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MODELING CRUSTAL STRUCTURES OF SOUTHERN NIGERIA BASINS FROM AEROMAGNETIC DATA: IMPLICATION ON HYDROCARBON PROSPECTIVELY

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ABSTRACT: *Aeromagnetic data has been used by many authors worldwide in evaluation of subsurface basin configuration.This study covers parts of five basins (Niger Delta, Calabar Flank, Anambra Basin, Mamfe Basin, and Lower Benue Trough) in Nigeria.The study utilized twenty aeromagnetic maps on a scale of 1:100,000. The maps were digitized manually along flight lines and a total of 16,689 data points obtained. The data was processed using computer techniques including map merging, reduction to pole, polynomial and power spectrum filtering for residual and regional anomaly separation,and forward and inverse 2.5D saki modeling .Results obtained from power spectrum depth analysis indicate depth to magnetic sources vis – a –vis sediment thickness from the Niger delta area (2.75km -3.75km), Anambra basin (1.5 km – 2.6 km), Calabar Flank (1.3 km – 2.3 km), Mamfe basin (2.0 km – 3.4 km), and Lower Benue Trough (1.5 km – 3.2 km). Also, depth to basement results from forward and inverse modeling indicate the Niger Delta has thickness of sediments ranging between 1.0 km- 8.0 km, Anambra basin (1.4 km – 2.7 km),Calabar Flank (0.8 km- 2.5 km), Mamfe Basin (1.0 km – 2.7 km), and Lower Benue Trough (1.4 km – 2.7 km). Also, results from modeled number of intrusives indicate that the Calabar Flank has five intrusives , Niger Delta has four intrusives , Mamfe basin has six intrusives , Anambra basin has five intrusives, and Lower Benue Trough has four intrusives. The implications of the increased number of intrusives is that generated hydrocarbons might be converted to gas ,this is more likely in areas around Calabar Flank, Mamfe basin and Anambra basins, given the high number of occurrence of intusives within these areas. whereas areas around the Niger Delta and Lower Benue Trough with significantly increased depth and lower number of intrusive are less proned to excessive heat from the intrusive and may produce more oil .The study support futher exploration activities within the Niger Delta and Lower Benue Trough areas.*

KEYWORDS: Configuration, Intrusives, Power Spectrum, Aeromagnetics, Basement.

INTRODUCTION

The southern Nigeria has major and minor sedimentary basins.This study covers parts of 5 sedimentary basins in southern Nigeria, this include the Niger Delta, Benue Trough, Calabar Flank, Mamfe basin and Lower Benue Trough. The area is located within latitude 4^{o} o'oo'' – 7^{o} o' oo''N and longitude 7^{o}o' oo'' – 9 ^{o} o' oo''E. The studied Sedimentary basins are flanked by the exposed basement rocks which extends towards the Cameroon (Oban Massif and Afi Mountains). Previous work done by earlier researchers using magnetic method involves using limited local data which was not possible to correlate regional features across different basins (okiwelu, et; al. 2012, Ako, et; al.2014, Obi, et; al. 2008, Obi, et; al. 2013, ofoegbu, 1991.)

This study, will emphasize comparing the regional implications of different subsurface modeling of basinal configurations and possible effects of tectonic activities affecting hydrocarbons emplacements within these basins.

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Geology of the Study Area

The study area covers parts of Southeast and Southsouth States in Nigeria. The area extend from the Niger Delta cutting across Calabar Flank Sedimentary basin and extending towards the Lower Benue Trough, passing through the Anambra basin and Mamfebasins.geologically, the evolution of the Benue Trough gave rise to other basins, it is a Cretaceous basin and the oldest basin in Nigeria (Olade 1975, Reijers 1996, Esssien et;al.2005 ,Edet and Nyong 1993). The Benue Trough was formed from the opening of the Benue rift system in the Mesozoic, when the South American plate drifted away from the African plate thus creating a triple junction. The events that lead to the formation of the formation of the Calabar Flank Sedimentary basin is well documented in Olade1975, Burke et; al.1972 .

The Calabar Flank also known as part of the Lower Benue Trough is made of mainly Cretaceous deposits. A series of tectonic episodes characterized the formation of the Cretaceous Benue Trough (Albian – Tertiary). The Awi Formation is sitting directly on the Oban Massif basemrntrocks , the formation has sequences of transgressive and regressive cycles of sedimentart deposits of Sandstones, Shales and Carbonates. Also sitting on the Afi Mountain basement rocks is the cyclic deposits of Eze- Aku, and Agwu formations, these formations cover parts of Mamfe basin and the Lower Benue Trough (Fig.1). Sediments deposition within the Benue Trough was controlled by different episodes of Trangrssiveand regressive controlled by different tectonic episodes which lead to the emplacement of Afikpo Syncline and the Abakaliki Anticlinorium (Olade 1975, Burke et; al.1972). The Afikpo and Nkalagu areas withness deposition of Eze-Aku, Agwu, Mamu, Ajali , and Nsuka Formations. The area has Basaltic intrusions which provided the intense heat which characterize the Benue Trough and Anambra basins. Sedimentation patterns within the Anambra basin latter developed the Niger Delta basin formed as a result of basin subsidence from gravity wedge deposits slopping downwards along ancient sutured fractured zones growth (faults).Sedimentation patterns within the Niger Delta has three formations, the topmost Tertiary Benin Formation, followed by the middle Agbada and Akata Formations. This area covers almost half the study area (Fig .2). The Benin Formation are mainly sandstones , the Agbada Formation has mainly alternation of Sandstones and Shales forming the major exploration targets , while the Akata Formation are mainly made of shales. The geologic map in this study area display only the top tertiary Benin Sandstones Formation

(Fig.1) .

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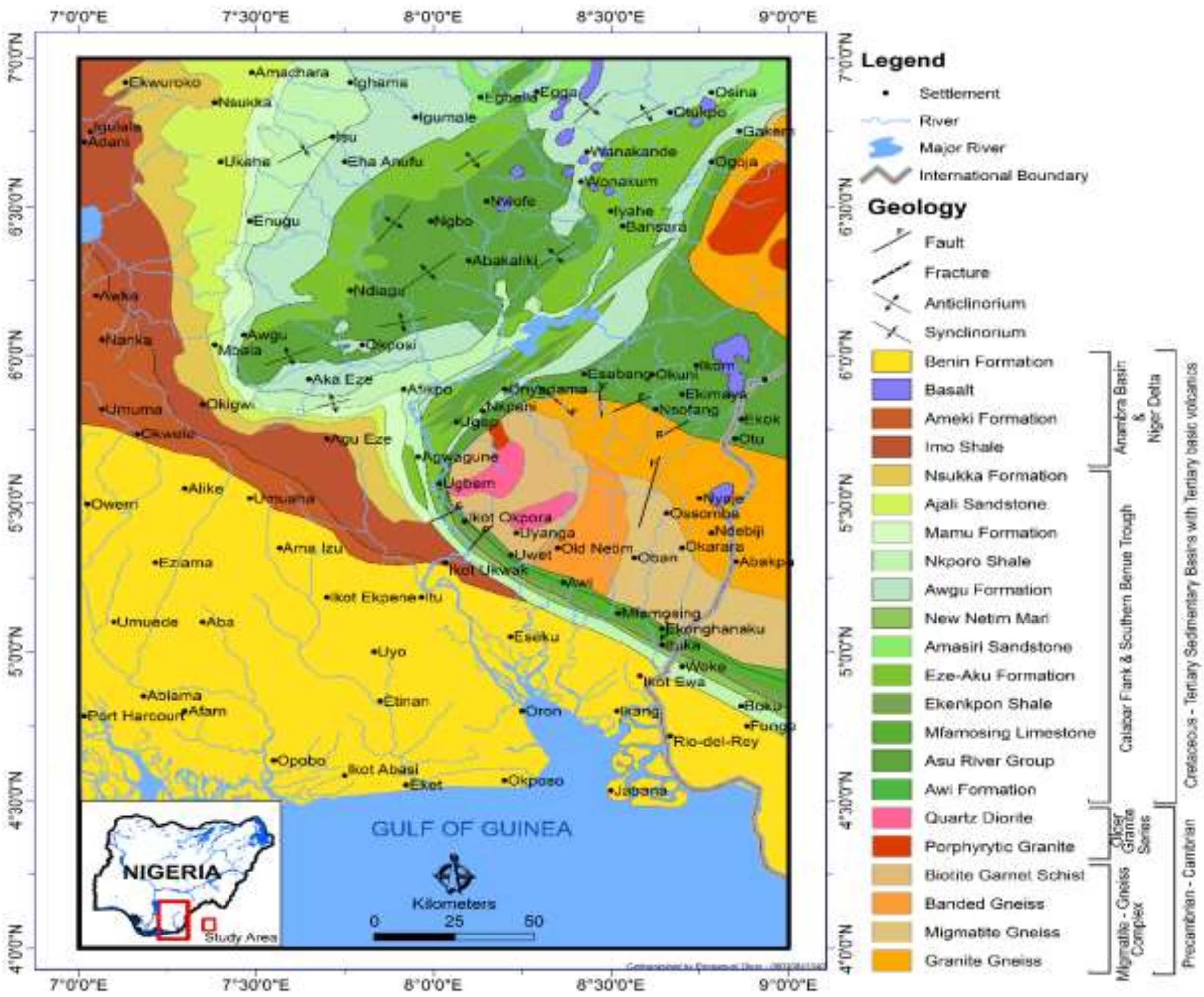

Fig. 1 Geologic map of the study area.

METHODS OF STUDY /DATA ANALYSIS

Twenty aeromagnetic maps on a scale of 1: 100,000 were acquired from Nigerian Geological Survey Agency Kaduna. The maps were digitized manually along flight lines at 1.0 km intervals and a total of 16,689 data points were obtained for futher processing. The processed data points were stored in a folder and used as input file in a batch of computer software programs (potential field version 2.2) acquired from the United States Geological Survey (U.S.G.S). The digitized magnetic data was merged and contoured using surfer 9.0 software to obtain the coloured merged Total Magnetic Total Intensity field map of the study area (Fig.2). Futher processing was done using the batch of U.S.G.S. softwares (phillips, 1997) which include ADDGRD , JMERGER, DETOUR, A2XYZ , GEOCON, CK_DIMS ,PLUGGRD, FFTFIL , F_RTP, PREP5, DE-PREP5 to produce the reduction to – pole map (Fig.3

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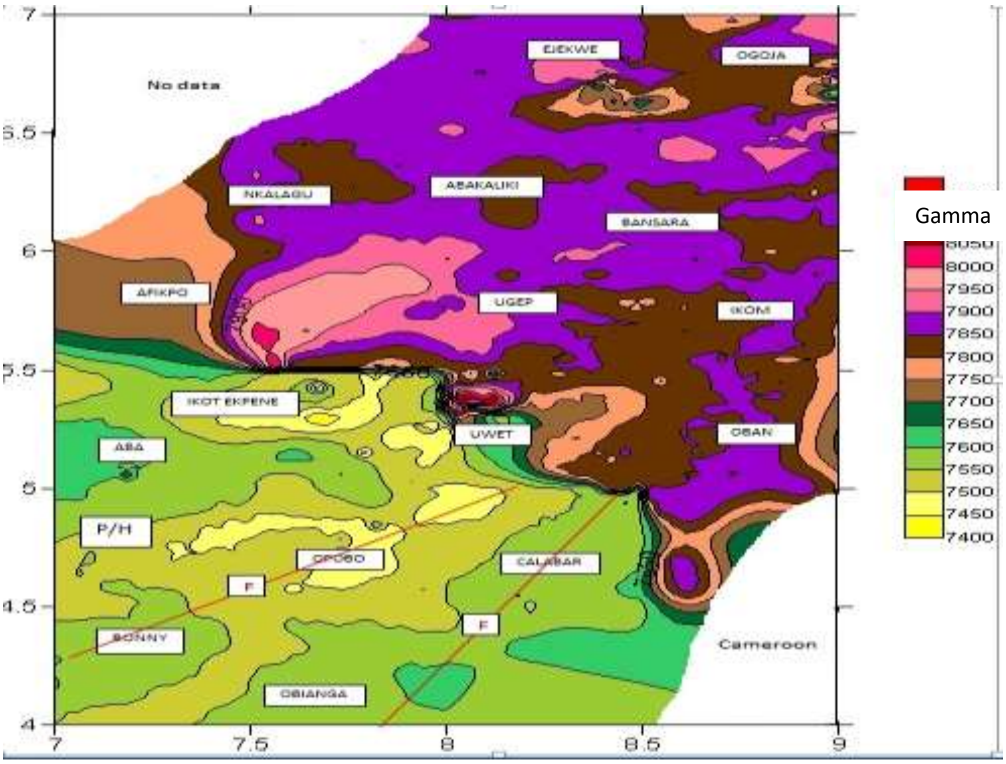

Fig. 2 Total Magnetic Field Intensity Map (Contoured at 50nT)

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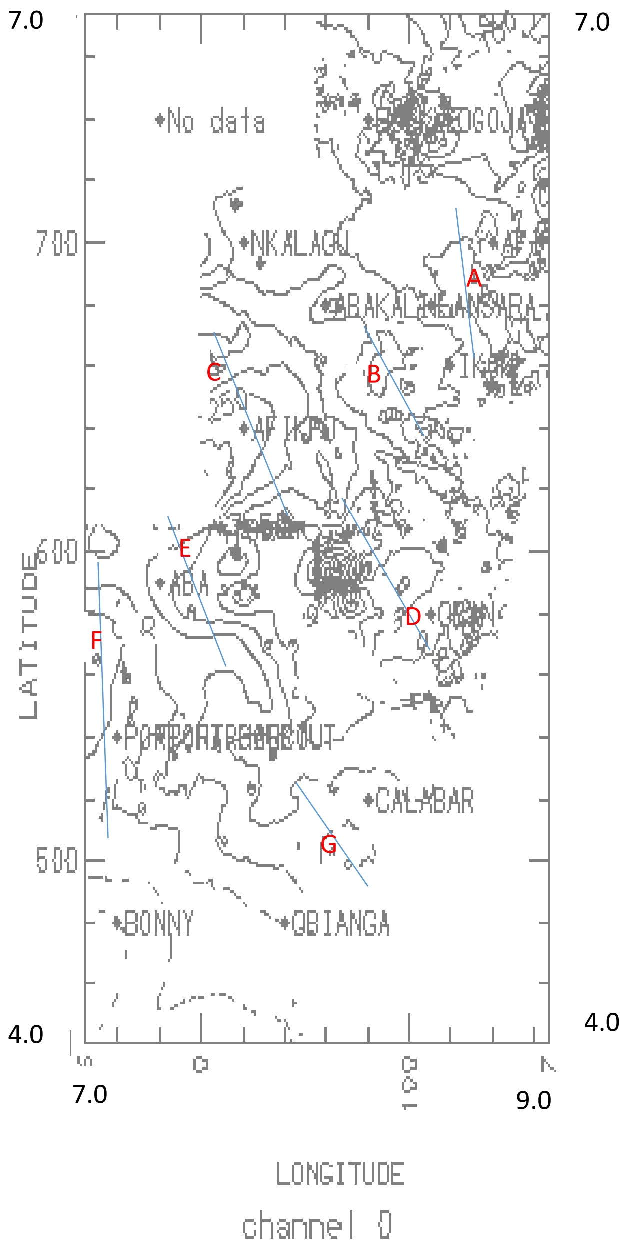

Fig. 3 Reduced to pole polynomial residual map of the Study area (contoured at 50nT showing positions of modeled profiles)

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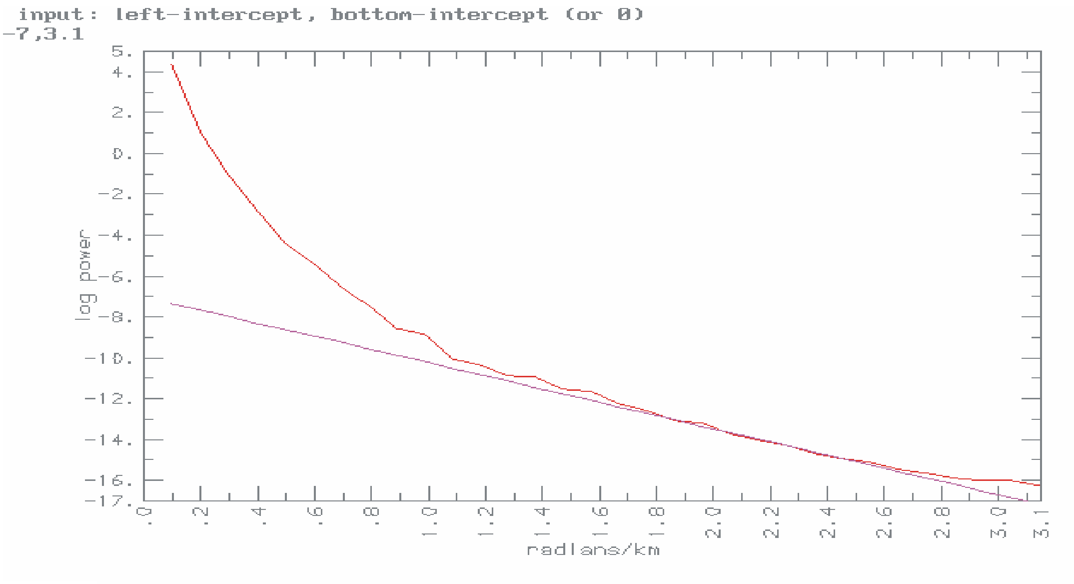

Fig.4 PROCESSED SPECTRAL ANALYSIS DEPTH OF LAYER (1) ONE OF UGEP BLOCK

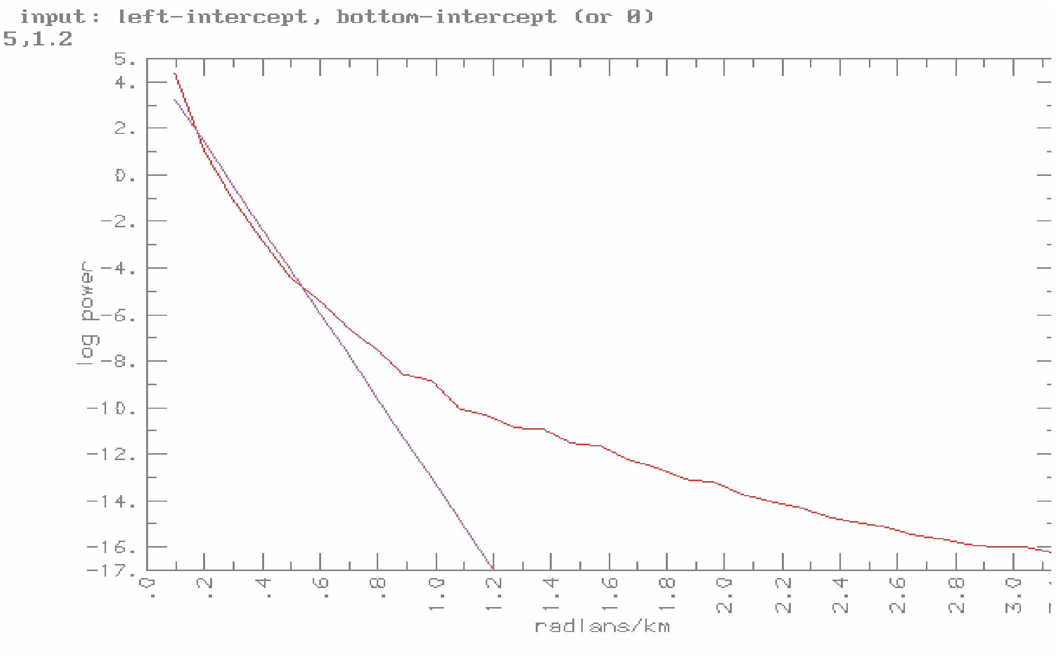

Fig 5 PROCESSED SPECTRAL ANALYSIS DEPTH OF LAYER (2) OF UGEP BLOCK

The data was subjected to anomaly separation using a software (SURFIT) to produce theresidual magnetic map of the study area (Fig.3).The residual grid file was gridded into twenty blocks and used in a batch of software programs (MFINIT, MFFILTER, MFDESGN) used in computing the depth to the magneticbasement (Blackely and Simpson,1986; Webring,1985; Hahns et; al. 1976) .The results as displayed in figures 4 and 5 as log power and radians/km plots indicating different depth layers as layer 1 and layers 2 where layer 1 indicate shallow depths to magnetic basement vis- a- vis sediments thickness in the top layer and layer 2 indicate deeper magnetic sources representing basement depths (Hahns, et; al.

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1976, Naidu, 1970, Webring, 1985). The results of each depth point in each block was considered during forward and inverse modeling. Forward modeling was done using P-DEPTH software where a profile line was extracted with the aid of PROFILE-X software creating an input file used for the forward modeling. Seven profiles were chosen along prominent anomalies perpendicular to the anomalies regional trends and Several input parameters used in the modeling, which include total magnetic field, profile azimuth, inclination , declination, minimum and maximum longitude and latitude, and number of bodies ,the program runs to produce a modeled file eg. Obi.mod which is then used for the inverse modeling. The Saki software program use the output of the forward modeled file as its input file and performs several mathematical iterations to produce a best fit curve or match between an observed plotted magnetic field curve and a calculated generated curve with a minimal percentage error to about 5% (phillips, 1997). The results of the forward and inverse modeling are presented in table 1.0 and figures 6 , 7 , 8 , 9 , 10 , 11 and 12.

TABE 1. RESULTS OF FORWARD AND INVERSE MODELING OF DEPTHS (KM) DERIVED FROM MAGNETIC BASEMENT FROM SAKI MODELED PROFILES

PROFILES/ TOWNS	NO OF INTRUSIVES	MAGNETIC SUSCEPTIBILITIES OF INTRUSIVES	RMS%	AVERAGE SHALLOW DEPTH OF SEDIMENTS(KM) THICKNESS	EXTIMATED DISTANCES FROM PROFILES (KM)	AVERAGE MAXIMUN DEPTH OF BASIN SEDIMENTS (KM)	EXTIMATED DISTANCES FROM PROFILES (KM)	BASIN EXPLORATION PROSPECTS
A (Ikom –Edor)	2	0.0055 0.0035	1.2	0.5 – 1.4	15.0	1.4 – 1.8	4.5	Poor (Mamfe basin)
B (Bansar – Ikom)	2	0.005 0.0025	1.0	0.5 -1.0	15.0	1.0 – 2.6	7.5	Good (Mamfe basin)
C (Afikpo Nkalagu)	1	0.005	1.85	0.5 -1.0	14.0	1.0 -1.7	7.5	Poor (Anambra Basin)
D (Ugep – Oban)	1	0.0025	1.2	0.5 -1.4	15.0	1.4 – 1.7	20.0	Poor (Lower Benue towards Oban massif)
E (IkotEkpene – Uwet)	2	0.0025 0.0025	1.75	0.5 – 1.5	3.5	1.5 -2.7	12.0	Good (Calabar Flank)
F (Porthar court– Bonny	2	0.0085 o.0020	1.75	1.0 – 2.5	14.0	2.5 – 8.0	15.0	Very Good (Niger Delta)
G (Calabar – Uwet)	3	0.0015 0.0025 0.0035	1.85	0.5 -1.5	3.5 -	1.5 – 2.3	12.5	Good (Calabar Flank)

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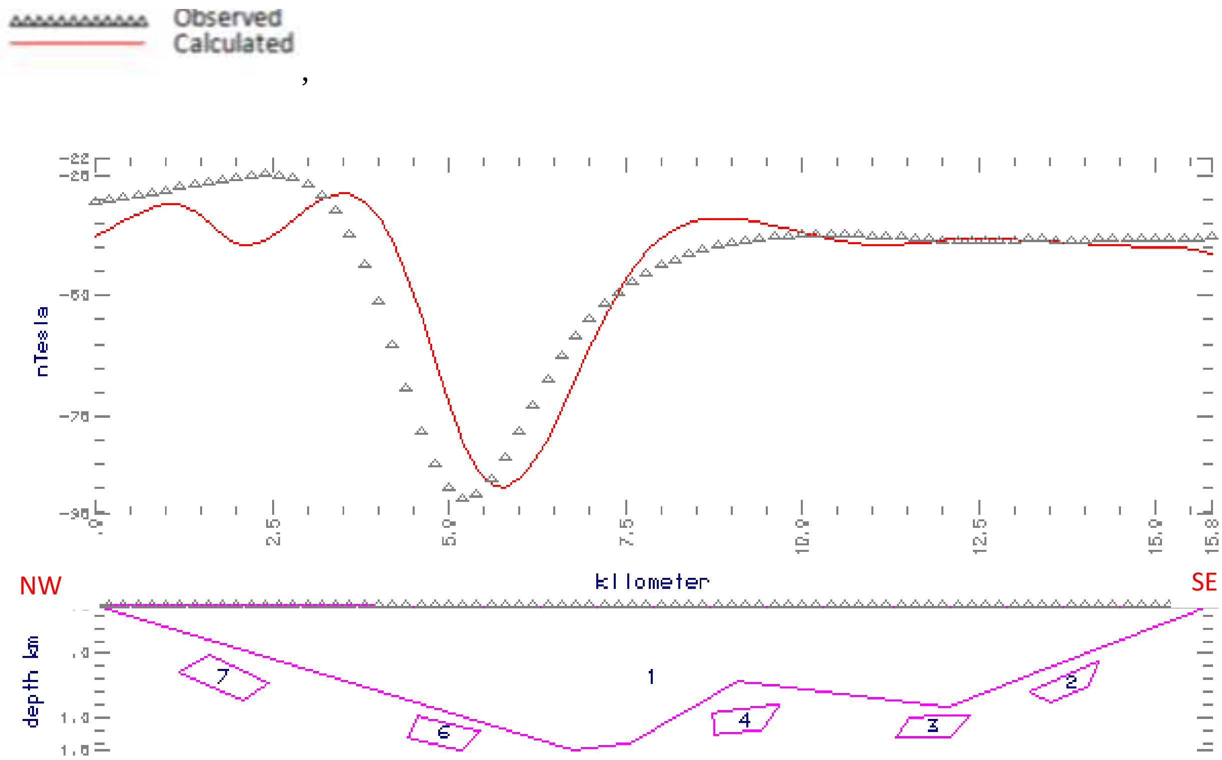

LEGEND:

Sedimentary rocks = 1

Intrusives= 5,6

Basement rocks = 2,3,4,7

Fig. 6 Modeled Forward and Inverse Profile (A) along Ikom towards Edor

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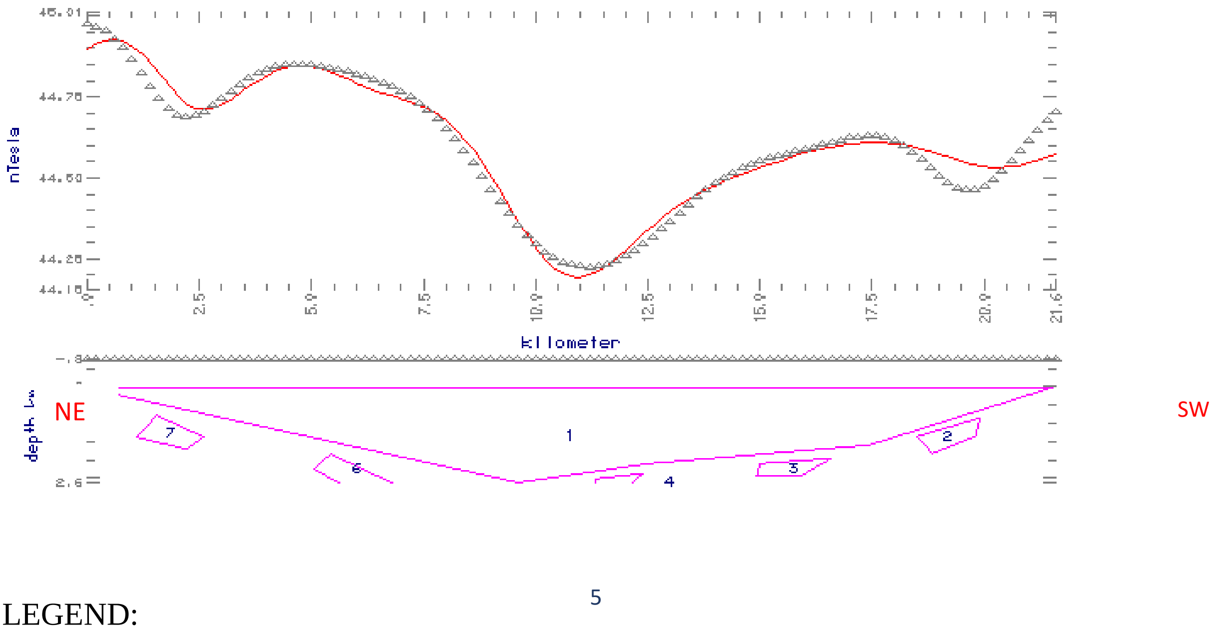

LEGEND:

Sedimentary rocks = 1

Intrusives= 2,4,5

Basement rocks = 3,6,7

Fig. 7 Modeled Forward and Inverse Profile (B) along Bansara towards Ikom

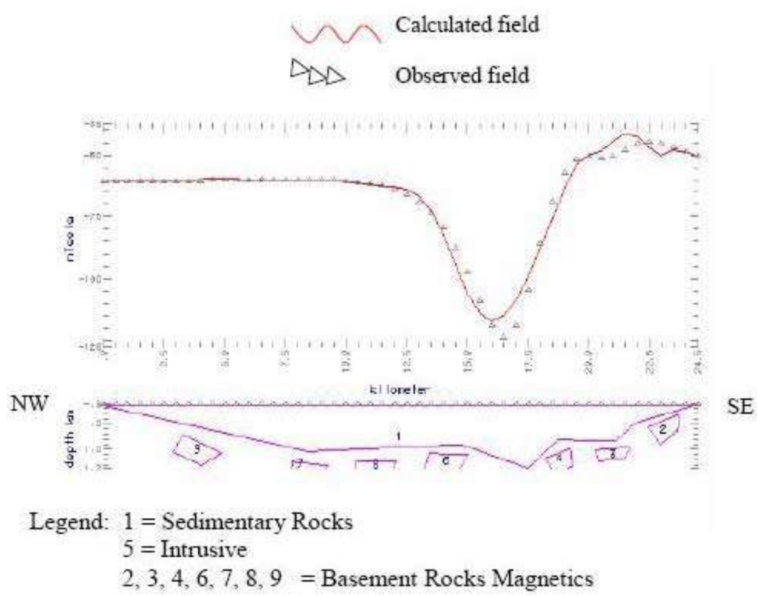

Fig. 8 Modeled Forward and Inverse Profile (C) along AfikpotowardsNkalagu

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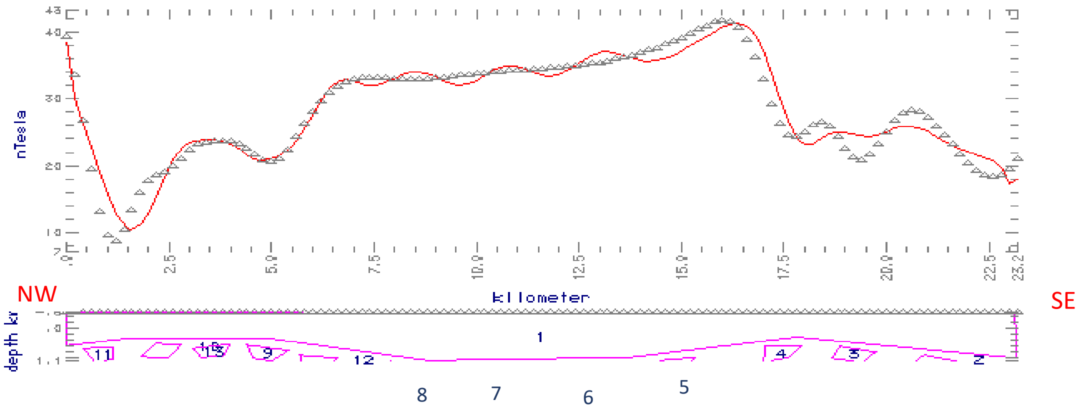


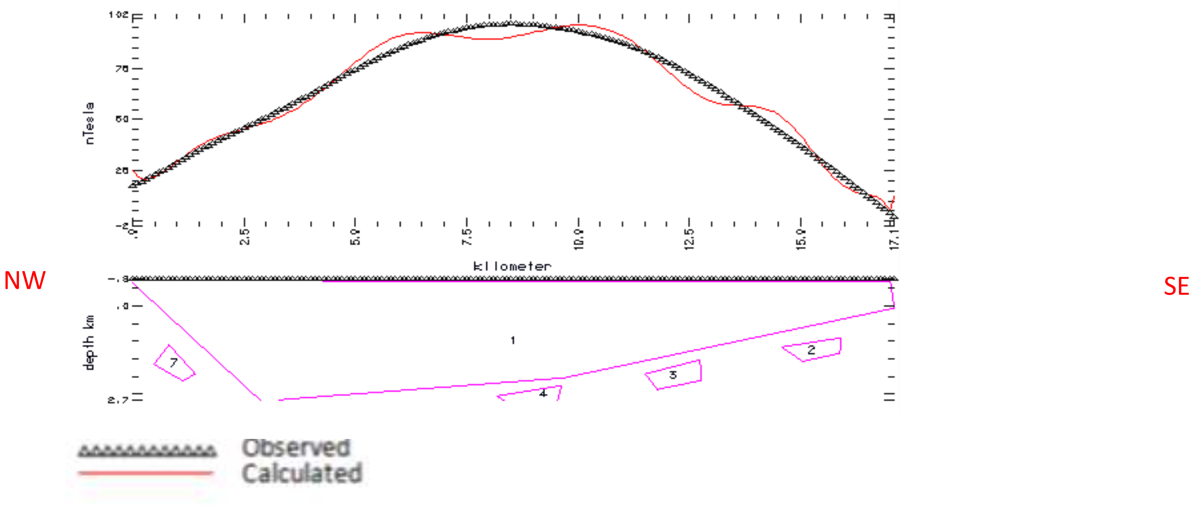
LEGEND:

Sedimentary rocks = 1

Intrusives= 5

Basement rocks = 2,3,4,6,7,8,9,10,11,12

Fig. 9 Modeled Forward and Inverse Profile (D) along Ugep towards Oban



Legend: 1= Sedimentary Rocks
3,4,5,6,8 = basement rocks magnetics
2,7 = Intrabasement Intrusive

Fig. 10. Forward and Inverse Modeled Profile (E) along Aba towards IkotEkpene

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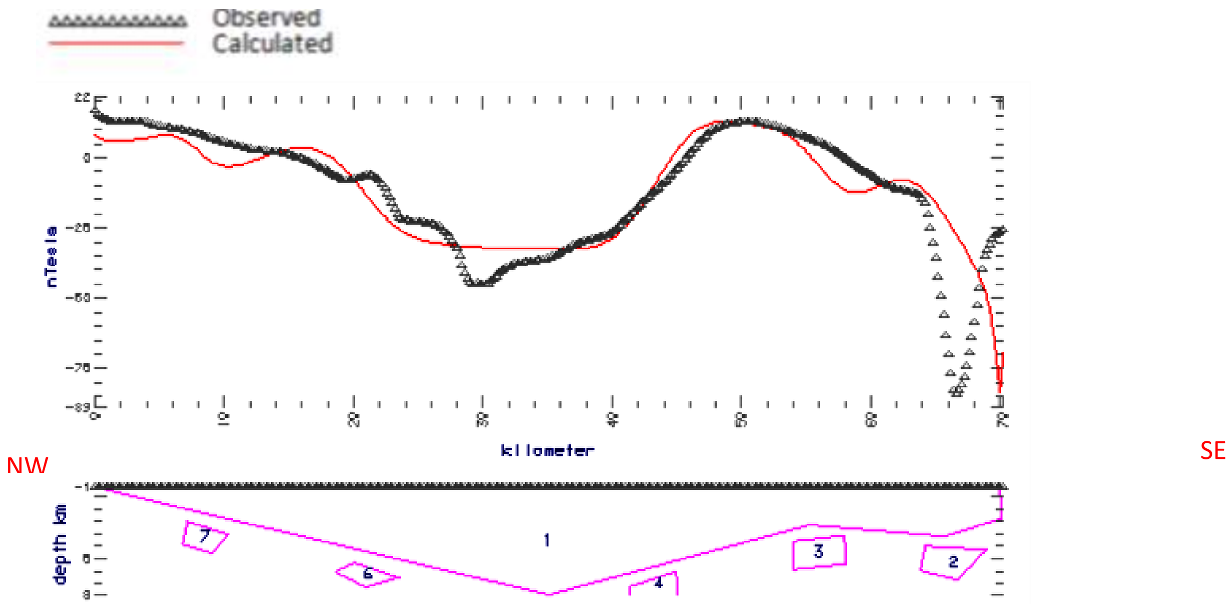
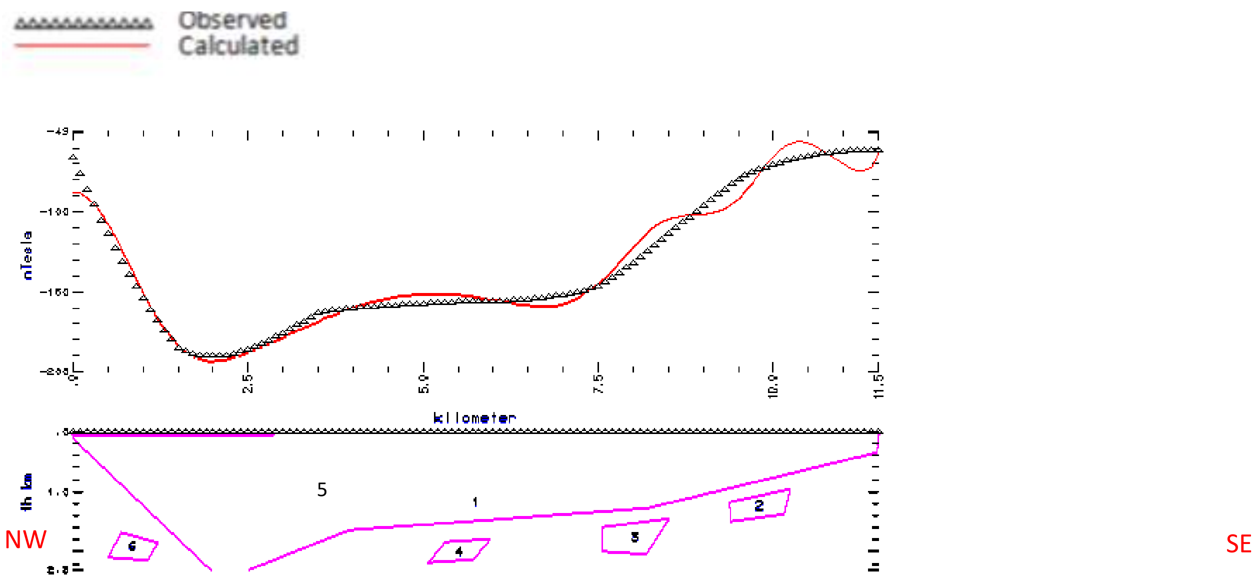


Legend: 1= Sedimentary Rocks
3,4,6,7,8 = basement rocks magnetics
2,5 = Intrabasement Intrusive of basaltic

5

Fig. 11. Forward and Inverse Modeled Profile (F) Along Port Harcourt



Legend: 1 = Sedimentary Rocks
2,6 = basement rocks magnetic
3,4, 5 = Intrabasement Intrusive

Fig.12 Forward and Inverse Modeled Profile (G) Along Calabar toward Uwet

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DISCUSSION OF RESULTS

The presence of the Chain and Charcort fracture zones that extended from the atlantic ocean toward the opening of the Benue Troughis clearly seen and marked as `FF' along two prominently deep seated anomalies cutting across Obianga towards Calabar and Bonny towards Opobo (fig.2).Seven profiles were selected along prominent anomalies from the reduced to pole residual contoured map(fig.3) and used for forward and inverse modeling, the results reveals basin structure and configuration . Also the identified intrusive occurrences serves as a guide to the amount of geothermal temperatures associated with these basins. Three profiles E, F,and G were cut across the Niger Delta basin (Fig.10,11,12), sediments thickness is greatest along profile F, Portharcourt towards Bonny (3.0km - 8.0km) along a profile length of 10.0km – 15.0 km. profile E, is along Aba – IkotEkpene with depths between 2.0km- 2.5km, while profile G is along Calabar - Uwet, these profiles has depth ranging between 2.5km – 3.5km. Basin depth decreases from Niger Delta towards the Calabar Flank sedimentary basin and towards the Lower Benue Trough, this is evidence in profiles A, and D where profile D runs along the Calabar Flank towards the Lower Benue Trough with depth ranging between 1.7km – 2.6km and profile A run across the Mamfe basin towards the Lower Benue Trough with depth ranging from 1.8km – 2.6km. Also, two profile B and C run across the Anambra basin and the Lower Benue Trough, where profile B run across Abakaliki towards Ugep with depth ranging from 5 km – 2.1 km, and profile C run across Afikpo towards Nkalagu with depth ranging from 1.7km – 2.7km .

During modeling, several parameters were used to evaluate the presence or absence of intrusive rock within the study area, this was necessary to evaluate the possible thermal history of the various basin and their possible effects on the hydrocarbon generating potentials.The presence of intrusive were recognized using susceptibility of 0.000005 for Sedimentary rocks, 0.0025 – 0.0050 - for Rhyolites , and 0.025 – 0.050 for Basalts.The areas close to the Oban massif around Uwet, Ikot-ekpene, and Calabar are more prone to an increased number of intusves, also, the areas close the Afi mountains around Ikom ,and Bansara has an increased number of intrusives both areas has over twelve major intrusives, other areas around the Niger Delta, Anambra basin, and Lower Benue Trough have a fairly equal number of intusives (Table.1). Generally, the Niger Delta area which include part of the Calabar Flank Sedimentary basin has intense ongoing hydrocarbon exploration activities, the study reveals high numbers of intusives along Uwet, Ikot-ekpene, and Calabar axis these areas are less prone to hydrocarbon generation as the effects of these intrusives may over convert formed oil to gas. The Mamfe basin though has good sediments thickness of hydrocarbon generation have many intrusives that may render the basin gas prone. The Niger Delta with a low number of intrusives and great depth of sediments thickness (8.0 km) has good potentials for oil generation . Also, the Lower Benue Trough and Anambra basins are similar in moderate depth of sediments thickness (2.5km) and a low number of intrusives, these makes them fairly good prospecting basin for hydrocarbon exploration.

CONCLUSION

The significance of this study is the wide range appraisal of the basin architecture and configuration of the offshore and inland basins in Southern Nigeria. The Niger Delta basin areas of Portharcourt, Bonny with sediment thickness of about 8.0km and less intrusives remains the most viable area for exploration of hydrocarbons. The Bansara area within the

Mamfe basin has (2.6km) sediment thickness that could generate hydrocabonsgiven that other condition are favourable, but the presence of numerous intusives may makes the area prone to excessive heat and may produce more gas than oil. The Anambra basin and the Lower Benue Trough have moderate depth of sediments thickness(2.5km) and less number of intrusives , this make these areas second to the Niger Delta among the studied basins for good prospects in hydrocarbon exploration investigations.

In conclusion, this study reveal the order of preference of the choice of investigating the hydrocarbon prospective potentials of Southern Nigerian basins using the potential field magnetic method, it is recommended that other geophysical methods such as gravity ,and seismic be used to identify possible hydrocarbon habitats within the inland basins of Southern Nigeria Basins.

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