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Mustapha Meghraoui · Narasimman Sundararajan ·
Santanu Banerjee · Klaus-G. Hinzen · Mehdi Eshagh · François Roure ·
Helder I. Chaminé · Said Maouche · André Michard *Editors*

Advances in Geophysics, Tectonics and Petroleum Geosciences

Proceedings of the 2nd Springer Conference of the Arabian Journal of Geosciences (CAJG-2), Tunisia 2019

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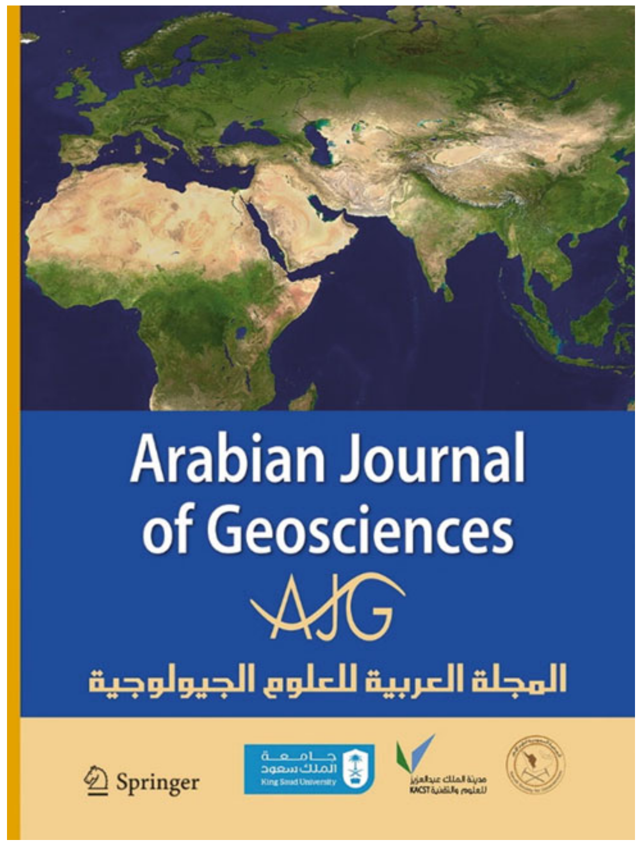
About the 2nd Springer Conference of the Arabian Journal of Geosciences (CAJG-2), Tunisia 2019



The Arabian Journal of Geosciences (AJG) is a Springer journal publishing original articles on the full range of Earth sciences in partnership with the Saudi Society for Geosciences. The journal focuses on, but is not limited to, research themes which have regional significance for the Middle East, the Euro-Mediterranean, Africa, Asia and some other regions of the world. The journal receives on average 4000 submissions a year and accepts around 1000 papers for publication in its 24 annual issues (acceptance rate around 25%). It benefits from the participation of an editorial team of 100 international Associate Editors who generously help in evaluating and selecting the best papers.

In 2008, Prof. Abdullah Al-Amri, in close partnership with Springer, founded the Arabian Journal of Geosciences (AJGS). In 2018, the journal celebrated its 10th anniversary. To mark the event, the founder and Editor-in-Chief of the AJGS organized the 1st Conference of the Arabian Journal of Geosciences (CAJG) in close collaboration with Springer on 12–15 November 2018. The conference was an occasion to endorse the journal's long-held reputation and brought together 450 authors from 70 countries, who work in the wide-ranging fields of Earth sciences. The dynamic four-day conference in a stimulating environment in Hammamet, Tunisia provided attendees with opportunities to share their latest unpublished findings and learn about the latest geosciences studies. The event also allowed attendees to meet and talk to the journal's editors and reviewers. Three field trips were organized alongside the conference, and many participants enjoyed the wonders of the geology of Tunisia.

In a continuation of the successful 1st CAJG, the 2019's conference aimed to bring geoscientists from all over the world to present and discuss their most recent findings. The 2nd CAJG was an occasion to publish the newest findings in its proceedings by Springer and a special issue in the AJGS, with a clear mission to drive greater North-South (Europe-Africa) scientific cooperation and to open doors to new and enriching collaborations with geoscientists based in Asia and the Americas. The 2nd CAJG devoted a special session (workshop) to studies focusing on unraveling the undiscovered oil and gas resources in the Mediterranean and North Africa. Many international experts took part in the discussion.

The conference covered all cross-cutting themes of geosciences and focused principally on the following 15 tracks:

- Track 1. Atmospheric Sciences, Meteorology, Climatology, Oceanography
- Track 2. Biogeochemistry, Geobiology, Geoecology, Geoagronomy
- Track 3. Earthquake Seismology and Geodesy
- Track 4. Environmental Earth Sciences
- Track 5. Exploration & Theoretical Geophysics, Seismic & Well Logging Methods, Mathematical Geosciences
- Track 6. Geo-Informatics and Remote Sensing
- Track 7. Geochemistry, Mineralogy, Petrology, Volcanology
- Track 8. Geological Engineering, Geotechnical Engineering
- Track 9. Geomorphology, Geography, Soil Science, Glaciology, Geoarchaeology, Geoheritage
- Track 10. Hydrology, Hydrogeology, Hydrochemistry
- Track 11. Marine Geosciences, Historical Geology, Paleoceanography, Paleoclimatology
- Track 12. Numerical and Analytical Methods in Mining Sciences and Geomechanics
- Track 13. Petroleum and Energy Engineering, Petroleum Geochemistry
- Track 14. Sedimentology, Stratigraphy, Paleontology, Geochronology
- Track 15. Structural Geology, Tectonics and Geodynamics, Petroleum Geology

The dynamic four-day conference provided more than 400 attendees with opportunities to share their latest unpublished findings and learn the newest geosciences studies. The event also allowed attendees to meet and discuss with the journal's editors and reviewers.

More than 710 short contributing papers to the conference were submitted by authors from more than 74 countries. After a pre-conference peer review process by more than 500 reviewers, 462 papers were accepted. These papers are published as chapters in the conference proceedings which consist of four edited volumes, each edited by the following group of Arabian Journal of Geosciences (AJGS) editors and other guest editors:

Proceedings Volume 1: New Prospects in Environmental Geosciences and Hydrogeosciences

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Contents

Determination of Sedimentary Thickness of Parts of Middle Benue Trough, Northeast Nigeria, Using High-Resolution Aeromagnetic Data

Kazeem Adeyinka Salako, Abbass Adebayo Adetona, Abdulwaheed Adewuyi Rafiu, Usman Defyan Alhassan, Aisha Alkali, and Abdulateef Aliyu

Abstract

The sedimentary thickness covering parts of middle Benue Trough, Northeast Nigeria, was determined with the purpose of assessing its hydrocarbon potentials. Longitude 9° E covers the area—10° E, and Latitude 8° N—9.50° N, and with total area coverage of 18,150 km^2. Polynomial fitting method of order one was used to obtain its regional–residual separation. The residual data obtained were analysed using the analytic signal, source parameter imaging (SPI) and spectral depth analytical techniques. Results from the analytic signal technique showed that the area is made up of high and low magnetic anomaly amplitude. The high amplitude anomaly dominates the northern region while the southern region is dominated with low amplitude anomalies. Similarly, results from the SPI revealed a sedimentary thickness ranging between 101.8 and 2550.0 m while that of the spectral analytical method showed that the sedimentary thickness of the study area ranges between 1.20 and 3.20 km. The highest sedimentary thickness from both methods agreed in terms of space. This sedimentary covered could be found around the central and southern parts of the study area, which also agreed with the areas with low amplitude anomalies of the analytical signal results. The estimated depths from the spectral analytical method were contoured to portray the basement isobaths for the study area. The sedimentary thickness of about 3 km ***might*** be sufficient for hydrocarbon maturation in the area.

Keywords

Aeromagnetic data • Polynomial fitting • Source parameter imaging • Spectral analytical • Sedimentary thickness and hydrocarbon maturation

1 Introduction

Exploration of the subsurface Earth has been of particular concern to geoscientists who seeks to investigate the subsurface structures using various means, basically to acquire the knowledge of the subsurface lithology, for exploration activities such as minerals and hydrocarbon (oil/gas) deposits for economic growth of a nation (Azizi et al. 2015; Farhi et al. 2016; Adewumi and Salako 2018).

Efforts are geared towards the exploration of the Cretaceous segment of Nigeria looking for possible hydrocarbon presence and bearing in mind its mineral resources potentialities. The present study seeks to estimate the sedimentary thickness over parts of the middle Benue trough section of the Cretaceous sediments of Nigeria for possible hydrocarbon potentials. If it is probable, it will add to the country's hydrocarbon reserve, however, with the confirmation of other methods.

The magnetic method is **one** of the best geophysical techniques (in terms of coverage and or as a reconnaissance tool) used in delineating or estimating sedimentary thickness and other subsurface structures (Azizi et al. 2015; Farhi et al. 2016; Adewumi and Salako 2018; Salako and Udensi 2015).

1.1 Location and Brief Geology

The study area (Fig. 1) lies in the north-eastern part of Nigeria and lying between Latitudes 8°.00′ N and 9°.50′ N and longitudes 9°.00′ E and 10°.00′ E. It is housed by middle Benue Trough (Fig. 1). (Abdullahi et al. 2014) pointed out that the

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Benue Trough generally has been geographically and structurally subdivided into three parts, namely: the "lower Benue Trough", the "middle Benue Trough" and the "Upper Benue Trough". The study conducted by Benkhelil (1989) distinguishes six sedimentary Formations in the middle Benue trough only, which are Asu River Group, Keana Formation, Awe Formation, Ezeaku Formation, Awgu Formation and Lafia Formation. The work of Benkhelil (1989), Offodile (1976), Cratchley and Jones (1965), Burke et al. (1970), Offodile (1984), Osazuwa et al. (1981), Ofoegbu (1985) has more on the geology of the Benue Trough.

2 Materials and Methods

(i) Six aeromagnetic maps with sheets numbers 190, 191, 211, 212, 231 and 232 covering the study area were acquired from the Nigerian Geological Survey Agency (NGSA) Abuja as part of the across the nation aeromagnetic survey carried out in 2009 by Fugro Airborne survey. The survey was conducted along NW–SE flight lines, and tie line along NE-SW direction with 500 m flight line spacing, terrain clearance of 80 m and line spacing of 2 km were used. The magnetic data recording interval during the survey was 0.1 s. All grid data were saved and delivered in Oasis Montaj Geosoft raster file format. Each 1:100,000 topographical sheet covers an area of about 3025 km^2 (i.e. 55 km × 55 km) totalling a superficial area of 18,150 km^2.

(ii) The residual anomaly map was later subjected to three automated processing techniques to determine the depth to magnetic basement. The three automated processing techniques are (i) analytic signal, (ii) source parameter imaging and (iii) spectral analysis.

(iii) Analytical Signal the equation used is (Nabighian 1972):

$$|A(x,y)| = \sqrt{\left(\frac{\partial M}{\partial x}\right)^2 + \left(\frac{\partial M}{\partial y}\right)^2 + \left(\frac{\partial M}{\partial z}\right)^2} \quad (1)$$

where

$A(x, y)$ amplitude of the analytic signal at (x, y) and
M observed magnetic field at (x, y).

(iv) The SPI method (Thurston and Smith 1997) estimates the depth parameter using the local wave number of the analytical signal (Thurston and Smith 1997). The two wave numbers as related by Hilbert transformation (⇔) are given as:

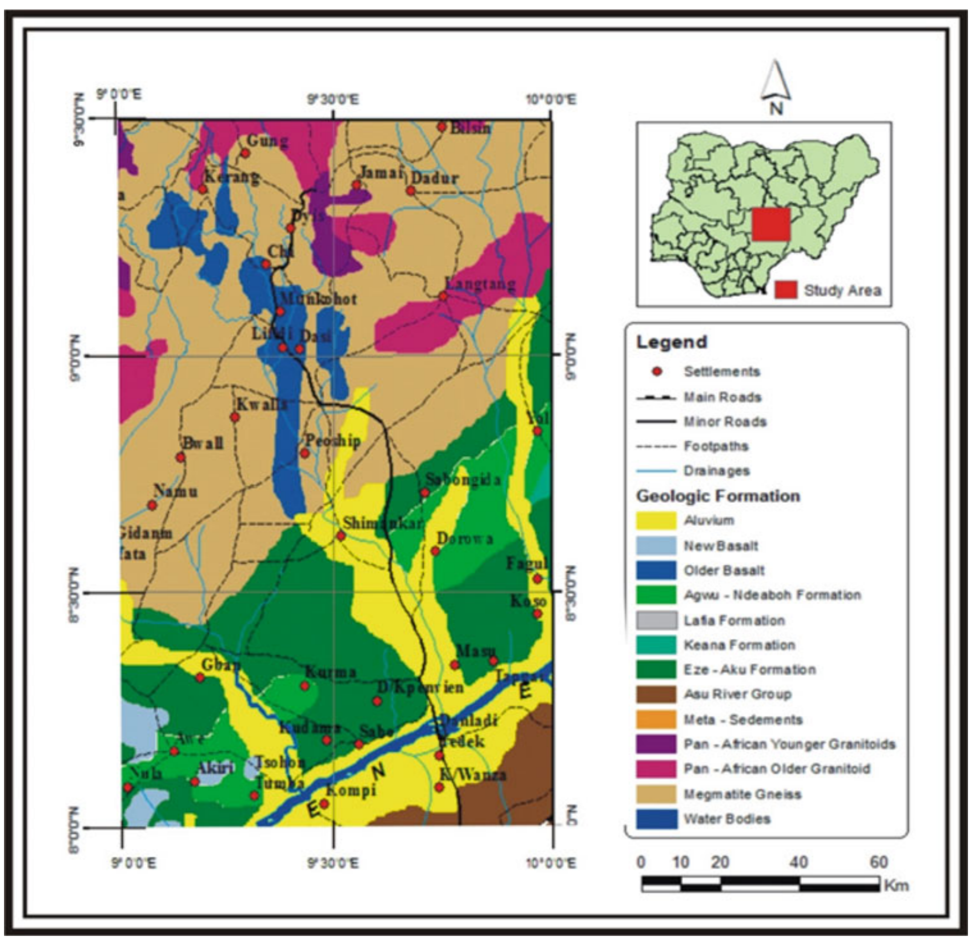


Fig. 1 Geological map of part of middle Benue Trough (Geological Survey of Nigeria 1984)

$$k_1 = \frac{\partial}{\partial x}\tan^{-1}\left[\frac{\partial M}{\partial z}\Big/\frac{\partial M}{\partial x}\right] \quad \text{and}$$
$$k_2 = \frac{\partial}{\partial x}\tan^{-1}\left[\frac{\partial^2 M}{\partial^2 z}\Big/\frac{\partial^2 M}{\partial z \partial x}\right] \tag{2}$$

for analytical signal defined for the first (A_1) and second (A_2) order, respectively.
The k_1 and k_2 are used to determine the most appropriate model and depth estimate of any assumption about a model.

(v) Spector and Grant (1970) demonstrated that the depth could be made using the equation

$$E(r) = e^{-2h}; \tag{3}$$

where

$E(r)$ is the spectral energy,
r the frequency and
h the depth.

The energy or amplitude spectrum is plotted on the logarithmic scale against frequency. The plot shows the straight line segments which decrease in slope with increasing frequency. The slopes of the segments yield estimates of depths to magnetic sources.

3 Results and Discussion

3.1 Results (Analytical Signal)

Figure 2 shows the analytical signal of the study area. The high amplitude magnetic anomalies were very much pronounced in the northern part and at the edges of the study area. The low amplitude magnetic anomalies were located at the central part and trend towards the south-eastern parts. The high amplitude magnetic anomaly is probably due to basement intrusion close to the surface.

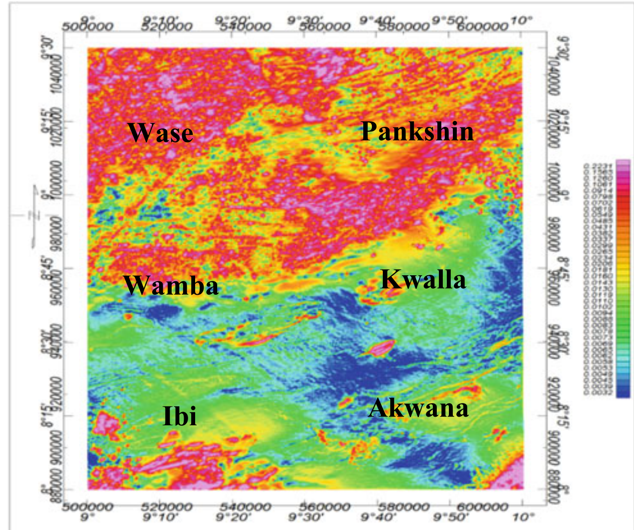


Fig. 2 Analytical signal map of the study area (unit: A/m)

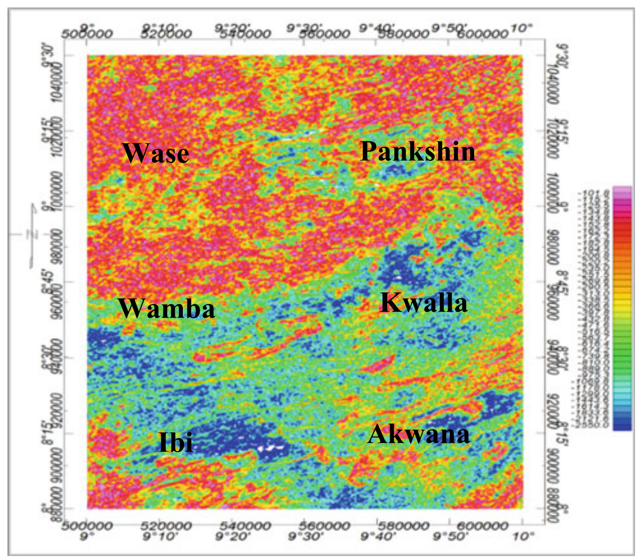


Fig. 3 Source parameter imaging map of the study area (unit: m)

3.2 Results (Source Parameter Imaging)

The source parameter imaging (Fig. 3) of the study area shows that most of the features were aligned in the same manner and trends like the results obtained from the analytic signal map (Fig. 2). The area of highest sedimentary thickness in SPI (Fig. 3) conforms to the area of lower amplitude magnetic anomalies in the analytical signal map (Fig. 2).

From Fig. 3, the depth (below mean sea level) to sedimentary/basement interface varies between 101.8 and 2550.0 m. The highest sedimentary thickness dominates the southern portion of the area while the least basement depth dominates a significant part of the southern portion. However, relatively lower depths are seen scattered around the southern part.

3.3 Results (Spectral Depth Analysis)

The residual map of the study area was divided into fourteen (Blocks A–N) overlapping magnetic sections in which none of the blocks has less than 55 by 55 km data coverage window (Table 1). The sedimentary thickness of 1.20 km to a maximum of 3.20 km were obtained from the spectral analysis

Table 1 Results from spectral plots

Blocks	Longitude (°)	Latitude (°)	Sedimentary thickness Z_t (km)
A	9.25	9.25	2.04
B	9.75	9.25	2.50
C	9.25	8.75	2.14
D	9.75	8.75	1.98
E	9.25	8.25	1.20
F	9.75	8.25	1.40
G	9.5	9.25	2.00
H	9.5	8.75	3.20
I	9.5	8.25	1.70
J	9.5	9.0	1.50
K	9.5	8.0	1.84
L	9.25	8.25	2.08
M	9.75	8.25	1.86
N	9.5	8.25	1.65

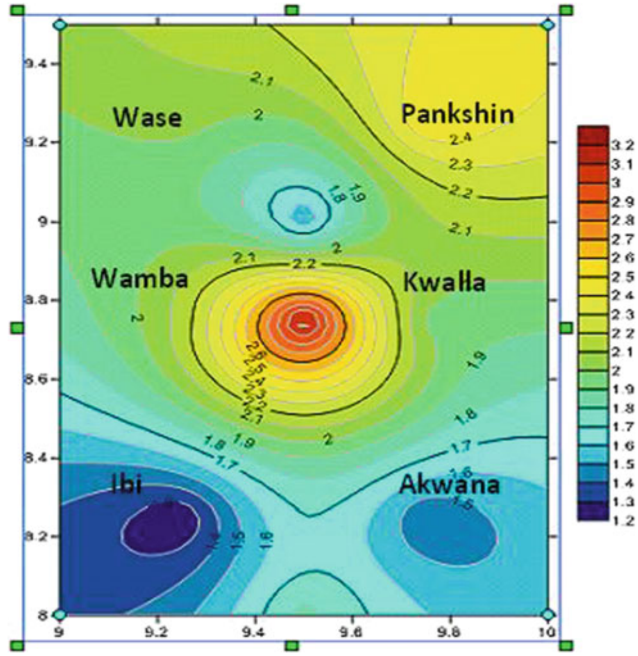
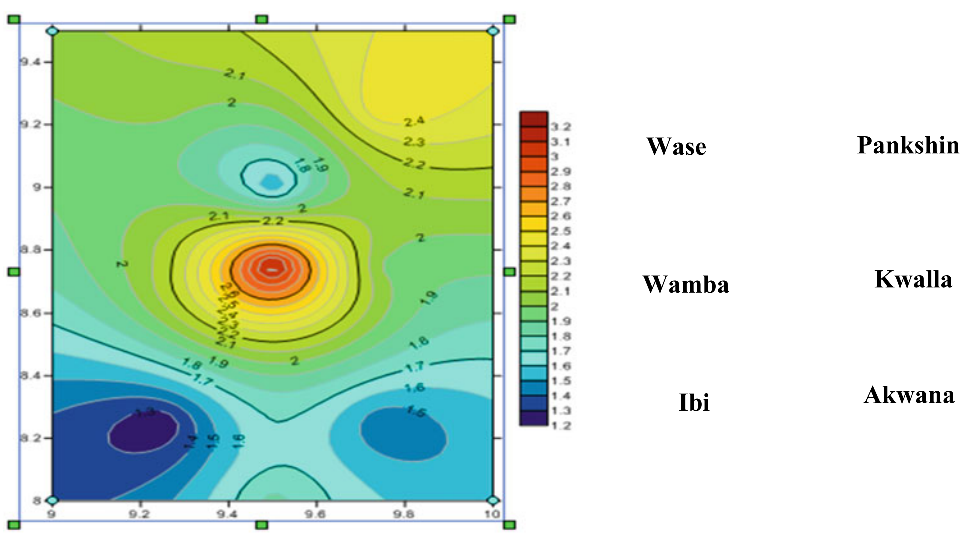


Fig. 5 Residual map of the study area

agrees mostly with the result obtained earlier with SPI, most notably concerning the location (Figs. 4, 5, 6 and 7).

Results from the two depths estimate approach agreed largely with other published works in the studied area. Nwogbo (1997) got 2–2.62 km for deeper source from spectral analysis of upper Benue trough; (Aliyu et al. 2018) obtained two-layer depths with the deeper magnetic sources varying between 1.2 and 4.8 km and the shallower magnetic sources varying between 0.5 and 1 km. (Salako and Udensi 2015) got an average depth of 1079.5 m for shallower source while the deeper magnetic source bodies have an average depth of 4.5 km. Similarly, (Nwogwugwu et al. 2017) using spectral analysis obtained values ranging between 1.22 and 3.45 km for depth to magnetic basement and (Mohammed et al. 2019) and (Salako 2014) got the sedimentary thickness of over 4.0 km while working over upper Benue trough and Bornu Basin, Nigeria, (Ofoha et al.

Fig. 4 Contour map of the sedimentary thickness (unit: km)



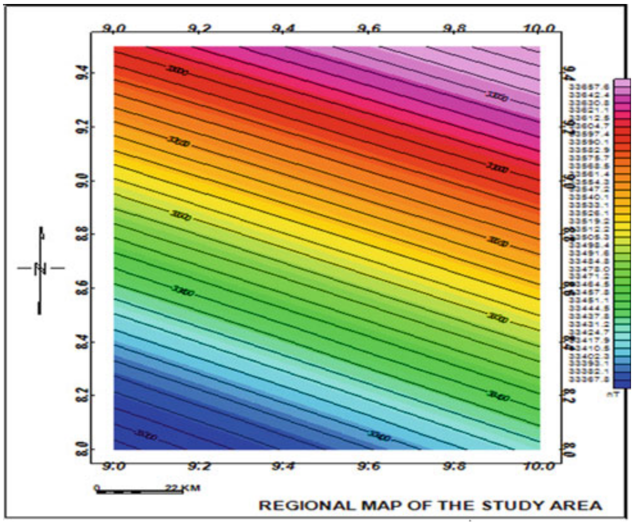


Fig. 6 Regional map of the study area

2016) got sedimentary thickness of less than 3 km while working Sokoto Basin, Nigeria, where the highest sedimentary thickness was obtained from SPI, and spectral methods agreed with the areas with low amplitude anomaly of the analytical signal.

4 Conclusions

The results of this study suggest that the sedimentary thickness of the study area varies between 1.20 and 3.20 km. The highest sedimentary thickness of about 3 km can be obtained from the central part to the south-eastern part of the study area. These areas correspond to areas delineated as low amplitude anomaly of the analytical signal. However, according to Wright et al. (1985), the minimum thickness for the concealment of hydrocarbon is about 2.3 km; hence, the sedimentary thickness of over 3 km might be sufficient for hydrocarbon (at least for gas) maturation in the area.

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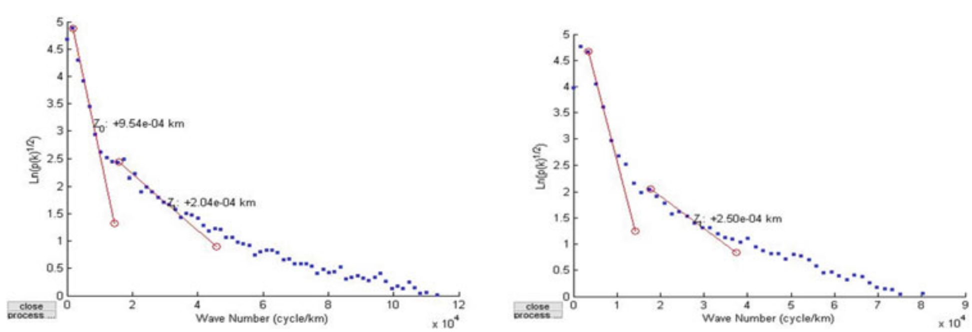

Fig. 7 Typical plots of the logarithm of spectral energies against frequencies obtained for blocks A and B

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