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Ground Electromagnetic Prospecting for Potential Ore Mineralisation Zones in Tsohon-Gurusu Area of Minna, North-Central Nigeria

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ABSTRACT

Very low electromagnetic method was used to investigate potential ore mineralisation zones in Tsohon Gurusu Area of Minna, North-Central Nigeria. A total of six (6) profiles were investigated, each with length of 500 metres, 100 metres inter-profile spacing and 20 metres inter-station distance. The VLF data were collected using Scrintrex Envi VLF instrument. The acquired data sets were subjected to analysis and interpretation using MICROSOFT EXCEL, KHFFILT and OASIS MONTAJ software. The result of the study indicated a general structural trend of N-S direction with significant conductivity responses due to inferred fracturing units containing conductive minerals as indicated by the peak responses of the current distributions and the geologic features in the investigated profiles. Areas of high conductivity were observed in all the six (6) profiles corresponding to fracture zones of interest as indicated in the current density sections, with profile 5 having the highest conductivity response of 464.3 mS/m and profile 6 with the least conductivity response of -262.5 mS/m. It is generally observed that the depth of the major conductive bodies to be 80m.

Keywords: *Fraser filtering, Conductivity, Cross-cutting, In-phase, Mineralisation, VLF-EM*

1 INTRODUCTION

VLF-EM method is applicable in the investigation of geological conductive bodies as well as serving as a powerful tool for mapping shallow subsurface structural anomalies.

This method detects subsurface zones of anomalous electrical conductivity. Since these bodies (unlike common rock forming metals are insulators) are characterized by considerable amount of electrical conductivity distinguished by their ranges in electrical conductance, such zones of anomalous high electrical conductivity (or inversely low electrical resistivity) are potential subsurface water and conductive ore mineralisation zones (Telford et al.,2001).

Mineralisation is featured by fractured zones of dual purpose such that, it serves as channels for the mineralisation solution and a flash point for mineral deposition. General trends of geologic features are pathfinders in tracing target of interest in mineral prospecting and localized features such as contact and shear zones are responsible for the localization of ore deposit (Abubakar, 2012).

A country's ore and other mineral deposit constitute her natural wealth upon which hinges her development and prosperity (Prasad, 2012). This realization led to mining and the search for metals since the earliest times (Telford et al., 2001). Consequently, ore mineral deposits are in substantial amount embedded within the subsurface structures of the Earth, as such, systematic techniques in exploring such bodies are vital to minimize environmental degradation of the Earth's surfaces (Oluwaseun, 2013).

1.1 VLF-EM SURVEYING

VLF signal frequencies are generated by very powerful radio transmitters from Military bases in the United States of America and from other countries for the purpose of communication with their submarines and they are typically within the ranges of 15-30 kHz, transmitted for hundreds or thousands of kilometers, the curvature of the wave fronts is so slightly that they are effectively flat (Alan *et al.*, 2000). The transmitted e-m wave travels over or near the earth surface, the induced magnetic generated by the displacement current is defined by the primary magnetic field and shifts in phase when a conductive body is encountered, hence, the conductive body becomes a source of another field (secondary). As such, electrical characteristics of the subsurface can be determined by comparing the primary and secondary field.

The depth of penetrations of the transmitted electromagnetic waves depends on their frequencies and the electrical conductivity of the subsurface. This depth increases as both the frequencies and subsurface conductivity decreases (kearey *et al.*, 1984).

$$\delta = \sqrt{\overline{}} \qquad \overline{\sqrt{\sigma f}} \qquad 0\sqrt{-} \tag{1}$$

δ = Skin depth in meters (Depth of penetration of e-m wave passing into a conductor in which the amplitude of the wave is attenuated to - of its amplitude at the surface of the conductor).

μ_o = Magnetic permeability of free space = Henry/m.

ω= Angular frequency ($2\pi f$)

σ = Electrical conductivity of earth material (mho/m)

ρ = Electrical resistivity
f = Signal frequency.

At very large distances from a source of electromagnetic waves, attenuation of this type would control the depth of investigation. Effective depth of investigation Z_e, defines the maximum depth a body can be buried and still produce a signal recognizable above the noise. It is given as (kearey *et al.*, 1984)

$$100\sqrt{-} \tag{2}$$

The VLF instrument detects the primary and secondary fields, and separates the secondary field into in-phase and quadrature components based on the phase lag of the secondary field. These two components of the secondary field are sometimes referred to as the tilt (in-phase) and ellipticity (quadrature), (Pirttijärvi, 2004). When the VLF-EM method is used for geophysical survey, the in-phase response is sensitive to metal or good conductive bodies (Lazarus *et al.,* 2013). The quadrature response, on the other hand, is sensitive to the variation of the earth electrical properties (Jeng *et al.* 2004).

$$\mathrm{n}(\alpha) \tag{3}$$

$$\tag{4}$$

The VLF electromagnetic method is a proficient tool for high grading mineralised area in preparation for competent mine development and is of significant contribution to an integrated geophysical investigative effort, Mbah *et al.* (2015).

1.2 LOCATION

Tsohon Gurusu is on the extreme south-west of Bosso Local Government area of Niger State and on latitude 9.625°N to 9.625°N and longitude 6.608°E to 9.604°E with an area extent of 250,000 square meters. The areal distance estimate is about 4.5 km from Maitumbi roundabout, Minna of which the site is about a km South-East off Minna-Gwada road and it is spanned by a well accessible road either by foot or by vehicle.

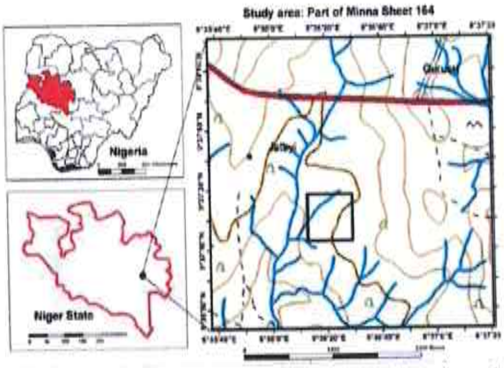


Figure 1: Part of Minna Sheet 164 Showing the (Kogbe, 1976)Location of the Study Area

1.3 GEOLOGY OF THE AREA

The study area lies within the Basement Complex of Nigeria. About half of the total area of Nigeria landmass is underlain by rocks of the Precambrian age known in the country as the Basement Complex. The remaining half is covered by Cretaceous to Quaternary sediments and volcanics. The basement complex is divided into the Western and the Eastern province. The Western Province is approximately west of longitude 8⁰E, typified by N-S to NNE-SSW trending schist belts separated from one another by migmatites, gneisses and granites. This trend is believed to be the result of Pan African orogeny involving collision between the West African Craton and the Pan African mobile terrain with and eastward dipping subduction zone (Ajibade *et al.,* 1979). The schist belts are differently interpreted as small ocean basins (Ajibade *et al.,* 1989), in filled rift structures (Ball, 1980) or synclinal remnants of an extensive supracrustal cover (Barley *et al.*, 1989).

The study area lies on the Kushaka schist belt. The Kushaka Schist Formation forms a number of curving schist belts, separated by domes and anticlines of gneiss (Obaje, 2009). The main rock type is semi-pelitic biotite-muscovite schist, in places containing garnet and staurolite. Other rocks are phyllites, metasiltstones and graphitic schists. Several thick units of banded garnetgrunerite iron formation are interbedded with the schists. A variety of amphibolites and amphibole, epidote, chlorite and talc-bearing schists correspond at least partly to tholeiitic basalt (Elueze, 1981). The Kushaka schist belts are invaded extensively by plutons of granite, granodiorite and syenite, which often penetrate the axial zone of the belts (Obaje, 2009).

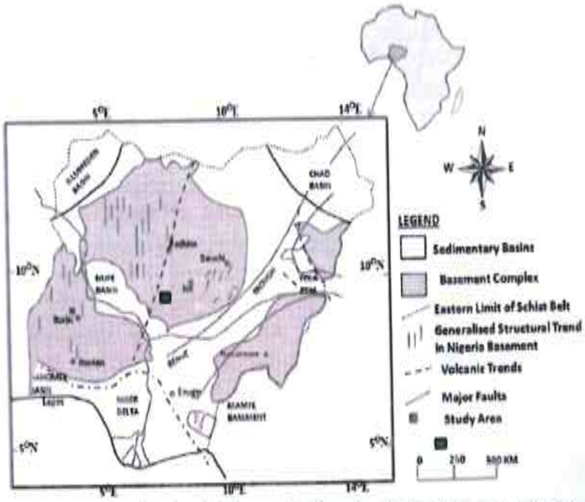


Figure 2: Geological Map of Nigeria Showing the Study Area. Source: (Kogbe, 1976).

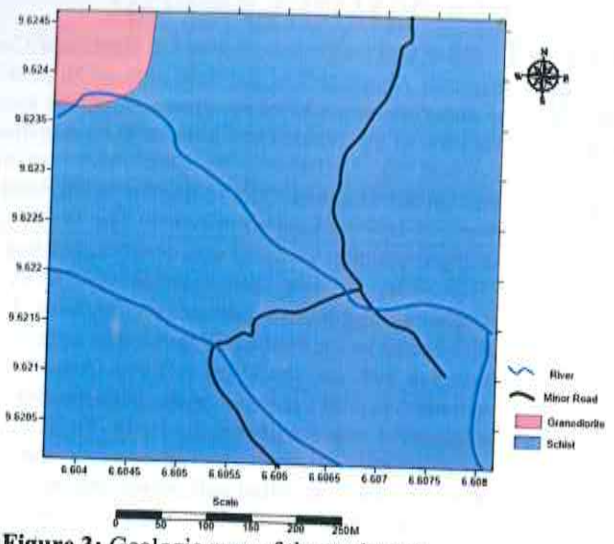


Figure 3: Geologic map of the study area

2 METHODOLOGY

The areal expanse was established by defining boundaries for investigation using a GPS and geological reconnaissance of the delineated work area was conducted to determine the regional strike of the rock foliations, established to trend in the North-South direction. Geological mapping was also carried out to generate the map indicating the different outcrops of rocks in the area.

A total of six (6) survey profiles with East-West orientations having inter-profile distances of 100 meters and inter-station spacing of 20 meters along each profile were generated across the strike formations, hence a total of 156 VLF stations were established, and from which VLF data was generated from each point of interest. This inter-profile and inter-station spacing is sufficient to give a very high density of data that will reveal high resolution subsurface geological image of the area.

The Scrintrex Envi VLF Instrument was oriented along the frequency transmitter, and a frequency of 21.1kHz signal with callsign RDL from Russia having the best signal strength was selected. VLF data was then collected at the established stations which are along the dip direction (along profiles) of the rock outcrops in order to reveal the lithologic variations, (because lithologic variations occur along the dip direction and the dip direction is perpendicular to the strike).

The data acquired from the VLF survey was then interpreted using MICROSOFT EXCEL, KHFFILT and OASIS MONTAJ software.

3 RESULTS AND DISCUSSION

The VLF-EM data were analyzed and presented in profiles indicating regions of high and low conductivities, putting into cognizance the factors which gave rise to these anomalies. The data were presented in the Fraser filtered format using KHFFILT software so as to eliminate the noise in the data caused by geologic and cultural features of less interest. Corresponding current density pseudo sections were also featured to give a 2D view of the current distributions with an average skin depth of 80 meters.

Peaks corresponding to cross cutting between the real (in-phase) and imaginary (quadrature) in the positive amplitude gave rise to interesting target locations with activities of higher current distributions and those in the negative gave lower current distributions. Conduction in earth materials are factored by the electronic, ionic and metallic conduction, with each having characteristic means of the conduction processes. Therefore, areas with high conductivity can be inferred to areas with fractures, developed pore spaces (as in sandstone) containing water, or highly mineralised zones containing conducting minerals.

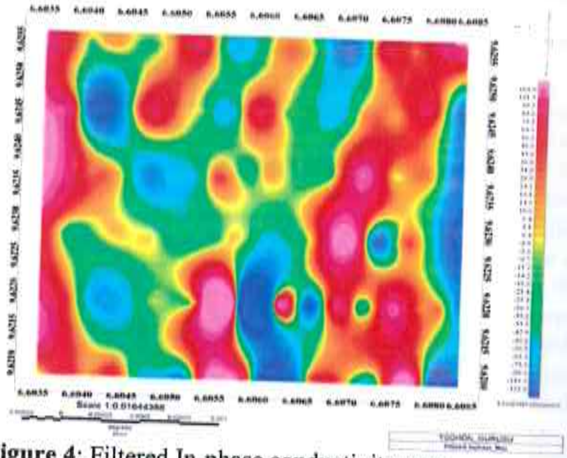
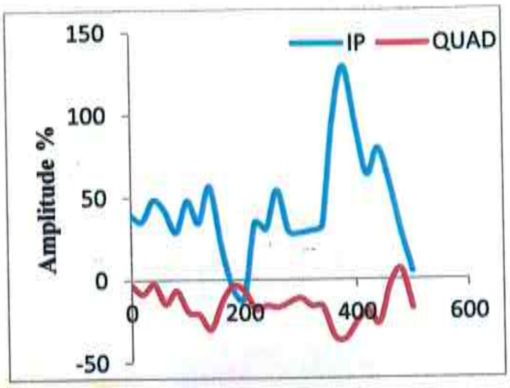


Figure 4: Filtered In-phase conductivity map

(a)



(b)

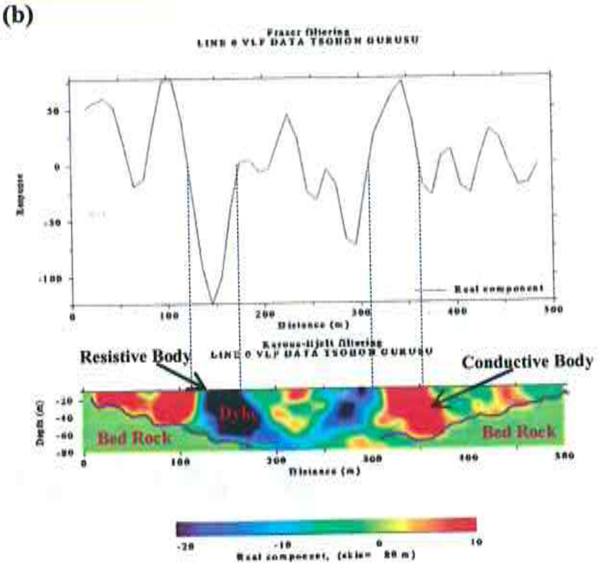
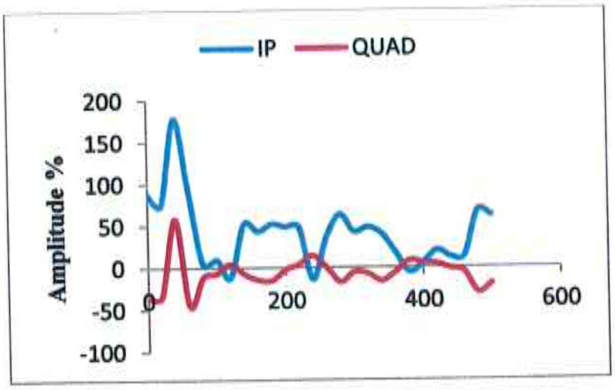


Figure 5: **Profile 1**; **(a)** unfiltered real (IP) and imaginary (Quad), **(b)** Fraser filter graph and 2D current density pseudo section.

(a)



(b)

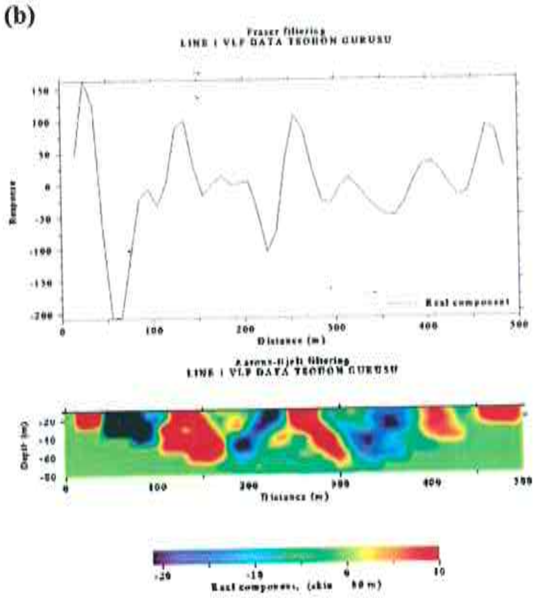
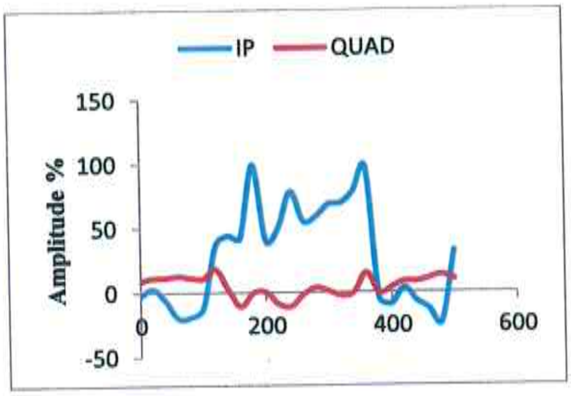


Figure 6: **Profile 2**; **(a)** unfiltered real (IP) and imaginary (Quad), **(b)** Fraser filter graph and 2D current density pseudo section.

(a)



(b)

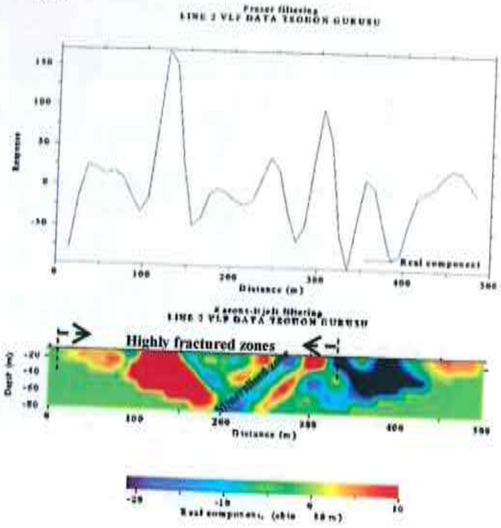
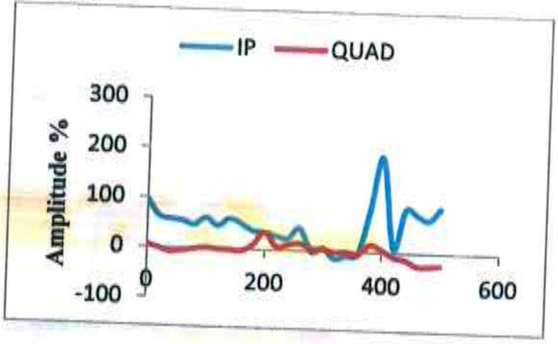


Figure 7: Profile 3; (a) unfiltered real (IP) and imaginary (Quad), (b) Fraser filter graph and 2D current density pseudo section.

(a)



(b)

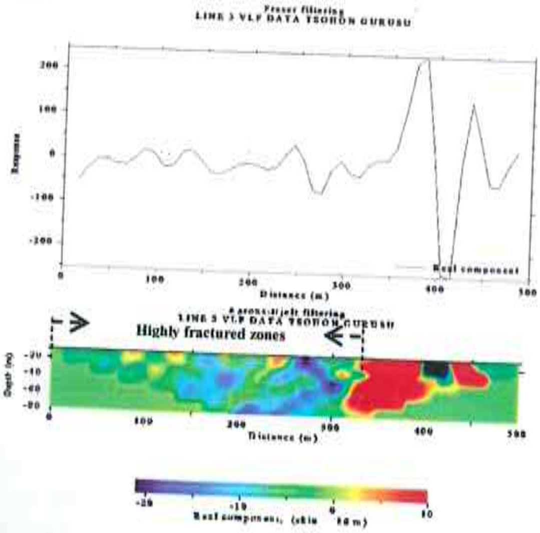
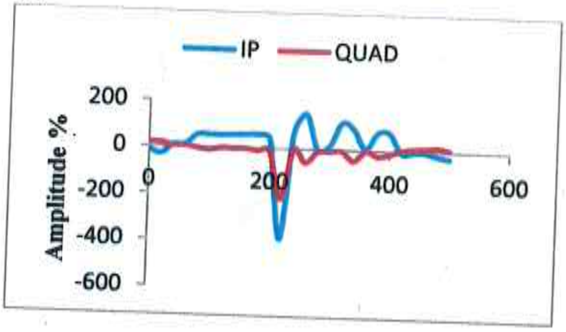


Figure 8: Profile 4; (a) unfiltered real (IP) and imaginary (Quad), (b) Fraser filter graph and 2D current density pseudo section.

(a)



(b)

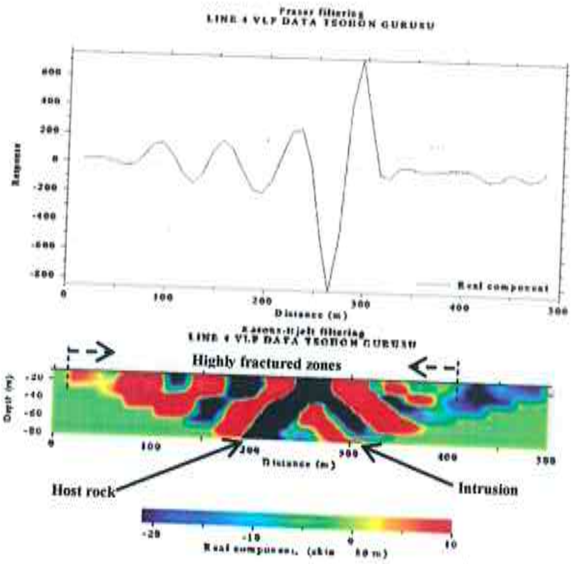
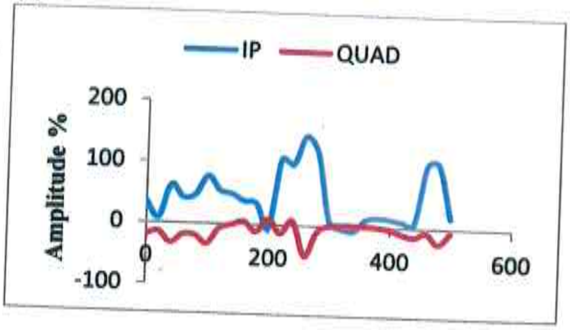


Figure 9: Profile 5; (a) unfiltered real (IP) and imaginary (Quad), (b) Fraser filter graph and 2D current density pseudo section.

(a)



(b)

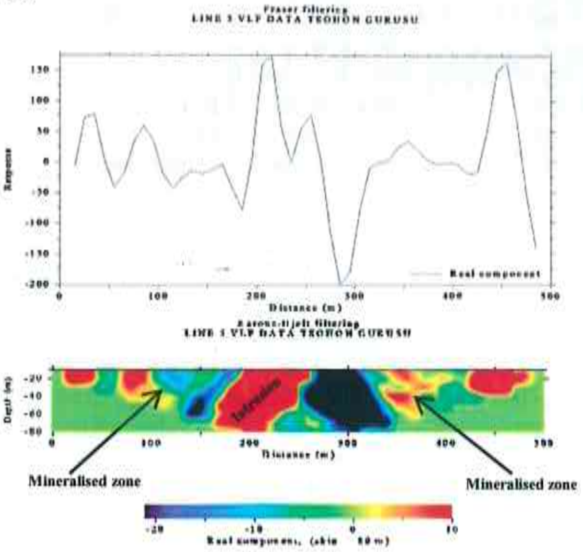


Figure 10: **Profile 6**; **(a)** unfiltered real (IP) and imaginary (Quad), **(b)** Fraser filter graph and 2D current density pseudo section.

Profile 1

The profile (Figure3) runs from E-W direction and lies between latitude 9.6255°N to 9.6254°N and longitude 6.6082°E to 6.6036°E indicating the highest percentage in amplitude of the in-phase response between 75m to 125m (128.9 mS/m) and 300m to 360m (56.6mS/m) with corresponding maximum response of 125% indicating a highly conductive zone which can be inferred to contain conductive minerals due to the high response.

A low conductive dyke spans from 125m to 300m, with an approximate of 80m from the surface, serving as a host to a conductive body due to facture features.

Profile 2

The profile (Figure4) trend along the W-E direction and lies between 9.6245°N to 9.6246°N and longitude 6.6036°E to 6.6082°E with significant conductivity signatures along 10m to 40m (126.5 mS/m), 100m to 175m (98.1 mS/m), 250m to 310m (83.2 MS/m) having 110% in-phase response indicative of mineralisation and juxtaposed between low conductive bodies.

Quartzite outcrop in this profile spans from 40m to 100m with corresponding low conductive signature (-254 mS/m). There is also an outcrop of granodiorite at 200m and an outcropping dyke of quartzite with low conductivity (-76 mS/m).

Profile 3

This profile runs along the E-W direction (Figure 5) and lies between latitude 9.6237°N to 9.6236°N and longitude 6.6082°E to 6.6036°E with interesting features of fractures and intrusions of high conductive bodies hosted by low conductive bodies, trending NW-SE and spanning from 150m to 325m.

The points of inflections of cross-cutting of the real and imaginary component gave rise to the highest conductive signature of 189.4 mS/m as the highest in this profile with in-phase response of 160% lying spanning from 100m to 150m with an estimated depth of 60m from the surface, trending along the NE-SW direction.

Profile 4

This profile (Figure6) trends along the W-E direction and lies between latitude 9.6227°N to 9.6228°N and longitude 6.6036°E to 6.6082°E having the highest conductivity from 340m to 400m (288.8 mS/m) at an approximate depth of 80m from the surface with an outcropping low conductive body between 400m to 430m serving as an intrusion.

From the start point to 300m, a body of low and intermediate high conductivities seems to dominate. As, such, suggest fracture zones susceptible to mineralisation.

Profile 5

This profile (Figure7) is along the E-W direction and lies between latitude 9.6219°N to 9.6218°N and longitude 6.6082°E to 6.6036°E. This profile registers the highest conductivity response compared to all the previous profiles as shown in the 2D section, of about 464.3 mS/m at an approximate depth of 60m from the surface with a NE-SW trend direction and spans from 280m to 320m. The general feature is that fracturing units in the profile are highly pronounced.

At distance of 262m a very low conductive response is shown by a body hosting a high conductive body which can be inferred to be an aquifer or a mineralised zone.

Profile 6

This profile (Figure8) runs on the W-E direction and lies between latitude 9.6209°N to 9.6210°N and longitude 6.6037°E to 6.6082°E. The highest conductivities response is shown at 450m (190.3 mS/m) and 200m (177.6 mS/m) on the profile with the least conductive response at 300m (-262.5 mS/m) corresponding to a geologic outcrop of quartzite which is highly resistive.

CONCLUSION

On a general scale, the area houses regions of highly fractured structures, intrusions, dykes, conductive bodies and massive resistive bodies. The highest conductivity responses on the profiles are shown on each 2D pseudo sections corresponding to profile with profile 1 having its highest conductivity response between 75m to 125m (128.9 mS/m), profile 2 records it between 10m to 40m (126.5 mS/m), profile 3 has its highest between 100m to 150m (189.4 mS/m), in profile 4, the highest conductive zone lies between 340m to 400m (288.8 mS/m), profile 5 has its highest conductivity response between 280m to 320m (464.3mS/m) which is the highest among the profiles. Profile 6, shows high conductivity response at 450m (190.3 mS/m) and an interesting relatively low conductivity at distance 300m (-262.5 mS/m) which corresponds significantly to some geologic outcrop of highly resistive quartzite body.

The fracturing units described with respect to the high conductivity patterns as indicated in the conductivity map and the 2D current density pseudo section, suggests that the average depth of the major conductive bodies is approximately 80m with significantly high conductive responses. As such, it can be inferred that zones in this area exhibiting such features are zones of mineralisation. Thus, other geophysical investigative methods such as magnetic method and geochemical analysis can be carried out on the area to ascertain the specific mineral contents, presence and extent of mineralisation.

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REFERENCES

Abubakar, Y. (2012, May). An Integrated Technique in Delineating Structures: A Case Study of the Kushaka Schist Belt Northwestern Nigeria. *International Journal of Applied Science and Technology, 2*(5), 164-167.

Ajibade A.C., and Wright J.B. . (1989). The Togo-Benin-Nigeria Shield: evidence of crustal aggregation in the Pan-African belt. . *Tectonophysics, 165*, 125-129.

Ajibade A.C., Fitches W.R, and Wright J.B. . (1979). The Zungeru Mylonites, Nigeria: recognition of a major tectonic unit. *Rev. De Geol. Phys. 21*,, 359-363.

Alan E. Mussett and Aftab Khan. (2000). *Looking into the Earth: An Intoduction to Geological Geophysics.* New York: Cambridge University Press.

Ball, E. (1980). An example of very consistent brittle deformation over a wide intercontinental area: The late Pan-African fracture system of the Taureg and Nigeria shield. . *Tectonophys. 61*, 363-379.

Barley M.E., Eisenlohr B., Groves D.I., Perring C.S., and Vearncombe I.R. (1989). Late Archean convergent margin tectonics and gold mineralisation. A new look at the Norsema-Wiluma belt, western Australia. *Geology 17*, 826-829.

Elueze, A. (1981). Petrograhic Studies Of Metabasic Rocks And Meta-Utramafites in Relateion to Mineralisation in Nigerian Schist Belts. *J Mining Geol*, 18:31-36.

Jeng Y., Lin M.J., Chen C.S. (2004). *A very low frequency-electromagnetic study of the geo-enviromental hazardous areas in Taiwan.* Taiwan: Environ. Geol., 46.

Kearey P. and Brooks M. (1984). *An introduction to geophysical exploration.* Oxford: Blackwell.

Kogbe, A. (1976). *Geology of Nigeria.* Ibadan, Nigeria.: Elizabethan Publishers.

Lazarus G. Ndatuwong, Yadav G.S. (2013). Analysis and Interpretation of In-Phase Component of VLF-EM Data Using Hilbert Transform and the Amplitude of Analytical Signal. *Journal of Environmental and Earth Science, 3*(11), 11-24.

Mbah Victor O, Onwuemesi A. G., Aniwetalu, Emmanuel U. (2015). Exploration of Lead-Zinc (Pb-Zn) Mineralisation Using Very Low Freqency Electromagnetic (VLF-EM) in Ishaigu, Ebony State. *Journal of Geology and Geocsiences, 4*(4), 1-7.

Obaje, N. G. (2009). *Geology and Mineral Resources of Nigeria* (Vol. 772). (B. S. Bhattacharji, Ed.) Berlin: Springer.

Oluwaseun, I. G. (2013). *Mineral Prospecting and Exploration (with special references to Nigeria).* Ibadan: Disaster and Risk Management, Department of Geography, University of Ibadan.

Pirttijärvi, M. (2004, February 20). Karous-Hjelt and Fraser filtering of VLF measurements. Oulu, Oulu, Finland.

Prasad, U. (2012). Economic Geology. In U. Prasad, *Economic Geology* (pp. 318-319). New Delhi: CBS.

Telford W. M., Geldart L. P., Sheriff R. E. (1990). Applied Geophysics, Second Edition. In W. M. Telford, *Applied Geophysics, Second Edition* (pp. 283-290). New York: Cambridge University Press.