

## STRUCTURES DEDUCED FROM GRAVITY DATA IN THE LOWER NIGER BENUE RIFT (CONFLUENCE) AREA, NIGERIA.

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### Abstract

Based on a recent gravity data collected over the area, the Lower Niger and Lower Benue basins are interpreted to comprise five major structural zones. The locations, trends, extent and relationships between most previously known structures in the area are confirmed and detailed by the data. However, the structure mapped in the Ankpa area that lies between Abejukolo, Ayangba, Ankpa and Otukpo is a broad gravity minimum that suggests a sedimentary basin hereby referred to as "Ankpa Basin". On the other hand, the gravity high to the northeast of this anomaly which is centred around Umaisha in the Lower Niger, and which is referred to as the "Umaisha high" is interpreted as an intrabasement basic intrusion existing at shallow depth (2 km). Similarly, the gravity high around Abaji hereby known as "Abaji high" is interpreted as having a depth extent of about 2.0-4.2 km. Another broad linear positive gravity anomaly trending NE and located to the northeast of the Ankpa basin is interpreted as a basic intrusive ridge lying under the northern margin of the Lower Benue. Another previously unrecognized broad positive anomaly is located around Idah area. The anomaly is interpreted as a ridge structure made up of known highly metamorphosed or folded basement. To the southeast of the basin, the broad positive gravity anomaly hereby referred to as "Oju high" and which is located around Igumale, Agila and Oju areas is interpreted as part of the northern edge of the previously known Abakaliki anticlinorium. Thus, in detail, the study area from this work is interpreted to be a structural junction evolved by faulting, block subsidence, uplift, folding and intrusions.

**Keywords:** Gravity, Niger-Benue (Confluence) basin, rift, structures, evolution.

### Introduction

Briefly, Newton's Law of gravitation gives the vertical component of gravity  $gz$  given by:

$$gz = G(M/r^2)(z/r) = G(V\Delta\sigma/r^2)(z/r) \quad (1)$$

where  $G$  = Universal Gravitational Constant ( $6.67 \times 10^{-8}$  dynes)

$M$  = mass of the causative body

$=$  product of volume  $V$  and density  $\sigma$ .

Thus, since the depth of burial,  $z$ , of the body and its distance  $r$ , from point of observation are fixed, the gravity signature will vary with density or density contrast  $\Delta\sigma$ , between the material of the causative

body and those of its surrounding. Occurrences of such bodies are so detected, and are valuable in deducing geological structures in areas of investigation.

The lower NigerBenue (Confluence) area is a junction of two Cretaceous-Tertiary basins containing Mid-Albian to Tertiary sediments in the Benue Trough and Campanian to Maastrichtian in the Niger Trough. Each of the Niger and Benue Basin is about 1000 km long in NW and NE trending depressions, with surface widths of about 100 km and 130200km, respectively.

The lower Niger Benue area (Fig.1)

covered by the present gravity data is delineated by latitudes  $6^{\circ}30'N$  and  $9^{\circ}57'N$  and longitudes  $6^{\circ}00'E$  and  $8^{\circ}38'N$  and covers an area of about  $80500 \text{ km}^2$ . The

regional gravity survey was carried out by the authors, between 1988 and 1990, to investigate the regional structures and the underlying geology within the basins.

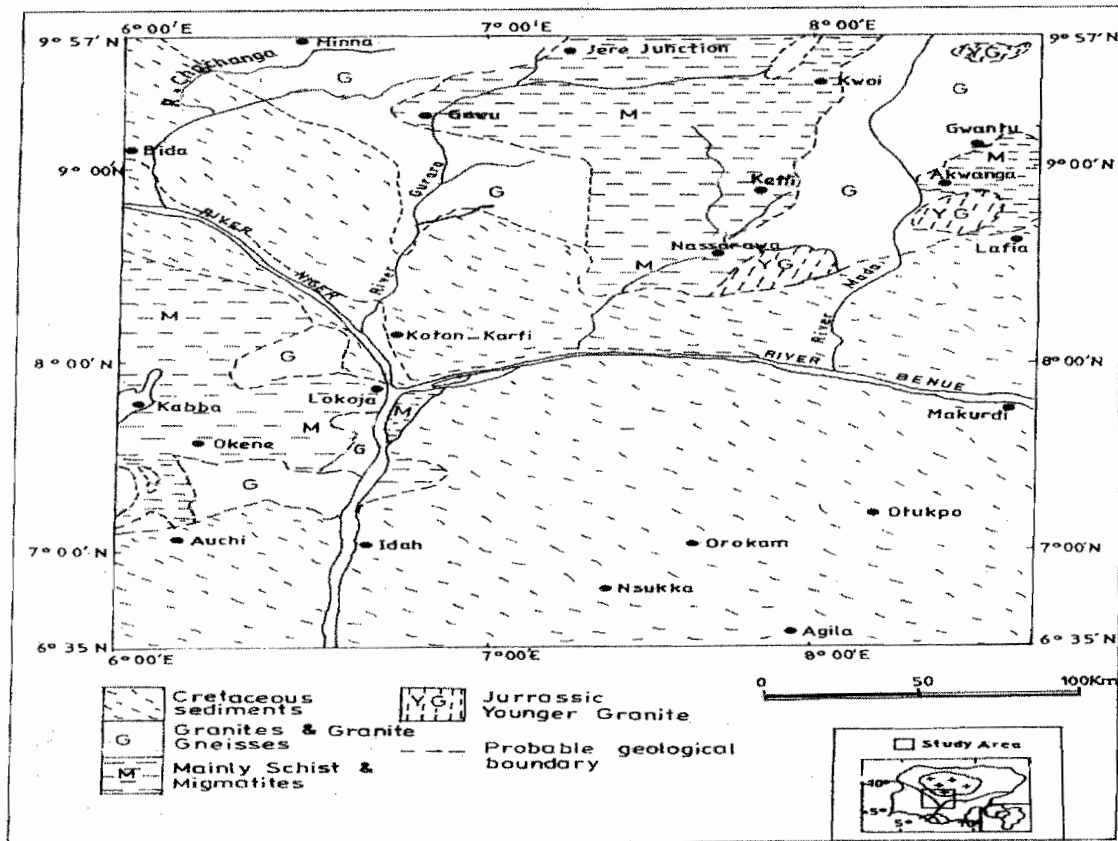


Fig.1: General geology of the Lower Niger- Lower Benue (Confluence) area. (Insert: Map of Nigeria showing the area of study).

Previously known structures peculiar to the Benue Trough are the folding of sediments in it parallel to its axis NE- (Wright, 1981, 1970) and the abnormal width of the trough (Ajayi and Ajakaiye, 1981) which is about two or three times that normally associated with rift valleys (Holmes, 1978). Other peculiarities associated with the Benue trough explained by Ajayi and Ajakaiye (1981) from interpretation of gravity data in the Middle Benue are the existence of two parallel rifts of normal width each of about 40 km buried under the Cretaceous cover and separated by an axial ridge (the Keana and Igbor anticlines) which partly explain the abnormal width of the trough. Another previously known structure in the Middle

Benue (Ajayi and Ajakaiye, 1986) is a SE trending gravity minimum located just to the east of River Katsina Ala and interpreted as zone of subsidence associated with block faulting. The Lafia anticline (Maastrichtian in age) mentioned in Offodile (1976) trends SE, the axis of which is perpendicular to the structural trend of the Benue but parallel to the axial trend (NW-) of Niger (Ajayi, 1979) and the adjacent basement structures in Gawu and Muro area (Ikpokonte, 1997) of the lower Niger and Benue troughs respectively. Most of the adjoining basement structures known to exist in the lower Benue and Niger troughs have been inferred from aerial photographs and Landsat imageries by Kogbe (1983). Other similar structures



more explanations of the origin and evolutionary relationship of the two basins.

### Data Collection and Analysis

The work discussed in this study results from a gravity survey over the confluence area of the Lower Niger and Lower Benue Basins carried out between October, 1988 and October, 1992 by the authors. The gravity data stations were located along all access roads and tracts at 34 km intervals between observations and extended beyond the margin of the basins into the adjacent basement areas.

The details of the data correction and reduction are contained in Ikpokonte (1997). It involves the usual steps taken in reducing raw gravity data to Bouguer values from which the Bouguer anomaly map (Fig. 2) was produced. Figure 2 shows the access roads and data points of measurements over the area. The base network and loop corrections were carried out with recorded maximum error of 0.150 mGal (Ikpokonte, 1997). The regional

anomaly values were determined by trying a first, second and third order polynomial surface fitting which were not quite effective due probably to the complex geology of the area. A first order surface obtained using robust polynomial fitting (Beltrao *et al.*, 1991; Ojo and Kangkolo, 1997) was adopted for the smooth gently inclined plane over the area negatively dipping towards the NE. The process of separating the regional involved digitizing (at 10 km square grid) the Bouguer map contoured at 2 mGal interval (Fig. 2). This helps to filter off near-surface narrow anomalies of shorter wavelength occurring in the basement regions probably due to granite bodies of shallow depth extent thus leaving the longer wavelength mega-structural bodies of interest. This regional anomaly inclination (Fig. 3) is in good agreement with that deduced by Ojo and Ajakaiye (1976) in the Middle Niger Basin to the west of the area. Moreover, this regional anomaly is probably due to a very deep sub-lithospheric origin. The residual gravity values were contoured at 4 mGal interval using appropriate software,

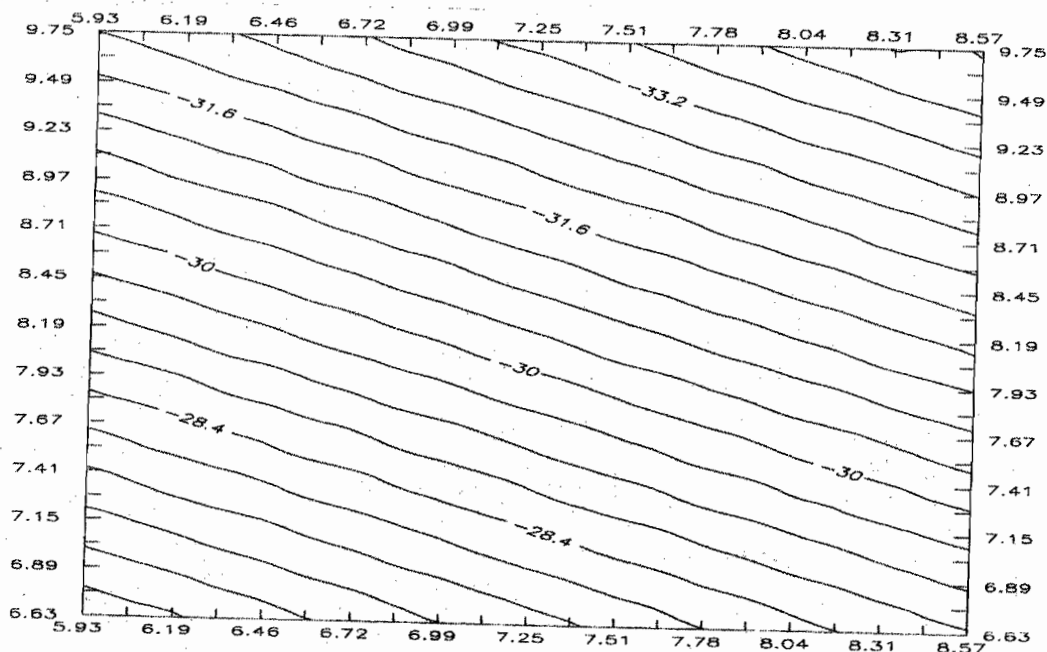


Fig. 3: The Regional gravity map of the study area. Contour Interval= 0.4 mGal

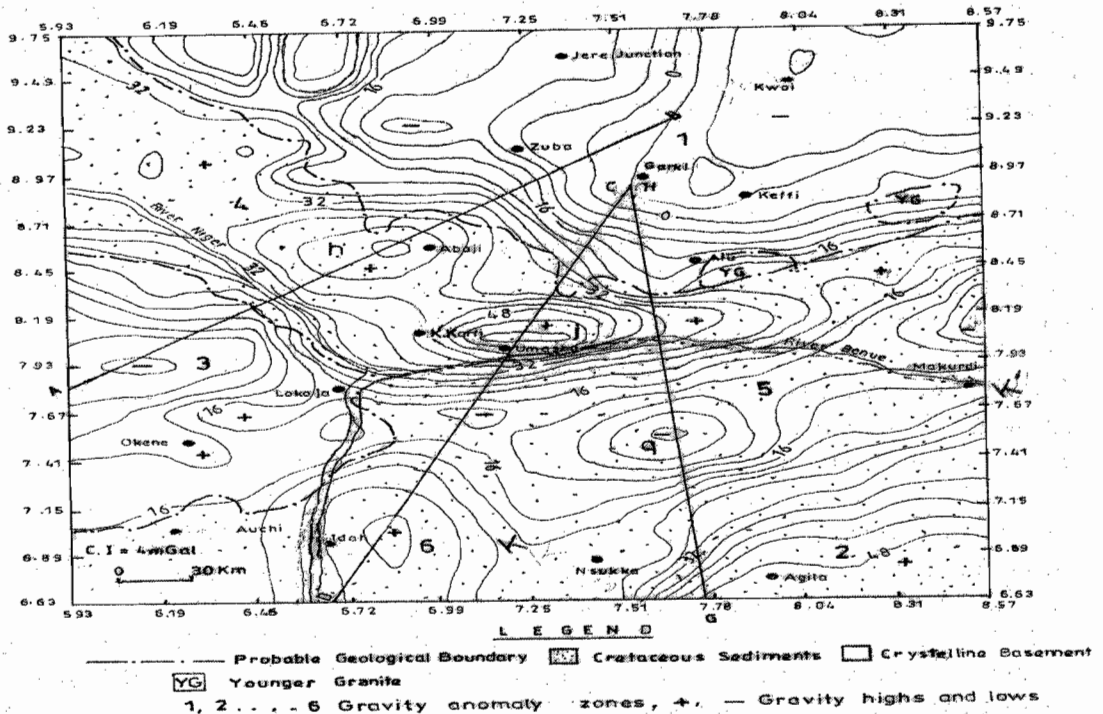


Fig. 4: Residual Gravity Map of the Study Area. Contour Interval = 4 mGal. Lines AB, DC, and HG are the Interpreted Profiles drawn across the Major Anomalies, h, j, q within the basins and structural zones. Numbers 1, 2, ... 6. show the structural zones of interpretation; KK' shows a linear structural boundary of the zones.

(Golden Software Inc. U.S.A) and superposed with a simple undifferentiated surface geology of the area (Fig. 4) for meaningful interpretation of the subsurface geology.

Density measurements were made on fresh sampled rocks numbering up to 307 collected over the area (Ikpokonte, 1997). As a result, the interpretation of the gravity data were then carried out using average densities of  $2680\text{--}2700\text{ kg/m}^3$  for the metamorphic crystalline basement rocks,  $2670\text{ kg/m}^3$  for the shallow crust, and the averages ranging from  $2520\text{--}2380\text{ kg/m}^3$  for the Cretaceous to Recent sedimentary fill, respectively, in the Niger and Benue basins.

### The Gravity Anomaly Maps: Interpretations and Discussions.

The Bouguer (Fig. 2) and residual (Fig. 4) anomaly maps of the area are here given qualitative interpretations of some of the anomalies of interest in the basins and

adjacent basement regions. Profiles taken across the basins over the anomalies are also quantitatively interpreted in detail to support the qualitative interpretations. The study area is being divided into six structural zones based on the gravity anomaly configurations with the surface geology. These anomalies are considered to be due to variations in density contrast existing within the basement regions, the Cretaceous sediments and their underlying basement structures. The interpretations subdivided into structural zones follow the shapes, sizes, magnitude and skewness of the contours defining the anomaly.

#### Zone 1: The Northern Basement Area

Zone 1 (Figs. 2&4) is occupied by the rocks of the Basement complex in the area comprising granites, and migmatites and contains the negative gravity anomaly values ranging from 0.0 to  $-50\text{ mGal}$  Bouguer values (Fig. 2) and from 0.0 to  $-20\text{ mGal}$  residual values (Fig. 4). The anomalies trend general N-S and the

magnitude increases negatively in the NE towards the Younger Granite province of the Jos Plateau region (not shown). However, some anomalous distortions center mainly around area of isolated granite bodies labeled a, b, c and v (Fig.2), which comprise the Gawu, the Minna, and the Keffi-Kwoi-Gwantu areas. This suggests that the anomalies are due mainly to these granitic bodies.

### Zone 2: The Igumale-Oju Area

The residual anomaly in this zone occupies the southeastern extreme of the map Fig. 4. The anomaly is broad, circular and bounded to the north by a sharp gradient linear anomaly average 1.36 mGal/km, trending NE-. The anomaly is a positive high of about 28 mGal above the surrounding values and could extend southeastwards beyond the study area.

This zone lies entirely on the Cretaceous sediments (Fig. 4) namely, shales of the Asu River Group and the shales, calcareous sandstones and shelly limestones of the Ezeaku (Keana-Makurdi) formations (Offodile, 1976). The Asu River Group (the oldest Cretaceous sediments) and the younger formations occur centrally within the closure of the residual anomaly. The geological boundaries run about parallel to the contours of the gravity field (SS') in this zone (Fig. 2). The residual anomaly of this zone is therefore attributed to the structural flank of the northern part of Abakaliki uplift (anticlinorium). This suggests that the anomalous structure is therefore an uplifted block or horst. This idea is further supported by the fact that the area of Abakaliki high has the oldest Cretaceous sediment folded and intruded by volcanics (Uzuakpunwa, 1974). These rocks might have been consolidated, and so contribute to its high-density contrast with immediate surrounding. Figure 4 shows that the linear anomaly trend KK' is probably a faulted boundary zone marking the northern edge of the structural uplift. The extension of this lineament-bounding

uplift zone to the NE- marks the southern boundary of the Benue trough and suggests that this uplift can be linked with the proposed 'Igbor Ridge' or 'Horst' of Ajayi and Ajakaiye (1986). The authors therefore are of the opinion that this anomaly can be attributed to the extension in the NE- of the Abakaliki uplift. Consequently, the authors tentatively refer to this anomaly structure as 'Oju high'.

### Zone 3: The Southwestern Basement Area

This anomaly zone (Fig. 2) occurs to the southwest and occupies the basement area of Lokoja, Okene, Kabba, Ajaokuta, and Auchi regions. Generally, zone 3 is characterized by isolated Bouguer anomalies that are short wavelength, elliptical in the E-W trend and separated by sharp gradient anomalies. The magnitude of the Bouguer anomalies in this zone is generally negative, ranging from -22 mGal in Kabba area to 4 mGal in the area lying between Okene and Lokoja. The Okene, Ajaokuta and Igara areas are dominated by migmatites, gneisses, and schists that probably bear the main E-W orientation of the basement fabric (Odeyemi, 1988). These rocks mainly characterize this anomaly zone. The closed anomalies of this zone are attributed to intrusive granite bodies and metasedimentary structures. About four closed anomalies identified in this zone are labeled i, k, l, and m. Anomaly 'i' is wide, broad and trends E-W occupying the area underlain by younger metasediments and gneisses of the Kabba-Jakura formation (Hockey *et al.*, 1986). This anomaly is a negative low with amplitude of -14 mGal above the surrounding and centre in Kabba town area. The anomaly shape is rectangular and is bounded by sharp gradient anomaly contours that could extend west of the area in the form of graben structure. This suggests tentatively, that anomaly 'i' is due to the younger metasedimentary structure within the basement. Anomaly 'k' occupies the area between Okene and Lokoja

underlain by migmatites, gneisses and iron ores. The fact that the amplitude of the anomaly 'k' is positive (4 mGal) above it's surrounding suggest that the iron formations has contributed to the positive gravity.

#### **Zone 4: The Lower Niger Basin.**

Zone 4 comprises the sedimentary area of the Lower Niger Basin (Figs. 2 & 4). The zone is bounded by sharp gradient linear anomalies AA' to the north and BB' to the south of it. Anomaly zone AA' extends from Umaisha-Toto to the south of Minna areas and beyond to the NW-. The zone BB' marking the southern boundary of Zone 3 also extends from area between Idah and Nsukka through Lokoja to the NW. The closed isolated en echelon gravity anomalies are generally superimposed on the large, broad, positive anomaly over the basin. These anomalies marked 'j', 'h', and 'f' and 'd' have Bouguer magnitudes of about 40, 18, 24, and 14 mGals respectively above their surroundings trough margins. These positive anomalies need more detailed investigation for isolated interpretation. The broad positive residual anomalies of Zone 4 may be due to intrusions of high-density materials within the deep crust along the trend NW or crustal thinning. This view is supported by the fact that the zone is covered by relatively thin Upper Cretaceous to Tertiary sediments having thickness less than 2 km (Ojo and Ajakaiye, 1976; Ojo, 1990). Furthermore, the gravity residual in this zone is everywhere positive above the adjacent northern and southern metamorphic basement anomaly values. For example, anomalies 'h', 'j', and 'd' have positively higher values above their immediate surrounding basin and the basin in turn generally has a maximum amplitude of about 22 to 40 mGal above the adjacent basement anomalies. This fact suggests mantle uplift (crustal thinning) under the basin.

Interpretations were, however, made of the anomalies 'j' and 'h' at Umaisha and south of Abaji area respectively in this work along profiles AB and CD (Fig. 4). A characteristic feature common to these anomalies is that their residual values are highly positive over the sedimentary basin. Since the sedimentary cover has a negative density contrast relative to the basement, the assumptions then are that anomalies 'j' and 'h' are caused by high-density intrusive bodies lying within either the basement or the sediments. Referring to fig. 4, the anomalies 'j' is ellipsoidal in shape with long axis following the 2-D en echelon gravity high of the Lower Benue northern margin while 'h' is mainly spherical and is also associated with the en echelon positive high gravity of the Lower Niger basin. Available geological information such as the basement-sediment density contrasts, the approximate sediment thickness, the basement-sediment contacts, the locations of nearby geological boundaries in the area, were used where applicable in constraining the models.

Anomaly 'h' (Figs. 5 & 6), a positive residual gravity anomaly lying at the immediate west of Abaji occupies a surface area having a maximum length of 63 km and width of 50 km. Fig. 5 shows an interpretation along profile AB taken perpendicular across the Niger axial trend starting from Kabba area northeastwards. Fig. 5a shows the resolution of a long wavelength (about 200 km) residual component of the anomaly on the profile to enable interpretation of the short wavelength residual component. This component, superimposed on the background is mainly a narrow positive anomaly centered over the basin, flanked by two low negative anomalies over the basement margins. The long wavelength anomaly values increase from -8.0 mGal on basement to -33 mGal centered over the sedimentary basin. The trend and magnitude of this anomaly over the Niger is similar to the large broad positive residual

anomaly generally observed over the Benue rift as a whole by past workers (Ajayi and Ajakaiye, 1986; Fairhead and

Okereke, 1987). Figure 5b shows the lithospheric structural interpretation of the resolved regional anomaly as due to uplift

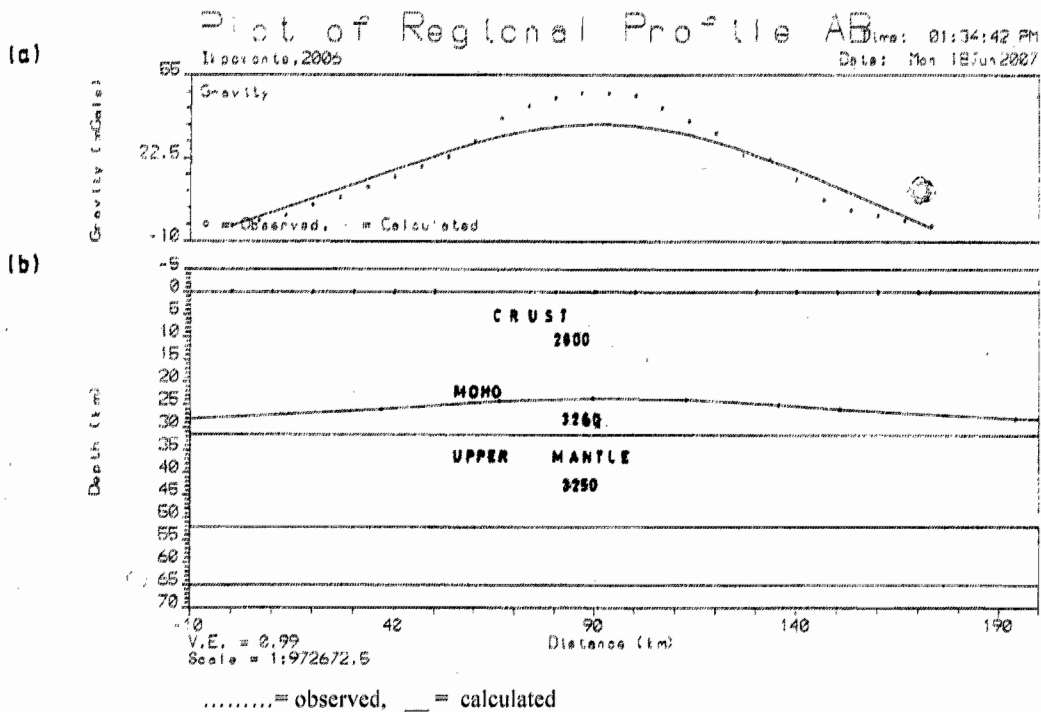


Fig. 5: The gravity profile AB-line across the Lower Niger basin, (a) shows the associated long wavelength anomaly resolution for deep lithospheric interpretation, (b) an interpretation of the deep lithospheric structures showing crustal thinning, Moho uplift to about 25 km.; assumed densities  $\rho$  (=2800, 3260, 3250 kg/m<sup>3</sup>) for the lithospheric layers.

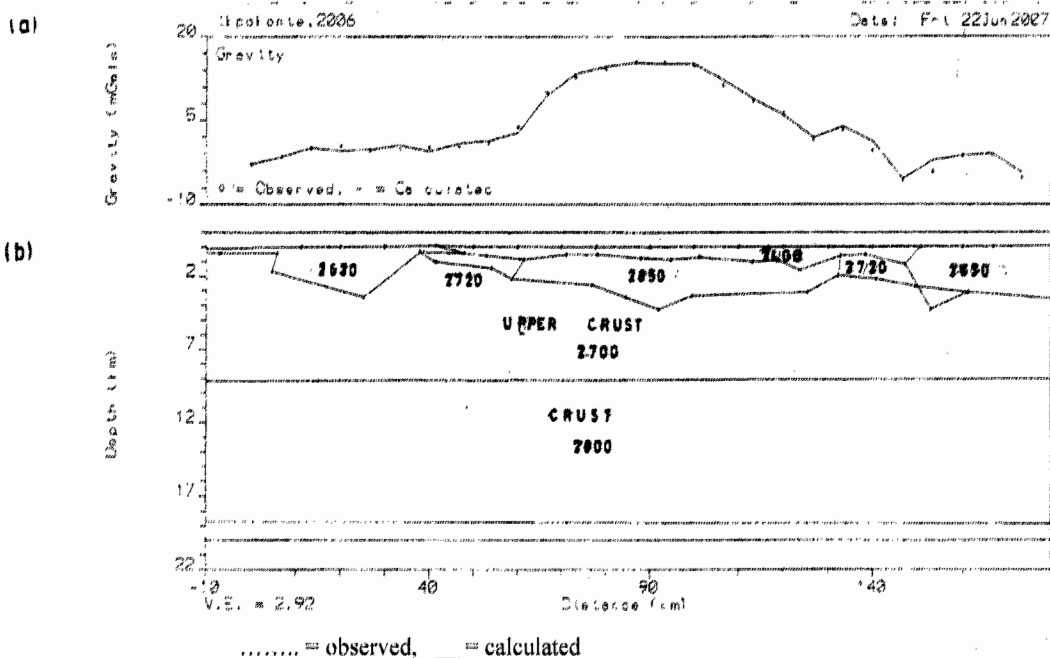


Fig. 6: Plot of the Residual Anomaly Profile (ABRES) along the line AB across the Lower Niger Basin obtained by subtracting the long wavelength anomaly in Fig. 5 from the observed. a). shows the plot of the obtained values and calculated values. b) an interpretation of the shallow crustal structures along the profile; assumed densities  $\rho$  (=2800, 2670, ....., in kg/m<sup>3</sup>) for the structures.



of the mantle under the Lower Niger. The interpreted Moho surface is uplifted from normal 34 km observed under continents, through about 28.0 km at the flanks of the basin to a maximum of about 23 km centered over the basin.

Figure 6 shows the interpretation of the resulting short wavelength residual anomaly (ABRES) along the profile AB. Figure 6a shows that the residual has low negative values ranging from -6.0 to -0.14 mGal at both basement flanks, and rising with low gradient to a maximum of value of about 15 mGal centered over the basin. Figure 6b shows the detail interpretation of the short wavelength residual along the profile. The model assumes a metamorphic basement ( $2700 \text{ kg/m}^3$ ) under the basin. The interpretation shows granitic bodies (density,  $2630 \text{ kg m}^3$ ) at the extreme ends of the profile. This is followed by a shallow more metamorphosed material body ( $2720 \text{ kg/m}^3$ ) at the flanks or rim of a major basic or mantle derived intrabasement body ( $2850 \text{ kg/m}^3$ ) centered under the sediments. It is assumed that the en echelon high gravity bodies in the Niger basin (Fig. 4) intruded through central weak zone along the basin and emplaced. The causative body of anomaly 'h' might have emplaced as a diapiric structure, considering the spherical nature of its gravity contour closure in Fig. 4. The basement contact rim of the body, therefore acquires higher density ( $2720 \text{ kg/m}^3$ ) than the basement ( $2700 \text{ kg/m}^3$ ) as a result of metamorphic effect of the intrusion. The irregular surface of the intrusion under the thin sediments (density,  $2400 \text{ kg/m}^3$ , maximum thickness, 1.60 km) show a slightly folded basin, whose crustal resistance is believed to be due to high density ( $2700 \text{ kg/m}^3$ ) metamorphic crust (schist belt) under the Niger basin (Ojo and Ajakaiye, 1976; Ikpokonte, 1997). The model shows that the causative body for anomaly 'h' has a width of about 50 km, a depth-to-top

ranging from 0.54 to 1.59 km and a depth-to-bottom of about 2.20 to 4.22 km with a density of  $2850 \text{ kg/m}^3$ . Considering the dimensions of the body, it is also a sheet-like body or laccolith. The authors are of the opinion that anomaly 'h' is caused likely by intrabasement mantle derived intrusive material of the same origin as anomaly 'j'. Consequently, the anomaly 'h' is tentatively referred to as 'Abaji high'.

Anomaly 'j' occupies the area around Umaisha town area. The anomaly was modeled along a 2-D profile CD across the Lower Benue. Figures 7 & 8 show an interpreted profile CD drawn across the Benue trend starting from Garki area in the northern basement and ending in the area around Idah in the south. The anomaly along this profile has a long wavelength (about 250 km) residual background. Shorter wavelength residual anomalies superimposed on this background are narrow and positive at the northern and southern margins of the trough and separated by a major broad negative anomaly that centers over the sedimentary basin of the trough. Figure 7a shows a detailed resolution of this anomaly along the profile to interpret the shallow crustal basement structures bounding the margins of the trough. The long wavelength residual anomaly increases in value from -9 mGal to 65 mGal. Figure 7b shows the lithospheric structural interpretation of the resolved anomaly along this profile (CD) as due to mantle uplift under the confluence area. The Moho surface is uplifted from about 31 km in the northern basement to about 24 km in the south beneath Idah area. Figure 8 shows the interpretation of the residual anomaly (CDRES) along this profile CD. Figure 8a shows the residual gravity anomaly value of about -10 mGal over the basement and banded iron formation in the area east of Abaji town, a narrow positive anomaly over the northern margin and a broad negative of about -53 mGal centered over the basin. The narrow positive residual anomaly over the trough margin is followed

with sharp gradients. The interpreted model along the profile (Fig. 8b) shows at both north and south ends probable metamorphic basement crust (with banded iron formation, av. density,  $2700 \text{ kg/m}^3$ ); and a possible basic ridge (density,  $2920 \text{ kg/m}^3$ ) under the faulted boundary at basement-sediment contact, buried at depth to top of about  $0.89 \text{ km}$  with depth extent of  $2.55\text{--}3.08 \text{ km}$ , a width of about  $50.82 \text{ km}$  and thickness of about  $1.93 \text{ km}$ . This shows a laccolithic (sheet) structure within the basement fault. This structure is best described as a ridge as it forms part of the 2-D structure characterizing the northern Benue margin gravity anomaly. Also, the basement (density,  $2670 \text{ kg/m}^3$ ) underlying the undifferentiated sediment (density,  $2450 \text{ kg/m}^3$ ) is most probably folded and faulted along with the

basement. About three (3) to four (4) step faults characterize each of the N and S boundaries of the Lower Benue along this profile, showing a compressive folding effect within the deep basin graben margins. This shows at least two (2) episodes of events (Ajayi and Ajakaiye, 1981), and at least four (4) episodes of faulting (extension), subsidence, graben and folding. The extension and subsidence might have brought the basin to depth of sediments thickness reaching about  $6 \text{ km}$  at center of basin along the profile. Fig. 8b also shows that the metamorphic crust underlying the sediment in the southern end of the profile probably extends southwards to form the Idah high (ridge). This metamorphic crust has a surface outcrop at Itohe road cutting. The interpretation of the ridge along the profile at the southern end

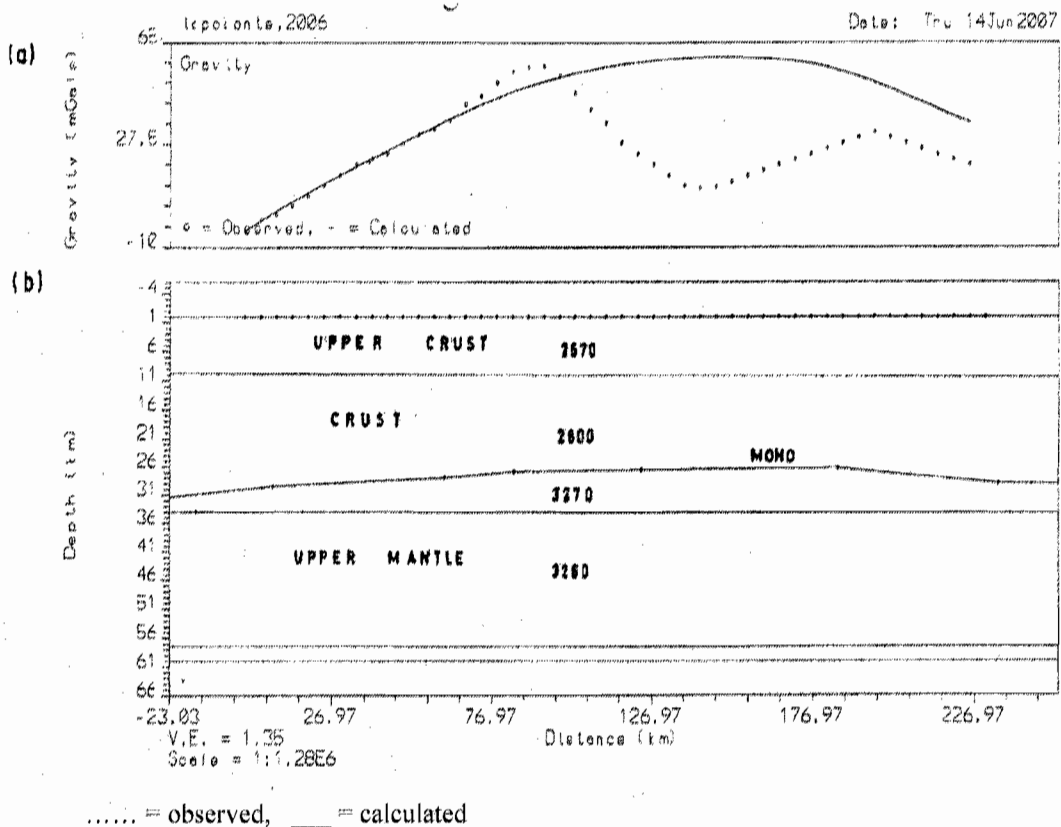


Fig. 7: Plot of gravity profile along line CD across the Niger-Benue (confluence) area, (a) shows the associated long wavelength anomaly resolution for deep interpretation, (b) an interpretation of the deep lithospheric structures showing crustal thinning, Moho uplift to about  $26 \text{ km}$ .; assumed densities  $\rho$  ( $=2800, 3270, 3260 \text{ kg/m}^3$ ) for the lithospheric layers.

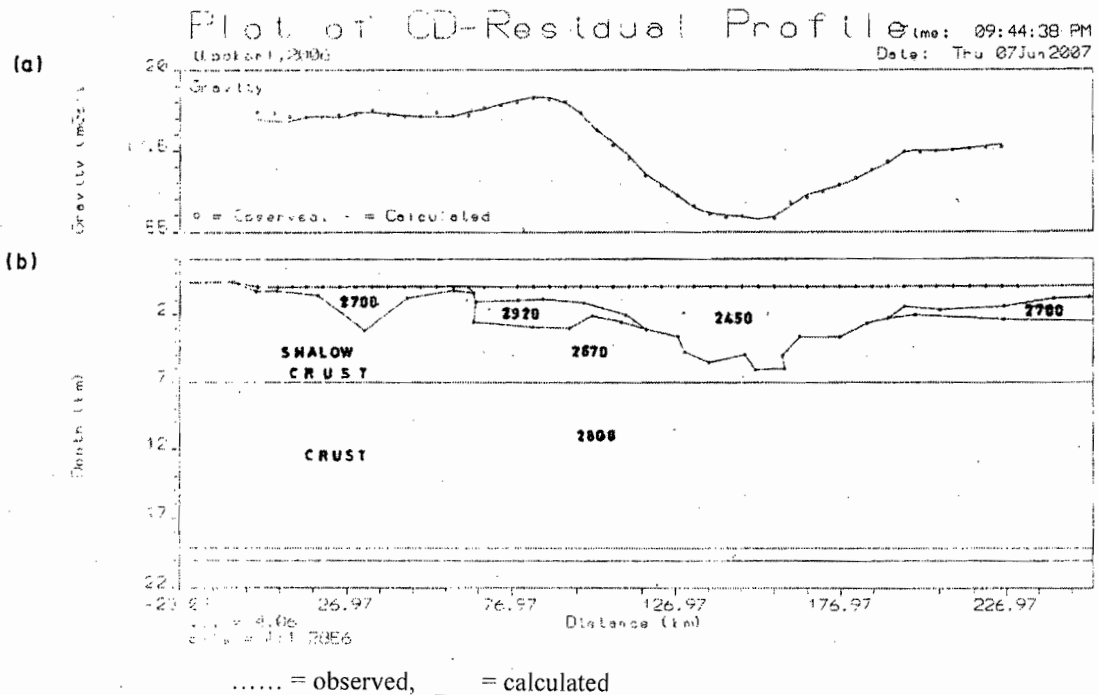


Fig. 8: Plot of the residual gravity component along the line CD, obtained by subtracting the long wavelength anomaly values in Fig. 7 from the observed values. a). shows the plot of the obtained values and calculated values. b) a resulting interpretation of the shallow crustal structures along the profile; assumed densities  $\rho = 2800, 2670, \dots$ , in  $\text{kg/m}^3$ , for the structures.

Thus, the authors are of the opinion that anomaly 'j' is most likely a shallow intrusive of basic or mantle derived material. Consequently, the name "Umaisha high" is tentatively suggested for the anomalous area. The basic nature and structural position of anomaly 'j' relative to the structural intersection of the Benue and Niger basin and its association with the several episodes of folding and uplift appears significant in the evolution of the troughs.

### Zone 5: The Lower Benue Basin

Zone 5 anomalous zone covers the sedimentary basin area of the Lower Benue around Abejukolo-Ayangba-Ankpa region to the southwest and stretches to Makurdi-Otukpo region to the northeast. The surface geology around Ayangba-Ankpa-Abejukolo areas suggests the existence of a closed sedimentary basin in that region of the study area (Ikpokonte, 1997). The zone is characterized by a

general NE- trending negative gravity anomaly centers marked 'q' and 's' with values of  $-36.0$  mGal and  $-40$  mGal respectively. Anomaly 'q' occupies the Ayangba-Ankpa area and is elliptical in shape. Its axis elongated in the NE-direction, is along the trend of the basin. Anomaly 's' is spherical in shape and is centred on the area that lies between Lafia and Makurdi towns. The contour-geometry in Figs. 2 and 4 suggests that this anomaly most likely extends beyond the present study area, a fact that was supported by the survey of Ajayi (1979) in the Middle Benue. This anomaly interpreted by Ajayi (1979) in a survey along Lafia-Makurdi-Igbor profile show existence of isolated basin with 6 km depth to basement in this area. The generally negative gravity anomaly of zone (5) then is probably caused by negative density contrast due to the huge sedimentary fill in a depressed crystalline basement surface under the lower Benue valley. The existence of the

broad negative anomalies 'q' and 's' is most likely due to depressions and irregularities of the underlying basement surface of the basin.

Profile HG shown in Fig. 4 is taken from Garki to the area between Nsukka and Agila, across the anomaly 'q'. This anomaly shows amplitude of 52 mGal along the profile with the peak over the sediments of the Lower Benue Trough. This profile (Fig. 4) is interpreted in order to estimate the maximum depth of the part of the sedimentary basin anomaly 'q' (Fig. 2), and to show its relationship with the basement contact boundary zones trending NE- in the linear sharp gradient anomalies FF', located in the area south of Afu, and KK' located in the area south of Ankpa-Makurdi. The modeling was carried out using a 2-D program based on algorithms of Talwani *et al.* (1959) and Nagy (1964). The models assumed 2-D structure for the polygonal cross-sections of the granites and migmatites on the Basement Complex, together with a 2-D basin structure with a strike length of about 1000 km filled with sediments and some intrusive (e.g. volcanic) for the Benue trough. However, the surface geology was strictly used to constrain the interpretations. In modeling the residual gravity profiles in the Lower Benue area then, the basic geologically possible models are proposed with the assumptions that;

- i. The basins are filled with undifferentiated sediments of measured density range 2400-2520 kg/m<sup>3</sup> with an average value of 2450 kg/m<sup>3</sup> underlain by irregular basement surface which may be intruded by shallow intrabasement mantle derived materials of density range 2720-2930 kg/m<sup>3</sup>.
- ii. The average density values are 2670 kg/m<sup>3</sup> for the shallow crust, 2800 kg/m<sup>3</sup> deep metamorphic crust and 3260 kg/m<sup>3</sup> for the Upper Mantle.

Figure 9a shows the resolution of the long wavelength residual trend across the basin.

The interpretation shown in Fig. 9b suggests this anomaly to be probably due to uplifted Moho to about 24 km. The detail short wavelength residuals on this profile were so obtained.

The resulting interpretations shown in Fig. 10 suggest the occurrence of a sedimentary basin with a maximum depth-to-basement of about 8 km around the area; over a folded basement with basic intrusive ridge at margin. Fig. 10 also suggests the existence of high angled normal (step) faults at both margins north and south of the basin. These marginal faults correspond to the linear sharp gradient anomalies FF' and KK' (Fig. 4) bounding the north and south margins of the Lower Benue Trough area of study (Ikpokonte, 1997). With the above geology and interpretation of the anomaly 'q' the authors are of the view that this fault-bounded structure is a graben, or deep basin, elliptical in shape. Consequently, it is here tentatively "Ankpa Basin". Also, the basement at the margins of the trough is probably gently folded parallel to the trend of the trough under this profile. Also in Zone 5, an echelon positive gravity residual anomaly zone occur along the northern margin of the Lower Benue area of study. These anomalies marked "u" and "t" in Fig. 4 occupies the area east of Umaisha and stretches through Doma area to Lafia in a NE- trend. Anomalies "u" and "t" have positive values of about 12 and 14 mGal respectively. They are entirely covered by sediments of the Lafia Formation, which are in contact with the basement and the Younger Granites (Afu and Mada Complexes). These interpretations along profiles (Fig. 10) show that the northern margin of Lower Benue is intruded by a basic ridge-like body of density range of 2780-2910 kg/m<sup>3</sup>, striking NE- in the area. This high gravity structure is bounded by the NE- trending linear gravity anomalies EE' to the north and FF' to the south of it. The linear anomaly zone EE' is also occupied by the two Younger Granite complex bodies (Afu and Mada) with their

bodies-structure trending NE- with sheared margins (Ikpokonte, 1997). Recent work in the opposite southern boundary of the Lower Benue around Gboko (Najime, pers. com.; Umeji, 1988) confirms surface occurrences of basic dykes sheared along the NE-trending fractures. It therefore appears that basic intrusives characterize both the sheared margins of the Lower Benue trough. The authors consequently refer to the positive gravity intrusive along the northern margin as the 'Doma Ridge'. It appears that the continuation of this body is the one

referred to in the NE-trend, north of Lafia, as basic dyke intruding a sheared zone by Smuliskowski and Olatunji (1980), and by Ajayi and Ajakaiye (1986). This anomaly marked 't' in the present work (Fig. 2) is closed-up by gravity anomaly contours of Ajayi (1986). The positive anomaly amplitude of Ajayi and Ajakaiye (1986) is 10 mGal above its surrounding area, while that of anomaly 't' in the present study is about 14 mGal at immediate area north of Lafia (Fig. 2). It is therefore, suggested here that this "Doma Ridge" probably forms the en echelon gravity high that terminates in the NE- south of Arikya area

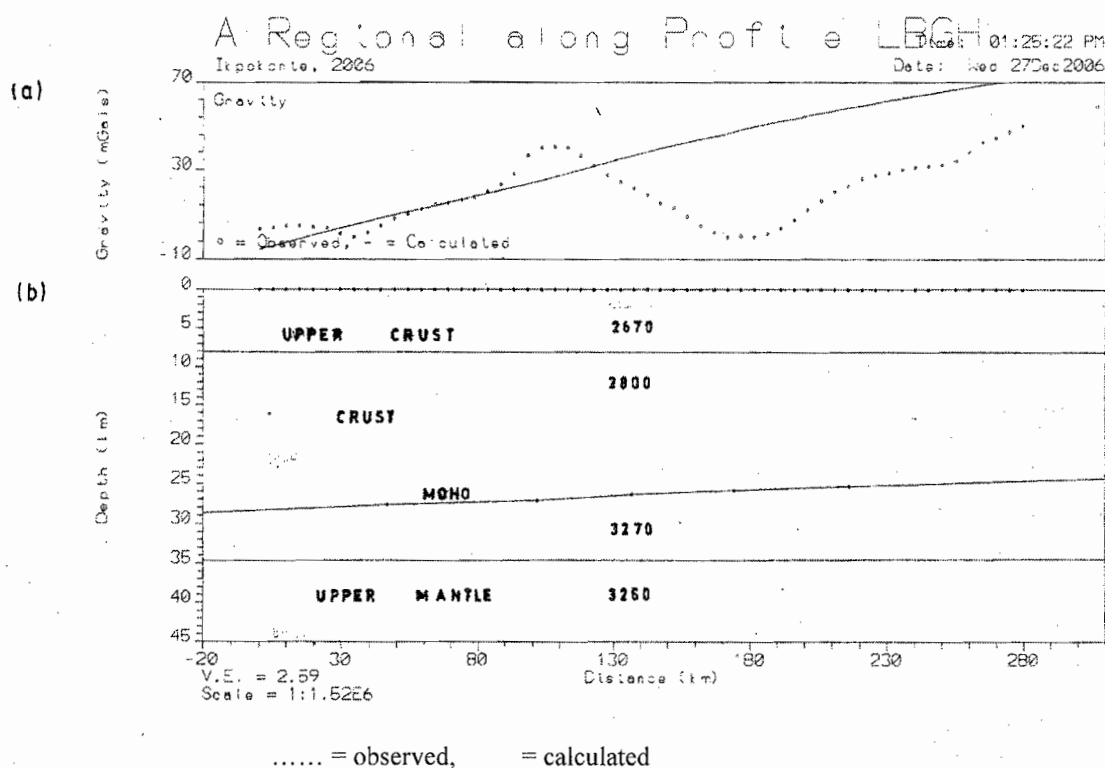


Fig. 9: The gravity profile along the line HG across the Lower Benue (Confluence) area. (a) shows the resolution of the associated long wavelength anomaly, (b) shows the resulted interpretation of the deep lithospheric structures showing crustal thinning, Moho uplift to about 25 km.; assumed densities,  $\rho = 2670, 2800, 3270, 3260 \text{ kg/m}^3$  for the lithospheric layers.

(Ajayi and Ajakaiye, 1986) beyond the area of study at the basement-sediment contact.

### Zone 6: The Southwest Central Area

Zone 6 in the residual anomaly map (Fig. 2) occurs in the Southwest Central part of

the study area in the Idah area, and is entirely occupied by Cretaceous-Tertiary sediments. This zone is characterized by positive anomaly with amplitude of about 15 mGal above its immediate surrounding and is elongated in the N-S direction with a nose terminating just east of Ajaokuta area.

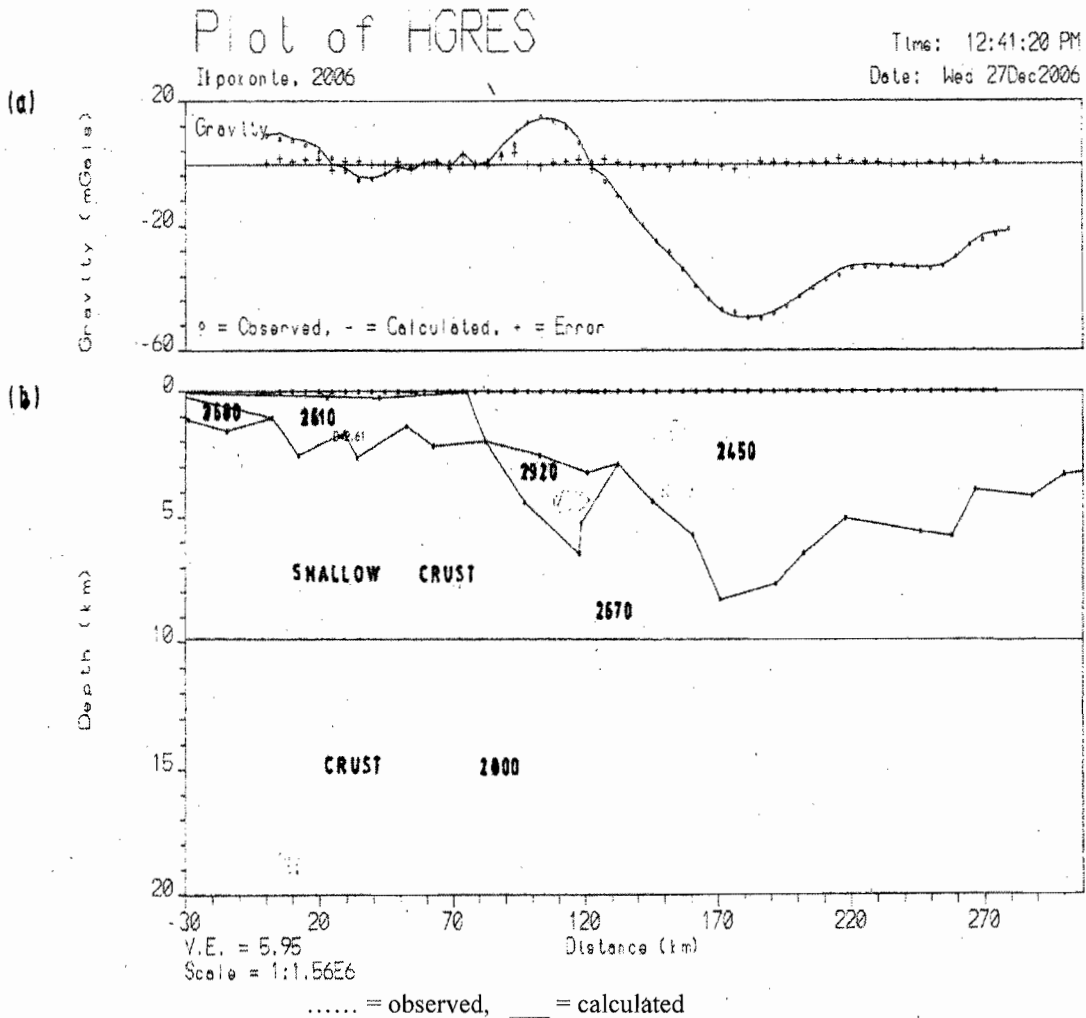


Fig. 10: Plot of the residual gravity component along the line HG, obtained by subtracting the long wavelength anomaly values in Fig. 9 from the observed values. (a) shows the plot of the obtained values and calculated values. (b) a resulting interpretation of the shallow crustal structures along the profile; assumed densities  $\rho$  ( $=2800, 2670, \dots$ , in  $\text{kg/m}^3$ ) for the structures.

This anomaly high and surface geology suggests a folded basement surface ridge or an intrusion underlying a thin sedimentary cover at the basement sediments contact margin based on Hockey *et al.*, (1986). From the rectangular shape of the anomaly and the most probably extension of it southwards beyond the study area (Fig. 2), the authors are of the opinion that the folded structure is a prominent ridge extending southwards to give a gravity high around Onitsha south of Idah area along the Lower Niger River. This structure is therefore tentatively named "Idah ridge".

### Conclusion

The major findings from the present study summarized below are however, tentative with regards to the fact that more definitive geophysical methods such as seismic or otherwise are yet to confirm these results.

1. The Lower Niger-Lower Benue confluence area of study comprises six structural regions considered here as zone 16. These structural zones are defined by their characteristic gravity residual anomalies separated definitely from each other by linear sharp gradient anomalies of the suggesting existence of normal (step) faults boundaries of the zones. Two of the

zones (Zones 1 and 3) are known orogenic basement regions. The rest are zones of prominent pre-Cretaceous and Cretaceous structures.

2. One major structure in Zone 2 in the southeastern extreme of the area associated with gravity high of about 30 mGal is the northeast trending 'Oju high', an uplifted basement anticlinal structure, which is a fault, bounded northern end of the Abakaliki anticlinorium. The Oju high probably extends NE to form the Igbor Ridge in the Middle Benue.

3. A prominent structure in Zone 5 in the northern basement boundary of the Lower Benue is the NE-trending 'Doma Ridge' or sub-surface thick dyke of basic intrusive. This structure marks the contact between the basement and the Cretaceous basin of the Benue in the area along which a shear marginal contact with step faults are located in the area. The Doma Ridge is a typical rift bounding structure whose opposite southern trough marginal equivalent basement is the volcanic of NE-trending shear intrusive dykes described around Gboko-Yandev area by Umeji (1988) and also by Ajayi and Ajakaiye (1986). These structures likely predate the Cretaceous events of the main opening of the Benue with main phase of rifting which suggest an idea of rupturing of the Precambrian prior to the Cretaceous event.

4. The anomalous Zone 4 in the Lower Niger contains two closed anomaly highs, the 'Abaji high' and 'Umaisha high' both of which are interpreted to suggest basic laccolithic intrusive of mantle derived materials in the shallow basement. These intrusive bodies might have been emplaced following major event involving upper mantle during main Cretaceous events in the confluence area of the troughs during evolution. The gravity high previously described as "Ankpa high" by Cratchley and Jones (1965) is that now located as 'Umaisha' northeast of Ankpa area. The later is a low gravity structure found in the present study and referred to as 'Ankpa Basin'.

5. Zone 5 is most likely a region of thick sedimentary overlay created as a result of subsiding basement block bounded north and south by step faults in the Lower Benue confluence area of study. This northeast trending low gravity zone forms the structural 'Ankpa basin' of about 78 km maximum depth ever recorded in the Benue Trough. The sister basin previously located by Ajayi (1979) 'the Kardako basin' about 6 km maximum depth is in the immediate northeast of the Ankpa Basin and lies between Makurdi and Lafia area. Both basins form broad en echelon gravity lows of the Lower Benue Trough of the Abakaliki anticlinorium.

6. Zone 6 that occupies the Idah area is a region of thin Cretaceous sedimentary cover with a N- trending positive gravity high. This structural zone is most probably a ridge of folded basement structure likely of the Paleozoic surface geology (Hockey et al., 1986). This structural high, the 'Idah Ridge' forms another prominent N-S trending structure marking the southeastern sediment-basement contact boundary of the Lower Benue Trough south of Ajaokuta. This structure runs N-S and most likely provides a structural control of the River Niger south of Lokoja, as well as marking the western edge of the Anambra basin in the Lower Benue Trough. These results show the involvement and deformations of the Precambrian-Paleozoic basement during the opening of the Cretaceous Lower Niger-Benue Troughs within the study area.

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