

APPLICATION OF AEROMAGNETICS AS A BASIN DEPTH DISCRIMINATING TOOL PRIOR TO SEISMIC EXPLORATION: A CASE STUDY OF CENTRAL NIGER DELTA, NIGERIA

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ABSTRACT

The importance of aeromagnetic as a basin depth discriminating tool is the emphasis in this study. Eight sheets of aeromagnetic total field intensity maps on a scale of 1:100,000 were analysed and the depth to magnetic basement compared with available drilled well data. The data was processed, filtered and transformed to other grids using either Oasis Montaj and USGS potential field software with their associated extension packages. Anomaly Separation, Spectral Analysis, Euler Deconvolution, Horizontal Gradient Magnitude were done using Oasis montaj and U.S.G.S softwares. The results of spectral analysis, Euler Deconvolution and horizontal gradient depth maps generated clearly indicates that the well bottom (well B) depth of 3.234km compared with the different thematic magnetic basement depth from spectral 4.2km, Euler 6.421km, and HGM 4.0km is effective in basement depth discrimination. The result show a unique closeness when compared between already drilled depth with interpreted magnetic depth results. This indicate that the method can be reliable as a basin depth determining tool in virgin sedimentary basins prior to seismic explorations.

KEYWORDS: Aeromagnetic, Euler Deconvolution, Spectral analysis, Horizontal gradient magnitude, Exploration.

INTRODUCTION

The study area is mainly onshore central Niger Delta with the south western end offshore. It is bounded within the geo-referenced location of Latitude $5^{\circ} 0' 00''$ - $6^{\circ} 0' 00''$ N (north of the Equator) and Longitude $5^{\circ} 0' 00''$ - $7^{\circ} 0' 00''$ E (east of the Greenwich Meridian). It is drained by several distributaries southward into the Atlantic Ocean. States within the study area include Ondo, Delta, Bayelsa, Rivers, Imo and Anambra States, as

shown in figure 1. Aeromagnetic data is known for determining depth to magnetic basement mostly in virgin areas. However, the present study is done in an already known highly explored basin using seismic and drilled oil well known in different locations. So, this work is meant to compare the depths derived from known oil wells location with those of different magnetic depth to basement techniques and the degree of accuracy of the method will serve as a guide for reliable usage in virgin areas where seismic methods are not available.

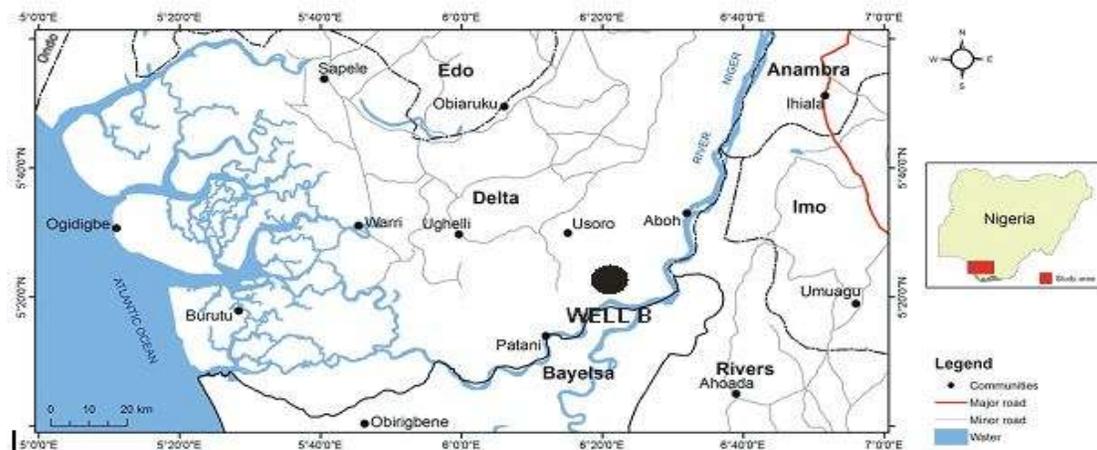


Fig.1: Location map of the study area.

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Geology of the study area

The Study area is within the present day Niger Delta which is genetically related to the Benue Trough in terms of its evolution. The Niger Delta have tertiary sedimentary deposits of about 12,000 meters in thickness with three major lithostratigraphic units, the Akata Formation which is the bottom unit consist of thick marine Shales followed by Agbada Formation which is an alternation of Sandstones and Shales units in almost equal proportions (Petters 1991, Reijers 1996,

Whiteman 1982.). The Agbada Formation is overlain by the topmost Benin Formation consisting of mainly Sandstones and Alluvium deposits. However, the geologic map reveals the Ameke group (Eocene) as the oldest consisting of Sandstones with minor Shale's intercalations (Fig.2). This unit is overlain by the Ogwashi – Asaba Formation (Oligocene – Miocene) with Deltaic plain Sandstones and Mudswamps, this unit has several alternations that formed the successive overlain deposits to the topmost recent alluvium deposits.

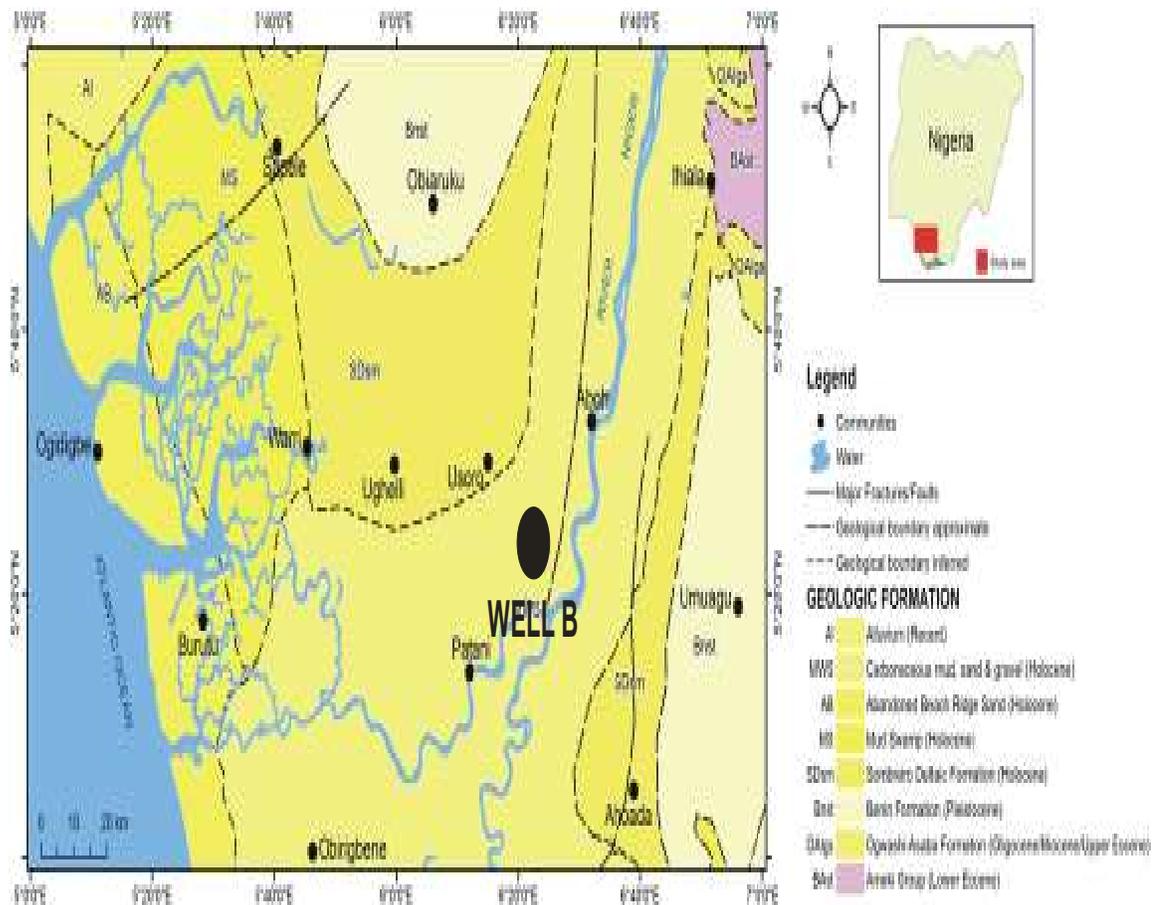


Figure 2: Geologic map of the study area.

Data analysis / Results

The materials used in this study include the following: (i) Eight sheets of aeromagnetic total intensity field maps (0.5° X 0.5°) and high resolution aeromagnetic softcopy data covering the area. (ii) Well data with geo-referenced location of 6.603571E (6° 36' 21" E) and latitude 5.49807N (5° 30' 00" N). (iii) Interactive Petrophysics and arc- GIS software. (iv) Oasis Montaj and U.S.G.S potential field software's (v) Surfer 9.0 software

The hard copy aeromagnetic data have a terrain clearance of 762m above sea level, flight line spacing of 2000m, flight line orientation 020°/200° NE – SW, tie line spacing of 20,000m, and tie line orientation 110°/290° NW. The softcopy high resolution aeromagnetic data has a terrain clearance of 80m above sea level, flight line spacing of 500m, flight line orientation in the NW – SE direction, tie line spacing of

2000m and tie line orientation in the NE – SW direction. The data was acquired from Nigerian geological survey agency. A well data titled well B was obtained from Agip Oil Company and was used as a control during the data analysis. It has a well coordinate is 6.603571E (6° 36' 21" E) and latitude 5.49807N (5° 30' 00" N), well Top is 1295.1028m, well Bottom is 3234.0000m, well depth is (3234.0000 – 1295.1028) 1938.8972m and has log suites of gamma ray log (GR), acoustic travel time log (DT), resistivity induction deep log (ILD), neutron porosity log (NPHI) and bulk density log (RHOB) which run from top to bottom.

Aeromagnetic maps were digitized manually and data processed using MS-DOS program in XYZ format which is the accepted by the USGS subroutine software programs referred to as PF (version 2.2) for potential fields. Gridding and map merging was done using ADDGRD, P2GRD, and JMERTGER software's (Philips, 1997).

Reduction to the pole was done using FFTFIL and R_TP softwares while anomaly separation was done using power spectrum SURFIT software for polynomial fitting techniques (Sheriff, 1991, Reeves 2005) in separating regional and residual fields. Results generated are presented in figure 3, 4, 5, 6, 7 and table 1.0 and 2.0. These results are similar to those obtained by other workers in similar areas. (Ofogebu and Onuoha, 1992; Spector and Grant, 1970; Ferdi *et al.*, 1997; Cordell and Grauch, 1985 Obi *et al.* 2008).

Euler Deconvolution depth analysis was done with the Geosoft Oasis Montaj software based on the work by Mushayandebvu *et al.* (2001) and result presented in figure 9.0

Horizontal Gradient Magnitude Depth Analysis was done using the USGS potential field software version 2.2 and result presented in figures 10, 11, and 12. The horizontal gradient method is a simple approach to estimating contact locations and depth (Blackely and Simpson, 1986, Philips 1997, Roeset *et al.*, 1992).

In all computer depth estimation techniques, horizontal gradient magnitude (HGM) has the greatest number of assumptions about the sources (Philips, 1997). It is the least susceptible to noise in data because it only involves calculation of the two first-order horizontal derivative of the magnetic field.

Well log estimates/lithostratigraphy.

Lithostratigraphic chat of well B was prepared using interactive petrophysical software and result presented in figure 13. Three log suites are plotted as gamma ray log (GR), neutron log (NPHI) and density log (RHOB) however, only the gamma ray log was used in this analysis for lithostratigraphic interpretations. (Asquith and Gibson, 1982, North 1985). Basically, was used in identifying sands and shales units to depths of 3200 m, these depth point was posted to the various depth maps generated for correlation of subsurface depth estimates

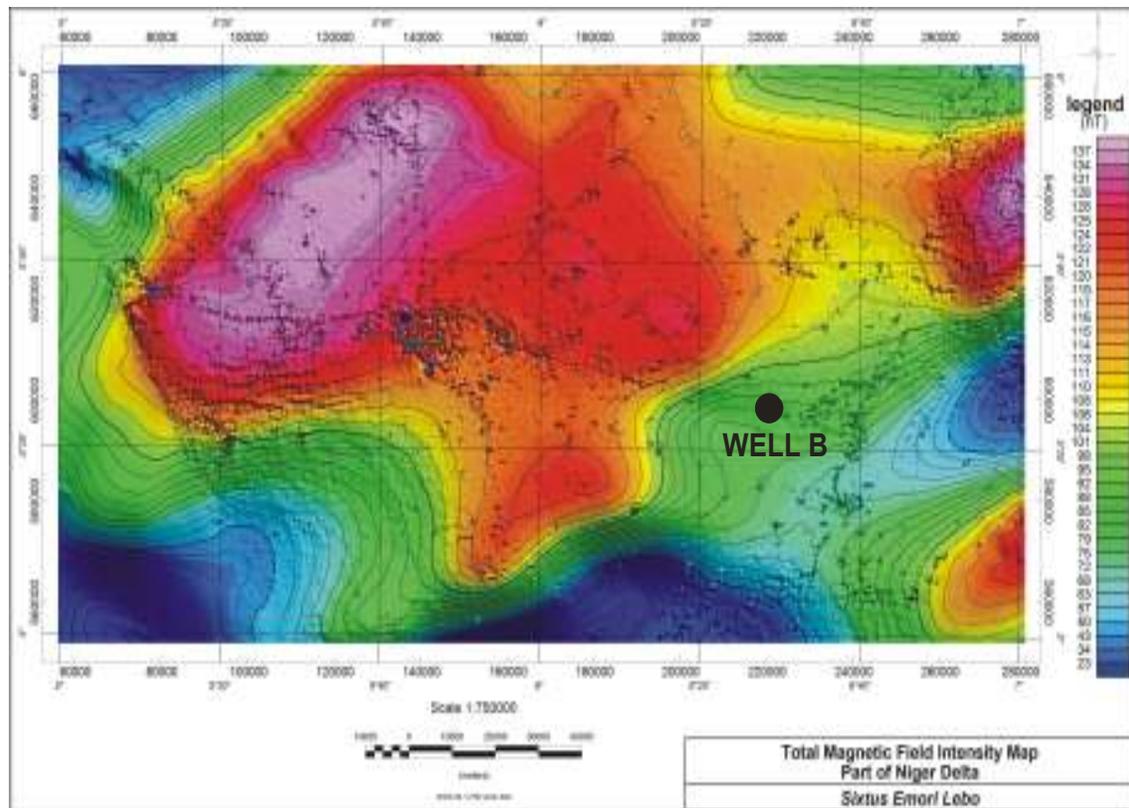


Fig. 3: Coloured High Resolution Total magnetic field intensity map of the study area (Field values are relative to a 32,000 γ base).

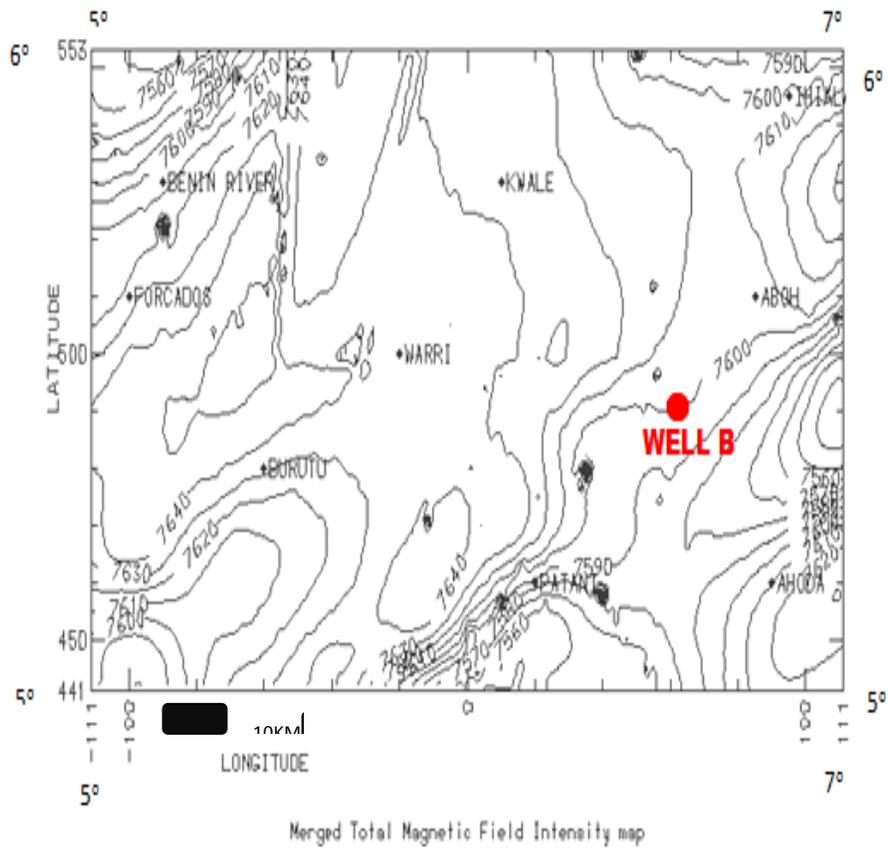


Fig. 4: Digitized Merged Total Magnetic Field Intensity of the Study area {Field values are relative to a 25,000 γ (Contoured at 10nT interval)}.

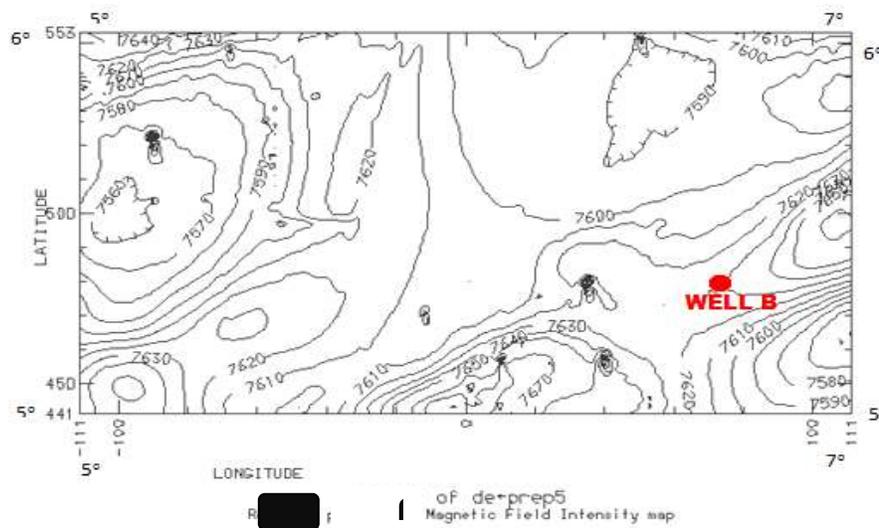


Fig. 5: Reduced to Pole Total Magnetic Field Intensity Map of the Study Area {field values relative to a 25,000 γ base (Contoured at 10nT interval)}.

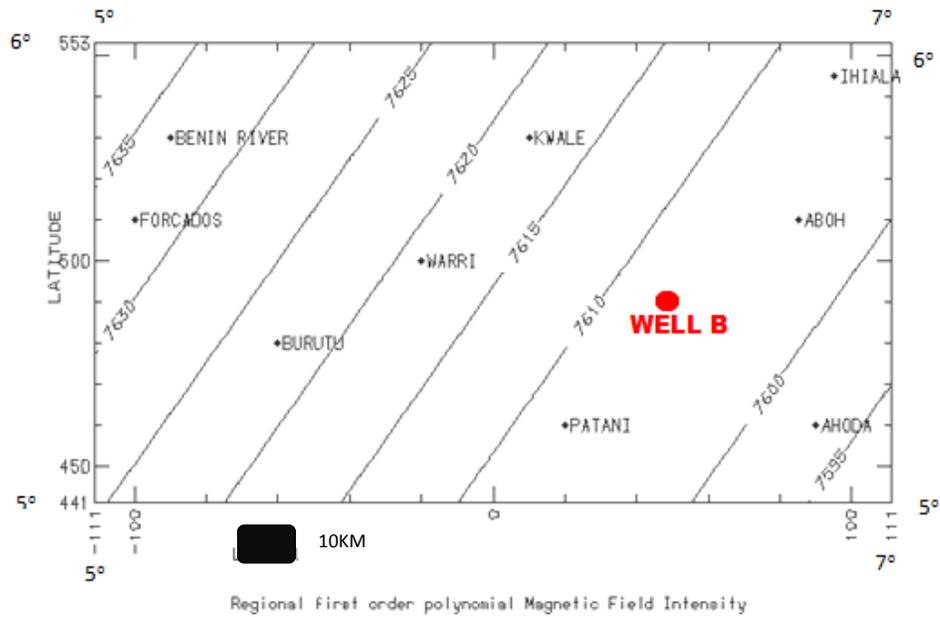


Fig. 6: Regional First Order Polynomial Magnetic Field Intensity of the Study Area (field values relative to a 25,000 μ T base (Contoured at 5nT interval)

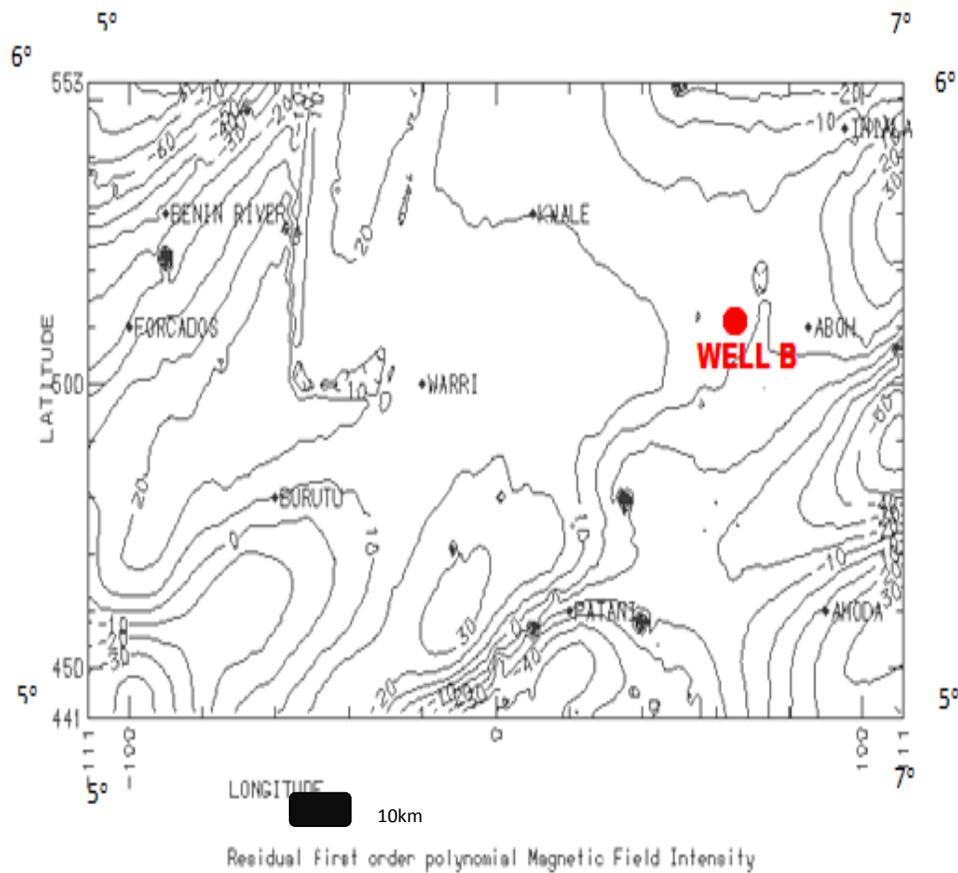


Fig. 7: Residual Polynomial Magnetic Field Intensity Map of the Study Area (Contoured at 10nT interval)

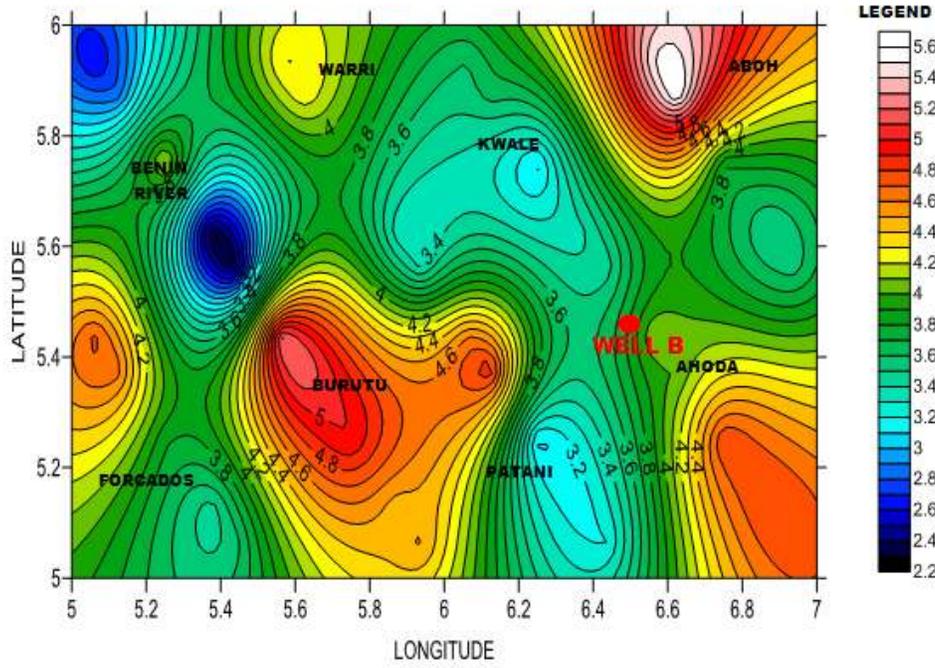


Fig. 8: Spectral depth map of the study area (Contoured at 0.1km interval).

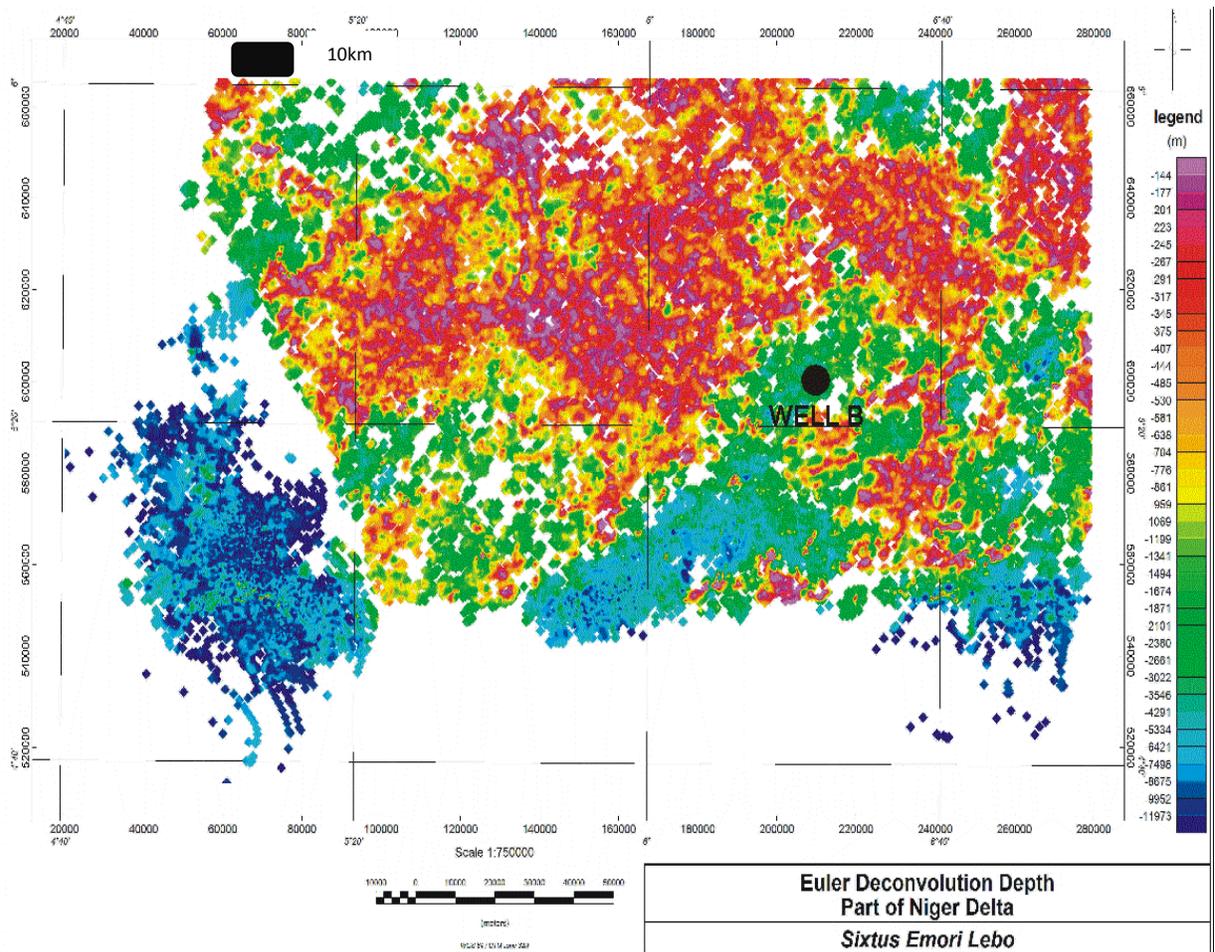


Fig. 9: Euler Deconvolution depth map of the study area.

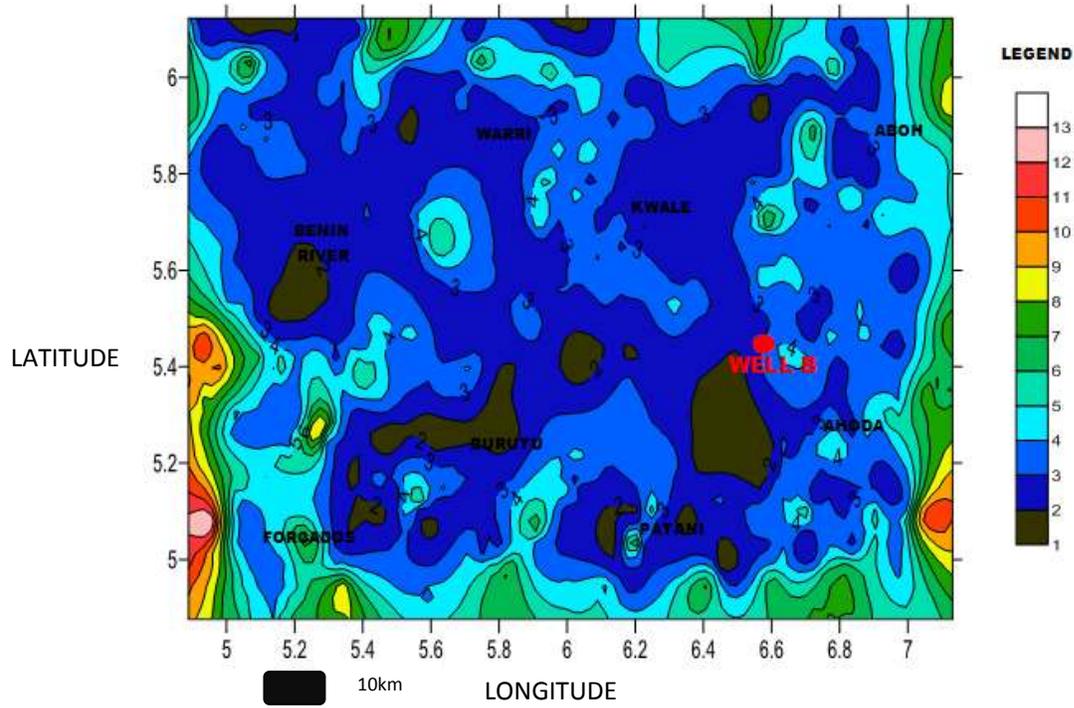


Fig. 10: Horizontal gradient magnitude depth map of the study area (Contoured at 1km interval)

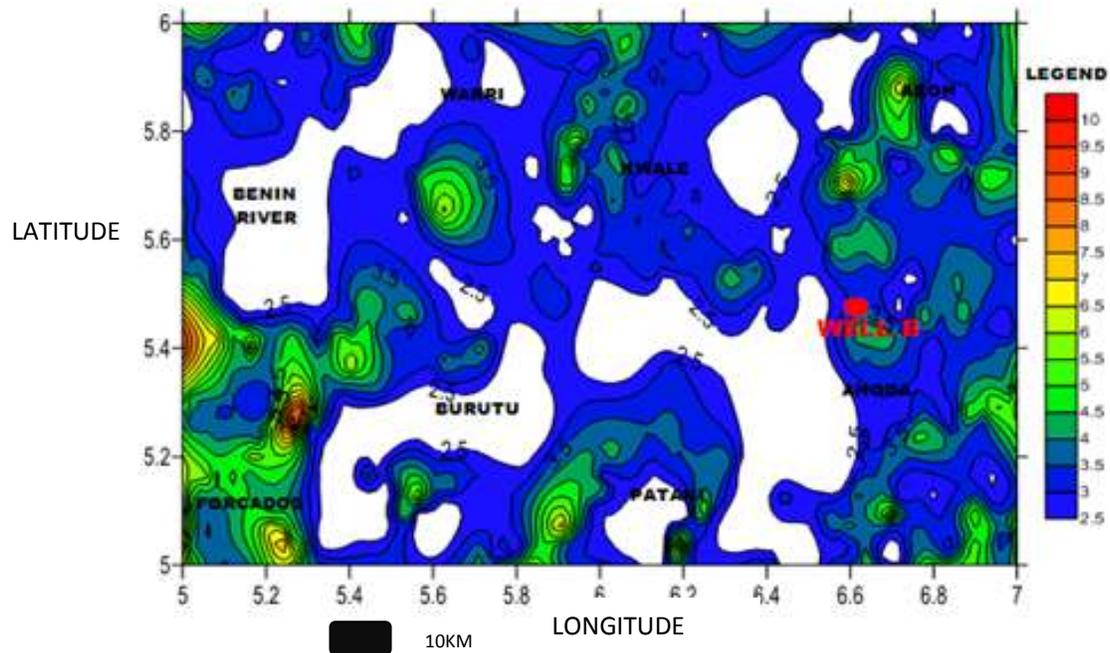


Fig. 11: Horizontal gradient magnitude depth map of the study area discriminating from 2.5km (Contoured at 0.5km interval).

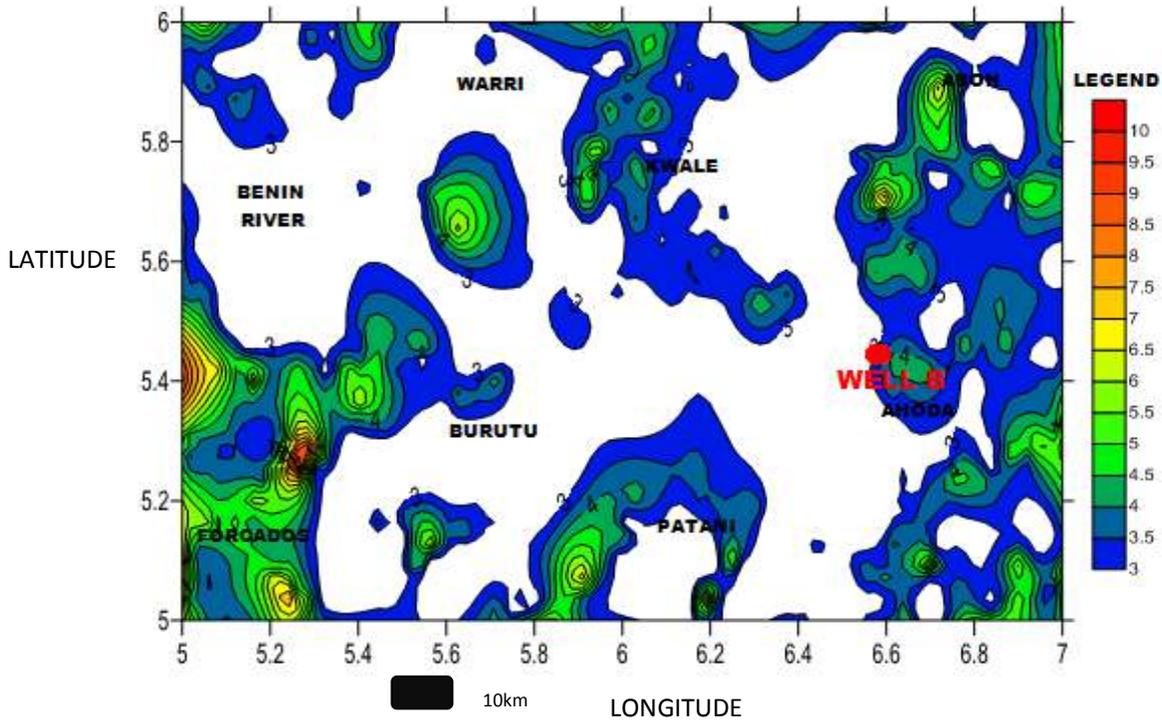


Fig.12. Horizontal gradient magnitude depth map of study area discriminating of sediment thickness 3.0km (Contoured at 0.5km)

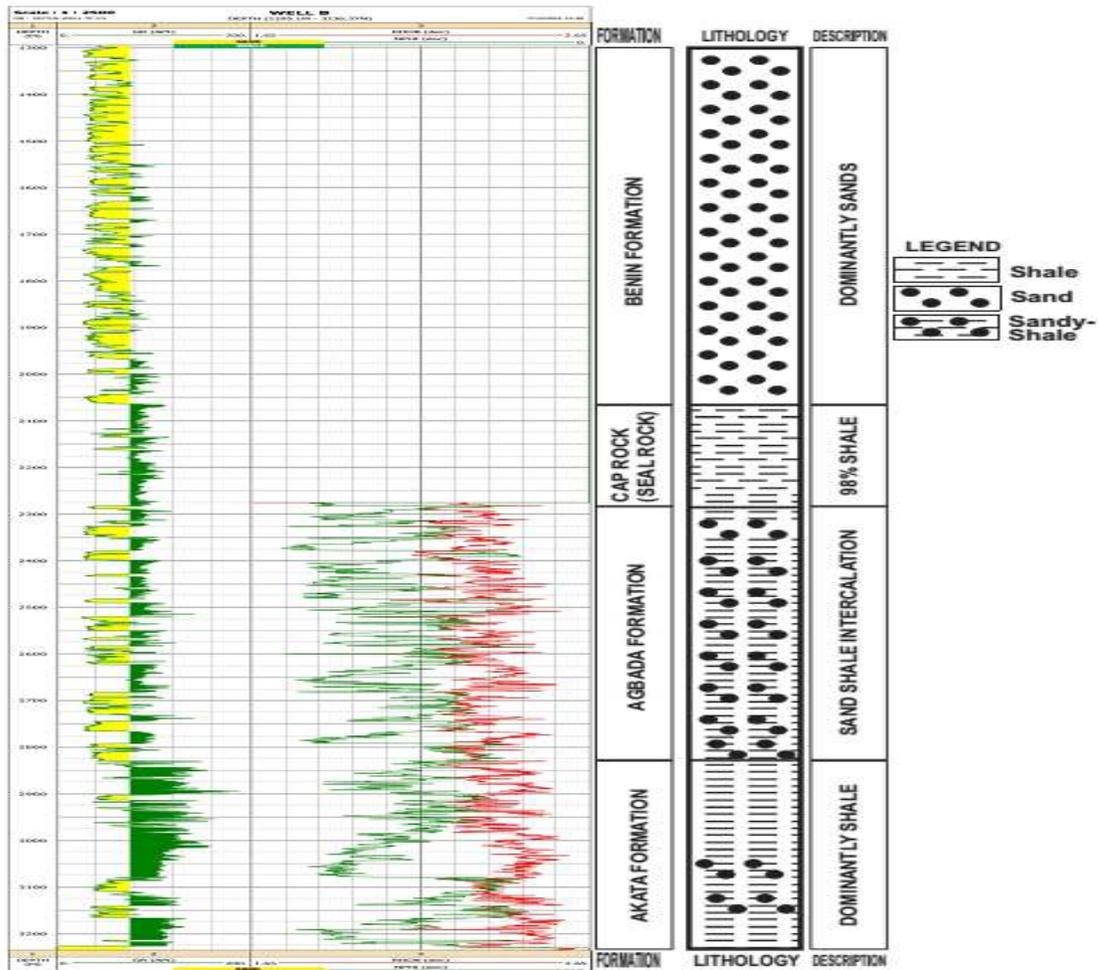


Table 1:
Table of different depth comparison within the well in the study area

S/N	Depth type	Depth value (Km)
1	Spectral depth	4.2
2	Euler depth	7.498
3	HGM depth	4.0
4	Well depth	3.234

Table 2: Spectral depth of some part of the Niger Delta

S/N	MAP	D-1 (KM)	D-2 (KM)	D-3 (KM)	A-1	A-2	A-3	X	Y	DEPTH
1	BENIN RIVER 1	1.0660	4.1670	16.2500	0.1054	0.6065	12.8000	5.2500	5.7500	4.17
2	BENIN RIVER 2	0.8079	2.8400	12.5000	0.1520	0.6065	11.4000	5.1250	5.8750	2.84
3	BENIN RIVER 3	0.9231	2.3080	8.6670	0.8208	12.1800	12.1400	5.3750	5.6250	2.31
4	BENIN RIVER 4	0.8217	2.6000	11.5000	0.1440	0.6065	10.7400	5.0625	5.9375	2.60
5	BENIN RIVER 5	0.9321	2.3380	8.4500	0.8210	11.9000	10.6800	5.4375	5.5625	2.34
6	FORCADOS 1	0.7160	3.8200	9.6880	0.0249	0.3172	4.4820	5.2500	5.2500	3.82
7	FORCADOS 2	0.9708	4.6430	10.2600	0.0153	0.3679	7.3890	5.1250	5.3750	4.64
8	FORCADOS 3	1.8330	3.4480	7.9400	0.8200	0.6065	12.1800	5.3750	5.1250	3.45
9	FORCADOS 4	0.8503	4.7200	11.5000	0.0143	0.3540	6.8930	5.0625	5.4375	4.72
10	FORCADOS 5	1.7420	3.5500	8.2000	0.8405	0.3544	6.3210	5.4375	5.0625	3.55
11	WARRI 1	0.8754	3.8200	11.7900	0.0247	0.3172	7.3890	5.7500	5.7500	3.82
12	WARRI 2	1.1140	4.2800	10.6300	0.0673	0.3670	4.4820	5.6250	5.8750	4.28
13	WARRI 3	0.8754	3.3400	8.0560	0.1111	1.6490	12.180	5.8750	5.6250	3.34
14	WARRI 4	1.0150	4.3000	10.5400	0.0672	0.4250	4.3820	5.5625	5.9375	4.30
15	WARRI 5	0.9241	3.3800	8.2000	0.1141	1.5490	11.9200	5.9375	5.5625	3.38
16	BURUTU 1	0.9677	5.0000	9.1670	0.0673	0.6065	4.4820	5.7500	5.2500	5.00
17	BURUTU 2	1.1940	5.1790	11.0700	0.0638	2.7180	4.4820	5.6250	5.3750	5.18
18	BURUTU 3	1.0350	4.4230	13.6400	0.1111	1.0000	20.0900	5.8750	5.1250	4.42
19	BURUTU 4	1.1500	5.2100	12.0400	0.0652	2.6080	5.1250	5.5625	5.4375	5.21
20	BURUTU 5	1.0250	4.5200	13.5000	0.1340	1.1000	22.0500	5.9375	5.0625	4.52
21	KWALE 1	1.194	3.065	13.0	0.0302	0.3679	7.389	6.2500	5.7500	3.07
22	KWALE 2	0.4775	3.650	10.90	0.0067	0.06066	12.18	6.1250	5.8750	3.65
23	KWALE 3	1.401	3.387	10.38	0.0820	0.3679	4.482	6.3750	5.6250	3.39
24	KWALE 4	0.5420	3.602	10.60	0.0064	0.6165	13.20	6.0625	5.9375	3.60
25	KWALE 5	1.440	3.450	10.50	0.0835	0.6666	4.220	6.4375	5.5625	3.45
26	PATANI 1	0.7162	3.065	14.55	0.0208	2.7180	90.02	6.2500	5.2500	3.07
27	PATANI 2	0.8276	4.88	13.30	0.8208	4.482	90.02	6.1250	5.3750	4.88
28	PATANI 3	1.114	3.167	13.50	0.1353	1.6490	20.09	6.3750	5.1250	3.17
29	PATANI 4	0.7520	4.60	12.82	0.8102	4.320	91.01	6.0625	5.4375	4.60
30	PATANI 5	1.112	3.20	13.20	0.6320	1.550	21.18	6.4375	5.0625	3.20
31	ABOH 1	0.618	3.820	12.14	0.0024	0.2231	12.18	6.7500	5.7500	3.82
32	ABOH 2	1.290	5.62	12.50	0.0024	0.6065	12.18	6.6250	5.8750	5.62
33	ABOH 3	0.9549	3.50	11.43	0.0142	0.3679	7.389	6.8750	5.6250	3.50
34	ABOH 4	1.250	5.50	12.30	0.2453	0.6162	12.25	6.5625	5.9375	5.50
35	ABOH 5	0.8540	3.55	11.20	0.0135	0.3240	7.214	6.9375	5.5625	3.55
36	AHODA 1	0.9708	4.80	12.50	0.1111	0.718	90.02	6.7500	5.2500	4.80
37	AHODA 2	1.194	4.00	11.79	0.8200	4.482	148.4	6.6250	5.3750	4.00
38	AHODA 3	1.607	4.8	13.75	0.6065	54.600	1097	6.8750	5.1250	4.80
39	AHODA 4	1.125	4.100	11.75	0.8200	4.4180	145.2	6.5625	5.4375	4.10
40	AHODA 5	1.625	4.780	12.70	0.6365	48.500	1058	6.9375	5.0625	4.78

DISCUSSION / CONCLUSION

The availability of drilled well data within the basin makes it easier for the thematic magnetic depth estimates generated be correlated or tied at the well as shown in table 1. There are no wells drilled to basement within the study area, so the available drilled well B, was used for correlation purposes. The reduction to pole map (fig. 5) show well centered anomalies with well defined outlines which were not well displayed in the observed total magnetic field intensity map (fig.4). The regional field map (fig.7) indicate a North-East to South-West orientation of the regional magnetic field, this trending is same as the regional trends of the Benue Trough. The residual polynomial magnetic field map (fig.8) have eight prominent anomalies where three of the anomalies are deep seated along Burutu, Benin River, and Warri and the other five anomalies are Shallow seated along Patti, Ahoda, and Aboh. The deep seated anomalies are recognised by widely spaced contours while closely space small and rounded contours represent Shallow seated basement rocks, which also represents areas of thin sedentary rocks deposits.

The Spectral depth map of the area (fig.9) indicate a progressive increament of basin thickness from Patani (3.2km) towards Ahoda (4.4km) and also progress by increasing in depths towards Burutu (5.2km), and begin to shallow out towards Kwale (3.6 km), Benin River (3.0km). The results reveals areas with greater sediment accumulation which could serve as better exploration targets. Also, Euler Deconvolution depth map (fig.10) indicate a progressive increament in sediment accumulation from Ahoda towards Burutu and Forcados reaching depths of 12.0 km. The Horizontal Gradient Magnitude depths maps (figs. 11, 12, 13) show subsurface depth variations contoured at different contouring intervals which discriminates areas of different sedimentary depth thickness 3.0 km and above (fig.13) which are found in large portions around Forcados towards Burutu.

From the result generated using the interactive petrophysical software (IP) as shown in figure 13, different formations were identified and interpreted based on approximate depth intervals associated with them. The well has a well top of 1295.1028m, well bottom of 3234.00m and well interval of (3234.00 – 1295.1028) = 1938.8972m. Depth interval of 1295.1028 – 1965.0000m (669.8972m) is made up of dominantly sand and it is interpreted as the Benin Sand Formation. Interval of 1965.0000 – 2285.0000m (320.0000m) is made up of mainly shale and interpreted as cap rock (seal rock), while 2285.0000 – 2825.0000m (540.0000m) is made up of intercalations of sand and shale and it is interpreted as Agbada Formation. The last interpreted formation starts from 2825.0000m – 3234.0000m (409.0000m). It is dominantly shale and it is interpreted as Akata Formation. Computed depth to the top of magnetic basement within the well area is as follows:

Spectral Depth estimate is 4.2km, Euler depth estimate is 7.498km and Horizontal Gradient Magnitude depth is 4.0km and the well depth is 3.234km as shown in table 1. From the above correlation, the magnetic basement depth estimates are greater than the drilled depth, which makes the result from magnetic analysis

reliable. From the HGM depth discriminating maps, seismic exploration is most favourable in areas of sediment thickness above 2.5km which coincide with the Forcados, Patani, Kwale, Ahoda and Aboh areas.

Conclusively, this method has demonstrated that depth to basement information obtained from magnetic analysis using the above depth discriminating techniques is reliable as a depth to basement investigating tool that could assist in planning seismic reflection explorations surveys in relatively unexplored basins.

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