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STRUCTURAL STYLES INTERPRETED FROM AEROMAGNETIC AND LANDSAT DATA OF BEL AND ADJOINING AREAS, MIDDLE BENUE TROUGH, NIGERIA.

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Abstract

The analysis of the structural styles of Bel and adjoining areas using aeromagnetic and Landsat data has been carried out with a view to determining the depth to the magnetic basement, establishing the basement morphology, delineating the structural features and inferring the effects of such structures on the general tectonic history and basin geodynamics of the study area. The landsat imagery generated was processed using ILWIS 3.2 Academic and Erdas imaging softwares while the aeromagnetic data were reduced using Geosoft Oasis Montaj 6.4.2.HJ version, Surfer 10 and Matlab 7.5. From the landsat data it was revealed that the dominant structural trend of the study area is in the NE-SW direction. The drainage is dendritic suggesting lithologic heterogeneity. Results of the 2-D spectral analysis revealed a two-layer depth model: a shallow layer of magnetization with depths ranging from 0.234km to1.234km and average depth of 0.727km and a deeper layer of magnetization having depths ranging from 1.746km to 4.750km and average depth of 2.975km. The shallower magnetic anomalies are as a result of basement rocks which intruded into the sedimentary rocks while the deeper magnetic anomalies are associated with intra-basement discontinuities like faults. The average sedimentary thickness of 2.975km estimated in the study area shows that the area is good for magnetic mineral exploration and not favourable for hydrocarbon prospecting as the temperature accompanying tectonic activity in the area must have cooked the source rock, if any, beyond the oil window phase of maturation.

Key words: Aeromagnetic, Basement depth, Landsat, Lineament, Middle Benue Trough.

1. Introduction

The study area – Bel and its environ is located within longitudes $10^{0}30'$ E – $11^{0}30'$ E and latitudes 7^{0} $30'$ N – $8^{0}30'$ N. It is located within the middle Benue Trough. The Benue Trough is seen as an intercontinental Cretaceous basin about 1000km in length stretching in a NE-SW direction and resting unconformably upon the Precambrian Basement. The origin and evolution of the Benue Trough are fairly well documented ([1], [2], [3], [4], [5]). The Benue Trough is characterized by the occurrence of several minerals of economic importance ranging from Coal, Barytes, Lead and Zinc etc. The data used in this research work are airborne aeromagnetic map obtained from the Geological Survey of Nigeria (GSN) and the seven-band Landsat 5 TM imagery acquired in 2011. Both systems are used in providing quick, fast, and cost-effective reconnaissance survey of the study area. The magnetic anomaly signature characteristics are results of one or more physical parameters such as the configuration of the anomalous zone, magnetic susceptibility contrasts as well as the depth to the anomalous body. Depth to basement, faults in the basement surface, and the relief of the basement surface have direct relevance to the depositional and structural history of an area [6]. The use of satellite imagery for regional mapping of geologic units and structures has long been demonstrated as a vital tool for regional geologic mapping. This is as a result of its ease of operation, speed, accuracy, low cost and coverage. Interpretation of satellite imagery has found application in producing new geologic maps as well as revision of old ones. In the area of hydrogeology, the importance of satellite imagery is heavily felt in the search for potable water especially within areas underlain by the basement complex. The objective of the study is to determine depth to the magnetic basement, delineate the basement morphology and relief, delineate the structural features associated with the area and to infer the effects of such structures to the general tectonic history and basin geodynamics of the study area.

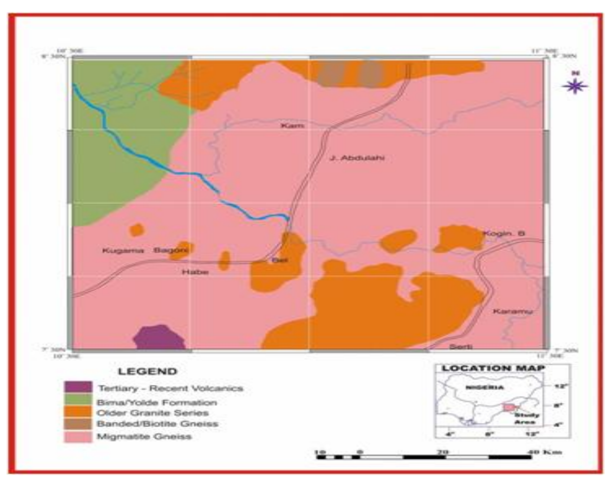


Figure 1. Geological Map of the Study Area.

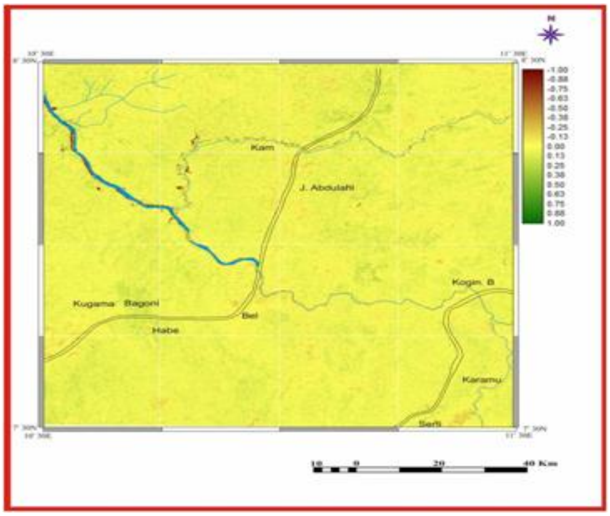


Figure 2. Normalized Difference Vegetation Index (NDVI) map of the study area

2. Geology of the Study Area

The oldest geologic unit observable in the study area is Migmatitic Gneiss. This dominates the central portion of the area. This was followed by the Banded/Biotite Gneiss which only outcropped in the northern part of the area (Figure 1). The Banded Gneisses show alternating light coloured and dark bands and exhibit intricate folding of their band. The Biotite Gneisses are normally fine grained with strong foliation caused by parallel arrangement of alternating dark and light minerals. The Older Granite series were first distinguished from the Younger or Plateau time-bearing Alkalic Granite, [7]. They range in size from Plutons to Batholiths. The Older Granites include rocks of a wide range of compositions, Granites, Granodiorites, Andamellite, Quartz, Monzonites, Syenites, Pegmatites; Granitic Granodiorite composition are most common. They are disseminated in the Northern and Southern part of the area. Little part of the study area proceeds into the Upper Benue Trough which is a sedimentary environment. Two Formations, the Bima sandstone and Yolde Formation outcropped. The Bima sandstone according to [8] ranges in age from late Albian to Turonian. Beds containing a lower Turonian fauna overlie the Bima sandstone and therefore in the absence of uncomformity the formation must be Albian and Cenomanian age. Fossil wood occurs sporadically and fragmentary Pelecypods have been found in the Lamurde anticline. Yolde Formation is interpreted as being transitional from terrestrial to marine sedimentation. Fossils like Molluscs are always seen. Tertiary-Recent volcanics occur within the Southwestern axis. The volcanic rocks are almost invariably altered to red to green clays.

3. Materials and Methods

The materials, equipment and methods of data acquisition, processing, interpretation and analysis are presented as follows. The data used for the study were compiled using the geological map of the study area comprising Numan (sheet 195), Dong (sheet 194), Shellen (sheet 175) and Guyuk (sheet 174) ,each at a scale of 1:100,000 and satellite image - Landsat 5 TM, Bands 432 with wavelengths 0.76-0.90µm (near – IR), 0.69 µm (Red) and 0.52-0.60µm (green). It has high spatial resolution of 30mx30m ground area. A high speed large memory digital electronic PC with a coloured printer and plotters for map printing as well as a colour monitor for visualization of image were used. A table scanner was used to scan all the relevant maps used for the study. Erdas imagine was used for sub setting the study area from available satellite data. Integrated Land and Water Information System (ILWIS) version 3.2 academic was used for creating several themes or layers from the satellite image. This software has the capabilities for various image enhancement techniques such as linear enhancement, statistical analysis, principal component analysis and normalized difference vegetation index (Figure 2). The aeromagnetic data used were subjected to a low pass filtering operation. The nature of filtering applied to the aeromagnetic data in this study in the Fourier domain was chosen to eliminate certain wavelengths and to pass longer wavelengths. Several potential field softwares with different analytical modules were used in the interpretations of the aeromagnetic map. These include Geosoft Oasis Montaj 6.4.2.HJ version, U.S. Geological Survey Potential-Field geophysical software Version 2.0, Surfer 10 and Matlab 7.5. Regional - residual separation was carried out using polynomial fitting. This is a purely analytical method in which matching of the regionals by a polynomial surface of low order exposes the residual features as random errors. For the magnetic data, the regional gradients were removed by fitting a plane surface to the data using multi- regression least squares analysis. Sixteen (16) spectral blocks were created as shown in Table 1 below. The data were modeled to get the basement depth contour map of the study area. Also the first to fourth degree regional magnetic field as well as the first to fourth degree residual (polynomial) magnetic field map of the study area were generated.

4. Results Discussion and Interpretation

After the pictorial quality of the image was improved via linear enhancement and filtering of the image, various visual interpretation of the satellite image was carried out. The drainage of the area is easily visible in the landsat TM image. The drainage pattern was digitized on-screen as segment map using ILWIS. The drainage linear of the area was also produced from existing topographic map. The drainage pattern is dendritic which is indicative of lithological, structural, and topographic differences (Figure 4). The drainage texture of the area is variable (coarse to fine) (Figures 5, 6 and 7). It is characteristic of sedimentary rock and variable permeable soil material, such as the alluvium and Bima/Yolde Formation. The direction of flow of surface water can be seen on the image too. The flow directions are northwest and north south directions controlled by topography and geological structures. Digital image processing technique was carried out to highlight areas in the image where vegetations/green plants are more active. Two major classes of objects in the shades of gray in the landsat image are light tone and dark tone. The very light tone areas are areas where vegetation occur and the light –dark tone areas represent rock out crops/bare surfaces, and very dark tone represent water bodies (Figure 2). Simple digital image processing techniques were applied on the image to enhance the edges or linear features. This was followed by computer aided visual interpretation of lineaments. The result of the lineament analysis shows that numerous fractures and lineation occur at the northeastern and southern sides of the satellite image. The common orientations of the lineaments are NE-SW Figures 9 and 10 show the colour classified coded and image maps of the total field aeromagnetic data of the study area respectively. It will be observed that the dominant structural trend is in the NE-SW direction. This is equally evidenced in the shaded relief map of the area (Figure 11). The first to fourth degree regional maps (Figures 14 and 15) show NE-SW and NW-SE structuraltrends. The NE-SW trend could indicate the Charcot fracture zone which is believed to be extending towards the West African region [9]. The first to fourth degree residual (polynomial) maps (Figure 16) show small clusters which indicate igneous intrusions, granitic rocks, mineral bodies, rhyolite, granodiorites etc, outcropping at the surface or near the surface.and NW-SE (Figure 3). The drainage linear was derived from the drainage pattern of existing topographic map and the satellite image. This is to correlate the trends of drainage and structural orientation in the whole area to establish whether the drainage is structurally controlled. The result of the statistical analysis of the drainage linear and visual observation of it indicates that the drainage follow weak parts in the earth such as fractures and faults. Visual interpretation of lineaments was complemented by some simple digital image processing techniques that highlight linear features. A good technique that was used is the directional edge enhancement and convolution filtering. These techniques will make conspicuous all linear features and boundaries seen on the image. Apart from man-made structures, the result shows that the area has numerous linear features, which include drainage channels, fractures and joints. The strikes and lengths of all lineaments were measured and computed to obtain the rose diagram (Figure 8). The important structural trends are NE-SW, NW-SE, N-S and E-W.

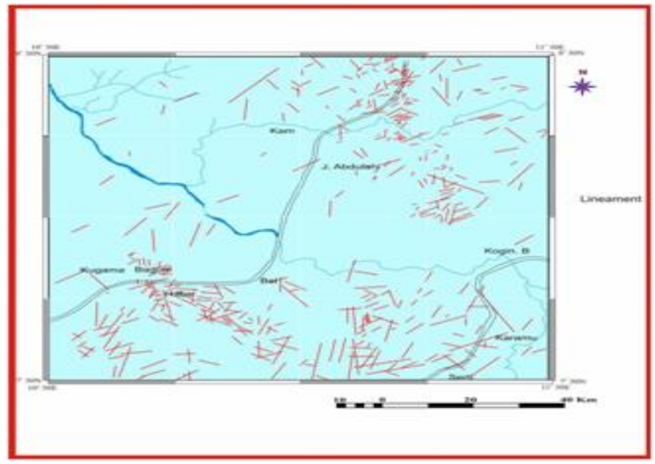


Figure 3. Lineament map of the study area

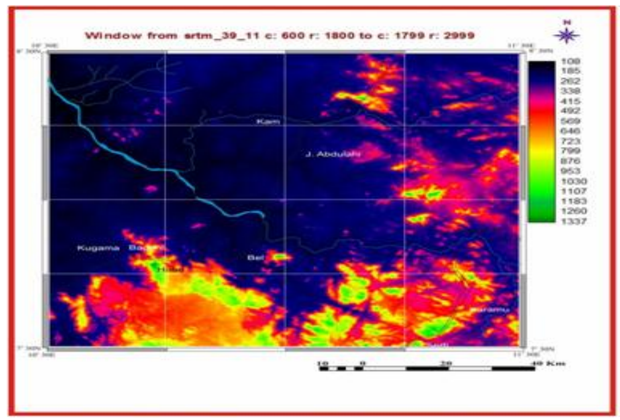


Figure 4. Digital Elevation Model (DEM) of the study area

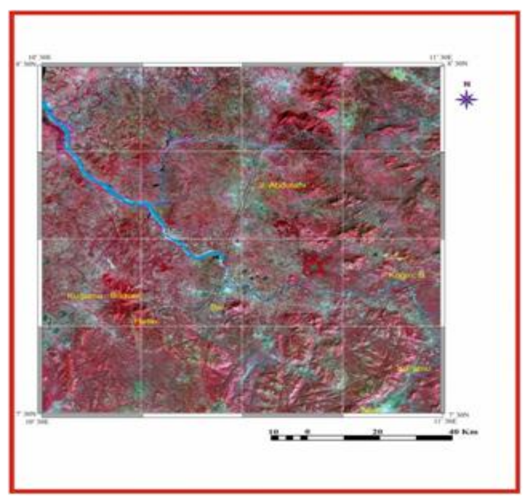


Figure 5. False Colour Composite map (RGB 432)

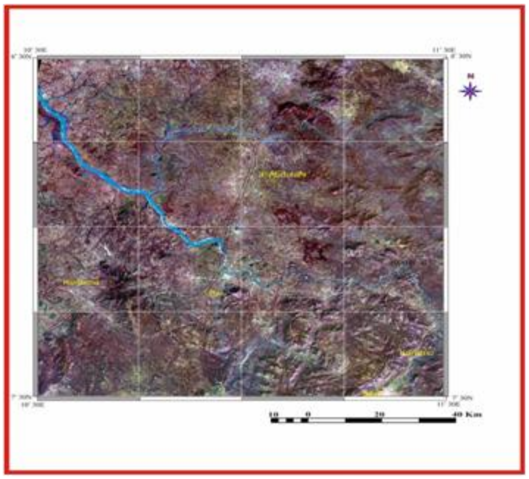


Figure 6. False Colour Composite map (RGB 532)

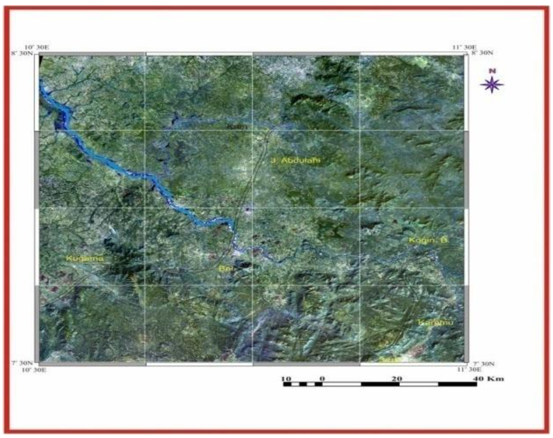
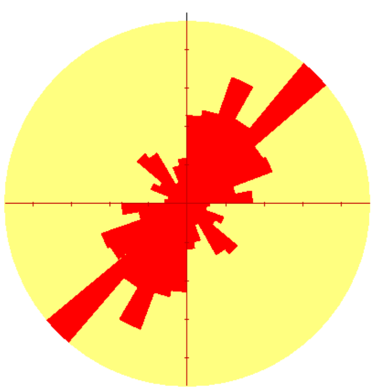


Figure 7. False Colour Composite map (RGB 752)



Number of data plotted = 393; Sector Interval Angle = 10°; Scale spacing = 3% [12 data]; Maximum = 14.2% [56 data]; Mean Resultant Direction=036; Circular Mean Deviation= 44°.

Figure 8. Rose diagram of the lineaments showing the azimuth directions in the study area

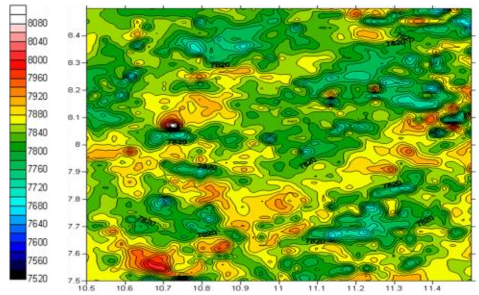


Figure 9. Total Field (Colour Classified Coded) Map of the Aeromagnetic Data of the Study Area

Spectral analysis of the aeromagnetic data was done using software that runs on MATLAB 7.0, developed by [10]. For the spectral determination of depths to layers of magnetization [11], the study area was divided into four (4) blocks containing 14×14 data points. In doing this, adequate care was taken so that essential parts of each anomaly were not cut by the blocks. In order to achieve this, the blocks were made to overlap each other. The estimated depths to magnetic basement are shown as D_1 and D_2 (Table 1). The first layer depth (D_1), is the depth to the shallower source represented by the second segment of the spectrum. This layer (D_1) varies from 0.234km to 1.234km with an average depth of 0.727km. The second layer depth (D_2) varies from 1.746km to 4.750km with an average depth of 2.975km. The 3-Dsurface map of the study area (Figure 12) reveals the magnetic basement morphology and relates same with the undulating relief shown. From the map, depth to basement is high at the northeast and southeast of the area and low at the northwestern and southwestern part. The basement depth (sedimentary thickness) contour map of the study area is shown in Figure 13.The average sedimentary thickness of 2.975km estimated in the study area shows that the area is good for magnetic mineral prospecting and not favourable for hydrocarbon prospecting because of the Tertiary-Recent intrusions in the area. It should also be noted that trapped hydrocarbon could be baked as a result of contact metamorphism at the point of intrusion.

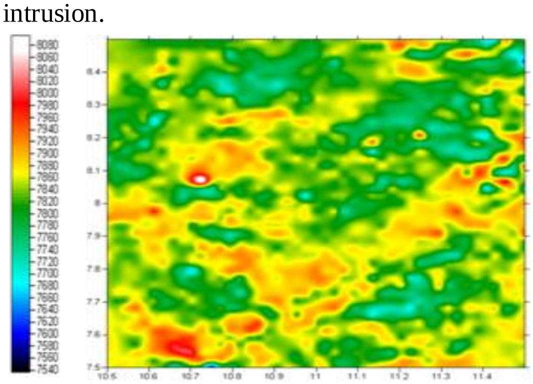


Figure 10. Image map of the total field aeromagnetic data of the study area

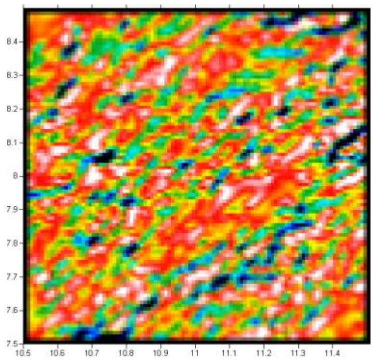


Figure 11. Shaded Relief Map of the Aeromagnetic data of the Study Area

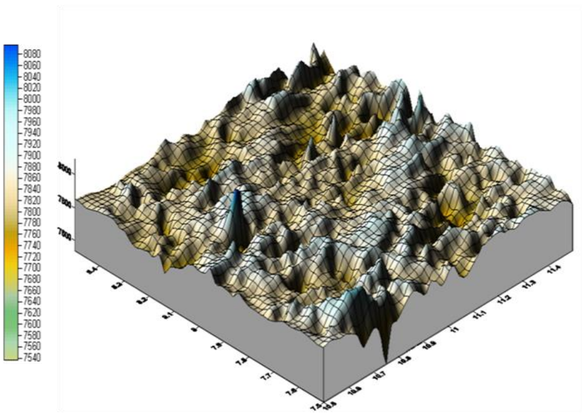


Figure 12. 3-D Surface map of the study area showing magnetic basement morphology

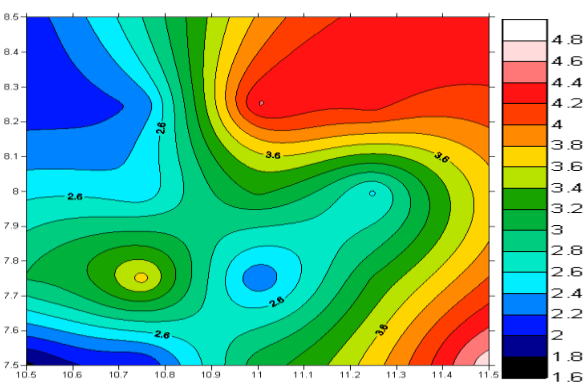


Figure 13. Depth to basement (sedimentary thickness) map estimated from spectral inversion contoured in meters

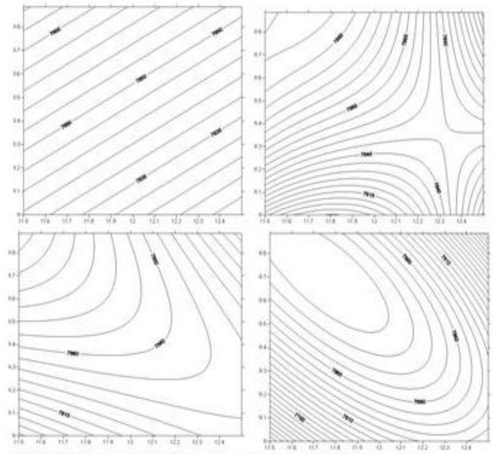


Figure 14. First to Fourth degree regional magnetic field of the study area

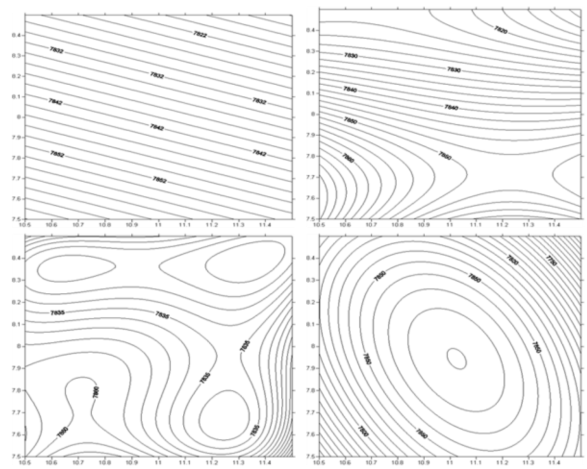


Figure 15. First to Fourth Degree Regional Field of the Aeromagnetic Data of the Study Area.
(Generated from polynomial fitting)

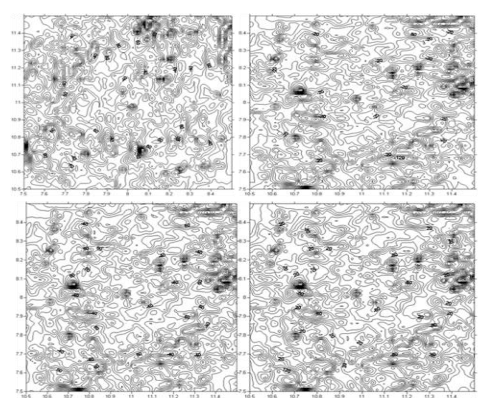


Figure 16. First to Fourth Degree Residual Map of the Aeromagnetic Data of the Study Area

Table 1. Spectral depth estimation of the aeromagnetic data in the study area

S/ NO	SPECTRAL BLOCK	LATITUDE		LONGITUDE		DEPTH(KM)	
		Y1	Y2	X1	X2	D1	D2
1	Bakundi-01	8.25	8.50	10.50	10.75	0.492	2.098
2	Bakundi-02	8.25	8.50	10.75	11.00	0.956	2.233
3	Bakundi-03	8.00	8.25	10.50	10.75	1.234	2.546
4	Bakundi-04	8.00	8.25	10.75	11.00	0.234	2.456
5	Beli-01	7.75	8.00	10.50	10.75	0.333	3.013
6	Beli-02	7.75	8.00	10.75	11.00	0.786	3.688
7	Beli-03	7.50	7.75	10.50	10.75	0.988	1.746
8	Beli-04	7.50	7.75	10.75	11.00	0.534	1.987
9	Kam-01	8.25	8.50	11.00	11.25	0.675	4.420
10	Kam-02	8.25	8.50	11.25	11.50	0.756	4.289
11	Kam-03	8.00	8.25	11.00	11.25	0.987	3.245
12	Kam-04	8.00	8.25	11.25	11.50	0.987	2.567
13	Serti-01	7.75	8.00	11.00	11.25	0.887	2.223
14	Serti-02	7.75	8.00	11.25	11.50	0.82	3.225
15	Serti-03	7.50	7.75	11.00	11.25	0.522	3.120
16	Serti-01	7.50	7.75	11.25	11.50	0.435	4.750

Average depth, d_1 = 0.727km
Average depth, d_2 =2.975km

5. Conclusion

The interpretation of Landsat imagery and aeromagnetic data of the study area reveals that the structures in the area have a dominant NE-SW trend. The drainage pattern is dendritic which is indicative of lithological, structural and topographic differences. Economically, the basin has low petroleum potential because the average sedimentary thickness of 2.975km is very thin for entrapment of crude oil. Another reason put up is that high magnetic anomalies may be associated with igneous and/or metamorphic rocks which have high susceptibility than sedimentary rocks. This implies that the temperature accompanying tectonic activity in the area must have cooked the source rock, if any, beyond the oil window phase of maturation. Therefore, the study area will be viable for magnetic mineral exploration.

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