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Ground Magnetic and Electrical Resistivity Mapping for Basement Structurs over Charnokitic Terrain in Ado-Ekiti Area, Southwestern Nigeria

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ABSTRACT

A combined Magnetic and Vertical Electrical Sounding (VES) geophysical methods was carried out in parts of Ado-Ekiti in order to map the area for basement structures. The survey was designed to determine the overburden thickness, the relief and structural disposition of the bedrock within the study area. A total of fifteen traverses were established in the study area, and probed by the magnetic method using the GSM 8 Proton Precession Magnetometer (PPM) with station intervals of 10m. Also, six (6) VES data were obtained using Ohmega resistivity meter. The Schlumberger array was employed. The magnetic and VES data were qualitatively and quantitatively interpreted. The geomagnetic sections reveal an overburden thickness ranging from 5 m to 30 m. Also varying geologic (basement) structures (relief/configuration) such as ridges, depressions (some of which were interpreted as basement structural zones) were also identified. From the geoelectric section, four geologic layers were delineated, these are; the topsoil, the lateritic clay layer, the weathered basement and the fresh basement. The resistivity value in this area showed that the layers are dominated by clay materials with a little proportion of laterite. It could be deduced from the study (magnetics and electrical resistivity) that the basement is very close to the surface (usually less than 15 m overburden thickness), except in some areas on the magnetic sections and VES 3 with an overburden thickness of about 16 m, this VES point may be a structural zone and good for groundwater development.

Keywords: *Profiles, geomagnetic section, magnetic intensity, geoelectric section*

1. INTRODUCTION

The area under investigation within Ado-Ekiti metropolis is located approximately on latitude 07^{0} 36^{1} 14.1^{11}N (841070 mN) to 07^{0} 36^{1} 35.0^{11}N (841715 mN) and longitudes 05^{0} 14^{1} 01^{11}E (746439 mE) to 05^{0} 14^{1} 22.4^{11}E (747092 mE). The study area is in the southeast central portion of Ado-Ekiti along Ikare Road. The accessibility of the study area is mainly by road and footpaths. The location map of the study area is shown in figure 1.1. A total of fifteen (15) traverses were established, trending E-W, NW-SE, NE-SW and N-S directions covering the study area. The traverse length ranges from 60 m along traverse 2 to 460 m on traverse 11, while the station interval is 10 m. A total of 515 station points were occupied for magnetic mapping within the study area. The study area falls within the sub-equatorial south which extends from the coast to roughly 130-160 kilometers inland.

The aim of this study is to use the magnetic and electrical resistivity method to map parts of Ado-Ekiti for subsurface geologic structures relevant for groundwater development.

The objectives of the study include:

(i) to carry out geophysical investigation of the study area by employing the magnetic and electrical resistivity methods.
(ii) interpret the magnetic profiles by identifying geologic features from the geomagnetic section, such as contact zones, fractures and faults, etc.
(iii) determine the geo-electric parameters beneath each of the sounding points.
(iv) identify the basement structures associated with the study area.

Geomorphology/Climate/Vegetation

The climate condition is characterized by dry and wet season in a year. The dry season occurs between November and March. The month of December and January are the driest. The wet season lasts between April and October, with July and September recording the highest rainfall. The average annual rainfall is 1333.2mm. The annual mean temperature is 33^{0}C while the minimum is 18^{0}C. Evaporation is usually low from June through September, ranging from 3.3 mm to 4.0 mm per day. Relative humidity is normally over 90% in the early morning but falls within 60% and 80% in the afternoon, (Iloeje, 1981). Previous study has shown that this area is underlain by Precambrian rocks typical of the basement Complex of Nigeria (Fig. 2). The main rock type found in the study area is charnockitic rock which has undergone an intense weathering into reddish to dark brown medium grained lateritic layer of considerable thickness (Fig. 3)

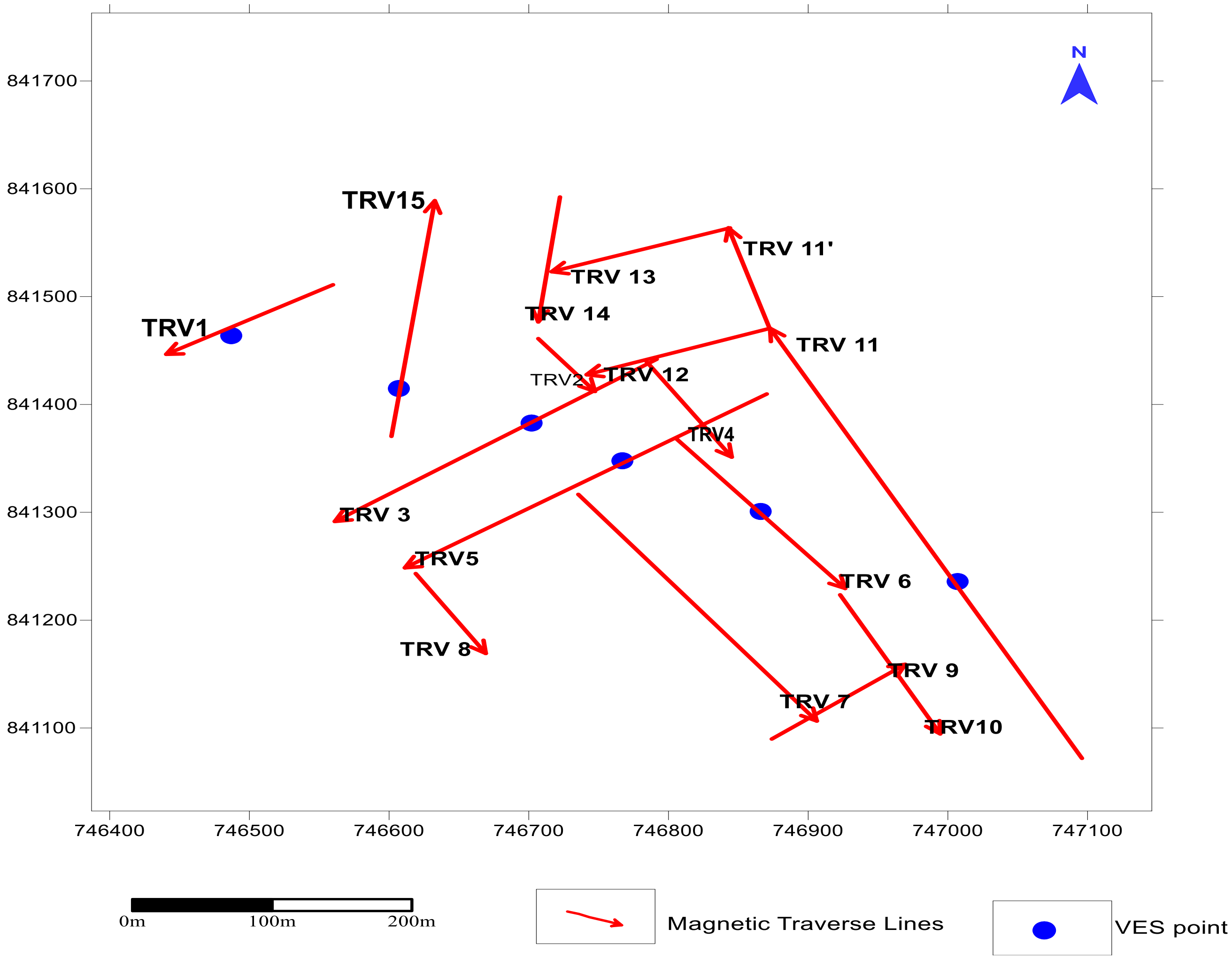


Figure 1.1: Data Acquisition Map

Local Geological Setting

The geology of Ado-Ekiti belongs to the basement complex (igneous rock) rock of South Western Nigeria. Major lithological rock units are basically crystalline basement rocks. These include coarse grained charnockite, fine grained granite, medium grained-granite and porphyritic biotite-hornblende granite with superficial deposit of clay and quartzite. Association of the fine-grained charnockite and the porphyritic biotite-hornblende granite suggest a common age (Omotoyinbo, 1994). A group of granites called younger granites, which are made up of Granites, Granite porphyry, Syenites, Gabbro, Rhyolite and others are regarded as Jurassic in age. A similar trace of these types of rock are found around Ado-Ekiti, Ikole, Ikere, Aramoko, all in Ekiti state and are referred to as charnockite series. The granite of Ado-Ekiti are referred to as older granites. These granites were emplaced during the orogenic cycle that followed early sedimentation. Three phases in older granites are recognized and distinguished: basic and intermediate plutonic rocks, fine grained granite and syn-tectonic granites. The older granites which are associated with pegmatites is of common occurrence and being resistant, smoothly domed inselbergs.

2. MATERIALS AND METHOD

The ground magnetic investigations were conducted on foot using Geometrics 856 Proton Precision Magnetometer and Garmin Global Positioning System (GPS) navigational Equipment for real-time measurements. A base station was carefully selected and established near the study area where the magnetometer was been continuously returned to correct for diurnal variations of earth magnetic field and other sources of external origin.

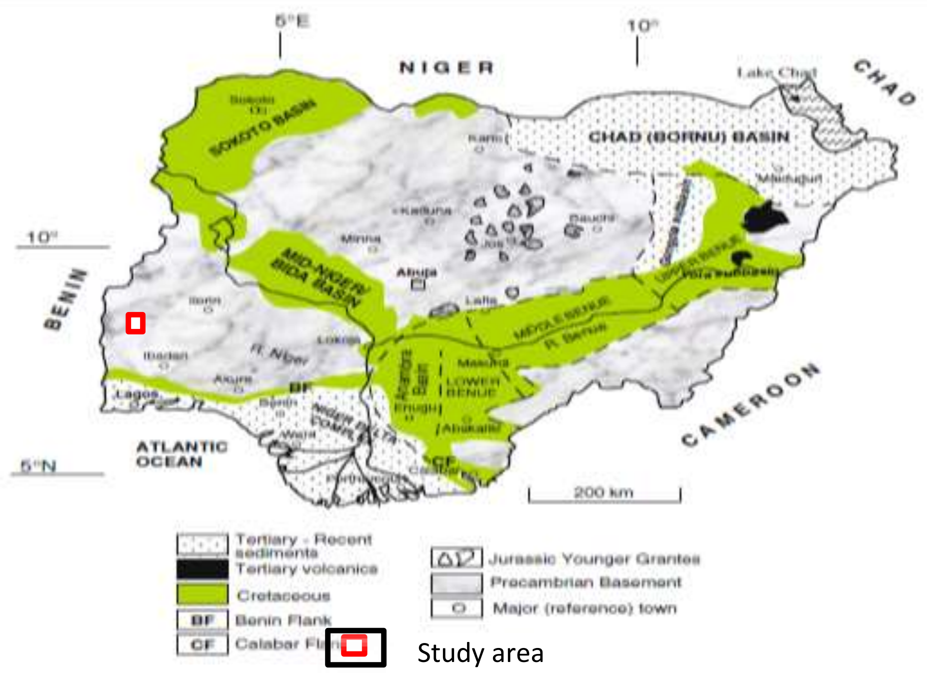


Figure 2 Geological Map of Nigeria showing showing the study area

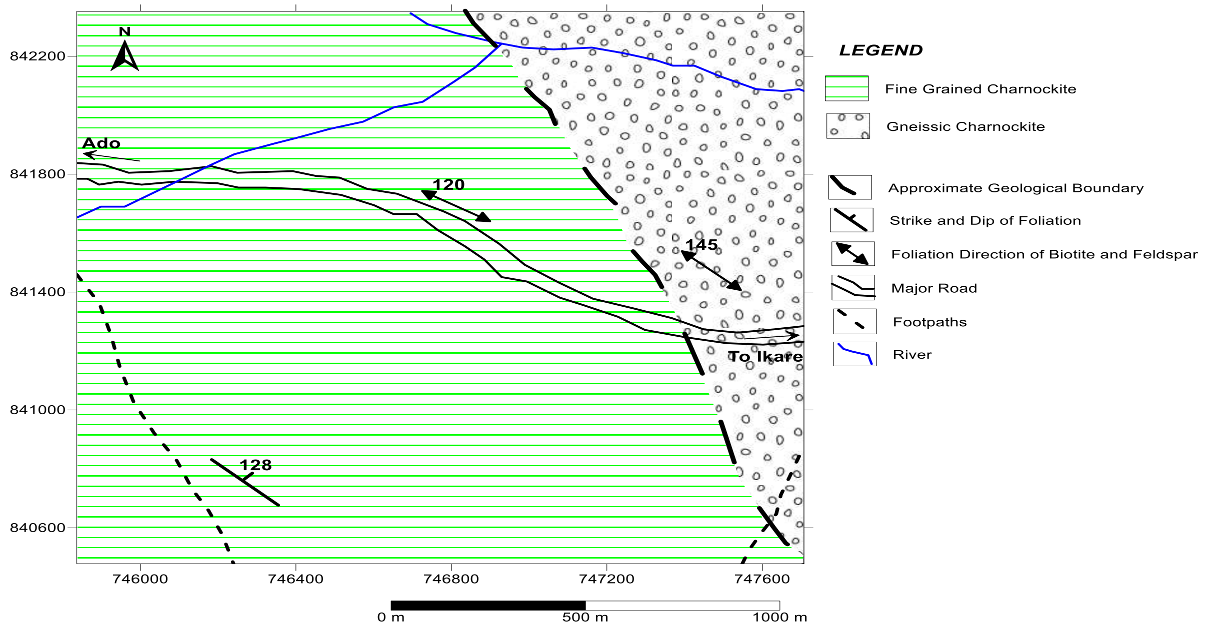


Figure 3 Geological Map of the Southwestern part of Ado-Ekiti (after Fadipe and Adeduro, 1990)

Two magnetic measurements were taken per station while a total of 10 readings was taken at the base stations together with readings of the time. The mean of the magnetic measurements was adopted as the raw data for each observed stations. The acquired data was drift corrected after which a three point moving average was used to filter the drift corrected values. Furthermore, the depths to the top of the anomalies on the profiles were estimated using the half slope method. Corrected magnetic data were plotted against station positions using Microsoft Excel to produce the magnetic profiles along the traverses. It was observed that the magnetic lows and magnetic highs which occur at different stations characterised the profiles (Figs. 4a and 4b). The magnetic lows are indicative of linear features such as fractures/faults, basement depression etc, which are groundwater accumulation regions in a basement complex terrain Oladapo (2013). The depth estimation of the basement in the area was carried out using half-slope method (Peters, 1949). Table 3.1 below shows the estimated depth to the top of the anomalies and their stations of occurrence across the profiles. This method was used as a geophysical tool to map out the study area for basement structures.

Six (6) vertical electrical soundings were conducted within the study area (Figure 1) using an ABEM-SAS 300C Terrameter. Schlumberger array was employed with electrode separations

(AB) ranging from 2 to 100 m. The six VES points were made across the traverses adopted for the magnetic survey; the apparent resistivity values were calculated. The apparent resistivity measurements at each station were plotted against electrode spacing (AB/2) on bi-logarithmic graph sheets. The curves were inspected to determine the number and nature of the layering. Partial curve matching was carried out for the quantitative interpretation of the curves. The results of the curve matching (layer resistivities and thicknesses) were fed into the computer as a starting model in an iterative forward modelling technique using RESIST version 1.0 (Vander Velper, 1988). From the interpretation results (layer resistivities and thicknesses), geoelectric sections along directions (NW-SE) were produced,

Table 1: Estimated Geomagnetic Depth and their Corresponding Station of Occurrence

Profiles	1					2		3							
Station of occurrence of the anomalies	25	70	90	105	145	14	33	16	54	88	110	144	186	216	235
Depth to bedrock	18.9	20	12.6	6.3	18.9	7.56	11.34	5.04	17.64	10.08	7.56	30.24	17.64	20.16	18.9

3. RESULTS AND DISCUSSION

The results of the magnetic and electrical methods are presented below as profiles, depth sounding curves, geomagnetic and geoelectric sections and map.

Magnetic Profiles

The magnetic data obtained along the fifteen traverses were presented in the form of profiles and geomagnetic sections. Inspection of the individual profiles revealed amplitude variation between -1179.7nT and 876.77nT. These values are not uncommon in a basement complex (Telford et al., 1990). The total component relative magnetic intensity varies with respect to different profiles which is a measure of the magnetic mineral content in the subsurface rock unit and its basement structural mapping.

Profile 1

The magnetic profile for traverse one is shown in Figure 4a. The profile shows amplitude variation between -44.18nT and 481.35nT. The varying magnetic intensity suggests varying magnetic materials associated with the rock types in the area. The high amplitude at a distance of about 140 m suggest the presence of basement rock occurring at a shallow depth below the surface, while the low negative amplitude between 0 and 80 m could be indicative of zone of weakness, which may be as a result of fracture or fault.

The geomagnetic section reveals the presence of basement structures such as; basement ridge (between 80 and 100 m) where the overburden is thin and basement depression (between 0 and 70 m and 120 to 160 m) where the overburden is thick. The basement depressions could serve as groundwater collecting troughs.

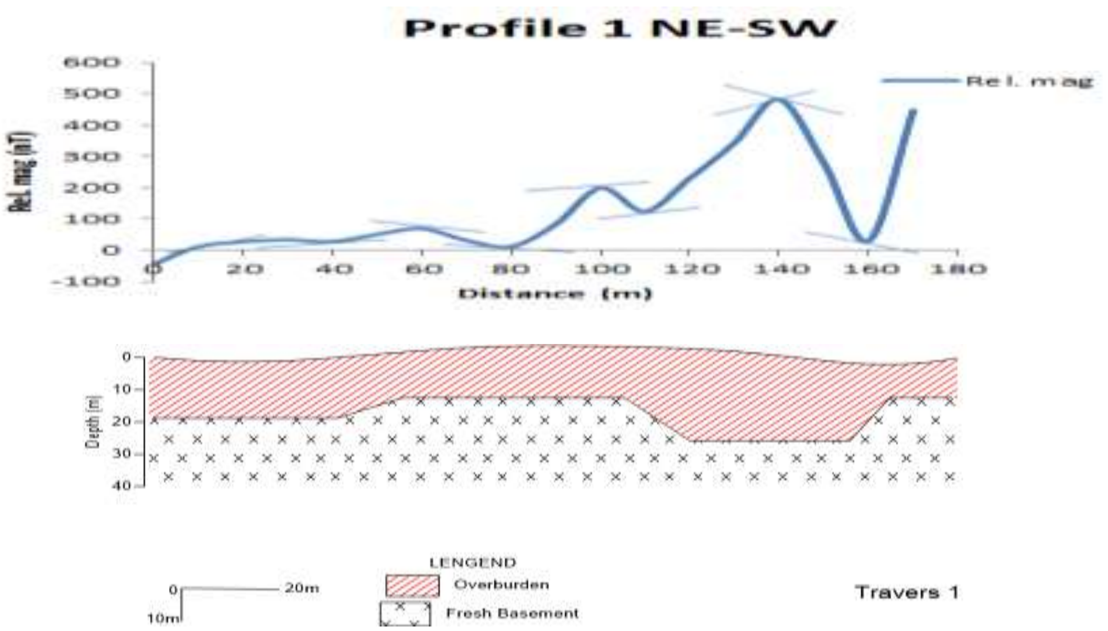


Figure 4a. Magnetic profile and its Corresponding Geomagnetic Section along Traverse 3 (NE-SW) of the Study Area

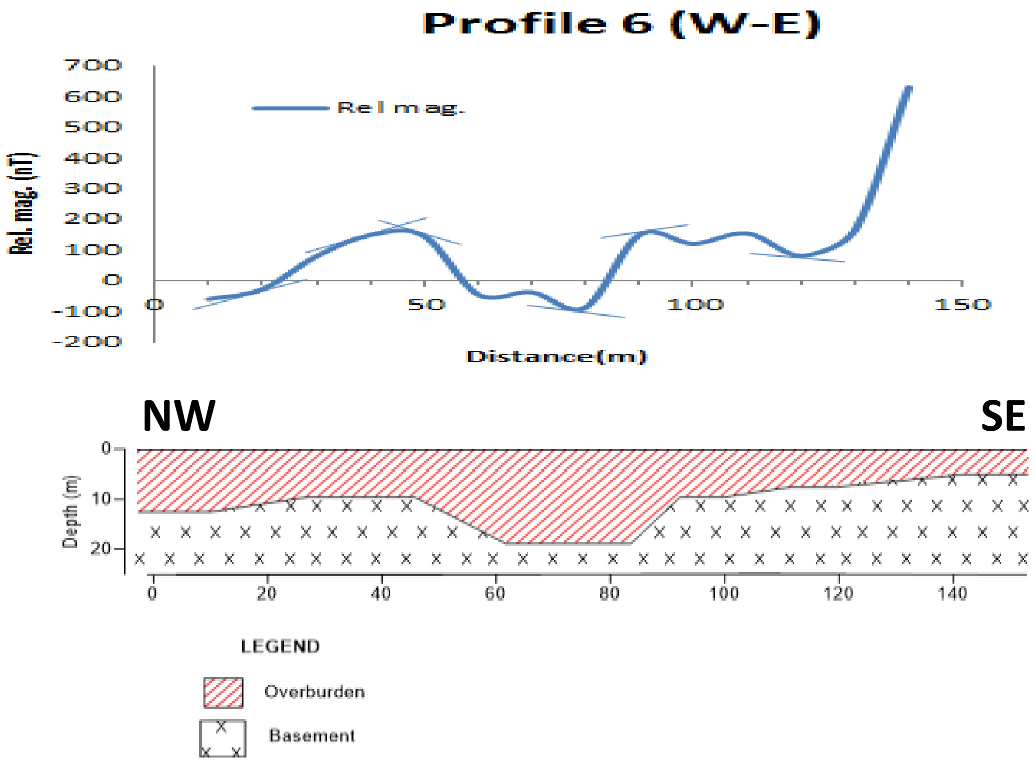


Figure 4b. Magnetic Profile and its Corresponding Geomagnetic Section along Traverse 6

(SE-NW) of the Study Area

Profile 6

The magnetic profile and geomagnetic section for traverse 6 is represented in figure 4b above. The profile shows amplitude variation between -88.28nT to 628.40nT, and a traverse length of 150 m. The presence of a thick dyke is indicated by the W-shaped anomaly between distance 60 m and 85 m. The geomagnetic section shows a gently undulating topography along the traverse. There is the presence of a basement ridge between 20 to 40 m and between 90 to 150m, and a basement depression with a depth range of 9.45 to 18.9 m located between points 60 and 80 m. This basement depression is typical of basement structural zone and could serve as good groundwater collecting trough.

Relative Magnetic Intensity Map

The relative magnetic intensity map of the study area is as shown in figure 5 below. The map reveals area of high and low relative magnetic intensity. The areas with high relative magnetic intensity are probably locations where the basement occur at shallow depth or outcrop to the surface. These cut across almost all the traverse in the study area. As observed from the profiles, areas with low magnetic intensity are locations where the basement structures (fracture, faults, bedrock depressions, etc) are found. These basement structures could serve as deposit centres for mineral resources including water (Kayode, 2010). The low magnetic intensity cut across almost all the traverses been predominant along traverse 5, 7, 8, 10, 11, 11', 12 and 15 corresponding majorly to the north, east, southwest to southeast of the study area.

Vertical Electrical Sounding

The vertical electrical resistivity survey data obtained from the field are quantitatively analysed in order to generate the sounding curves and geoelectric parameters.

The typical curve types obtained in the study area are the H and KH curve type. which depicts the varying nature of the sub-surface, and this complement the result of the magnetic profiles.

The geoelectric parameters obtained reveal information about the probable lithological sequence of the subsurface at the sounding locations. These parameters include the resistivity and thickness values of the encountered lithological units from which the overburden thickness could be determined.

Geo-electric Section

Figure 6 shows the geoelectric section trending in the NW-SE direction. This reveals three to four geoelectric layers. The geoelectric sequences delineated are the topsoil, lateritic clay layer, weathered layer and the fresh basement. The topsoil has a resistivity ranging from 26 to 54Ωm indicating that this layer is made up of clay materials. This layer is relatively thin with thickness ranging from 0.6 m to 1.1 m. The topsoil in VES 2 has high resistivity related to that of the lateritic layer, therefore, it seems to have been washed away due to erosion along this area or is merged with the lower lateritic layer. Beneath the topsoil is the lateritic clay layer. It has a resistivity value ranging from 107 Ωm to 444 Ωm. This layer also has thickness, ranging from 0.4 m to 2.9 m. The third layer is directly above the basement with layer resistivity ranging from 16 Ωm to 61 Ωm; this depicts that this layer is dominated by clay materials. Its thickness ranges from 1.7 to 12.6 m and it is the main aquifer unit in the study area. Absorbing the pressure of the overlying materials is the fresh basement rock with resistivity values ranging from 1468Ωm to ∞. The depth to this layer ranges from 3.2 m at VES 1 to 16.3 m at VES 3.

The geoeletric section shows that the basement is shallow in the study area, except beneath VES 3 with an overburden thickness of about 16 m which shows the feature of a basement structure and is a fairly good point for groundwater development.

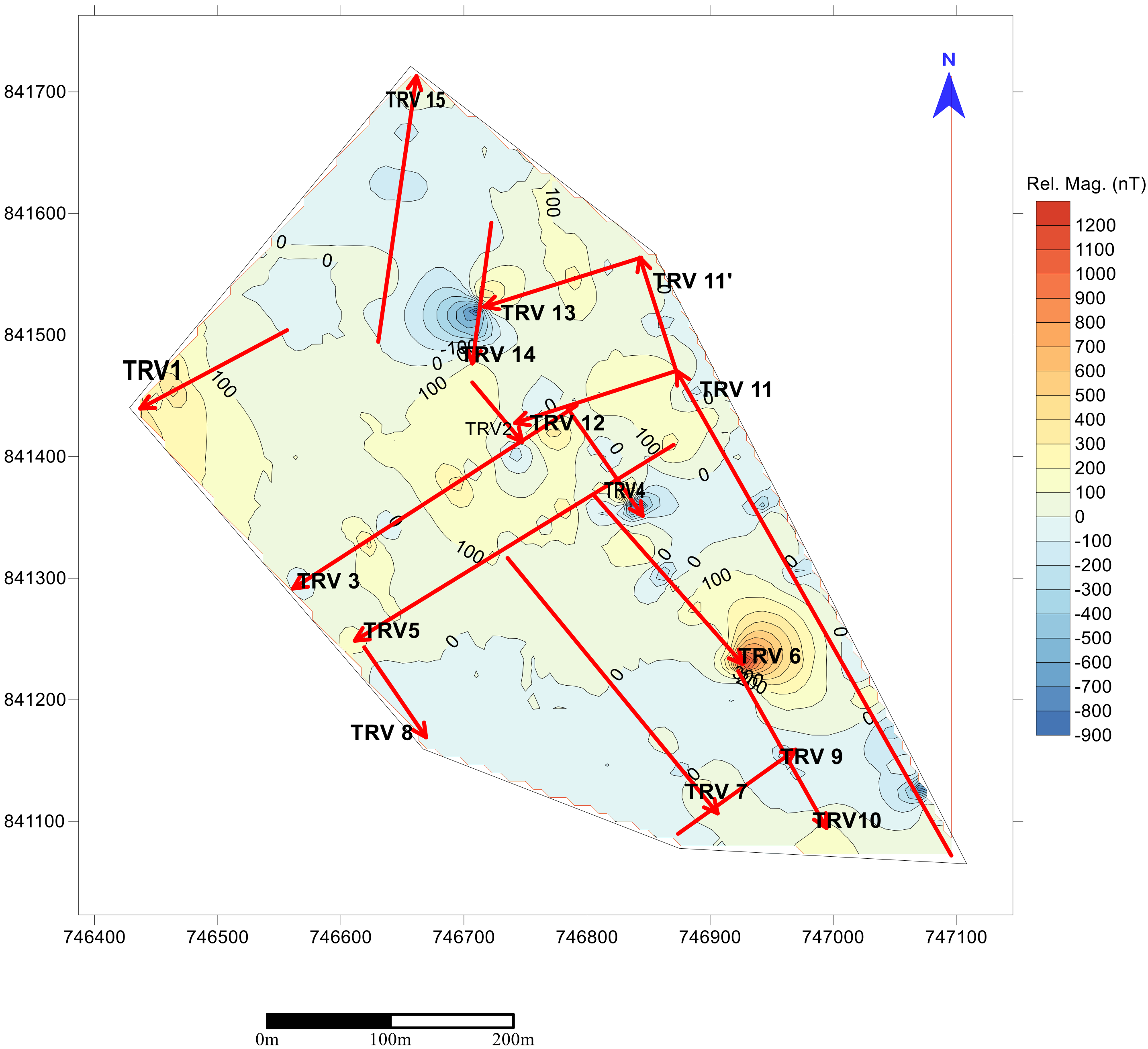
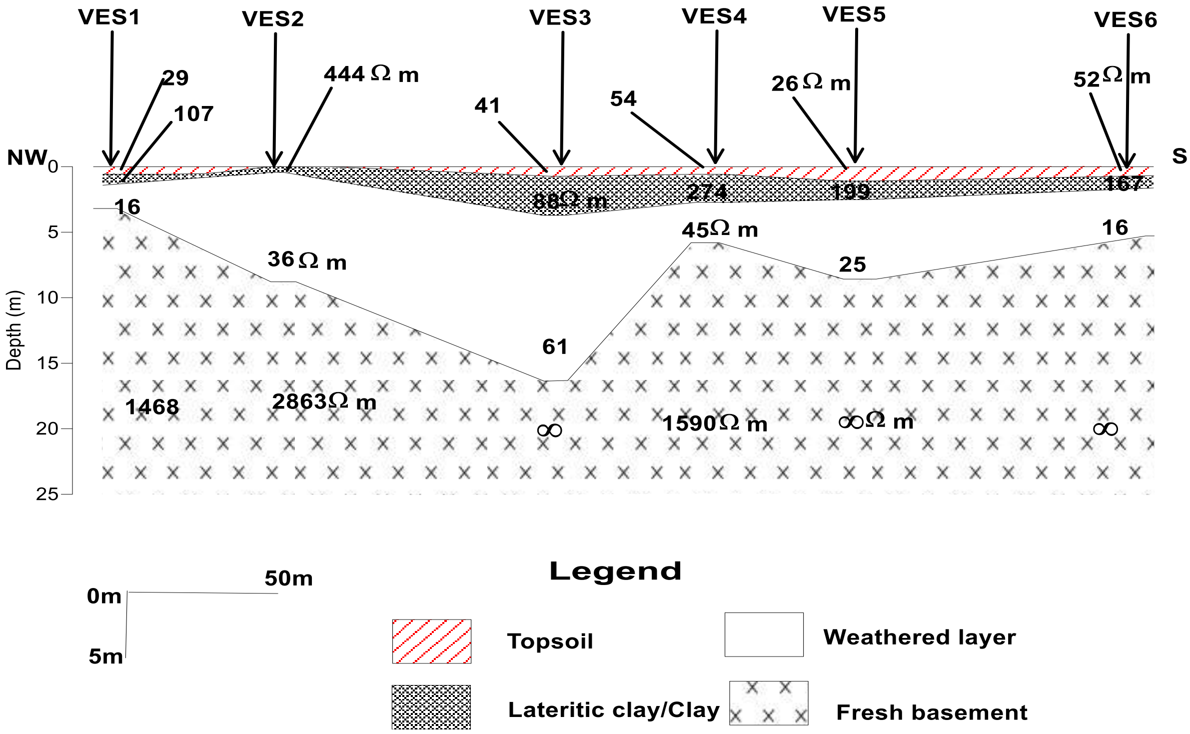


Figure 5: Relative Magnetic Intensity Map of the Study Area



4. CONCLUSION

The ground magnetic and electrical resistivity study for basement structural mapping of this area has helped in the delineation of the geologic structures such as bedrock topography; bedrock depression; and fractures/faults which serve as deposits centers' for mineral resources.

All the magnetic traverses show likely structural zones as bedrock depressions while traverses 6, 11 and 13 show structural areas typical of fault. However, most of these depressions occur at a shallow depth to the surface, and may only be suitable for hand dug wells except along traverses 3, 6, 11, 14 and 15 where the depression extend to a deeper depth below the surface. At a distance of 144 m along traverse 3 the overburden extend to a depth of 30 m, and along traverses 6, 11, 14, and 15, it is approximately 18 m. The result of the vertical electrical sounding reveals three to four layers. The resistivity values showed that the weathered layer is composed of clay. The geoelectric section reveals that the depth to the bedrock is shallow at most VES points (corroborating the results obtained from magnetic surveys), except at VES 3; with an overburden thickness of about 16 m which shows the feature of a basement structure.

The magnetic map shows magnetic low areas typical of basement structures in the north, east, southwest, southeast and south central of the study area. Based on the results of the integrated geophysical methods (magnetics and electrical resistivity), it could be stated that the groundwater potential of the study area is low due to the shallowness of the basement to the surface and the clayey nature of the weathered layer which is the main aquifer unit. More so, the hand-dug wells that could be drilled in such areas could dry-up during dry seasons due to the reasons mentioned above. It could therefore be concluded that ground magnetics and electrical resistivity methods are suitable for mapping basement structures in a typical basement terrain.

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