

Aeromagnetic Interpretation of Basement Structure and Architecture of the Dahomey Basin, Southwestern Nigeria.

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Summary

The present study investigates the structural configuration and basement architecture of the Dahomey Basin southwestern Nigeria. High resolution aeromagnetic data were subjected to various enhancement techniques including reduction to the equator, vertical derivative, tilt derivative and upward continuation to better characterize the basement morphology and tectonic framework of the basin. Determination of depth to magnetic sources and sedimentary thickness in the study area was achieved using the source parameter imaging (SPI) method. Results from the data interpretation indicated the presence of shallow and deep-seated structural features including faults and fractures, with major trends in the NE-SW, NW-SE, WNW-ESE and E-W directions respectively. Basement block pattern in the study area depicted a horst-graben architecture as observed on 2D model along a selected profile. Depth to anomalous causative bodies varied across the basin. However, a depth range of 3.5-5km was attained in the identified mini-basins. The study demonstrates the robustness of geopotential field data in providing enhanced images of subsurface geological features, basement architecture and sedimentary thickness in the Dahomey Basin for improved hydrocarbon prospectivity.

Keywords: Aeromagnetic, Basement architecture, Geopotential data, Dahomey Basin

Introduction

Significant yet untapped hydrocarbon resources still abound in the Nigerian sector of the Dahomey Basin, with estimated (prospective and proven) reserves upto 15-20 billion barrel of oil equivalent (Kehinde and Adedoyin, 2019). The basin is yet to reach its full potentials and yield expected exploration results unlike its analogous Cretaceous basins both in west and central Africa and other parts of the world where major discoveries have been made. Numerous geophysical studies have been conducted by many researchers attempting to characterize the structural and tectonic features of the basin (e.g. Ahmed et al., 2018; Okpoli and Ekere, 2017; Oladele et al., 2016; Oladele and Ayolabi, 2014; Osinowo and Olayinka, 2013; Opara et al., 2012). However, little attention has been paid to understand the tectonic controls on basement architecture and its influence on petroleum systems/play elements distribution across the basin. The present study provides additional insights on the basement structure and architecture of the basin on the basis of aeromagnetic data interpretation. The study area is located within the Gulf of Guinea and covers the southwestern part of Nigeria (Fig. 1).

Methodology

High resolution aeromagnetic (HRAM) data acquired from the Nigerian Geological Survey Agency (NGSA) were processed using the Oasis Montaj software. The enhancement filters applied to the dataset include reduction to the equator (RTE), first vertical derivative (FVD), tilt derivative (TDR) and upward continuation of the RTE map to 1km to better characterize the basement morphology and tectonic framework of the basin. Determination of depth to magnetic sources and sedimentary

thickness in the study area was achieved using the source parameter imaging (SPI) method, while 2D forward model along a selected profile gave insights to the basement block pattern and architecture in the basin.

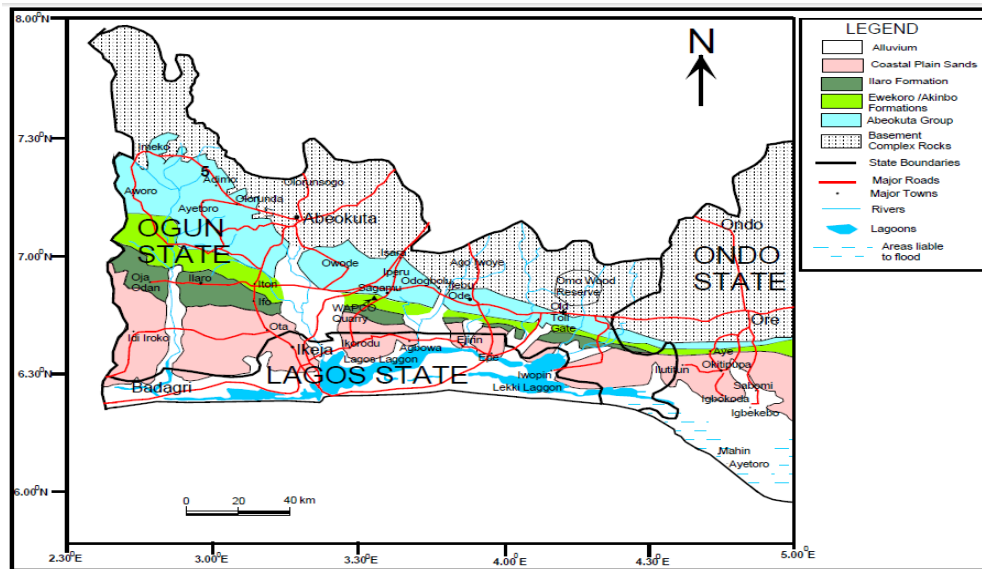


Fig. 1. Geological map of Dahomey Basin in the Nigerian sector and the states located on the basin (modified after Olabode and Mohammed, 2016).

Results and Discussions

Aeromagnetic Signatures of the Study Area

The RTE map of the study area (Fig. 2) revealed variations in magnetic anomalies ranging from -51.7 to +119.4nT. The anomalies show a strong trend in the NE-SW, NW-SE, WNW-ESE and E-W directions, respectively. The northeastern and southeastern portions of the map are characterized by high and low magnetic anomaly responses, while the central part of the map is characterized by high, intermediate and low magnetic anomaly responses. High and low magnetic anomalies dominate the northwestern and southwestern portions of the map. The anomalies exhibit sharp magnetic boundaries, which are typical of vertical or steeply dipping contacts.

Structural Framework of the Basin

Figure 3 is the FVD map of the study area. Shallow faults and other linear features on this map show different orientations in the NE-SW, NW-SE and E-W directions, respectively. As observed on the tilt derivative map (Fig. 4) and upward continued (1km) anomaly map (Fig. 5), the major pattern of deep-seated regional faults controlled the development of anomalous lower amplitude subtle features (fractures and lineaments) in the basin. Major trends of the deep-seated high and low anomalies in figure 5 are in the NE-SW and NW-SE directions, respectively. The low magnetic anomalies characterizing the northeastern portion of the upward continued (1km) map could be attributed to a basement drop with subsequent low susceptibility sediment infilling.

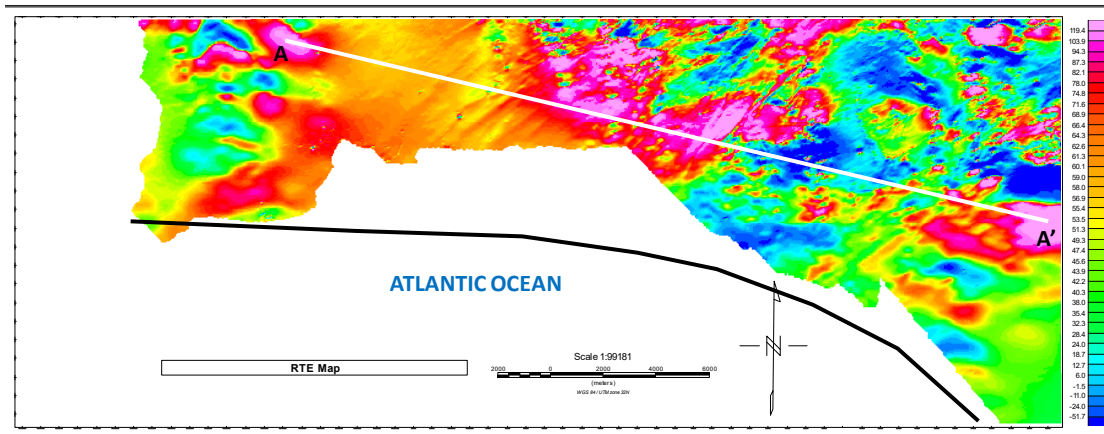


Fig. 2. Reduction to Equator Map of the Study Area. Black line represents Nigeria's coastal margin, while line A-A' is the 2D modeled profile in figure 7.

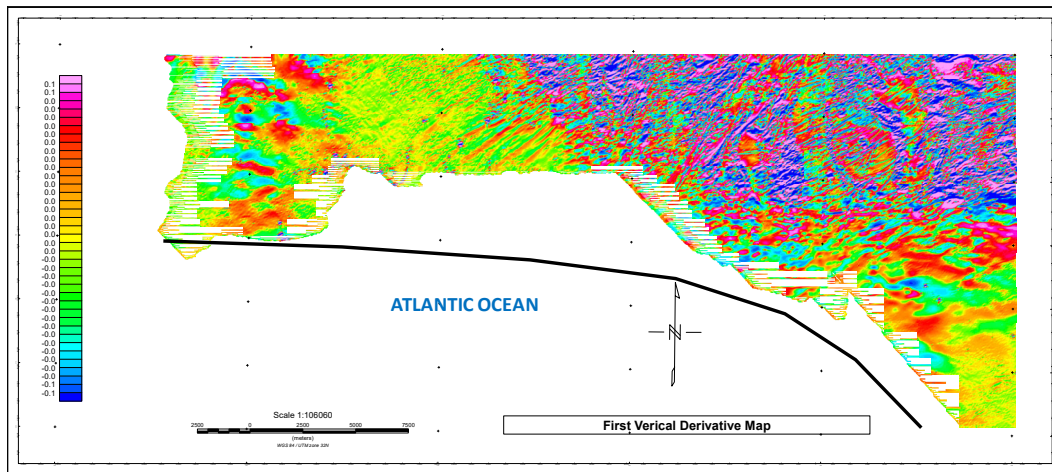


Fig. 3. First Vertical Derivative Map of the Study Area

Basement Block Pattern and Architecture

The magnetic anomalies show alternation of high and low signatures which suggests basement high (horst) and low (graben). High magnetic anomalies on the RTE map reflect regions with high magnetite content which in this case, is the crystalline basement rocks of southwestern Nigeria while regions with low magnetic anomaly suggests areas with relatively low magnetite content (Okpoli and Ekere, 2017). These variations reflect the block pattern and rugose morphology of the underlying basement rocks. The interpreted high and low magnetic responses indicate high susceptibility basement uplift and low susceptibility sediment-filled depression respectively. Major trends of the mapped shallow and deep-seated structural features are in the NW-SE, NE-SW, WNW-ESE and E-W directions, reflecting their processes of formation. The combination of fractures and faults imposed a horst and graben architecture on the basement of the study area as observed on the 2D forward model (Fig. 6).

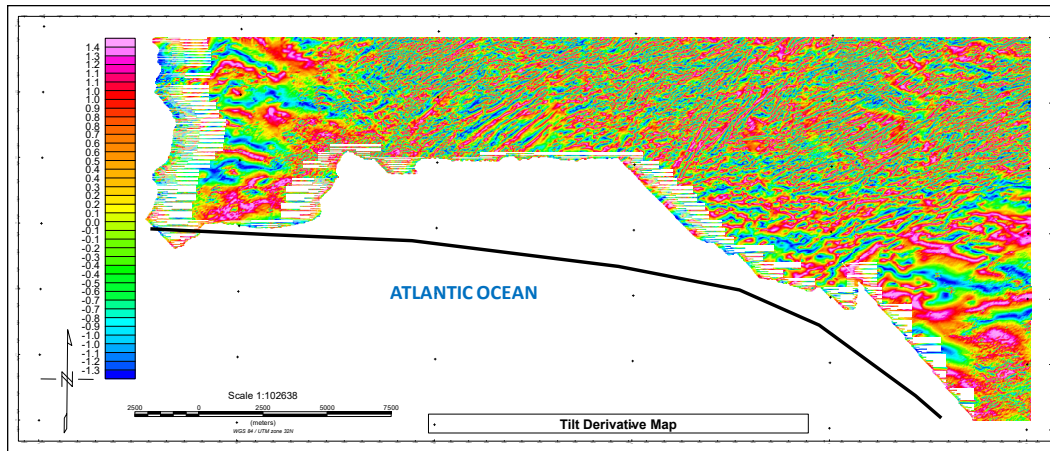


Fig. 4. Tilt Derivative Map of the Study Area

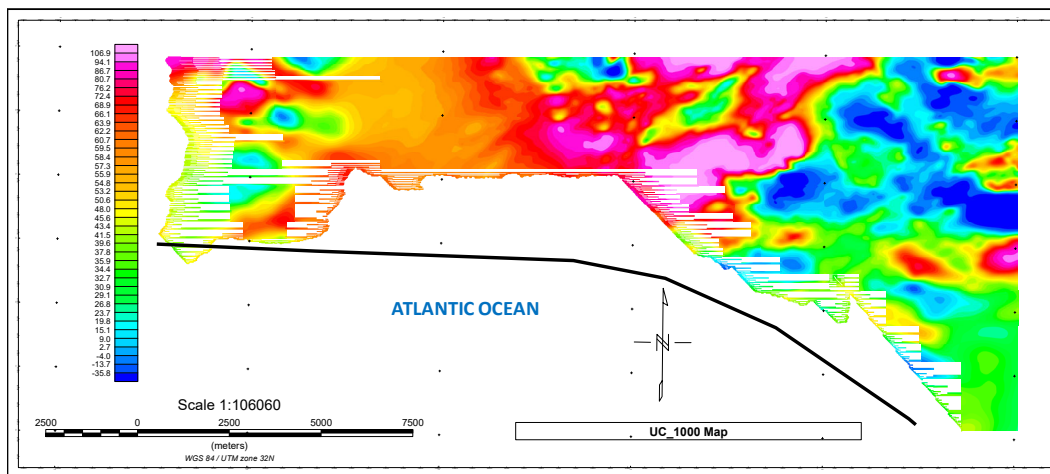


Fig. 5. Upward Continuation (1km) Map of the Study Area

Depth to Magnetic Basement

Estimation of depth to magnetic sources was established using the Source Parameter Imaging (SPI) method (Fig. 7). Depth to anomalous causative bodies varied across the basin. However, a depth range of 3.5-5km was attained in the identified mini-basins.

Conclusion

The robustness of geopotential data in providing enhanced images of subsurface geological features, the basement architecture and sedimentary thickness in the Dahomey Basin have been demonstrated in this study. Estimates of depth to magnetic sources revealed that sedimentary thickness varies across the basin with the offshore portions of the basin being adjudged to be deep enough to accommodate thicker sediments with sufficient depths of burial and possible higher levels of thermal maturation of organic matter. It therefore appears to make more sense to have exploration efforts concentrated in the offshore parts of the basin.

References

Ahmed, Z., Lawal, K. M. and Ahmed, A. L. (2018), Interpretation of Aeromagnetic Data of Part of Southwestern Nigeria for Subsurface Mapping. DUJOPAS 4 (2): pp. 221 – 235.

Oladele, S., Ayolabi, E. A. and Dublin-Green, C. O. (2016), Structural Characterization of the Nigerian sector of Benin Basin using Geopotential Field Attributes. *Journal of African Earth Sciences*, Elsevier, 121, 200–209.

Oladele, S. and Ayolabi, E. A. (2014), Geopotential Imaging of the Benin Basin for Hydrocarbon Prospectivity. *NAPE Bull.*, Vol. 26, No. 1, pp. 101 – 112.

Okpoli, C. C. and Ekere, V. (2017), Aeromagnetic mapping of the basement architecture of the Ibadan region, Southwestern Nigeria. *Discovery*, 53(264), 614 – 635.

Opara, A. I. (2011), Estimation of the Depth to Magnetic Basement in Part of the Benin Basin, Southwestern Nigeria. *Australian Journal of Basic and Applied Sciences*, Vol. 5(9), pp. 335-343.

Osinowo, O. O. and Olayinka, A. I. (2013). Aeromagnetic mapping of basement topography around the Ijebu-Ode geological transition zone, southwestern Nigeria. *Acta Geodesy and Geophysics*, 48: 451-470.

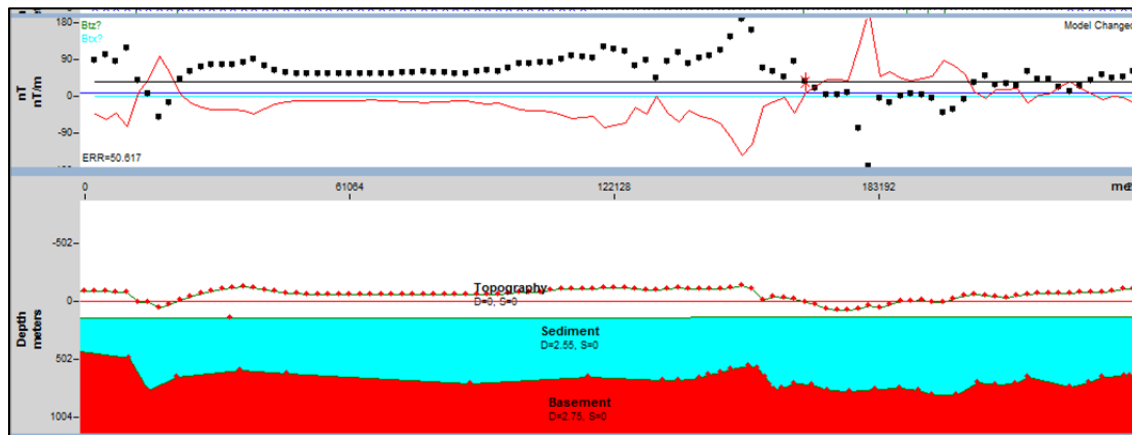


Fig. 6. 2D model of the study area depicting basement block pattern and architecture of the basin.

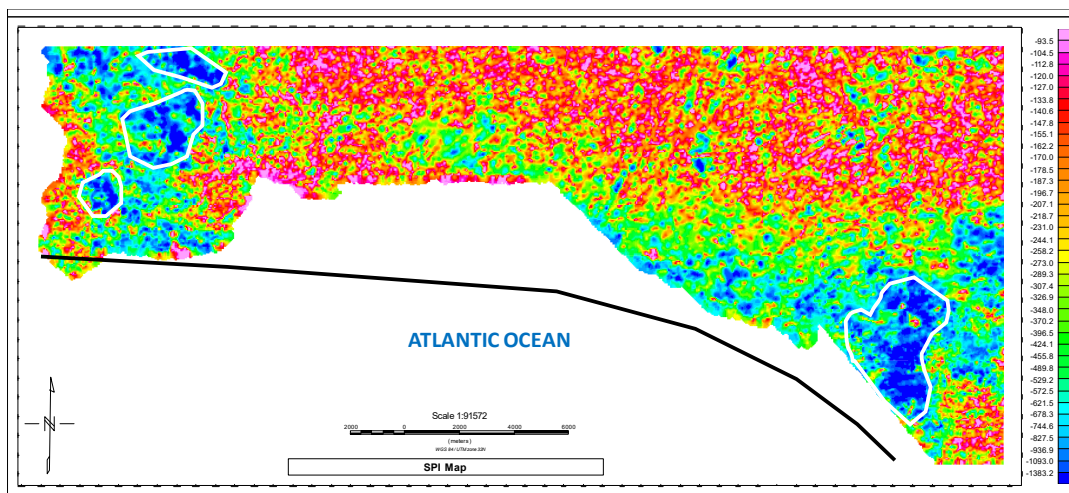


Fig. 7. SPI Map of the Study Area showing identified Mini-basins