Aeromagnetic Survey as Reconnaissance Technique for Groundwater Exploration in a Typical Southwestern Nigeria Basement Complex

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ORIGINAL RESEARCH

Abstract- This study was aimed at investigating the causes of reported boreholes failure in some parts of the Federal Polytechnic Ado Campus using aeromagnetic geophysical method. The aeromagnetic geophysical data covering the area was processed to enhance shallow anomalies using different enhancement techniques such as derivatives and wavelength filters. Total Magnetic Intensity ranges from -28 to 201 nT after removing regional component. Residual magnetic anomaly ranges from -21 to 127 nT; First vertical derivative ranges from -0.18 to 0.36 nT/m; Magnetic Analytic signal (AS) ranges from 0.03 to 0.36 nT/m. It was observed, by correlating the magnetic responses and geology of the area, that rocks underlain the area have close magnetic susceptibility. Consequently, the variations of earth's magnetism is mainly controlled by sediment thickness and suspected linear structures which are major factors in basement complex groundwater exploration. The probable depth to basement in the study area ranges from 8.13 to 74.05 m as revealed by AS and spectral method, which implies thicker regolith in southern part of the study area than northern part. However, linear structures are evenly distributed across the study area. Therefore, the groundwater potential of the southern part of the study area is higher due to regolith thickness. The failed groundwater boreholes that are prominent in northern part of the study area are not located on linear structures. Therefore, basement depth and linear structures should be considered during reconnaissance survey in groundwater exploration in a typical Basement Complex terrain.

Keywords- Aeromagnetic, Reconnaissance, Groundwater, Basement Complex

1 INTRODUCTION

There are incessant occurrences of groundwater borehole failure in some parts of Nigeria Basement Complex (Obasi et al., 2013; Olumuyiwa et al., 2016; Adeolu et al., 2018). Some of the listed responsible factors for borehole failure are: seasoning variation in water level; improper casing of overburden; damaged pump and hydrogeological factors. The factor that has not been given adequate attention is reconnaissance survey using remote sensing method before ground truthing geophysical campaign.

Aeromagnetic method is perhaps the most employed of all the geophysical methods that can be used as reconnaissance tools because the data is readily available (Joel et al., 2016; Chifu et al., 2019; Oni et al., 2019; Ahmed and Mohamed, 2021). It can as well be used for both shallow and deep-seated targets. Such applications include mapping of geological structures and igneous intrusions and the estimation of sedimentary basin thickness. Much of the shallow subsurface investigations are directed toward characterizing the sediments above the bedrock, defining the bedrock topography and delineating buried metallic objects (Keary, Brooks and Hill, 2002).

Several authors such as Olayanju et al. (2011) and Obasi et al. (2013), have reported failed groundwater boreholes and low groundwater potential in some part of the Federal Polytechnic Ado-Ekiti Campus despite the ground truthing geophysical survey. In order to cater for groundwater needs of increasing population of the students and staff. The polytechnic master plan must be tailored toward high groundwater potential zones; Therefore, this research is focusing on assessing the subsurface of the entire campus for groundwater potential evaluation using geomagnetic method.

2 LOCATION AND GEOLOGY OF THE STUDY AREA

The Federal Polytechnic Ado-Ekiti is situated along Ado-Ikare Road, opposite the Afe Babalola University Campus in Ado-Ekiti, Ekiti State. The study area lies within 7°33′00″N – 7°36′30″N and 5°16′00″E– 5°20′00″E of world geodetic system (WGS 84) (Fig 1). Geologically, the region is underlain by the Basement Complex of the southern Nigeria. Major rock types around the area are granites and migmatites (Figure 2). These Precambrian rocks have however, been subjected to tectonic activities and distributed in various ways resulting in fracturing, jointing, cracking among others (Ajayi et al., 2019).

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3 MATERIALS AND METHODS OF STUDY

3.1 SOURCE OF DATA
The aeromagnetic data used in this study were obtained from the Nigerian Geological Survey Agency (NGSA). It was acquired in 2008 through the airborne geomagnetic survey conducted by Fugro Surveys Limited for the NGSA, as part of the nationwide aeromagnetic survey in 2008. The flight height is 80 m and flight line spacing is 500 m. The aeromagnetic data were digitized along flight lines and plotted with a contour interval of 2.5 nT and across tie of 2 km for smoothening the data. -10.812 and -0.874° were respectively the average magnetic inclination and declination across the survey area.

3.2 DATA PROCESSING
The Long wavelength components were removed from magnetic data by deducting International Geomagnetic Reference Field (IGRF), 2020 values. The gridding of the data was done using Oasis Montaj™ 6.2 software. The result of Total Magnetic Intensity (TMI) obtained was reduced to equator because of the closeness of the survey area to the equator; which often place anomaly over their sources. Regional-residual separation was carried out on the reduction to magnetic equator data to enhance shallow anomalies. Application of first vertical/horizontal derivatives and analytic signal to airborne magnetic was used to inspect possible geological structures that could serve as conduit for ground water movement and storage. The probable depth to the top of the basement within the area was determined using analytic and spectra depth methods.

4 RESULTS AND DISCUSSION

4.1 TOTAL MAGNETIC INTENSITY (TMI) MAP
The two-dimension (2D) TMI map is as shown in Figure 3. The map is presented as colour shaded grid map for easy interpretation. The coloured maps aided the visibility of the anomalies on the magnetic maps and the ranges of their intensities were also shown on the scale bar. Positive anomalies areas could be interpreted to be underlain by high magnetic susceptibility rocks or shallow magnetic basement or area of exposed basement rock. Similarly, negative anomalies could be interpreted to be underlain by low magnetic susceptibility rocks or deep basement. The TMI values of the area ranges from -28.24 to 201.27 nT after IGRF correction, which shows that the area is magnetically heterogeneous. As shown in Figure 3, High intensity anomalies is concentrated in the northern part while low intensity anomalies are concentrated in the southern part of the area which implies shallow basement or high susceptibility rocks in northern part of the area.

Both geological map (Figure 4) and drainage patterns map (Figure 5) are generated to inspect their effects on the magnetic signature. The TMI response is not geologically zoned and drainage patterns is dendritic across the study area. However, magnetic heterogeneity across the study area could be as a result of variation in sediment thickness or basement rock configuration.
4.2 REDUCTION TO EQUATOR (RTE) MAP
This can make the data easier to interpret without losing any geophysical meaning. As shown in the TMI map, the trend remains the same in the reduction to equator map (Figure 6) but the image was enhanced and boundary definition was improved. RTE filter helps in properly position anomaly on the causative geological object. Therefore, as shown in the figure 6, basement is likely to be shallow in northern part of the study area compare to the southern part of the study area.

4.3 RESIDUAL ANOMALY MAP
Residual anomaly is the high wavenumber, low wavelength component of the total magnetic field intensity. Residual anomalies vary from -63 nT to 86 nT across the study area. As depicted by the figure 7, existence of high amplitude anomaly in northern part of the study area and low amplitude anomaly in southern part of the study area as presented by TMI and RTE maps also present in residual anomaly. This implies that the causative objects originated from near surface.

4.4 FIRST VERTICAL DERIVATIVE MAP
The vertical derivative is commonly applied to total magnetic field. It filters magnetic data and emphasizes near surface geological features. As shown in Figure 8, the first vertical derivative values in the study area ranges from -0.18 to 0.23 nT/m. According to Michael and Stephen, 2014; Its maxima coincide with the top of the geological structures such as fault and fracture which could serve as a conduit for groundwater movement as shown in figure 8. These peaks of first vertical derivative were enhance in northern part of the study area because of shallow basement than southern part of the study area which is of higher sedimentary cover.

4.5 ANALYTIC SIGNAL
The study area is magnetic equatorial region (magnetic inclination is -10.81° and declination is -0.87°). Since the magnetic analytic signal depends upon the strength and not the direction of body magnetism. It is particularly
useful for analysing data from equatorial regions, where total magnetic intensity provides limited spatial resolution and where the source carries strong remanent magnetization (MacLeod et al., 1993). As shown in Figure 9, the magnitudes of analytical signal ranges from 0.03 to 0.36 nT/m. The analytic signal is useful in locating the edges of magnetic source bodies.

The top of geological structure coincides with the peak of the analytical signal, particularly where remanence and/or low magnetic latitude complicates interpretation (Michael and Stephen, 2014). Geological linear structures are evenly distributed across the study area but they are more visible in the northern part of the study area due to shallow basement. This shows the existence of lineament which could serve as groundwater conduit and storage.

4.6 TOTAL HORIZONTAL DERIVATIVE (THD) MAP
The boundaries/faults, which is the hope of groundwater in the northern part of the study area, are located at the maxima of the horizontal gradient since basement is likely to be shallower vis-à-vis thin sedimentary cover. Figure 10 shows the THD map and suspected linear structures across the study area.

4.7 MAGNETIC BASEMENT DEPTH
Both analytic depth and power spectrum methods were used to estimate the magnetic basement depth as shown in figure 11 and 12. The depth to magnetic basement ranges from 8 to 74 m (analytic depth) which is consistent with the range estimated by the power spectrum method and previous geophysical study in the area such as Obasi et al., 2013. Northern part of the study area is characterized by shallower basement while the southern portion is characterized by deeper basement. The result is validated by georeferencing failed and productive boreholes on horizontal derivative and depth maps. Productive boreholes are either located on the linear structure or deeper basement or both. This implies that major factors controlling groundwater potential in a typical basement complex are thickness of the regolith and linear structures.
5 CONCLUSION
This study was carried out to investigate the causes of reported borehole failure in some part of the Federal Polytechnic Ado Campus using aeromagnetic geophysical method. The geophysical data was processed to enhance shallow anomalies using different enhancement techniques such as derivatives, continuation, analytic and wavelength filters. It was observed that rocks underlain the area have close magnetic susceptibility. Therefore, the response of earth’s magnetism is mainly controlled by sediment thickness (depth to basement) and suspected linear structures. The probable depth to the magnetic basement in the study area ranges from 8 m to 74 m as revealed from analytic depth and radial spectrum depth methods. This result is consistent with previous geophysical study in the study area.

Northern part of the study area is characterized by shallower basement 8 to 24 m and southern part of the study area is characterized by deeper basement 30 to 74 m. However, linear structure such as lineament, faults and fractures are evenly distributed across the study area. Consequently, the groundwater potential of the southern part of the study area is higher. The development of the campus should be tailored towards southern part of the study area to cater for the upsurge in students’ population. It can be deduced that linear structures and basement depth are the major factors controlling the groundwater potential in Nigeria Basement complex.

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