A Review of Hydrocarbon Prospects in the Lower Benue Trough, Nigeria: Another Insight from Potential Field Study*

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Abstract

Spectral analysis techniques were employed to evaluate aeromagnetic anomalies of Afikpo – Ogoja axis in the Lower Benue Trough, covering about 27,225 km^2 of the area. On the average, depth to the basement varies from 100 to 1,680 m for shallow magnetic sources while for deeper sources vary from 1,870 to 3,980 m. The results reveal sedimentary cover to be relatively thin except for parts of Igumale, Nkalagu, Enugu and Ogoja areas. The estimated crustal thickness on the average varies from about 10 km around Afikpo area to less than 25 km at Obolo Eke – Abakaliki Axis. The results show the study area may likely be composed of mainly continental magnetized crust. Three zones of geothermal gradient identified are 16 – 28°C/km for zone of low geothermal gradient, 28 – 42°C/km for zone of intermediate geothermal gradient, and 42 – 58 0C/km for zone of high geothermal gradient. The results reveal that Igumale, Nkalagu, Enugu and Ogoja areas underlain by Asu River Group, Ezeaku Formation, Awgu Formation, and Nkporo Formation lies within the zone of intermediate geothermal gradient. This zone of intermediate geothermal gradient falls within the oil-generating window and could have moderate hydrocarbon prospects.

Introduction

Most rifts and aulacogens in the world are believed to contain numerous mineral and hydrocarbon resources. The Benue Trough is a failed rift arm (aulacogen) and is believed to be among the least studied aulacogen in the world. This study looks at re-evaluating Afikpo – Ogoja Axis of the lower portion of the Benue Trough Nigeria from potential field data to assess the hydrocarbon potential of the area. The reason for this study is partly due to the recent finding and production of hydrocarbon within the Anambra basin, which is one of the inland basins of Nigeria and a neighbouring basin to the study area. This discovery has motivated most investors to start looking into the other inland basins of Nigeria like the Chad Basin, Bida Basin, Sokoto Basin, and Benue Trough for further discovery. This study perhaps will provide more geological information for hydrocarbon exploration companies, government agencies, and prospective investors. The principal objectives are: (a) to delineate geological boundaries; (b) to estimate depth to magnetic basement (thickness of sediment) which is an important exploration consideration for basin modelling; (c) to obtain geothermal gradient; and (d) to estimate the thickness of the magnetized crust in the study area.

To achieve the above objectives, aeromagnetic data, gravity data, and geological information covering about 27,225 km^2 were employed for this study. The geology of study area is dominated by mainly Cretaceous sediments, which make up the Lower Benue Trough and lay uncomformably on rocks of the crystalline basement (Oban - Obudu massif) which are Precambrian in age (Figure 1).

Data and Methodology

A composite aeromagnetic map of Afikpo – Ogoja area consisting of Nine (9) sheets were assembled for this study; covering a total area of about 27,225 km^2 and these include: Igumale (288), Ejekwe (289), Ogoja (290), Nkalagu (302), Abakaliki (303), Bansara (304), Afikpo (313), Ugep (314), and, Ikom (315). Gravity data (Adighije, 1981) was also used to view the gravity anomaly from a regional perspective. Each of the contoured aeromagnetic maps was digitized at 1 km intervals to avoid error due to aliasing effects. The total magnetic intensity map was generated by gridding the digitized data using minimum curvature technique and the resulting grid was contoured at 20 nT intervals. The residual magnetic anomaly plot was obtained by subtracting the regional trend from the observed magnetic data after fitting a polynomial to the observed data. The residual anomaly map (Figure 2) obtained were subjected to spectral analysis along selected profiles to estimate depth to the magnetic anomaly source. This was achieved by using gradient of each selected segment (Figure 3) to determine the depth to the basement (Spector and Grant, 1970; Onwuemesi, 1997). Three simple geological models (Figure 4) were selected to show the behavior of magnetic signature across the study area while the depth to magnetic basement map (Figure 5) shows the distribution of sediment in the study area. The spectral method was also used for Curie – point depth estimation from the magnetic data. In this case, the basal depth of the magnetic source is given as $Z_b = 2Z_o – Z_t$. The obtained basal depth (Z_b) of the magnetic source is assumed to be the Curie - point depth and this usually reflects the average curie – point depth value of the area. The temperature at depth (Figure 6) and geothermal gradients of the area were computed by assuming that the temperature changes within the earth are linear and in the form: $T_h = mh + T_o$.

Assessment of Hydrocarbon potential of Afikpo – Ogoja axis of the Lower Benue trough Nigeria

Depths to magnetic basement for the study area were obtained using one – dimensional spectral analysis. On the average, the depth values obtained varies from about 100 to 1,680 m for shallower sources while for the deeper sources, the sediment thickness ranges from 1,870 to 3,980 m. These results reveal sedimentary cover to be relatively thin except for parts of Igumale, Nkalagu, Enugu and Ogoja areas (Figure 4). The thickness of the magnetized crust in the study area estimated varies from 10 km at Afikpo area to less than 25 km at Obolo Eke – Abakaliki Axis as seen in one of the cross – sections (Figure 7). The results show the study area may likely be composed mainly of continental magnetized crust. The geothermal gradients obtained in the study area vary from 16°C/km to about 580°C/km with an average value of 31.31°C/km. Three zones of geothermal gradient variations were identified in the study area and they include 16 – 28°C/km for zone of low geothermal gradient, 28 – 42°C/km for zone of intermediate geothermal gradient and 42 – 58°C/km for zone of high geothermal gradient.

These results reveal that areas underlain by the Asu River Group, Ezeaku Formation, Awgu Formation, and Nkporo Formation fall within the zone of intermediate geothermal gradients. The Geothermal gradient values obtained compare favourably with studies done in the same area by Nwachukwu (1985) using time – temperature index (TTI). He observed that most part of the Asu River Group (Albian Shale) have the potential of generating oil and gas, while parts of Nkporo Shale, Awgu Formation, and Ezeaku Formation have the potential of generating mainly oil. Various studies from geochemical evaluation in this area are in agreement with this finding and could be used to draw logical conclusion about the hydrocarbon potential of Afikpo – Ogoja area of the Lower Benue Trough Nigeria. Akande et al. (2012) also evaluated hydrocarbon potential of Cretaceous sediments in the Lower Benue and Middle Benue using new source rock facies. They suggested Ezeaku Formation (Turonian - Coniacian) is dominated type II and type III kerogen, Awgu Formation (Turonian - Coniacian) is dominated by type III kerogen and Mamu Formation (Lower Maastrichtian) is dominated by type III kerogen. These formations have proven potentials as oil and gas source rocks. Onuoha and Ekine (1999) estimated the geothermal gradients and heat flow values within the Anambra Basin using ten exploratory wells. Their results for geothermal gradients and heat flow values vary from 25 ± 1 to 41 ± 6°C/km, and 48 ± 3 to 76 ± 6 mWm^{-2} respectively. Onwuemesi (1997), using one-dimensional spectral analysis of aeromagnetic data determined that the geothermal gradients in the Anambra Basin range from 20°C/km to 35°C/km with an average result of 29 ± 5°C/km. On the average, the geothermal gradient and heat flow results calculated for the study area, which are 16 ± 2 to 58 ± 2°C/km and 40 ± 5 mWm^{-2} to 145 ± 5mWm^{-2} respectively, compare favourably with that of the Anambra Basin.

Conclusions

- Depth to magnetized crust (sediment thickness) varies from 100 to 1,680m for shallower magnetic sources while deeper sources vary from 1,870 to 3,980m.
- The thickness of the magnetized crust estimated vary from 10 km around Afikpo area to less than 25 km at Obolo Eke – Abakaliki Axis depicting the area to be composed mainly of continental magnetized crust.
- Three zones of geothermal gradient identified are 16 – 28°C/km for zone of low geothermal gradient, 28 – 42°C/km for zone of intermediate geothermal gradient and 42 – 58°C/km for zone of high geothermal gradient.
- The results reveal that Igumale, Nkalagu, Enugu and Ogoja areas underlain by Asu River Group, Ezeaku Formation, Awgu Formation, and Nkporo Formation lies within the zone of intermediate geothermal gradient. This zone of intermediate geothermal gradient falls within the oil-generating window. Hence, the above-mentioned areas have moderate hydrocarbon prospects and it is recommended for further detailed seismic reflection and geochemical studies.

Acknowledgements

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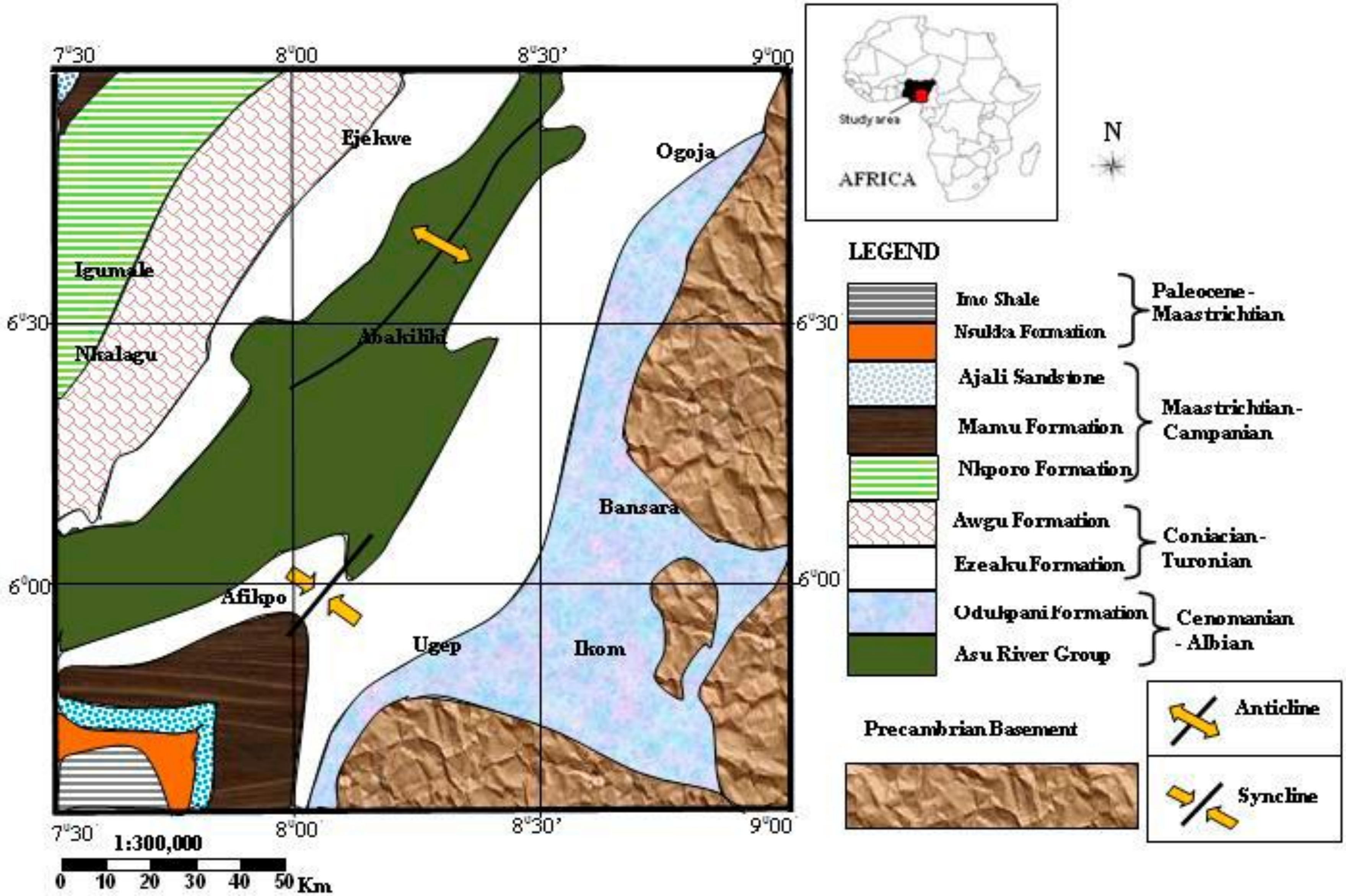

Figure 1. Geological map of Afikpo – Ogoja area of the Lower Benue Trough Nigeria (Modified from Onuoha et al., 1989).

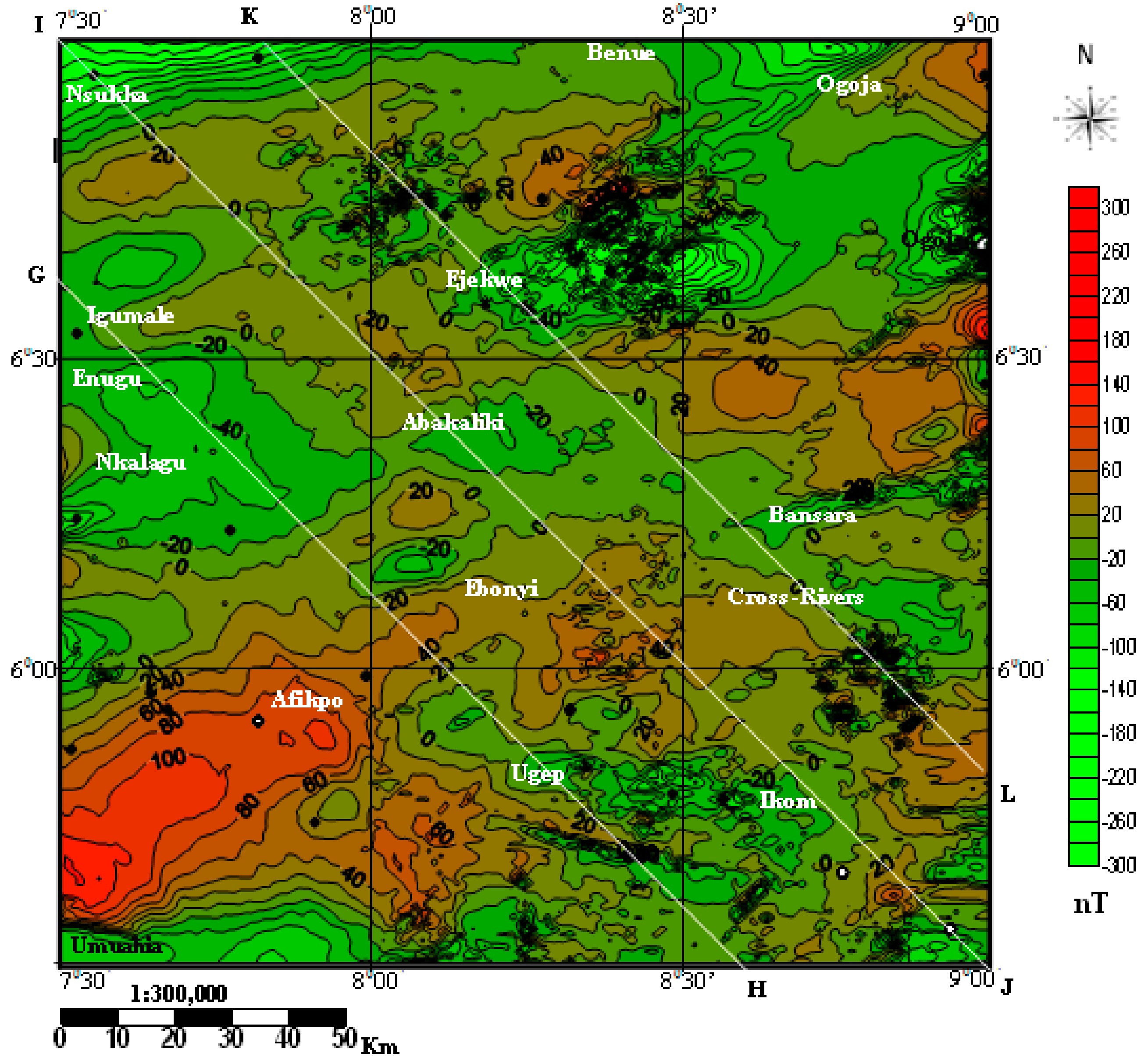

Figure 2. Residual magnetic anomaly map of the study area showing selected profiles (G-H, I-J, and K-L).

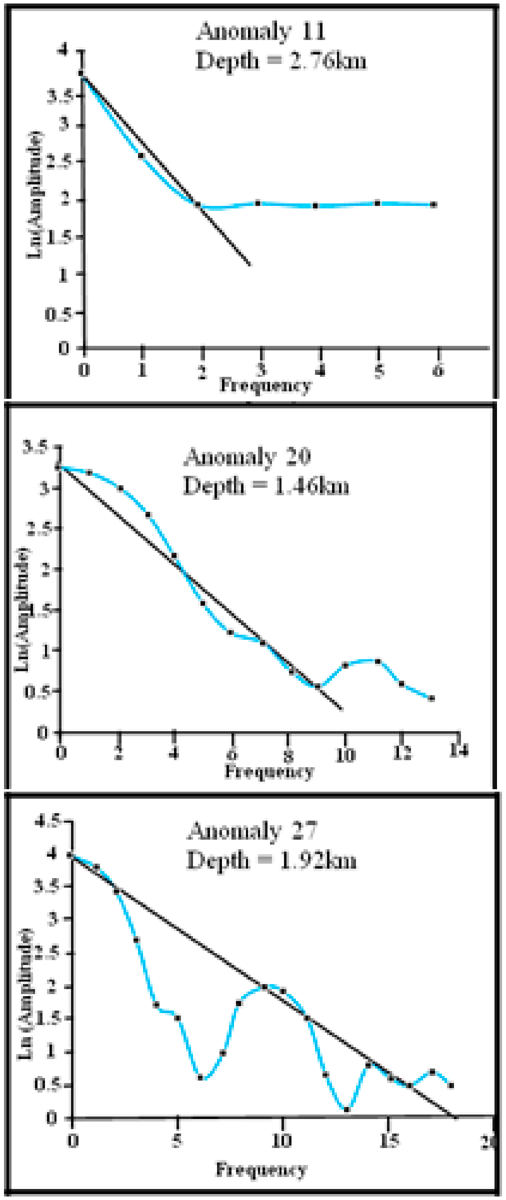

Figure 3. Spectral plots along the selected profiles (G-H, I-J, and K-L) of the study area.

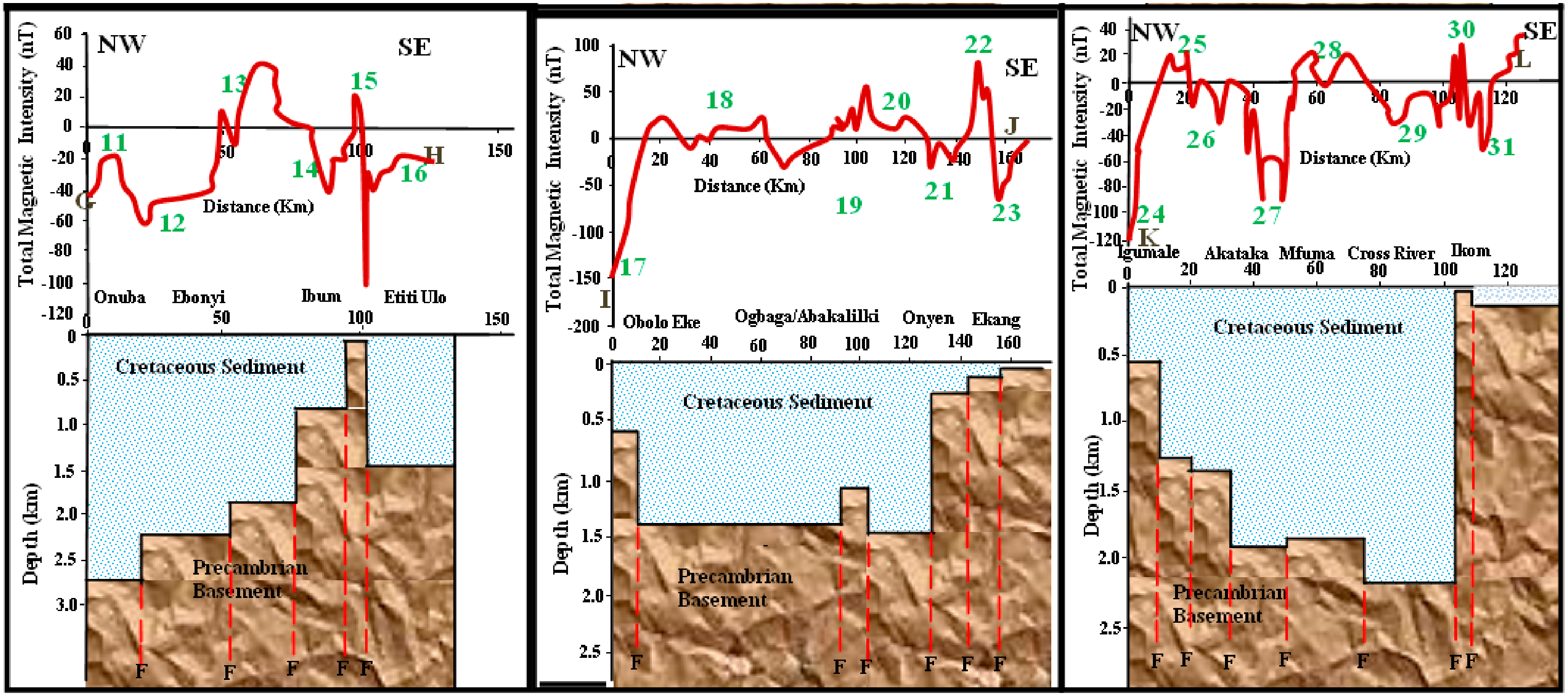

Figure 4. Simple geological models from selected profiles (G-H, I-J, and K-L) in the study area.

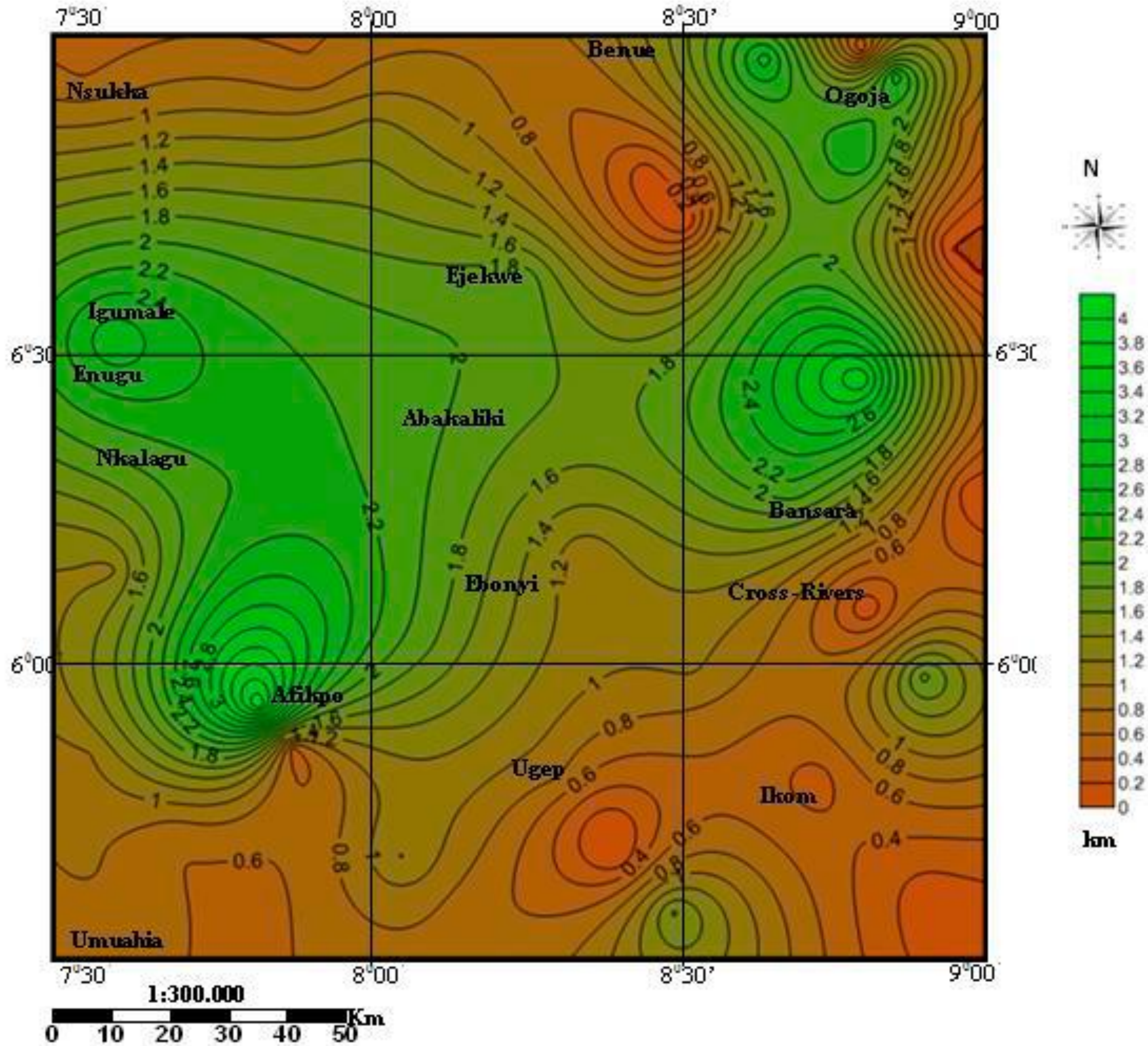

Figure 5. Depth to basement map of the study area (Contour interval~0.2km).

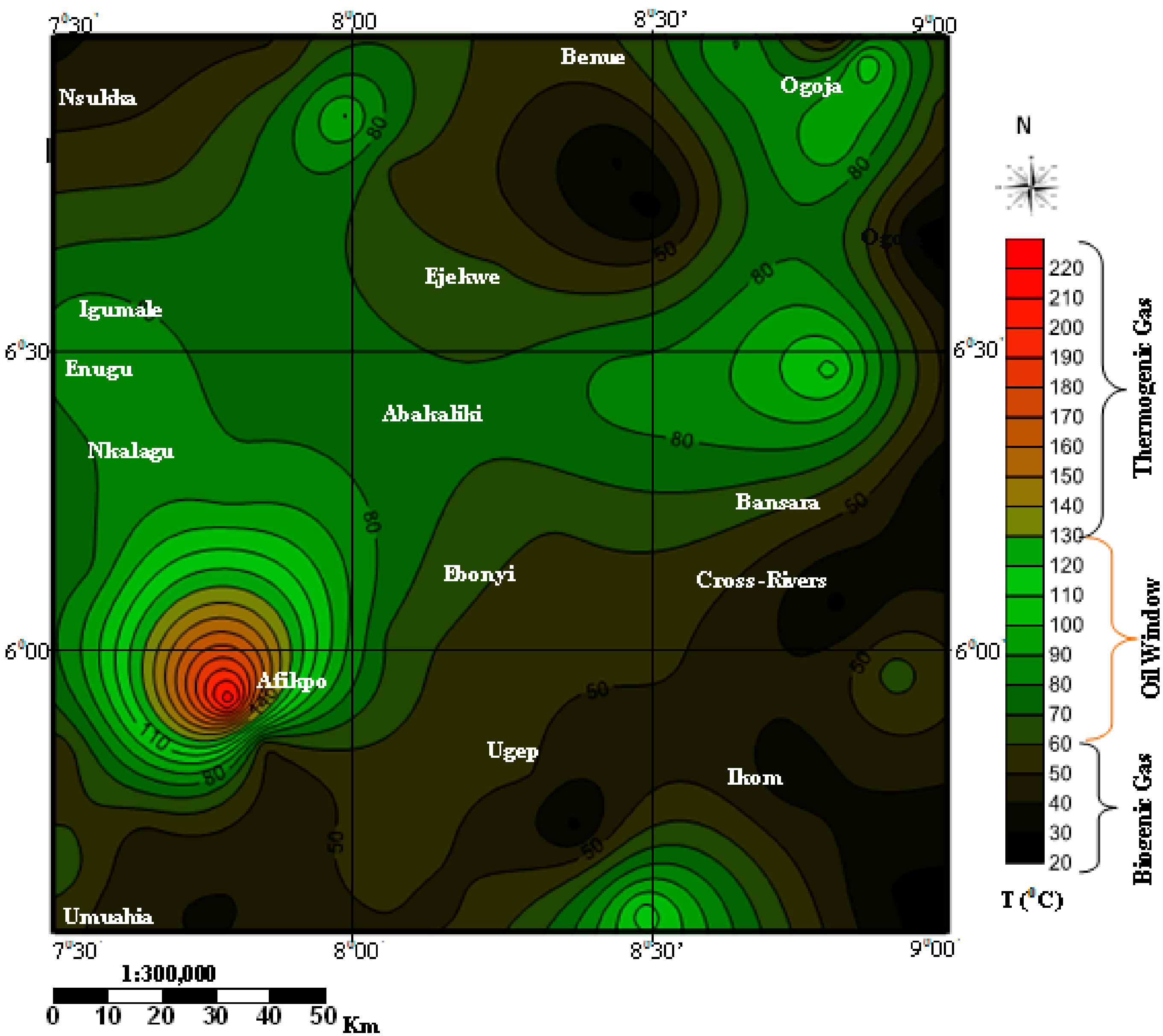

Figure 6. Temperature map of the study area (Contour interval ~10°C).

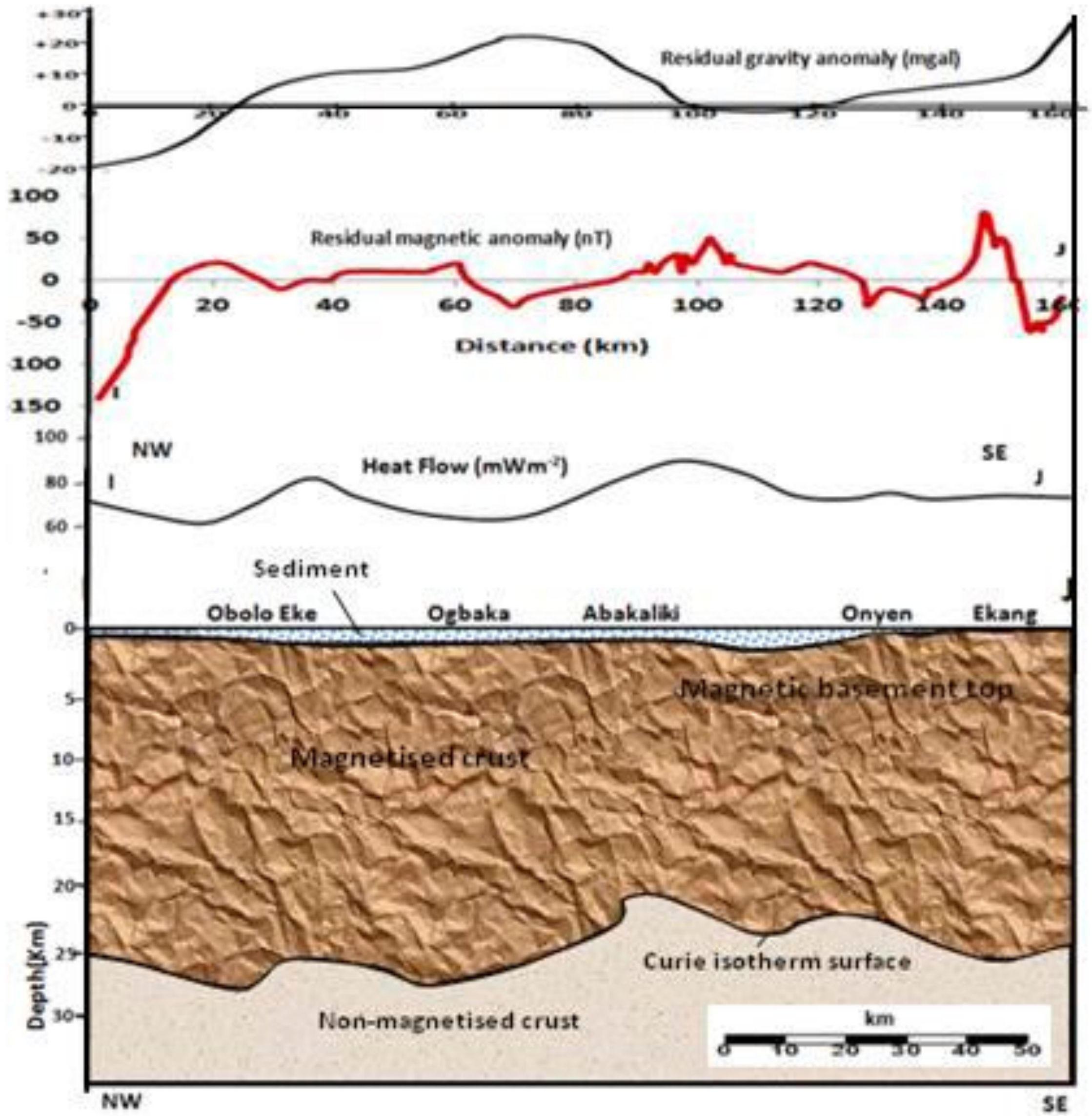

Figure 7. A cross – section (I-J) of the Lower Benue Trough showing Curie depth, Heat flow, magnetic and gravity anomalies.