



GEOPHYSICAL EVALUATION OF ROCK TYPES IMPART ON THE AQUIFER SYSTEMS IN THE BASEMENT COMPLEX TERRAIN, SOUTHWESTERN NIGERIA

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ABSTRACT

A study was carried out to determine the Landsat ETM+, aeromagnetic and vertical electrical sounding (VES) data covering Ado-Ekiti with the intent of delineating the lithological contact, basement structures and aquifer systems in the area. The Landsat imagery generated was processed using PCI Geomatica software, aeromagnetic data procured was processed using Oasis Montaj™ and VES data was processed with partial curve matching technique assisted with 1-D forward modelling. The lineaments density (Ld) from the analysis of Landsat ETM+ ranges between low to high. Ld is higher over and around lithological contacts and areas underlain by felsic rocks. Interpretation of aeromagnetic data allows identification of series of anomalies suspected to be lithological contacts through the application of analytic signal, tilt derivative and Euler deconvolution. Qualitatively analysis of the two hundred and sixteen (216) sounding curves showed that the study area was predominated by A, H, KH, HK, QH and HKH –type curves. The VES interpreted result showed three subsurface geologic layers; the topsoil, the weathered layer, the partly weathered/fractured layer/the fresh basement. The study area has both weathered layer as well as fractured layer aquifers. Areas with weathered layer aquifers are underlain by granite with high lineament density while quartzite which also associated with high lineament density underlain the fractured layer aquifer zones. The charnockite and migmatite gneiss are associated with no lineament density and low lineament density respectively.

Keywords: *Lineament, analytic signal, weathered layer, aquifer.*

INTRODUCTION

The study area, Ado-Ekiti is underlain by the rocks of the Precambrian Basement Complex of Nigeria with the main lithologic units of migmatite gneiss, charnokite, quartzite and granite. The geology of this area is complex in nature thereby leading to unpredicted aquiferous zones, which may require integrated methods of study. A lot of works have been done in the Basement Complex of Nigeria by many researchers (Ogundana and Talabi, 2014, Rahaman, 1988) concerning the subsurface geologic structures and aquifer systems, among others. Hydrogeology, geo-morphology and geologic structure influence storativity and yield of groundwater in an area. Types of aquifer in the area will depend on the underlying geologic formations and structures, while the rate of recharge of the aquifer can also be influenced by climatic conditions (Ademilua and Ogungbemi, 2013). In basement complex area, groundwater occurs within the weathered and fractured rocks (Ademilua and Ogungbemi, 2013). A lot of places in Ado-Ekiti are in short supply of groundwater especially area around Irona Oniposi at the southeastern part and federal housing estate at the eastern part of Ado-Ekiti and there is a need to under study the geology of the environment. Subsurface information is revealed by using electrical resistivity method in hydrogeological investigation to delineate aquifer, geological structures and lithologic boundaries (Bose *et al.*, 1973, Ademilua and Ogungbemi, 2013). Airborne data, which are usually targeted at delineating possible rocks, zones and structures which can host fractured bedrock aquifer work effectively in the Basement Complex (Amigun and Anu, 2013). Analysis of remote sensing data and imageries are efficient in delineating geological structures (Rahaman, 1988, Ogunmola *et al.*, 2014, Akinlalu *et al.*, 2018, Ogungbemi *et al.*, 2018). This research work focus on the integration of Landsat imageries, aero-magnetic and vertical electrical resistivity data over Ado-Ekiti metropolis, Southwestern Nigeria in order to delineate both the lithological contact and aquifer units within the study area.

MATERIAL AND METHODS

Geology and Description of the Study Area

The study area is within Ado-Ekiti metropolis, Southwestern Nigeria. The area lies within Latitudes $7^{\circ} 35'N - 7^{\circ} 40'30''N$ and Longitudes $5^{\circ} 10'E - 5^{\circ} 18'E$ (Fig. 1). It is underlain by migmatite gneiss, quartzite, charnokite and granitic rocks of the Precambrian Basement Complex Rock (Rahaman, 1976). Migmatite gneiss covers over 50% of the study area, which host intrusion of other rocks (Fig. 2).

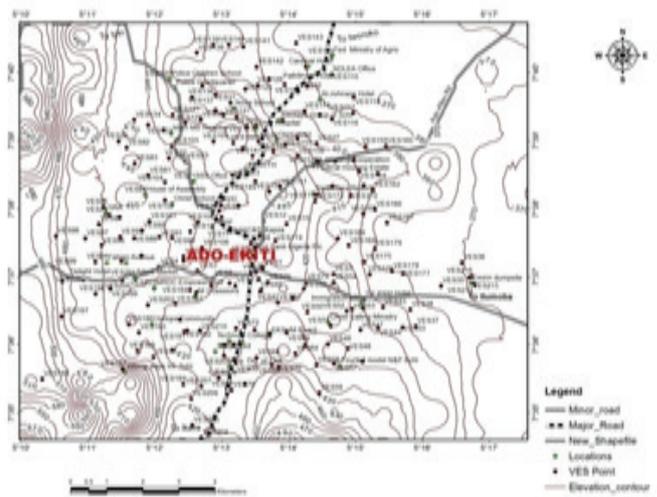


Figure 1: Location map of the study area showing the VES location

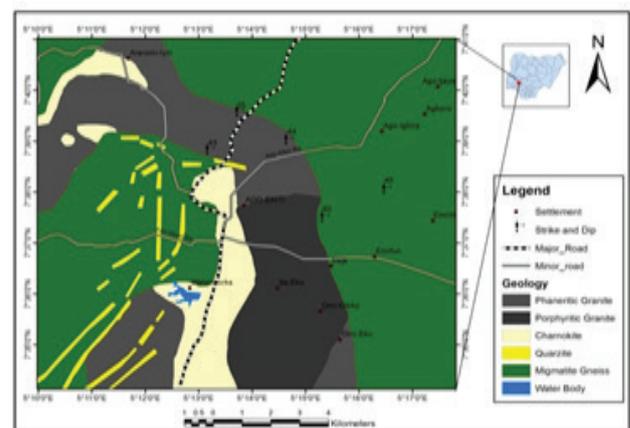


Figure 2: Geological Map of the study area (After NGSA, 2006)

Landsat image, aeromagnetic (Ado aeromagnetic grid maps, sheet 244) procured from Nigeria Geological Survey Agency (NGSA) and VES data were acquired for this research. Total magnetic field intensity was recorded at a constant flight height of 80 m above sea level, while the flight line and tie line spacing are 500 m and 2000 m respectively. The direction of the flight line is NW-SE and the Tie lines direction is NE-SW. The Landsat imagery was analysed spectrally using Arc GIS 10.3 software and was filtered for visual enhancement of lineaments, while the lineaments were manually digitized and geo-referenced to WGS 1984 and UTM Zone 31N. The magnetic data was analysed and upward continuation filter of 200 m height was applied in order to discard the influence of shallow sources and to improve the anomalies signature of the magnetic intensity map. After the removal of the effect of shallow sources and noise in grids, reduction to equator (RTE) filter was applied to the magnetic intensity map. The RTE filter assists in dismissing the asymmetry accompanied with low latitude anomalies, it also removes the effect of magnetic inclination and centres the tops of the magnetic anomalies over their sources. Removing the regional field from the

main RTE field gives the resultant residual magnetic intensity map of the area. Series of filters were applied in order to improve the magnetic anomalies, edge effects, enhance shallow geologic features and making smaller anomalies more readily visible in area of strong regional disturbances. In order to enhance signal, delineate structures and detect edges, the residual magnetic anomaly (RMA) was subjected to different enhancement techniques, which are applied for edge detection such as analytic signal (AS), tilt angle derivative (TAD) and total horizontal derivative (THD). Spectral frequency analysis and 3D-Euler deconvolution methods were used for depth estimation of subsurface structures in the study area. The gridding techniques were achieved on the MAGMAP program of the Oasis montaj™ Software. The relevant grids are entered and the fast Fourier transform was applied. A total of two hundred and sixteen (216) Schlumberger soundings were acquired across the study area. Maximum current-electrode separation (AB/2) range between 1 - 150 m and SAS 300 Abem terrameter was used.

RESULTS AND DISCUSSION

The total magnetic intensity (TMI) over the study area varies from -177.7 to 140.2 nT (Fig. 3) and pattern in the magnetic intensity map shows an acute diversity in the magnetic intensity revealing variations in the lithology. The RTE (Fig. 4) was done to maintain the low angle of inclination at the equator. The Magnetic intensity varies from -153.4 to 131.8 nT after reduction to equator has been applied to the Total intensity map over the area. The highest positive peak values of the magnetic anomalies are observed in the northwestern and southeastern parts, while negative peak magnetic anomalies of felsic rocks signature are showed in the northeastern and southwestern parts (migmatite gneiss area) of the study area. Figure 5 shows the analytic signal (AS) map and it is useful for locating geological contact in areas of low magnetic latitudes like the study area. The AS map ranges in values from 0.012 to 0.159 nT. A variation in lithology or geological contact was observed between the central part and eastern part which are the area underlain by granite (central) and migmatite (eastern part) as also shown in Figure 6.

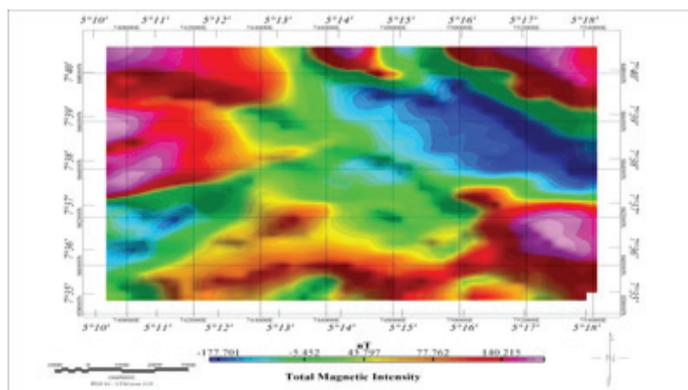


Figure 3: Total Magnetic Intensity Map (TMI) of the study area

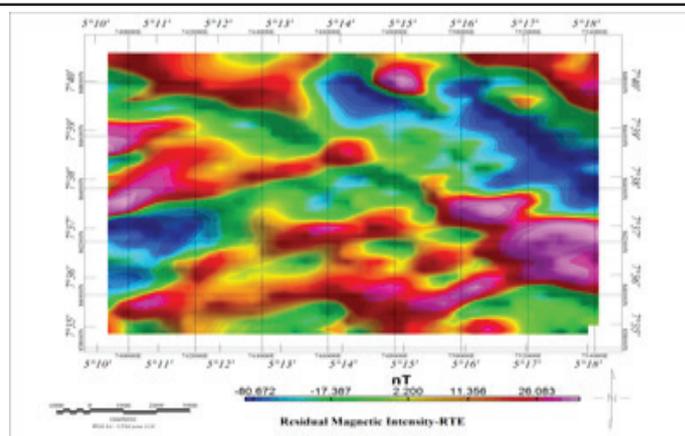


Figure 4: TMI-Reduction to Equator Map (RTE)

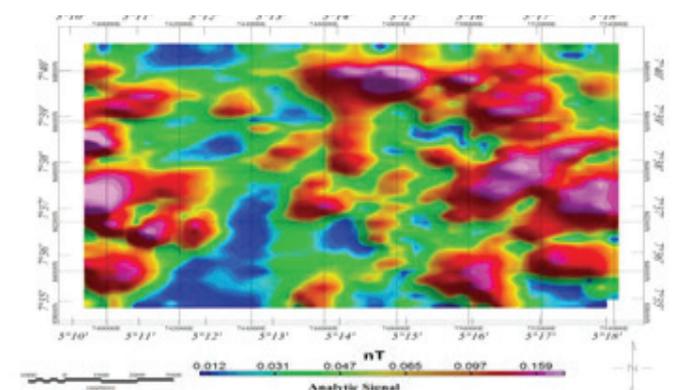


Figure 5: Analytic signal map (AS)

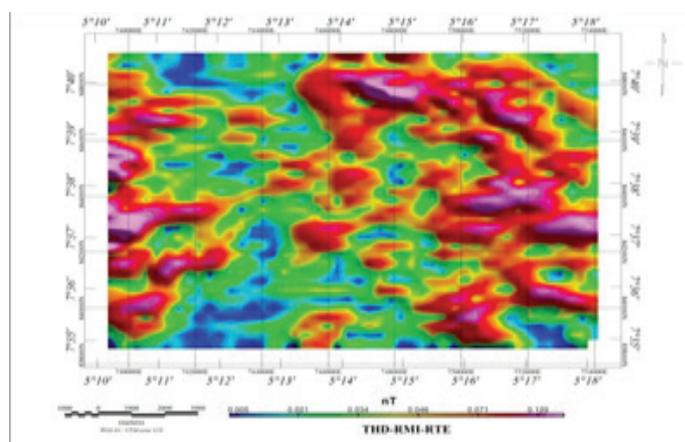


Figure 6: Total horizontal derivative map (THD)

The Tilt derivative filter (TDR) is a very good edge detection filter (Fig. 7) and reveals the presence of magnetic lineaments which corresponds to geologic structures in the study area. Delineation of fracture is important indices to rock types and aquifer set up in the area. The high magnetic amplitude of the signal probably results from the ferromagnesian rich rock. Figures 8 and 9 revealed the results of the Euler deconvolution of the magnetic intensity data obtained from structural index of 0.5 for faults and lineament features. The NW solutions (quartzite area) are presumed to be characteristic of fault/lineament features, which agree with the geology

of the study area. The composite lineament and composite lineament density maps of the study area are presented in Figures 10 and 11. Lineaments were extracted from the information obtained from the Landsat image, edge detecting filters and 3-D Euler deconvolution of the magnetic data. Lineaments showing consistent trends from both Landsat and magnetic data interpretation were identified and explored in extracting the lineaments presumed to be associated with the lithology in the study area. The Rose Diagram shows high lineament density around zones underlain by quartzite and low to medium around Charnokite. Quartzite is highly fractured, therefore fractured bedrock aquifer will be more pronounced on it, which is likely to be influenced by percolations of water from near surface areas. The major orientation of the lineaments was in NE and SW direction (Fig. 12).

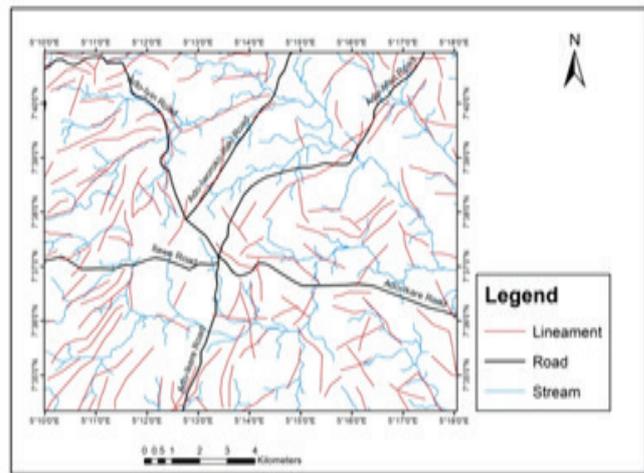


Figure 10: Composite Lineament Map of the Study Area

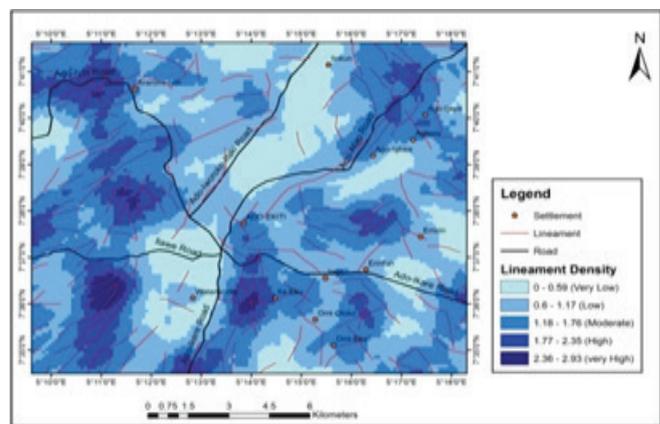


Figure 11: Composite Lineament density map of the study area

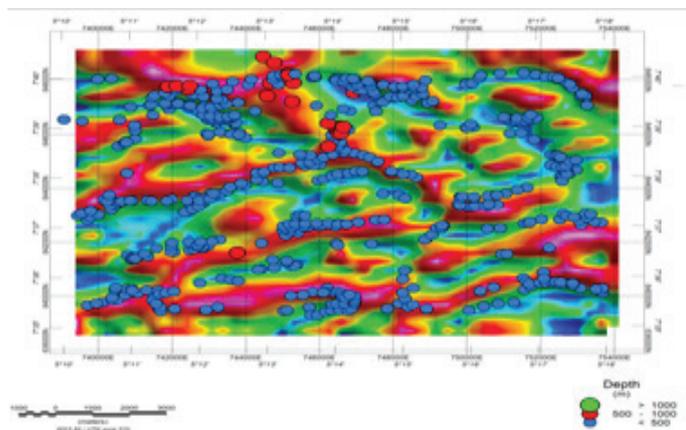


Figure 7: Tilt Derivative Map (TDR)

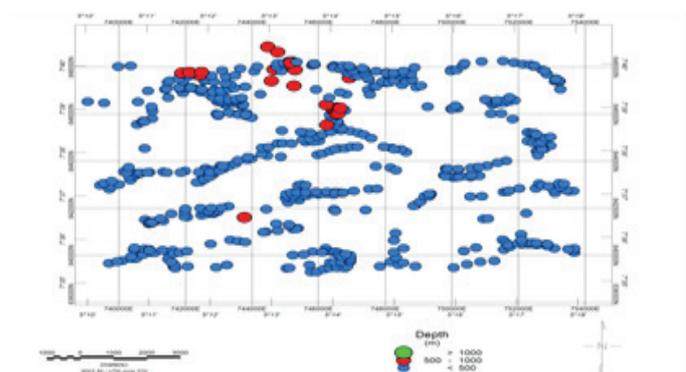


Figure 8: 3-D Euler Deconvolution Map

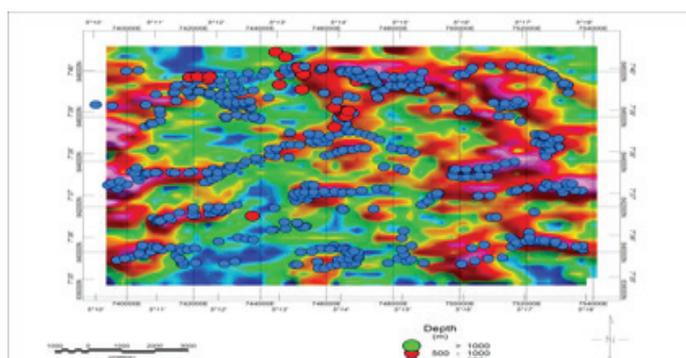


Figure 9: Combine TDR and 3-D Euler Deconvolution

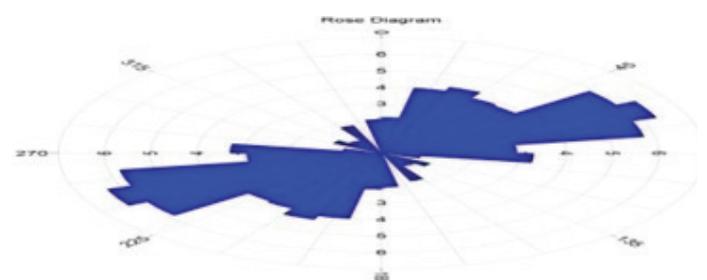


Figure 12: Rose Diagram in terms of direction of lineaments

Fourteen different VES curve types were identified from the interpretation of the electrical resistivity sounding data in the area (Fig. 13). The simple three-layer case to complex five-layer case of the curve types suggest impacts of heterogeneity, weathering, fracturing, and changes in geologic units over the area. The H-type curve (54.6%) dominates the curve types, where the weathered layer is the aquifers, while the other type curves (KH, AKH, HKH, KHK)

are diagnostic of fractured layer aquifers (Ogunmola *et al.*, 2014). The deduction from this is that the study area has both weathered layer aquifers as well as fractured layer aquifer units, with varying degree of infiltration from near surface groundwater and recharge rate.

in mapping geological structures, rock types and to delineate the aquifer zones within the study area. Quartzite, granite, charnokite and Migmatite gneiss are the major rock types in the area. The study area has both weathered layer aquifers (central and eastern parts) as well as fractured layer aquifers at the western part. Four to five layers' curve-types that represent water bearing formation dominate the western part of the area. The charnokitic rock underlain the central part of the area is associated with no lineament density which inform the scarcity of water in the area.

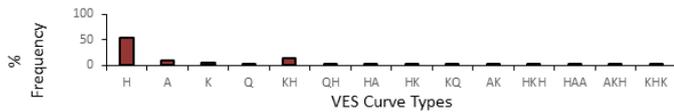


Figure 13: VES curve-types and percentage frequency

CONCLUSION

The integration of Landsat ETM+, aeromagnetic and vertical electrical sounding results have helped

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