodies.

Several methods have been suggested for the computation of the pseudo-gravimetric field (e.g. Baranov and Naudy, 1964; Cordell and Taylor, 1971; Bott and Ingles, 1972; Baranov,1975; Savinskiy,1976; Tantrigoda, 1982; Ofoegbu, 1986 and Tantrigoda and Ofoegbu, 1989). The details of the mathematical formulae used for this study can readily be found Tantrigoda and Ofoegbu (1989).

The residual magnetic data figure 3 was

Table I. Summary of stratigraphic succession in the Benue Trough (After Nwajide, 1990)

	Age	Southern Benue Trough	Middle Benue Trough	Northern Benue Trough
	Eocene	Ameki Fm / Nanka Fm / Nsugbe Ss	Volcanics	Volcanics
			Keri - Keri Formation	
54.9	Paleocene	Imo Formation	Volcanics	Volcanics
65	Maastrichtian	Nsukka Formation Ajali Sandstone Mamu Formation	Lafia Formation	Gombe Sandstone
		Owelli Sandstone / Otobi Sandstone →		Lamja Ss / Gongila Fm / Fika Shale
73	Campanian	Enugu Formation / Mkporo Formation		
83	Santonian	Agbani Sandstone / Awgu Formation →		Numanha Fm / Gulari Ss
87.5	Coniacian			Sekule Formation
88.5	Turonian	Shale Units Agala Ss / Igumale Lst Amaseri Sandstone Nkalagu Limestone Shale Units Ogoja Sandstone	Makurdi Fm (incl. Wadatta Lst) Zurak Formation Keana Sandstone	Jessu Formation Dukul Fm / Gongila Fm
93	Cenomanian	Odukpani Formation Awi Formation	Awe and Uomba Fms / Kumberi Fm / Yolde Formation Arufu Limestone Yandev Limestone / Muri Ss / Bima Sandstone	
100	Albian	Okposi Formation Unnamed units Abakaliki Shale		
119 my	Aptian Barremian Hauterivian	Unnamed units	Pre-Bima Sandstone	
	Precambrian - Cambrian	Basement Complex		

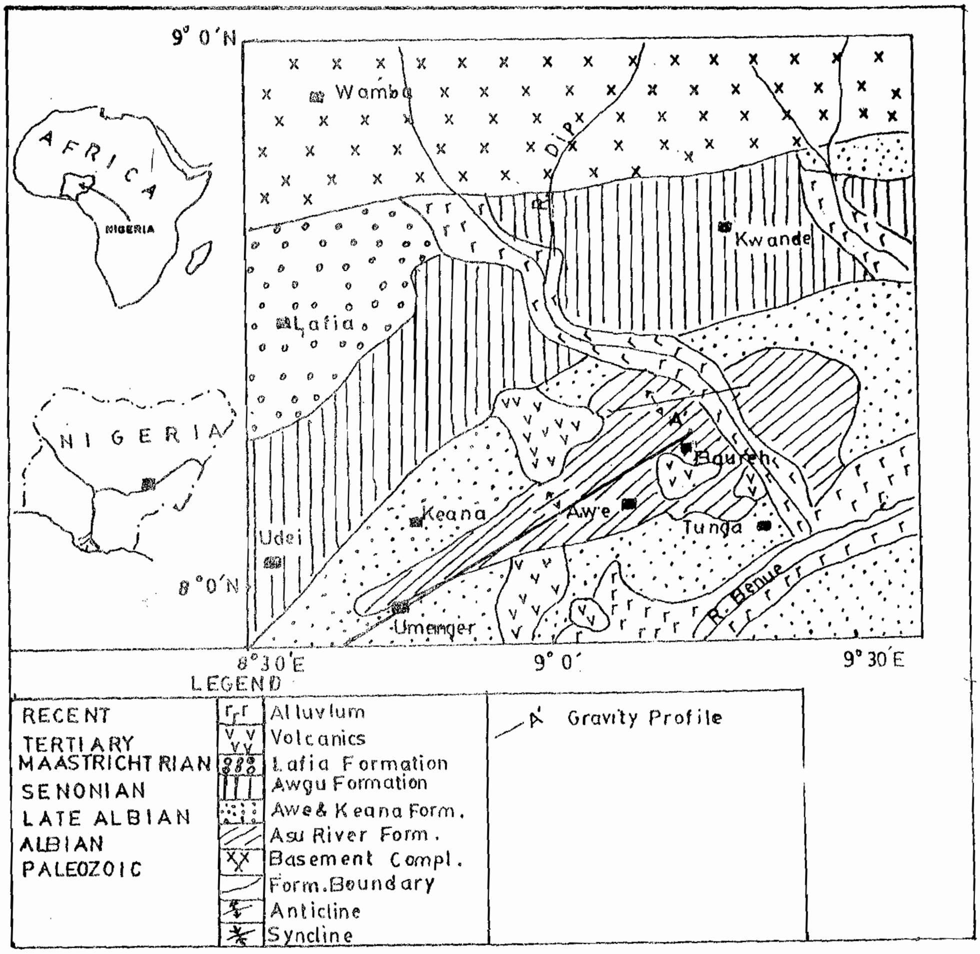

Fig. 2: Geological Map of the Middle Benue Trough
(After Geological Survey of Nigeria, 1984)

Table 2. Summary of depositional packages in the Central Benue Trough (After Nwajide, 1990).

Age	Depositional Sequence	Tectonic Regimes
Campanian-Maastrichtian	Paralic, marine and fluviatile onlap	New basin formation consequent on Santonian folding.
Turonian-Santonian	Paralic, marine and fluviatile;pyroclasti extrusion	Adjustment of basement fault blocks and drape folding.
Aptian-Cenomanian	Paralic, shallow alluvial fan and fluviatile	Graben formation i.e. rifting.

utilized as an input into a two dimensional pseudo-gravimetric transformation. The resultant pseudo-gravimetric values obtained from the analyses are shown in figure 4. In order to carry out spectral analysis, the calculated pseudo-gravimetric data of the study area was divided into sixteen blocks, and each block contains 16 x 16 data points. Table 2 summarizes the depth estimates from the analyses of the sixteen blocks making up the study area. More information about the spectral analysis could readily be found in Nur et al., (1994).

Hilbert transform.

In recent years, the Hilbert transformation has been shown to be useful for transformation of magnetic anomalies (Nabighian, 1972; Ram Babu et al.,1989 and Ofoegbu & Mohan 1990). Nabighian (1972) applied two-dimensional Hilbert transformation to compute the vertical derivatives of magnetic field from horizontal derivatives and vice versa.

Ofoegbu and Mohan (1990) presented a more simplified mathematical expression of 3-D Hilbert transformation for observed magnetic field anomalies. The present paper uses two-dimensional Hilbert transform and the mathematical expressions are well explained by Nur (2000).

The pseudo-gravimetric data figure 4 was used as input into a two dimensional Hilbert transform program, and the resultant amplitude spectra or analytic signal is shown in figure 5.

Table 3. Summary of depths for the sixteen blocks obtained from the spectral analysis of pseudo-gravimetric data over the Middle Benue Trough, Nigeria. (All depths D1 and D2 are in km).

Block 1 D1=0.725	Block 5 D1=0.705	Block 9 D1= 0.847	Block 13 D1=0.617
Block 2 D1=6.530 D2=1.000	Block 6 D1=5.279 D2=0.950	Block 10 D1=2.758	Block 14 D1=2.848 D2= 0.754
Block 3 D1=1.345	Block 7 D1=1.344 D2=0.444	Block 11 D1=4.263 D2=0.779	Block 15 D1=3.227
Block 4 D1= 1.531	Block 8 D1=3.205 D2=0.641	Block 12 D1=3.388 D2=0.685	Block 16 D1=2.219 D2=0.594

DISCUSSION OF THE RESULTS

Determination of sediment thickness in the Middle Benue Trough was obtained from spectral analysis of pseudo-gravimetric data. As shown in table 3 the computed sediment thickness in the study area varies between 1344 m and 6530 m. From the analysis two sub-basins, which contain more than 3000 m,

spectral analysis of pseudo-gravimetric data. As shown in table 3 the computed sediment thickness in the study area varies between 1344 m and 6530 m. From the analysis two sub-basins, which contain more than 3000 m, were identified. The first was found to have east-west direction and located at east of Lafia (Blocks 2 & 6). The second sub-basin with

Table 4. Summary of depths for different 16x16 blocks obtained from the spectral analysis of magnetic data over the Middle Benue Trough, Nigeria .(All depths D1 and D2 are in km).(After Nur. et al.,1994).

Block 1 D1 = 0.242	Block 5 D1 = 0.731	Block 9 D1 = 0.447	Block 13 D1 = 0.066
Block 2 D1 = 2.631 D2 = 0.800	Block 6 D1 = 3.283 D2 = 1.066	Block 10 D1 = 2.771 D2 = 1.212	Block 14 D1 = 2.514 D2 = 0.737
Block 3 D1 = 3.250 D2 = 0.800	Block 7 D1 = 2.132 D2 = 0.873	Block 11 D1 = 1.593 D2 = 0.658	Block 15 D1 = 2.086 D2 = 0.737
Block 4 D1= 2.696 D2= 0.554	Block 8 D1 = 3.252 D2 = 0.546	Block 12 D1 = 4.938 D2 = 0.642	Block 16 D1 = 2.645 D2 = 0.814

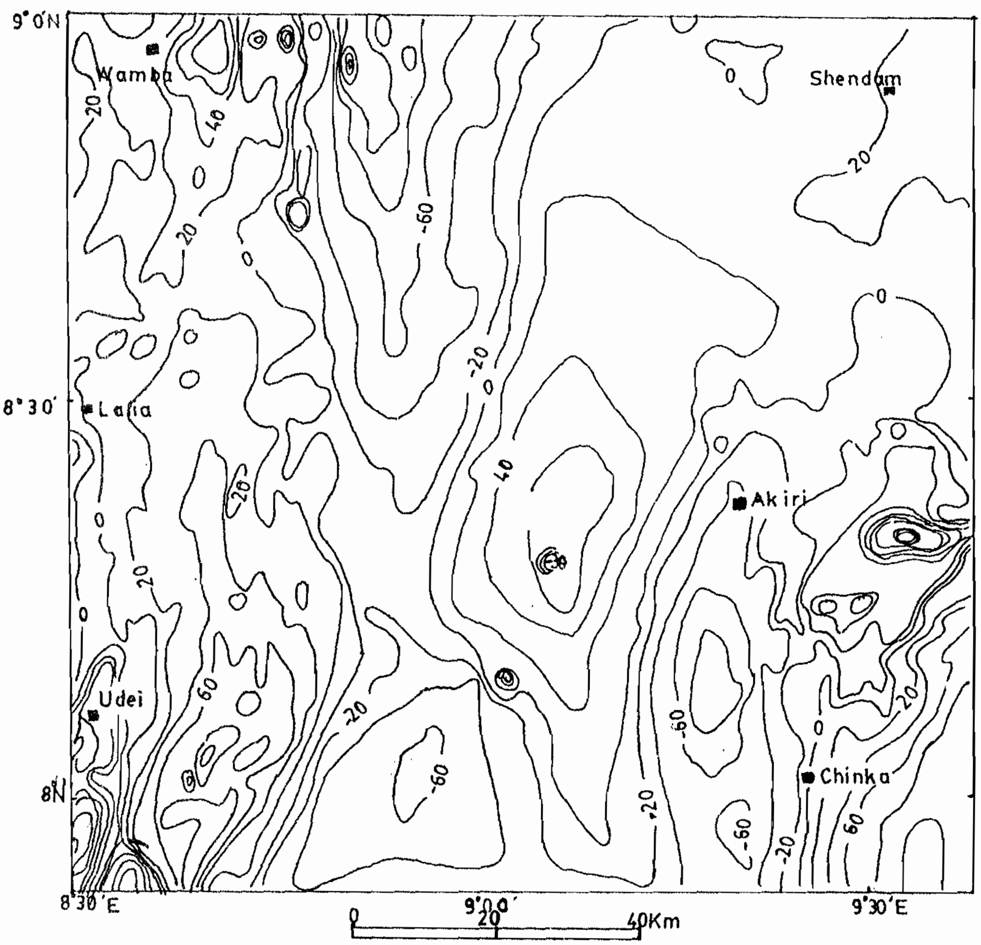

Fig. 3: Residual magnetic map over the Middle Benue Trough (Contour Interval 20nT)

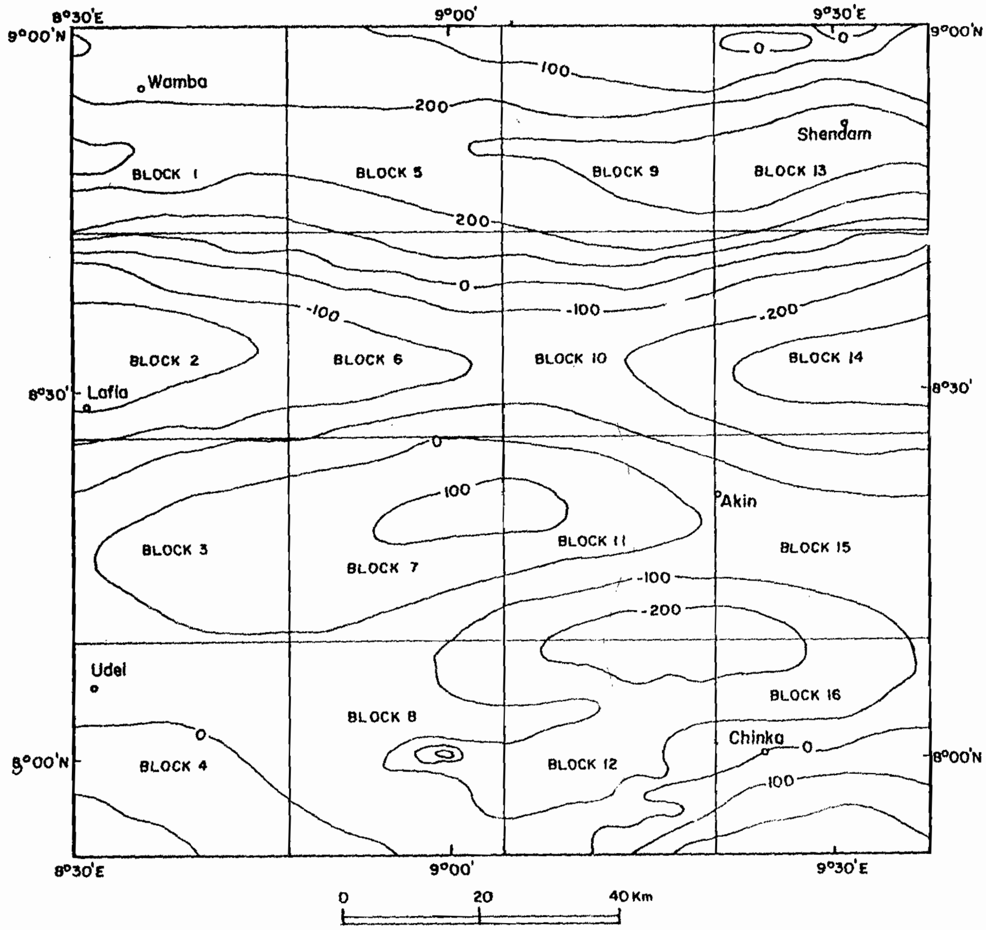

Fig. 4: Computed Pseudogravity map over the Middle Benue Trough
(Contour Interval 100 g.u./km)

northeast southwest direction and is located in the southwestern part of the study area (Blocks 8,11,12,14,15).

A comparison of the sediment thickness in the study area with those previously estimated from gravity and magnetic data analysis show good agreement. For example, Ajayi and Ajakaiye (1986) obtained sediment thickness that range from about 2000 meters to about 5800 meters. One of the profiles they interpreted passes in the southeastern part of this present study and is shown in figure 9. The location of the profile is shown in figure 1. From magnetic data interpretation, Nur et al., (1994) working in the same area have obtained sediment thickness that range from 1600 m to 4900 m. (Table 4).

The shallower sources bodies in the study area indicate the presence of intrusive bodies located either at shallow depths or on the surface. These shallow source bodies in the present study constitute about 50% of the whole area while Nur et al., (1994) from spectral analysis of magnetic data obtained 75% of two source depths. From the spectral analysis of the pseudo-gravity data there are two sub-basins separated by an uplifted basement ridge. This confirms the horst-graben structure of the floor, which was reported from different parts of the Benue Trough.

The contoured map (figure 5) shows the presence of remarkable features which agree quite well when compared with the geologic map (Figure 2). By looking at figure 5, there are minor edge effects in the western and eastern parts of the map. The most important is that the inferred NE-SW, E-W and NW-SE are clearly shown on the map. The NE-SW striking features may be interpreted as major fault zones such as the normal fault of Umenger (figure 6) suggested by Ajayi and Ajakaiye (1986). These inferred features could be considered as evidence of a multi-tectonic events of different times affected during the formation of the Benue Trough.

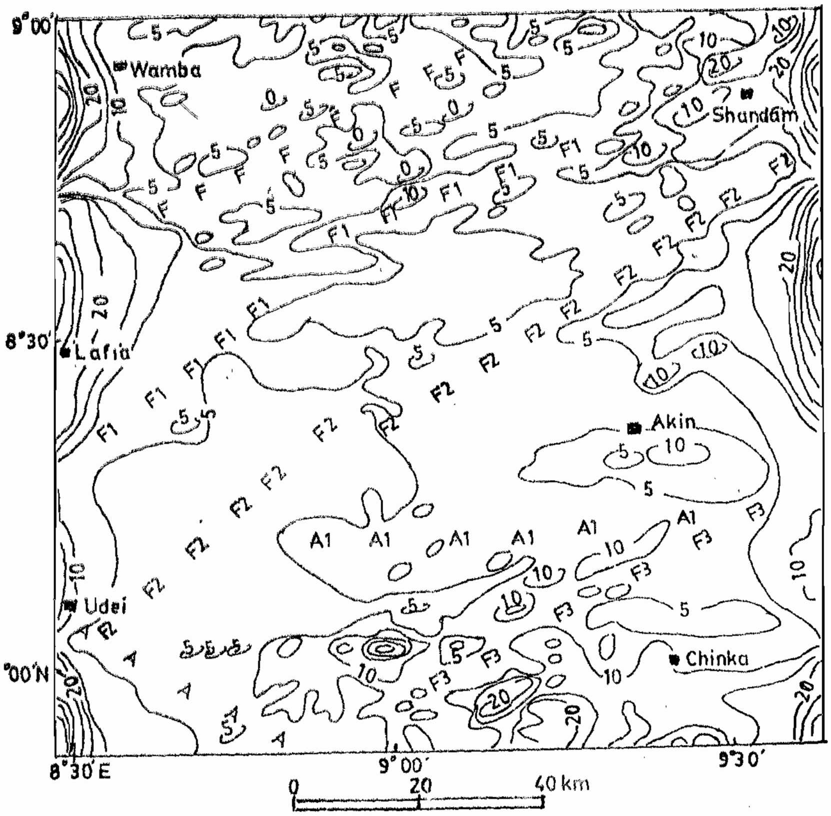

Fig. 5: Amplitude or Analyric Signal over the Middle Benue (Contour Interval 5 g.u./km)

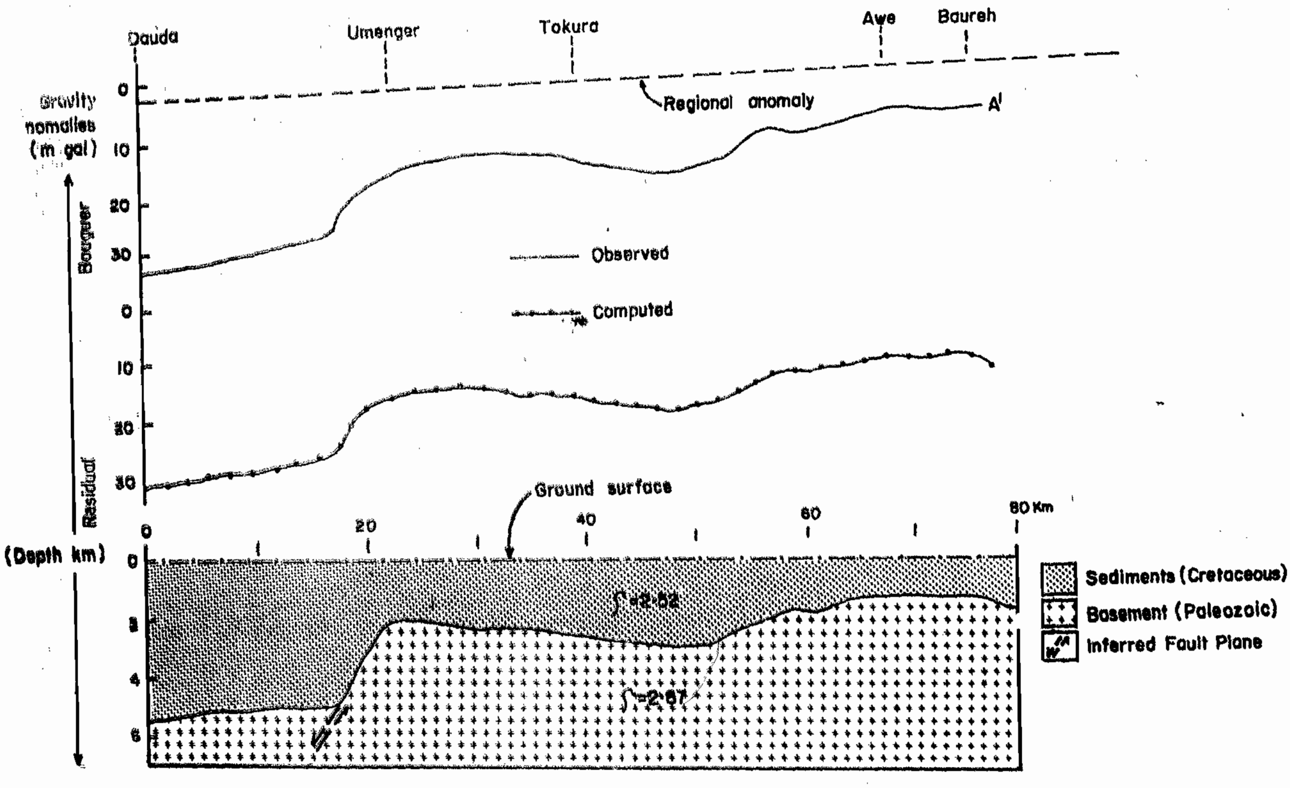

Fig. 6: Interpretation of the Dauda-Baureh Profile (After Ajayi and Ajakaiye, 1986)

A close look at the results obtained from this work reveals that the two sub-basins mentioned above would give an encouraging start for more detailed geophysical investigations, particularly seismic, for hydrocarbons in the Middle Benue Trough.

CONCLUSION

Depths to the Basement complex in the Middle Benue Trough have been determined from spectral analysis of pseudo-gravimetric data over the area. Sediment thickness varies across the area, with the thickest sediment cover found around east of Lafia and the central-southern part of the study area. Results from the present study show the irregular nature of the floor of the Middle Benue Trough with sub-basins being separated by horst-like features.

The results from the Hilbert transformation confirm the existence of lineaments of NE-SW, E-W and NW-SE directions resulting from the multi-tectonic events during the formation of the Benue Trough. The results obtained here are in agreement with results from previous geological and geophysical study in the area. From the point of view of sediment thickness alone, the sub-basin in the study area may provide good prospects for hydrocarbon exploration in future.

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