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Ground Magnetic Survey in Otukpo Area Benue State Nigeria

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Abstract
Ground Magnetic data was obtained along four profiles during a field work lasting three weeks where a G-816 model portable proton magnetometer was used for the survey. The survey was accomplished along a 30km Utoton – Oturkpo road at a sampling frequency of 1km., a 50m sampling frequency was used for Oturkpo – Okpamaja, 15 km traverse, while 1km frequency was used for both Oturkpo –Adoka, a 32 km traverse and Oturkpo –Aliade, a 51.5 Km traverse. High and low frequency components of the profiles were isolated by moving average filters. Depths to magnetic sources were calculated for the resulting high and low frequency anomalies on the profiles. High frequency anomalies were interpreted to arise from narrow steeply dipping dykes or fractures which in some cases are mineralized at shallow depths of about 20m-1.66km while low frequency anomalies were the result of low dipping sills or basement surfaces with a depth range of 1.66-5.006 km. The profile intersecting a broad aeromagnetic east-west anomaly south of Oturkpo is known to be mineralized in veins within sills of dolerite with magnetic susceptibility in the range of 0.299 - 0.34 electromagnetic units. Model direction of magnetization is $10^{0.}$ Sills and dykes dipping southward or northwards within the Asu River Group Formation and Ezeaku formations/ Markudi sandstone underlying the study area are responsible for folding and faulting with associated magnetic anomalies.
Keywords: Magnetic profiles data, modelling, interpretation

1. Introduction

Oturkpo is one of the local government areas in Benue State, North Central Nigeria. The area is covered by sheet 270 of the 1:100,000 scale topographical map published by the Federal Survey Agency of Nigeria. It is bounded by longitude 8^0 00 E to $8^0$30 E and latitude 7^0 00 N to 7^0 30 N respectively.
Oturkpo is underlain by Cretaceous Sediments of the Benue Trough, mainly comprising shale, sandstones and limestone considered to be non-magnetic (Ogah, 2010). These units were extensively mapped regionally by Shell Petroleum Development company as well as the Geological agency of Nigeria and the British geological survey (Macdonald 2001.) Major Santonian deformation is known to give rise to numerous folds, faults and fractures in this area (Benkhelil, 1989). The chain fracture zones were initiated by Crustal Stretching resulting from high thermal conditions attested by intensive magmatic activity and low grade metamorphism (Wright, 1976).
The magnetic data for the study were collected during a three weeks field work in 2009 to complement existing airborne (magnetic and Landsat) data for the area.
Airborne anomaly indications have been so clear and definitive that ground-follow-up (ground magnetic) was limited to defining the major sites, which appeared geologically promising. The geophysical work involved ranging (surveying), clearing and cutting and data collection.

1.1 ***The objective of the survey includes:***

i) To measure variations in magnetic (anomaly) field and to attempt to interpret the magnetic in-homogeneities indicated in terms of geologic detail, relevant to the occurrence and accumulation of existing mineral resource of the area.
ii) To assess the susceptibility of magnet bodies responsible for the anomalies.
iii) The location and delineation of magnetic ore body
iv) To determine altitude, depth to magnetic sources and identify probable geologic structures/fault fractures etc.

1.1 Methodology

1.1.1 The Instrument, Principle and Limitations

Model G-816 portable proton magnetometer was used for the field survey. This instrument measures total field intensity, the accuracy of each measurement is independent of sensor leveling. The inherent simplicity of the G-816 proton magnetometer allows rapid, accurate, high resolution measurements of the field to be obtained from a rugged, compact field instrument. Proton precession magnetometer is so named because it utilizes the precession of spinning protons or nuclei of the hydrogen atom in a sample of hydrocarbon fluid to measure the total magnetic intensity. The processing protons then generate a small signal in the same coil used to polarize them, a signal whose frequency is precisely proportional to the total magnetic field intensity and independent of the orientation of the coil, i.e. sensor of the magnetometer. The proportionality constant which relates frequency to field intensity is a well-known atomic constant, i.e. the gyromagnetic ratio of the proton. The precession frequency, typically 2000Hz, is measured by modern digital counters as the absolute value of the total magnetic field intensity with an accuracy of 1 gamma (Breiner, 1973).

Among very diverse applications of portable magnetometers especially the total proton (nuclear precession) magnetometers are their uses in mineral and petroleum exploration, geological mapping, search for buried or sunken objects, magnetic field mapping, geological research, magnetic observatory use, measurement of magnetic properties of rocks or ferromagnetic objects, paleomagnetism, archaeological prospecting, gradiometer surveying, and magnetic modeling etc.

1.1.2 **Limitations of a Proton Magnetometer**

Several operational restrictions exist, which may be of concern under special field condition. First, the proton precession signal is sharply degraded in the presence of a large magnetic field gradient greater than 200 gammas per foot (approximately 600 gammas per meter). Also small signal can be rendered immeasurable by the effects of nearby alternating current electrical power sources. For this last reason, it is important that the earth's magnetic field is not disturbed by allowing magnetic objects to come close the sensor. Such articles include rings, keys, watches, belt buckles, pocket knives, metal pencils, zipper, some hats, steel chips, magnetic dirt etc.

1.1.2 **Field Procedures**

Prior to survey operation, a number of steps should be performed to correctly tune and turn on the magnetometer. (Guidelines are provided in the operator's manual by manufacturer). The average ambient magnetic field and magnetic inclination used in this work is 33000nT and 10^0 respectively.

To ensure optimum results, the sensor is marked with an arrow and the letter 'N'. The arrow should be roughly pointed north or south. In the field, the North direction for the sensor was used in all the traverses. This procedure allows the sensor axis to be placed perpendicular to the earth's field and produce optimum signal.

During survey operation and after the instrument is turned to the local field intensity, the operator need only depress the READ button and note the reading each time in a field notebook. If a reading is in question, i.e. a sudden shift of several hundred gammas, another reading should be taken. The one count repeatability and sensitivity of the G-816 can always be verified by repeating a measurement with the sensor in the exact same location.

Measurements are made at regular intervals along a grid or otherwise selected path whose locations are noted for subsequent plotting. In this survey, traverses were selected along pathways or other accessible routes. At each station, the time, magnetic readings, altitude and coordinates of the location is noted. Three readings are taken at each station. The average of the readings per station would later be used to draw a profile. In this way, some of the surface noise is averaged out.

The survey traverse G to H covered, a distance between Utonkon to Oturkpo of 30km and the station interval is 1km. The traverse M to N is from Oturkpo to Okpamaju a distance of 15km was at 50m pacing. Traverses between Oturkpo to Adoka (L to K) and Oturkpo to Aliade (I - J) covering distances of 32km and 51.5km respectively were both surveyed at station intervals of 1km each. Within the mineralized location in Ogyoma forest the station pacing was at 20m interval. The area is indicated by a deep blue spot in figure 1. Materials used during the field work include: *Instruments:* Magnetic compass, 12 Channels Global Positioning System (GPS), Proton Magnetometer, Sensor, Sensor Staff, Micro Kappa Meter, Time Piece. *Field Vehicles:* Motor Car, Motor Cycle, a*nd Other Materials*: Geological hammer (1kg), sample bags, field note book, shovels, tape, cutlasses, pegs, ranging poles, pick axes, ruler, masking tape, marker, weighing scale.

1.1.4 **Data Reduction**

The raw data were corrected for diurnal variation of the earth's magnetic field by a three point moving average filter. In proton magnetometer there are no calibration problems and inherently it is drift free. Exact orientation is not necessary since the total field is measured rather than any component.

Elevation and Terrain corrections are therefore insignificant. In local surveys, corrections for changes in the main field with position are also often too small to be of importance and even if appreciable may be extracted as a 'regional'.

1.1.5 **Model study**

A pentagonian model of the origin of the earth's magnetic field fig. 1 was adopted. This model consists of an earth of molten core shaped like a pentagon with apexes as the bulges of continental masses of Africa, Australia, the Americas, Europe, Asia and Antarctica. The oceans are between continents. Evidence of bulges are conformed from seismic tomography as equatorial bulge with fiducial points in the Gulf of Guinea and the Pacific Ocean (EOS 18^{th} June 1858). East-west rotation of molten oblate mass of homogeneous mantle gives rise to magmatic domains whose field trajectory is that of a horse shoe magnet. The magnetic field has a zero inclination at the equator and dips about 90^o at the poles (Plummer and Mcgeary 1996). The field intensity (H) is polarization per unit volume of the earth of radius R. The magnetic field is thus

$$H_x^o = 1/\mu_o K_o Ƥ/R^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots 1.$$

Here K_o is the magnetic susceptibility of rocks comprising the whole space, while μ_o is magnetic permeability and Ƥ is magnetic polarization. At the dip equator where the field inclination, (E) is about 10^o the inducing field becomes

$$H_z^o = H_x^o \sin E \qquad \ldots\ldots\ldots\ldots\ldots\ldots 2.$$

Multiple inducing fields such as high conducting horizons like the Mohorocivic layer are functions of the radius of the earth. If a dipping dyke is introduced to intersect the horizons but whose strike is perpendicular to the ambient H_x^o , magnetic induction (B) results.
A dyke with dip (d) would be induced with a total field along the dip as

$$B_z^d = 4\pi H_z^o K \cos^2\beta + H_z^o \qquad \ldots\ldots\ldots\ldots\ldots 3.$$

Here β is the angle 90^o- d, while B is constitutively equal to 1 + 4πK. If there are multiple sources then there is the need to migrate the source positions to their true dip positions along the dyke and to subsequently sum up the resultants field as

$$B_z^T = H_z^o + \sum_i^N K^i H_z^{oi} \cos^2\beta \qquad \ldots\ldots\ldots\ldots 4$$

Thereafter the field 4 is rotated to other field positions on the surface than on the dipping dyke.

1.1.6 Estimation Susceptibility (K)

The susceptibility contrast K of the survey area can be extracted from profile Amplitude anomaly term 'A' by a reduction to the pole using the following relation derivable from equation 4: (Nwachukwu 1973)

$$A = 2KTW \sin d \qquad \ldots\ldots\ldots\ldots\ldots\ldots 5$$

Where A = Total amplitude (i.e. peak to peak deflection), W is the width of body, and T = Total intensity of the inducing field (33,000 gamma). Being the average ambient magnetic field of the area. A calculated average magnetic susceptibility K range from .03406 for sediments in the area to 0.47 emu for steeply dipping rocks.
Measured magnetic susceptibility of rock samples obtained from the study area using Microkappa meter field instrument was in the range of 1.65 emu for sediments, and 0.14 emu. for pyrite ore.

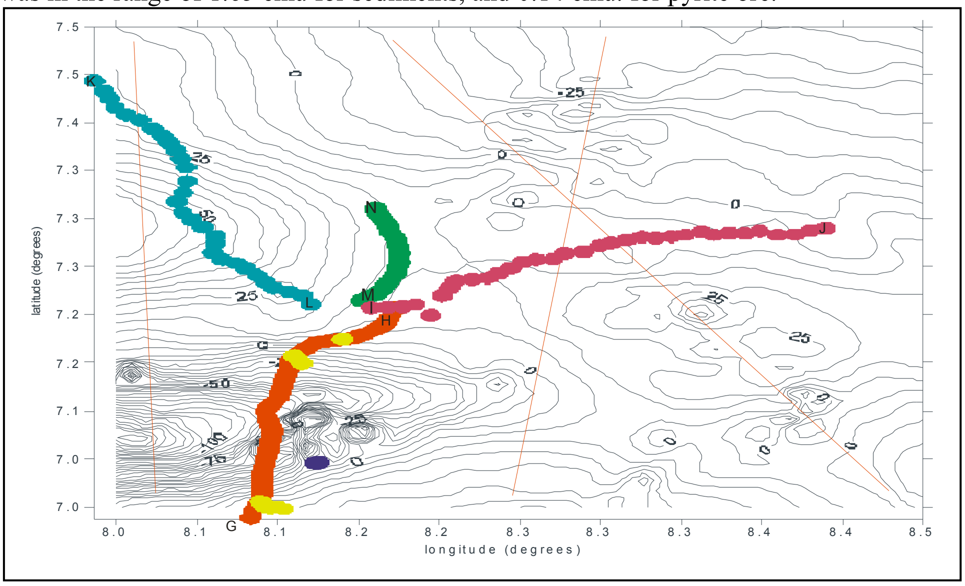

Fig 1. Aeromagnetic map of study showing profiles for ground magnetic survey

2. Results

Ground magnetic profiles fig. 1, GH, orange; IJ, purple; KL, blue; MN, green; and OP, blue; figs 2,3,4,5, were obtained and interpreted.

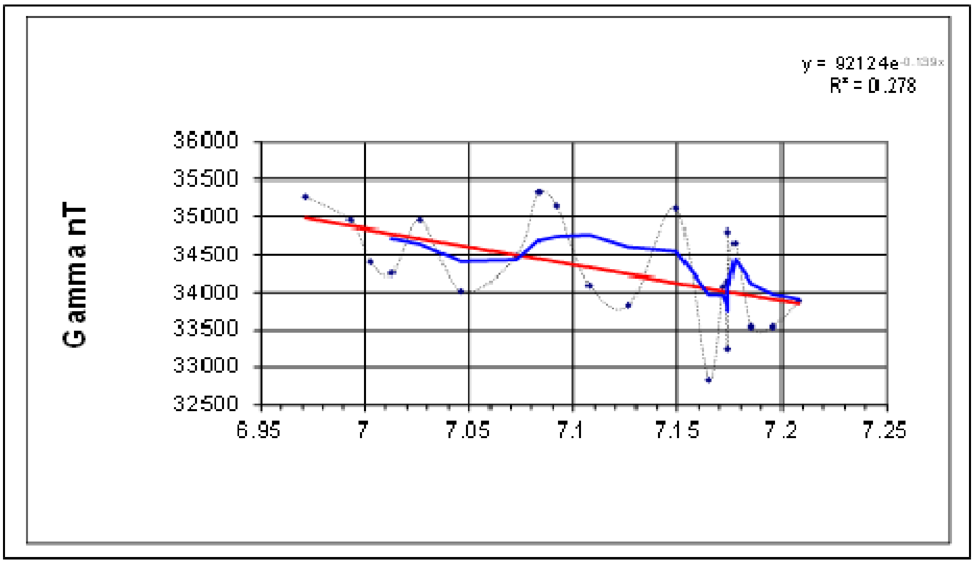

Fig 2 shows ground magnetic profile GH (black), Filtered curve (blue), and exponential regression trend (red). Filtering was by a four point moving average procedure.

Fig 2 displays the magnetic profile data as black curve along a north orange trend on the aeromagnetic map. The figure also shows a filtered blue curve with prominent positive anomaly bounded by high frequency anomalies. The regional trend is taken as the red exponential regression trend line y = 92124e-0.1389latitude. Depth to the basement ($\hat{Z}$) is therefore interpreted by computing it using the one third rule Telford 1978 as

1/3 (7.161 – 7.071) * (6375 x 2π ÷ 360) = 3.19 km ………..6

Fig 3 is the cross section through aeromagnetic broad east – west anomaly south of the study. It displays east - west high magnetic trends with adjoining basins whose depth is estimated as 3.19km. High frequency components have been models by computing dyke models 20m depth and 60^o dips southwards and northwards at their respective basin edges. Magnetization is from an inclined 10^o from the horizontal primary inducing field of susceptibility taken as .30604 electromagnetic units.

Fig 3 displays east - west high magnetic trends with adjoining basins whose depth is estimated as 3.19km. High frequency components have been modeled by computing dyke models 20m depth, susceptibility 0.4700 emu, and 60^o dip fig 4 using equation 4.

Fig 5 on the other hand displays the ground magnetic profile data (IJ purple) on the aeromagnetic map as hatched and dotted black curve along an eastern trend (IJ). The figure also shows a filtered blue curve with prominent negative and positive anomalies. Negative anomalies are usually the result of grabens with sediment fills while positive anomaly may be the result of intrusion of high magnetic susceptible material. The regional trend is taken as the red exponential regression trend line $y = 380294e^{-0.013 longitude}$. Depth to sediment ($\hat{Z}_s$) is therefore interpreted by computing it using the half width rule Telford 1978 as

1/2 (8.28 – 8.22) * (6375 x 2π ÷ 360) = 2.78 km ………………7

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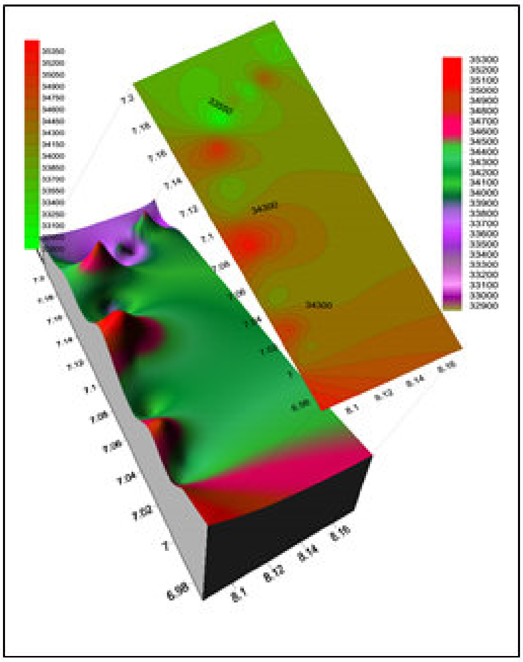

Fig 3 shows 2D and 3D magnetic profile data across broad aeromagnetic anomaly to the south of the study

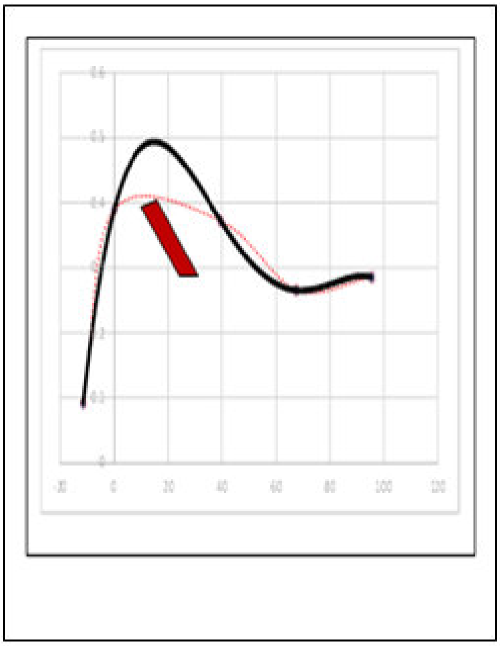

Fig 4. Shows model of dipping dyke with with a 60^{O} slope and depth of 20m

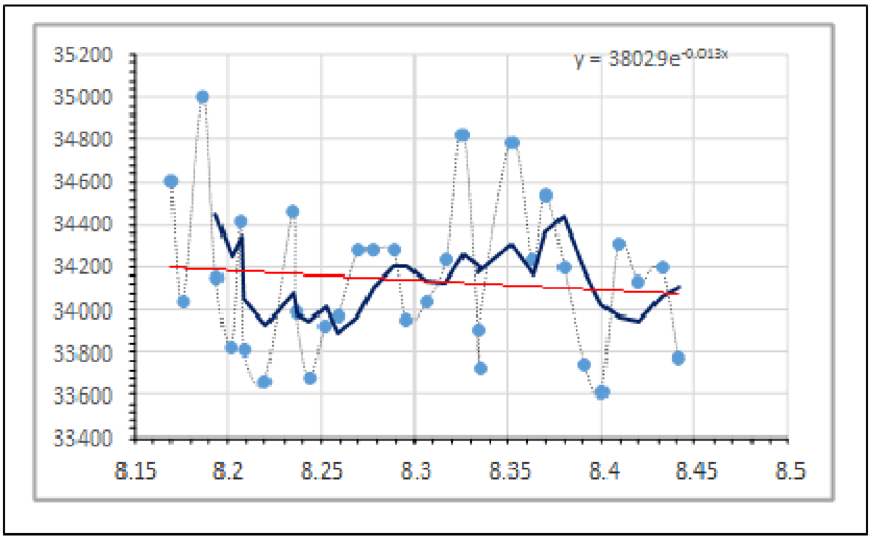

Fig 5 sows ground magnetic profile Ij

Fig 5 displays the ground magnetic profile data (IJ purple) on the aeromagnetic map as hatched and dotted black curve along an eastern trend (IJ). The figure also shows a filtered blue curve with prominent negative and positive anomalies. Negative anomalies are usually the result of grabens with sediment fills while positive anomaly may be the result of intrusion of high magnetic susceptible material. The regional trend is taken as the red exponential regression trend line y = 380294e-0.013longitude. Depth to sediment ($\hat{Z}$s) is therefore interpreted by computing it using the half width rule Telford et. al. 1990 as

$$1/2\ (8.28 - 8.22) * (6375 \times 2\pi \div 360) = 2.78\ \text{km} \quad \ldots\ldots\ldots\ldots\ldots\ldots 7$$

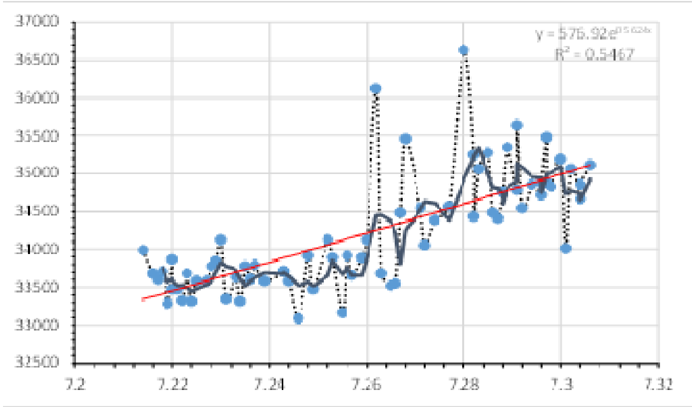

Fig 6 shows MN profile and filtered data.

In contrast Profile MN fig 6 is similar to profile IJ but the profile has rather northerly orientation. The figure also shows a filtered blue curve with prominent negative and positive anomalies. Negative anomalies would usually result from grabens with sediment fills while positive anomaly may be the result of intrusion of high magnetic susceptible material. The steep regional trend is taken as the red exponential regression trend line y = 576.92e0.5624latitude. Depth to sediment (Ẑs) is therefore interpreted by computing it using the half width rule Telford 1978 as

1/2 (7.262 – 7.232) * (6375 x 2π ÷ 360) = 1.66 km ……………8

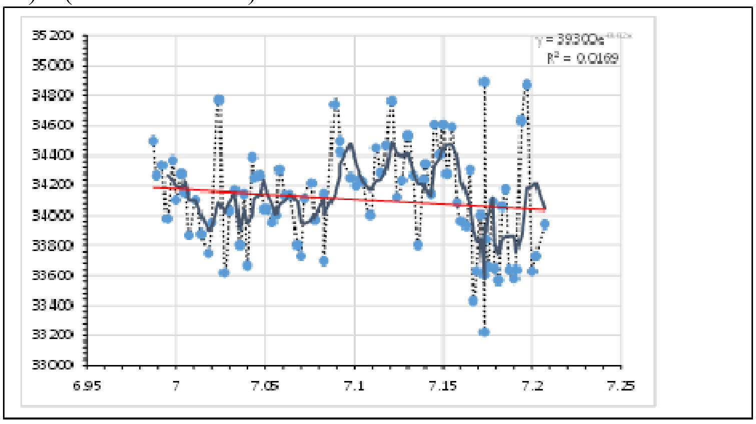

Fig 7 shows Op ground magnetic profile.

Profile OP which is a northerly profile, also reveals negative and positive easterly trending anomalies similar to 3D fig 3. An ensuing interpretation is an anomaly due to faulted basement rocks. Negative anomaly would be attributed to sedimentary sequence of low susceptibility with thickness of up to 5.006km as determined by half width rule

1/2 (7.095 – 7.005) * (6375 x 2π ÷ 360) = 5.006 km …………9

While high frequency portion indicate shallow depths of 1.27km.

Similarity of regional slope of profile OP to profile IJ indicates similar magnetization of deeply buried sediments. The interpreted depth of 5.006km positive anomaly is from a basement source of higher susceptibility. In this model if the basement is faulted then the sediment filled area would have low susceptibility while the positive down faulted basement has been intruded into by materials with high susceptibility. The minimum between the high frequency closures is due to the wedge of relatively low density material between intrusions. The magnitude of this minimum anomaly is governed by the density contrast and the thickness of the wedge. Pyrite is a primary vein mineral with susceptibility between 0.299 to 0.32 emu and is also known to be deposited within shale sediments in the area by secondary processes. Both negative and positive anomalies are punctuated by high frequency high susceptibility materials associated with modeled shallow 20m – 1.27km sources

3. Discussion and Conclusion

The amplitudes of the anomalies are directly related to the strength of magnetization of the sources. The study of these anomalies, their interpretation has given insight into their causes; such as basement rocks; intrusions and sedimentary basins. The study confirms the existence of NE-SW, NW-SE and E-W lineaments. The result of this work also confirmed the existence of shallow (20m) hypabyssal intermediate intrusive as probably the source of high frequency magnetic anomalies.

The tectonic activity remained localized along the major fault zones but also resulting in a sub meridian mineralized fractures in which pyrite was deposited. Pyrite is also a hypogene mineral deposit that derives its source directly from magmatic materials. Their mode of emplacement lends credence to the source of low frequency magnetic anomalies associated with sediments where they occur as disseminated sulphides. Depths to low frequency anomalies range from 1.66km to 5km.

Granite, granitic detritus, and silicic volcanic ash and flows are other magnetic source rocks. Some of these were leached from the source rocks and carried in solution by oxygen rich ground water and surface water that then migrated into porous sandstone and conglomerate beds known to occur in the area. Sulphur as a constituent of Pyrite and Marcasite which accompany the base metal sulphides appear as an accessory mineral in eruptive rocks, with a very uniform, brass-yellow colour. Gangue deposit of pyrite is thus useful in making sulphuric acid.

Our results have demonstrated that careful analysis of magnetic data can (i) delineate with fair to good precision the location and approximate relief of structures (ii) determine the lithology and the configuration of the anomalous zone, hence the source of mineralization. (iii) Determine the involvement of basement in an exploration prospect structure.

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5 References

Benkhelil, J. (1989). The Origin and Evolution of the Cretaceous Benue Trough.Journal of African Earth Sciences, 8, 257-282

Bhattacharyya, B.K. (1966). Continuous Spectrum of the total magnetic field anomaly due to a rectangular prismatic body. Geophysics, V. 31, p. 97-121.

Breiner, S. (1973). Applications Manual for Portable Magnetometers. Geometrics 395 Java Drive Sunnyvale, California 94086, USA p.1-21.

EOS transactions of American geophysical union, Cover story, vol. 66, no. 25 June 18 1985

Federal Surveys, Nigeria, (1970). Topographic Sheet, 1:100,000, Oturkpo Sheet 270. Federal Survey, Kaduna.

Geometrics; Model G 816 Portable Proton Magnetometer Manual. 395 Java Drive, Sunny Vale, California 94086 USA p. 1-13

Grant, F. S. and West, G. F. (1965). Interpretation Theory in Applied Geophysics. McGraw Hill Book Company, New Yorck. p. 4-15

Hood, P. and Mcchure, D. J. (1965). Gradient Measurement in Ground Magnetic Prospecting. Geophysics, 30.pp 403-410.

Macdonal, A.M, (2001) Report on visit to Water Aid project Nigeria, British Geological survey internal report, 1R/101/18

Nwachukwu S. O., (1973) Rapid calculation of two dimentional magnetic anomaly best parameter set, Geoexploration vol. 11, pp 187-191.

Ogah, V. E. (1998). Interpretation of Aeromagnetic Data across the Jos Plateau.
M.Sc. Thesis. Nnamdi Azikwe University, Awka. p. 2-5

Ogah, V. E. (2013). Metallic Minerals Exploration in Oturkpo Local Government Area of Benue State, Nigeria. Unpublished. p. 60-69, 74 – 79.

Plummer C, c, McGreary D, (1996), Physical geology, C Brown Publishers, 539pp

Telford, W.M., Geldart, L.P. and Sheriff, R. E. (1990). Applied Geophysics. 2nd Ed.
Cambridge University Press, Cambridge, New York, Port Chester Melbourned Sydney, p.3.

Wright, J. B. (1976). Origin of the Benue Trough. A Critical Review: In Geology of Nigeria. Elizabeth Publishing Co. Lagos, Nigeria. p. 309-317.

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