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2-1/2 Dimensional Modeling of the Major Structures Underlying Dong and Shelleng of the Upper Benue Valley, Using GM-SYS Computer Modeling

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Abstract: Airborne magnetic data over part of Dong and Shelleng area of the upper Benue Valley, N-E basement complex of Nigeria's was carried out to investigate the deep and thick structures of the underlying geology and their relationship with granitic intrusion. These features are interpreted in terms of deep geologic structures, and/or susceptibility variations within basement rocks. The residual separation exercise revealed the area is underlain by a NE-SW regional trends, which shows it is in agreement with Benue trough, presumed they have the same structure control. Furthermore, the 3-D residual magnetic anomaly map suggests Dong is likely to be the sedimentary basin. It shows that the magnetic field there is smoother, which is masked off by the effects of the stronger magnetic basement. High amplitude of the anomalies which outcrop at eastern part of Dong where the profile cut across 6 could be the presence of Ngurore basalts. The thickness revealed by the model (D-D^1), Northwestern part Numan has a maximum thickness of 1.4km and minimum of 0.2km. In D-D^1 modeling, it revealed a porphyritic granite with non- uniform thickness of about 1.1Km and minimum of 0.17Km with a width approximately 2.9Km. The first sedimentary layer reveals has a thickness of about 1.0Km and the second varies from 1.0 to 1.6km thick. The width is about 4km.The Alluvium thickness increases progressively between 0.2Km to 0.7Km and the width of about 18km, reveals by the model. The thickness of the basin varies between 0.9km to 2.9Km. The model reveals the width of the basin to about 136Km.
Key Word: Geologic Map, Total Field Map, Regional Field, Residual field and 3-D Residual Field, Model D-D^1

1.0 Introduction

The purpose of the magnetic survey is to detect rocks or minerals possessing unusual magnetic properties; which reveal themselves by causing disturbances or anomalies in the intensity of the earth's magnetic field. However, there are differences which increase the complexity of magnetic interpretation (Keary and Brooks, 1984). Sometimes individual magnetic anomalies are found; which can clearly be distinguished from neighboring effects. This is simple appearance and can be to a single magnetized body. In such cases, quantitative methods can be used most effectively to deduce the shape and size of the magnetic formation.
Potential fields are inherently ambiguous. Theoretically, an infinite number of solutions may be obtained for the physical property distribution, giving rise to a specific anomaly. However, only a limited number can be due to geological factor.
In this regard, the choice of modeling is required to detect such geological features. There are several methods of modeling bodies. These methods are divided into three. Two-Dimensional (2D) techniques are usually applied in modeling elongated bodies with length to width ratio greater than 10, as in the case of dykes. Thus, the length is assumed to be infinite. In 3-D techniques, many simple geometric forms have been used to model magnetic anomaly fields. Some of these forms, such as the vertical and inclined prisms, have been particularly successful, especially in near surface exploration work. A simple geometric form which can be used in a closed-shaped arrangement for modeling anomalies is the finite depth, vertical-sided rectangular prism developed by Bhattacharyya (1964). The study proposed a closed-form equation for the total field magnetic anomalies of prismatic models. Complicated 3-D shapes can also be modeled by other methods such as the Talwani method (1965). In this technique, the outline of the body is defined by horizontal polygonal shaped depth contours. A large number of sides in the polygons and highly dense contours can accurately represent any complex structure or sloping boundaries. In calculation, these contours are replaced effectively by horizontal laminae. Therefore, the magnetic effect of the body can be calculated by numerical integration with respect to depth.
The 2-1/2D modeling technique is an improvement of the 2D and approximation to the 3-D model. In this method, the length is made finite though considerably longer than the width of the body. The technique applied in any survey depends on the structures intend to model and the purpose of the survey. Cosequently, the two dimensional (2D) technique can readily be used to quantitatively model dykes (such as schist) since their length

to width is usually greater than 10. Alternatively, the three dimensional (3D) modeling technique can be conveniently used in modeling batholiths while moderately elongated slabs can be modeled using the 2-1/2D method (Talwani, 1965; Gemerle, et al.,1991).
The purpose of this research is to model the shape and depth of the major structures underlying part of Dong and Shelleng which is model D-D^1 , cut across the area at 45 degrees.

2.0 Location of the Study Area

The upper Benue Valley is a northeasterly structured, about 1000 km long; and between75 to 150 km wide. The Yola arm is an easterly branch of the trough. The study area covered lies between latitude $9^0 30^/$ N and $10^0 00^/$ N and longitude 11^0 $30^/$ E and 12^0 $30^/$ E, which are Numan, Guyuk ,Shellem and Dong. This work will only focus on the profile model of D-D^1 which is part of Dong and Shelleng of the study at 45^0.

2.1 Geology

As part of this study, a geological survey of part of the area was undertaken with emphasis on structure. The following gives a brief description of the lithological units found and structural features. The geological map is presented in figure1.0.

2.1.1 Lithological Unit:

Basement Complex

The basement rock units in the north and south parts of the study area are made up of older granites, gneisses and migmatite. However, basic extrusive (basalt) and intrusive also occur. Whilst sedimentary rock units comprising mainly sandstones, limestone, clays and shales outcrop within the central portion of the study area (Cater et al., 1963).

Volcanic Rocks and Igneous Intrusion

The extensive igneous activity which took place on the lower Cretaceous of Nigeria was most intense during the late Albian time (Ofoegbu 1985a). The intrusions are widely distributed throughout the area; and the younger intrusive are represented by volcanic plugs, dyke, silts in the study area. Smaller dykes of basic masses; occasionally produce contact metamorphism in the sediments, characteristic of a short time interval between segmentation, folding and intrusion (Cratchely and Jones 1965).

Alluvium: Quaternary -Recent

The Quaternary alluvium is a superficial deposit; comprising mainly argillaceous stuff called Benue valley alluvium. The soil is black to dark-gray clayey sediment formed by the weathering of volcanic (basaltic) and shaley rocks. It is marshy and covered by shrubs forming stripes of 500m to 1km radius range, beyond which they are intercalated with poorly sorted sands and gritty clays (typical of the Benue valley Alluvium). In the study area, the Quaternary Alluvium uncomformably overlies the Bima formation obscuring it in most sections.

Bima Sandstone

The Bima sandstone is classified into three layers: the lower, middle and upper Bima. The upper Bima consists of medium to coarse grained feldspathatic sandstone. In the Lamurde anticline, the maximal thickness reaches up to 1, 700m but may vary considerably elsewhere. The sequence was deposited under fluvaital to deltaic environment (Cater et al, 1963) with late Albian/Cenomanian age assigned to it. The Middle Bima **is** composed of very coarse grained, feldspathic sand stone with bands of clay, shale and occasional calcareous sandstones. In the Lamurde anticline, the thickness is 800m but may vary elsewhere. This sequence was laid down in fluvaital and the deltaic environment (Carter et la 1963) with a tentative middle Albian age assigned to it. Lower Bima is the oldest sediment known in the area which appears in the core of the Lamurde anticline comprising coarse grained feldspathic sandstone. It also alternate with red, purple shale and occasional band of calcareous sandstones and silts stone. The visible thickness in the Lamurde anticline is 390m (Cater et al, 1963). This basal sequence was deposited in lacustrine environment with a brief marine incursion (Cater et al, 1963). An upper Aptian/ Albian age has been recently assigned to this part of Bima sandstone assuming palynological date. Figure 1.0 shows the geologic map of the study area.

3.0 Materials and Method

3.1 Data Acquisition

The data sets used in this study were compiled from four aeromagnetic maps with index numbers of 174,196,175 and 195, for Numan, Dong, Guyuk and Shelleng respectively. These maps were obtained from the Geological

survey's Agency, Kaduna, Nigeria. The maps were produced between the year 1974 and 1980 and published on $1/2^0$ by $1/2^0$ sheets contoured manly at 10 gammas interval. The maps are published on scale 1:100,000. The present work covers 196 and 175. The contour lines in all the maps were dense; therefore, it was easy to adopt the flight line digitization used with very minimal errors of human judgment. The magnetic values were plotted at the 10nT (gamma) intervals. The maps were numbered and named according to the places covered for easy reference. A total of 340 maps covered the entire country. The actual magnetic values were reduced by 25,000 gammas before plotting the contour maps (Huntings, 1976). Therefore, the value of 25,000 gammas should be added to the contour values to obtain the actual magnetic field at a given point.
The maps were digitized on a grid of 1km imposing a Niquisit Frequency of ½ km^{-1} so that the narrowest magnetic feature that can be defined by the digitized data has a width of "2" km. The anomalies are wider than 2km and therefore, lie in a frequency range from aliasing, which do not occur with a 1km digitizing grid.
Consequently, the aeromagnetic map was digitized such that the data was stored in 55x 55 coding sheets. Each record contains the boundary longitudes and latitudes, the map number, and name of the town overflow. The data were entered into a computer file, thereafter became the input file for a computer program. It picked all the data points row by row, calculate their longitude and latitude and the magnetic value for coordinates respectively. Each output file for this operation was given a meaningful name for easy identification. The three dimensional coordinates from x, y, z, is made to be acceptable to a contouring package "SURFER 7.0." This is a menu-driven interactive computer programme, which places each magnetic data point according to their longitude and latitude bearing and thereafter produces contour maps to ensure that they correspond with their respective original maps. The maps are figures.2, 3, 4 and 5.
The compilation of the aeromagnetic maps of Numan, Dong, Guyuk and Shelleng form the composite map figure 6. The most flexible and applicable analytical known as Polynomial fitting method was used for determining regional magnetic field (Skeels, 1967; Johnson, 1969 and Dobrin 1976). Usually by least square, which is the mathematical describable surface giving the closest fit to the magnetic field produces regional field, and the residual field is the difference between the magnetic-field values as actually mapped and the regional field thus determined. The resultant map is shown in figure 7. The subtracting values of the regional filed from the total magnetic field value at grid points produce the residual field (shown in figure 8a) . The magnetic (high and low) was also determined as presented in figure 8b. Further analyses of the residual field map generated the 3-D residual anomaly field is presented figure 9.

3.2 Gravity/Magnetic Software System (GM-SYS)

GM-SYS, written by Gemperle *et al,* (1991) is a programme used for the easy interactive modeling of 2D and optionally 2½D geological cross section, with the ability to quickly calculate and display the gravity or magnetic response from the cross section. The 2½D option was used to calculate the magnetic response within the study area. The method is used for calculating the magnetic response based on the methods of Talwani *et al;* (1959);Talwani and Heirtzler; (1964) using the algorithms described in Wen and Bevis (1987). However, the 2½D calculations are based on Rasmussen and Pedersen (1979).
The computer program can give a composite model of the thickness of the basin, the surface topography of the basement below the basin, the structures and depth of any intrusion into the sedimentary terrain.

3.3 The Modeling of major anomalies

The magnetic residual map (figure8a) of the study area is complicated as expected in magnetic studies. Nevertheless, some major anomalies stand out which profiles were drawn across on the magnetic residual anomaly map as shown in figure.(10). For modeling the shape, depth of the causative bodies and the thickness of the sedimentary basin within the profile $D\text{-}D^1$ that cut across Dong and Shelleng at 45 degrees to the area. The anomalies were selected for modeling; numbered 6 for easy identification (figure10). Profiles $D\text{-}D^1$ runs across anomalies 6. Additionally, the DD^1 profile was drawn in order to estimate the width of the causative basin; it was necessary to draw profiles perpendicular to the strike length. Less disturbed area was chosen so that the effect of topography rather than lithology will lead to better accuracy in modeling the profile. The basin is assumed to be underlain by granite gneiss, which is the dominant rock type of the basement complex of Nigeria.Furthermore, migmatite often associated with basaltic rock and intrusive as well as sedimentary rock units comprising mainly sandstones, limestones, clays outer or within the central portion are also present (Carter *et al,* 1963). However, a study by Ajakaiye *et al,* (1991) reported ranges of 0.0059 – 0.0097 SI units and 0.15 – 1.030 SI units respectively for granite – gneiss as the magnetic susceptibility values in the neighboring Benue Trough. Another study by Ojo (1990) used a value of 0.12 SI units for the granite gneiss of the Nupe Basin. The value used in this study was 0.016 SI, since the modeling package uses the Gaussian's unit, this value translates to 0.0013 Gaussian units using a conversion factor of 4π from SI unit to Gaussian unit. The average ambient magnetic field, magnetic inclination and declination values used for this study are 33000gammar, 4^0 and 5^0 respectively.

4.0 Result:
The result indicates that Southeastern part of the Dong area possesses the most dense closures. Some major closures were observed in the upper Eastern part of Dong particularly in the middle area located towards NE-SW. The total field map indicated lineament closures focusing NE-SW direction.
The regional map of the study area computed with polynomial coefficients revealed of 5nT in the lineament and trending NE-SW as presented in Figure: 7. The subtracted values of the regional filed from the total magnetic field at grid points generated a residual and the high and low magnetic field observe in figure 8a & 8b. Further analyses of the residual field map in Figure 8a generated 3-D residual anomaly field. Some parts in the study were observed to be smoother, particularly the northeastern part of Dong and Southeastern part of Guyuk as observed in Figure.9.
Using available geological information and magnetic susceptibility as stated in (Figure11), bodies were fitted to the anomalies and subsequently adjusted until a good fit was obtained between the calculated anomalies and observed residual anomalies. This infinite number of models is possible in this way; but geological and other constraints often limit these to be only acceptable.
Results of (figure11) show the model of profile D-D^1 which cut across Dong and Shelleng at 45degrees to the study area.

4.1 Discussion

From the results, the residual map (Figure 8a), there are noticeable closures, NE-SW & E-W trending features, which the situation looks different because the contour lines of the total residual magnetic field are concentrated more in the Northern & Southern portion of the study area. This could be that the basement complex outcropping there is not homogeneous. Mineralogically, in addition to the presence of basement faults in the area granitic and pegmatitic dykes were also observed. This inferred zone may be interpreted as major fracture zones of the weakness within the trough. The NE-SW lineaments (found predominantly in pan Africa granite) were observed towards the northeast and souteastern part of the study area. However, with some extension to the southwestern part.The NE-SW structures are found to be faults and foliation. This structural direction is related to the West African rift system made up of the north easterly Benue Trough and Cameroon volcanic line (Flitton, 1983) (Bassey, 2006). These features are foliation and shear zones trending towards NW-SE features. The lineaments are among the longest and invariably are of deep crustal origin (Odeyemi et al, 1999). East-West lineaments are the youngest as they cross cut structures of all other directions. They are mainly basement normal faults, while others are granites. .

This profile passes through west of Dong and cut across the field at 45 degrees to the east south of Shelleng (figure11). It revealed the porphyritic granite which has maximum thickness about 1.1km and minimum of about 0.17km. The width is about 2.9km. The first sedimentary layer has thickness of about 1.0km and the second sediment varies from 1.0 to 1.6km thick. They have width of about 4km, the alluvium was reveled from the profile which has maximum thickness of about 0.7km and minimum of 0.2km thick. The width is about 18km. The Ngurore basalt which the profiles reveal along the NW part of Numan has the maximum thickness of 1.4km and minimum 0.2km. The width is about 31km. The thickness of the basin and the width are 3km and 131km respectively. The basement migmatite gneiss outcrop Northeast of Shelleng with thickness of about 0.2km.The model inferred the basin width to about 136Km.This is in agreement with spectral depth estimation of Nur.A (2001)

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4.2 Conclusion
The regional field has shed light on the geology and structure of this part of Nigeria's basement complex that has been relatively understudied. The study revealed NE-SW trending, which correlate with the geology of the area showing that the Benue trough trends NE-SW, indicating that the underlying geological structures have the same structural control with the trough. The study which also revealed NE-SW structures as the youngest in the Nigerian Basement (Olumide 1988; Ene and Mbono, 1988; Ekwueme, 1994).The major lineaments observed to have been accounted for in terms of faults and foliation. The lineaments have the regional extension into Niger, Chad and Cameroon.

More so, residual field legend shows the magnitude of an anomaly from -200 to 120 nT. From the 3-D residual field, the area is characterized by residual positive anomalies ranging from 60 to 90 nT. In this study, it is assumed that the anomalous magnetic field of the crustal rocks is due to induced magnetization in the area. It could be the fact that some locations have a high component of remnant magnetism in the anomalies' field.

High-sensitivity aeromagnetic data over the area contain both low-amplitude, linear anomalies produced by structurally deformed magnetized layers near the top of the sedimentary section and high amplitude, broad anomalies produced within the basement.

Matched-filtering has been successful in separating the anomalies produced by these two source regions. In this work, it is assumed that the anomalous magnetic field of crusted rocks is due to induced magnetization from 3-D residual field. This could be due to the fact that some locations may have a high component of remnant magnetization in the anomalous field. In conclusion this research calls for more geophysical studies within the area to correlate the result of this work Therefore, a thorough and widespread determination of the direction and magnitudes is recommended before further studies are carried out in the area. More so, studies on the susceptibilities of the rocks in the area should be carried out as these will enhance the results of the further studies.

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Reference

Ajakaiye, D.E, Hall, D.H., Ashiekaa, J. A and Udensi E.E (1991): Magnetic anomalies in the Nigerian continental and mass based on aeromagnetic surveys Tectonophysics, 192: 211-230.

Bassey N.E (2006): Structuer of Madagali hill's NE Nigeria from Airborne magnetic and satellite data over Hawal basement complex. Global journal of geological science volume 4 No 1. Pg

Cratchely C.B and Jones. G.P. (1965). An interpretation of the Geologic and gravity anomalies of the Benue Valley, Nigeria Geophysics paper. Overseas Geological Survey. London.

Dobrin, M (1976): Introduction to Geophysical Prospecting. McGraw-Hill book Co(Third Edition) New York.

Ekwueme, B.N. 1994. Structureal features of southern Obudu Plateau, Bamenda Massif, SE Nigeria: preliminary interpretations. J. Min Geol, 30(1) pp.45-49

Ekwueme, B.N.2003. The Precambrian geology and evolution of the Southeastern Nigerian Basement Complex. University of Calabar Press, 135p.

Ene, K.E and Mbonu. W.C 1988: The metasedimentary belts of Nigerian Basement Complex, facts, fallacies and new frontiers. In: P.O. Oluiyide (coordinator), Precambrian geology of Nigeria. Geol. Sur.Nigeria Pub... pp53-67

Fitton J.G 1983 Active versus passive continental rifting: evidence from The West African Rift system. Tectnophysics: 94:473-481

Huntings Geology and Geophysical Ltd (1976):Aieborne Magnetometer survey Map of contour of Total Magnetic field intensity Geological survey of Nigeria. Airborne Geophysical series.

Johnson, W.W.(1969).The least-squres method of interpreting magnetic anomalies caused by twoDimensional structures.Geophysics, 34: 65-74.

Nabighian, et al, 2005, The historical developmentof the magnetic method in exploration: Geophysics, **70**, no. 6, 33ND–61ND

. **Nur, A. (1991):** Analysis of aeromagnetic data over Yola arm of the upper Benue

Trough, Nigeria. Dept. of Geology, Federal University Technology,Yola.

Nur, A.2001. Spectral analysis and Hilbert transformation of gravity data Over southwest of Chad Basin, Nigeria.J.M.Geol.37 (2) pp.9-98

Odeyemy, I.B, ANIFOWOSE, Y.B. AND ASIWUJA-BELLO Y.A.1999: Multtechnique graphical analysis of fractures from remote sensing images of Basement regions of Nigeria.J.MIN.GEO.35 (1) PP.9-21

Ofuegbu .C.O. (1985). Interpretation of a linear Magnetic features near Mutum Biyu, Nigeria.

Ojo, S. B. (1990). Origin of a major Magnetic anomaly in the Middle Niger Basin, Nigeria. Tectonophysics 185:15.
Revister Brasiteria Geoscience 3, pg 91-95.

Olumide, P.O.1988.Structural trends in the Nigerian Basement Complex. In: P.O Oluiyide. (Coordinator), precambrian Geology of Nigeria, Geological Survey of Nigeria, Kaduna, pp.93-98.

Osazuwa, I. B., (1981): analysis of the structure of part of upper Benue Rift valley on the basis of new Geophysical data. Earth evaluation science 2, pg. 126-135.

Rasmussen, R. and Pedersen, L.B. (1979): End corrections in potential field modelling. Geophysical prospecting, 27: 749 – 760.

Syberg, F.J.R., 1972, A Fourier method for the regional-residual problem of potential fields: Geophysical Prospecting, v.20, p.47-75.

Talwani, M. and Heirtzler, J. R. (1964): Computation of magnetic anomalies caused by two-dimensional bodies of arbitrary shape, in parks, G.A, Ed, Computers in the mineral industries, part 1: Stanford Univer. Publ., Geological sciences, 9, 464 - 480.

Talwani, M. (1965): Computation with the help of Magnetic Anomalies caused by arbitrary. Geophysics 30:797–817.

Telford et al; 1972, Applied Geophysical Cambridge University Press.

Wen, I. J., and Bevis, M; 1987. Computing the gravitational and magnetic anomalies due to a polygon: algorithms and fortran subroutines: Geophysics, 52, 232 -238

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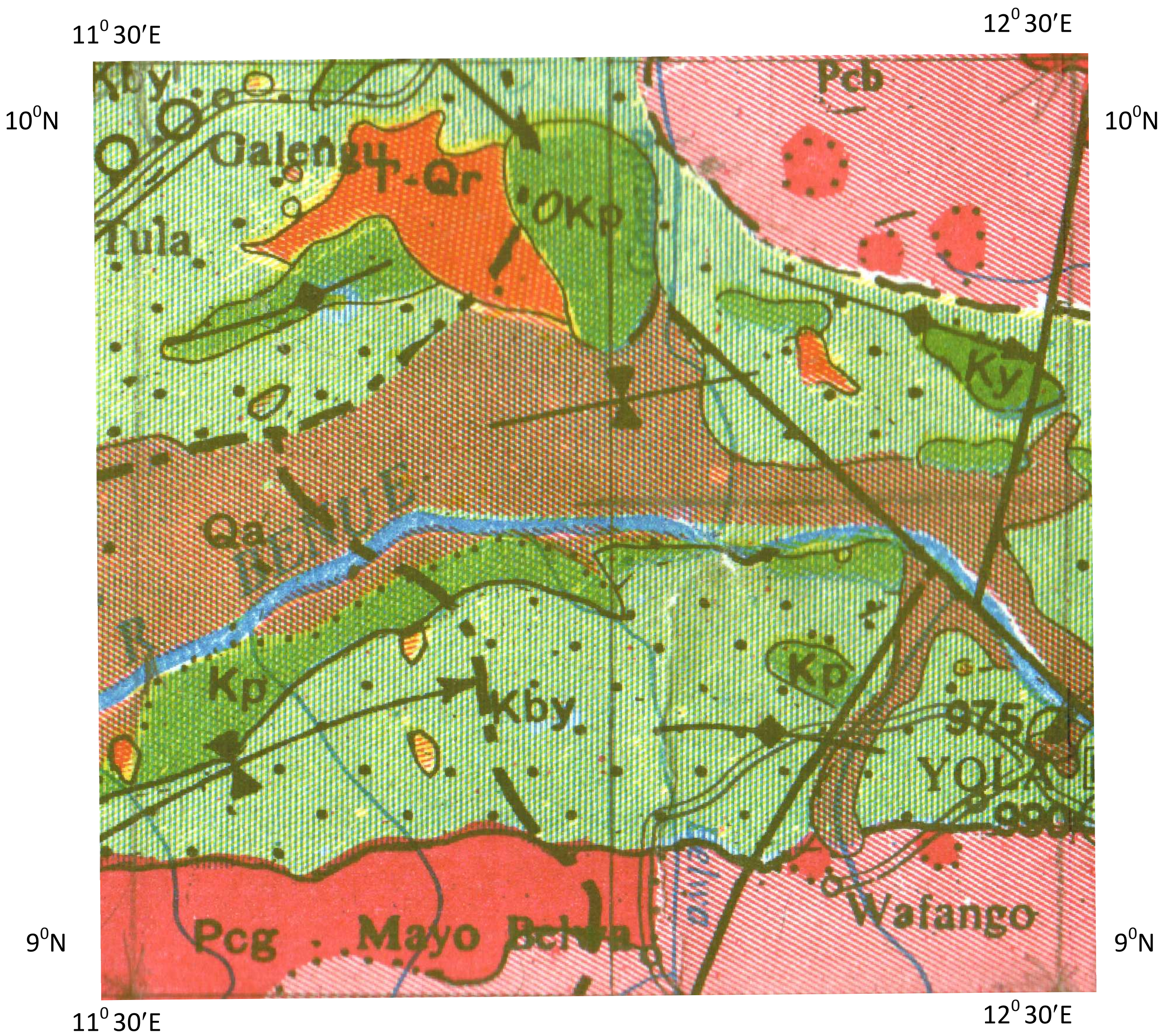

Fig. 1: Geologic Map of the study area after Nigeria Geolog. Surv. Agen:2005

LEGEND

Pcg = Granite

Qr = Basult

Qa = River Alluvium

Kby = Feldspatic sandstone, clay, shales, calcareous sandstone and shelly

Kp = shale and limestone

Pcb = Gneiss-migmatite (complex)

Ky = Medium and coarse grain feldspatic sandstone

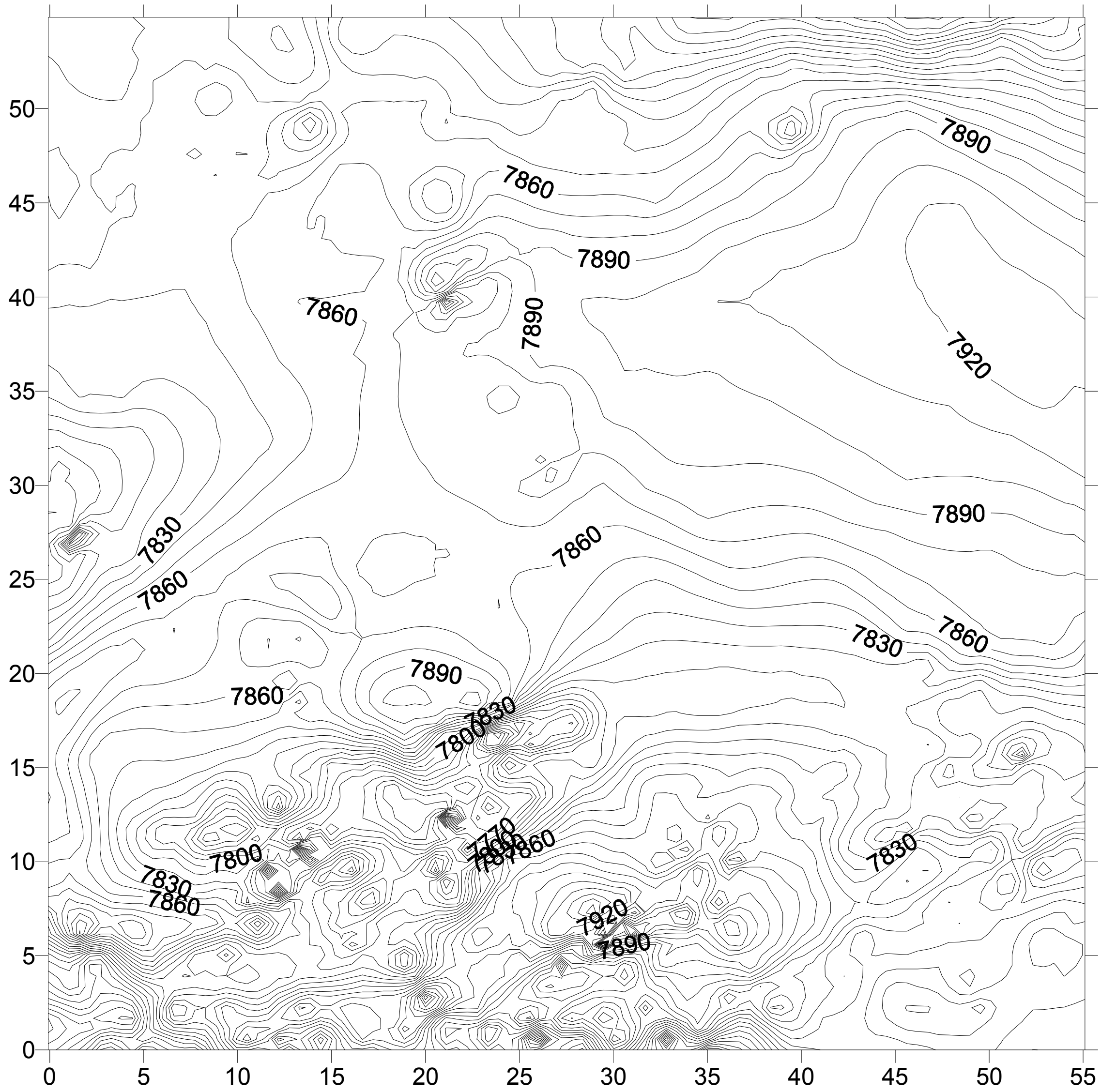

FIG 2: Aeromagnetic Map of Numan Contoured at interval of 10nT

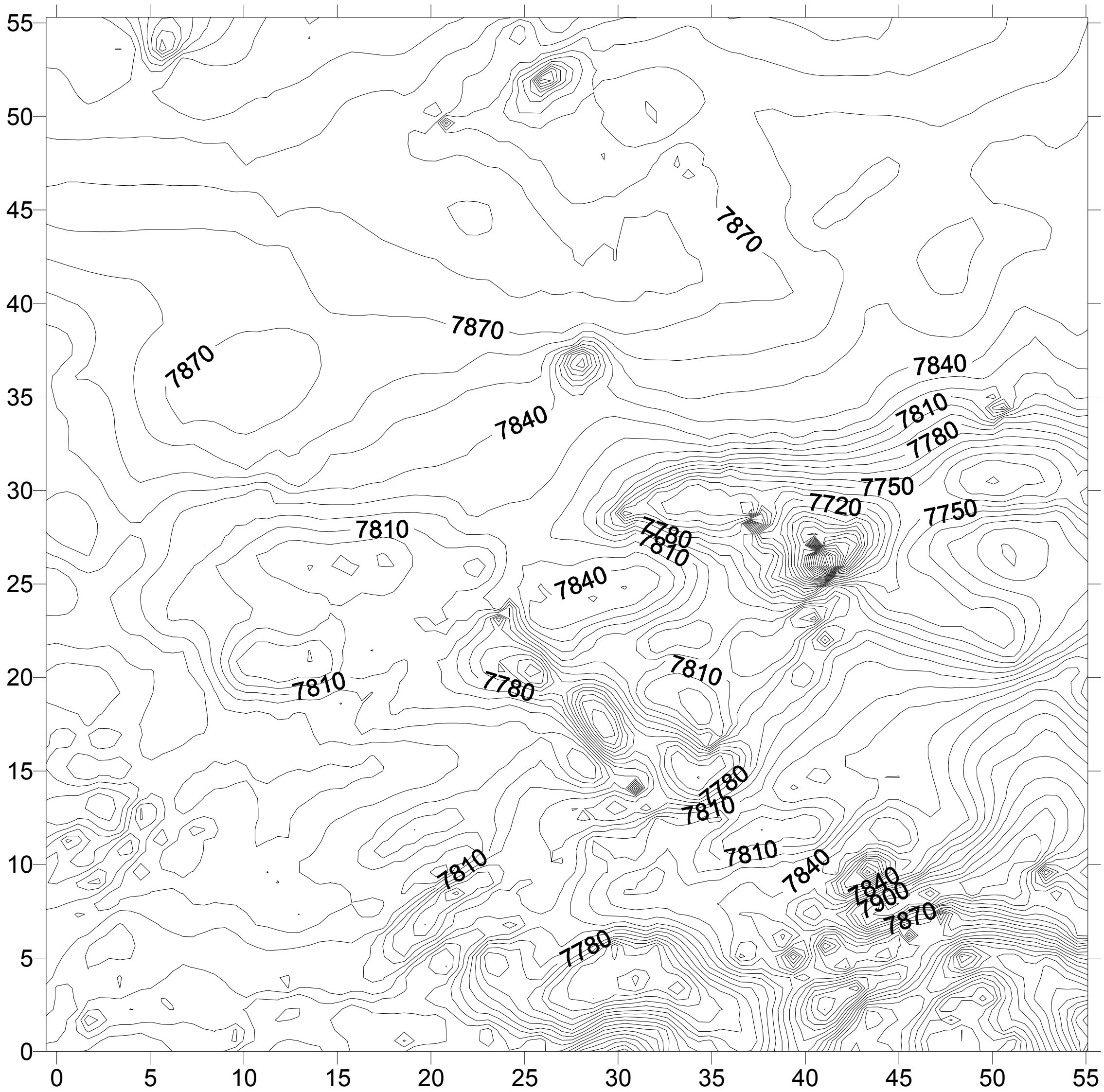

FIG.3: Aeromagnetic map of Dong contoured at interval of 10nT

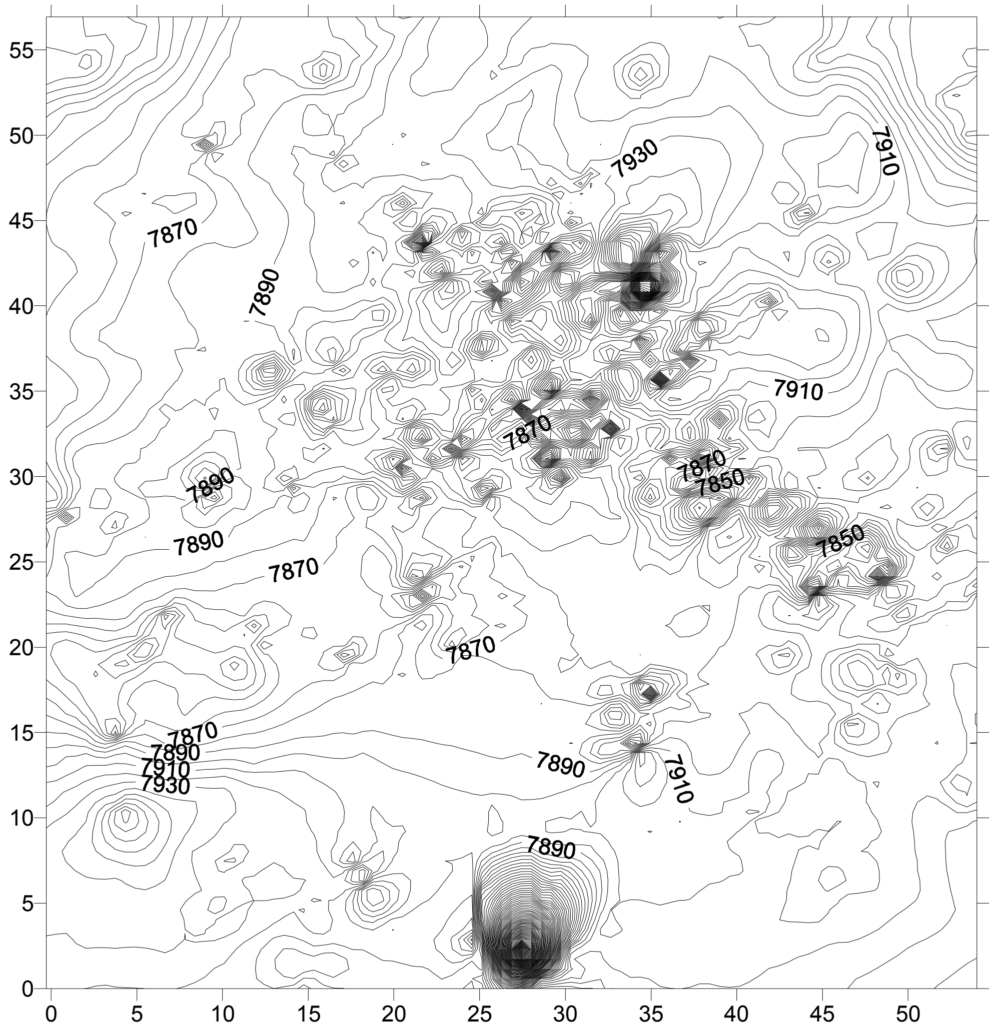

Figure.4: Aeromagnetic map of Guyuk contoured at interval of 10nT

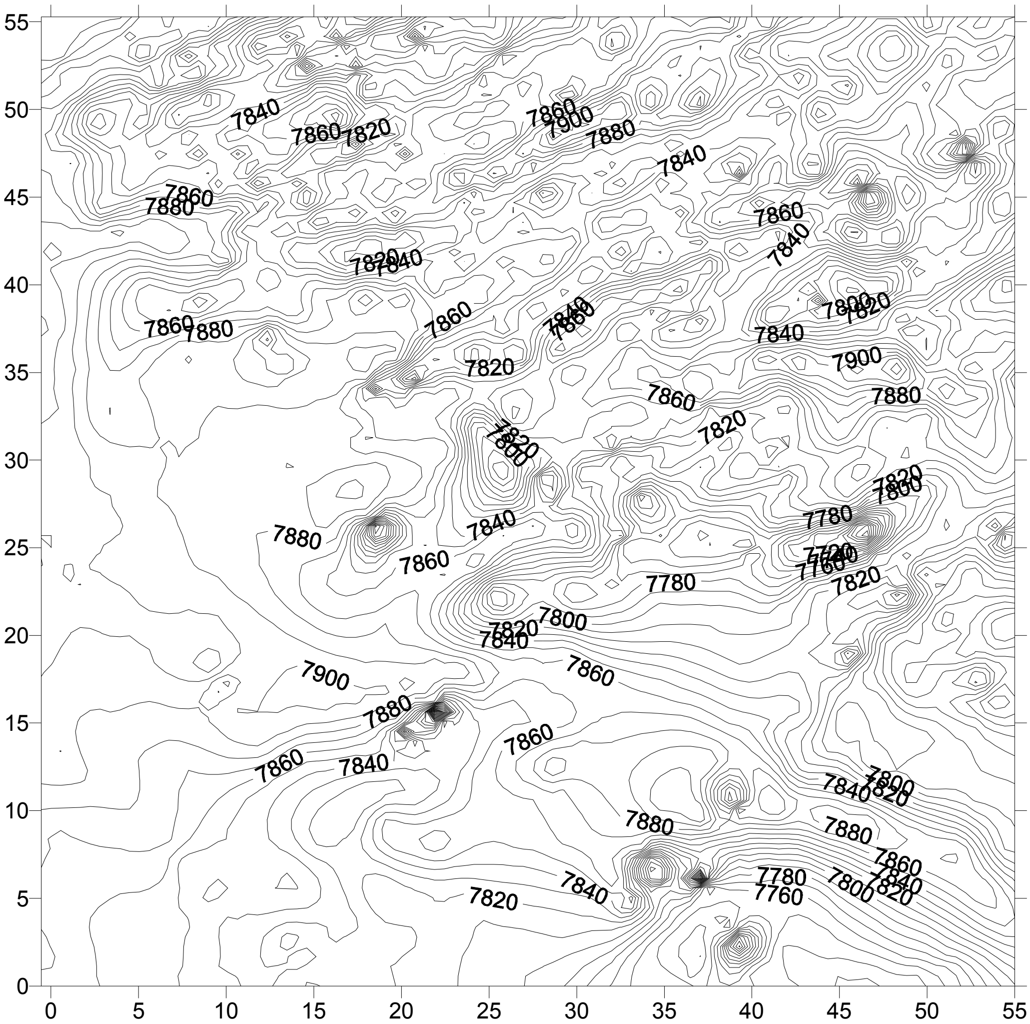

Figure.5: Aeromagnetic map of Shelleng contoured at interval of 10nT

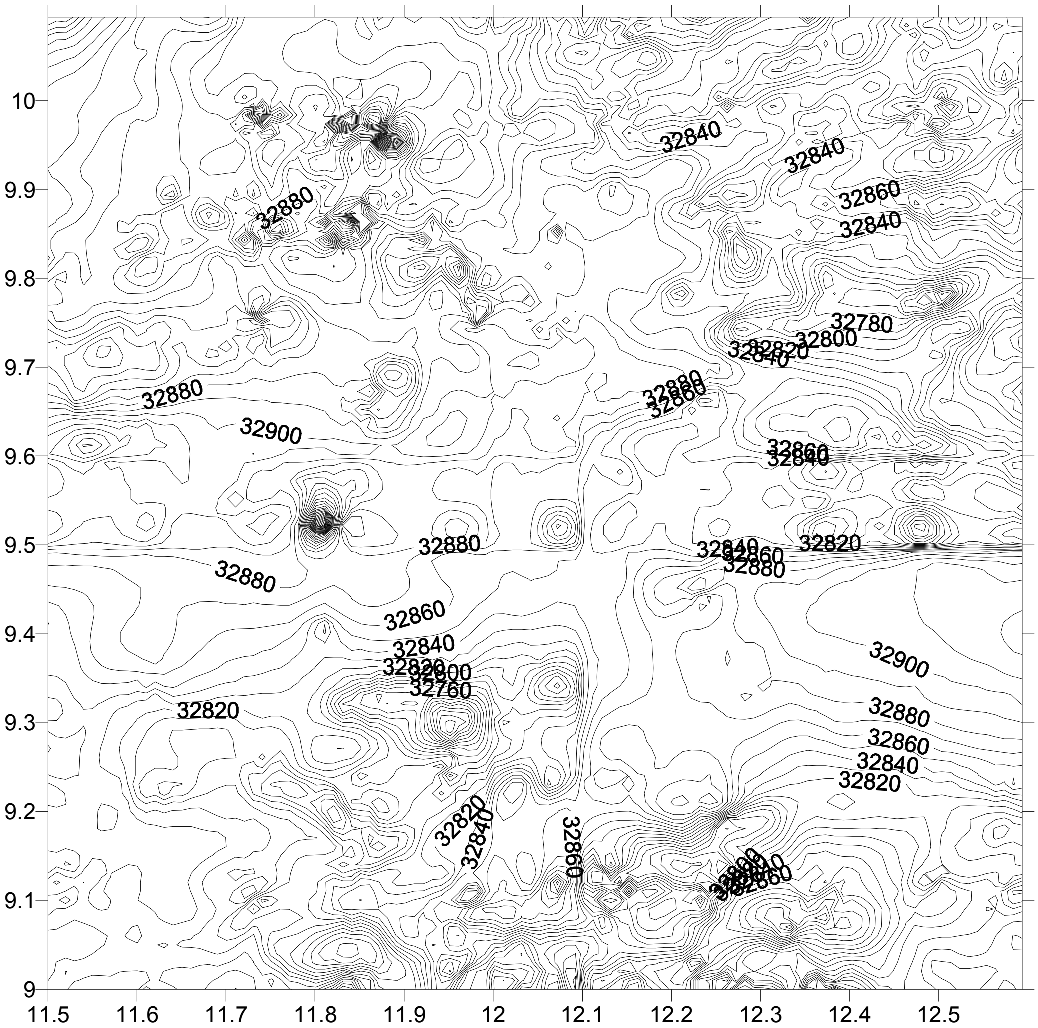

Fig6: Total Aeromagnetic field of the study area contoured at interval of 10nT

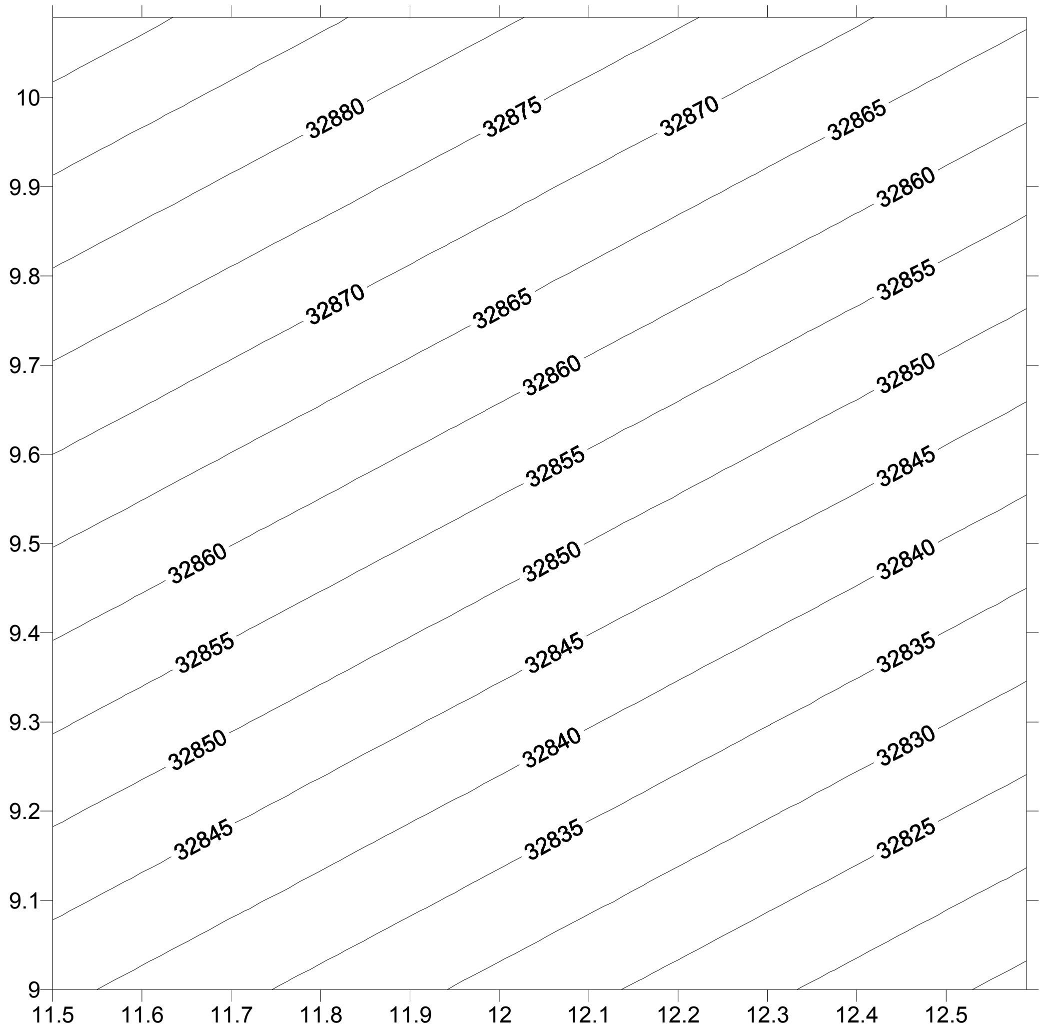

Fig 7: Regional map of the study area contoured at interval of 5nT

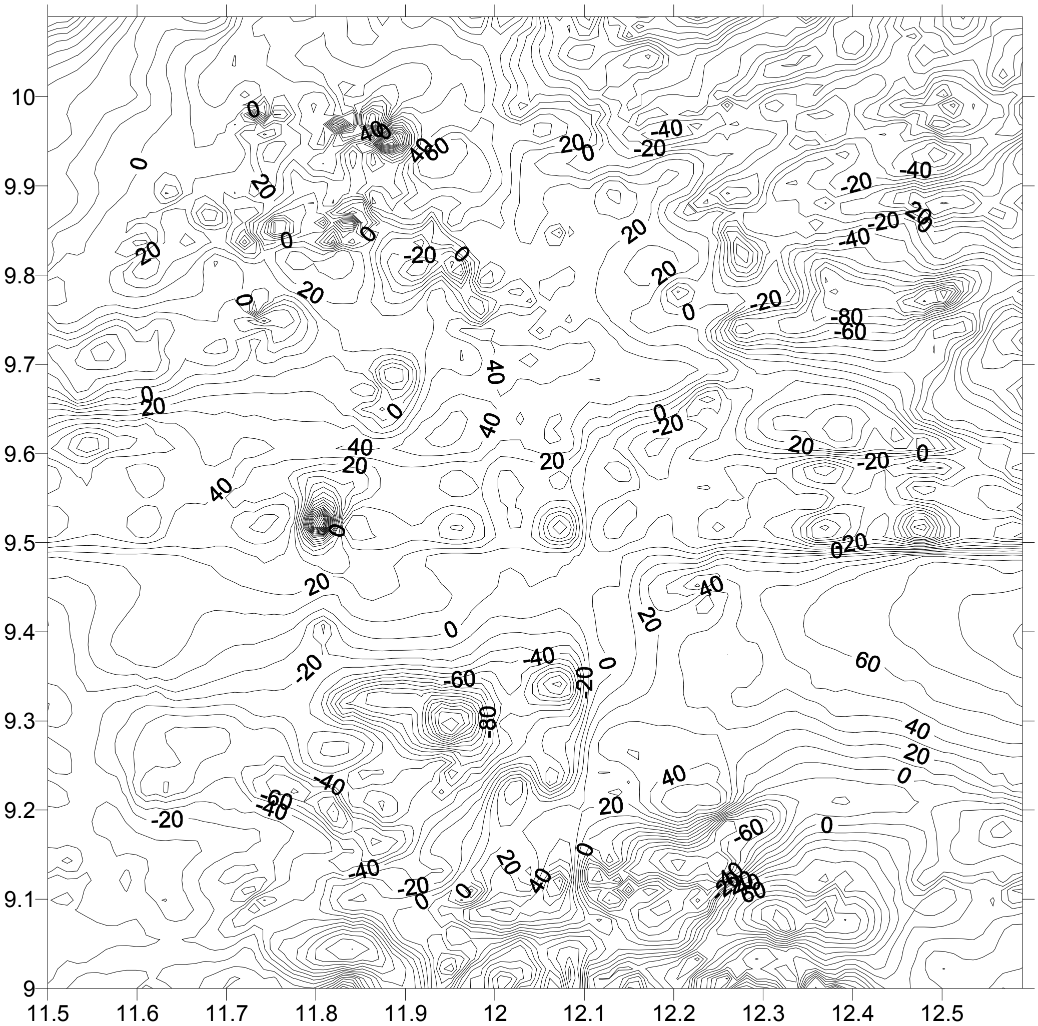

Figure 8a: Residual map of the study area contoured at interval of 20nT

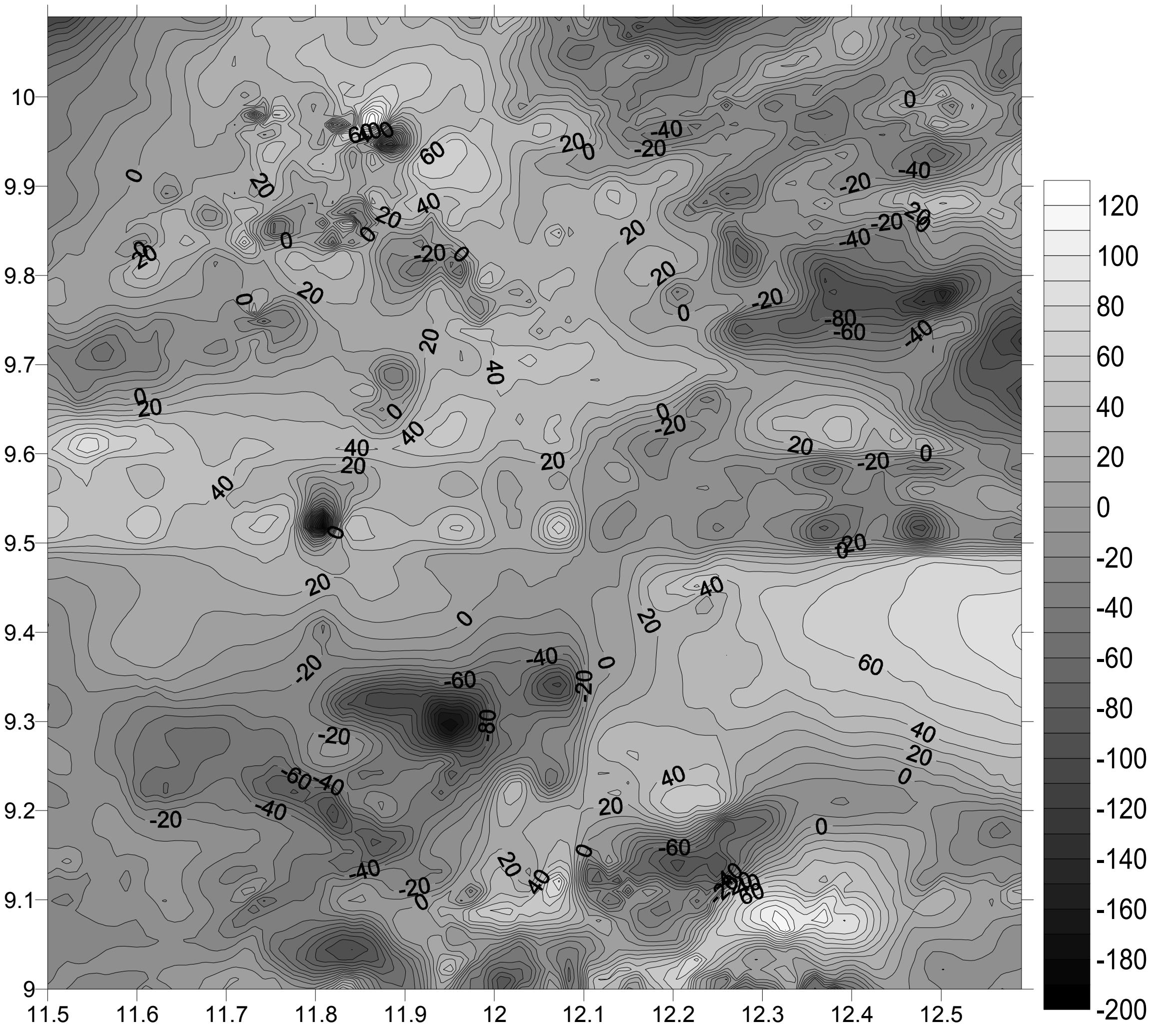

Fig8b: Residual magnetic map of the study area showing magnetic high and low contoured at interval of 20nT

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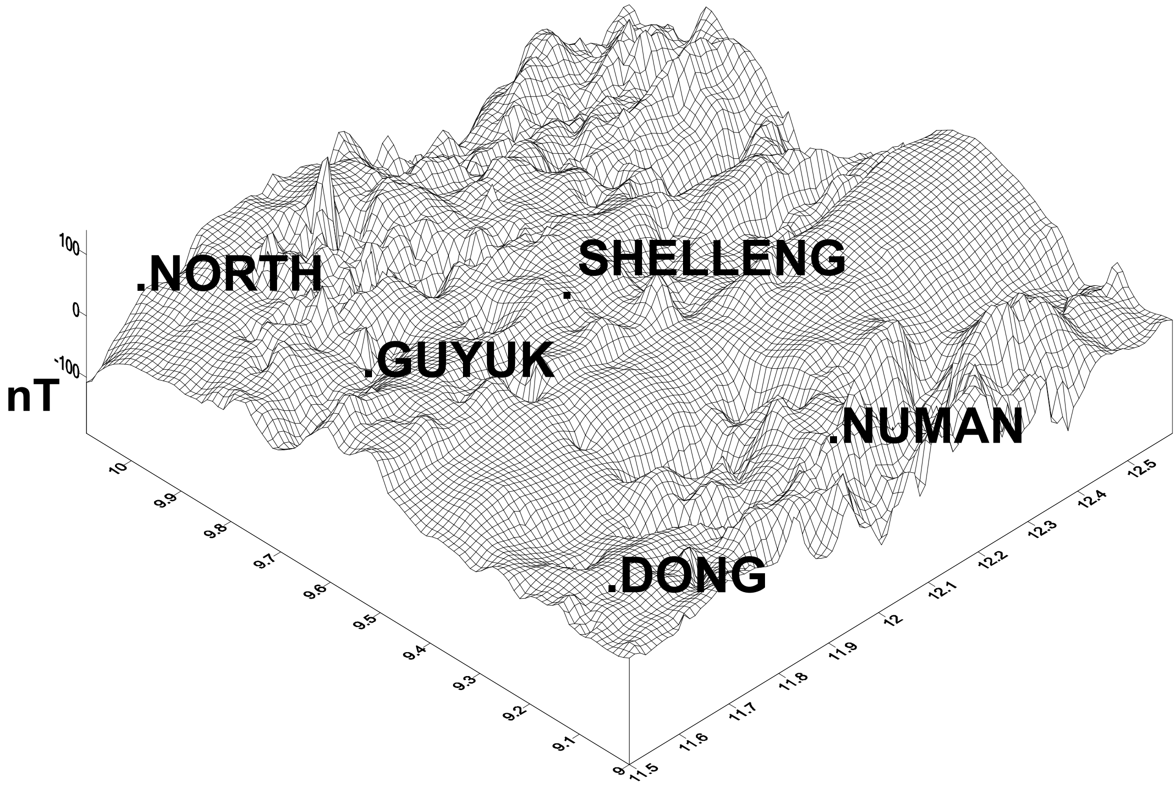

Figure 9: 3-D Residual magnetic anomaly map of the study area

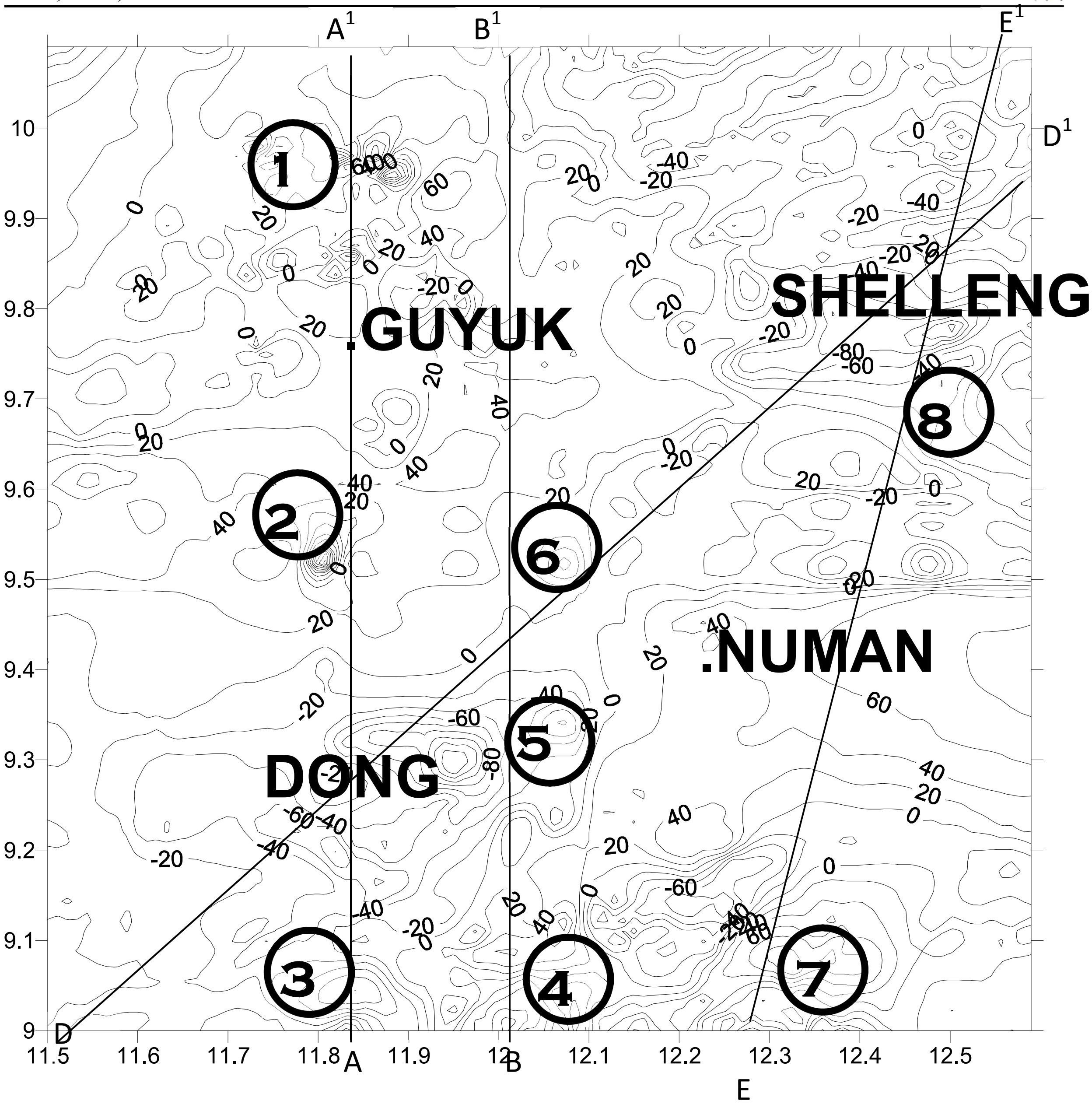

Fig.10: Residual Magnetic Map of the study area With Profiles contoured at 20nT Intervals

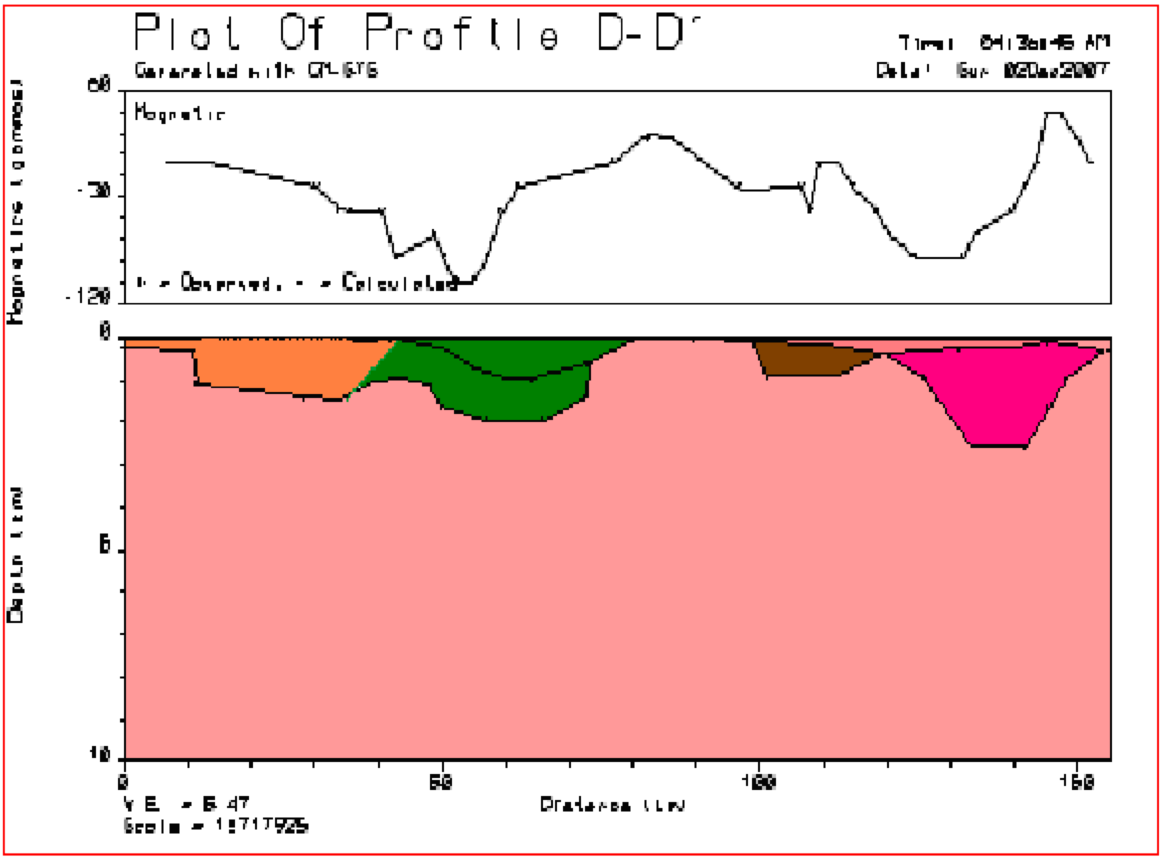

Figure 11: Model profile D-D[1]

LEGEND

Pcg = Porphyritic Granite

Kby = Feldspatic sandstone, clay, shales, calcareous sandstone and shelly limestone

Qa = River Alluvium

Qr = Ugurore Basalt

Pcb = Gneiss-Migmatite (complex)