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STRUCTURAL CLASSIFICATION USING AEROMAGNETIC DATA AND PSEUDOGRAVITY TRANSFORMS: A CASE STUDY OF PATEGI AREA OF BIDA BASIN, NIGERIA.

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ABSTRACT

The structural classification with 3D Euler deconvolution method in the Pategi area, a transition environment between the Basement complex rocks of the southwestern Nigeria and the Sedimentary rocks of the Nupe Basin was carried out. It was aimed at identification of the structural features responsible for the hydrogeology and mineralization potentials of the area. This work involves the qualitative and quantitative analysis of aeromagnetic data and pseudogravity transforms using Oasis Montaj™. The 3-D Euler deconvolution of the acquired aeromagnetic data and pseudogravity transforms using Oasis montaj™ software and the geologic information on this area was employed in the structural classification work. The extracted faults and lineament features are mostly trending in the NW/SE and NE/SW directions. Earlier workers have recorded oil seepage within this Sheet (204), which is adjacent to the pegmatite rich Lafiagi area. Also, the abundance of 2D and 3D structures that are commonly associated with gemstones and precious minerals explain why the study area is a prospective mineralized zone.

Key words: Euler Deconvolution, Transition, Hydrogeology, Mineralization, Lineaments.

INTRODUCTION

The Gravity and Magnetic (GM) techniques have been employed worldwide by geoscientists to explore for oil and solid minerals which abound in the subsurface structures of the earth. The use of Euler deconvolution as an interpretation tool to determine source location of potential field anomalies is well established (Mushayandebvu et al. 2004). Other methods for structural study include: 2D Forward modeling and inversion (Talwani and Heirtzler, 1964); the estimation of the structural index (Barbosa et al. 1999) amongst others.

The Study Area

The study area covers Pategi (Sheet 204) in the transition environment of Bida Basin and the Southwestern Nigerian Basement Complex. The study area is bounded by latitudes $8^{\circ}30'$ and $9^{\circ}0'$ N and longitude $5^{\circ}30'$ and $6^{\circ}00'$ E with an area extent of approx. 3190 km^2 (Fig. 1). The vegetation is of the Guinea savannah type with two distinct seasons (rainy and dry). The Bida Basin is a NW-SE trending embayment perpendicular to the main axis of the Benue Trough and the Niger Delta Basin of Nigeria.

Sequel to the oil seepage within this Sheet, a preliminary geological mapping and prospectivity study of this basin as well as geochemical analysis of drilled wells and outcrops was carried out by earlier workers (Obaje et al. 2013). The thin sedimentary cover overlying the Basement rock in this transition environment is said to be responsible for the low depth to sources along magnetic profiles (Megwara and Udensi, 2014).

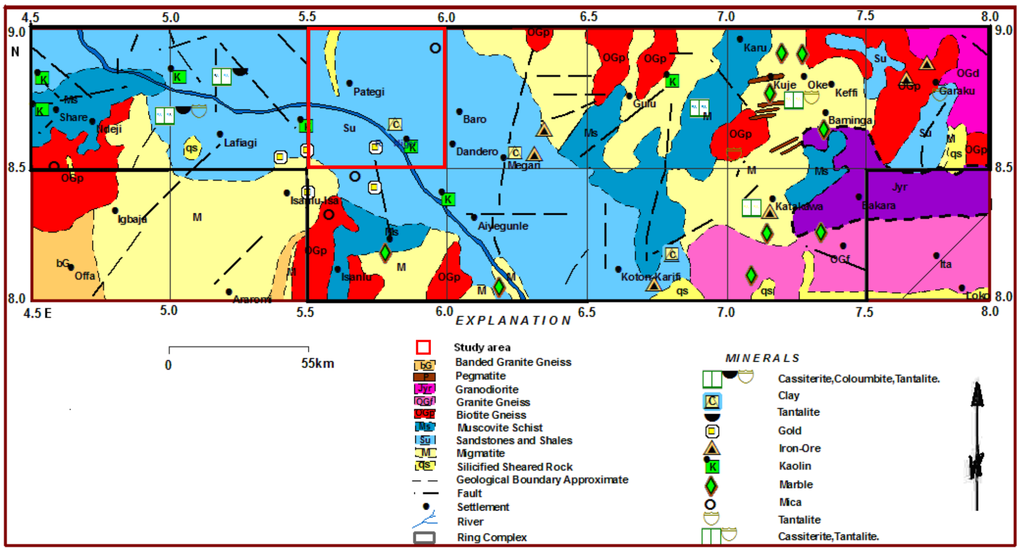

Figure 1: Geological and Mineral Map of the Survey Area (Adapted from Megwara and Udensi, 2014)

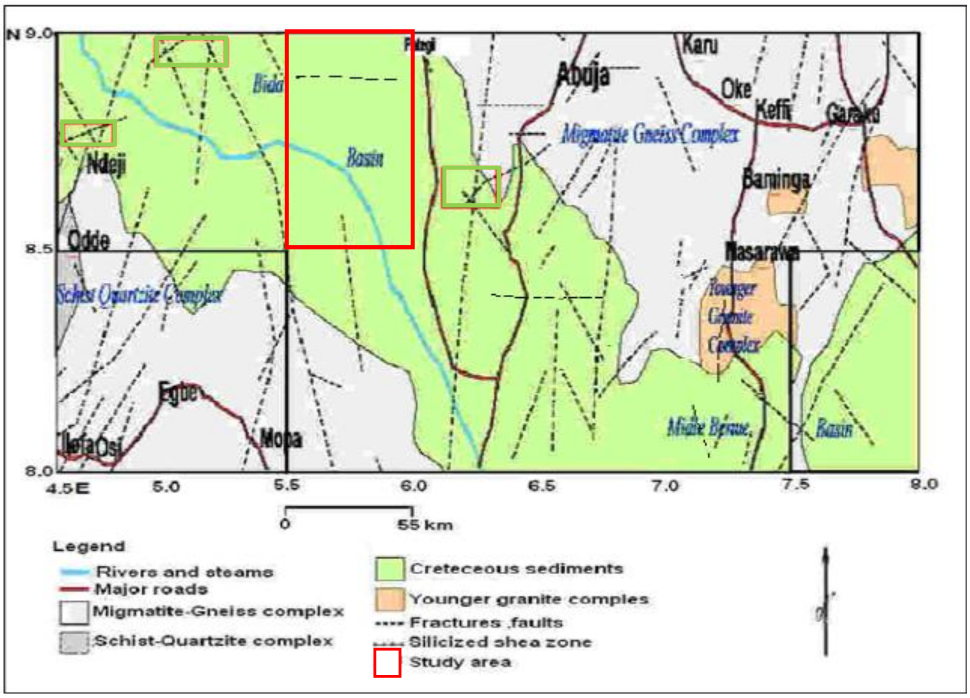

Figure 2a: Lineament Map of Pategi Study Area (Adapted from Udensi and Megwara, 2014).

The present study has been carried out to identify the structural features responsible for the hydrogeology and the prospective mineralized zones of the Pategi area of Bida Basin using 3D Euler deconvolution method.

Structural Geology and Hydrogeology

Megwara and Udensi (2014) have revealed the presence of lineaments within the Bida basin. The study area has lineaments trending northwest-southeast and east-west (Fig. 2a). The basin has also been confirmed to be bounded by a system of linear faults trending NW-SE, using geophysical data (Kogbe et al. 1983). In the Crystalline Basement Complex rocks of Nigeria, groundwater occurs either in the weathered mantle or in the joint and fracture systems in the un-weathered rocks (Ako and Olorunfemi, 1989 and Olayinka and Olorunfemi 1992). According to Bello and Makinde (2007), "the aquiferous zones in the sedimentary environments are primarily found within the Nupe Sandstone Group in the Northern and Central parts of the Edu and Pategi LGA".

MATERIALS AND METHODS

Data Source and Analysis

The soft copy of digital aeromagnetic data (i.e. Pategi, Sheet 203), was procured from the Nigeria Geological Survey Agency (NGSA), Abuja, Nigeria. The survey which was aimed at mineral and ground water development through improved geological mapping was collected at a nominal flight altitude of 80 m, flight line spacing of 500 m, and tie line spacing of 2000 m. The Flight Line direction was NW - SE whereas the Tie Lines were NE - SW. For ease of processing, the data was stripped of a common value of 32,000 nT. Data collection for this area was done in 2006, so a 2005 epoch International Geomagnetic Reference Field (IGRF) was used to calculate Inclination and Declination as follows: Field Strength = 33129.9632nT; Inclination = -6.87339275; Declination = -2.51357917.

Figure 2b is the Reduced Aeromagnetic Intensity map of the study area. The map emphasizes the intensities and the wavelengths of the local anomalies that reveal information on the geometry, strike, contacts between rocks and intensities of magnetization within the study area. The 3D Euler deconvolution technique permits the use of TMI grid, a gravity grid, or the first vertical derivative of these grids as the starting grid (Whitehead and Musselman 2005).

The 3D Euler Deconvolution Method:

The 3D Euler deconvolution technique is an equivalent method based on the Euler's homogeneity equation as developed by Reid et al. (1990) following Thompson's (1973) suggestion and operating on gridded magnetic data. The equation relates the magnetic field and its gradient components to the location of the source, with the degrees of homogeneity n, which may be interpreted as a structural index (Thompson 1982). The structural index (SI) is a measure of the rate of change with distance of the field (Whitehead and Musselman, 2005). The SI of 0.0, 2.0 and 3.0 (magnetic) and 0.0, 1.0 and 2.0 (gravity) represent step, pipe and sphere respectively. The correct SI for a given feature is that which gives the tightest clustering of solutions.

The 3-D Euler Deconvolution processing routine of the Oasis Montaj^{TM} is a semiautomatic location and depth determination software package for gridded magnetic and gravity data. The Euler derived interpretation requires only a little a priori knowledge about the magnetic source geometry and information about the magnetization vector (Barbosa et al. 2000).

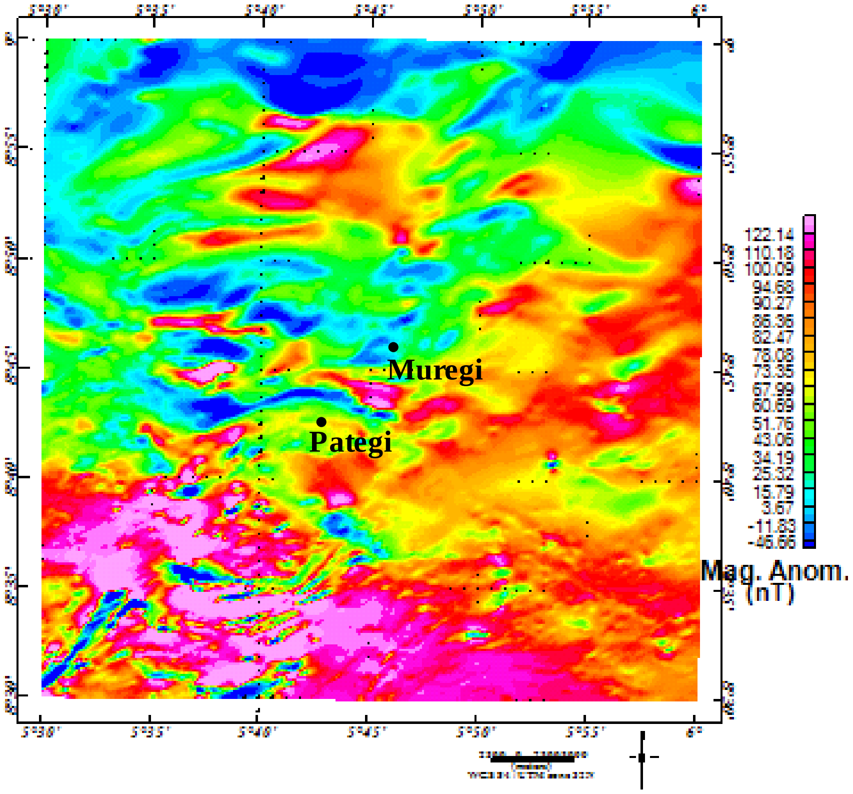

Figure 2b: Reduced Aeromagnetic Map of Pategi (Sheet 204).

Theory of Euler Deconvolution Method:
Any three-dimensional function *f (x,y,z)* is said to be *homogeneous* of degree *n* if the function obeys the expression (Whitehead and Musselman, 2005):

$$f(tx, ty, tz) = t^n f(x, y, z) \quad (1)$$

From this it can be shown that the following (known as *Euler's equation*) is also satisfied:

$$x\frac{\partial f}{\partial x} + y\frac{\partial f}{\partial y} + z\frac{\partial f}{\partial z} = nf \quad (2)$$

Thompson (1982) has shown that simple magnetic and gravity models conform to Euler's equation. The degree of homogeneity, *n*, can be interpreted as a *structural index* (SI). Reid et al. (1990) have shown that a magnetic contact will yield an index of 0.5 provided that an offset A is introduced to incorporate an anomaly amplitude, strike and dip factors:

$$A = (x - x_0)\frac{\partial T}{\partial x} + (y - y_0)\frac{\partial T}{\partial y} + (z - z_0)\frac{\partial T}{\partial z} \quad (3)$$

Given a set of observed total field data, we can determine an optimum source location (x_0, y_0, z_0) by solving Euler's equations for a given index n by least-squares inversion of the data.

RESULTS AND DISCUSSIONS

Pattern Interpretation of the Aeromagnetic Data and Pseudogravity Transforms

The Reduced - to - Equator (REDE) aeromagnetic and pseudogravity maps (Figs. 3 and 4) have been divided into four distinct

zones and subzones of various magnetic and gravimetric characteristics. These include:
(i) Zone A which is characterized by low to intermediate magnetic relief (i.e. subzones A1`to A5; Fig. 3) with corresponding high density relief (i.e. subzones A1 to A5; Fig. 4) along the NW-SE axis and in the extreme North of the study area. The anomalies in this zone have amplitudes varying mostly from -39 nT to 86 nT and 0.001 to 0.031 mGal for magnetic data and pseudogravity transforms respectively. Although the whole area is covered by Cretaceous sediment and alluvial deposits (Fig. 1), yet the sediments in this area are not expected to be very thick.

(ii) Zones B and C are characterized by anomalies with moderately high to very high amplitude and occasional low magnetic relief (i.e. subzones B1, B2 and C1; Fig. 3) with corresponding low density relief (i.e. subzones B1, B2 and C1; Fig. 4) in the Northern, Northeastern and Southwestern part of the study area. The NW-SE and NE-SW trends shown by these anomalies are characteristic of lineament features. Their amplitudes vary mostly from 55 to approx. 140 nT and from -0.045 to approx. 0.018 mGal for magnetic data and pseudogravity transforms respectively. The rock here is composed mainly of Cretaceous sediments and alluvial deposits (Fig. 1) and they are expected to be thicker than that of zone A.

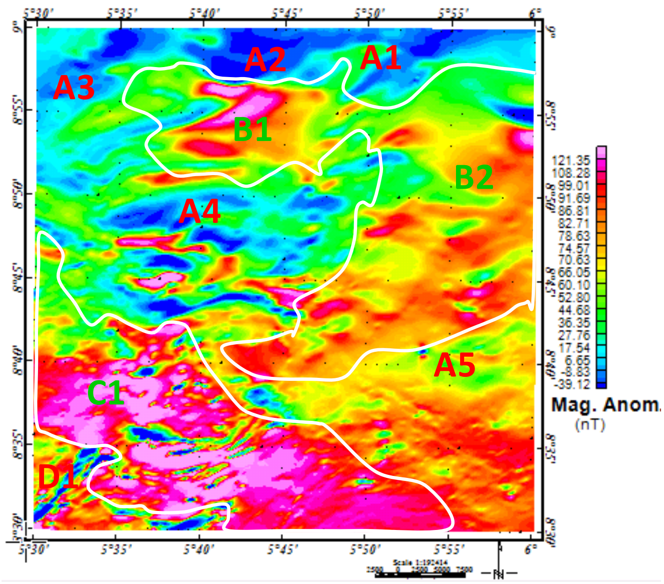

Figure 3: Reduced to Equator (RTE) Aeromagnetic Map of Pategi (Sheet 204).

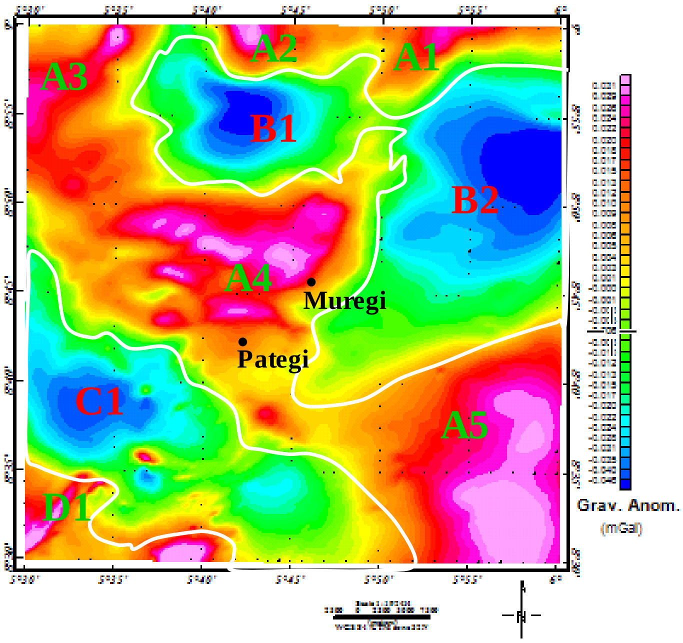

Figure 4: Pseudogravity Map of Pategi (Sheet 204).

(iii) Zone D is characterized by a mixed magnetic (Fig. 3) and moderate to high gravity (Fig. 4) relieves that is characteristic of transition or mixed environment. The amplitudes range from approximately -39 to 86 nT (magnetic) and 0.006 to 0.035 mGal (pseudogravity).

Zone Coloured Euler Solutions for Different Geologic Structures

Figs. 5 – 9 show the results obtained for structural indices 0.0 to 3.0 (i.e. faults with large depth to sphere model; magnetic), representing the different geologic structures. Fig. 5 shows the result obtained for structural index of 0.0 (i.e. deep seated faults/step, dyke and sill model; magnetic) while Fig. 6 shows the result obtained for structural index of 0.5 (i.e. near surface faults/step, dyke and sill model; magnetic). Some of these solutions which are intra-sedimentary or intrusive cluster in a linear manner on the map. The faults are mostly oriented in the NW/SE or NE/SW direction typical of the post-PanAfrican structures.

The structural index of 0.5 has been used to map fault/lineament features and/or structurally controlled drainages (Olawuyi et al. 2015). Fig. 7 shows the result obtained for structural index of 1.1 (i.e. dyke/ribbon model; magnetic). Fig. 8 shows the result obtained for structural index of 2.0 (i.e. deep seated dyke/ribbon and sill model; magnetic). The structural index 2.0 (magnetic) of 3D Euler deconvolution has been used worldwide to detect or explore for Kimberlite pipe which is well known for hosting large quantity of minerals (diamonds and garnet) and rocks (peridotite and xenoliths) (Paterson et al. 1991, Yaghoobian et al. 1992, see also Olawuyi et al. 2016). Figure 9 shows the result obtained for structural index of 3.0 (i.e. sphere or dipole model; magnetic).

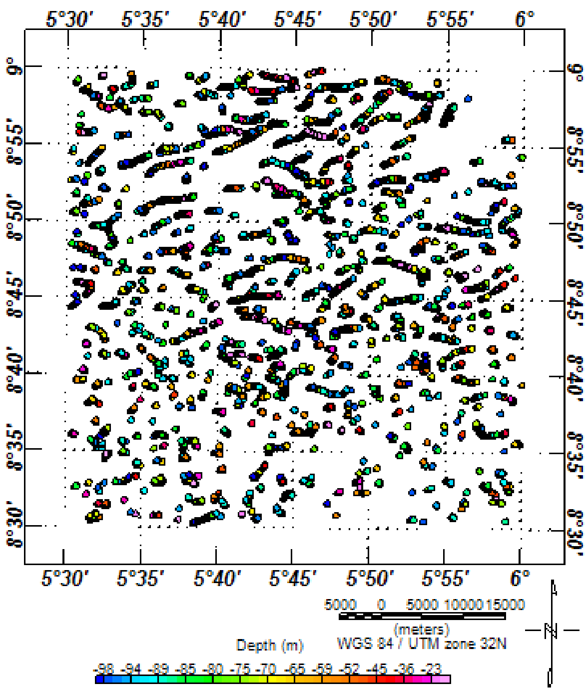

Figure 5: Magnetic (REDE) Euler Solution Map for Deep Seated Fault (SI = 0.0)

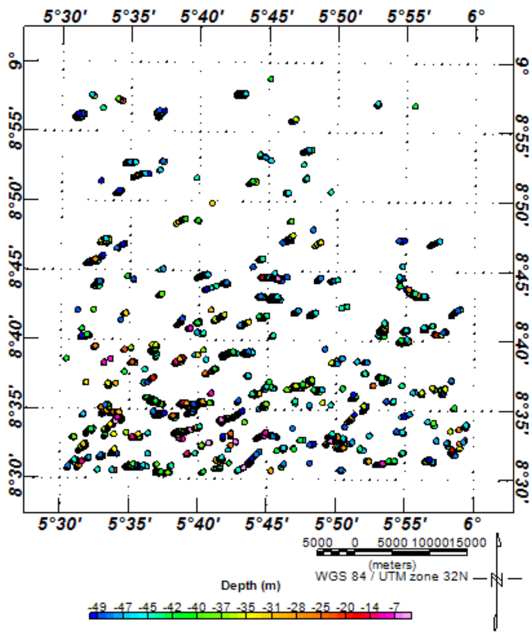

Figure 6: Magnetic (REDE) Euler Solution Map for Near Surface Fault (SI = 0.5)

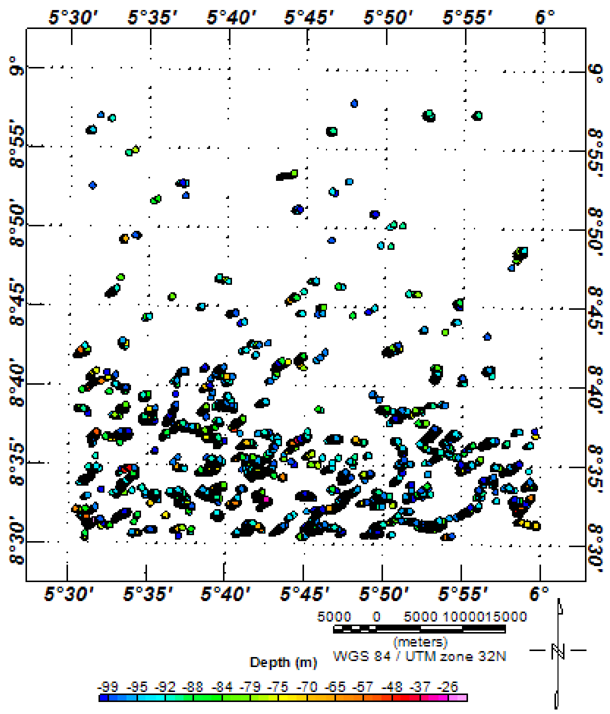

Figure 7: Magnetic (REDE) Euler Solution Map for Deep Seated Dyke/Ribbon (SI = 1.1)

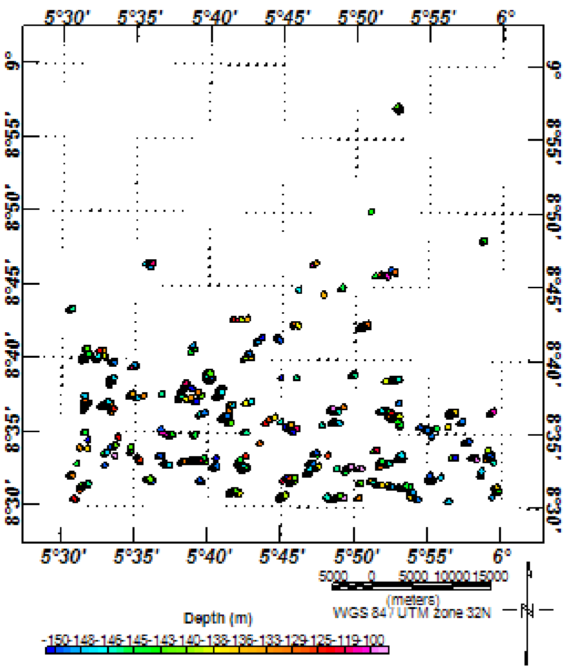

Figure 8: Magnetic (REDE) Euler Solution Map for Deep Seated Dyke/Ribbon and Sill (SI = 2.0)

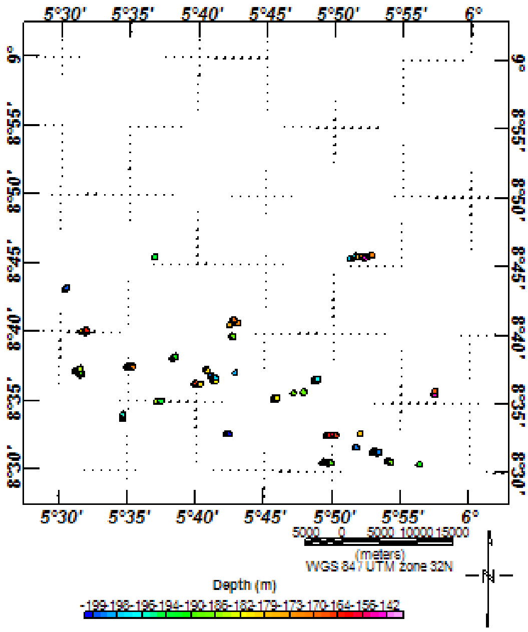

Figure 9: Magnetic (REDE) Euler Solution Map for Sphere (SI = 3.0)

The structural index 3.0 (magnetic) of 3D Euler deconvolution has been used worldwide to detect or explore for tanks and drums (or metalliferous bodies) (Yaghoobian et al. 1992, Marchetti and Settimi, 2011, see also Olawuyi et al. 2016). Many of these pipe-like and spherical features cluster in a circular manner and are found mostly at the southern half of the study area, confirming that the area is rich in mineral resources.

Figs. 10 – 13 show the results obtained for structural indices 0.0 to 2.0 (i.e. near-surface and deep seated faults to sphere model; gravity), representing the different geologic structures. Fig. 10 shows the result obtained for structural index of 0.0 (i.e. near surface and deep seated faults/step, dyke and sill model; gravity). The faults are mostly oriented in the NE/SW or NW/SE direction typical of the post-PanAfrican structures. The structural index of 0.0 has been used to map fault/lineament features and/or structurally controlled drainages (Olawuyi et al. 2015). Fig. 11 shows the result obtained for structural index of 0.5 (i.e. ribbon, dyke and sill model; gravity). Fig. 12 shows the result obtained for structural index of 1.1 (i.e. dyke and pipe model; gravity). The structural index 1.1 (gravity) of 3D Euler deconvolution has been used worldwide to detect or explore for Kimberlite pipe which is well known for hosting large quantity of minerals (diamonds and garnet) and rocks (peridotite and xenoliths) (Paterson et al. 1991, Yaghoobian et al. 1992, see also Olawuyi et al. 2016). Figure 13 shows the result obtained for structural index of 2.0 (i.e. sphere or dipole model; gravity). The structural index 2.0 (gravity) of 3D Euler deconvolution has been used worldwide to detect or explore for tanks and drums (or metalliferous bodies) (Yaghoobian et al. 1992, Marchetti and Settimi 2011, see also Olawuyi et al. 2016). Many of these pipe-like and spherical features cluster in a circular manner and are found mostly at the southern half of the study area, confirming that the area is rich in mineral resources.

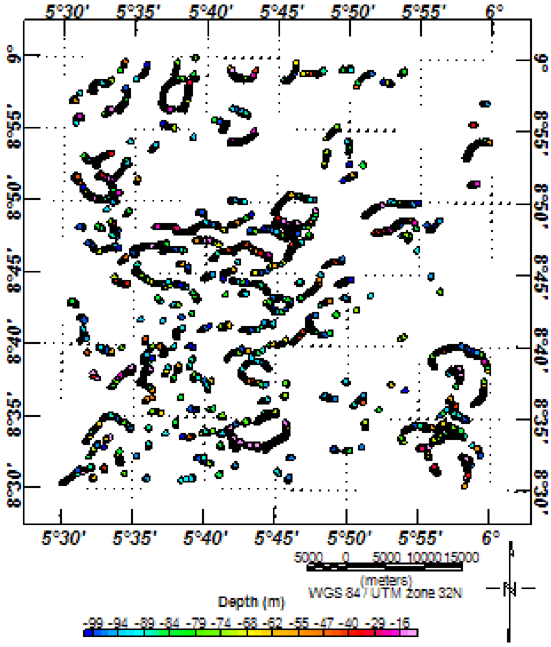

Figure 10: Pseudogravity Euler Solution Map for Near Surface and Deep Seated Fault (SI = 0.0).

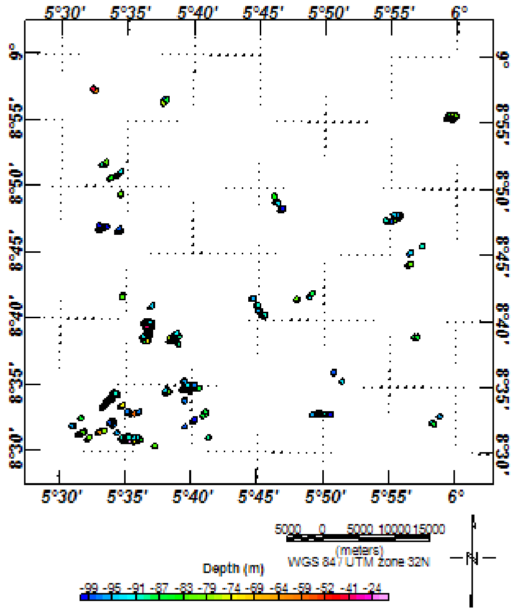

Figure 11: Pseudogravity Euler Solution Map for Ribbon/Dyke/Sill (SI = 0.5)

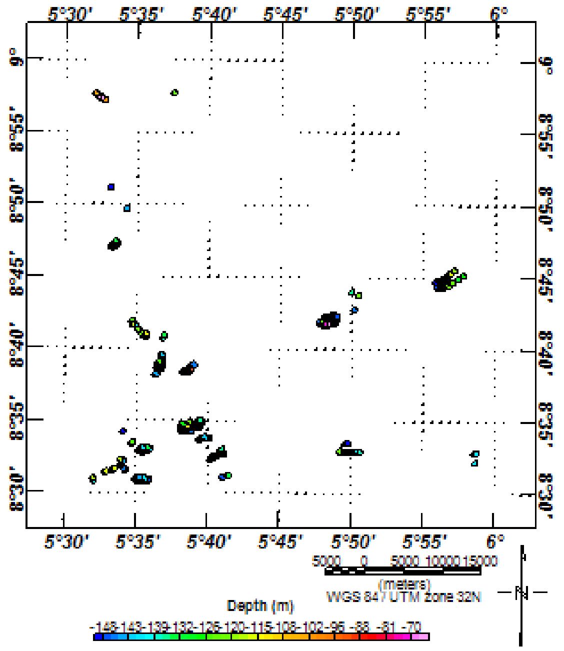

Figure 12: Pseudogravity Euler Solution Map for Dyke and Pipe (SI = 1.1)

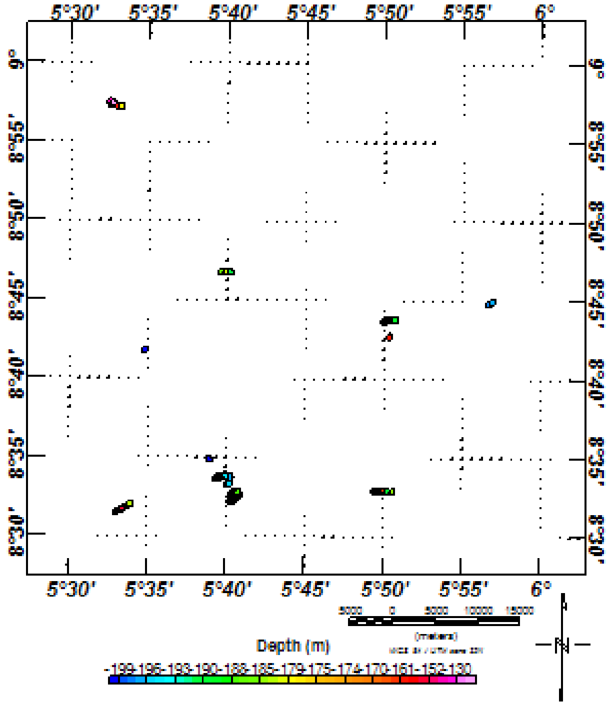

Figure 13: Pseudogravity Euler Solution Map for Sphere (SI = 2.0)

CONCLUSIONS

This research has evaluated the geologic structures within the Pategi Study area using aeromagnetic data and pseudo-gravity transforms. The geologic structures which range from fault/ contact to sphere are found in large quantity in the study area. The lineament features which might have resulted from the reactivation or reworking of the crystalline basement complex region of West- African craton after the Pan-African orogeny (Leblanc, 1981) are generally oriented in the NW-SE or NE-SW direction (Figs. 6, 7 and 10) and correlate with the general geologic strike of the area, corroborating the fact that the Pan African in Nigeria was followed by conjugate strike slip fault systems which averaged in the NE-SW and NW-SE directions (Ball, 1980).

The structural indices of 2.0 (i.e. vertical or horizontal cylinder model; magnetic) and 1.1 (i.e. pipe and dyke model; gravity) of 3D Euler deconvolution have been used worldwide to detect or explore for Kimberlite pipe which is well known for hosting large quantity of minerals (diamonds and garnet) and rocks (peridotite and xenoliths) (Paterson et al. 1991and Yaghoobian et al. 1992) while the structural indices 3.0 and 2.0 (i.e. sphere or dipole model) in magnetic and gravity respectively have been used worldwide to detect tanks and drums (or metalliferous bodies) (Yaghoobian et al. 1992 and Marchetti and Settimi, 2011). The proximity of this area to Lafiagi pegmatite rich zones and the abundance of pipe-like (e.g. Figs. 8 and 12) and spherical (e.g. Figs. 9 and 13) features in the study area confirm the area as a prospective zone for mineral exploration.

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