Application of Magnetic Method and Electrical Resistivity Tomography for Imaging Archaeological Structures at Iyekere, Ile-Ife Southwestern Nigeria

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Summary

Magnetic and electrical resistivity tomography geophysical techniques were integrated to locate subsurface archaeological materials. The magnetic survey comprises seven profiles in N-S and E-W direction with station interval of 0.5 m. [Orthogonal set of] 2D electrical resistivity tomography data consisting of four parallel and three perpendicular profiles were collected using Wenner array with electrode spacing ranging from 0.5 – 3.0 m. Trial pits carried out at regions of high total magnetic intensity and model resistivity yield burnt pipes "TUYERE", iron slag, iron smelting, and pottery fragments.

Introduction

Archaeological and environmental impact assessments as part of planning applications often require geophysical surveys. The geophysical surveys are designed to detect and define archaeological structures and features that may be hidden beneath the soil. Assessments normally take place in advance of projects such as road or pipe corridors, the building of single houses or estates and the development of industrial zones or mineral extraction sites. In the case of research projects and monument delimiting surveys, where there are known or visible archaeological monuments, geophysical surveys can be used to assess their possible hidden sub-surface extension and preservation, preservation potential or to prospect for undiscovered monuments in the locality.

Geophysical methods provide fast, efficient and non-destructive reconnaissance techniques often required by archeologists. Also, geophysical techniques offer rapid, uniform, reconnaissance of an entire site together with a synoptic view of the interrelationships within the site (Weymouth and Huggings, 1985). Geophysical methods has been used to map healths, klins, buried bricks, building foundations, middens (trash heaps), burial tombs, ditches and soils compacted or excavated by previous human activities (Weymouth, 1986; Loperte *et al* 2011). In this study, high resolution geophysical methods involving magnetic method and electrical resistivity tomography (ERT) imaging have been used in the search for archaeological materials (iron slag pottery materials, burnt pipes or tuyere). The locations and approximate depths of these archaeological materials were obtained from the resulting geophysical images; pitting were carried out at these locations to verify the accuracy of the geophysical results.

The study area, Iyekere, is within the ancient city of Ile-Ife in southwestern Nigeria. It is boarded by latitudes $4^0$30' N and $4^0$33' N and longitudes $7^0$22' E and $7^0$25' E (Fig. 1.1). Other settlements around the study area include Isoya, Alapata and Toro among others (Fig.1a). The rock types are predominantly granite-gneiss and pegmatite of the Older-granite complex. Schist and epidiorite complex belonging to gneiss-schist complex of the basement complex are the dominant rock type in north-eastern part of the area (Oyawoye, 1972) (Fig. 1b).

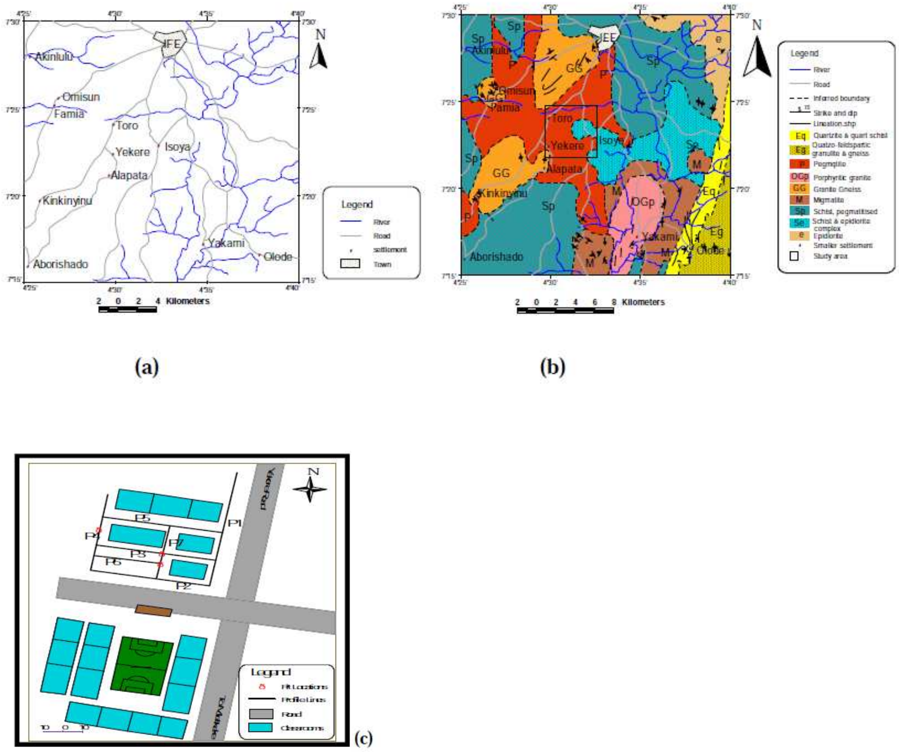

Fig.1: (a) Location and drainage map of Iyekere, (b) Ile-Ife Geological map of Iyekere and Its environs after NGSA, 2004 (c) geophysical Survey base map showing profile lines.

Method

The magnetic measurements were recorded using a proton magnetometer G-856AX that involves measuring the total magnetic intensity component at each data point along the survey line. Seven profiles involving four in-lines and three cross-lines were established (Fig.1c). Station interval of 0.5 m was maintained across each profiles making a data density of 770 points. The sensor was oriented north during the survey, while the survey staff was maintained at 0.3m above the ground surface.

The magnetic data collected in the study area were processed using MagMap 2000 so as to prepare the data set for interpretations, these involves drift correction due to diurnal variations and plotting of the relative total magnetic intensity profiles for each traverse. The total magnetic intensity Image map of the site was also generated.

Similarly, a total of seven multi-electrodes 2D geoelectrical resistivity imaging lines were measured using the Wenner-alpha array. The maximum 2D traverse line was 75 m in length, while the minimum was 30 m and they form an orthogonal set. The electrode spacing ranged from 0.5 to 3 m with an interval of 0.5 m. Line 2, 3, 5, and 6 were ran in E-W direction whereas the other three 2D traverses (lines 1,4,and7) were ran in N-S direction (Fig. 1c).

RES2DINV computer code (Loke and Barker, 1996a) was used in the inversion of the 2D data. Nonlinear optimization technique which automatically determines 2D resistivity model of the subsurface for the input apparent resistivity data (Griffiths and Barker, 1993; Loke and Barker,1996a) together with least square inversion and smoothness constraints were applied.Three trial pits of 1m x 1m x 1m were excavated, two of which coincides with areas of total magnetic intensity and high resistivity from the results of magnetic method and the 2D resistivity tomography inversion modelling, while the other which coincides with the area of low total magnetic intensity and resistivity serves as control.

Results and Discussion

The 2D resistivity tomography inversion model sections of the E-W and N-S traverses which are perpendicular to each other are presented alongside the total magnetic intensity profiles for proper integration to aid the general interpretation. The RMS errors for the image lines are generally less than 9% except for Line 1 (Fig. 2) that appears relatively noisy because of near surface large resistivity variations. Along the total magnetic profile plot for each traverse, regions of magnetic high corresponds to those of high resistivity on the 2D tomography inversion model (Fig.3). A major sharp drop in magnetic signature was observed between 24 m and 40 m data points centring on 32 m point along Line 4 , which was about the lowest (-250 nT) in the entire study area. This is interpreted to be an evidence of a backfilled ditch or well (Weymouth, 1986; Herwanger, et. al., 2000). The total magnetic intensity contour map of the area (Fig.4a) depicts region of very high magnetic intensity values concentrated at the centre of the study area. These high magnetic intensity areas are thought to be the target areas for artefacts in archaeogeophysical studies (Mullins, 1974; Weymouth, 1986; Noel and Xu, 1991; Kvamme, 2001; Hammerstedt, et al. 2010) and can be inferred to be the points of intersection of both the E-W Lines (lines 3 and 6) with the N-S Line 7 on the base map. These points coincide with the beginning of line 6 and within 25 m and 33 m data points on Line 3 as observed on 2-D tomography inversion modelling results.

Conclusions

Geophysical techniques involving magnetic and electrical resistivity tomography has been effectively used to delineate the locations and depths to archaeological materials at Yekere, Ile-Ife, southwestern Nigeria. The results obtained from the magnetic field survey are similar to that of electrical resistivity survey. Corroborative evidence from trial pitting shows that pits located at regions of high total magnetic intensities and resistivities yield high quantities of archaeological materials while the one that is located at low magnetic intensity and resistivity was almost sterile. The study confirmed that geophysical techniques are non- destructive, and provide the capability to map and analyse subsurface archaeological features.

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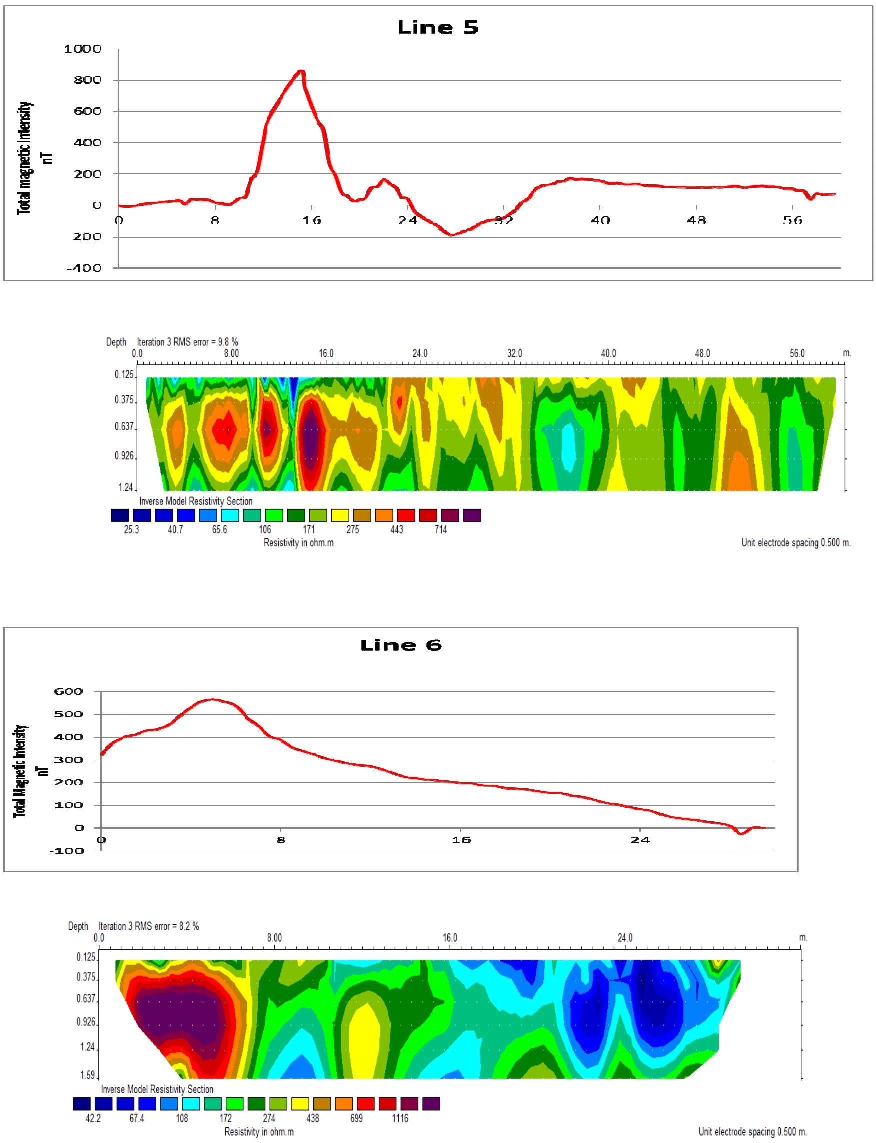

Figure 3: Line 5 and Line 6 showing magnetic profiles and corresponding 2-D tomography imaging

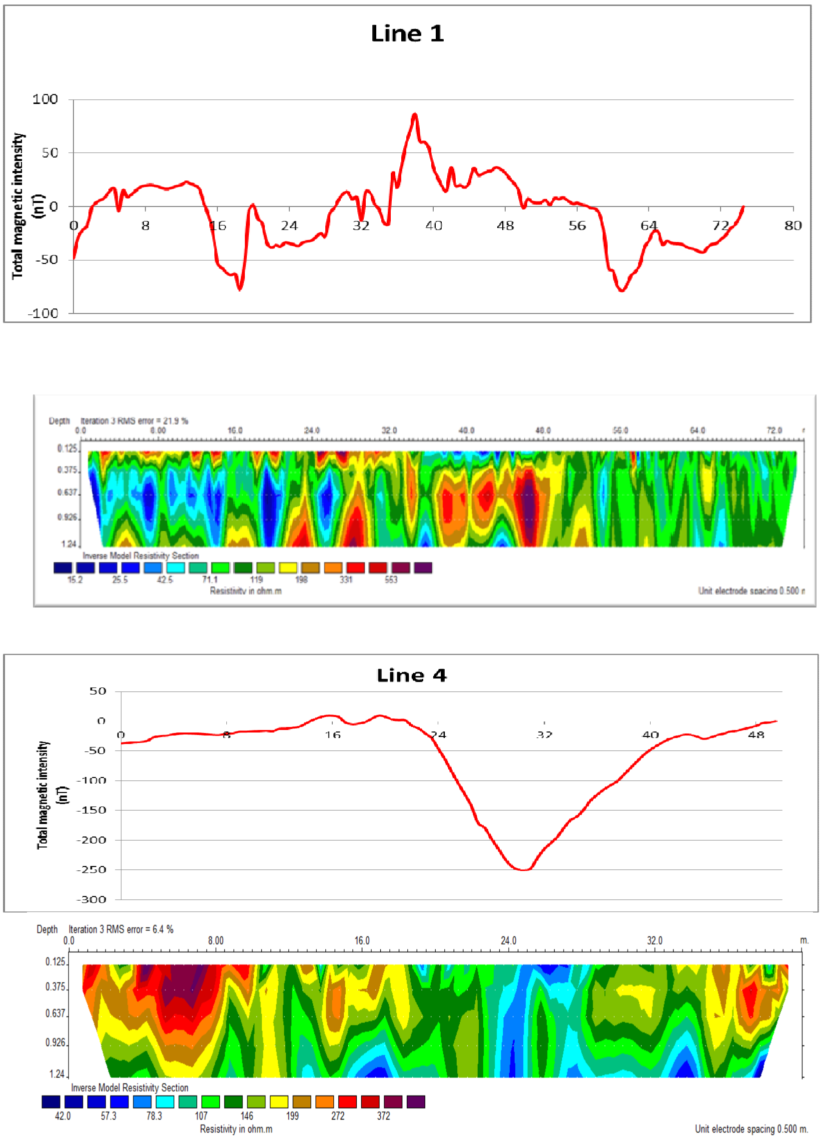

Figure 4: Line 1 and Line 4 showing magnetic profiles and corresponding 2-D tomography imaging

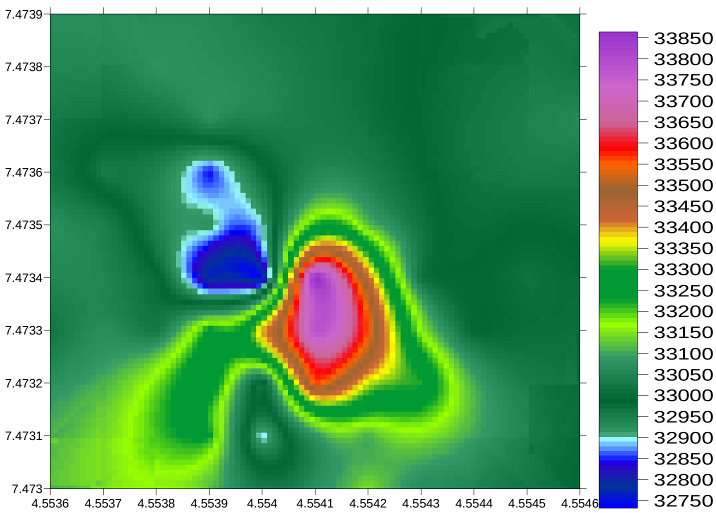

Figure 5: Total magnetic intensity colour image map of the study area