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Identification Of Hydrocarbon Regions In Southern Niger Delta Basin Of Nigeria From Potential Field Data

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Abstract: Potential hydrocarbon regions in the southern region of the Niger delta Basin of Nigeria have been identified from gravity and magnetic data. The enhanced residual data obtained from least square analysis method was interpreted by inverse and forward modeling techniques using Potent-3D software. The results reveal potential hydrocarbon environment at depths of between 1,000 m to 3, 500 m from the gravity data and depths of 2,183 m to 4,385 m from the magnetic data. The identified structures trend in NS, EW and NE-SW directions of the basin.

Index Terms: Basement, Density contrast, Forward and inverse modeling, Niger Delta, magnetic susceptibility, potential hydrocarbon regions, sedimentation.

1 INTRODUCTION

THE Niger delta sedimentary basin is one of the most prolific petroleum occurring regions in the world [1]. Therefore, knowledge of the subsurface geology and depths of potential reservoirs in the region is necessary to enhance petroleum exploration and reduce cost of production. Many studies have been carried out to determine the structural geology and depths of sedimentation in this region especially with seismic and borehole data [2], [3], [4]. However, the cost and challenges of collecting data in inaccessible regions is a major problem that requires use of other methods to overcome. The gravity and magnetic methods can be used to achieve this. Both methods also called the potential method are natural, non destructive and can give structural and reservoir information at greater depths [5]. Density contrast is basically the physical parameter of interest in the interpretation of gravity data, while the magnetic susceptibly contrast is the interest in the magnetic method. Anomalies due to structural features or trends often are attributed to deformation in sediments, density or susceptibility contrast in the basement or both. Probable petroleum entrapment regions can be inferred from the density contrast values in a formation while a measure of the rock susceptibility enables discrimination between sedimentary rocks, which are potential petroleum regions, and basement rocks. In this work, combinations of forward and inverse techniques were used to obtain information on the structural trends and depths of potential hydrocarbon entrapment areas in the region.

2 LOCATION AND GEOLOGY OFSTUDY AREA

The study area is south of the Niger delta Basin of Nigeria within longitudes $6^o\,00'$ to $7^o\,30'$ E and latitudes $4^o\,30'$ to $5^o\,30'$ N (Fig.1). According to Opafunso [6] the Niger delta itself lies between longitudes $5^o\,00'$ to $8^o\,00'$ E and latitudes $4^o\,00'$ to $8^o\,00'$ N covering a land mass of about 150, 000 m^2 and depobelt area of about 300,000 m^2. The Niger delta is the youngest sedimentary basin within the Benue trough [7] and its depositional history began in the early Tertiary with sediment supply mainly from the Niger and Benue Rivers. These sedimentations resulted in three lithostratigraphic units with sedimentation thickness as much as 12, 000 m in some regions [2]. The base of this sedimentary basin is the Akata Formation that is composed mainly of shales, turbidite sands and minor silts and this is the petroleum source bed of the basin. This formation is overlain by the Agbada Formation that is the petroleum bearing unit of

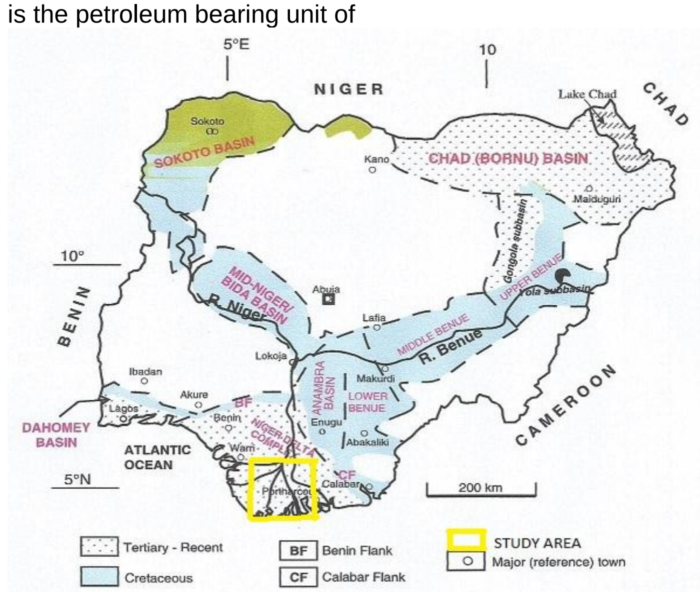

Fig. 1 *The sedimentary basin of Niger delta and the and the study area modified from Obaje [7].*

the basin and composed mainly of paralic siliclastics. The topmost formation is the Benin Formation and is composed of coastal sandstones that are up to 2, 000 m thick in some regions. Ekweozor and Okoye [8] shows that almost all the petroleum accumulations in the Niger delta occur in the sands and sandstones of the Agbada Formation where they are trapped by rollover anticlines related to growth fault development.

3 MATERIALS AND METHODS

The high resolution airborne data (gravity and magnetic) used for this study was obtained from the Nigerian Geological Survey Agency (NGSA) Abuja. It was collected by Fugro Airborne Survey Limited for the agency in 2010 as part of a

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nationwide high resolution airborne geophysical survey aimed at assisting and promoting mineral exploration in Nigeria. The digitized data used were from sheets 319, 320, 321, 327, 328 and 329 for the aeromagnetic data and sheets 319, 220, 327 and 328 for the gravity data. The data were collected at 1km and 4 km line spacing respectively for the gravity and magnetic data at a tie-line of 2 km for the magnetic data with terrain clearance of 80 m. Least square analysis was used to separate the regional anomaly from the residual anomaly. Different orders of polynomial used gave the best fit for the regional as the second order polynomial equation

$$g_r = a_o + a_1 x + a_2 x^2 + \dots\dots\dots\dots + a_n x^n \dots\dots\dots [1].$$

The residual anomaly was obtained from the observed field data using Oasis montaj software. This residual anomaly was enhanced by passage of a high pass filter and application of a first order derivation operation [9], [10], a downward continuation equivalent to grid size and reduction to pole operation for the magnetic data [11], [12]. The enhanced data were gridded [13] and selected potions modeled using Potent 3-D of the Oasis montaj software. Forward modeling technique was used to estimate the geometry of the source and the distribution of density/magnetization by trial-and-error approach while the inversion process was used to determine some parameters of the source geometry from the distribution of density/magnetization and the depth to basement. The fit of the theoretical and observed field curves were controlled by the root mean square error set at 1.5. The modelings were achieved using PotentQ-3D, an extension in the Oasis Montaj^{TM} software. The forward and inverse modelings were implicit; changes to the model were automatically applied to calculated profiles and images using non-linear least square method. The models that were geologically plausible and consistent with the observed physical values of the field were spheres, dykes and cylinders.

4 Results

Figs. 2 (a) and (b) show the gridded base map from the gravity and magnetic data respectively indicating modeled areas, while Figs. 3 (a), (b), (c) and (d) show the model results from gravity data. Figures 4 (a), (b), (c) and (d) show the model results for the magnetic data. Tables 1 and 2 are summary of the results of the modeling.

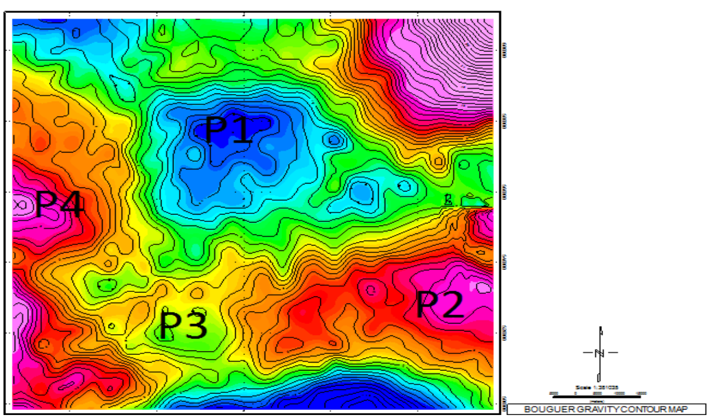

Fig. 2 (a) *Residual Bouguer gravity base map of the study area indicating modeled points [14].*

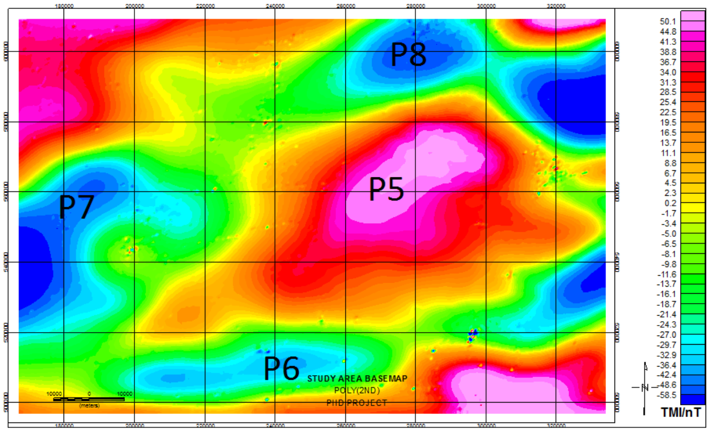

Fig. 2 (b) *Residual TMI base map of the study area indicating the modeled points [14].*

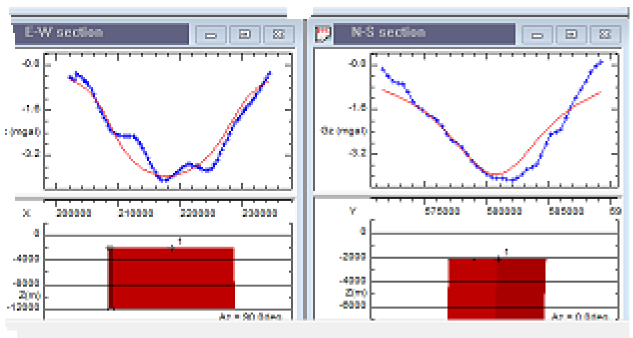

Fig. 3 (a) *Profile model for point P1 [14]*

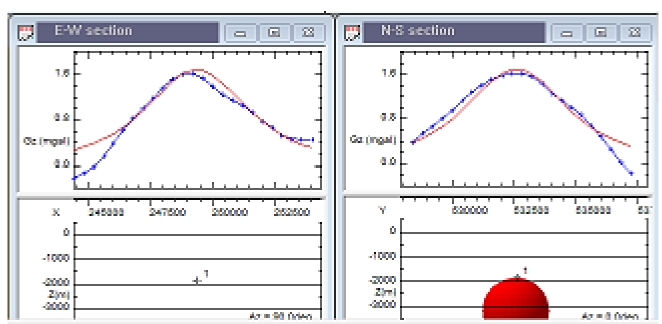

Fig. 3(b) *Profile model for point P2 [14]*

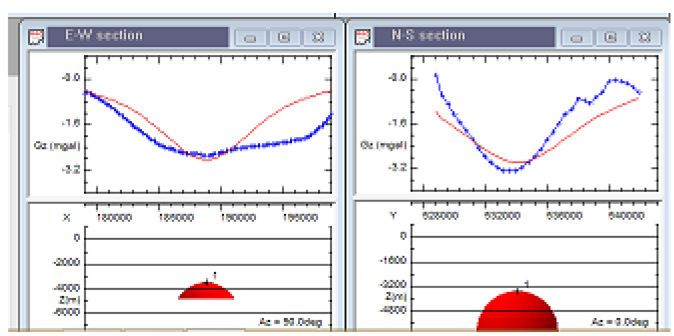

Fig. 3(c) *Profile model for point P3 [14].*

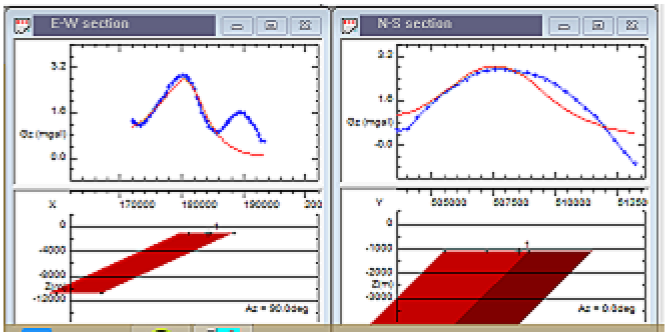

Fig. 3(d) *Profile model for point P4 [14].*

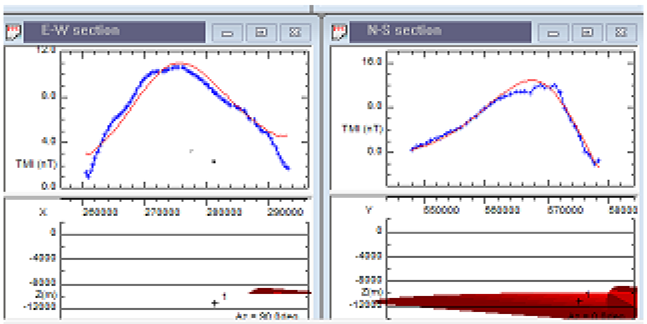

Fig. 4(a) *Profile model for point P5 [14].*

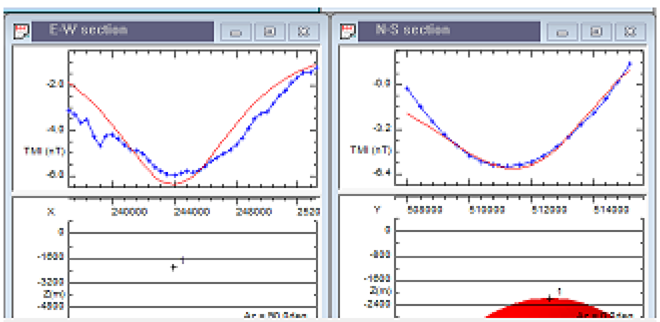

Fig. 4(b) *Profile model for point P6 [14].*

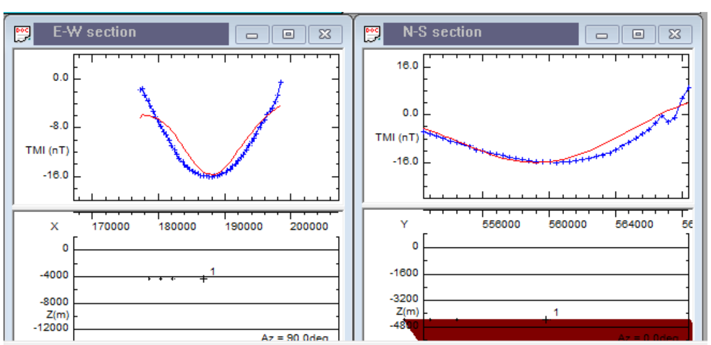

Fig. 4(c) *Profile model for point P7 [14].*

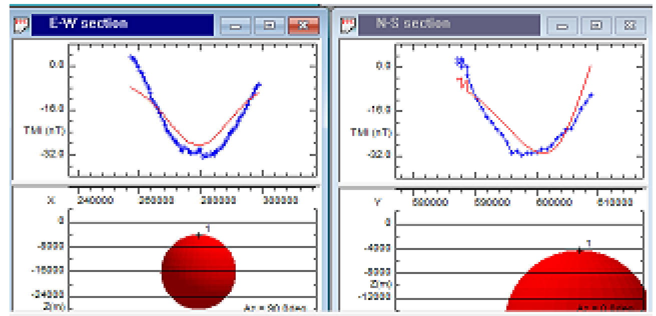

Fig. 4(d) *Profile model for point P8 [14].*

Table 1 *Summary of model result for Bouguer gravity data*

model	P1	P2	P3	P4
Model shape	dyke	sphere	sphere	dyke
Depth to anomalous body/m	2, 083	1,855	3,538	1,094
Density contrast/g cm-3	0.062	0.259	0.0.223	0.076
Possible cause of anomaly	petroleum	petroleum	petroleum	petroleum

Table 2 *Summary of modeled result for TMI data*

Model	P5	P6	P7	P8
Model shape	Cylinder	sphere	dyke	sphere
Depth to anomalous body/m	11, 218	2,183	4,354	4,276
Susceptibility contrast/SI	-0.0464	0.0026	0.0100	0.0100
Possible cause of anomaly	basement	petroleum	petroleum	Petroleum

5 DISCUSSIONS

The base maps reveal syncline and anticline structural anomalous features trending in NS, EW and NE-SW directions of the study area. From the modeling, the best fit for these structures are mostly spheres and dykes. The interpretation is that these anomalous structures are probably due to faults, diapers, folds or basement [15]. Profile P1 modeled as a dyke reveals a north-east trending syncline structure with dip and plunge angles of zero indicating that it is a horizontal bedding plane while the strike angle indicates its rotation about the height. This structure occurs at a depth of 2,083 m and from the density contrast of the anomalous body and depth of occurrence, it is a favorable environment for hydrocarbon reservoir. Profile P2 modeled as a sphere shows an anticline horizontal bedding plane anomalous body trending in the north-east direction and occurring at a depth of 1,855 m. The depth of occurrence also makes it a probable hydrocarbon reservoir. Similarly, profiles P3 and P4 were modeled as a sphere and a dyke respectively. Their results reveal horizontal bedding syncline and anticline anomalous bodies trending in a north-east and southwest-northeast directions respectively. Their depth of occurrence (3,538 m and 1,094 m) also makes them probable petroleum reservoirs. Profile P5 modeled as a cylinder shows a broad wavelength anomalous body at a depth of 11,218 m. The cause of this anomaly is probably the basement as this depth corresponds to those from Euler depth estimation [14]. Profiles P6, P7 and P8 modeled as spheres and dyke reveal east-west trending syncline anomalous bodies for P6, P7 and P8. Their depths of occurrence which lie between 2,183 m and 4,354 m make them probable hydrocarbon sources. The results from the Forward and Inverse modeling interpretation for the gravity and aeromagnetic data were able to reveal syncline and anticline bodies using sphere and dyke models. The gravity data results show possible hydrocarbon entrapment regions at depths between 1,000 m to 3,500 m, while the magnetic data revealed similar structures at depths of between 2,000 m to 4,300 m including a probable basement depth of 11,200 m.

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