INTEGRATED GEOPHYSICAL INVESTIGATION OF IJEBU-IMERI ARCHEOLOGICAL SITE, SOUTH WESTERN NIGERIA

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Abstract

Integrated geophysical investigations involving ground magnetic and electrical resistivity methods were conducted at Ijebu-Imeri archeological site, Ogun state, Southwestern Nigeria. The site served as a location for fabrication of tools used for construction of Sungbo Eredo for defensive purpose 600 years ago. The surveys were aimed at locating, determining the spatial distribution and depth of burial of artifacts, thereby reducing wild-cats excavation.

Magnetic data were acquired using proton precession magnetometer while resistivity data were acquired using the Campus Ohmega resistivity meter. The magnetic survey comprises thirty-one profiles in N-S and E-W directions with station interval of 5 m and inter-profile spacing of 5 m while the electrical survey comprises five parallel and four perpendicular profiles selected based on result of magnetic data. Wenner configuration with electrode spacing ranging from 1.0 – 6.0 m was employed for 2D electrical resistivity tomography. Profile length ranges from 1.0 - 100 m in the E-W direction and 0 – 68 m in the N-S direction for both methods. The magnetic data were processed and analyzed using Oasis Montaj Geosoft™ software while the resistivity data were processed and analyze using DIPRO for Windows software.

Results of processed data were integrated and it revealed a distribution of the buried archaeological features within the study area. From the magnetic maps, regions of magnetic highs correspond to those of high resistivity on the 2D subsurface structure models. It was concluded that the areas with high magnetic and resistivity anomalies are possible areas that has buried artifacts with depths ranging 0 - 2 m. Trial pits located at regions of high total magnetic intensity and model resistivity yielded burnt pipes (TUYERE), iron slag; pottery fragments (POTSHERDS) and charcoal occurring at 0 – 0.6 m. The geophysical results therefore provided reliable and useful guide in pre-excavation of archaeology materials.

Introduction

Archeology is the study of the lives of past people through physical remains left behind (Feder, 1999).Archeological investigation usually involves visual inspection and classification of group objects called artefacts. These remains called artefacts can be found on the ground surface (Mooketsi, 2009). Archeological features commonly concealed are furnaces and furnace fragments, pottery kilns, burnt

bricks (or brick walls), fire hearths and fired soil, Ceramic materials such as tiles, plates, clay pots and potsherd, "lost" graves and buried void space (Clark, 1996).

Archeologists are mostly concern with retrieving features that are of archeological interest primarily through field survey, excavation and proper documentation of the archeological findings, archeologists know where to search, but they don't really know where to dig, therefore the archeologist results to test pitting and excavation.

Environmental friendly pre-excavation geophysical methods are virtually the best routine in archeological prospection because surfaces of archeological have often times been altered by anthropogenic activities such as farming and depth to which artefacts are buried are often not known. Geophysical methods therefore provide fast, efficient, non-destructive and non-invasive reconnaissance techniques often required by archeologists (Weymouth, 1986).Geophysical investigations have been used with considerable success in archaeological prospection (Fassbinder, 2015, Oyeyemi *et al*., 2014 and Olurunfemi *et al*., 2015)

This study focuses on the application of integrated geophysical methods involving magnetic and electrical resistivity for locating archeological artefacts (iron slag, potsherds, burnt pipe or 'Tuyere') at Ijebu-Imeri Archeological site located in Ogun State South western Nigeria.

Site description and Geology

The study area is located at Ijebu- Imeri (Fig.1) $06^0$46'53''N and $003^0$58'23''E; it is surrounded by "Sungbo-Eredo". The Sungbo Eredo served a defensive purpose when it was built in 600 years ago. The total length of the Eredo wall is more than 160 km. it is situated within the eastern Dahomey Basin in Abeokuta Formation. The Abeokuta Formation in surface outcrops comprises mainly sand with sandstone, siltstone, silt, clay, mudstone and shale interbeds. It usually has a basal conglomerate which may measure about 1 m in thickness and generally consists of poorly rounded quartz pebbles with a silicified and ferruginous sandstone matrix or a soft gritty white clay matrix.

Objectives and Methodology

The geophysical survey was carried out on Ijebu-Imeri archaeological site April 2017, the objectives of the study was to (1) map buried structures (2) locate buried artefacts (3) identify point of excavation rapidly, thereby my reducing costly and wild cats excavation; and (4) to evaluate the application of geophysics as a pre-excavation tool in Archaeology.

Ground magnetic data were acquired using a Geometries UNIMAG G-856AX proton precession magnetometer that involves measuring the total magnetic intensity component at each data point along the survey line. This instrument has an accuracy of ±1 nT. Readings were taken with the sensor oriented north during the survey, while the survey staff was maintained at 0.2 cm above the ground surface, at 5 m intervals along the same traverse and inter-profile spacing of 5 m. Two magnetometer readings were taken at each position and averaged; the magnetic survey comprises thirty-one profiles in N-S and E-W directions, thirteen in-lines and eighteen cross-lines were established making a data density of 469 points. The magnetic data were processed and analyzed using Oasis Montaj Geosoft^{TM}software; the data were enhanced using Gaussian and Analytic Signal Filters (Montaj^{TM} Tutorial, 2004).

Electrical resistivity survey was carried out using Campus Ohmega Resistivity meter adopting the Wenner-alpha array. A manual data collection technique was employed, the electrical survey comprises five parallel and four perpendicular profiles selected based on result of magnetic data. The 2D traverse line was 100 m in length in the East-West direction and 68 m in North – South direction and they form an orthogonal set. The electrode spacing ranged from 1 m to 6 m that is six data level. Line 1, 2, 3, and 4 were run in N-S direction whereas the other five 2D traverses (lines 5,6,7,8 and 9) were run

in E-W direction. The electrical resistivity data were processed and analyze using DIPROofWIN 4.01 software.

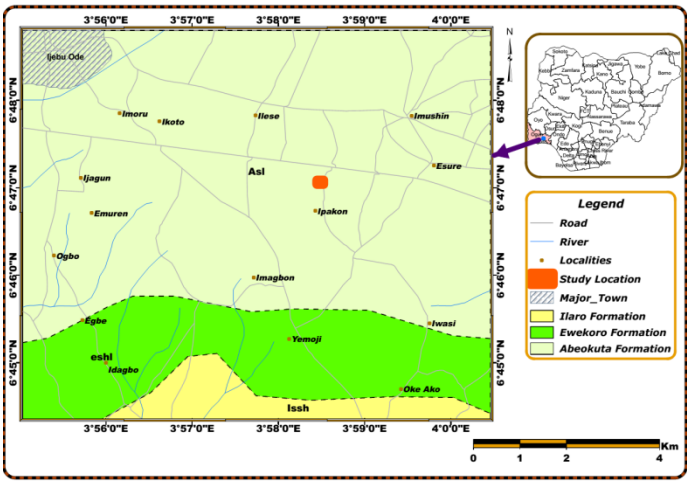

Figure 1.Map showing the geology of the Study Area.

Results and Discussions

Magnetic Anomaly Contour Map

The total magnetic intensity contour map of the area is presented in Figure 2. The map was based on the raw magnetic field data after acquisition without processing; regions of very high magnetic intensity values are concentrated nearly at the center of the study area. This region constitutes the area of interest in archeological prospection. The magnetic highs were observed in the northern part of the study area and the central of the area.

Magnetic Anomaly Image Maps

The magnetic anomaly maps of the study area, which involves the total magnetic intensity (TMI) and the Analytic signal maps obtained from the field data. The areas of high total magnetic intensities are localized and occurred towards the center running north south. The test pit 2 on profiles 7 was established within the high total magnetic map.

Total Magnetic Intensity (TMI) Anomaly Map

The total magnetic intensity map (Fig.2) is a map showing the measurement from the magnetometer after a model of the earth's normal magnetic field is removed. It is generally a reflection of the average magnetic susceptibility of the features in the study area.

Analytic Signal (AS) Anomaly map

The analytic signal has the property that it generates a maximum directly over discrete bodies as well as their edges. Local peaks in the analytic signal profile are interpreted as corners of the source bodies and the shape of the peak contains information about the depth of the corner (Nabighian, 1974). Figure 3 is the analytic signal map showing high magnetic intensity denoted by pink to red colour while areas with low magnetic intensity are denoted by green to blue. The areas with high analytic signal are likely areas of archeological interest.

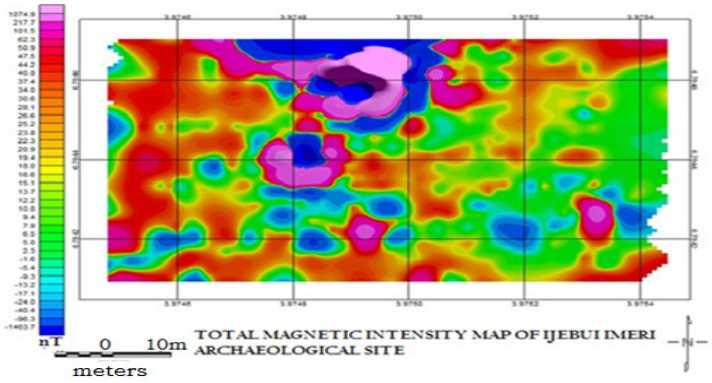

Figure 2: Total Magnetic Intensity Map of Ijebu-Imeri Archeological Site Showing High and Low Magnetic Intensity

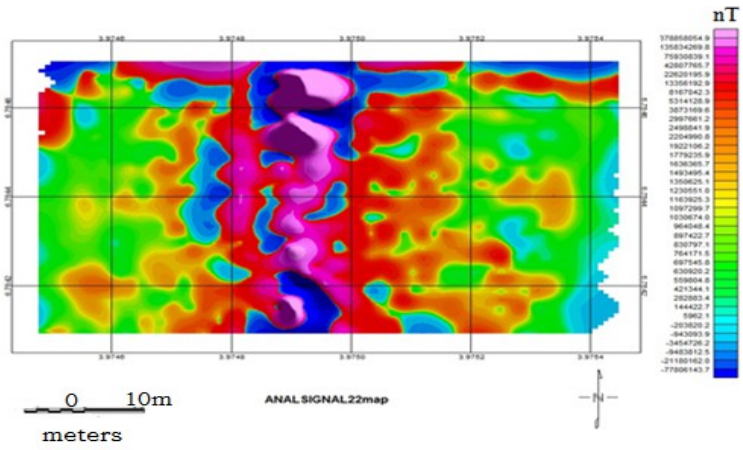

Figure 3: Analytic Signal Map of Ijebu-Imeri Archeological Site showing the peak of anomalies over the causative bodies

Electrical Resistivity Survey Data

The electrical resistivity survey data are presented as 2-D electrical resistivity imaging. Figures 6 and 7 are representative sections for the in-line and cross-line profiles.

2-D Subsurface Images

The result of profile 3 (fig.4) shows high resistivity values between 1100 to 2000 Ωm across the profile at relatively shallow depth. Regions with high resistivities could be assumed to contain some archaeological remains. Low resistivity zones with values between 350 to 622 Ωm as observed between 94- 97 m along the profile are typical of clayey Formation/ lateritic clays.

Figure 5 shows the result of profile 7 conducted in north-south direction. High resistivity values ranging between 1100 to 4000 Ωm were observed across the profile, such anomalous high resistivity probably indicate the presence of archaeological features, while the relatively low resistivity regions

(>660 Ωm) could indicate the presence of clayey/lateritic materials or backfilled trenches where ironstones was scooped into nearby furnaces for iron smelting. The anomalous high resistivities are suspected to be areas of buried artefacts which can further be confirmed through excavation.

Pitting Results

Test pits were located in regions of high magnetic susceptibility and high resistivity to confirm the results from the combined methods.

Test pit 1 located on profile 3 was between 89- 91 m with a dimension of 2 x 2 m and 2 m deep. Few artefacts such as ironslags, potsherd and a lot of ironstones were recovered in the pit.

Test pit 2 located between 41 – 43 m along profile 7 was 0.6 m deep at 2x1 m dimensions. Artefacts like broken pottery (Potsherds), Tuyere or burnt pipes, iron slag and charcoals were recovered during the excavation. The ironslags recovered from test pit 2 were weighed and found to be 281kg which confirmed interpretation from combined methods.

The inventory of the archaeological materials, the lithology and the munsell's soil colour classification for each soil type and artefacts encountered in test pit 2 is shown in Table 1

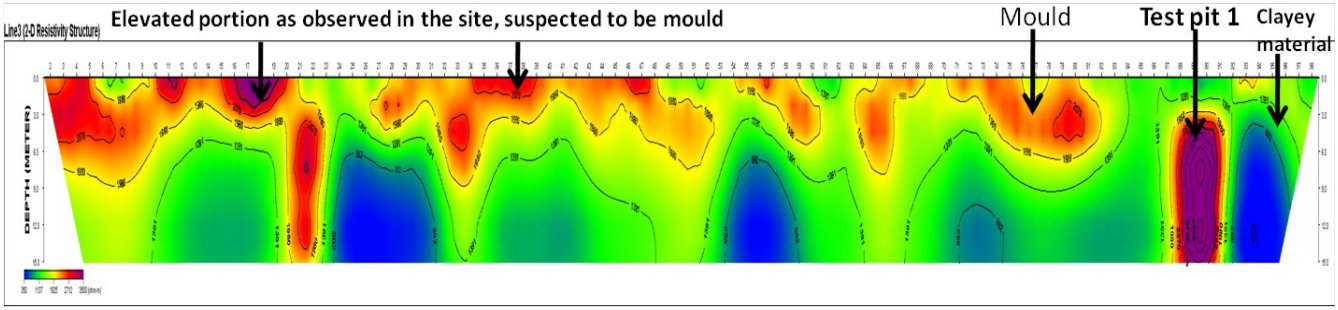

Figure 4: 2-D Resistivity Subsurface Structure along Traverse 3 E-W Direction

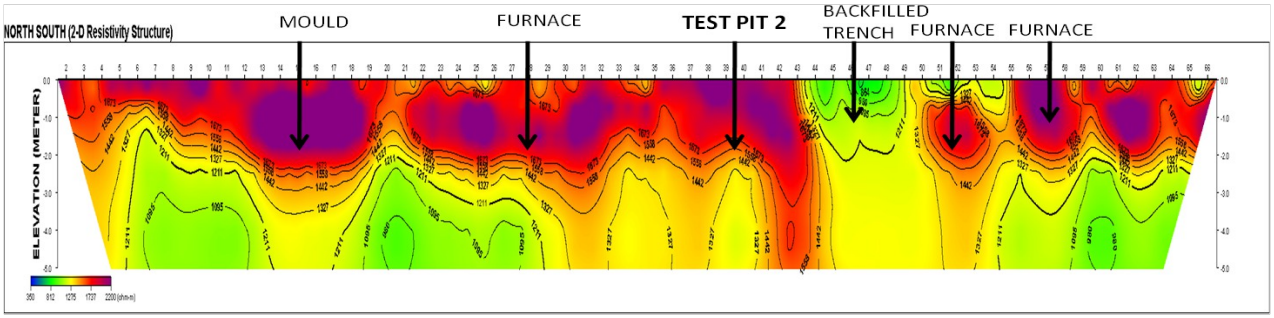

Figure 5: 2-D Resistivity Subsurface Structure along Traverse 7 N-S Direction

Table 1: Inventory of the Archaeological features recovered in Test pit 2 along profile 7

depth (cm)	LITHOLOGY	DESCRIPTION	MUNSELL'S SOIL CLASSIFICATION	ARCHEOLOGICAL FEATURES RECOVERED
0		Topsoil (loamy soil)	Hue 10YR- 2/2 very dark brown	Potsherd, Ironslags.
10		Cultural layer	Hue 10YR- dark greyish brown	Potsherds, Iron slags, Tuyere or burnt pipes and Charcoal specks
60		Sterile layer	Dark reddish brown	no artefacts

Conclusions

The Ijebu-Imeri archaeological site in Ogun State, southwestern Nigeria, has been investigated using the magnetic and electrical resistivity methods of geophysical prospecting. The magnetic method involved the use of proton precession magnetometer for data acquisition while electrical resistivity data were acquired using the Campus Ohmega resistivity meter.

The results of the magnetic survey showed regions of high and low magnetic intensity, this result was used in selecting areas were electrical resistivity survey profile lines were located. The 2-D resistivity structure identified priority zones within the top soil along profile 7 which was corroborated by follow-up excavation. Archeological artefacts including potsherd, Iron slags, charcoal were recovered within the archaeological interest zone (Table 1). The research further confirmed that geophysical methods are rapid, non-invasive, non-destructive and environmental benign thus providing the wherewithal to map and locate subsurface archaeological materials.

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