INTEGRATED GEOPHYSICAL INVESTIGATION OF YEMOO GROVE ARCHAEOLOGICAL SITE IN ILE-IFE, OSUN STATE, SOUTHWEST NIGERIA.

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ABSTRACT

Integrated geophysical investigation involving the electrical resistivity and magnetic methods was carried out at Yemoo Grove archaeological site at Ile-Ife in Osun State, Southwest Nigeria. The resistivity survey involved 1-D Vertical Electrical Sounding (VES) with the Schlumberger array and 2-D Dipole-Dipole resistivity imaging (profiling) technique. The VES data were interpreted quantitatively by partial curve matching and computer assisted 1-D forward modelling with the W-GeoSoft/WinSev 5.1 software. The 2-D Dipole-Dipole data were inverted to 2-D subsurface structure with the DIPRO for Windows software. The VES delineated a stratigraphic sequence composed of the topsoil, lateritic clay and weathered basement within the upper 14.0 m. The topsoil, which is the most archaeologically relevant horizon, had thicknesses of up to 2.0 m. The 2-D structures identified four priority zones with relatively thick topsoil (up to 2.0 m) along the existing trench and at the shoulders of the flanking ridges. Three of these zones were excavated plus one random location. Archaeological artefacts ranging from ceramics, potsherd pavement, charcoal and stone concretion were identified within the excavated priority zones while nothing was found at the randomly located site. The 2-D structure along one of the traverses identified a terraced surface on the underlying lateritic layer. This was corroborated by excavation. No metallic artefact was identified. The geophysical results provided a reliable guide to archaeological prospection at the Yemoo Grove Site.

Keywords: Geophysics, Archaeology, Artefacts, Subsurface Imaging

INTRODUCTION

Feder (1999) defined archaeology as the study of the lives of past people through the physical remains they left behind. Archaeological investigation usually involves visual inspection and classification of groups of objects (artefacts); laboratory studies involving analysis and dating of recovered objects and samples from buried archaeological sites and geophysical investigations including remote sensing. The former two methods require destructive excavations at archaeological sites. Pre-excavation geophysical investigations, which are non-invasive and environmental friendly, are virtually becoming a routine because surfaces of archaeological sites have often times been altered by anthropogenic activities such as farming and physical (urban) development. Also locations, exact nature and extent of archaeological objects are often not known. Geophysical investigations are also engaged to reduce cost of excavation by constraining (guiding) locations to be excavated.

Geophysical methods are relevant in archaeological prospection because of the existence of detectable contrasts in physical properties, such as resistivity or conductivity, magnetic susceptibility, density and elasticity, between archaeological artefacts and the surrounding earth materials. This makes the electrical resistivity, electromagnetic, ground penetrating radar, magnetic, microgravity and even seismic methods of geophysical prospecting relevant (Clark, 1996; Gaffney and Gater, 2003; Witten, 2006; Oswin, 2009; Dolphin, 2011 and Dalan, 2012). Geophysical investigations have been used with considerable success in archaeological prospection (Eluyemi *et al.,* 2012a; Kuhne *et al.,* 2013; Fassbinder *et al.,* 2014 and Fassbinder, 2015). Geochemical analysis, direct metal detection and aerial photographs/remote sensing have also found useful applications in archaeological prospection (Kennedy and Jones, 2009; Eluyemi *et al.,* 2012b).

YEMOO GROVE (known to the local community as Ita Yemoo), in Ile-Ife, southwest Nigeria, is a renowned archaeological site and one of such sites being overseen by the National Commission for Museum and Monuments under the Federal Ministry of Culture and Tourism. Archaeological works started at this site in 1957 by Frank Willet. However, prior to Frank Willet's visit, seven bronze sculptures were discovered by builder's labourers during construction works at the site. Apart from bronze sculptures, other artefacts that have been recovered at this site include terra-cottas, stone sculptures, ritual vessels, glass beads, fused but unused glass, fragments of crucibles for making glass and potsherd pavements (Willet, 1959).

The French Government, through the third co-author, has recently provided funding for the excavation of part of the archaeological site. A preliminary integrated geophysical investigation of the site was embarked upon as a fast recognisance technique capable of providing information on artefact-laden vs barren ground that can be used to guide excavation works thereby reducing cost. The geophysical investigation involved the electrical resistivity and magnetic methods.

Description of the Project Environment

The Yemoo Grove archaeological site is situated in the ancient city of Ile-Ife in Ife East Local Government Area (LGA) of Osun State, Nigeria

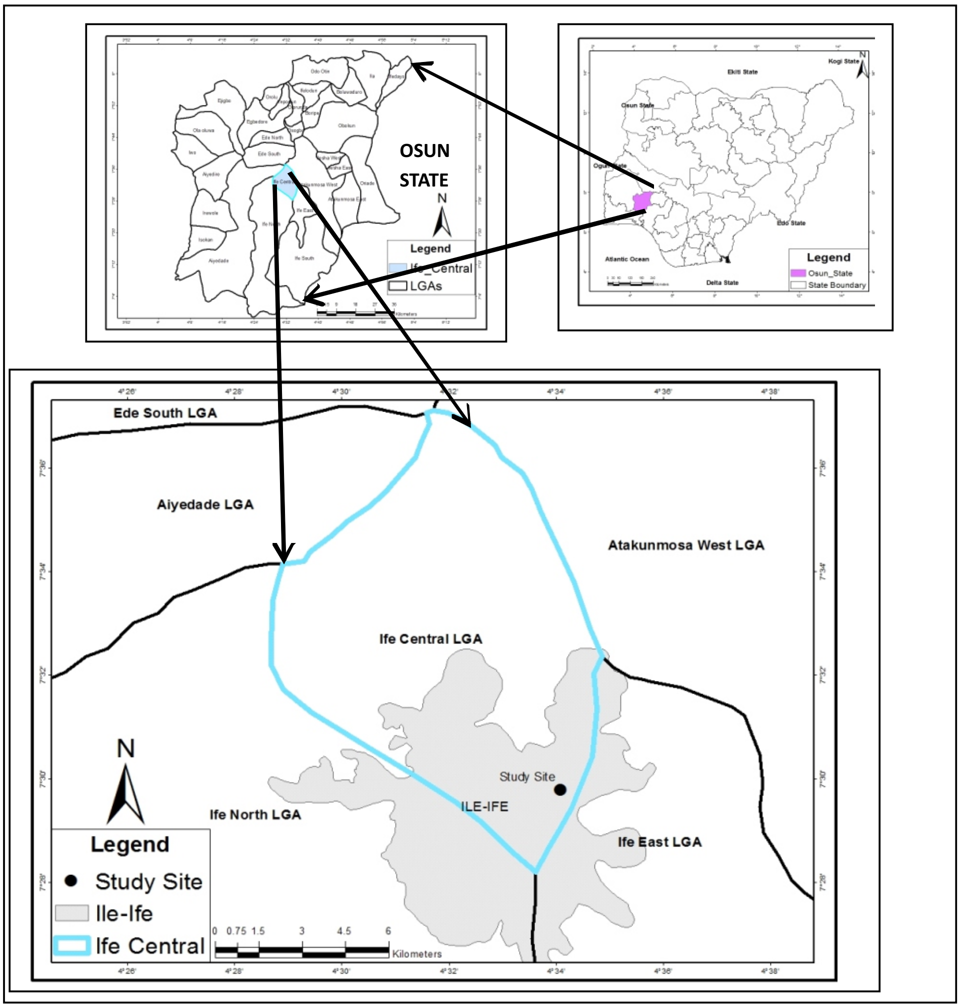

Figure 1: Map Showing the Study Site in Ile-Ife, Ife Central LGA of Osun State, Nigeria

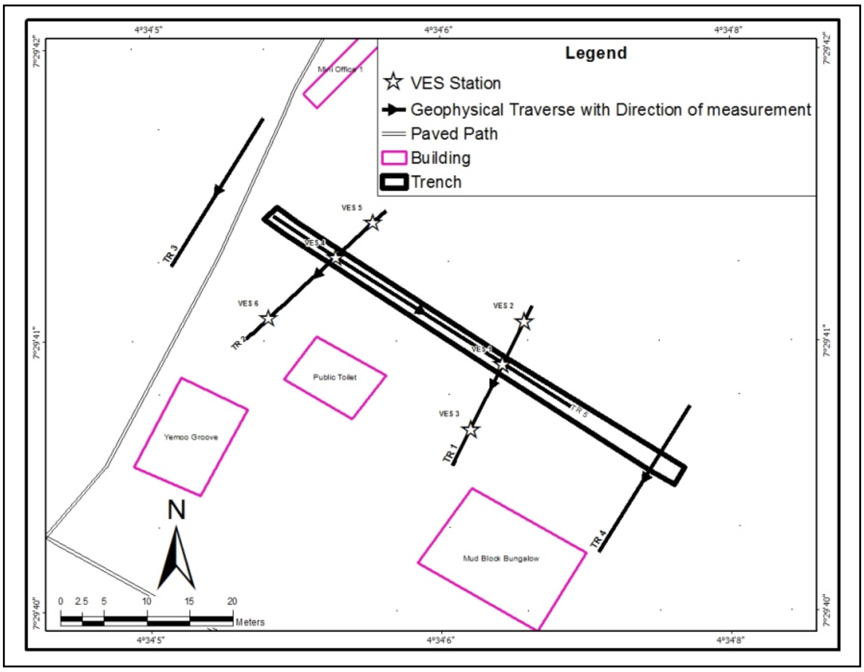

Figure 2: Map of the Premises of Yemoo Groove Showing Geophysical Traverses andVertical Electrical Sounding Stations

geographic co-ordinates of Latitudes 7° 29' 40" - 7° 29' 42" and Longitudes 4° 34' 04"- 4° 34' 08" (or Northings 828642 to 828703 mN and Eastings 672998 to 673121 mE)(Fig. 2). The study area is underlain by the Precambrian Basement Complex rocks (Fig. 3). The archaeological site is located within pegmatised schist characterized by clay/lateritic clay topsoil overlying a clayey weathered basement. Rock outcrops are rare except along river and stream channels.

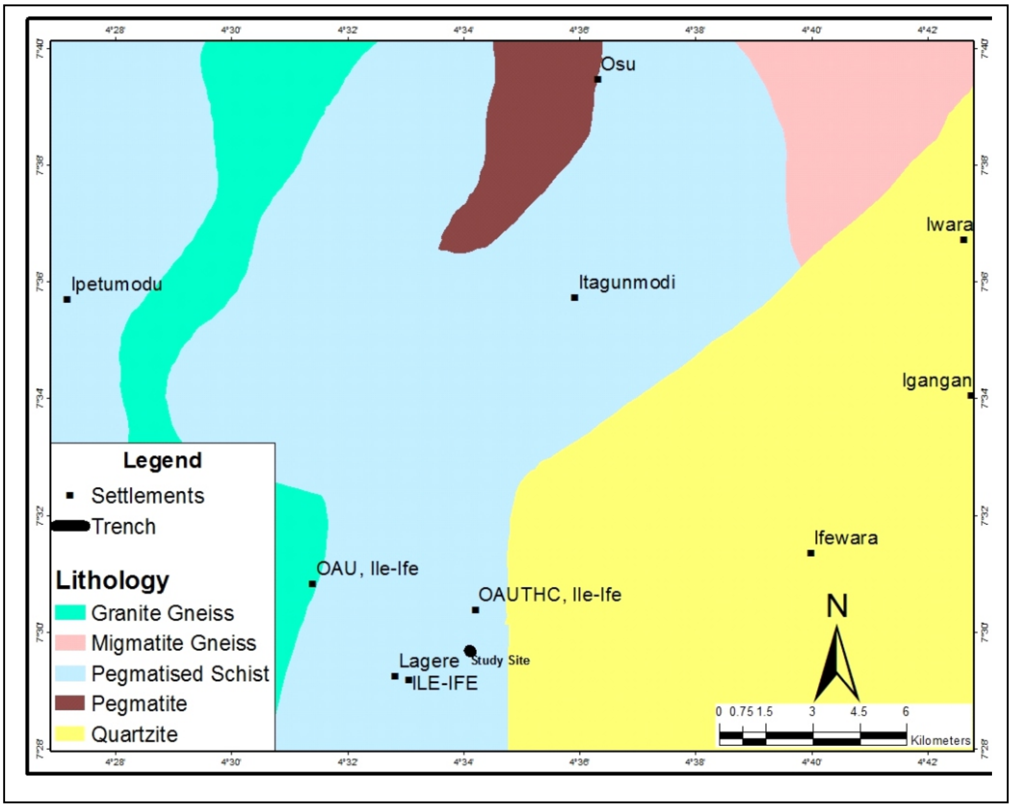

Figure 3: Geological Map of the Area around Ile-Ife

METHODOLOGY

The geophysical investigation involved the electrical resistivity and magnetic methods. Five traverses (TR 1-4, each 20 m long and TR 5, 33 m long) were established across an existing trench, as shown in Figure 2. The traverses were marked out at 1 m interval and all the marked stations were geo-referenced. 2-D resistivity imaging with Dipole-Dipole array was carried out along traverses TR 1&2 while magnetic profiling was carried out along all the five traverses. The Dipole-Dipole profiling utilized 1 m dipole length and expansion factor, n, that varied from 1-5. Total field magnetic measurements were made at 1 m interval with the Proton Precession Magnetometer. Six (6) Schlumberger Vertical Electrical Sounding (VES) stations were carried out along traverses TR 1&2 with the locations constrained by the 2-D images. The electrode spacing (AB/2) was varied from 1 to 32 m. The resistivity measurements were made with PASI 16gl Digital Resistivity Meter.

The VES data were presented as sounding curves (Fig. 4) and interpreted quantitatively by partial curve matching and computer assisted 1-D forward modelling with the W-GeoSoft/WinSev 5.1 software. The VES interpretation results were used to generate geoelectric sections along the two traverses occupied. The 2-D Dipole-Dipole data were inverted into 2-D subsurface images (resistivity structures) using the DIPRO for Windows V. 4.0 software.

The magnetic data were corrected for diurnal variation and offset and the residual magnetic field presented as magnetic profiles.

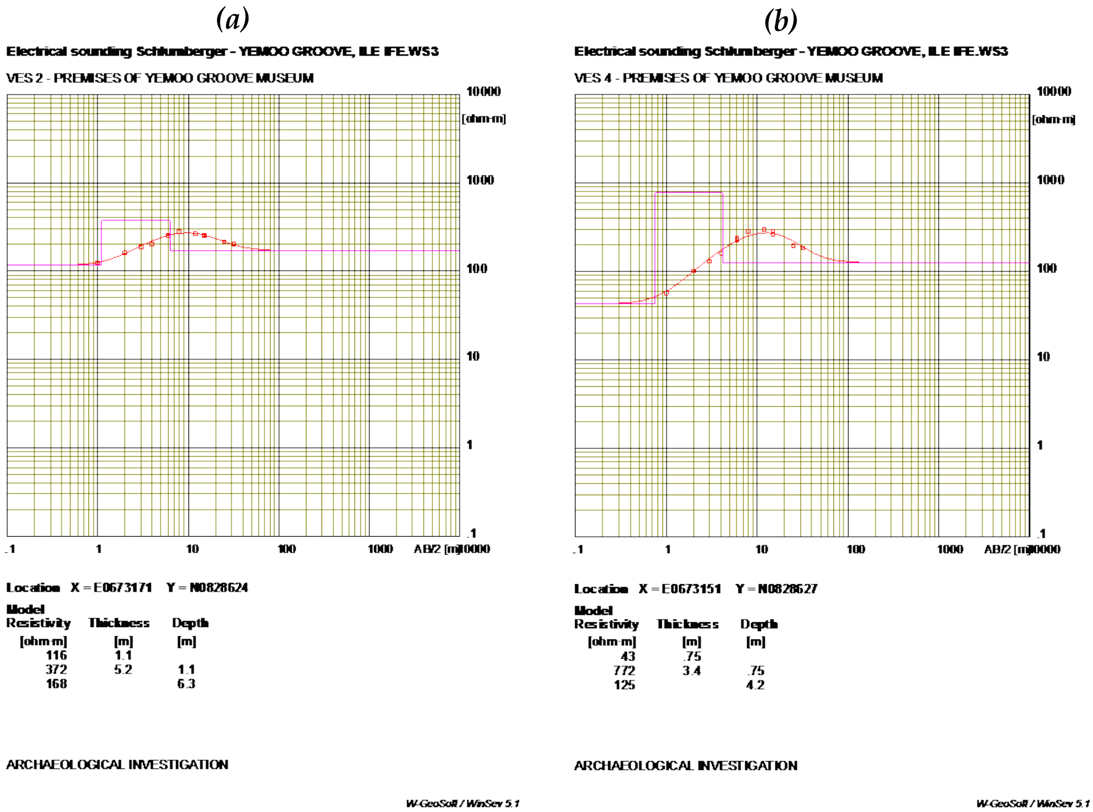

Fig. 4 Typical VES Type Curves and the Interpretation Models

RESULTS AND DISCUSSION

Characteristic VES Curves and the Subsurface Sequence

With the exception of VES 3, the K type curve characterized the study area. The geoelectric sections (Fig. 5) delineated three subsurface geologic layers in the upper 14.0 m along traverses TR 1&2. These include the topsoil, laterite (lateritic clay) and the weathered basement. The topsoil resistivity varied from 43-1515 ohm-m and is composed of clay/sandy clay. The thicknesses varied from 0.7-2.0 m. This layer is the most relevant in archaeological prospection, at this site. The lateritic clay second layer displayed resistivities and thicknesses that varied from 171-1952 ohm-m and 3.4-6.2 m respectively. The upper segment of the horizon could be relevant in archaeological prospection. The weathered basement layer resistivity values varied from 120-247 ohm-m. This horizon is composed of sandy clay.

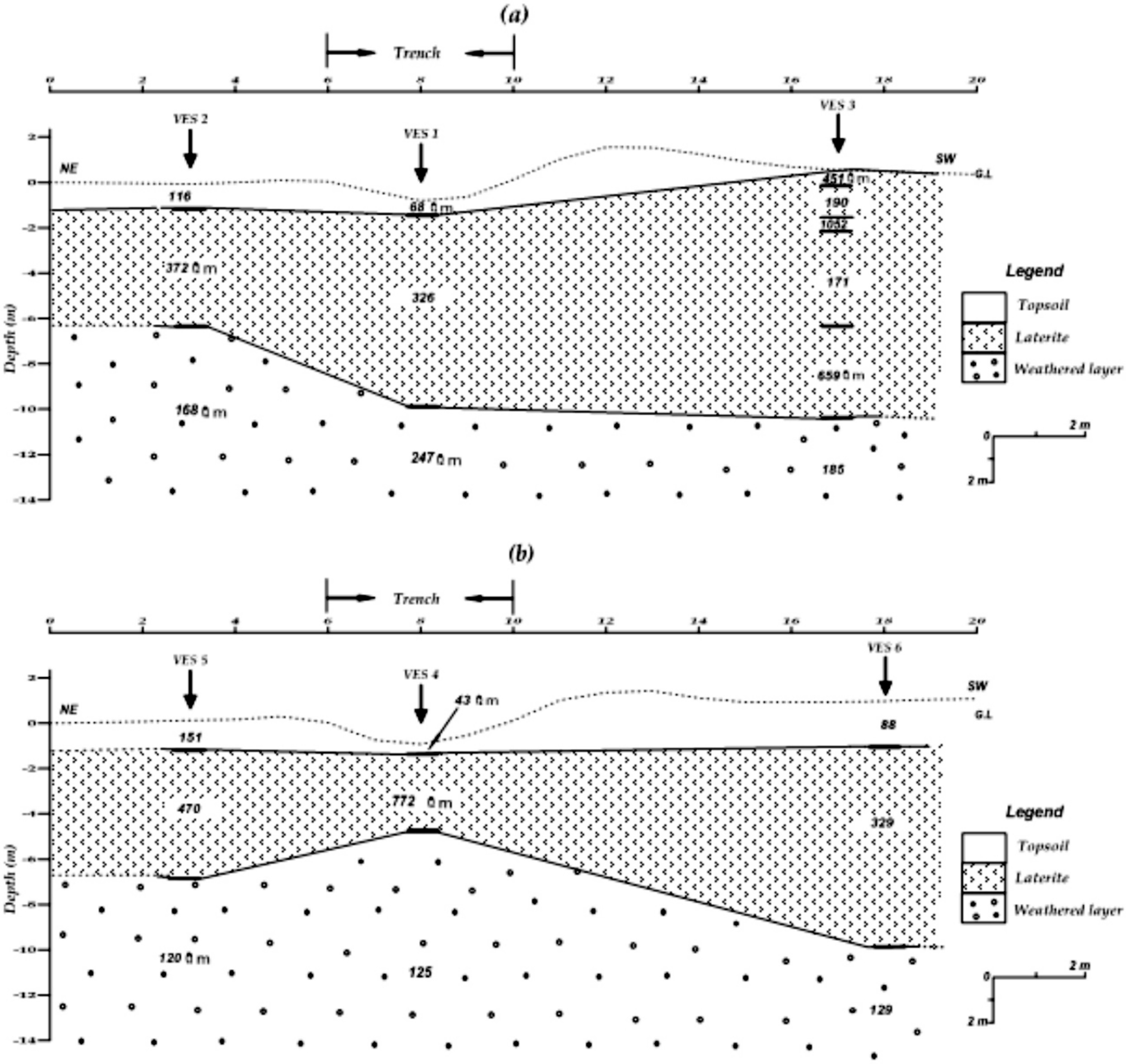

Fig. 5 Geoelectric Section Beneath (a) Traverse TR 1 (b) Traverse TR2

2-D Subsurface Image

Figures 6(c) and 7(c) present the 2-D resistivity structures (2-D images) along traverses TR 1&2 respectively. The inversion of the Dipole-Dipole data compensated for topographic variation along both traverses. The 2-D structures imaged the upper 3.0 m of the subsurface sequence – the topsoil and the upper segment of the lateritic layer, in the geoelectric sections (see Fig. 5).

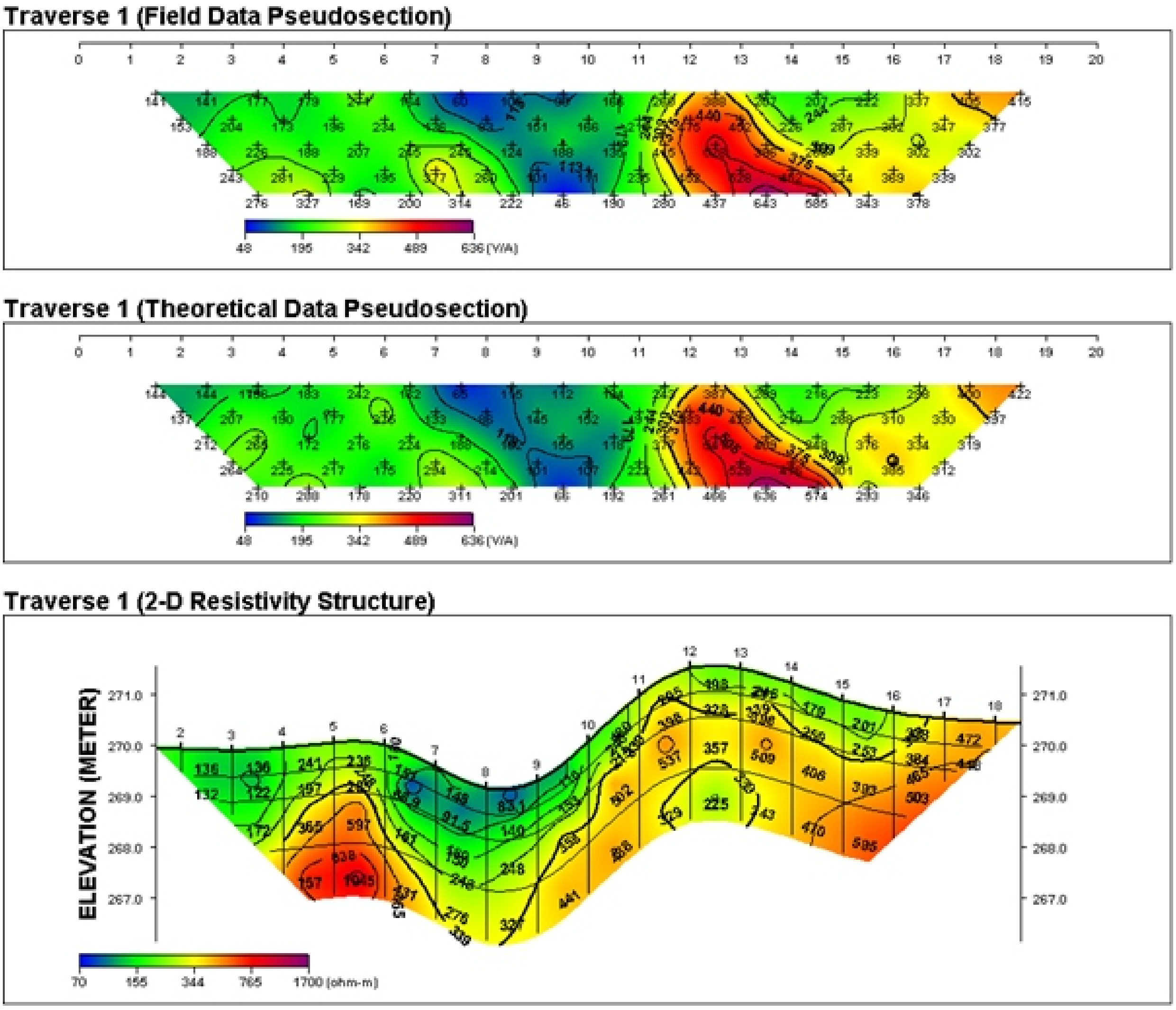

Fig. 6(a) Observed Pseudosection (b) Theoretical Pseudosection and (c) 2-D Resistivity Structure along Traverse TR 1

Along traverse TR 1, Figure 6 imaged the topsoil in blue/green colour with resistivity values varying from 70-248 ohm-m (68-116 ohm-m from VES) and thicknesses of 0.5-1.5 m (0.7-1.1 from VES). The underlying layer, in brownish/red colour, is the lateritic clay layer with resistivity values varying from 253-1157 ohm-m (171-1052 from VES). The lateritic layer outcrops between stations 11-12 and 16-20. This is corroborated by the geoelectric section (Fig. 5a). The subsurface image showed a terraced surface of the laterite on the southwest flank. It is suspected that this ancient structure must have been created when the trench was being dug, for easy access. The topsoil is the stratigraphic unit of importance in archaeological prospection at this site and is relatively thick (up to 2.0 m) beneath the trench (between stations 6-9 with centre at station 8) and on the northeast flank beneath station 3 (up to 2.0 m thick).

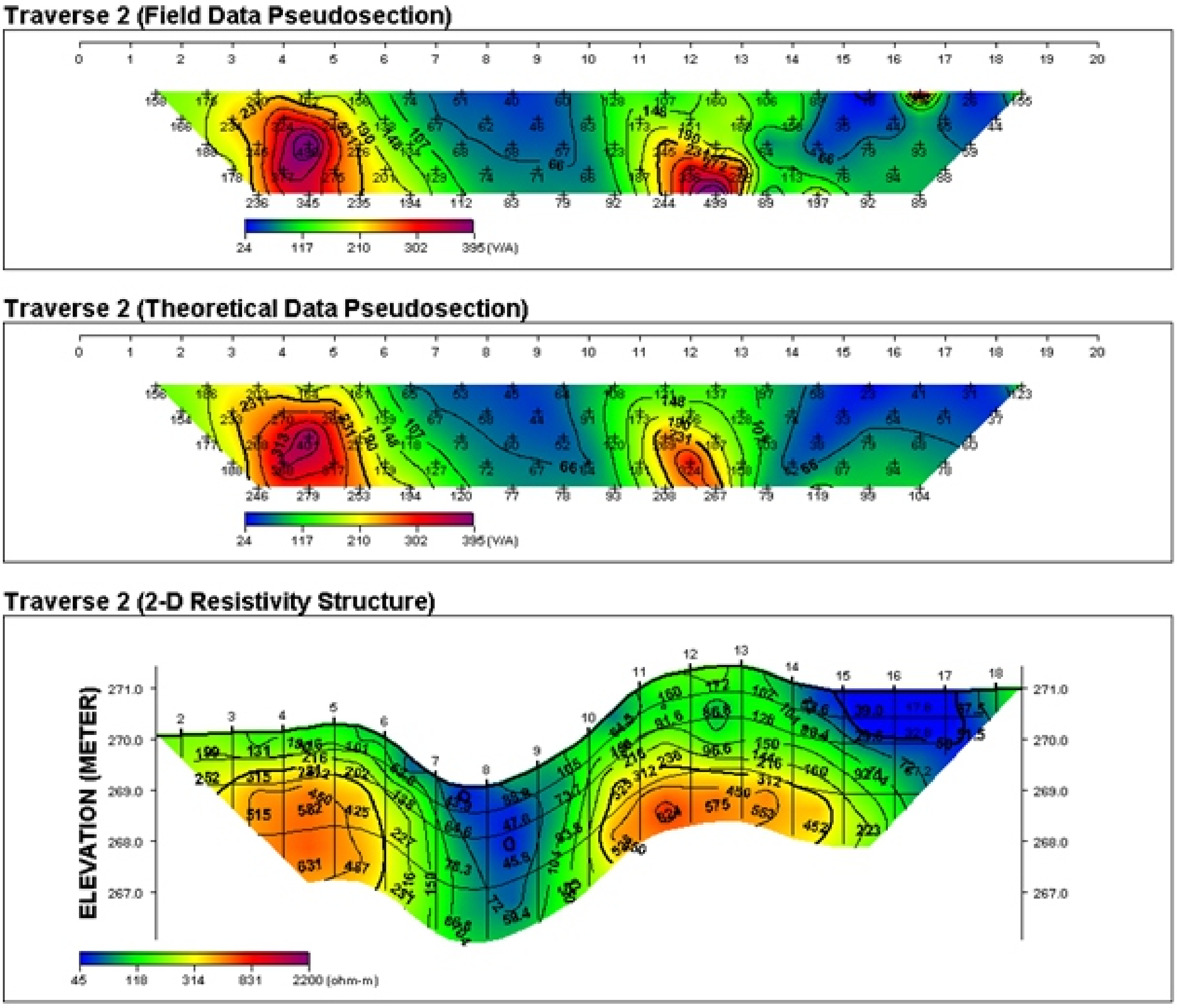

Fig. 7(a) Observed Pseudosection (b) Theoretical Pseudosection and (c) 2-D Resistivity Structure along Traverse TR 2

Along traverse TR 2, Figure 7 imaged the topsoil also in blue/green colour with resistivity values ranging from 45-223 ohm-m (43-151 ohm-m from VES) and thicknesses of between 0.5 and 2.0 m (0.8-2.0 m from VES). The lateritic layer, in brownish/red colour, had resistivity values varying from 227-824 ohm-m (329-772 ohm-m from VES). The zones of archaeological interest with significantly thick (up to 2.0 m) topsoil are the trench (between stations 6 and 10 with centre at station 9) and the crest of the ridge on the southwest flank between stations 11 and 14 with centre at station 13. The very low resistivity zone (in deep blue colour) between stations 14 and 18 represents an effluent chamber (soak away).

Figures 8a-e show the residual magnetic profiles along the five traverses. The magnetic measurements at the northeast edge of traverses TR 1 & 4 (Figs. 8a&d) were influenced by an installed wire gauze at the top of an adjoining brick wall fence while the magnetic anomaly around station 5 along traverse TR 2 (Fig. 8b) was due to a steel reinforced standing pillar. The anomalous zone at the southwest edge of same profile was due to a metal rod reinforced top of an effluent chamber (soak away). The magnetic profiles along traverses TR 1,2 and 4 (Figs. 8a,b &d) which cut across the trench (Fig. 2) show relatively flat magnetic anomaly indicating non-existence of a metallic artefact along the tunnel. However, the magnetic profile (Fig. 8e) observed along the trench (TR 5) identified an anomalous zone beneath a refuse dump. The magnetic profile along traverse TR 3 taken outside the trench displayed two low amplitude peak negative magnetic anomalies due to buried metal pipes. The magnetic survey, therefore, did not identify any metallic artefact within the survey area.

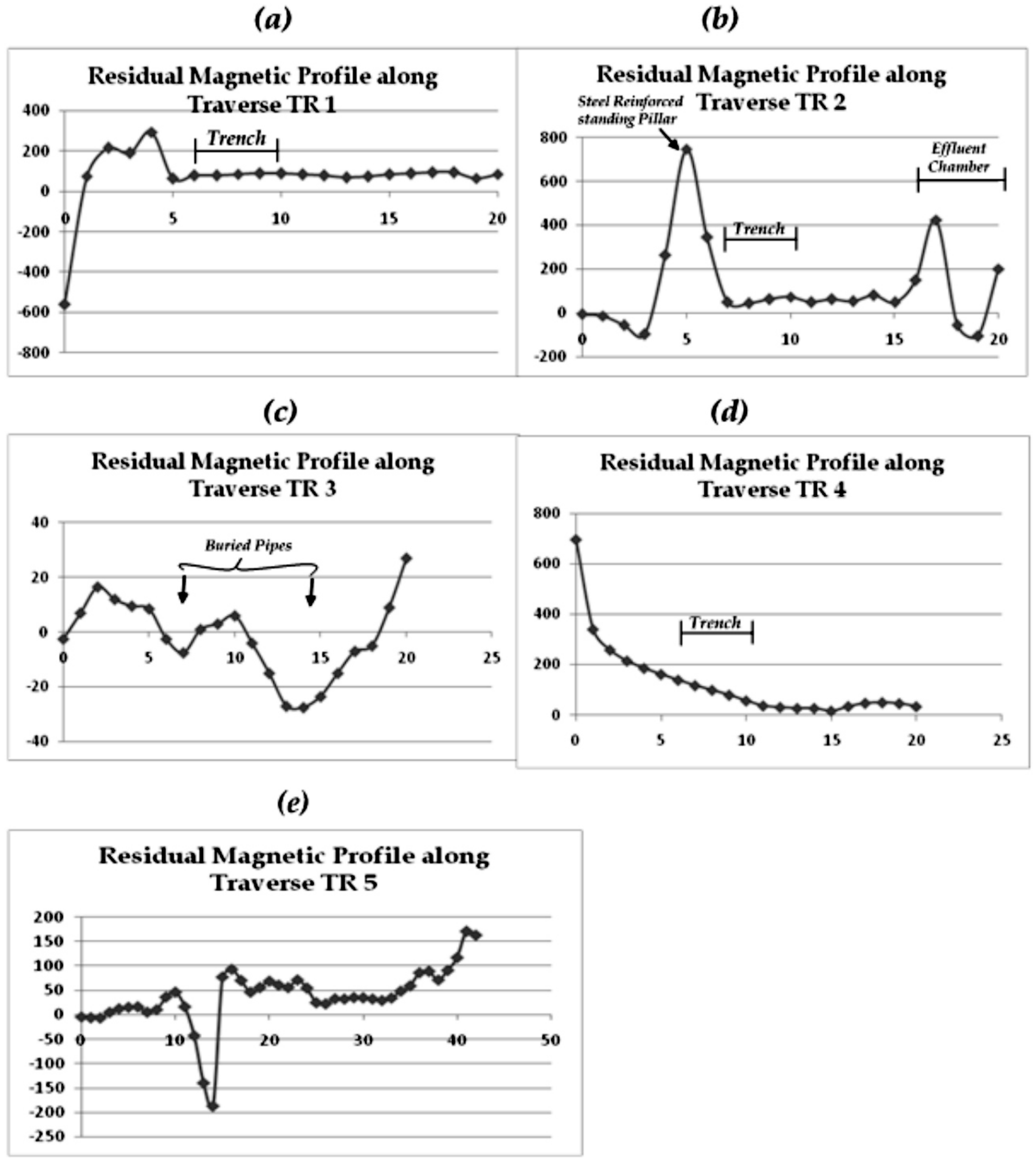

Fig. 8 Magnetic Profiles Along (a) Traverse TR 1 (b) Traverse TR 2 (c) Traverse TR 3 (b) Traverse TR 4 and (e) Traverse TR 5

Deductions from the Geophysical Investigation

The table below presents suspected artefact-laden zones identified from the results of the geophysical investigation.

Traverse TR 1		
Zone of Archaeological interest	Depth Range (m)	Classification
Stations 2-4 with centre at station 3	0 – 2	Priority(2)
Stations 6-10 with centre at station 8 (trench)	0 – 2	Priority(1)
Traverse TR 2		
Station 6-10 with centre at station 9 (trench)	0 – 2	Priority(1)
Stations 11-14 with centre at station 13	0 – 2	Priority(2)

Followed-up Archaeological Excavation

Along traverse TR 1, priority (1) (station 8) was excavated to a depth of 1.9 m and was rested on the lateritic layer. Priority (2) (station 3) was excavated to 0.67 m depth and abandoned before the lateritic layer was reached, while station 16 was also excavated but abandoned on lateritic layer at a depth of about 0.4 m. Along traverse TR 2, priority (2) was excavated to a depth of 1.7 m.

Archaeological artefacts such as ceramics and charcoal were found at priority(1) along traverse TR1 while charcoal, potsherd pavement (Fig. 9) and stone concretion were found at priority(2) along traverse TR 2. Excavation works at priority (2) along traverse TR 1 was prematurely terminated at shallow depth with some artefacts recovered while priority (1) along traverse TR 2 was not excavated. Excavation at priority (1) along traverse TR 1 from station 8 (trench) and up to the ridge crest on the southwest flank identified a terraced surface of the underlying laterite (Fig. 10). No artefact was found at the randomly selected location (station 16) along traverse TR 1.

CONCLUSION

The Yemoo Grove archaeological site in Ile-Ife, southwest Nigeria, has been investigated using the electrical resistivity and magnetic methods of geophysical prospecting. The electrical resistivity method involving 1-D (VES) and 2-D (Dipole-Dipole) subsurface images delineated the stratigraphy in the upper 14.0 m of the subsurface sequence. The VES identified an archaeologically relevant topsoil with thicknesses of up to 2.0 m while the 2-D structures identified priority zones with relatively thick topsoil along the existing trench and at the shoulders of the flanking ridges. Archaeological artefacts including ceramics, potsherd pavement, charcoal, stone concretion were identified within the priority zones (fig. The 2-D structure along traverse TR 1 identified a terraced surface of the underlying lateritic layer which was corroborated by excavation. The magnetic survey did not identify any metallic artefact in the study area.

Fig. 9 Excavation Works at Priority Site 2 along Traverse (TR) 2
Showing Identified Stone Concretion and Potsherd Pavement.

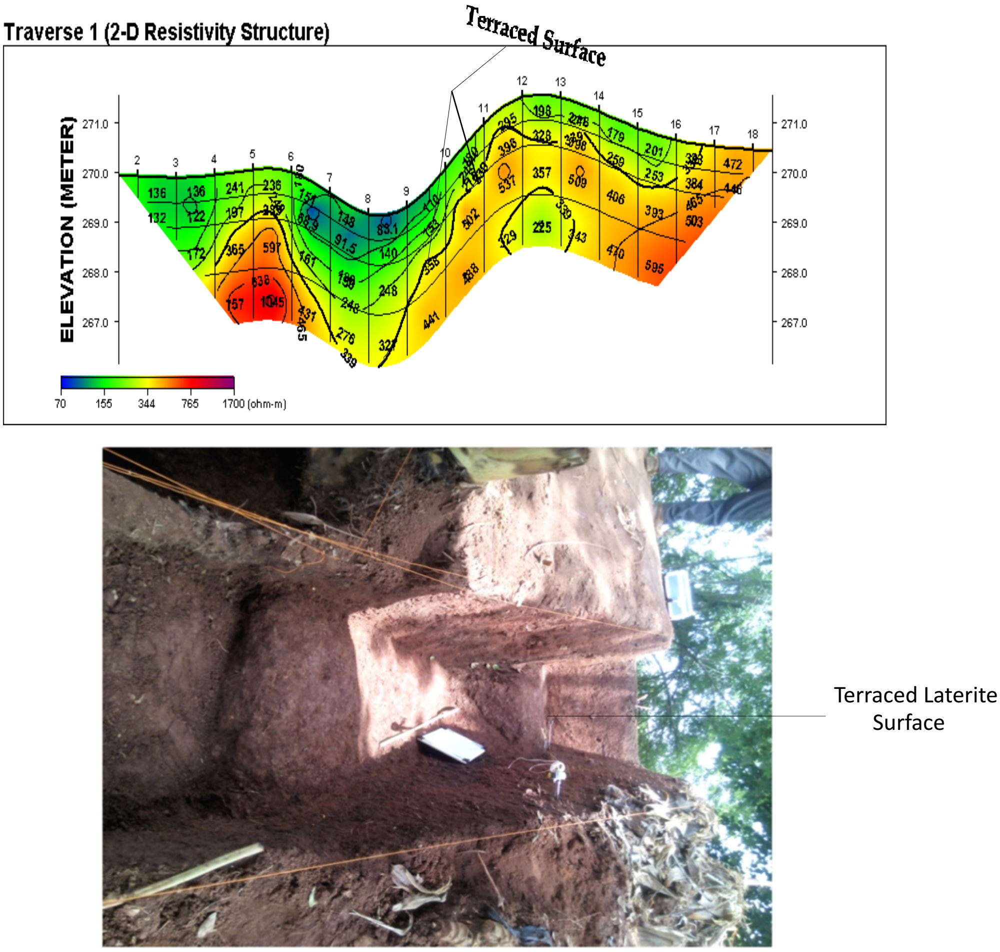

Fig. 10 Correlation of Geophysical Result and Cross Section of Excavation Portion along Traverse TR 1

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