AN AEROMAGNETIC STUDY OF THE LOWER BENUE TROUGH, NIGERIA

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ABSTRACT Aeromagnetic profiles have been taken across the Lower Benue Trough of Nigeria. Two-dimensional interpretation of these profiles showed that they are best interpreted in terms of basic intrusive bodies which could occur either within the Cretaceous sediments filling the trough or within the metamorphic basement or both. The model intrusive bodies have magnetization in the range 1.10 A/m to 3.80 A/m and are thought to be associated with the tectonic evolution of the Benue Trough. The Benue Trough, the Gulf of Guinea and most Northeastern Brazilian Basins being genetically related, it is thought that knowledge of the structure and tectonic evolution of the Benue Trough could well help in the understanding of the structural and tectonic evolution of the Northeastern Brazil.

RESUMO Perfis aeromagnéticos foram feitos através da zona inferior da Fossa do Benuê na Nigéria. As interpretações bidimensionais destes perfis mostraram que a melhor interpretação é em termos de corpos intrusivos básicos, que poderiam ocorrer dentro de sedimentos cretáceos que preenchem a Fossa, dentro do embasamento metamórfico, ou em ambos. O modelo dos corpos intrusivos apresenta magnetização na faixa 1,10 A/m a 3,80 A/m. Considera-se estes corpos associados com a evolução tectônica da Fossa do Benuê. Como a Fossa do Benuê, o Golfo da Guiné e a maior parte das bacias do nordeste brasileiro acham-se relacionadas, acredita-se que o conhecimento da estrutura e evolução tectônica da Fossa do Benuê poderia contribuir bastante para a compreensão da evolução estrutural e tectônica do nordeste do Brasil.

INTRODUCTION The Benue Trough is an elongated Cretaceous rift trending north easterly to attain an approximate length of 800 km (Fig. 1). It is about 130-150 km wide and is filled by cretaceous rocks whose ages range from Middle Albian to Maestrichtian (Tab. 1). These cretaceous rocks attain a thickness of about 6 km in the Lower Benue Trough. Characterizing the axis of the Benue Trough are numerous mafic and felsic intrusives and basaltic lavas (Olade 1978, Uzuakpunwa 1974, Ofoebu 1983a) as well as a narrow zone of lead-zinc mineralization (Cratchley & Jones 1965). On either sides of the sediments are the Pan-African granites and gneisses which make up the crystalline basement. The lead-zinc mineralization which characterizes the Benue Trough combined with suspected oil accumulation in the area has turned the Benue Trough into an area of great economic importance.

Previous geophysical studies on the Benue Trough have been restricted in the main to the interpretation of the gravity field over the trough (Cratchley & Jones 1965, Adighije 1979, 1981a, b, Ajayi & Ajakaiye 1981, Artsybashev & Kogbe 1975). The results obtained by the authors show that the observed axial gravity high over the Benue Trough can be interpreted in terms of the combined effect of a zone of basic to intermediate intrusions, a shallow basement and a thinning of the crust. In addition to the gravity studies mentioned above the interpretations of local magnetic anomalies were done by different other researchers (Myada 1979, Osazuwa 1978).

Before the separation and opening of the South Atlantic, the African and South American continents were in close proximity and the Benue Trough has been said to represent an adjustment in the shape of Africa to the loss of South America (Stoneley 1966, Wright 1968). Figure 2 shows the relative positions of Africa and South America in the Middle Albian and Turonian times

respectively. The Benue Trough, Gulf of Guinea and most Northeastern Brazilian basins, such as the Potiguar, São Luís, Recôncavo-Tucano Sul and Sergipe-Alagoas basins, are genetically related (Burke 1976, Asmus & Ponte 1973, Campos *et al.* 1974). Cretaceous rocks in both the Benue Trough and Brazilian basins have been found to have similar compressional features. However, the Northeastern Brazilian basins are generally without volcanics and this tends to make the timing of their development difficult though Early Cretaceous has been accepted as the age of initial rifting of most basins and the oldest marine sediments in the region have been assigned an Albian age (Burke 1975).

Different ideas have been put forward to account for the evolution of the Benue Trough. These range from those based on geomorphological evidence (Lees 1952, King 1950, Farrington 1952) to tectonic models of Wright (1968, 1981), Grant (1971), Burke *et al.* (1971, 1972), Olade (1975), Ajayi & Ajakaiye (1981).

INTERPRETATION OF ANOMALIES The data used in this work were in the form of aeromagnetic maps obtained from the Geological Survey of Nigeria, Kaduna. The non-linear optimization techniques and interactive techniques were used in the interpretation of the observed anomaly profiles (Fig. 3). Interpretation has been carried out in terms of two-dimensional structures, although some of the observed anomalies may appear three-dimensional. The observed profiles have been interpreted in terms of two-dimensional structures because of the apparent difficulties involved in the interpretation of a single profile in terms of several three-dimensional bodies. This use of two-dimensional structures might only marginally affect the depth estimates made in the present study.

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Figure 1 - Geology of Benue Trough (after Ofoegbu 1983a)

Figure 2 – Relative position of Africa and South America: A – in the Middle Albian times; B – in the Turonian times

Figure 3 – The Benue Trough showing the position of interpreted profiles

The direction of magnetization has been constrained to be as close as possible to the direction of the Earth's field because no palaeomagnetic studies have been carried out in the area until the present work has been completed. It is, however, known that the position of Nigeria has not changed much from its palaeolatitude in Cretaceous times

and the assumption of directions of magnetization closely parallel or against the present days field is a fairly valid one.

Interpretation of observed profiles in terms of several intrusive bodies. Several aeromagnetic profiles have been taken across the Lower Benue Trough (Fig. 3) and

Table 1 – Stratigraphic sequence of the lower-middle-upper Benue and Chad basins

AGE	ANAMBRA BASIN	LOWER BENUE-MIDDLE BENUE	UPPER BENUE BASIN			SOUTHERN CHAD BASIN
			Dadiya-Numanha	Zambuk-Gulani	Gombe-Pindiga	
PALEOCENE and YOUNGER	IMO FORMATION	Volcanics	Lamja sandstones	Gulani sandstones	KERRI-KERRI FM.	KERRI-KERRI FM.
MAASTRICHTIAN	NSUKKA FORMATION AJALI SANDSTONE MAMU FORMATION NKFORA FORMATION	LAFIA FORMATION			Gombe sandstones	Gombe sandstones
SENONIAN	CAMPANIAN		Numanha shales		PINDIGA FORMATION	Fika shales
	SANTONIAN		SEKULE FM.			
	CONIACIAN	AGWU FORMATION				
TURONIAN			JESSU FM.			
CENOMANIAN	EZE-AKU FORMATION	EZE-AKU FM. MAKURDI FM. KEANA FM. AWR FM.	DUKUL FM.			GONGILA FM.
MID – LATE ALBIAN	ASU RIVER GROUP OKPOSI FM. Sandstone and shale Abakaliki shales	ASU RIVER GROUP	YOLDE FM. Bima sandstones	Bima sandstones	YOLDE FM. Bima sandstones	Bima sandstones
PRE-CAMBRIAN	BASEMENT COMPLEX					

Note Unconformity = ~~~~~

interpreted in terms of basic intrusive bodies. The results of this interpretation for the profiles LB1 and LB4 are discussed below.

Figure 4 – Interpretation of profile LB1 in terms of intrusive bodies

Profile LB1 is a NS profile which lies to the East of Lokoja and Idah and runs through the town of Dekina, ending North of Adani (Figs. 1 and 4). It has been interpreted in terms of three intrusive bodies magnetized in opposite directions. The model bodies required to explain this profile are though to be deep-seated bodies with the depth to the top surface lying between 2 km and 8 km. Figs. 4a, 4b, 4c and 4d show possibly model bodies required to account for this profile. Fig. 4a shows the bodies at their minimum possible depths if a good fit is to be obtained between the observed and computed anomalies. The central body in this model has a magnetization of 1.60 A/m while the bodies to its right and left have magnetization of 1.25 A/m and 1.60 A/m respectively. While the model of Fig. 4a gives a reasonably good fit, it does not account equally well for all the wavelengths in the profile. Fig. 4b shows the intrusive bodies at greater depths and gives a better fit to the observed anomaly than the previous model. The central body here has a magnetization of 2.15 A/m. The model bodies of Fig. 4c are even deeper than those of Fig. 4b. The central body in this model has an increased magnetization of 2.5 A/m. Fig. 4d shows a model in which the intrusive bodies required to account for the observed profile have a minimum depth of about 6.0 km. This model requires more strongly magnetized bodies and has a central body having a magnetization of 2.8 A/m. These intrusive bodies could be placed further down the crust, but it was found that, at average depths of about 9 km and above, the model intrusive bodies require rather high values of magnetization, reaching for the central body a value of 3.50 A/m at 9 km depth and 4.17 A/m at a depth of 12.0 km. It was also found that beyond the depth of 8 km it is no longer possible to account for all the short wavelengths in the profile.

The profile LB4 is a NW-SE profile which passes to the West of Imane, Odoaba, Otukpa and Abakaliki and passes through Enugu-Ezike (Fig. 3). Several possible models of intrusions required to explain the profile LB4 are shown

Figure 5 — Interpretation of profile LB4 in terms of intrusive bodies

in Figs. 5a, 5b, 5c and 5d. The intrusive bodies of Fig. 5a have their top surfaces at depths of between 1.50 km and 3.80 km and magnetization ranging from 1.10 A/m to 2.20 A/m. Figs. 5b, 5c and 5d show the same set of bodies at greater depths. The bodies in Fig. 5b are at depths of 3.50 km to 5.40 km and have magnetization values lying between 1.12 A/m and 2.75 A/m. The magnetization values of the intrusive bodies in Fig. 5c range from 1.12 A/m to 3.05 A/m while the bodies modelled in Fig. 5d which are at depths of the order of 7.0 km have magnetization values ranging from 1.12 A/m to as high as 3.45 A/m.

Interpretation of anomalies in terms of a single body model The possibility of interpreting the observed magnetic anomalies over the Lower Benue Trough in terms of a single body has been investigated. The profile LB1 was reinterpreted in terms of a single body which could either be at a shallow depth or at a great depth.

Fig. 6a shows such a model body at a shallow depth. The body of the model in this figure has a magnetization of 1.20 A/m and in places comes as close as 0.40 km to the surface.

The mismatch to the right of the profile is suggestive of the fact that at least two separate bodies would be required to account for the anomaly at this depth. The position of the body required to explain the observed anomaly was changed by increasing the depth and consequently increas-

Figure 6 — Interpretation of profile LB1 in terms of a single body model

ing the magnetization and changing some dimensions of the body. It was found that with the causative body at a minimum depth of 2.0 km a magnetization of 1.36 A/m was needed for the model body (Fig. 6b). Obtaining an adequately good fit for the magnetic low in the middle of the profile, however, becomes increasingly difficult as the body becomes deeper. Fig. 6c shows this for a model of a causative body at about 4.0 km depth with a magnetization of 1.62 A/m. In Fig. 6d it is about 6.0 km deep with a magnetization of 1.98 A/m. It becomes difficult to obtain a good fit in the middle and at the right end of the profile. This suggests more than one body in agreement with the previous interpretation of the profile shallower. Although the use of a shallower body may have improved the fit over the middle section of the profile, it would have also led to greater misfit over other sections of the profile.

DISCUSSION OF RESULTS The results of the magnetic study presented here points to the fact that the magnetic anomalies over the Lower Benue Trough can be explained by the existence of intrusive bodies within the basement or within the Cretaceous sedimentary basin or both. The model intrusive bodies which may extended to greater depths than shown in Figs. 4 and 5 are most probably basic in composition on account of their magnetization.

The interpretation of the observed profiles in terms of intrusive bodies is in good agreement with results obtained

from the interpretation of gravity anomalies over the Benue Trough (Cratchley & Jones 1965, Adighije 1981b; Ajayi & Ajakaiye 1981). Support for the interpretation in terms of intrusive bodies can be further found from results obtained from geophysical studies over various rift systems such as the Baikal Rift (Zorin *et al.* 1975), Upper Rhine Graben (Bosum & Hahn 1967, 1970) and the Rift Valley in Kenya (Searle 1969, 1970).

The existence of intrusive bodies beneath the Lower Benue Trough is of obvious tectonic significance. It is thought that the Benue Trough is underlain by a stretched continental crust which has been invaded by igneous intrusive bodies and this may represent a thinning of the crust underneath the trough. Based on the results of this study of the lower Benue Trough and the results of previous geophysical studies of the Benue Trough, it

is here suggested that the tectonic evolution of the Benue Trough involved a cyclic sequence of mantle upwelling, crustal stretching, emplacement of intrusive igneous material and consequently rifting (Ofoegbu 1983b).

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