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BASINAL STRUCTURE OF YOLA ARM OF THE UPPER BENUE TROUGH NIGERIA; EVIDENCE FROM AEROMAGNETIC DATA

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ABSTRACT

Aeromagnetic data interpretation of the Yola arm of the Upper Benue Trough has previously been carried out. However, no detail modeling of the Crustal Structures has been undertaken. Two composite reduced Aeromagnetic maps on a scale of 1:250,000 were digitized and processed using computer techniques. Analytical Signal, Power Spectrum and Upward Continuation methods were used prior to modeling of the subsurface structures. Forward and inverse modelings were done to determine the subsurface basin configuration. The result shows two sub-basins; the Lau and Yola sub-basins. The variations in sediment thickness within the Lau sub-basin is in the range of 2.0 – 4.5 km and in the Yola sub-basin 2.0 – 3.0 km respectively. The basin configurations from the modeled profiles depict that of horst and graben features resulting to variation in sediment thickness evident in Lau (Barwa to Yanga) subsector and Yola (Muleng) axis. The upward continuation revealed lineament trends in the NE-SW Yola (Muleng) axis and NW-SE Lau (Barwa to Yanga) subsector.

KEYWORDS: Upper Benue Trough, Basin configuration upward continuation, Analytical signal, power spectrum.

INTRODUCTION

The Yola Basin is located within the Upper Benue Trough and is part of the failed arm of a Cretaceous Triple Junction (Burke *and Dewey* 1973, Olade, 1975). The basin is closely associated with the separation of Africa from South America and the opening of the South Atlantic Ocean (Okereke and Ofoegbu, 1989, Wright, 1981).

The study area lies within latitudes 9° 00' – 10°00'N and longitudes 11°00' – 13°00'E and covers an area of about 260 sq km (Fig. 1). Earlier aeromagnetic study of the Yola Basin by previous workers such as Okereke and Ofoegbu 1989, Nur 2000 has been carried out for the mapping of lineament trends and depths to magnetic source. No detailed attempt on the modeling of the basin structure has been done.

Therefore, the main intent of this study is to use aeromagnetic data to model the structure of Yola Basin and estimate the sediment thickness overlying the basin floor. To accomplish this objective therefore, both qualitative and quantitative analysis were performed using 12 software programs in producing analytical signal, power spectrum and upward continuation subsurface maps (Ferdi and Santis 1977, Philips, 1987, Jacobsen 1987). The depth estimates obtained from the above methods aided the forward modeling of the subsurface basin configuration.

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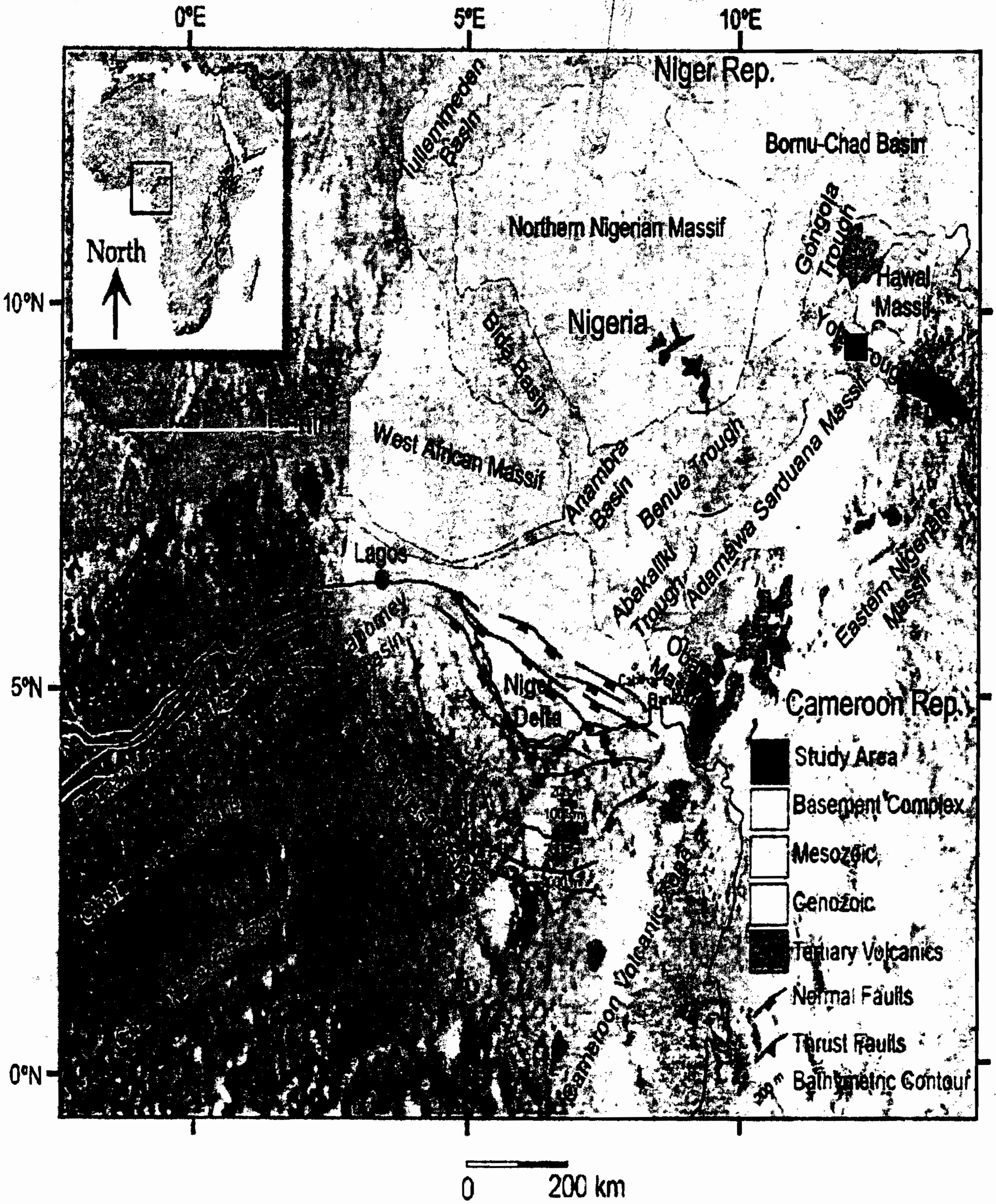

Fig. 1: Location map of the study area (modified from corridor, 2005)

GEOLOGY

The study area has mainly Upper Cretaceous Sediments that is overlying an ancient crystalline basement rocks (Fig. 2). The Cretaceous rocks cover about 90% of the study area and consist of the Bima formation which is Aptian-Albian in age. It is also the most widespread of all the formations, sitting directly on the magnetic basement rocks. Overlying the Bima Formation is the Yolde Formation, which consists of Caleareous beds interbeded with shalysandstones, found around Gatem and Gren areas. This bed is overlain by Dukul and Jessu Formation consisting of thick shales and sandstones.

The Numanha Formation is the topmost unit with massive deformation of shale deposits as a result of intense igneous activities (Granitoids) between Lau and Yola areas (Fig 2)

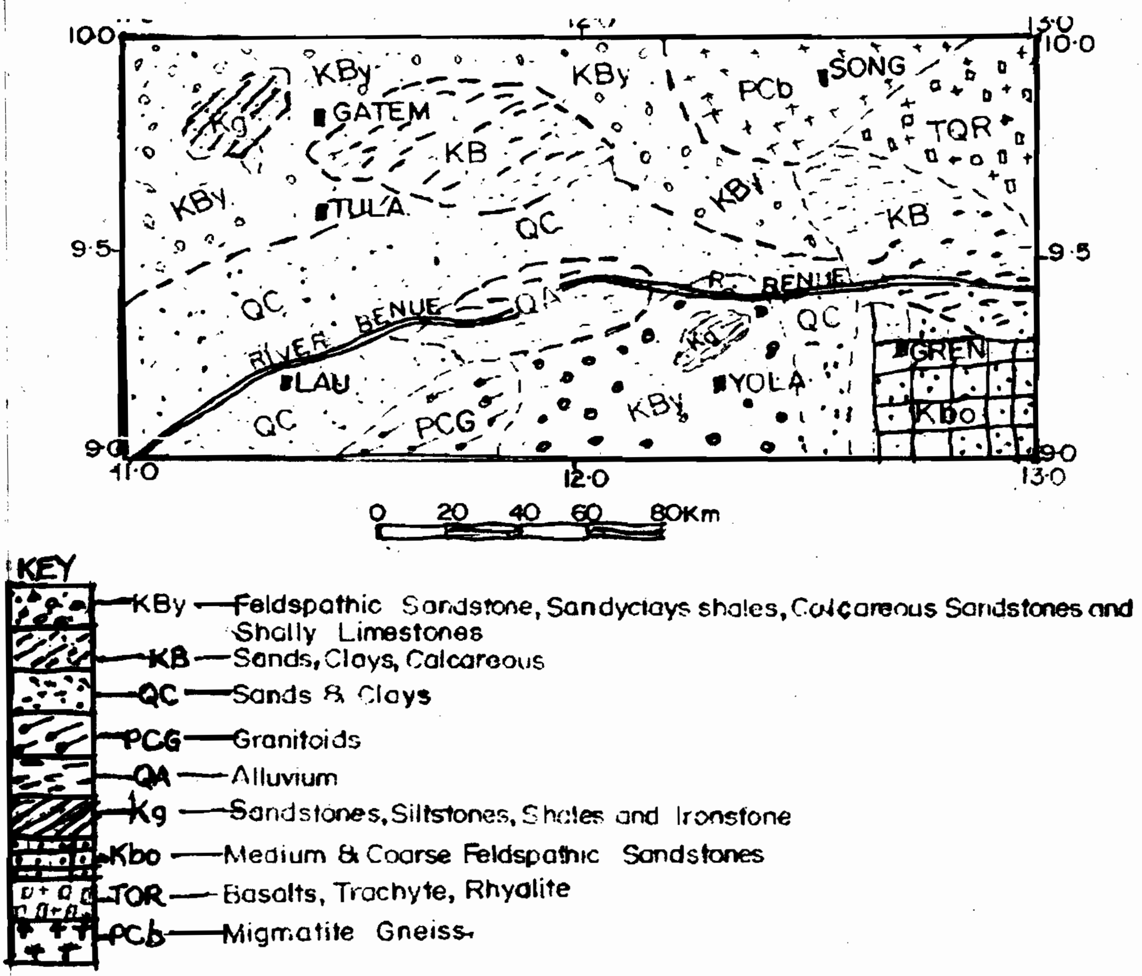

FIG. 2: Geologic Map of the study area. Modified from Geological Map of Nigeria, (1994).

DATA ANALYSIS

Two composite reduced one degree by one degree aeromagnetic total intensity field maps on a scale of 1:250,000 were acquired from the Geological Survey agency, Kaduna. The Survey was conducted along E-W profiles with a flight line spacing of 2.0 km and a tie line spacing of 20.0 km and a flight elevation of 0.5216km above sea level. The Geomagnetic gradient was removed using the International Geomagnetic Reference Field (I.G.R.F.) formula of first Janurary, 1974.

The first steps in the data analysis was to digitize the maps at 1.0 km interval to avoid the problem of frequency aliasing. This was followed by map merging directly without any continuation since both maps were flown at the same elevation above sea level. The following computer software programmes were used for this study P2GRD, MINC, Surfit, Addgrid, Jmerger, Contour, FFTFIL, Pdepth, Mfinite, Mf filter, Mf design and Saki. For a detail understanding of the applications of these programmes the interested reader should refer to United States Geological Services potential field version 2.2 software programmes.

The digitized data was gridded using the P2GRD and Minc programmes, the two grids were merged using Addgrid and Jmerger which does an arithmetic operation on point by point basis (Webring, 1985). The merged grided file is contoured to produce the total magnetic field intensity map of the study area (Fig. 3). Regional and Redidual anomaly separation was performed using the surfit software and the residual anomaly field used for further modeling of the subsurface structures (Fig 4). Upwards continuation was performed using the Fast Fourier Transformation software "FFTFIL" with a view to studying the subsurface deep fracture trends (Jacobsen 1987, Dobrin and Savit 1988, Naidu, 1970) (Fig. 5). Power Spectrum depth to the source determination from magnetic anomaly was performed using the software Mfinite; Mfdesign and Mffilter (Philips 1997, Hahn *et al.*, 1976, Nwogbo *et al.*, 1991), which by extension relates to the sediment thickness overlying the basin floor. The data was subjected to 0.25° by 0.25° grids at overlapping positions to generate over thirty five (35) depth points whose positions were digitized and contoured to show the sediment thickness variation within the study area (Fig. 6). The analytical signal technique was employed using the Pdepth software. This was done by taking four (4) profiles along prominent anomalous bodies seen on the residual map (Fig. 4), and the modeled profile digitized and contoured as analytical signal depth map (Fig 7). The result of the analytical signal computed depths was used to constrain the "Pdepth and Saki" forward and inverse modeling (Webring 1985, Nabighian 1972 and Shuey, 1972).

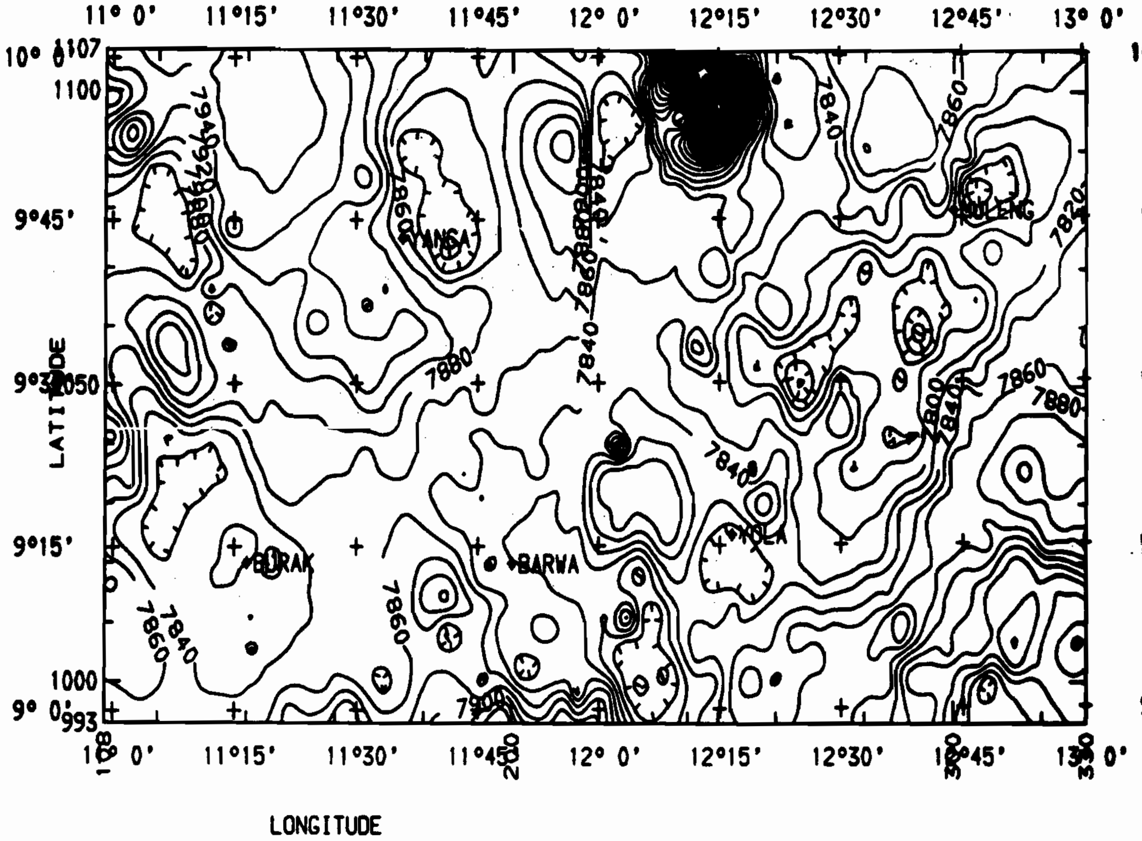

Fig. 3: Total Magnetic Field Intensity of Yola Basin (Contour Interval: 20nT).

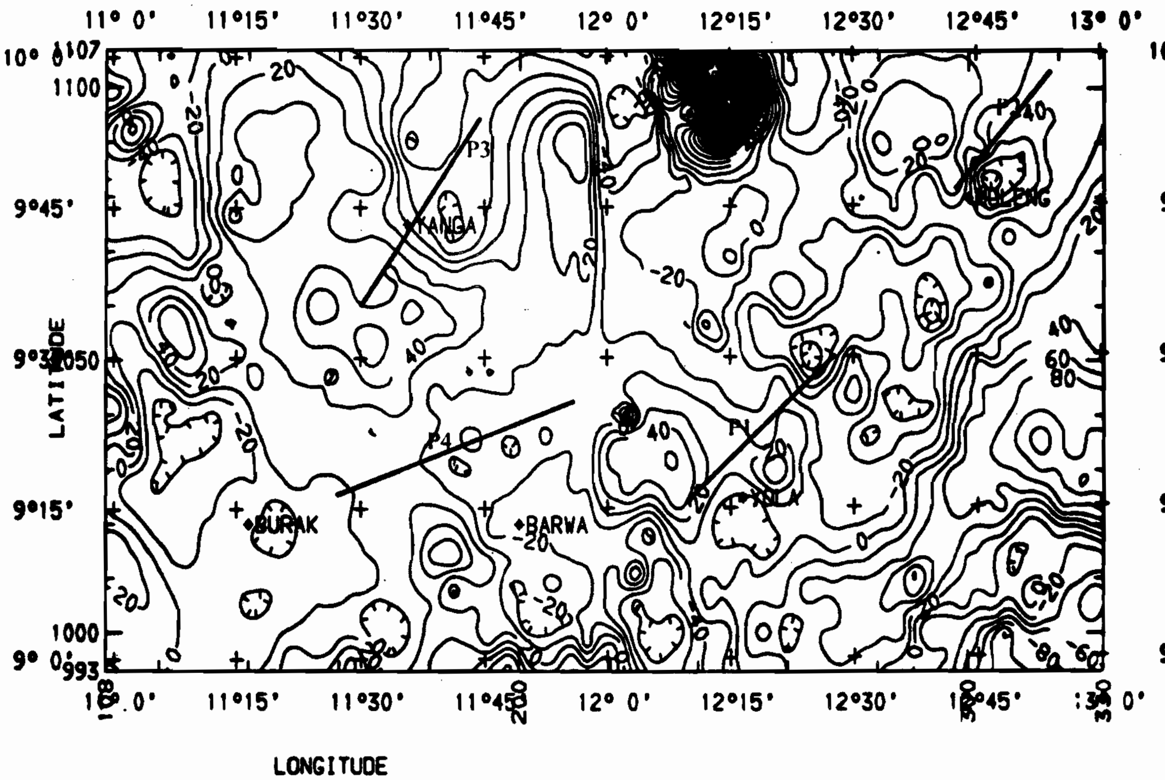

Fig. 4: Polynomial Residual Map of Yola Basin (Contour Interval: 20nT)

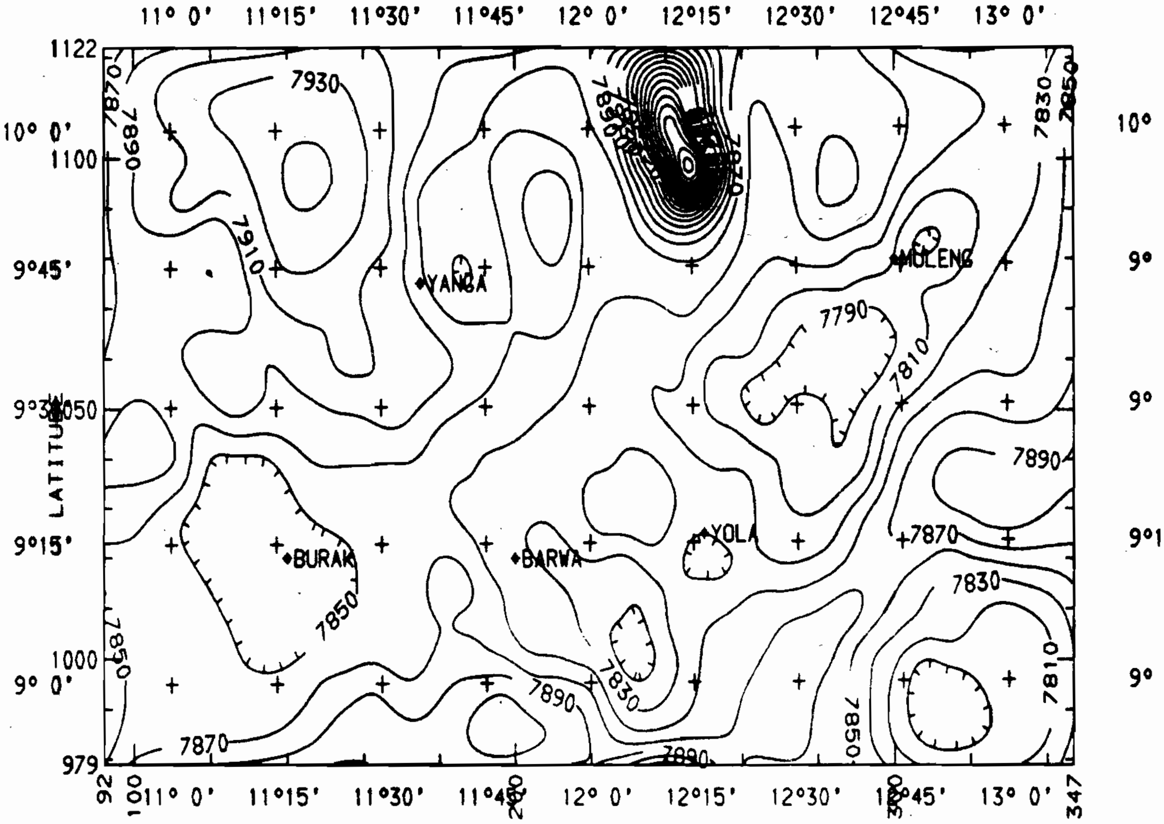

Fig. 5: Upward Continuation Map at 4 0km of Yola Basin Basin (Contour Interval: 20nT)

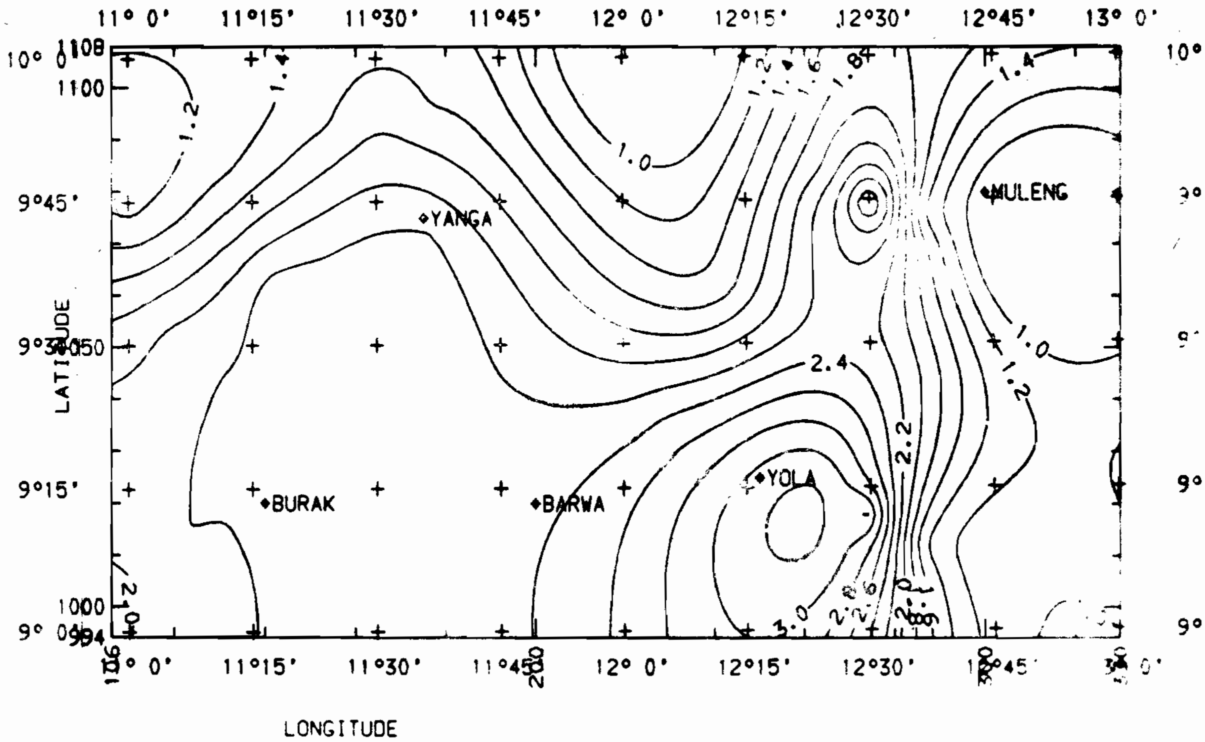

Fig. 6: Spectral Analysis Depth Map of Yola Basin Basin (Contour Inte

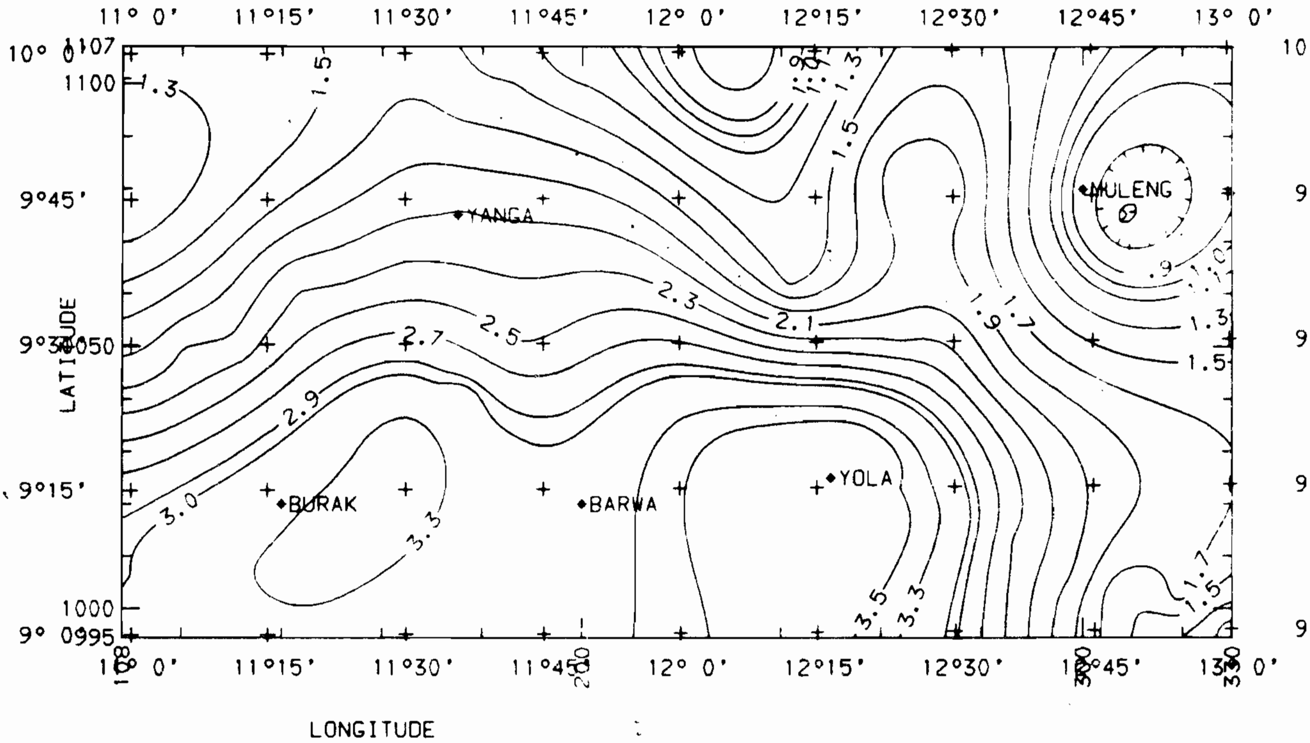

Fig. 7: Analytical Signal Depth Map of Yola Basin Basin (Contour Interval: 0.2km).

The modeled profiles (Fig. 8a-d) were generated using the software Pdepth, Saki and IGRFPT. The following modeling parameters as inclination = 4°, declination = 4°, and total field = 33541.60nT were generated using the IGRFPT software. While susceptibilities of intrusive = 0.012, sediments = 0.000005, and basement rocks = 0.001 - 0.0003 are basic S.I units (Dobrin and Savit 1988). The above parameters gave a good fit between the calculated and the observed fields with low root mean square error of <1.0%.

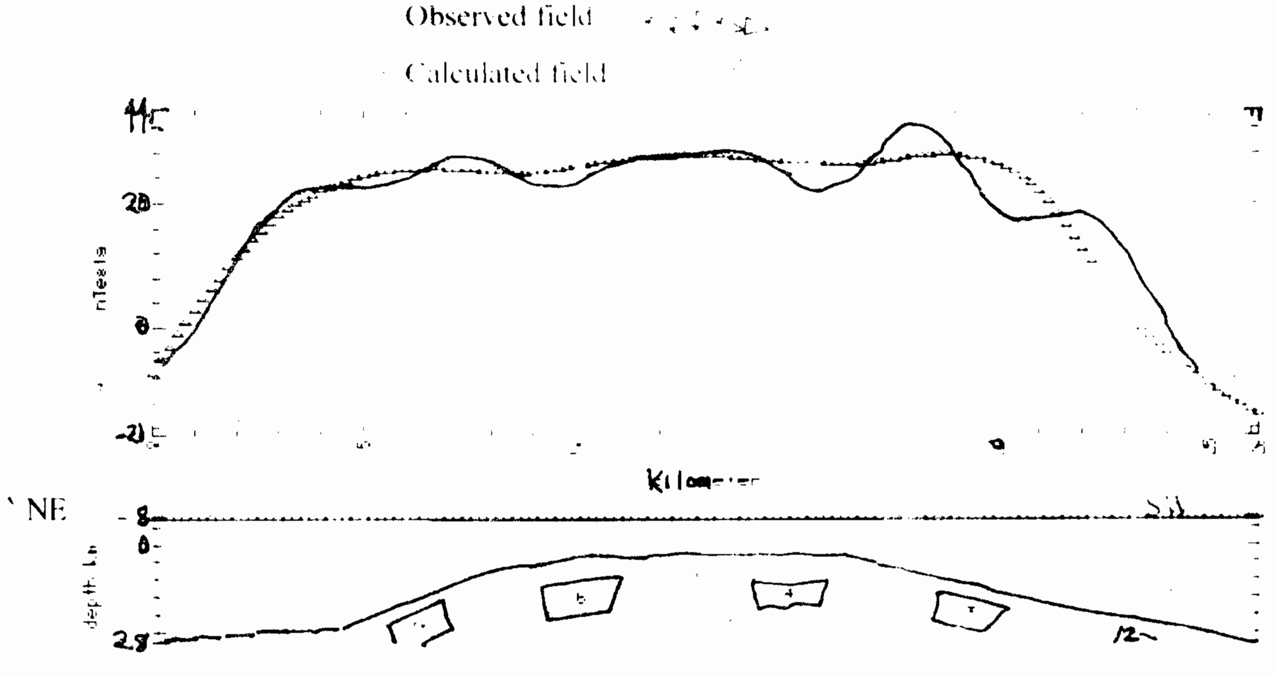

Fig 8a: Legend: 1 Sedimentary Rocks
2, 3, 6, 7 basement rocks magnetics
4, 5 Intrabasement Intrusive
2.5D Modelled profile 1 along Yola Sub-sector

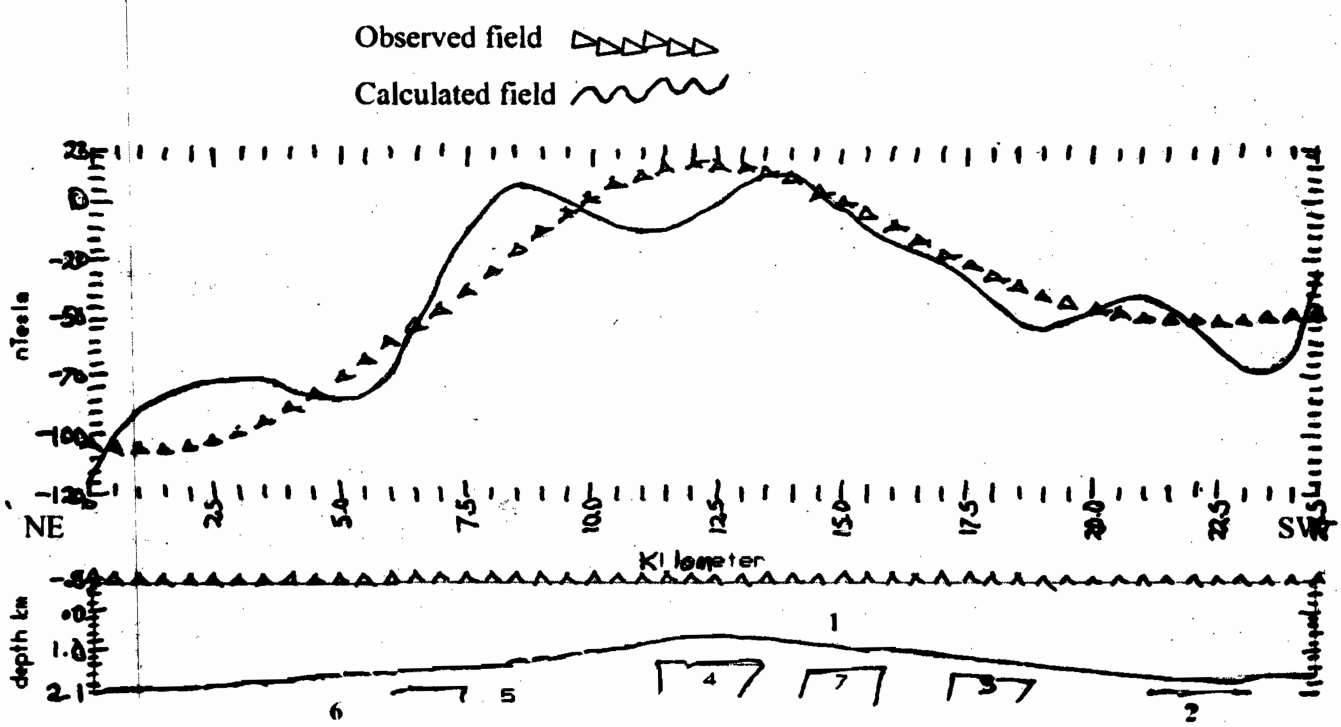

Fig 8b

Legend: 1= Sedimentary Rocks
2, 3, 5, 6, 8 = basement rocks magnetics
4, 7 = Intrabasement Intrusive

2.5D Modelled profile 2 along Yola (Muleng)

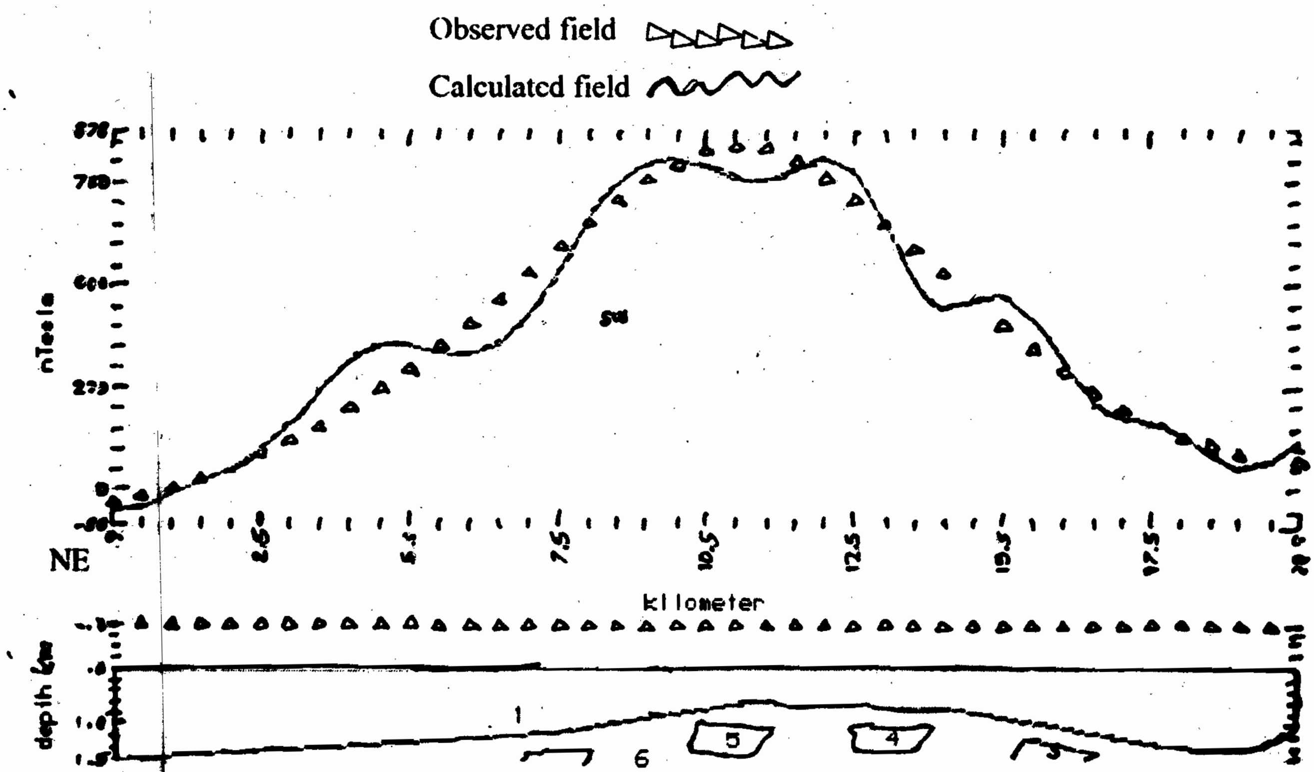

Fig 8c:

Legend: 1= Sedimentary Rocks
2, 3, 4, 5, 6, = basement rocks magnetics

2.5D Modelled profile 3 along Yanga Lau (yanga)

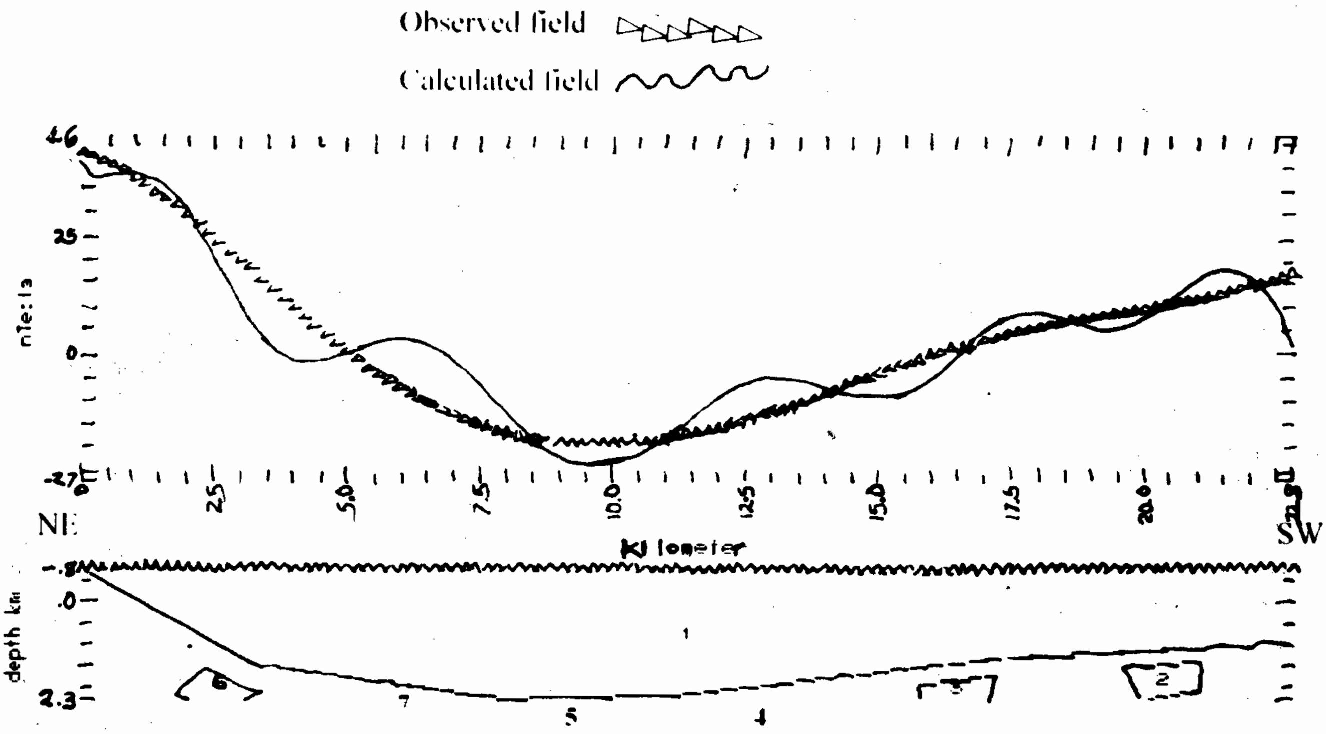

Fig 8d: Legend: 1 = Sedimentary Rocks
2, 3, 4, 5, 6, 7 = basement rocks magnetics
2.5D Modelled profile 4 along Barwa (Lau Basin subsector)

RESULTS

The residual anomaly map (Fig. 4) shows low magnetic contours of -20 to -40nT representing sedimentary rocks from Yola to Muleng axis trending NE – SW while the closely spaced positive anomaly at the NW of muleng represents probably exposed basement rocks. The Lau (Barwa) area also has low magnetic contour of -10 to -20nT of sedimentary origin which trends NW-SE and terminates towards Yanga area with high positive magnetic contours of +40nT. this trend runs from Yanga cutting between Lau (Barwa) and Yola, this is probably the Laminde Anticline

The upward continuation map (Fig. 5) reveals two major lineament trends. The Yola to muleng axis indicates a NE-SW trend while the Lau (Barwa) to Yanga axis indicate a NW-SE trend. The deeper lineament trends are better revealed and their orientation expressed clearly since the upward continuation filtering technique has eliminated shallow seated lineament trends. Results from the spectral analysis and analytical signal depth maps (Fig 6 – 7) reveals two sub-basins which are the Lau sub-basin with an average sediment thickness ranging from 2.0 – 3.5km, and the Yola sub-basin whose sediment thickness ranges between 2.0 to 2.5 km. The above results correlate well with depth estimates from the modeled profile (Fig 8a –d), which indicates that the basin configuration is that Horst and Garben with normal faulting. Sediment thickness increases in the downthrown blocks (Graben) with total intensity field values of -10nT to -30nT and decreases in the upthrown blocks (Horst) with values from -5nT to +23nT. Intrusive rocks are characterized by higher values of total intensity field from +23nT - +44nT. The modeled profiles indicate that the Yola sub-basin is characterized by four intrusive bodies with a sediment thickness that ranges from 2.1 km along Muleng to 2.8 km at Yola (Fig. 8a – b).

The Lau area of Barwa to Yanga has no intrusions and indicates a sediment thickness of 1.6 km to 2.3km over the Grabens and 1.2 to 1.0 km on the Horst. The sediments increase in thickness from the Yanga towards the Barwa areas (Fig. 8c – d).

The above models gave a good match between the calculated and the observed curves thus yielding a good structural configuration of the subsurface features (Olagundoye, 2004).

DISCUSSION/CONCLUSION

The Yola arm of the Upper Benue Trough has been studied to some detail using aeromagnetic data to unravel the subsurface basin configuration. Prior to this work no detailed modeling of the subsurface structures was made. The result obtained in this study corroborates that of other workers in adjacent sub basins (Okereke and Ofoegbu 1989, Nur 2000, Shemarg *et al.* 1989) in terms of orientation of the lineaments trend and average depth estimates. This study however highlights structure and basin configuration that has never been revealed. The study reveals an anticlinal feature of a positive magnetic high within the area with latitudes 9°5' to 9°7' and longitudes 11°5' to 11°7'. This feature is prominent on residual and basement depth maps. The area with basement and intrusive rocks are generally shallower as a result of the tectonic upliftment/emplacement of these rocks

The result has identified two sediment filled Troughs which may have good hydrocarbon prospects given that the areas has an appreciable sediment thickness of 2.0 -3.5 km as revealed by the spectral analysis and analytical depth maps. However, the identified intrusives within the Yola – Muleng areas makes it less favourable for hydrocarbon prospecting than the Lau – Yanga axis which has no intrusives. The Yola area may generate hydrocarbons but with the presence of numerous intrusive bodies, such generated hydrocarbon is likely to be "Overcooked" or well pass the oil window to produce only gas. The Lau area remains the best area for hydrocarbon exploration given that it has no intrusive and has an appreciable depth of 2.0 – 3.5 km.

In conclusion the major lineaments are revealed along two directions - the NE-SW and the NW-SE and the modeled architecture reveals an increase in sediment thickness of 2.0 km to 3.5 km toward the South-west and South-eastern portions with a decreasing depth of 1.0 km to 1.5 km towards the Northeast and Southwest portions. The Basin thins Northwards and deepens Southwards.

REFERENCES

Burke, K. and Dewey, J. F., 1973. Plume Triple Junctions: Key Indicators in applying plate tectonics to old rocks. J. Geol 81: 406-436.

Corredor, F., Shaw, H. J. and Bilotti, F. D., 2005. Structural Styles in Deep Water Fold and Thrust Belts of the Niger Delta. American Association of Petroleum Geologist Bulletin, 89: 753-780.

Dobrin, M. B. and Savit, C. H. 1988. Introduction to Geological Prospecting (4th Ed) New York: Mc Graw – Hill book Company.

Ferdi, M. Quarta, T. and Santis, D. A., 1977. Inherent Power-Law Behaviour of Magnetic Field Power Spectra from a spector and Grant ensemble. Geophyiscs, 62(4): 1143-1140.

Hahn, A. Kind, E. G. and Mishra, D. C., 1976. Depth Estimated of Magnetic Soures by means of Fourier Amplitude Spectra. Geophysical Prospecting 24 287-308.

Jacobsen, B. J., 1987. A case for upward continuation as a standard separation filter for potential field maps Geophysics 52(8): 1138 -1148

Nabighian, M. N., 1972. The analytical signal of two dimensional magnetic bodies with polygonal cross section; It's properties and use for automated anomaly interpretation Geophysics, 37(3): 507-517

Naidu, P. S., 1970. Fourier Transform of Large Scale Aeromagnetic Field Using a modified Version of Fast Fourier Transform. Fast Fourier Transform. PAGEOPH, 81:17-25.

Nur, A., 2000. Analysis of Aeromagnetic data cover the Yola arm of the Upper Benue Trough, Nigeria. Jour. Mining and Geol 36(1): 77-84.

Nwogbo, P. O. Ojo, S. B. and Osazuwa, T. B., 1991. Spectral analysis and Interpretation of aeromagnetic data over the Upper Benue Trough of Nigeria. Nigeria Journal of Physics, 3: 128-141.

Okereke, C. S. and Ofoegbu, C. O., 1989. Gravity and Magnetic data cover the Yola arm of the Upper Benue Trough (1989), In C. O. Ofoegbu (Ed) The Benue Trough: Structure and Evolution (pp. 161-169). Braun Schwelg: Vieweg and Sohn.

Olade, M. A., 1975. Evolution of Nigeria's Benue Trough (Aulacogen): A tectonic model, Geol Mag 112:575-583.

Olagundoye, O. O., 2004. Basin Structure in the Anambra Frontier Basin, SE Nigeria. Implications for hydrocarbon potential. Unpublished P.hD thesis University of Calabar, Nigeria.

Philips, J. D., 1987. Potential field geophysical software for the PC, Version 2.2 U.S. Geological Survey open-file report 97-725, 1-32.

Shemang, E. M. Ajayi, C. O. and Umego, M. N., 1988. The Structure of the Gongola arm of the Upper Benue Trough as revealed by gravity and magnetic studies. NAPE Bulletin, 13(1): 50-69.

Shuey, R. T., 1972. Application of Hilbert Transforms to magnetic profiles. Geophysics 37:1043-1045.

Webring, M., 1985. MINC; A gridding programme based on minimum Curvature U S Geological Survey open-file – report, 81-1224, 1-41.

Wright, J. B., 1981. Review of the origin and Evolution of the Benue Trough in Nigeria – Earth Evolution Sciences. 1(2) 98-103.