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Original Research Article

Structural Analysis of Selected Ring Complexes in Some Parts of the Nigerian Younger Granite Provinces

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Abstract

The study area falls within the basement complex of northcentral Nigeria and covers four adjacent quarter degree sheets of 126 (Ririwai), 127 (Kalatu), 147 (Lere) and 148 (Toro) in some parts of Kaduna, Bauchi and Plateau States, Nigeria. This paper is aimed at interpreting the Aeromagnetic data to delineate structures in some parts of the Nigerian younger granite province. This was achieved by determining depth to basement, and developing a 2D model of the shape, location and depth of structures in some parts of the younger granite province. The anomalies on the aeromagnetic map were defined by fitting a first order polynomial to the total fields, by the method of least squares to obtain the residual field data. First vertical derivative and analytic signal computed, defined distinct pattern of the magnetic signatures. Depths to the source of the geologic structures where obtained from Werner and Euler deconvolution solutions which gives an average depths range of 231.2 m to 1040 m, with very few solutions having depths less than 200 m, the most prominent structure particularly the Ririwai ring complex have a depth range of 337.5 m to 465.5 m. The depth to basement for Werner solution ranged from 60 m to 420 m and the depth to basement of the contact model is shallow with depth of (60 to 420m) as compared to the dike model (200 to 420 m).

Keyword: Werner Deconvolution; Euler Deconvolution; Analytic Signal; Model; Vertical derivatives; Younger Granite; Ring Complex.

INTRODUCTION

1.1 Introduction

The topography of Nigeria is influenced by planar and linear structures resulting from ductile and brittle deformational events [15]. The structures generally have N-S, NE-SW, NW-SE and sometimes E-W trends [23]. Regional strikes of foliations in basement rocks, lithologic boundaries, fold axes and axial planes maintain the N-S Pan-African imprint.

The younger Granite province of Nigeria occupies an area of about 22,000km^2 and is located in the central part of Nigeria. The Younger Granite are a set of Jurassic ring complexes of Pre-Cambrian age. About forty ring complexes have been reported to date and these are scattered over much of the central plateau region of Nigeria with a few located on the fringes of Benue Trough [16]. The Younger Granite are typically circular to elliptical in outline and have diameters which range from 10km to 25km. They are often composed of outer ring dyke of fayalite granite porphyry which surround down- faulted volcanic and basement rocks as well as an inner core of composite granitic intrusion [6]Younger Granite contains important precious minerals such as cassiterite, beryllium, columbite, ryanite, silimanite and other accessory minerals of economic importance. Nigeria's tin field which are among the most important in the world are closely associated with younger granite province. The ages of the granite decreases from North to South [22].

However since geologic features are often large, structural analyses are conducted on regional scales, to provide a comprehensive look and a concise information about the extent of faults, folds, lineaments and other structural features. These therefore require small-scale imagery to cover the extent of the element of interest. This study is intended to obtain information about the depths to magnetic sources, their orientation, shape and sizes. Thereby helps in gaining better insight of the structural set-up in the area.

2.1 Geology of the study area

The study area constitutes the western part of the Younger Granite Complex of North Central Nigeria which range from longitude 10º 00' E to 11º 00' E. and latitude 8º 30' N to 9º 30' N, and comprises the Nigeria geological survey sheets 126 (Ririwai), 127 (Kalatu), 147 (Lere) and 148 (Toro) in some parts of Kaduna, Bauchi and Plateau States, Nigeria.

The Younger Granite Province comprises of Precambrian to Lower Paleozoic basement rocks into which the Younger Granites suites are emplaced [18]. The basement rocks cover about three quarters of the province and consist of ancient sediments [18]. [12]. Gravity surveys carried out by Ajakaiye [2] across the Younger Granite province show negative Bouguer anomalies ranging from -94 to -25m Gals, Four major oceanic fracture zones cut the Atlantic coast to the northeast on approaching the coast of Guinea at the north and terminated at a relatively short distance inland [9,11]. They seem to have developed near pre-existing zones of weakness inherited from previous orogenic activities in the continents [16].

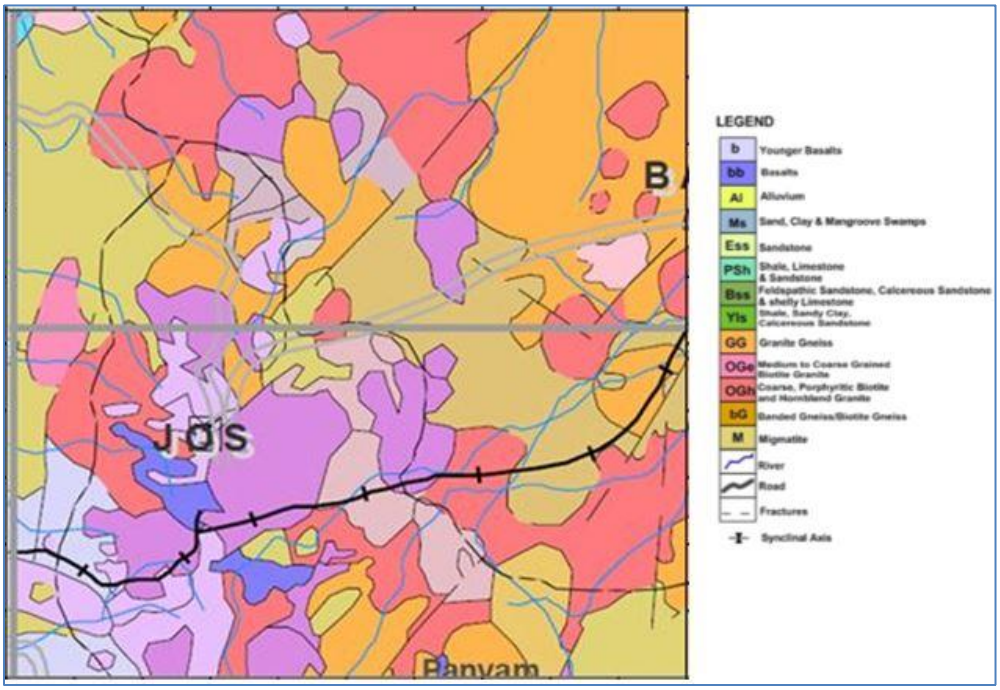

Fig-1.1: Geology Map of the study area

2.2 Data acquisition

Four High Resolution Aeromagnetic data of sh eet 126 (Ririwai), 127 (Kalatu), 147 (Lere) and 148 (To ro) which range from longitude 10º 00' E to 11º 00' E. a nd latitude 8º 30' N to 9º 30' N This data which covers t he entire study area were purchased from Nigerian Geol ogic Survey Agency (NGSA), which are on a scale of 1: 100,000. This data was acquired at a flight altitude of 8 0m, along NE-SW flight lines spaced approximately 50 0m apart.

3.0 METHOD

3.1 Data enhancement

Qualitative interpretation techniques in magnetic survey helps to apply a series of enhancement filters particularly the vertical gradient filters of magnetic anomaly. Enhancement of magnetic data is very important in the study of structural features because it enhances the edges of anomalies. The first vertical derivative (FVD) is represented by:

$$FVD = \frac{\partial M}{\partial z}, \qquad (3.1)$$

Where M represents the potential field anomaly. The vertical derivative was computed from the upward continuation map at (250m). This is very important to this research as it enhances linear features and sharpens the response of the target structures of the magnetic anomaly.

3.2 Upward continuation of residual field

This usually is a mathematical technique that helps project data at a particular elevation to a higher elevation. It is a filtering technique that removes noise caused by high frequency shallow anomalies which usually arise from near surface cultural features in the survey area [6]. The upward continued ΔF (the total field magnetic anomaly) at higher level (z = - h) is given by:

$$\Delta F\ (x, y, -h) = \frac{\mathrm{h}}{2\pi} \iint \frac{\Delta F(x,y,0)dxdy}{((x-x^0)^2+(y-y^0)^2+h^2)} \qquad (3.2)$$

The empirical formula [3] gives the field at an elevation h, above the plane of the observed field (z = 0) in terms of the average value ΔF at the point (x, y, o).

3.3 The Analytic Signal Technique

The analytic signal is a complex function formed through a combination of the horizontal and vertical derivatives of the magnetic anomaly. In 3D, the analytic signal of the magnetic anomaly field T is defined as:

$$A(x, y, z) = \frac{\partial T}{\partial x}\hat{x} + \frac{\partial T}{\partial y}\hat{y} + i\frac{\partial T}{\partial z}\hat{z} \qquad (3.3)$$

Where $\hat{x}$, $\hat{y}$ and $\hat{z}$ are unit vectors in the x, y and z directions, respectively $\frac{\partial T}{\partial z}$ is the vertical derivative of the magnetic anomaly field intensity, $\frac{\partial T}{\partial x}$ and $\frac{\partial T}{\partial y}$ are the horizontal derivatives of the magnetic anomaly field intensity [9].

The amplitude of the analytic signal in 3D is given by:

$$|A(x, y, z)| = \sqrt{\left(\frac{\partial T}{\partial x}\right)^2 + \left(\frac{\partial T}{\partial y}\right)^2 + \left(\frac{\partial T}{\partial z}\right)^2} \qquad (3.4)$$

3.4 Depth estimation of Magnetic source using Werner and Euler Deconvolution Method

To obtain the approximate depth to the source of the anomalies, Both Werner and Euler deconvolution method was applied to the residual field data. This technique provides automatic estimates of source location and depth. Therefore, Euler deconvolution is both a boundary finder and depth estimation method. Euler deconvolution is commonly employed in magnetic interpretation because it requires only a little prior knowledge about the magnetic source geometry, and more importantly, it requires no information about the magnetization vector [12, 9]. Euler deconvolution is based on Euler's homogeneity equation [12], showed that Euler's homogeneity relation could be written in the form:

$$(x - x_0)\frac{\partial T}{\partial x} + (y - y_0)\frac{\partial T}{\partial y} + (z - z_0)\frac{\partial T}{\partial z} = N(B - T), \qquad (3.5)$$

Where *B* is the regional value of the total magnetic field and x_0,y_0, and z_0 is the position of the magnetic source, which produces the total magnetic field *T* measured at x,y,z. *N* is called structural index. For each position of the moving window, an over-estimated system of linear equations is solved for the position and depth of the sources [12, 9].

The Werner deconvolution uses horizontal and vertical derivatives to calculate depth to the magnetic anomalies. The Werner deconvolution function assumes the source bodies to be either dikes or contacts with infinite depth extent and uses a least-squares approach to solve for the source body parameters in a series of moving windows that moves along the profile and continually solves for the four unknown parameters [20].

Considered a dike with infinite strike length and depth extent, the total anomalous field F(x) at a distance x along a measuring line perpendicular to the dike's strike, to the surface point (x_o) directly above the centre of the top of the dike, can be expressed in the form as.

$$F(x) = \frac{A(x - x_o) + BZ}{(x - x_o)^2 + Z^2} \qquad (3.6)$$

Where x_o is the surface point directly above the centre of the top of the dike, x is the measurement point and x-axis is normal to the strike, and z is the depth to the top. A and B (to be determined) are functions of the dike's geometry and mineralization [20].

3.5 2D Forward Modeling

In order to create or predict a geologic model for an area, measurements are taken so that a set of desired parameters such as location or size of a body or distribution of physical properties might be inferred. After these parameters have been inferred, the goal is to arrive at a representative model which is a best estimate of the parameters. Model, particularly as it concerns earth sciences and Physics can be described as a geological representation of geophysical data. The Oasis montaj GM-SYS (5.1) module which is based on the algorithm described [13, 21] was used for this research.

4.0. RESULTS

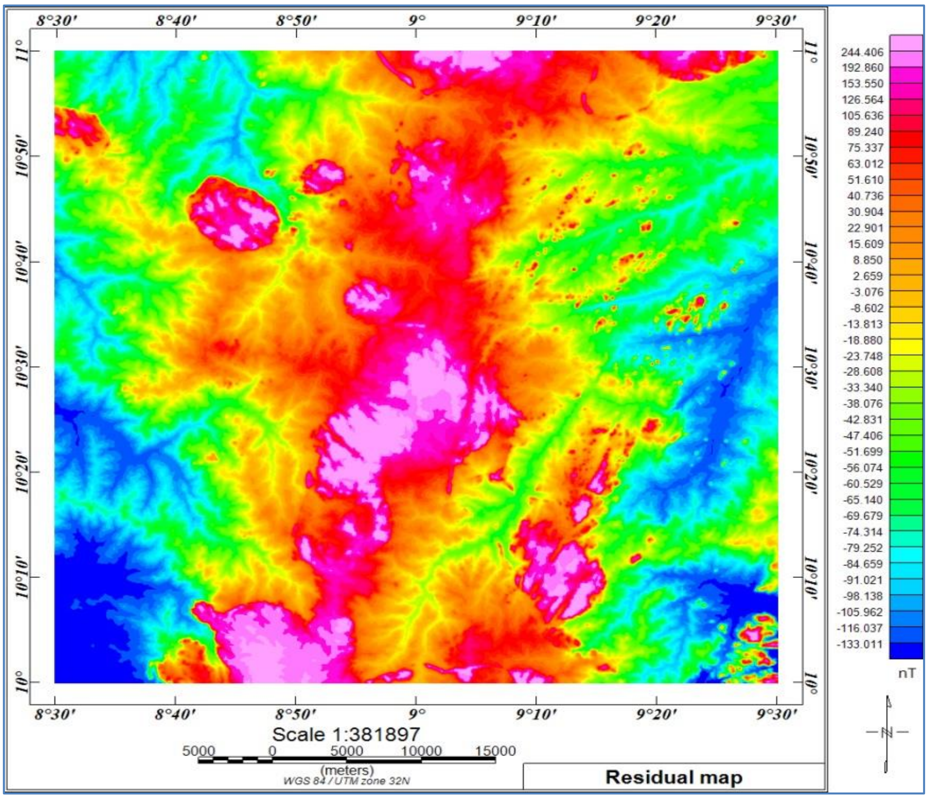

Fig-4.1: Residual Magnetic Intensity grid

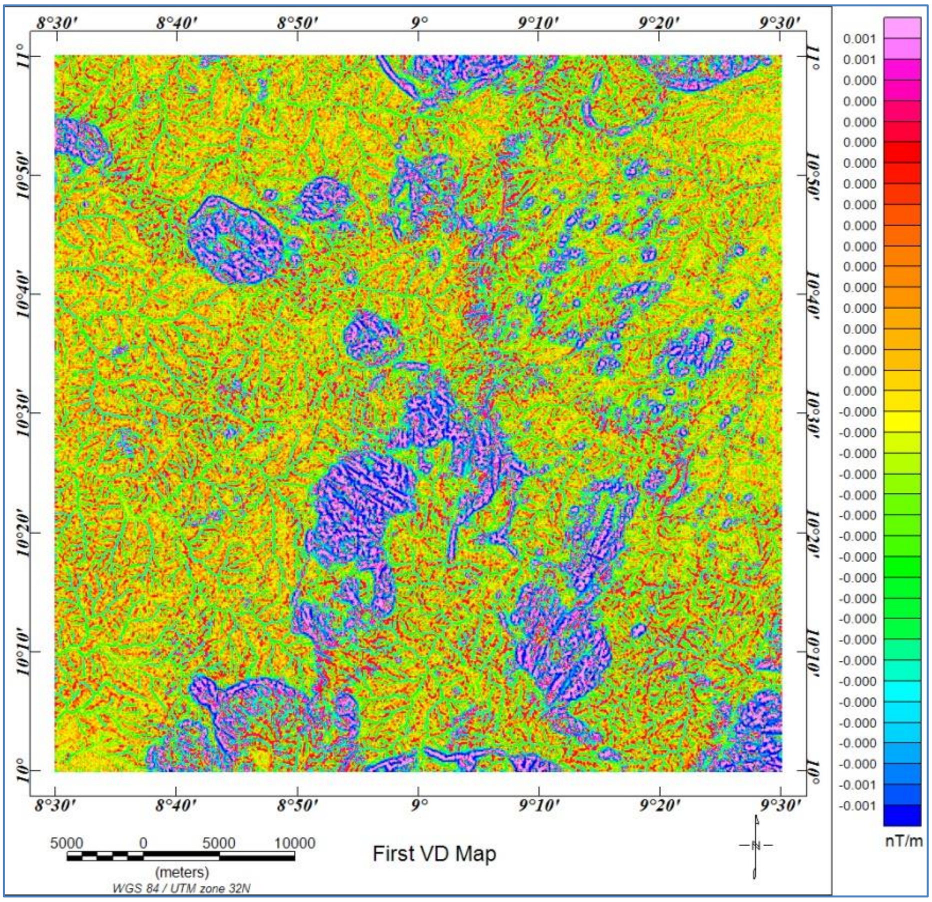

Fig-4.2: First vertical derivative map

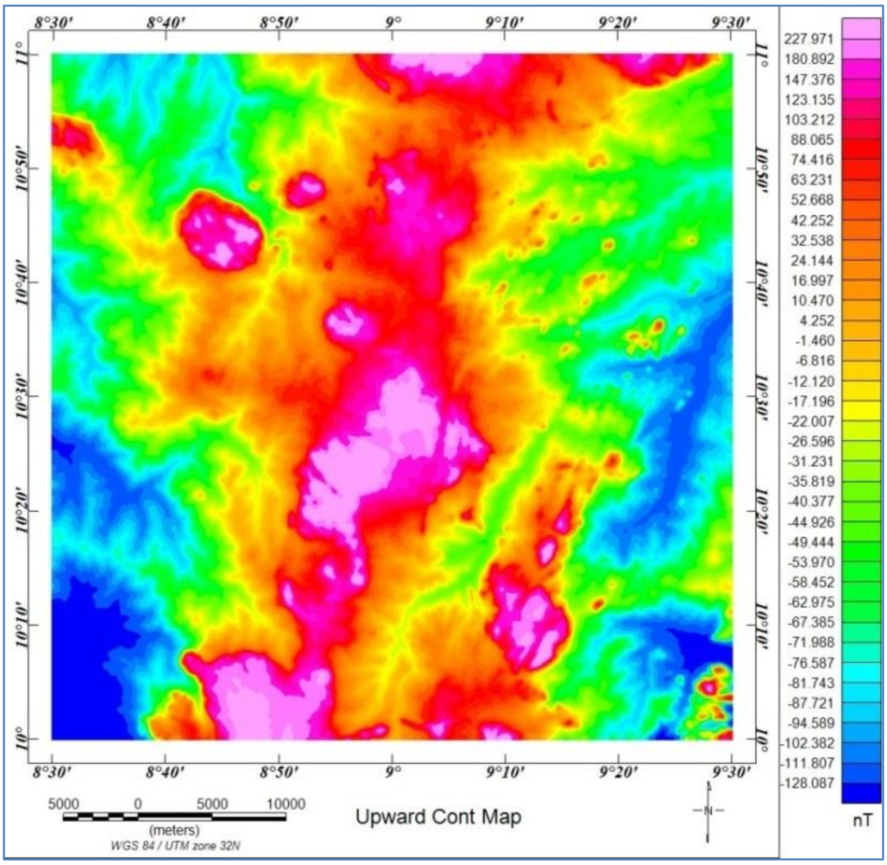

Fig-4.3: Upward continued map

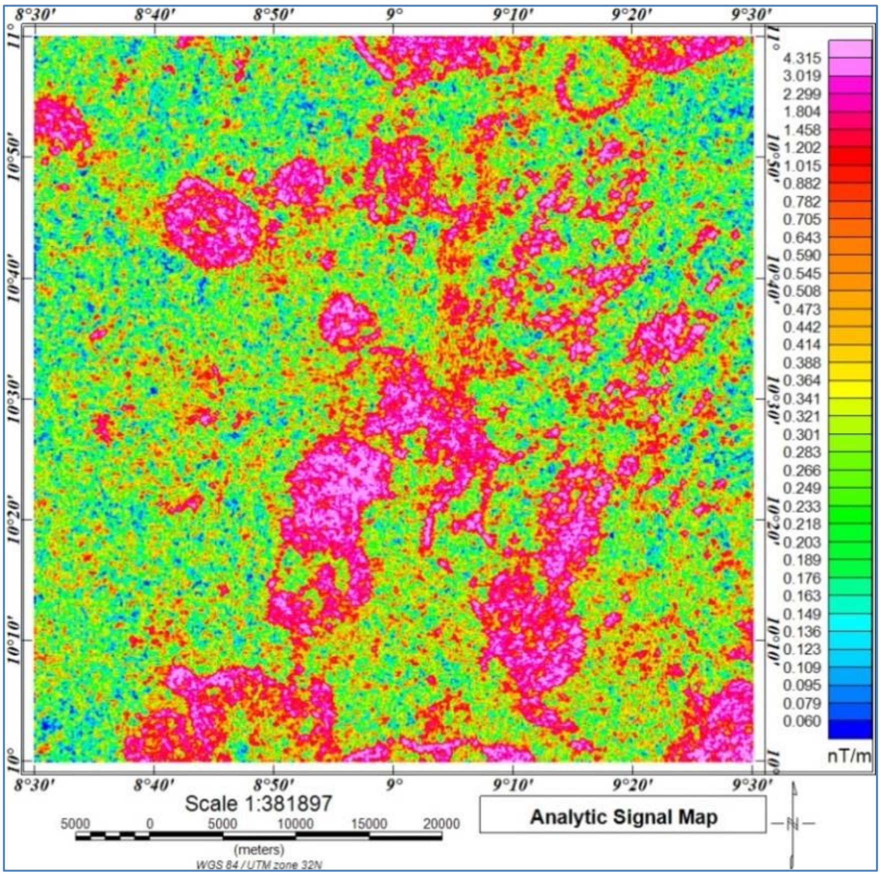

Fig-4.4 Analytic Signal map of the area

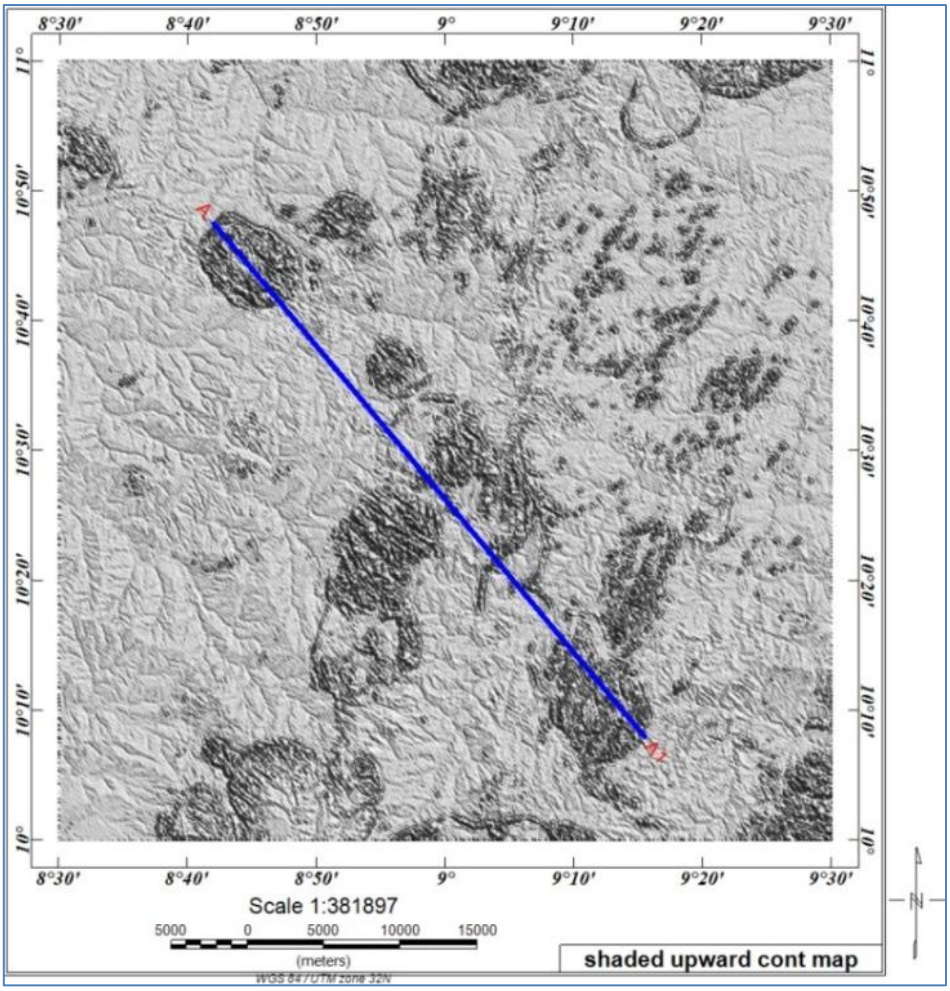

Fig-4.5: Shaded map indicating profile A-A1

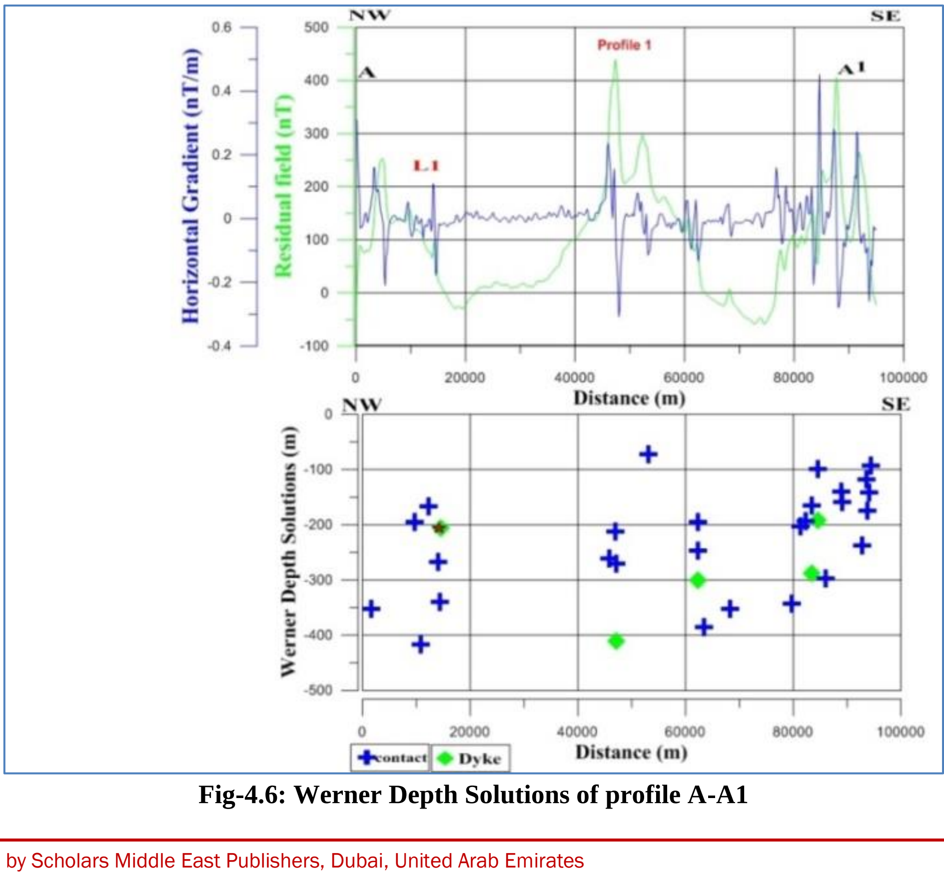

Fig-4.6: Werner Depth Solutions of profile A-A1

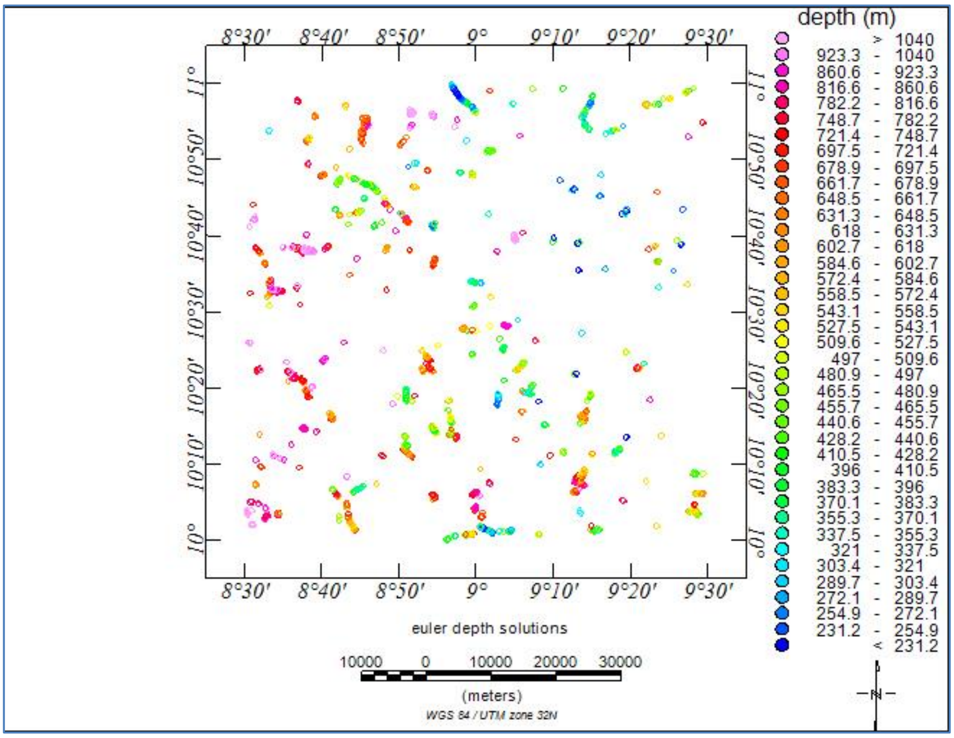

Fig-4.7: Euler Depth Solutions

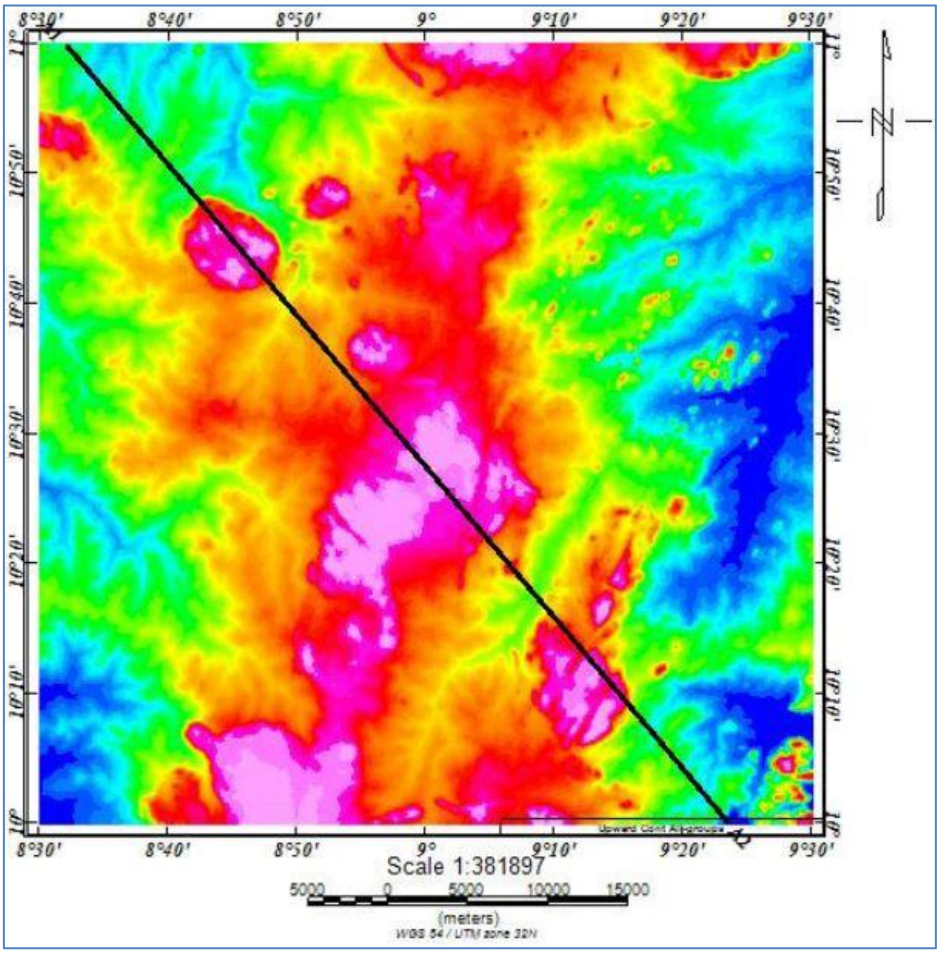

Fig-4.8: Profile A1-A2 Modeled Profile

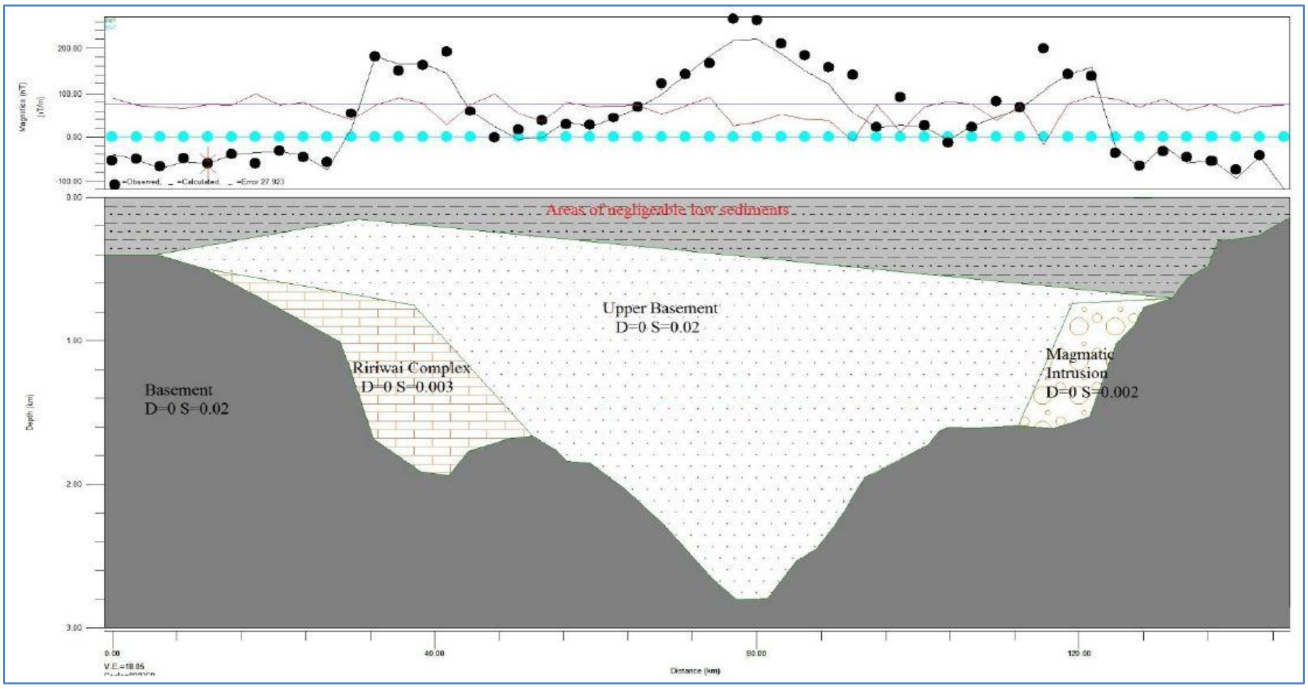

Fig-4.9: Modeled Profile Map

1.0 DISCUSSION OF RESULTS

4.1 Regional and Residual Separation of Magnetic Anomalies

This interpretation commences with some procedure that separates the smooth, presumable deep-seated regional effects from the observed field so as to obtain the residual effects, which are the anomalies of geological interest. The regional magnetic fields are large features which generally show up as trends and continue smoothly over very considerable areas, and they are caused by deeper homogeneity of the earth's crust [7]. The residual magnetic intensity map shown figure (4.1), was computed using Oasis Montaj software.

4.2 Data enhancement

First vertical derivatives were used in this research to enhance the upward continued field data, the first vertical derivative map is shown in figure (4.2) which corresponds to response of the target structures. The residual field was upward continued to 250m which is about half the inter profile spacing used in collecting the data. This helps remove noise caused by high frequency shallow anomaly. The upward continued field map is shown in figure (4.3).

4.3 The analytic signal map

The analytic signal map produced gives distinct pattern of structural and magnetic signatures in the area. The result obtained shows the orientation of the Ririwai ring complex. The map shows high analytic signal amplitude most prominently around the east-west flank, with medium to low analytic signal along the south western part of the area. To know the source positions of the magnetic anomaly regardless of direction and remnant magnetization in the sources, the analytical signal filter was applied to the RMI grid. Figure (4.4) shows the computed analytic signal map of the study area.

4.4 Werner and Euler depth estimation

In this work, we applied the Werner and Euler method on the Residual Magnetic Intensity grid using the Euler 3D extension module of the Oasis Montaj software for Euler solutions. The best clustering solution was obtained by selecting a structural index of one (i.e. SI = 1) (Figure 4.7). shows that the solution plotted clustered around the region where the geological structures are located with average depths range of 231.2 m to 1040 m, with very few solutions having depths less than 200 m, the most prominent structure particularly the Ririwai ring complex have a depth range of 337.5 m to 465.5 m. To estimate the depth to magnetic bodies, dip (orientation) and susceptibility (intensity) of the causative body, Werner deconvolution technique was employed when the sources are assumed to be dike and contact. The profiles were taken perpendicular to the strike direction of the anomaly to obtain the best estimate of the body's parameter from the selected profile Figure (4.5), the profile A-A^1 (Fig 4.5) is a 93 km section of a flight line which cuts across the Ririwai ring complex and other two prominent structures in the area and runs NW – SE. For profile A-A^1, 32 solutions were generated for the constrained depth solutions as shown in (Fig. 4.8), with the dike model and the model for the contact generating 5 and 27 solutions respectively. The depth to basement of A-A^1 ranged from 60 m to 420 m and the depth to basement of the contact model is shallow with depth range of (60 to 420m) as compared to the dike model (200 to 420 m). Both the Werner and Euler results agree considerably with the depth range and location of most of the structures particularly the Ririwai ring complex with almost the same depth range for all magnetic signatures in the area.

4.5 Modeling

Profile (A-A2) Figure (4.8) is the modeled profile; it is a 150-km section of a flight line. The choice of this profile is based on observations from Figure (4.8) which depicts that profile (A-A2) is perpendicular to the Ririwai ring complex along the southwestern part of the study area at a distance of 40-km, and a structure along the northeastern part at a distance of 120-km as shown in Figure (4.9). The depth estimate, magnetic susceptibility and dip of the source body obtained from profile (A-A2) are 166m, 95.8 degrees and 0.0004327SI respectively. Furthermore, a rock sample collected from the Ririwai ring complex was measured and found to have a magnetic susceptibility of 0.003 SI. These parameters were used as guide to produce a 2D forward model Figure (4.9) of the area.

5.0 CONCLUSION

The aeromagnetic data proved valuable in the delineation of most of the structures in the area. The depth to basement obtained ranged from 60 m to 420 m and the depth to basement of the contact model is shallow with depth range of (60 to 420m) as compared to the dike model (200 to 420 m). Both the Werner and Euler results agree considerably with the depth range and location of most of the structures particularly the Ririwai ring complex with almost the same depth range for all magnetic signatures in the area.

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