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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
Eight aeromagnetic maps and high resolution softcopy aeromagnetic data of the same area with available drilled well depth data were used for subsurface depth investigatuion in the Central Niger Delta, Nigeria. The data was processed, filtered and transformed to other grids using either Oasis Montaj and/or USGS potential field software with their associated extension packages. Anomaly Separation, Spectral Analysis, Euler Deconvolution, Horizontal Gradient Magnitude were done using the relevant 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 4.0kmis effective in basement depth discrimination. The result show a unique closeness in comaparism 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 exploratioin.

Introduction

The Niger Delta is an extraordinary delta located in the Gulf of Guinea. Its formation and evolutionis controlled by the Chain and Charcot Fault Zones which is linked to the opening of the Atlantic Ocean. It is situated at the south western end of the Benue Trough and bordered in the south by the Gulf of Guinea and the cretaceous tectonic framework of Anambra Basin, Abakaliki Anticlinorium and Afikpo Syncline inthe north etc. Regionally, the Niger Delta sedimentary basin is situated on the continental margin of the Gulf of Guinea in the equatorial West Africa, between latitude 3^{o}N and 6^{o} N and longitude 4^{o}E and 9^{o}E, (Mascle, 1976, Whiteman, 1982, Wright et al, 1985, Reijers, 1996, Nwajide, 2013).

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 $5^{0}\,0^{I}\,00^{II}$ - $6^{0}\,0^{I}\,00^{II}$ N (north of the Equator) and Longitude $5^{0}\,0^{I}\,00^{II}$ - $7^{0}\,0^{I}\,00^{II}$ E (east of the Greenwich Meridian). It is drained by several distributaries southward into the Atlantic Ocean. States within the study area include Ondo, Edo, Delta, Bayelsa, Rivers, Imo and Anambra States, as shown in figure 1.

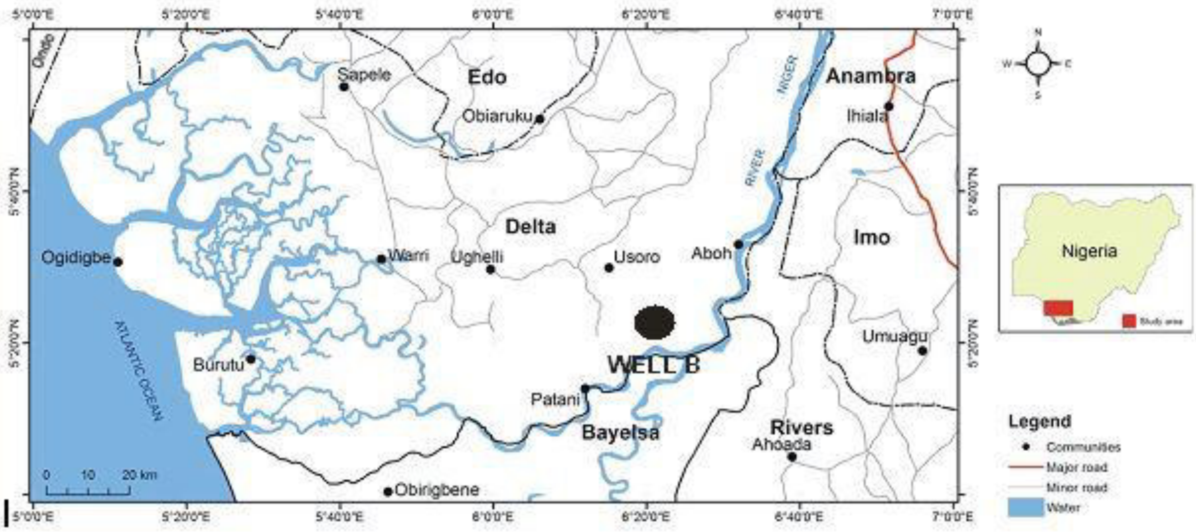

Fig.1 Location map of the study area.

Geology of the study area

The present Niger Delta is positioned on a triple junction. Itsgeology also covers some part of the Lower Benue Trough. It trends in the NW–SE direction (Peters, 1991) and is genetically related to the Benue Trough. The Trough defines the failed arm of triple junction formed during the formation of the Atlantic. The extension of the Ngaundere system rejuvenated in the Cretaceous and a phase of the extension of the Eastern Niger contemporaneous with the closing of the Benue Trough, (Cratchley et al; 1984). It is simply viewed as an elongate Intracratonic basin over 1000km long and 250 – 300km wide (Burke et al, 1971, Mascle, 1976, Wright et al, 1985, Benkhelil, 1989, Nwajide, 2013). It is part of the West and Central African Rift System which result from crustal stretching of African Plate prior to initiation of the Proto-Atlantic during the early Cretaceous (Genik, 1992).

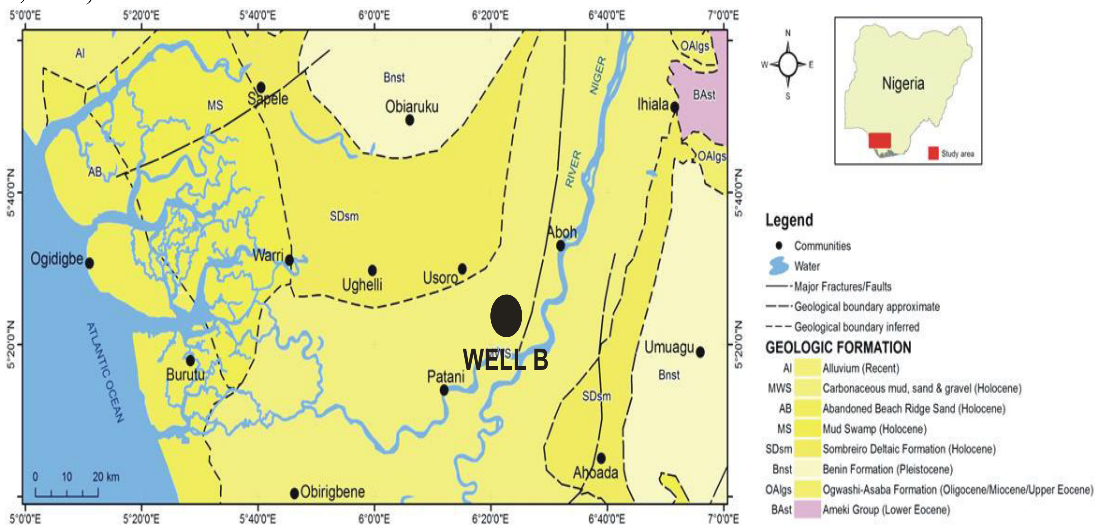

Figure 2: Geologic map of the study area.

Mapable geologic formations within the study are described as outcropped formations. These outcropped formations are as follows:

The Ameke group lower eocene is the oldest unit within the mapped area,this group is overlain byOgwashi– Asaba formation oligocen- Miocene,which is overlain by the Benin Formation defined by the top of the Agbada formation Pleistocene/Pliocene , the emplacement of lithologic sequences to the topmost unit is the Sombreiri – Warri Deltaic Plain formed part of the Late Quaternary Niger Delta Holocene , Mud Swamps formed part of the Late Quaternary Niger Delta Holocene ,Abandoned Beach Ridge Sand formed part of the Quaternary Niger Delta Holocene , Carbonaceous Mud, Sand and Gravel formed the last part of the Quaternary Niger Delta sediments Holocene (0.012 -0 Ma) and Alluvium (The Alluvium formed the most recent sediments in the Niger Delta) fig.2

MATERIALS AND METHOD OF STUDY

The data sets used in this analysis include the following:

1. Eight sheets of aeromagnetic total intensity field maps (0.5^{o} X 0.5^{o}) and high resolutionaeromagnetic softcopy data covering the area.
2. Well data with geo-referenced location of 6.603571E (6^{o} 36^{I} 21^{II} E) and latitude 5.49807N (5^{o} 30^{I} 00^{II}N).
3. The software used for this analysis include Geosoft Oasis Montaj version 6.4 (HJ), United States Geological Services (USGS) potential field software version 2.2 programmes and Interactive Petrophysical (IP) software and Arc GIS.

The hard copy aeromagnetic data have a terrain clearance of 762m above sea level, flight line spacing of 2000m, flight line orientation $020^{o}/200^{o}$ NE – SW, tie line spacing of 20,000m, tie orientation $110^{o}/290^{o}$ NW as shown in figure 5. 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 as shown in figure 4.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^{o} 36^{I} 21^{II} E) and latitude 5.49807N (5^{o} 30^{I} 00^{II}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 ADDGRDP2GRD, and JMERGER softwares (Philips,1997).

Reduction to the pole was done using FFTFIL and R_TP softwares while anomally 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 6, 7 and 8, 9 and table 2.0.

These results are similar to those obtained by other workers in similar areas . (Ofoegbu and Onuoha, 1992; Spector and Grant, 1970; Ferdi *et al.,* 1997; Cordell and Grauch, 1985).

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 10.

Horizontal Gradient Magnitude Depth Analysis was done using the USGS potential field software version 2.2 and result presented in figures 11, 12, and 13. 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.

Lithostraitigraphic chat of well B was prepared using interactive petrophysical software and result presented in figure 14. 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

RESULTS

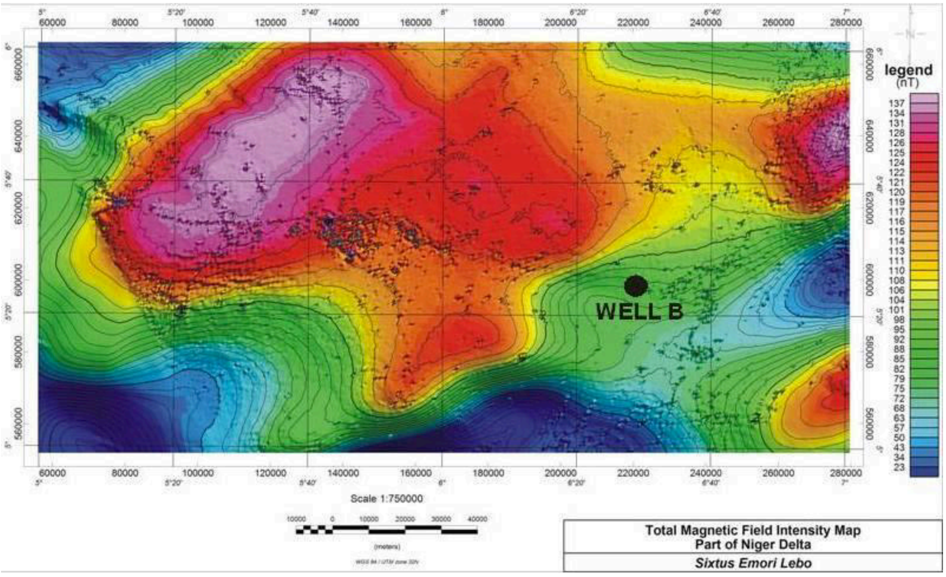

Fig. 3: Coloured High ResolutionTotal magnetic field intensity map of the study area (Field values are relative to a $32,000\gamma$ base).

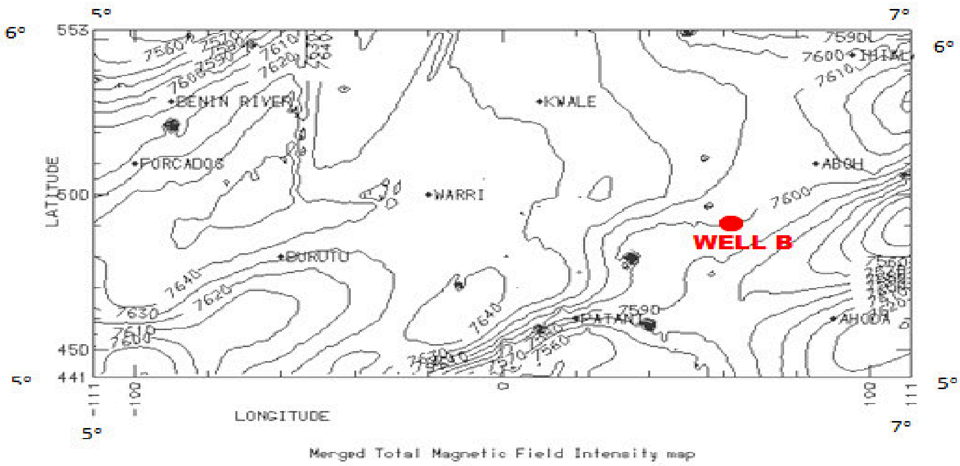

Fig. 4: Digitized Merged Total Magnetic Field Intensity Map of the Study area {Field values are relative to a $25,000\gamma$ (Contoured at 10nT interval)}.

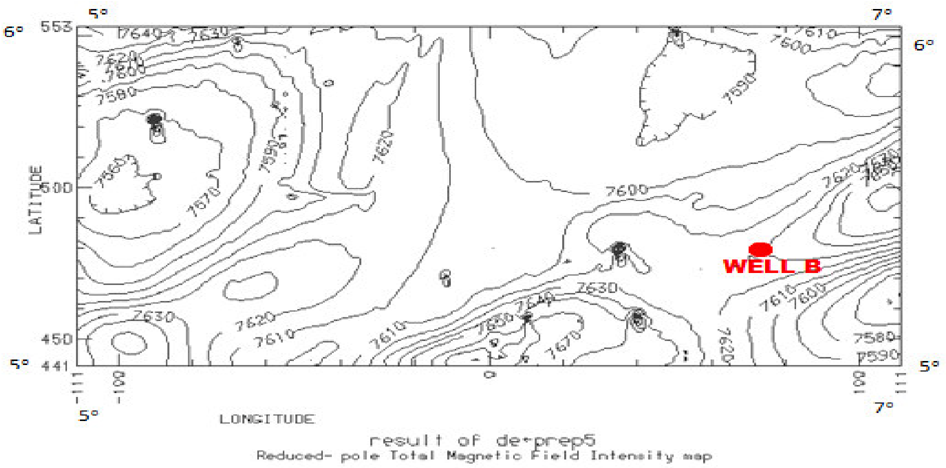

Fig. 5: Reduced to Pole Total Magnetic Field Intensity Map of the Study Area {field values relative to a $25{,}000\gamma$ base (Contoured at 10nT interval)}.

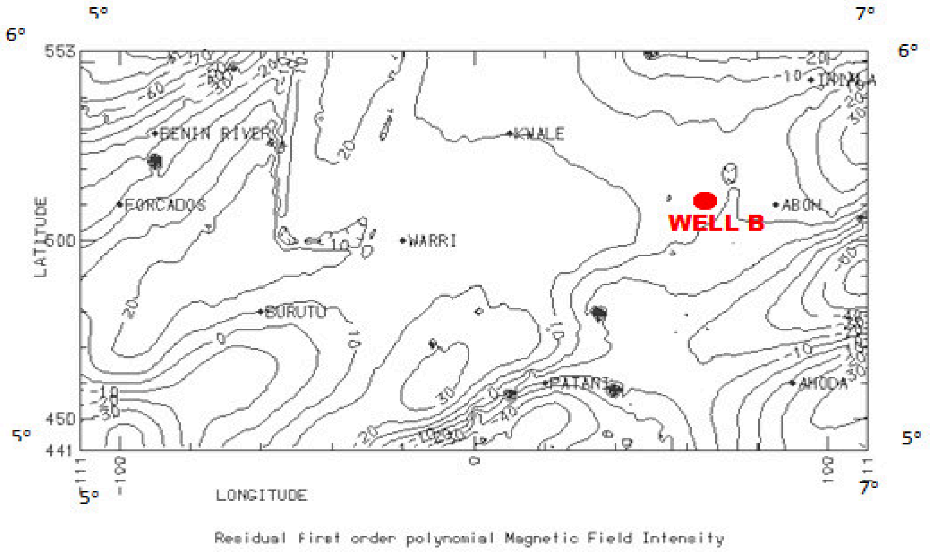

Fig. 6: ResidualPolynomial Magnetic Field Intensity Map of the Study Area (Contoured at 10nT interval)

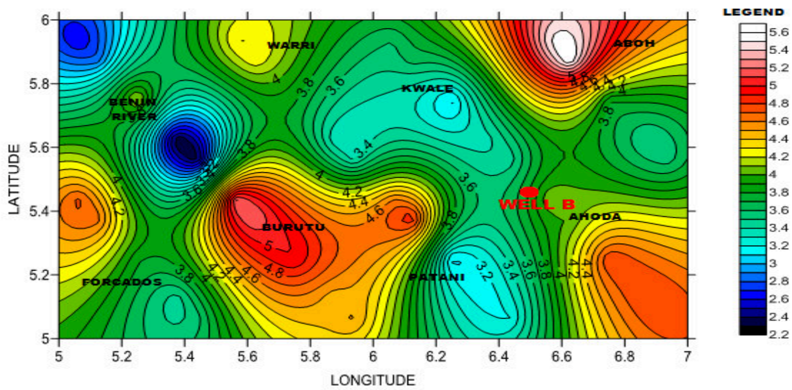

Fig. 7: Spectral depth map of the study area (Contoured at 0.1km interval).

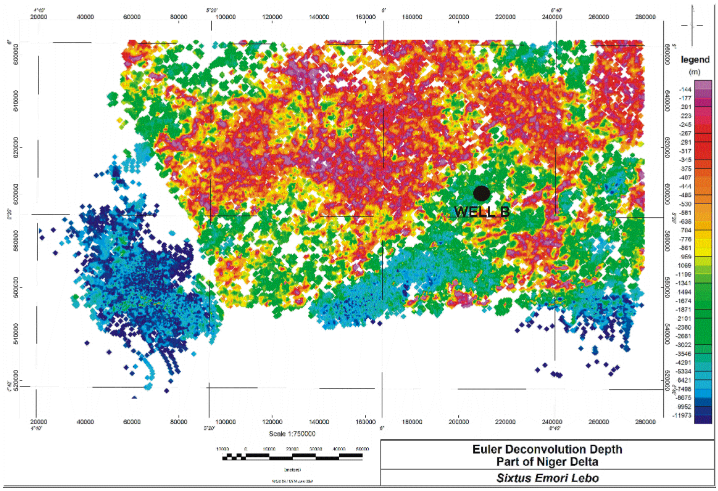

Fig. 8:Euler Deconvolution depth map of the study area.

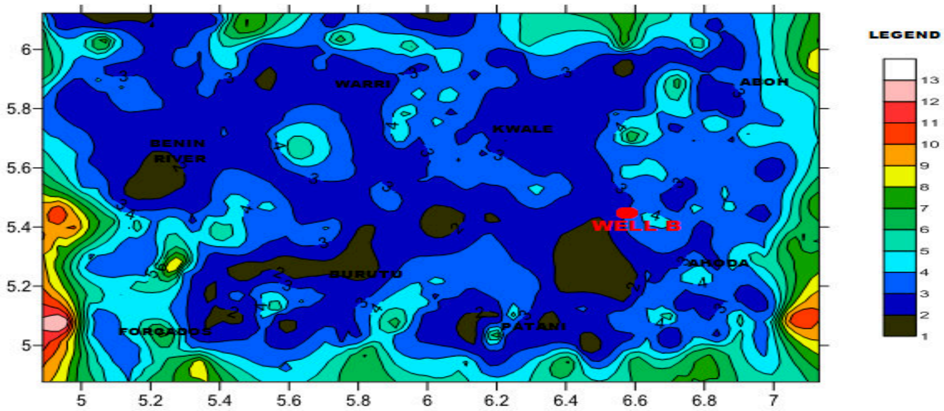

Fig. 9: Horizontal gradient magnitude depth map of the study area (Contoured at 1km interval)

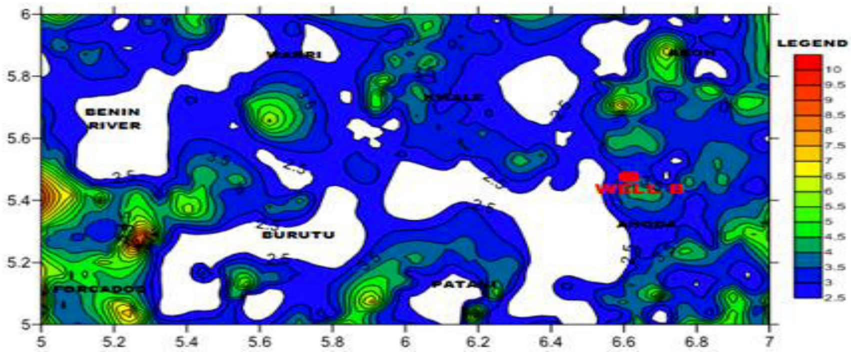

Fig. 12: Horizontal gradient magnitude depth map of the study area discriminating from 2.5km (Contoured at 0.5km interval).

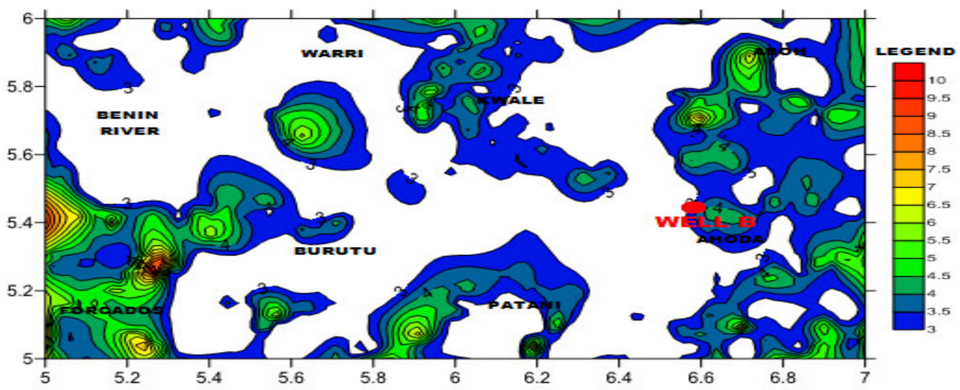

Fig. 13Horizontal gradient magnitude depth map of study area discriminating of sediment thickness 3.0km (Contoured at 0.5km)

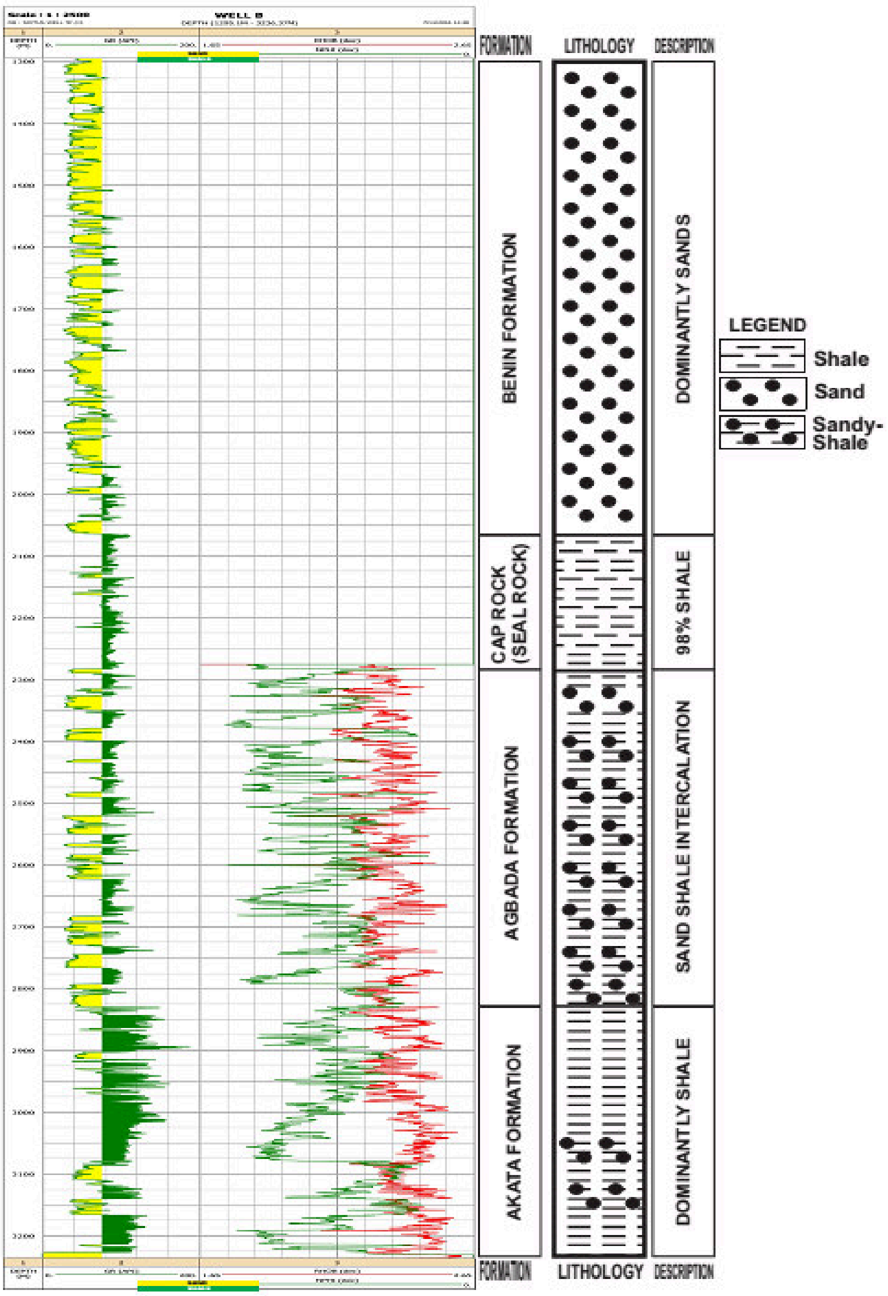

Fig. 14:Lithostratigraphic Chat of Well B.

TABLE 1
Table of different depth comparism 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

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.

From the result generated using the interactive petrophysical software (IP) as shown in figure 14, 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 3234.0000m 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), wile 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 tachniques 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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