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Magnetic Exploration of the Upper and Lower Benue Trough for Metallic Deposits and Hydrocarbons using 2D/3D

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Abstract
Digital Aeromagnetic data for Lower Benue Trough (Afikpo and Nkalagu) have been analyzed to locate specific basement targets for investigation using seismic methods in deep hydrocarbon exploration. This is motivated by the call of Nigerian National Petroleum Corporation (NNPC) to re-investigate all the basins in the country for hydrocarbon accumulation. In the Lower Benue Trough depths of the intrusive range from 3.2km to 3.9km while depths of deep structures range from 8.7km to 19.2km. The susceptibilities of the intrusive suggest that they are composed of granite, basalt, dolerite and rhyolite. Depths of deep structures in the Lower Benue Trough show thick sedimentary deposits that have potential for hydrocarbon exploration.
Keywords: Cretaceous age, megastructure, forward and inverse modeling, geometrical shapes

Introduction

Recently, The Nigerian National Petroleum Corporation (NNPC) in 2012 awarded contracts for geophysical re-investigation of all the basins in the country for the purpose of discovering new oil-bearing structures. They are well informed that deep- seated structures of continental extension starting from the Niger Delta to the Nile Delta yield abundant hydrocarbons in Niger Republic, Sudan, Libya and Egypt. (Nagy et al, 1976; Neev, 1977). According to Zboril et. al (1986) Dafur, Kordofan and Bahr El Ghazal provinces of Sudan produce 1000 tons of fuel per day. The transcontinental mega-structure is related to the lineament which was most active from the Middle to the Upper Cretaceous age (Kogbe, 1976b). Libya and Egypt within the megastructure are powerful oil producers. Offodile (1976) had noted that Benue Trough has favorable conditions for the genesis and accumulation of hydrocarbons in oil bearing traps because the oil source rocks are generated in a marine reduction environment and the reservoirs have sufficient porous sandstones of 'Gombe series'. Many authors have worked and written on the Benue Graben (Wright 1968, 1976 Burke et. al 1970; Grant 1971; Burke 1969, 1974; Okezie 1965; Okade 1978; Ofoegbu and Mohan 1990; Ofoegbu and Onuoha 1991; Ofoegbu 1984a, b; Ajakaiye 1981; Nwachukwu 1972; Obi et. al 2010; Obaje 2009; Ofoegbu 1985a, b 1988).

Geological Setting

The Basement Complex is exposed over nearly half of Nigeria (Figure 1). It extends in the West into the Dahomeyan of the Benin Republic and in the east into the Cameroun. In the remaining half of the country Cretaceous and younger sediments cover the Basement Complex. The Nigeria Basement Complex is believed to be mostly Precambrian in age and it probably contains intrusions of Paleozoic age (Oyawoye, 1964).

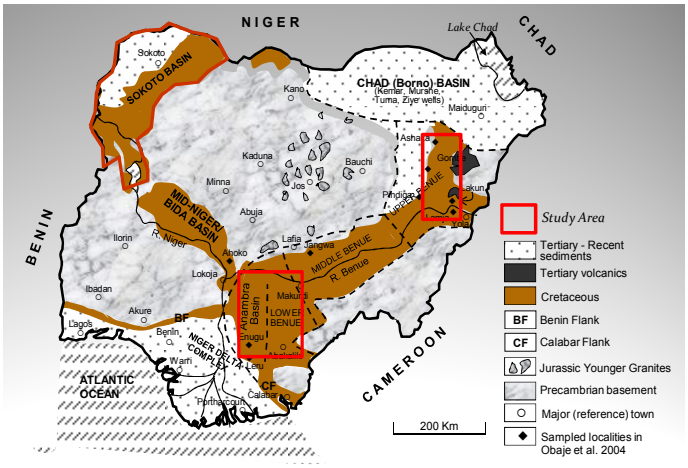


Fig 1. Geology of the study Area

Review of Previous Work

There have been reasonable measures of interest in the quatitative interpretation of aeromagnetic data in the Benue Trough. Notable researchers in this regard include Ofoegbu (I984a,b, 1985,1988); Ajakaiye et. Al, (1991), and Nur (2000). Other recent workers include Anudu et.al, (2008, 2012); Olasehinde et.al, 2012; Abubaka et.al, 2010, Omeje et. al, (2012); Ugwu and Ezema, (2012). Below is a table of authors and areas covered for aerogmagnetic survey of the Benue Trough.

Table 1. Aeromagnetic data interpretation of the Benue Trough

S/No	Author (s)	Date	Area	Depth to basement	Depth of shallow intrusives	Remarks
1	G.K. Anudu et. al	2012	Wamba, N. Central Nigeria	0.88-3.15km	0.23-0.79	Not favorable for hydrocarbon generation
2	A. Olasehinde et. al	2012	Riruwai Younger Granite Ring Complex	Depth not estimated	Depth not estimated	Identified intrusive rocks
3	C. O. Ofoegbu	1988	Upper Benue Lat 8° .11°', long 11°-13 °'E	4.6km	0.5km	Favorable area
4	C.O. Ofoegbu	1984	Lower & Middle Benue	Depth not estimated	Depth not estimated	
5	Y. I. Abubaka et. al	2010	Gongola Basin	4.03-5.39km	1.25km	Favorable area
6	L.N. Onuba et. al	2010	Upper Benue Trough	2km-2.8km	0.4-1.2k	Not favorable
7	M. Omeje et. al	2012	Dong & Shelleng Upper Benue Trough	0.9 – 2.9km	Not estimated	Not favorable
8	G.Z. Ugwu & Ezema P.O	2012	LOWER Benue Trough, Abakaliki	3.2-3.9km		Possible hydrocarbon for the location
9	Obi et al	2010	Lower Benue Trough	2km & above		Favorable areas

Data acquisition.

two aeromagnetic maps were acquired from the Nigerian Geology Survey Agency (NGSA). These are: Sheet 313 Afikpo (Lat 5.5^0 – 6^0N, Long 7.5^o - 8^0E) and Sheet 302 Nkalagu (Lat 6^0 – 6.5^0N, Long 7.5^o – 8^0E); 7.5^o – 8^0E). The data were acquired along a series of NW-SE flight lines with a spacing of 500m and an average flight elevation of about 80m, while tie lines were recorded at about 2km interval. The data were made available in digital form on scale of 1:50,000.

Interpretation

Interpretation was done with Potent software (Version 12.04) of Geophysical Software Solutions (GSS) of Australian Software Company. The software is about forward and inverse modeling. There are many geometrical shapes to choose from such as spheres, clinders, vertical prisms, slabs, dykes, lens and polygonal prism. Forward modeling is a process of calculating magnetic response from the parameters of the source to match the observed data while in averse modeling involves calculating parameters of the source from the observed data. This is not limited to simple shapes as very complex geometries can be modeled using an assemblage of vertical polygons, each having many sides. Figure2a &b are 2D image maps of the stations while Figure 3 shows the profiles. Figures 4 to 8 show sample models of profiles taken from the stations. Three profiles each were taken but only one each is displayed for lack of space.

Results

Nkalagu profile (Figure 4) covers a distance of about 60km and is modeled with 5 geometric bodies- one slab and four dykes. A dyke is a 2D elongated body while a slab is 3D. The 3rd and 5th dykes at depths of 5km are possible hydrocarbon potential.

The susceptibilities of the bodies are -0.1111, -0.0214, 0.0234, 0.0140 and 0.0234. Their depths are 2500, 2000, 5000, 1900 and 5000m respectively.

Afikpo profile (Figure 5) covers a distance of about 34km and is modeled with 2slabs and one dyke. Bodies 2 and 3 at depths of 5km are possible hydrocarbon potential. The depths to top of the bodies at Afikpo are 1900m, 5000m and 5000m respectively with susceptibilities of 0.0023 each.

FIG 2. 2-D image maps of the sheets.

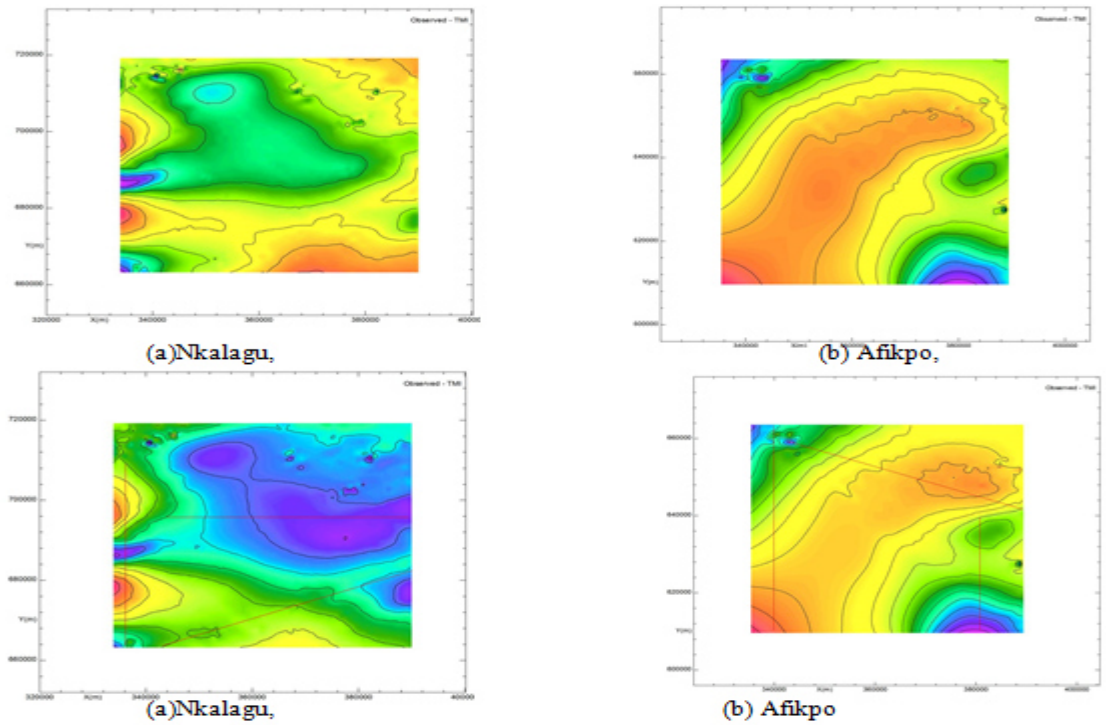


Fig 3: Profiles taken.

Nkalagu Profile

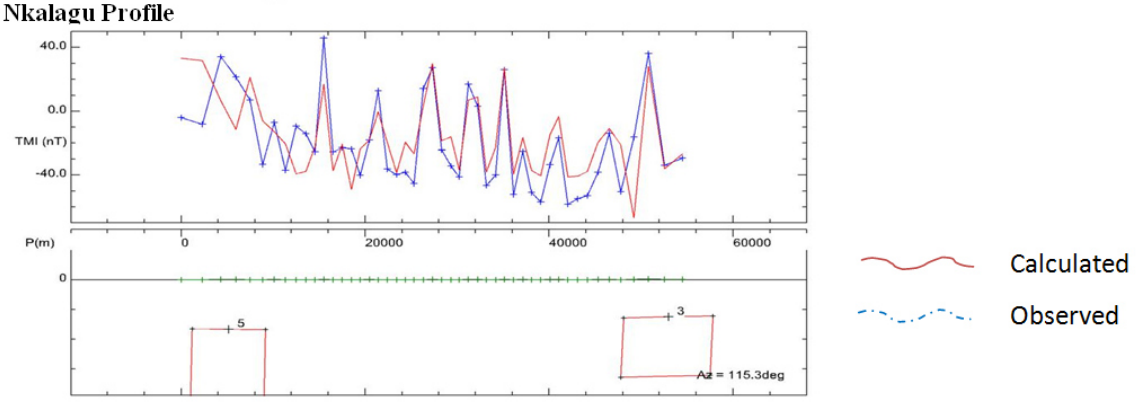
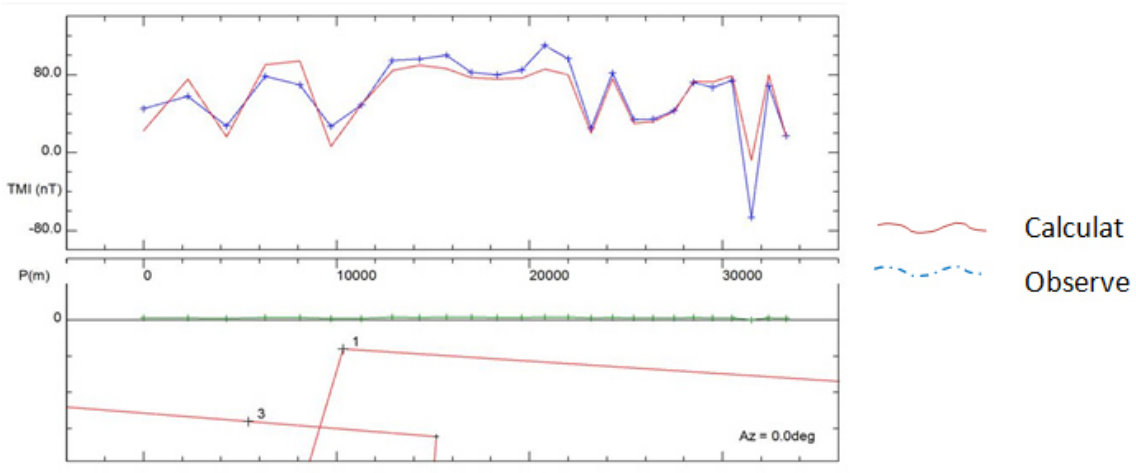
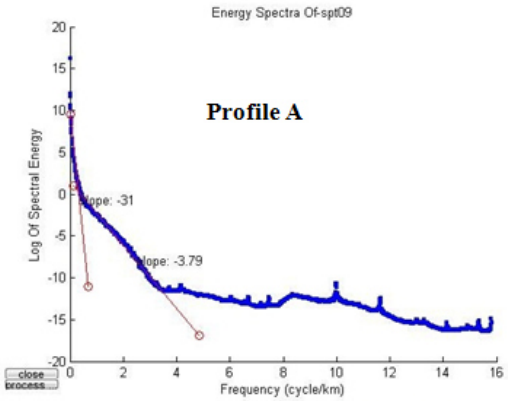


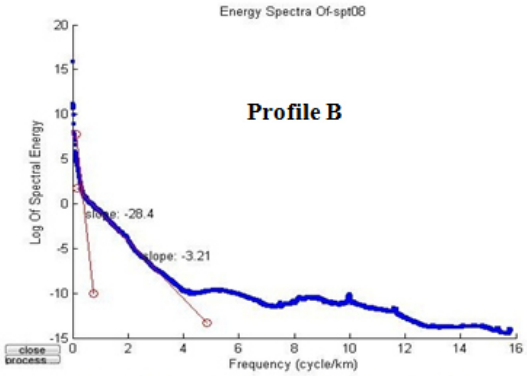
Fig. 4: Observed and calculated TMI Nkalagu Profile



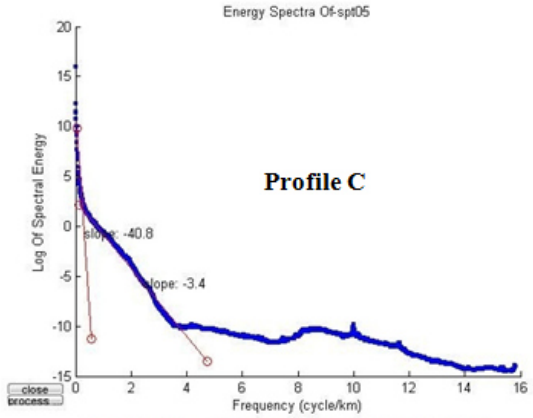
Nkalagu Spectral Analysis



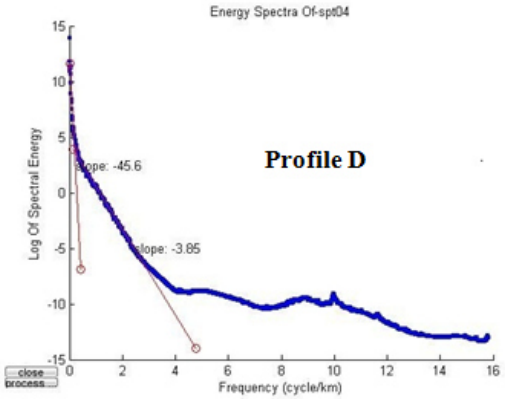
Spectral at long. $7^{0}45^{1}$E - 8^{0}E lat. 6^{0}N - $6^{0}30^{1}$N
Depth 1= 4.93km, Depth 2 = 0.60km



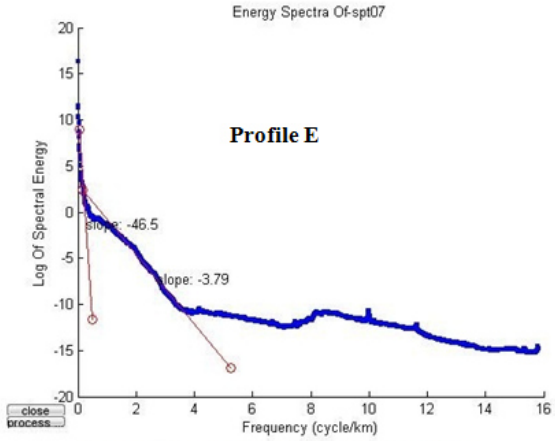
Spectral at long. $7^{0}30^{1}$E - $7^{0}45^{1}$E lat. 6^{0}N - $6^{0}30^{1}$N
Depth 1 = 4.52km, Depth 2 = 0.51km



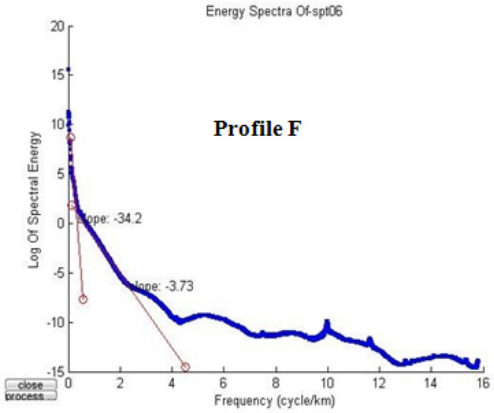
Spectral at long. $7^{0}30^{1}$E - $8^{0}30^{1}$E lat. $6^{0}15^{1}$N - $6^{0}30^{1}$N
Depth 1 = 6.50km, Depth 2 = 0.54km



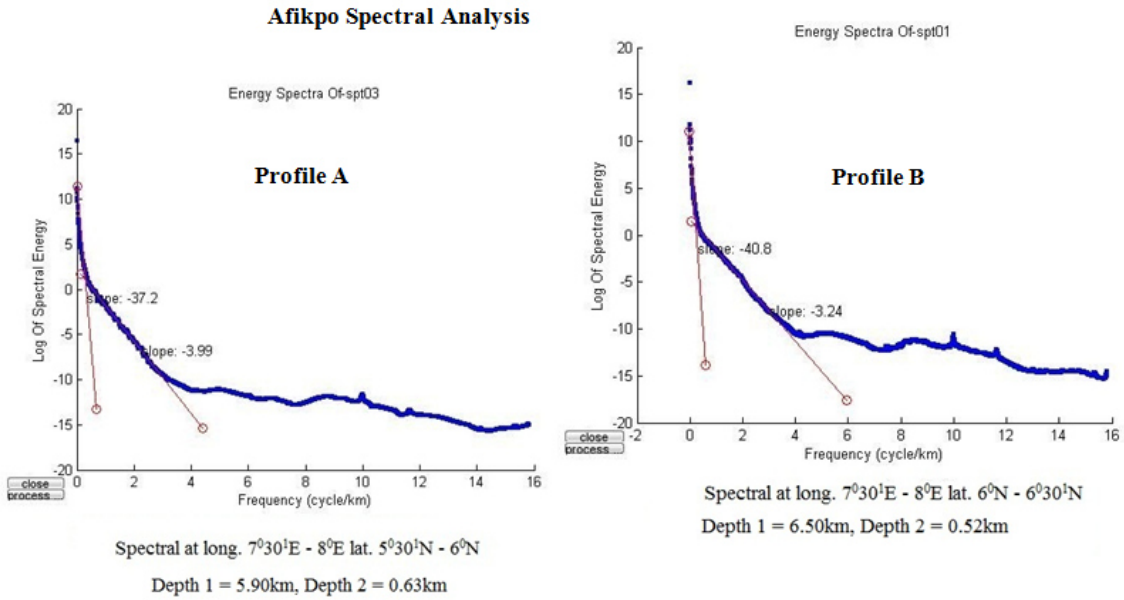
Spectral at long. $7^{0}30^{1}$E - $8^{0}30^{1}$E lat. 6^{0}N - $6^{0}15^{1}$N
Depth 1 = 7.30km, Depth 2 = 0.63km

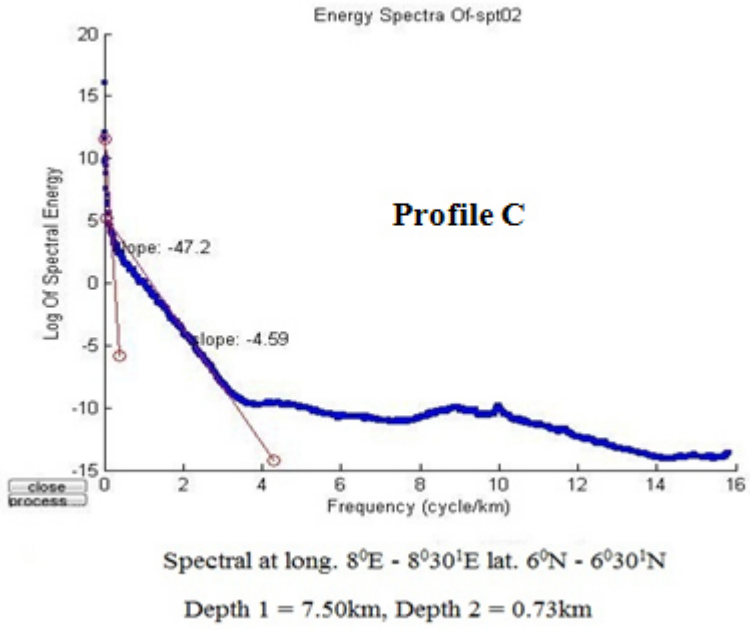


Spectral at long. $7^{0}30^{1}$E - 8^{0}E lat. $6^{0}15^{1}$N - $6^{0}30^{1}$N
Depth 1 = 7.4km, Depth 2 = 0.6km



Spectral at long. $7^{0}30^{1}$E - 8^{0}E lat. 6^{0}N - $6^{0}15^{1}$N
Depth 1 = 5.44km, Depth 2 = 0.59km





Discussion

Various profiles were taken at each station but only one is presented for lack of space. We also attempted spectral analysis for each station and present the results in Nkalagu and Afikpo. The spectral analysis shows maximum depths of 5.90km, 6.5km and 7.5km which corroborate modeled profile at 5km depths. The 2D/3D modeling has shown depths of areas between 3km and 5km of sedimentary thickness suitable for hydrocarbon generation. The basement rocks are granite, rhyolite, olivine-diabase and slate, based on the susceptibilities of the models. Afikpo and Nkalagu show signs of hydrocarbon potential and should be covered with detailed seismic survey. Our indicated depths are more reliable than those of other workers in Table 1. The 2D/3D geometrical shapes suggest dimensions of coverage of the hydrocarbon accumulation in the Lower Benue. At Nkalagu depths to instrusives range from 1.9km to 5km. These intrusives are mainly dykes which formed as a result of magma entering fractures of sedimentary and metamorphic rocks and cooling. These dykes are of infinite length having widths ranging from 4km to 8km and thickness ranging from 5km to 16km. They form impervious layer for hydrocarbon accumulation. At Afikpo we have slabs and a dyke whose depths range from 1.9km to 5km. Their widths range from 15km to 32km while their thickness range from 8km to 22km. They

form a good base for hydrocarbon accumulation.

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