Is petroleum exploration plausible in Nigerian inland basins? A case of spectral analysis of aeromagnetic anomalies of Sokoto basin

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Summary

This paper presents a regional evaluation of depths to top of magnetic sources (DTMS) from the spectral analysis of the recently acquired high resolution aeromagnetic (HRAM) data of the entire Sokoto Basin in northwestern Nigeria. The basin is bounded by latitudes 10.00^oN and 14.00^oN and longitudes 3.50^oN and 7.00^oE and has a total surface area of about 111,925 km^2. This work is in view of the Nigerian Federal Government's encouragement for extensive hydrocarbon exploration in inland basins. The acquired HRAM data was divided into twenty two (22) overlapping blocks and each block analyzed to obtain DTMS values. The results show that the DTMS (also regarded as sedimentary thickness) vary between 0.59 and 2.11 km with an average of 1.22 km. However, the minimum thickness of sediment required to achieve a threshold temperature for the commencement of hydrocarbon formation is 2.3 km. Therefore, hydrocarbon exploration may not be feasible in the basin.

Introduction

The Niger-Delta basin in southern Nigeria have been explored for hydrocarbon for several decades with considerable success (Nwachukwu,1985; Obaje et al., 2004) and for political reasons, the government has encouraged extensive hydrocarbon exploration in inland basins, especially in the northern part of the country. Therefore, the work presented in this paper is the assessment of the regional aeromagnetic anomalies of Sokoto basin (Fig. 1), Nigeria for reconnaissance petroleum studies.
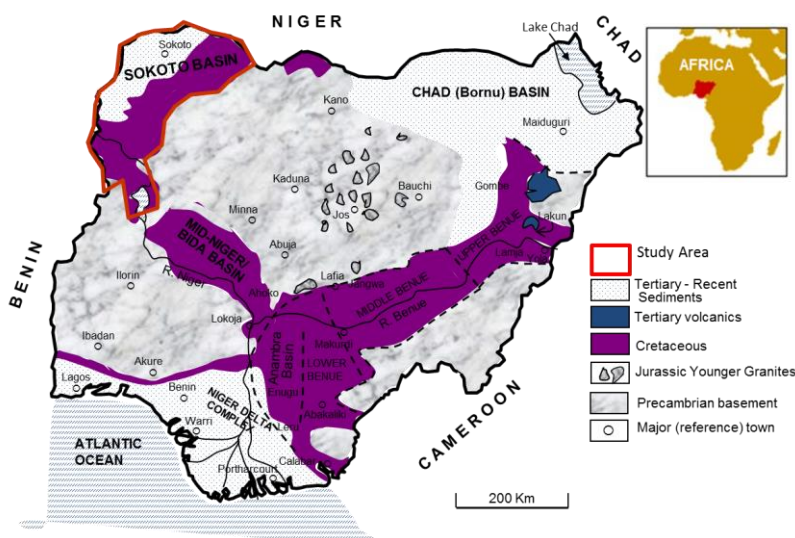

Fig. 1. Geological Map of Nigeria showing Sokoto Basin (after Obaje et al, 2004)

Theory and/or Method

Spectral models of magnetic interpretation are based on the examination of the shape of isolated magnetic anomalies (Bhattacharyya and Leu, 1975; 1977), statistical properties of magnetic ensembles (Spector and Grant, 1970) and power spectral density of total magnetic field (Blakely, 1995). The depth to the top of the magnetic source is consequently derived from the slope of high wavenumber portion of the power spectrum as (Tanaka et al, 1999):

$$\ln(P(k)^{1/2}) = B - |k| Z_t \tag{1}$$

where B is a constant, and Z_t is the depth to the top of magnetic sources.

Thirty eight (38) digital half degree high resolution aeromagnetic (HRAM) maps each having an area of 55 km x 55 km (sheet number 1 - 5, 8 – 13, 26 – 31, 48 – 53, 71 -74, 94 – 97, 116 – 119 and 138 - 139) on a scale of 1:100,000 with a total 7,426,917 data points were used in this work. The whole data, which were procured from the Nigerian Geological Survey Agency (NGSA) and assembled into composite total magnetic field intensity (TMI) map (Fig. 2), range between 32487.96 and 33423.06 nT with an average of 33060.70 nT and a standard deviation of 38.314. This nationwide regional scale data (HRAM) has been processed and corrected and a constant TMI value of 33000 nT was removed for easier computation by the NGSA before the eventual publication as HRAM colour Maps. The composite map was then divided into twenty two (22) overlapping blocks, for the purpose of 2D spectral analysis while ensuring that essential parts of the anomaly were not cut out by the blocks.
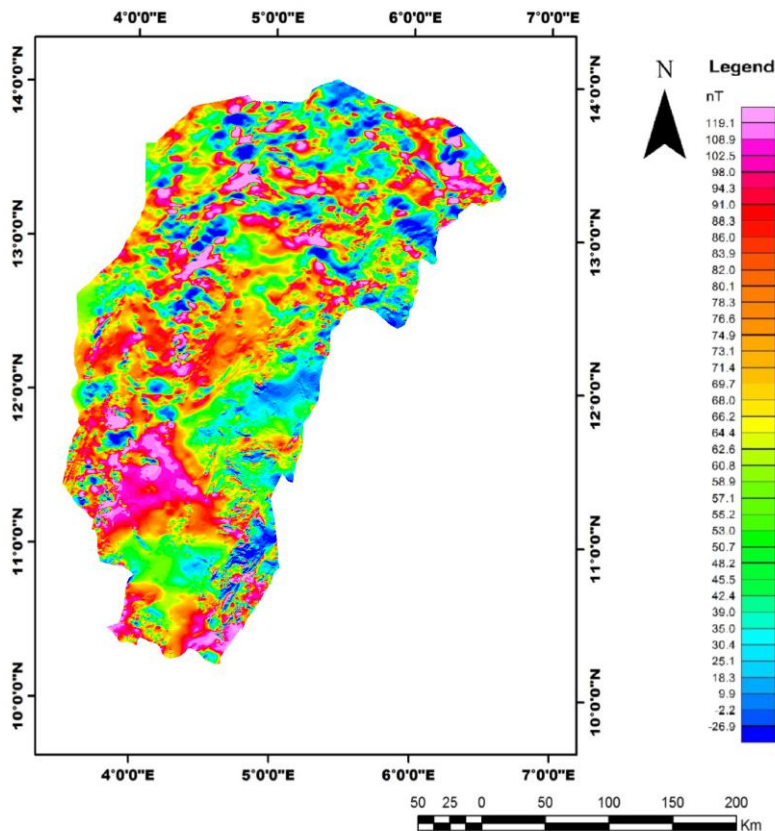

Fig. 2. Total Magnetic Intensity Map (TMI) of entire Sokoto basin. A constant 33000 nT removed.

Examples

The results of estimated depth extents for the 22 blocks show that the depths to the top of magnetic sources range from 0.59 to 2.11 km with an average of 1.22 km (Fig. 3). The variation of basement depths in the basin is found to be consistent with those of other workers (Umego, 1990; Shehu et al., 2004; Adetona et al., 2007; Bonde et al., 2014). In particular, Kurowska and Schoeneich (2010) explained that the thickness of the sedimentary layer in the basin is about 1 km but exceeds 2 km towards the Mali and Niger Republic territory.
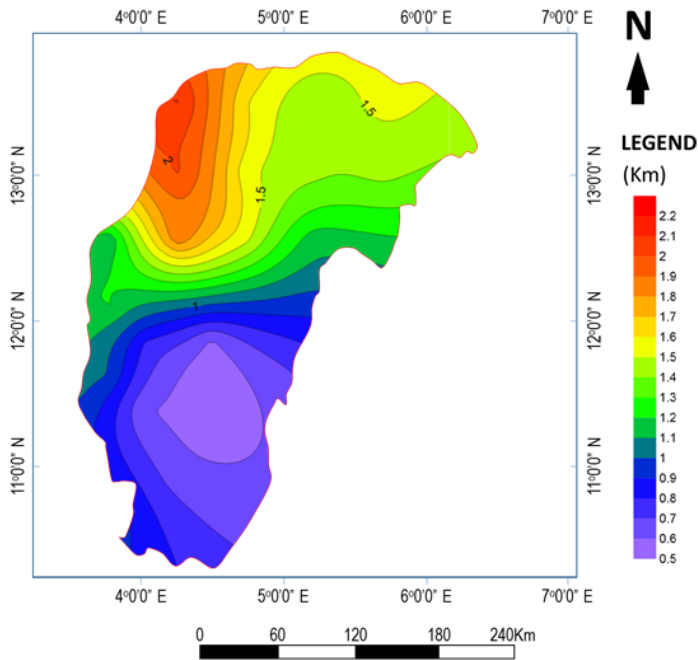

Fig. 3. Depth to the top of the magnetic source map of the study area (Nwankwo and Shehu, 2015).

Conclusions

Wright et al. (1985) argued that the minimum thickness of sediment required to achieve a threshold temperature for the commencement of hydrocarbon formation is 2.3 km. Therefore, hydrocarbon exploration may not be feasible in the basin.

Acknowledgements

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