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SEDIMENT THICKNESS DISTRIBUTION AND 2D DEPTH MODEL OF THE IKOM BASIN, SOUTHEASTERN NIGERIA, USING HIGH RESOLUTION AEROMAGNETIC DATA

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ABSTRACT

This study, necessitated by the availability of high resolution data, presents sediment thickness distribution of Ikom Basin in southeastern Nigeria and a depth model of a profile across the basin, by analysing aeromagnetic data obtained from the Nigerian Geological Survey Agency (NGSA). The magnetic survey method is a cost effective non-invasive tool for investigating the bottom boundary of sedimentary basins. The method of study involved processing total magnetic intensity (TMI) data with source parameter imaging and standard Euler deconvolution for depth estimation. Power spectrum analysis was also carried out to obtain a cut off, used in designing the low pass filter which generated regional magnetic field. From the regional field, a profile was digitized and modelled. The results for sediment thickness estimation show that depth to basement surface is less than 100 m to over 5000 m with the central portion of the Ikom Basin being deepest. The western and eastern extremes of the basin are intruded having depth values ranging 0 – 150 m. Also, the 2 D inverse model of a SW - NE profile through the central part of the basin has sediment thickness of 1 – 4 km, a width of 30 km overlying intruded metamorphic basement. This knowledge about sediment thickness distribution can be applied in various aspects of geological studies including petroleum, geothermal, and mineral exploration. For petroleum investigation, the depocenter of the basin is the central part where thickness is over 5000 m.

KEYWORDS: Ikom Basin, sediment thickness, depth, aeromagnetic data.

INTRODUCTION

Background

Ikom Basin is the eastward trending arm of the southern Benue Trough covering an area of about 40 Km^2 bounded to the north and south by Obudu Plateau and Oban Massif respectively (Figure 1). It extends beyond the Nigerian international border into southwestern Cameroon, generally referred to as Mamfe Basin.

The Ikom Basin crustal thickness, mechanism of rift formation and sediment thickness distribution, interpreted based on gravity and magnetic signatures have been reported by some authors including Okereke, 1988; Fairhead et al., 1991; Obi et al., 2013, Nzeuga et al., 2017. This study is aimed at analyzing and interpreting anomalies in the geomagnetic field with focus on depth to basement.

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Earlier studies were carried out with sparse data sets, whereas the current analyses were carried out on aeromagnetic data collected at 100 m station interval with flight line spacing of 500 m (NGSA, 2009) as against the old data which were on 2 km flight line spacing. This report serves to complement existing knowledge of the study area.

Geologic setting

Ikom Basin shares the same evolutionary history as the Benue Trough which formed during the early Cretaceous rifting that opened up the South Atlantic Ocean and extended into Africa. However, in the Santonian, rifting was terminated by a compressional event which prevented the successful development of the Benue Trough into an ocean. The Santonian event is evident by folded sediments in the Benue Trough (Murat, 1972; Fairhead, 1988). Fracture study by Oden et al., (2016) is in agreement with the above deformation episodes. Okereke (1988) agreed with the passive model as mechanism of continental rifting. The sedimentary fill of the basin (Figure 2) is Mamfe Formation (Wilson, 1928, Whiteman, 1982, Nwajide, 2013; Otele et al., 2018; Otele et al., 2021). Its thickness is generally less than 1000 m to over 4000 m (Petters et al., 1987; Obi, et al., 2013). The formation represents a complex set of lithofacies association, beginning with pebbly sandstone which rests unconformably on Precambrian basement, fining upward arkosic sandstones with intercalations of sandy limestones and shales (Essien et al., 2018; Otele et al., 2021). Mudrocks occur topmost in the sequence. The beds are locally carbonaceous, calcareous with thin lignite beds (Umeji, 2013; Njoh et al., 2015; Njoh et al., 2021).

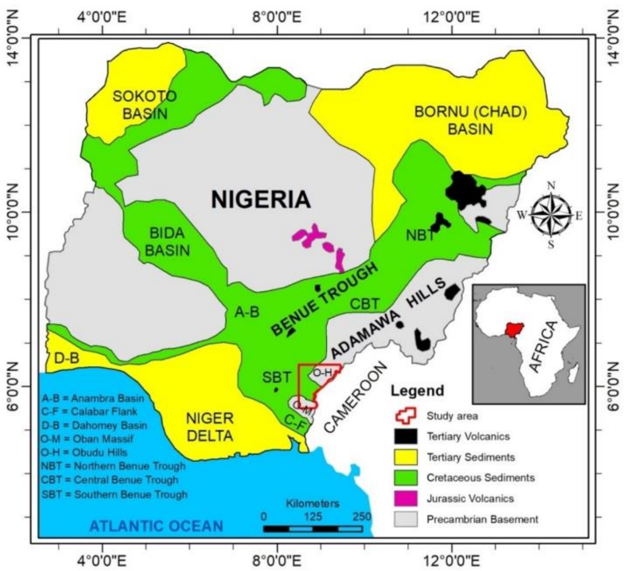

Figure 1: Simplified geological map of Nigeria showing the study area (NGSA, 2010).

The lithofacies assemblage of the basin represents various depositional environments; the Nigerian side is generally fluviatile with saline springs indicative of transitional or marine paleoenvironment (Asi et al., 2022). Njoh et al., (2021) encountered shallow marine microfauna in younger (Cenomanian) strata. The Precambrian metamorphic basement is made predominantly of granite gneiss intruded by younger basalts, granites and diorites (Figure 2)

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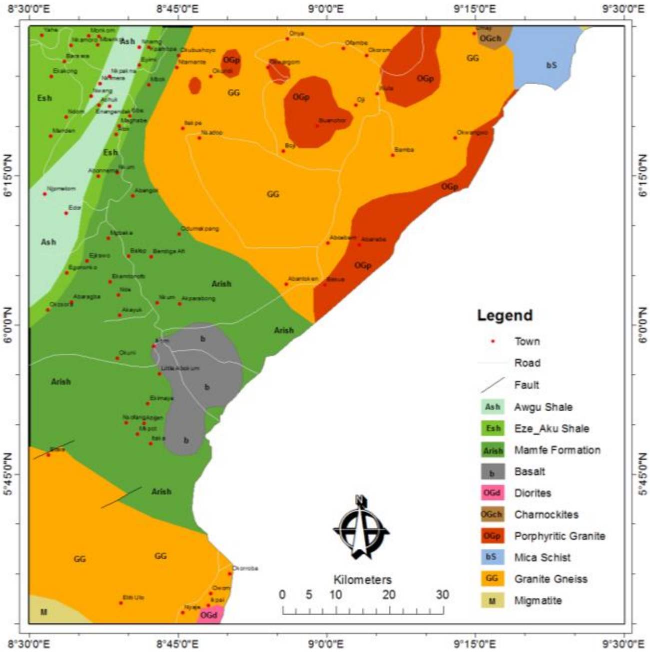

Figure 2: Geological map of the study area (NGSA, 2010).

MATERIALS AND METHODS

Materials

Total magnetic intensity (TMI) data, sheets 304 Bansara, 305 Mukuru and 315 Ikom were obtained from the Nigerian Geological Survey Agency (NGSA). The data acquisition was carried out by Fugro Airborne Surveys using three optically pumped magnetometers mounted on seven aircrafts flown at 80 m constant height above ground. Flown along 135° (NW-SE) 500 m spaced flight lines and tie lines of 45° (NE-SW) spaced 5000 m. Data were recorded at intervals of 100 m, using Universal Transverse Mercator system, zone 32 northern hemisphere, World Geodetic System 84 (WGS 84). Necessary reductions (diurnal reduction, instrument variation, aircraft heading etc, Ekwok et al., 2019) were carried out on the data by the contractor. Other materials were geological and elevation maps of the study area, computer software including Geosft's Oasis Montaj (version 8.4), ArcMap (version 10.4), and MS-Excel (2010).

Methods

The work flow in this research involved TMI map inspection, sedimentary rock thickness estimation, regional separation, profile extraction and modeling. Depth estimation was done using the source parameter imaging (SPI) and Euler deconvolution techniques. The SPI method estimates depth from the local wavenumber of analytical signal. At peaks in the local wavenumber grid, the source depth is equal to n/k where n depends on the source geometry (Smith et al., 1998; Fairhead 2007). This process was possible with Oasis Montaj by first calculating the horizontal and vertical gradients of the grid which were used during SPI calculation. Similarly standard Euler deconvolution was applied to TMI with structural index 1. After processing, models can be used as last part of interpretation to show subsurface architecture. A model is simply a structure with parameters such as size, shape, depth, and susceptibility that could account for the measured data (Mussett & Khan 2000).

The profile to be modeled was digitized from the regional magnetic field, obtained by lowpass filtering of inverted TMI grid (inversion was done so that the correct amplitude of the magnetic field will be used for modelling) using a wavelength of 20,000 m, obtained from power spectrum graph (Figure 3). The profile originated from the Oban Massif in the southwest through the Ikom Basin and terminates northeast in the Obudu Plateau. Using Geosoft database and GRIDPROF programmes, the data along the digitized profile were saved to database from where appropriate channels (columns) were exported to GM-SYS extension for modeling. The model was created by iteration, until a reasonable match of calculated and observed values was reached with less root mean square error.

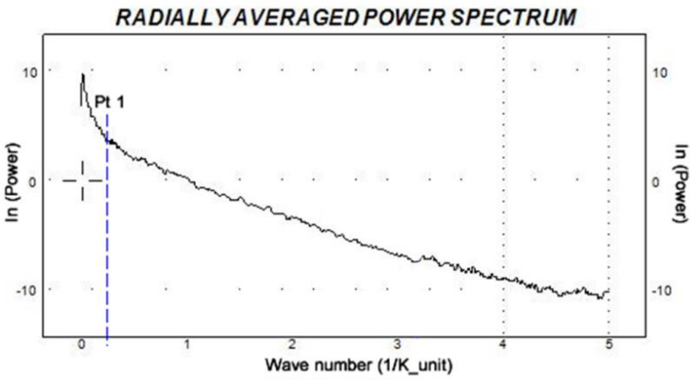

Figure 3: Interpreted spectral graph of the full TMI grid. Pt. 1 demarcates the long wavelength (ie low wavenumber) from short wavelength (high wavenumber) sources. The calculated cut-off wavelength is 20,000m.

Results and discussion

Depth estimation

Source parameter imaging and Euler deconvolution were applied to TMI for depth estimation (Figure 4 & 5 respectively). Both figures correlate well, from the legends depth ranges less than 100 m to over 5000 m. Focusing on the basin area alone, the western and eastern extremes are shallow, only the central portion has considerable depth

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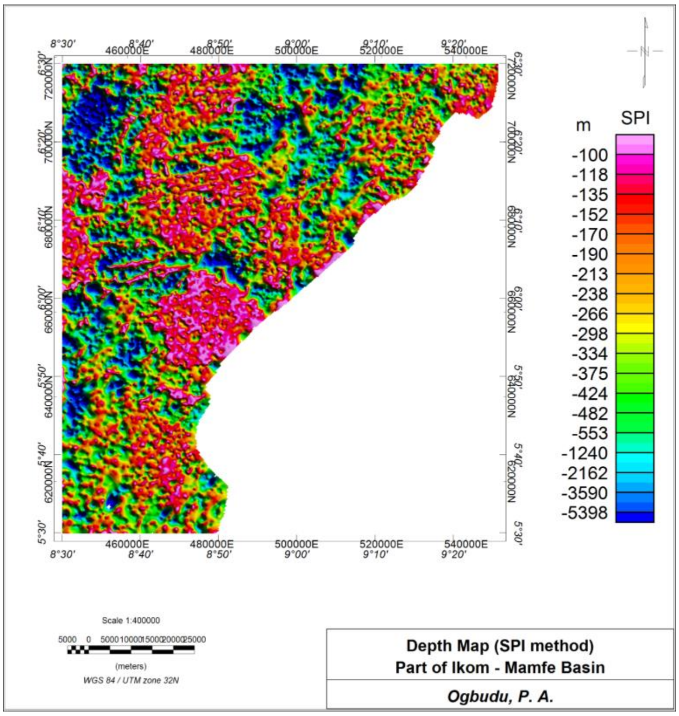

Figure 4: Depth map of the study area obtained from source parameter imaging method. Negative sign in values indicate subsurface. Map is colour shaded at 45°. Scale, 1:400,000.

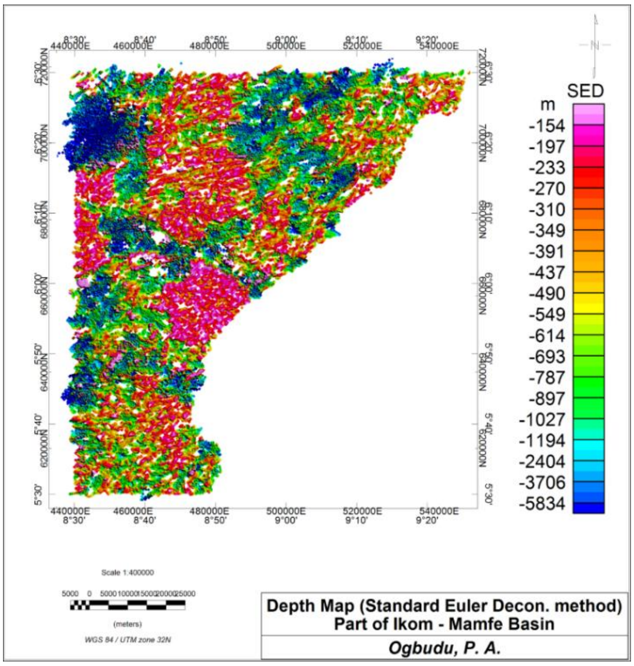

Figure 5: Depth map of the study area obtained by standard Euler deconvolution method, structural index = 1. Map colour shaded at 45°. Scale, 1:400,000.

Profile modelling

The digitized profile (Figure 6), taken from the southwest end in Oban Massif cutting through the basin and terminating northeast in the Obudu Plateau is a low amplitude anomaly sandwiched between high magnetic anomalies corresponding to basin and exposed basement respectively. The profile model (Figure7) represents an upper non-magnetic Mamfe Formation, underlain by a magnetic intruded basement. The width of the basin on this profile is approximately 30 km, depth extends over 4 km but is shallow in the central portion of the profile due to a basement horst. As Table 1 indicates, the model is made of different blocks. The metamorphic basement has been intruded. Magnetic susceptibilities of rocks are from 0.00001 – 0.04 SI. The following sources of information guided the model; SPI depth grid, regional field grid (from where basin width and intrusive positions were deduced), geological map and literature (from where nature of rocks and susceptibilities were gotten)

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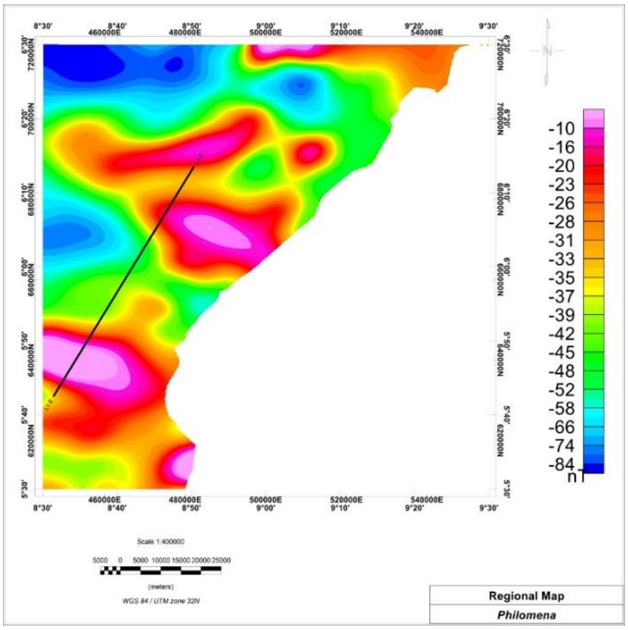

Figure 6: Regional field map showing the profile extracted for 2D modeling. Map scale, 1:400,000

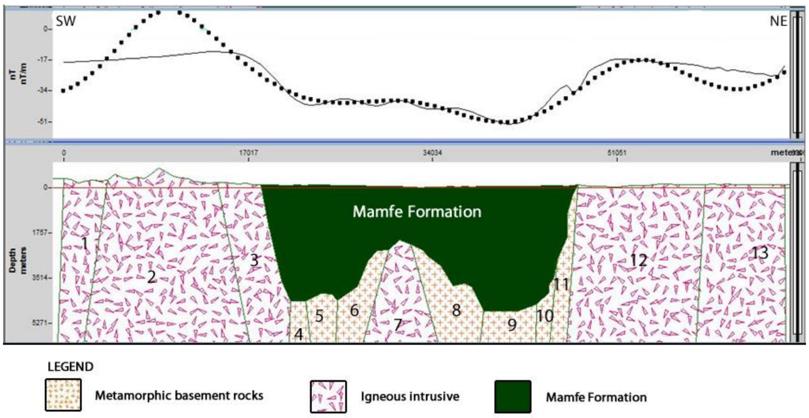

Figure 7: A 2D inverse model of the profile shown in Fig.6 above. Dotted line is the observed regional field, while the continuous line is the calculated field.

SUMMARY AND CONCLUSION

SUMMARY

This study analyzed the anomalous geomagnetic field of Ikom Basin to determine basin configuration. High resolution aeromagnetic data for latitudes 5°30´ - 6°30´ and longitudes 8°30´ - 9°30´ were obtained from the Nigerian Geological Survey Agency. The data consist of 1106 flight lines recorded at 100 m interval. The study area includes parts of Obudu Plateau, Oban Massif and Ikom Basin, but focus was on the basin, while the basement served as controls. The TMI map on inspection showed TMI values from -25 - ~95 nT (base value 33,000 nT). Source parameter imaging and Euler deconvolution methods were used to estimate depths which yielded values of < 100 - ~6000 m.

Table 1: General model characteristics of a profile across the Ikom Basin

Model	RMS Error	Min. Sediment Thickness (km)	Max Sediment Thickness (km)	Basin Width (km)	Body	Susceptibility (SI)	Deduction
Regional field	8.45	1.96	4.80	30	Mamfe Formation	0.0000	Sediment
					1	0.00001	Intrusive
					2	0.00001	Intrusive
					3	0.00001	Intrusive
					4	0.05153	Basement
					5	0.01384	Basement
					6	0.01635	Basement
					7	0.00567	Intrusive
					8	0.01509	Basement
					9	0.04085	Basement
					10	0.02577	Basement
					11	0.00315	Basement
					12	0.00127	Intrusive
					13	0.00127	Intrusive

A regional geomagnetic field was removed from an inverted TMI grid, after which a profile (SW - NE) across the basin was digitized from the regional field map and modeled. Residualization was achieved by using a lowpass filter with cut-off of 20,000 m designed from power spectrum graph. The model represents a 30 km wide basin overlying intruded metamorphic basement at depth ranging 1 – 4 km. Susceptibility values range 0 – 0.04 SI.

CONCLUSION

Basin thickness distribution is crucial information which finds application in various fields of geological studies. This study has shown the distribution of sediment thickness within the Ikom Basin. The flanks of the basin, the western and eastern ends are shallow due to the presence of intrusives, depth in these extremes range between 0 – 150 m.

The central portion of the Ikom Basin has considerable sediment thickness over 5000 m. In hydrocarbon exploration such information is useful for strategic planning of seismic surveys and drilling, also this type of setting where the depocenter is flanked to the east and west by intrusions which are structural highs could be favourable for hydrocarbon accumulation. The association of intrusions and depocenter of over 5000 m are good factors for geothermal exploration although this is subject to further investigation.

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REFERENCES

Asi, M. O., Adamu, C. I., **Okon, E. E.,** Neji, P. A., Nganje, T. N., Oli, O. O., and Eneogwe, C., 2022. Hydrocarbon potentials of sediments of the Ikom-Mamfe embayment, Southeastern Nigeria and Western Cameroon. Journal of African Earth Sciences, 185, 104411. https://doi.org/10.1016/j.jafrearsci.2021.104411

Ekwok, S. E., Akpan, A. E., and Ebong, D. E., 2019. Enhancement and modeling of aeromagnetic data of some inland basins, southeastern Nigeria. Journal of African Earth Sciences, 155, 43 – 53.

Essien, N. U., Otele, A. and Okon, E. E., 2018. Lithofacies analysis and petroleum potentials of parts of Ikom-Mamfe Embayment, Southeastern Nigeria. International Journal Geology and Mining, 4(2), 190 – 201.

Fairhead, J. D., 1988. Mesozoic plate tectonic reconstructions of the central South Atlantic Ocean: The role of the West and Central African rift system. In: C. R. Scotese and W. W. Sager (Eds.), Mesozoic and Cenozoic Plate Reconstructions. Tectonophysics, 155, 181 – 191.

Fairhead, J. D., 2007. Gravity and magnetics in todays's oil and mineral industry. Unpublished Lecture Notes, Department of Earth Sciences, University of Leeds, UK.

Fairhead, J. D., Okereke, C. S. and Nnange, J. M., 1991. Crustal structure of the Mamfe Basin, West Africa, based on gravity data. Tectonophysics, 186, 351 – 358.

Murat, R. C., 1972. Stratigraphy and palaeogeogragphy of the Cretaceous and Lower Tertiary in southern Nigeria. In: T.F.J. Dessauvagie and A.J. Whiteman (Eds.), African Geology, pp.251 - 266. Ibadan: Ibadan University press.

Mussett, A. E. and Khan, M. A., 2000. Looking into the Earth – an introduction to geological geophysics. Cambridge: Cambridge University Press.

Nigerian Geological Survey Agency, 2010. Geological map of Nigeria.

Nigerian Geological Survey Agency, 2010. "Airborne geophysical data". Retrieved February 27, 2018, from http://ngsa-nig.org/basic-page/airborne-geophysical-data.

Njoh, O. A., Nforsi, M. B., and Datcheu, J. N., 2015. Aptian – Late Cenomanian fluvio-lacustrine lithofacies and palynomorphs from Mamfe Basin, Southwest Cameroon, West Africa. International Journal of Geosciences, 6, 795 – 811.

Njoh, O. A., Essien, E. U., Udofia, M. E. Agyingi, G. M., Taku, J. A., and Bessonge, M., 2021. New lithostratigraphic data and depositional pattern of the Mamfe sedimentary basin, Cameroon, West Africa. Journal of Geology and Geophysics, S2:004, 1 – 14.

Nwajide, C. S., 2013. Geology of Nigeria's sedimentary basins. Lagos: CSS Bookshops Ltd.

Nzeuga, A. R., Nouajou, R., Nyam, F. E. and Fairhead, J. D., 2017. The use of aeromagnetic data interpretation to characterize the features in the Mamfe Sedimentary Basin Cameroon and a part of the east of Nigeria. International Journal of Science and Research (IJSR), 6(11), 617 – 624.

Obi, D. A., Obi, E. O. and Okiwelu, A. A., 2013. Basinal configuration and intrasediment intrusives as revealed by aeromagnetic data of southeast sector of Mamfe Basin Nigeria. IOSR Journal of Applied Geology and Geophysics, 1(5), 1 – 8.

Oden, M. I., Umagu, C. I. and Udinmwen, E., 2016. The use of jointing to infer deformation episodes and relative ages of minor Cretaceous intrusives in the western part of Ikom-Mamfe Basin, southeastern Nigeria. Journal of African Earth Sciences, 121, 316 – 329.

Okereke, C. S., 1988. Contrasting modes of rifting: the Benue Trough and Cameroon Volcanic Line, West Africa. Tectonics, 7(4), 775 – 784.

Otele, A., Essien, N. U., and Okon E. E., 2018. Granulometry, pebble morphometry and petrographic studies as indicators of Paleodepositional environments of the Mamfe Formation in Ikom-Mamfe Embayment, South Eastern Nigeria. Journal of Geography, Environment and Earth Science International, 17(1), 1 – 14.

Otele, A., Okon, E. E., and Essien, N. U., 2021. The Mamfe Formation, south eastern Nigeria, its paleoenvironments and paleoclimatic settings: evidence from petrography and grain size distributions. In: H. Yu (Ed). Modern Advances in Geography, Environment and Earth Sciences, 4, 14-28.

Petters, S. W., Okereke, C. S. and Nwajide, C. S., 1987. Geology of the Mamfe Rift. In: G. Matheis, and H. Schandelmeier (Eds.), Current Research in African Earth Sciences (pp.299 – 302).

Smith, R. S., Thurston, J. B., Dai, T.F., and Macleod, I. N., 1998. iSPI – the improved source parameter imaging method. Geophysical prospecting, 46, 141-151.

Umeji, P. O., 2013. The south and central Benue Trough: stratigraphic revisions. In: E. C. Ashano and A. E. Ogezi (Eds.), Proceedings of University of Jos PTDF chair endowment fund seminar (pp. 145 - 181). Jos: University of Jos, PTDF EMC.

Whiteman, A. J., 1982. Nigeria: its petroleum geology, resources and potentials (vol. 2). London: Graham and Trotman Ltd.

Wilson, R. C., 1928. Notes on the geology of the Ikom Division, Cameroon Province. Geological Survey of Nigeria Occasional Paper, No. 6.