




# Geophysical and Archaeological Survey in Igbo Oritaa (Iwo), Southwest Nigeria

Martins Olusola Olorunfemi ·  
Benjamin Adisa Ogunfolakan ·  
Ademakinwa George Oni 

Published online: 19 November 2019  
© Springer Science+Business Media, LLC, part of Springer Nature 2019

**Abstract** An integrated geophysical survey was carried out in Igbo Oritaa, a suburb of Iwo town (southwest Nigeria). The study was part of an archaeological investigation initiated by the Iwo community to identify and preserve the town's ancient sites. The geophysical investigations involved ground magnetic profiling, 1D vertical electrical sounding (VES), and 2D electrical resistivity imaging. The magnetic survey revealed anomalies of dyke-like features (central magnetic low [negative] flanked by low amplitude positive shoulders), linear depressions with prominent negative amplitude magnetic lows, and a moderately high amplitude magnetic anomaly coinciding with an old trench and several anthropogenic mounds. The resistivity survey also indicates the presence of subsurface archaeological features, including ditches and walls. Excavation units were selected based on these geophysical attributes. The excavations uncovered dense deposits of potsherds, animal bones,

shells, beads, iron slag fragments, a human pre-molar, metallic objects, a flute, and an architectural feature, possibly the foundation of a house. The geophysical survey and the test excavations confirm that Igbo Oritaa was an ancient settlement, consistent with the oral traditions. This paper presents the geophysical methods and results, the relationships between geophysical prospecting and test excavations, as well as the implications for community-focused archaeological research design, and site interpretation and preservation.

**Résumé** Une étude géophysique intégrée a été réalisée à Igbo-Oritaa, une banlieue de la ville d'Iwo (sud-ouest du Nigéria). L'étude faisait partie d'une enquête archéologique initiée par la communauté pour identifier et préserver les sites ancestraux de la ville. Les études géophysiques ont porté sur l'établissement de profils magnétiques au sol, le sondage électrique vertical 1D et l'imagerie de résistivité électrique 2D. Les cartes magnétiques ont identifié des anomalies aux caractéristiques archéologiques présumées: des anomalies ressemblant à des dykes (basse magnétique centrale [négative] flanquée d'épaules positives de faible amplitude); dépressions linéaires avec des dépressions magnétiques d'amplitude négative importantes; et une anomalie magnétique d'amplitude modérée qui coïncidait avec une ancienne tranchée et plusieurs monticules anthropiques. Ces caractéristiques ont été corroborées par les cartes de résistivité en tant que zones de résistivité faible ou élevée. Les unités d'excavation ont été sélectionnées en fonction de ces attributs

---

M. O. Olorunfemi · A. G. Oni (✉)  
Department of Geology, Obafemi Awolowo University, Ile-Ife,  
Nigeria  
e-mail: oniademakinwa@yahoo.com

M. O. Olorunfemi  
e-mail: mlorunfe@yahoo.co.uk

B. A. Ogunfolakan  
Natural History Museum, Obafemi Awolowo University, Ile-Ife,  
Nigeria  
e-mail: babaadii@yahoo.com

géophysiques. Les fouilles ont mis au jour des dépôts denses de tessons de poterie, d'os d'animaux, de coquillages, de perles, de scories de fer, d'une prémolaire humaine, d'objets métalliques, d'une flûte, et d'un élément architectural, éventuellement la fondation d'une maison. Les levés géophysiques et les fouilles expérimentales confirment qu'Igbo Oritaa était une ancienne colonie, conformant aux traditions orales. Cette article a examiné les relations entre la prospection géophysique et les fouilles archéologiques, ainsi que les implications pour la conception de la recherche archéologique communautaire, ainsi que pour l'interprétation et la préservation des sites historiques.

**Keywords** Igbo Oritaa · Iwo (southwest Nigeria) · Geophysical investigation · Community archaeology

## Introduction

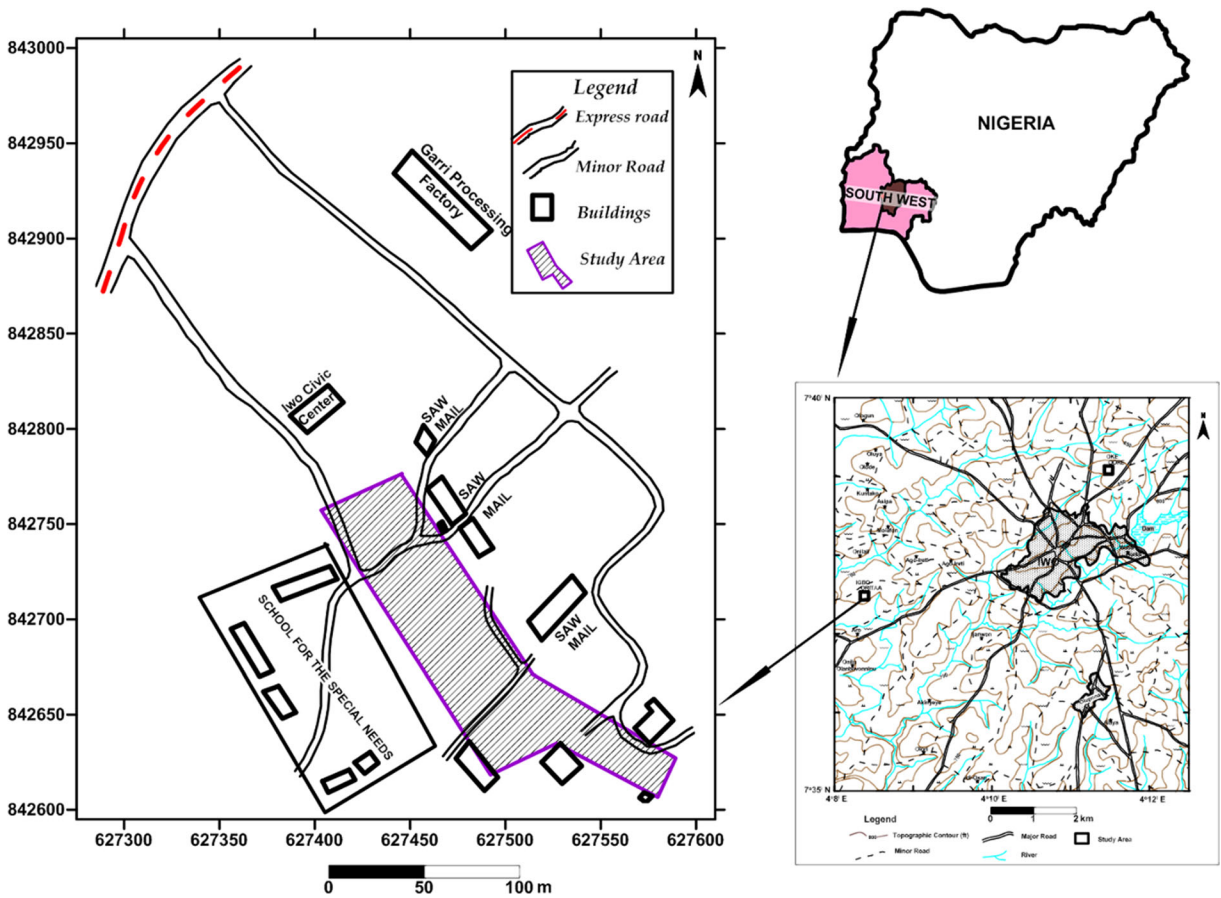
Geophysical applications in archaeology dated as far back as 1895 (Atkinson 1952; Pitt-Rivers 1898), but it is only in the past two decades that the use of geophysical methods has gained enormous grounds in archaeological field research (Leucci and Greco 2012). The rapidly evolving technology has made it possible for archaeologists to integrate sophisticated geophysical methods into their research design, especially for the survey and identification of subsurface archaeological deposits (Ekinci et al. 2014; Gaffney 2008; Leucci and Greco 2012; Oni 2018; Vanic and Rajovic 2014; Young and Droege 1986). African archaeology has witnessed a modest but reassuring progress in this regard (Magnavita 2016), as evident in the archaeogeophysical studies carried out at Songo Mnara in Tanzania, KoBulawayo in Zimbabwe, Zilum in Nigeria, Gamo Highlands in Ethiopia, and Diourbel region in Senegal, to mention but a few (Arthur et al. 2019; Fleisher and Sulas 2015; Gaffney et al. 2005; Magnavita 2017; Magnavita et al. 2006). In Nigeria, the past decade has witnessed the collaboration between geophysicists and archaeologists at several sites such as Yemoo Grove and Iyekere in Ile-Ife and Igbo Oje in Ogbomoso. Those collaborations have focused on using geophysical techniques for detecting subsurface archaeological features as part of the strategies for planning archaeological excavations

(Eluyemi et al. 2012; Olorunfemi et al. 2015; Oyeyemi et al. 2015). We have recently extended this collaboration to the archaeogeophysical survey of Igbo Oritaa, an ancient settlement near Iwo town (Fig. 1). The community of Iwo, led by the paramount ruler (*oba*), invited us to carry out the research: to identify and document archaeological features and materials, test the validity of the oral traditions about the chronology of the site, and provide an assessment of the place of Igbo Oritaa in the settlement history of Iwo.

Located in the central Yoruba region, only about 50 km from Ile-Ife, the cradle of Yoruba civilization (Fig. 1; Akinjogbin 1992), Igbo Oritaa is regarded in the oral traditions as one of the ancestral settlements from which Iwo town was founded. The oral traditions of Iwo follow the template of origin stories found in most other ancient Yoruba towns. According to the dominant official version, Iwo was founded by Adekola-Telumere (Adekola Telu), a prince of Ile-Ife, who was granted the authority to establish his kingdom and wear a beaded crown, the ultimate insignia of royalty in Yoruba political culture (Ladipo and Amoo 2017). Adekola Telu and his entourage first settled at Ogundigbaro, located at the confluence of Oba and Osun rivers. Due to the incidence of frequent flooding, they moved to Erunmu where they stayed briefly before relocating to Igbo Oritaa. After a while, the site was also evacuated, and from there, the people moved to the present-day Iwo town (Fig. 1). We expected the archaeological investigations at Igbo Oritaa to shed some light on the settlement history of Iwo in particular and of the central Yoruba region in general.

## The Study Area

The Igbo Oritaa archaeological site is situated on a relatively flat topography of about 214 m above sea level. It lies between latitudes N7° 37' 20.5" and 7° 37' 33.5" and longitudes E4° 09' 10.0" and 4° 09' 21.9". The site falls within the tropical hinterland climatic zone and the vegetation is the rain forest/derived savannah type (Iloje 1981). The geology of the area is characterized by migmatite–gneiss undifferentiated (Fig. 2). This group of rocks is the most widespread in the Basement Complex of



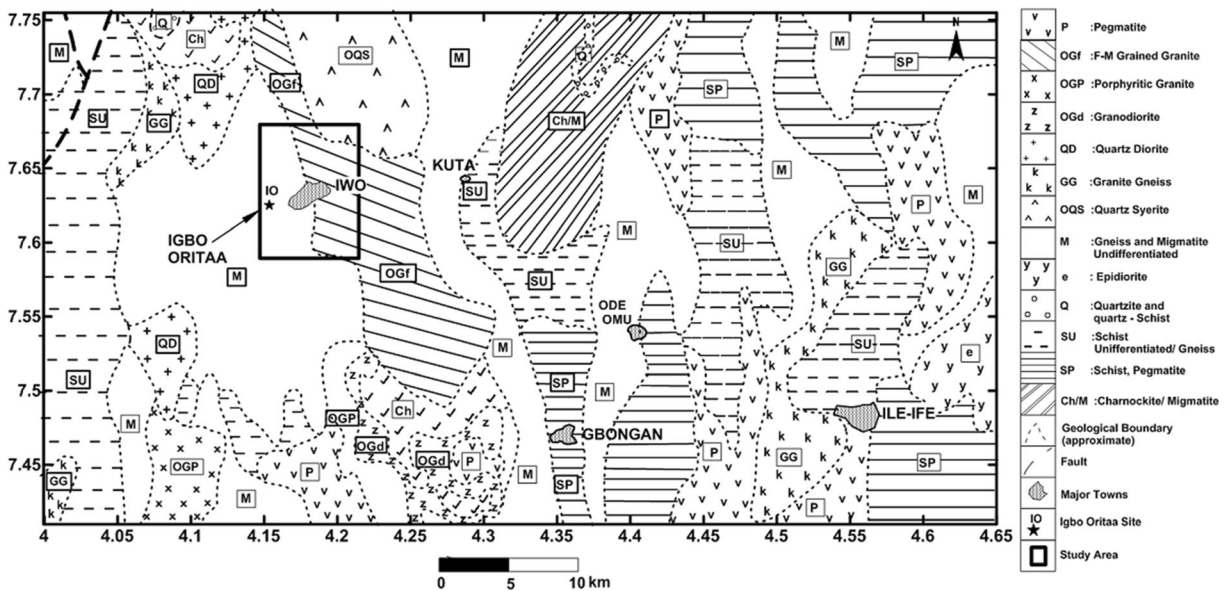
**Fig. 1** The Igbo Oritaa study area

southwestern Nigeria, and it comprises of gneiss, calc-silicate rocks, biotite–hornblende schists, amphibolites, and quartzite (Rahaman 1989). Although the basement rock at the survey site is concealed by a variably thick weathered layer, based on the geoelectric characteristic (layer resistivity of  $< 44 \Omega \text{ m}$  typical of clayey weathered layer), the underlying lithology is suspected to be schist. A large section of the study area is currently being used as a lumber yard (sawmill).

**Methodology**

This study began in 2018 with a reconnaissance visitation by the Iwo community leaders and us (archaeologists and geophysicists) to Igbo Oritaa, to assess the site’s archaeological potential (Fig. 3). The archaeological artifacts observed on the surface included ceramics, potsherds, and iron slag, and the following features were

also recorded: circular stone concentrations, an embankment with a ditch, mounds suspected to be the remains of ancient buildings or burials, and a sacred site marked by *peregun* (*Dracaena* sp.) tree. The reconnaissance visit was followed up with magnetic and electrical resistivity survey to understand the nature of the subsurface archaeological deposits. The limited space available for investigation and the obstruction caused by existing structures (buildings) and lumber processing activities necessitated that we divide the site into two zones (A and B) (Fig. 4). Zone A is about 160 m × 45 m in size and contains the remains of a shrine (demarcated by *Dracaena* sp.), iron slag fragments, and mounds. Zone B has a size of approximately 36 m × 20 m and it is located in a WNW–ESE direction to coincide with the orientation of the observed embankment–ditch complex. Eighty-one parallel ENE–WSW transects (TR1–81) at 2 m intervals were established within zone A. Except where obstructions were encountered, each transect was 45 m long, and was divided into 46



**Fig. 2** Geological map of the study area (Geological Survey of Nigeria 1974)

stations at 1 m interval for taking geophysical measurements (Fig. 4). Within zone B, 10 transects (TR82–91) were spaced at 4 m intervals. Each transect was 20 m long and divided into 21 stations at 1 m interval.

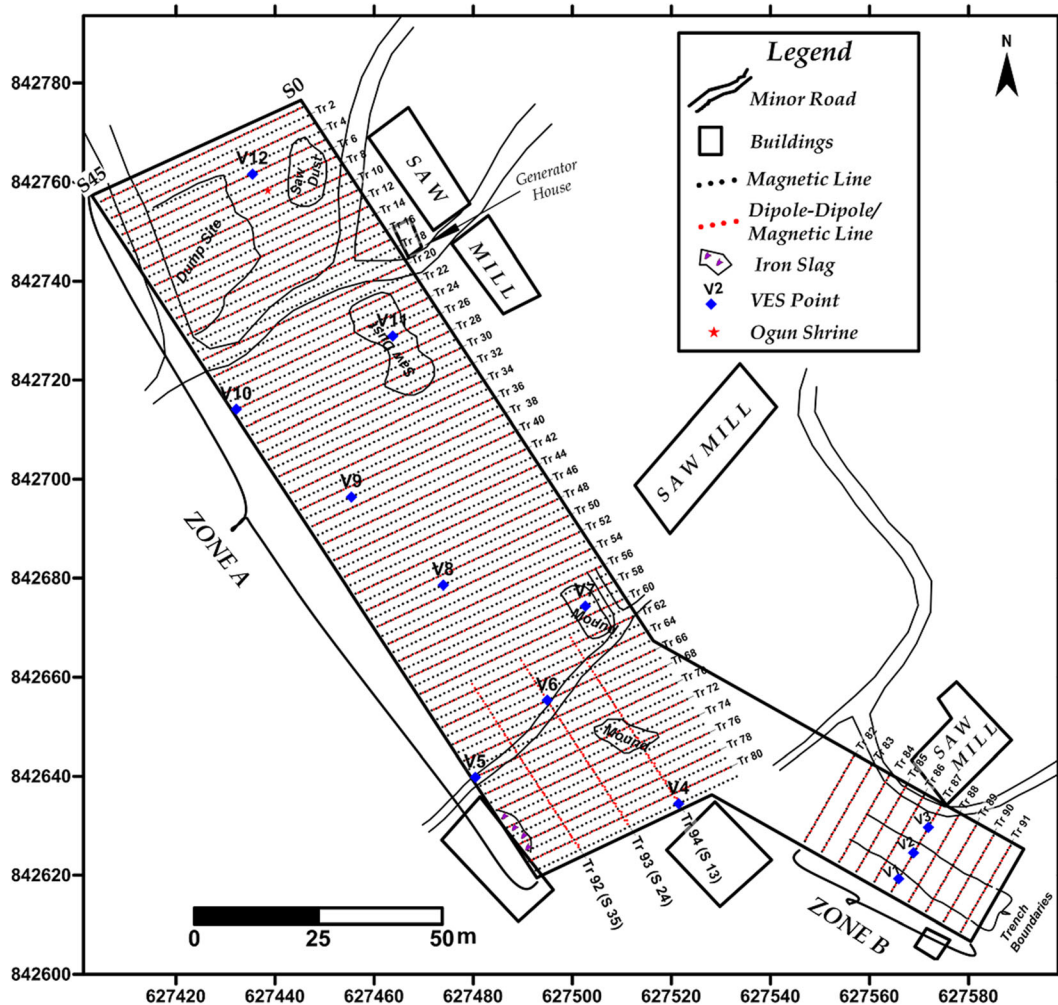
### Magnetic Profiling Survey

The total field magnetic measurements were made with the GSM 19T Proton Precession Magnetometer (PPM) along all the transects except TR19–21 (Fig. 4) where the overhead electric power line caused interference. Magnetic profiles were



**Fig. 3** Oba Abdulrasheed Adewale Akanbi (center) with Iwo community leaders, archaeologists, and geophysicists at Igbo Oritaa

recorded from east to west. Before the commencement of the data acquisition, a base station was established outside the site, in an environment that was free of cultural materials, to monitor the variation in the earth's magnetic field (diurnal variation). At the base station, four magnetic measurements were recorded within a few seconds to each other at regular time intervals throughout the survey period. The magnetic measurements and time were recorded to monitor the diurnal variations of the earth's magnetic field and to enable us to correct for such variations along the transects. Two magnetic measurements were recorded at each station on the transect. The time of the second measurement and the geographic coordinates were recorded, including observation of any feature in the vicinity of each station. We regarded the average value of the magnetic measurements at each station as magnetic field intensity. In total, we took magnetic measurements at 3,798 stations in both zones. The data acquired along each transect were corrected for diurnal variation and offset, plotted as profiles for trend analysis and data quality check. The corrected magnetic data were presented as residual magnetic map and reduced to the magnetic equator (RTE) to remove the asymmetry associated with magnetic anomalies due to nonzero magnetic inclination ( $I = -11^\circ$ ) in the survey area. Data enhancement techniques such as



**Fig. 4** Data acquisition map of Igbo Oritaa, showing zones A and B, magnetic and dipole–dipole transects, and locations of VES and visible features

first vertical derivative (FVD) and downward continuation (DWC) were applied to the RTE data to estimate depth of burial of target and accentuate shallow anomalies.

#### Electrical Resistivity Survey

The resistivity survey involved 1D VES and 2D imaging techniques. Twelve VES locations, VES 4–12 and VES 1–3 (Fig. 4), were investigated within zones A and B, respectively, using the Schlumberger array with half current electrode spread length ( $AB/2$ ) that varied between 1 and 40 m. We used the 1D VES technique for subsurface sequence delineation and overburden thickness estimation and to constrain the 2D dipole–

dipole inversion modeling. Fifty transects at 4 m intervals were used for the electrical resistivity dipole–dipole profiling. Three orthogonal (NNW–SSE) transects, TR92–94, established through stations S13, S24, and S35 along the ENE–WSW direction (Fig. 4), were set up within the relatively elevated grounds suspected to be collapsed structures (Fig. 4). 2D dipole–dipole data were acquired at 1 m interelectrode spacing and interdipole separation factor ( $n$ ) that was varied from 1 to 5 using the ABEM SAS 300C Resistivity Meter. The 2D dipole–dipole data were presented as pseudosections and inverted into 2D resistivity structures using the DIPRO for Windows version 4.0 software. Topographic variations data along the transects were incorporated into the inversion

process to correct for the effect of topography in the observed data. From the 2D resistivity structures, inverted (true) resistivity values at the mid-points of the spacing between the current and potential dipoles were extracted at different depth levels. These values, together with their corresponding coordinates, were used to generate 2D resistivity depth slice maps. The 1D VES data were presented as resistivity sounding curves and interpreted by partial curve-matching and computer-assisted 1D forward modeling using the W-GeoSoft/WinSev 5.1 software. We then used the VES interpretation results (layer resistivities and thicknesses) to generate 2D geoelectric sections. The VES curves were classified into type curves using layer resistivity combinations with principal type curves: H ( $\rho_1 > \rho_2 < \rho_3$ ), K ( $\rho_1 < \rho_2 > \rho_3$ ), Q

( $\rho_1 > \rho_2 > \rho_3$ ), and A ( $\rho_1 < \rho_2 < \rho_3$ ) (where  $\rho_1$ ,  $\rho_2$ , and  $\rho_3$  are the resistivity values for layers 1, 2, and 3) were used as reference.

## Results and Discussion

### Magnetic Maps

The residual magnetic intensity (RMI) map of the study area is presented in Fig. 5, while the reduced to the equator (RTE) map is displayed in Fig. 6. The amplitude of the RTE map varies from  $-160$  to  $300$  nT. Identified magnetic anomalies within the study area were blocked into zones and labeled A–T (Fig. 6). The magnetic attributes of these anomalies were classified into four groups

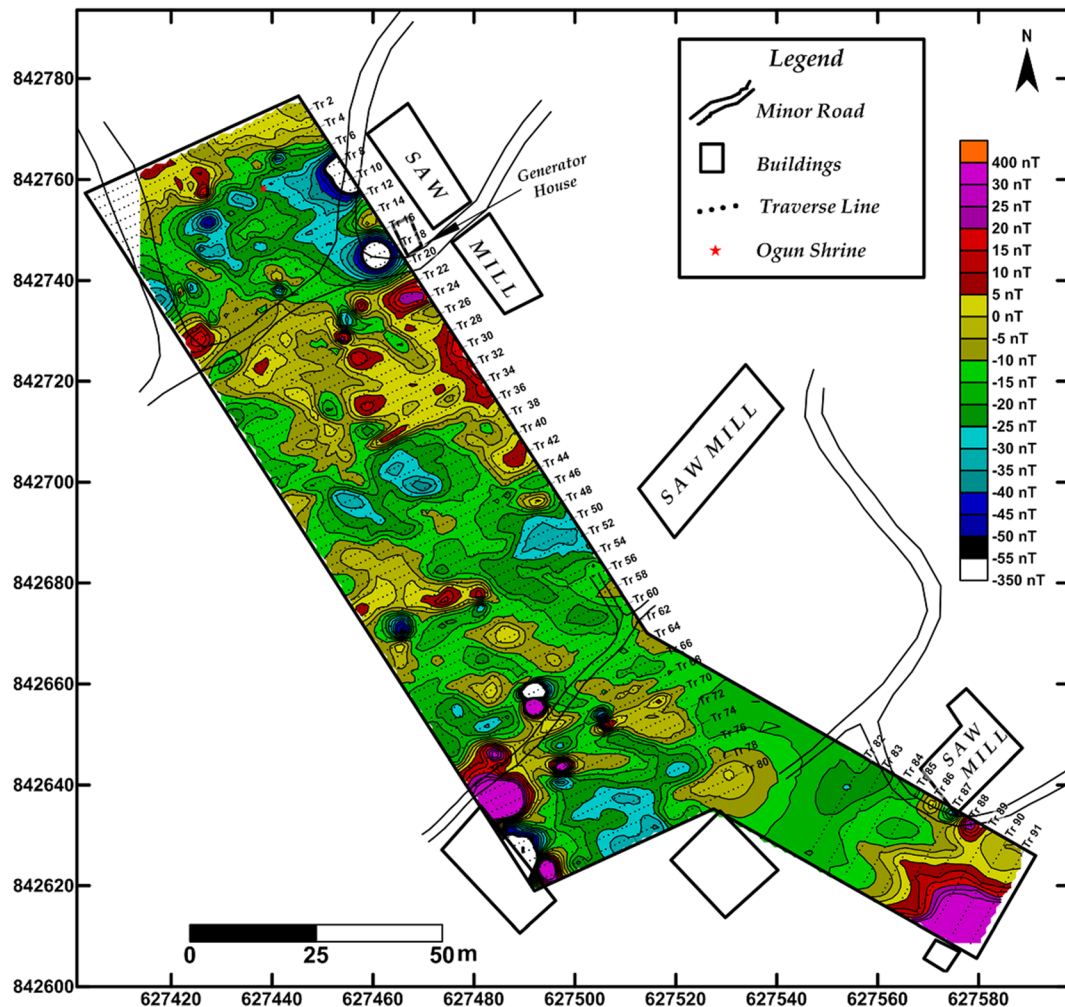


Fig. 5 Residual magnetic intensity (RMI) map of the study area

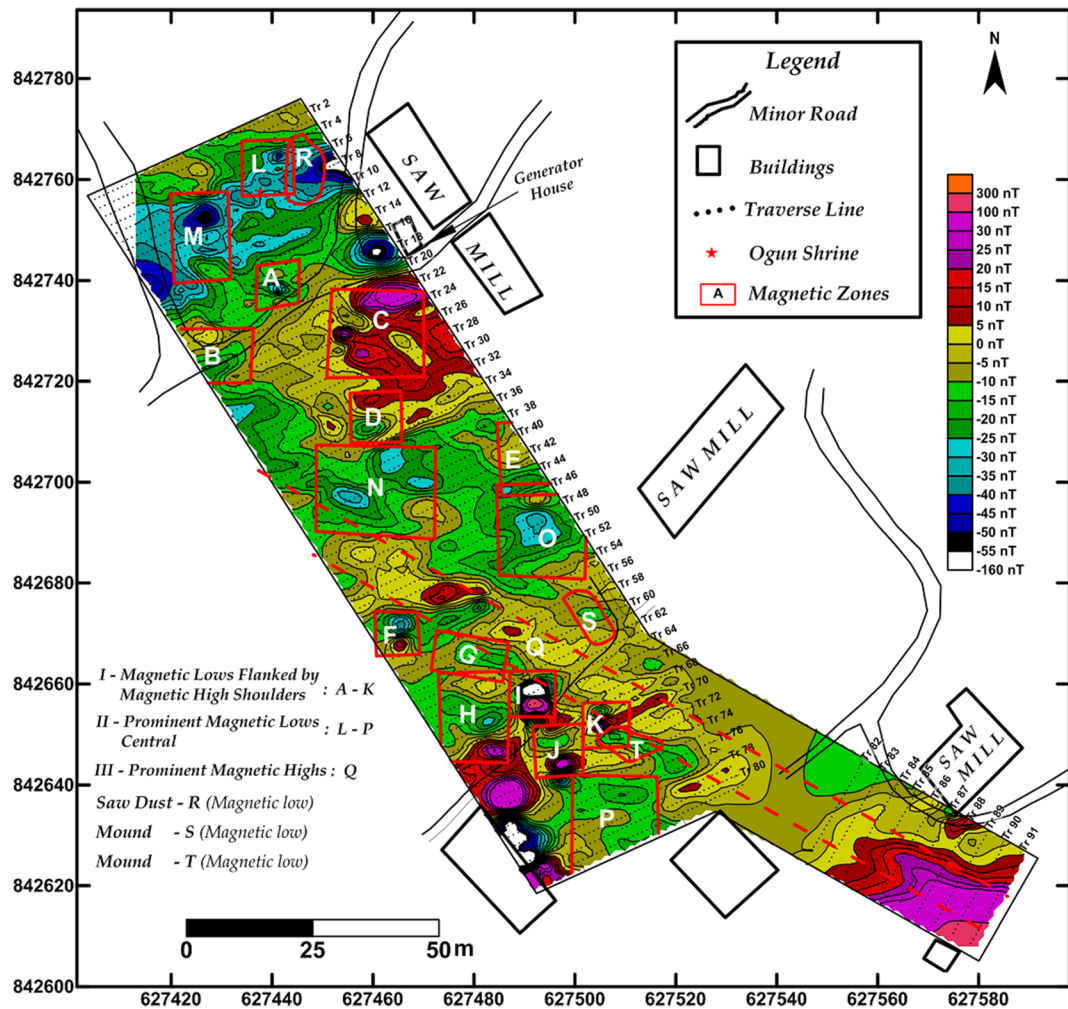


Fig. 6 Reduced to the equator (RTE) map

(I–IV) and used to characterize the Igbo Oritaa archaeological site. Group I consists of magnetic anomaly zones A–K with central negative magnetic lows flanked on both sides by low amplitude positive magnetic shoulders typical of dyke-like features. These zones were suspected of hosting possible magnetic (metallic) objects or objects containing some magnetic materials. Group II is characterized by prominent negative amplitude magnetic lows with regular geometric shapes that could be typical of objects with high magnetic susceptibility. Magnetic anomaly zones L–P fall within this category. Block L contains the sacred site (with *Dracaena* plant) that was likely the shrine of Ogun—the Yoruba deity of war and iron metallurgy, while M coincides with a refuse dump

site. Block N hosts two prominent magnetic lows, while blocks O and P host prominent magnetic lows. Blocks N, O, and P have no discernible surface features.

The only magnetic anomalous zone within group III is Q, characterized by a linearly structured, moderately high magnetic anomaly. This magnetic signature was recorded along what we already identified as an ancient embankment–ditch complex during our reconnaissance survey. These magnetic readings include patches of high amplitude magnetic anomalies with the southeastern end possibly influenced by the magnetic effect of the iron roof of the nearby building. The variability in the amplitudes of the anomalies could also be a manifestation of variable materials within the

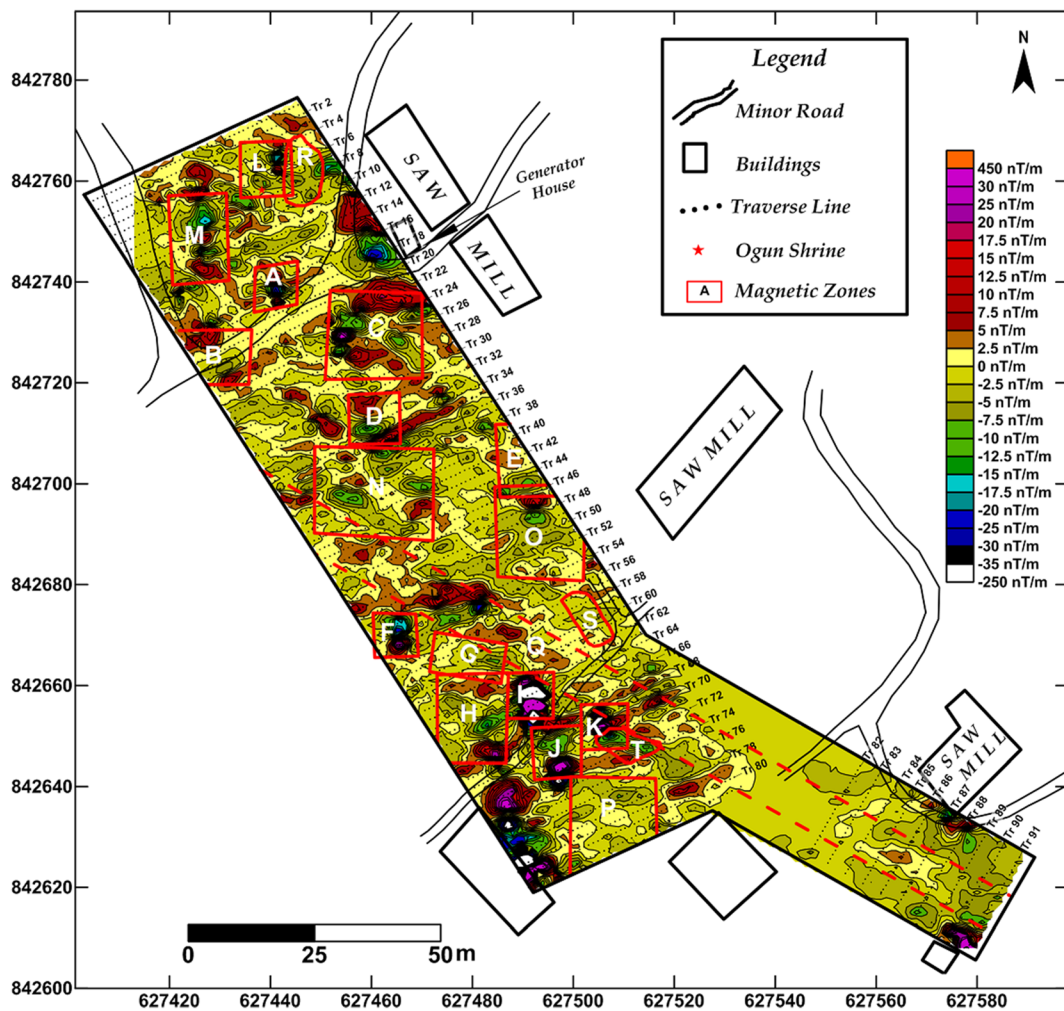


Fig. 7 First vertical derivative (FVD) map

ditch. Magnetic anomaly zones R, S, and T constitute group IV. Block R coincides with a sawdust dump site (lumber processing waste) in the north-eastern corner, while blocks S and T coincide with what we suspected to be mounds of collapsed structures or burials. These features are characterized by relatively low (negative) amplitude magnetic anomalies.

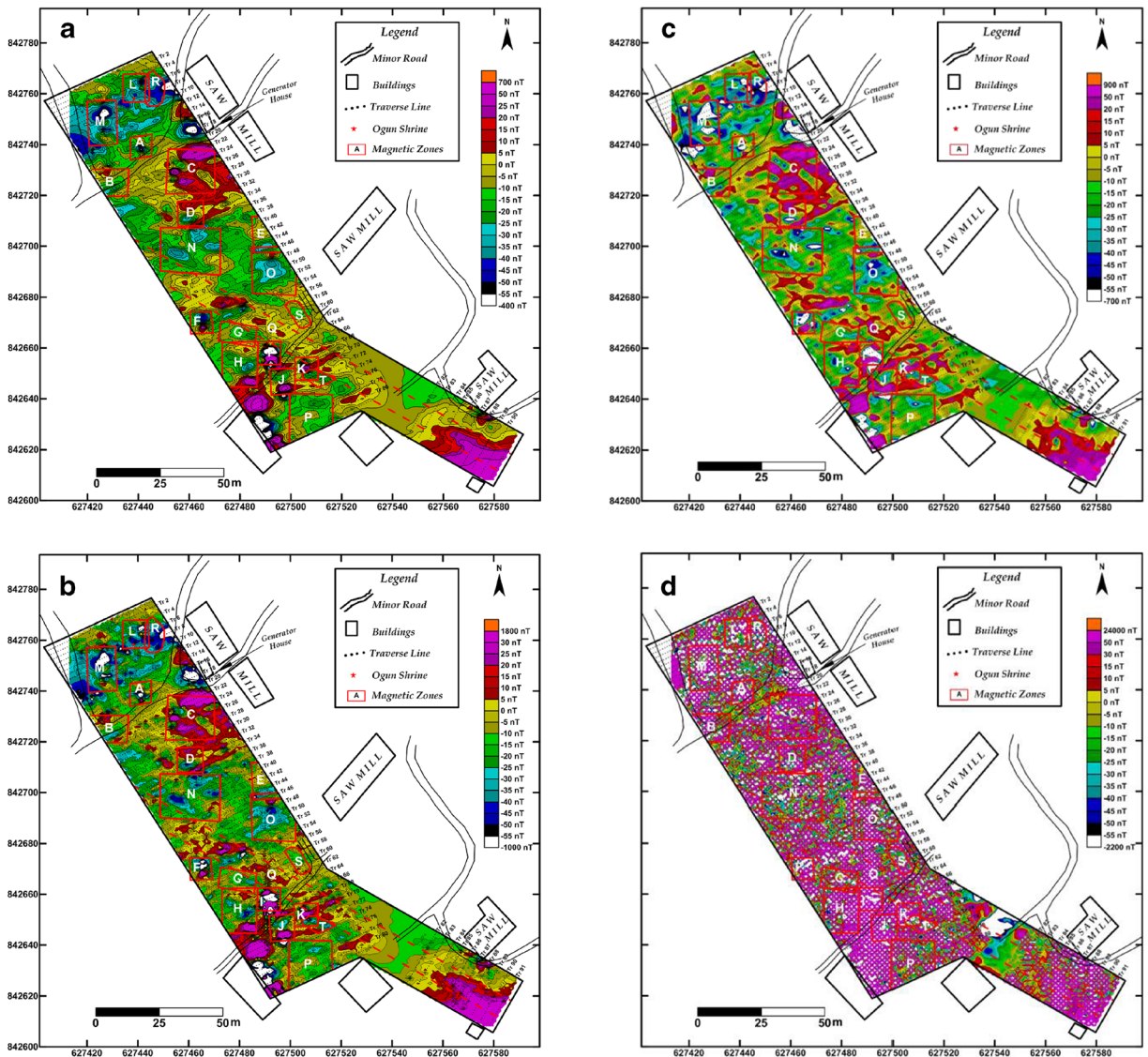
The FVD map (Fig. 7) identified all the previously delineated magnetic anomaly zones on the RTE map and, in some cases, accentuate them (see blocks B, C, I, and J). The downward continuation maps (Fig. 8a–d), especially within 1.5 m depth (Fig. 8a–c), also identify the magnetic zones and, in some cases, accentuate the anomaly amplitudes (e.g., blocks M, I, and J at 0.5 m; M, F, I, J, and K at 1.0 m; and M, A, I, J, and K at 1.5 m depth

levels). Beyond the 1.5 m depth level, the magnetic anomalies are poorly defined. This is an indication of the near-surface nature of the causative bodies. The rapid accentuation of the magnetic anomalies up to  $-1,000$  and  $1,800$  nT during the downward continuation exercise could imply that the magnetic anomaly zones A, F, I, J, K, and M are effects of contemporary anthropogenic objects as established within block I where two car tires were found.

#### VES Type Curve and Geoelectric Section

The VES curves are the H ( $\rho_1 > \rho_2 < \rho_3$ ), QH ( $\rho_1 > \rho_2 > \rho_3 < \rho_4$ ), and HKH ( $\rho_1 > \rho_2 < \rho_3 > \rho_4 < \rho_5$ ) types (Fig. 9), with the QH type predominating (70% of the total). The 2D geoelectric sections generated





**Fig. 8** Downward continued magnetic (DWC) map at **a** 0.5 m, **b** 1.0 m, **c** 1.5 m, and **d** 2.0 m

from the VES interpretation results identify four subsurface geoelectric layers that include the topsoil, lateritic clay, weathered layer, and the basement bedrock (Fig. 10a–c). The topsoil is composed of clay, sandy clay, and clayey sand/laterite with resistivity and thickness values that vary from 17 to 598  $\Omega$  m and 0.5 to 2.9 m, respectively. Underlying the topsoil is a lateritic clay layer with resistivity values of between 41 and 168  $\Omega$  m and thicknesses that vary from 1.4 to 4.2 m. The weathered layer's resistivity values vary from 13 to 43  $\Omega$  m, while its thickness is in the range of 4.5–29.7 m. The weathered layer is composed of plastic clay. The fresh basement constitutes the last layer with

resistivity values of between 148 and  $\infty$   $\Omega$  m. The depth to rock head varies from 6.8 to 33 m. The clayey nature of the overburden with characteristic low resistivity values could be diagnostic of a schist basement bedrock. The geologic layers of archaeological interest are layers 1 and 2 in the upper 1.5 m.

#### Resistivity Depth Slice Maps

The resistivity map at 0.25 m depth level (Fig. 11a) shows values that vary from <50 to 850  $\Omega$  m but are generally less than 600  $\Omega$  m. Most parts of the survey area have subsoil resistivity values of

Typical VES Type Curves of IGBO ORITAA, IWO, Archaeological Site

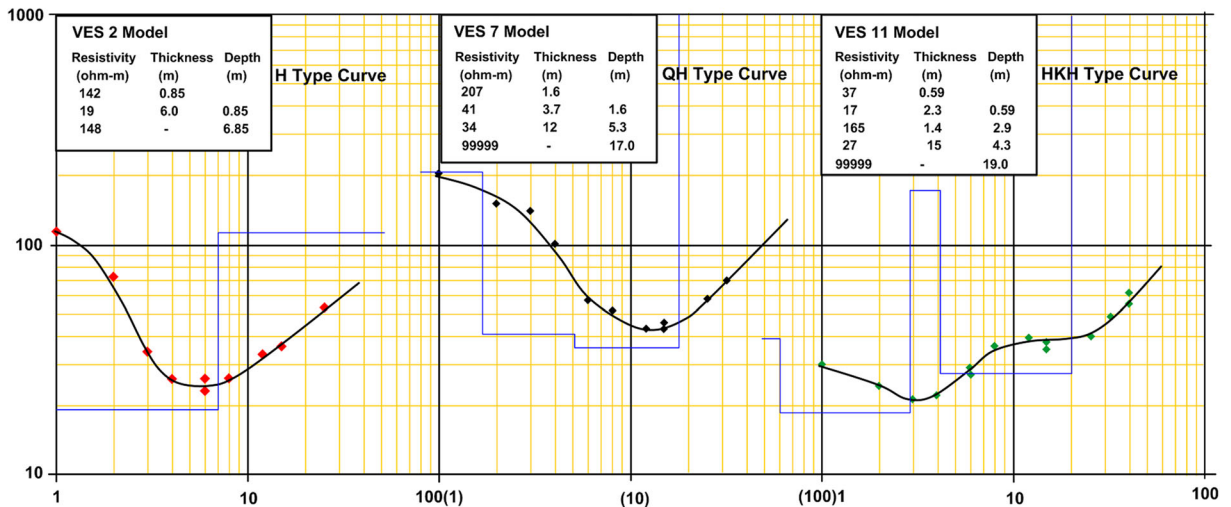


Fig. 9 Typical VES type curves (H, QH, and HKH)

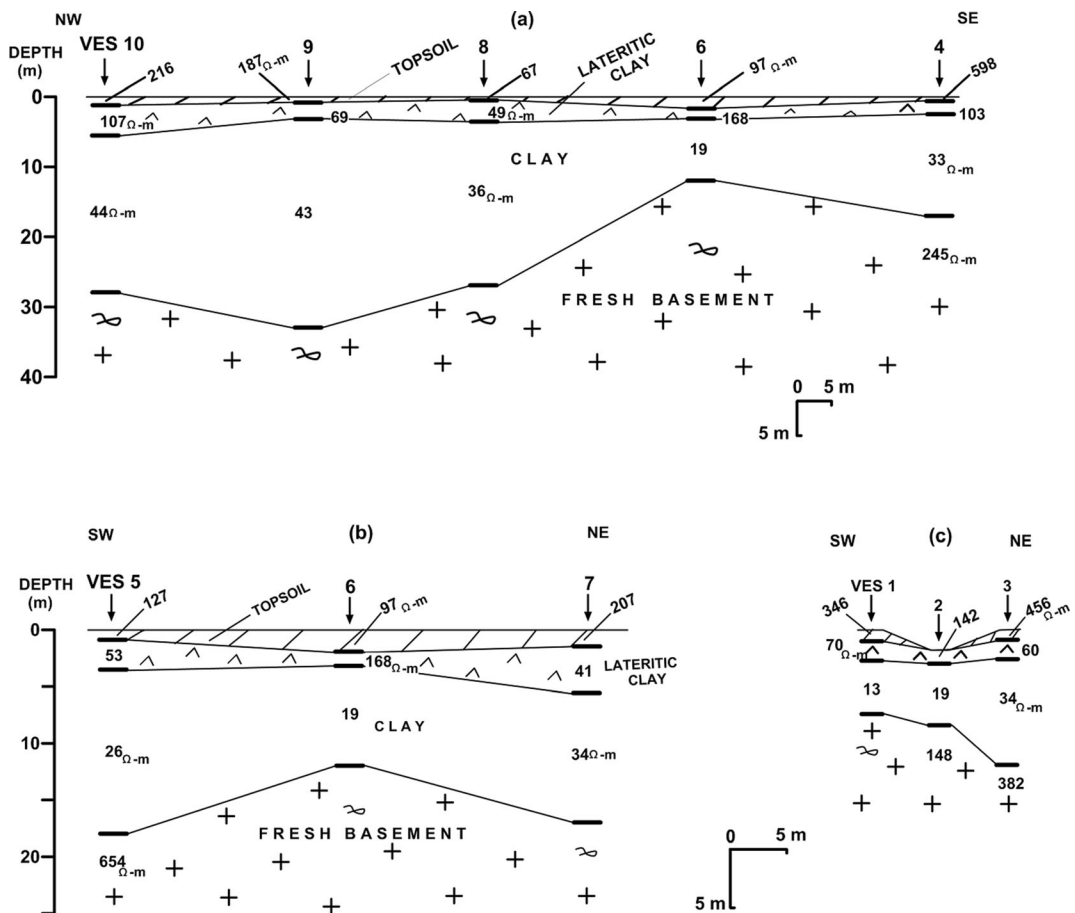
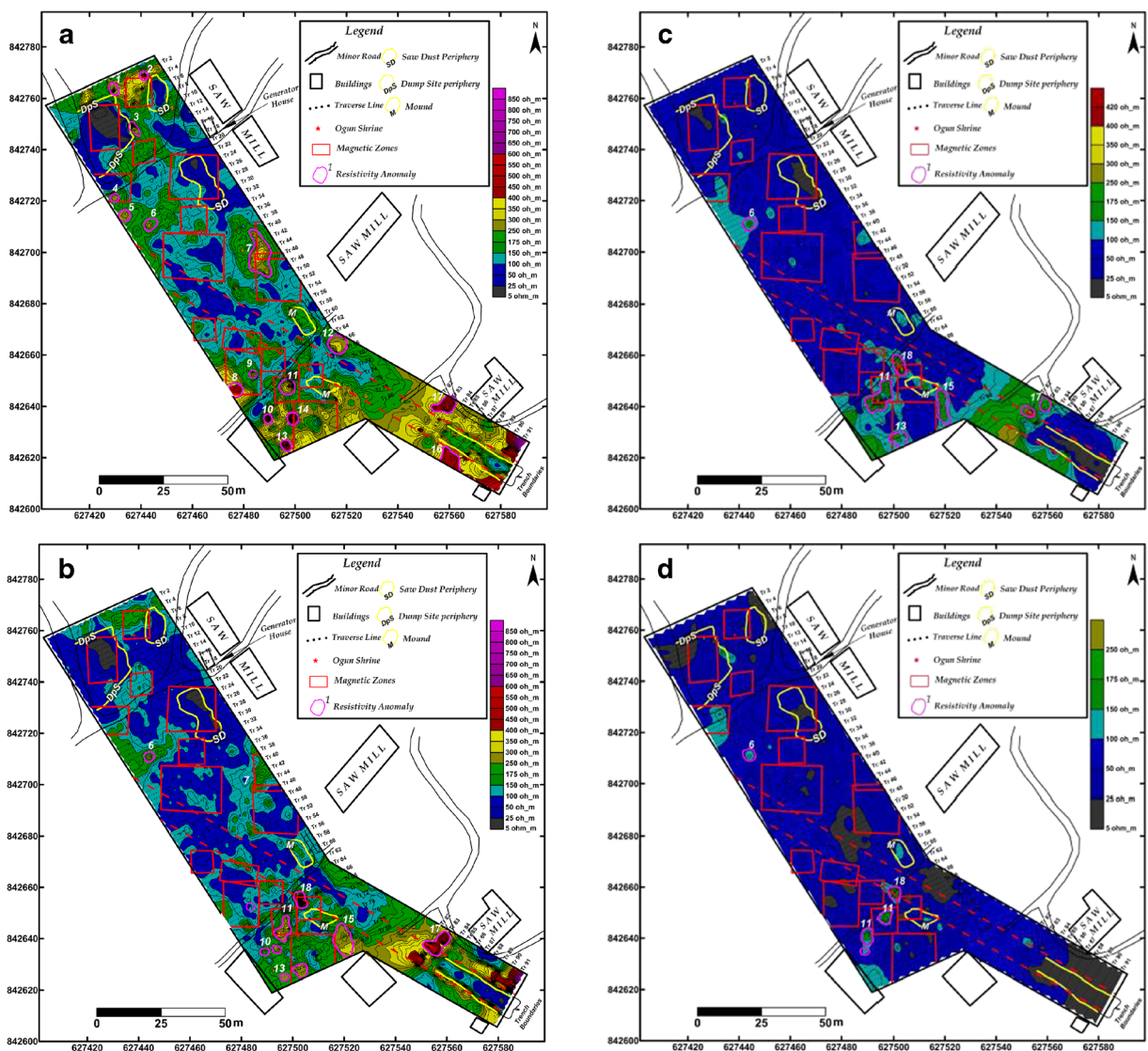


Fig. 10 Geoelectric section relating a VES 10, 9, 8, 6, and 4; b VES 5, 6, and 7; and c VES 1, 2, and 3 across a suspected trench

<250  $\Omega$  m, with about 40–50% of the area having resistivity values of <100  $\Omega$  m, typical of clay. The anomalous zones identified on the magnetic maps (see Figs. 6, 7, and 8) are replicated on the resistivity map either as low resistivity zones, e.g., M, R, B, C, N, O, G, and Q, or moderately high resistivity zones such as L, A, D, E, F, H, I, J, S, and P. In addition, the resistivity map identifies isolated high resistivity closures over the northern mound and those that are labeled as 1–17 (Fig. 11a, b). Novo et al. (2012) and Vanic and Rajovic (2014) established that at shallow depth, geometrically shaped and high resistivity anomalies are

indicative of artificially made objects or features typical of tomb as well as foundation and rubbles of collapsed structures. High resistivity closures 8–15 are concentrated within the area of the mounds. Closures 1–3 are located around the shrine. Closures 4, 5, 6, 7, 16, and 17 are also in the mound area, suspected to be collapsed structures.

At depth 0.75 m, the resistivity range is from < 50 to 850  $\Omega$  m with resistivity of the northwestern flank generally at <250  $\Omega$  m (Fig. 11b). As observed on the 0.25 m depth map, the southeastern wing has relatively high resistivity values, greater



**Fig. 11** Resistivity map at **a** 0.25 m depth, **b** 0.75 m depth, **c** 1.5 m depth, and **d** 2.5 m depth

than 250  $\Omega$  m. The high resistivity closures observed on the 0.25-m depth map and replicated at 0.75 m depth include 2, 6, 7 (bifurcated), 10, 11 (elongated), 13 (bifurcated), 17, and the closure observed over the mound (M). The other closures 1, 2, 4, 5, 12, and 14 disappeared into the moderately high resistivity anomalies (150–250  $\Omega$  m), while closures 3, 8, 9, and 16 completely disappeared. This means the causative features exist at depths shallower than 0.75 m. A new anomaly structure, closure 18, manifests at depths 0.75–2.5 m.

The 1.5-m depth resistivity map (Fig. 11c) shows a resistivity range of between <20 and 420  $\Omega$  m with more areas falling within the very low resistivity clayey zone of <80  $\Omega$  m. This corroborates the clayey subsoils identified in the geoelectric sections at depths >1.0 m. The high resistivity closures (6, 11, 13, 15, 17, and 18) observed on the 0.75-m depth level resistivity map are replicated on this map, showing their relatively considerable depth. At 2.5 m depth, the resistivity map (Fig. 11d) shows an image of the subsoil in the clayey weathered zone with a larger part (>90%) of the investigated area having resistivity values that are less than 100  $\Omega$  m. High resistivity closures, 6, 11, and 18, are replicated on this map with decreased resistivity values. These closures occurred outside the depth window of archaeological relevance which the downward continuation indicates to be less than 1.5 m.

The foundation of ancient structures is usually very shallow in the central Yoruba region and rarely more than 1 ft (about 0.30 m) deep as evident at Ile-Ife, Ilare, Itangunmodi, and other sites in the broader study area (Ogundiran 2002). Hence, the most relevant geophysical map for archaeological investigation of the remains of ancient house foundations would be the 0.25 m depth map recorded in the resistivity survey. Any closure with resistivity value deeper than 0.25 m, such as closures 6, 11, 13, 15, 17, and 18 (Fig. 11a–d), may be due to features other than the remains of collapsed structures. The high resistivity closures that could be further investigated by excavation are 1, 2, 3, 4, 5, 7, 8, 9, 10, 12, and 14 (Fig. 11a). Closures 1, 2, and 3 are in the vicinity of the Ogun shrine. Closures 8, 9, 10, and 14 are in the area suspected to hold residential units, and the prominent mounds in the area seem to indicate collapsed structures. A prominent elongated high resistivity closure 15,

identified around one of the prominent mounds, has a depth of 1.5 m and this could be a burial.

## Archaeological Excavation

Based on the integration of results of the magnetic and electrical resistivity survey, as well as the insights from oral traditions and surface archaeological features, 11 loci were selected for follow-up archaeological excavations as shown in Fig. 12. The geophysical characteristics of the sites and the suspected archaeological features and sources of anthropogenic disturbances (e.g., metallic objects) are illustrated in Table 1. The follow-up archaeological excavations in January and February 2019 attracted community attention. The *oba* of Iwo, His Royal Majesty (HRM), Oba Abdulrasheed Adewale Akanbi, was present to flag off the excavations. He did so with prayers and expressed his commitment to support the use of archaeology to expand the knowledge of Iwo history (see Fig. 3). Loci 1 (pit 1), 2b (pit 2), and 4 (pits 3 and 4) were the focus of test excavations in addition to a control unit, locus 12, with no visible archaeological feature (Figs. 12 and 13). The results of the excavations are discussed below.

### Locus 1 (Pit 1)

This locus is characterized by magnetic low (–ve)/high resistivity closure, and we suspect the feature is an indicator of a collapsed structure. The test unit (P1), 2 × 1 m, yielded many potsherds, animal bones, shells, cowries, beads, iron slag, a human premolar, and metal objects down to 1.5 m (Fig. 14). The potsherds (fired clays) and the metal objects must have accounted for the observed magnetic low (–ve) due to enhanced magnetic susceptibility. The high resistivity is due to the dry, low porosity, and compact nature of the potsherds, shells, and bones.

### Locus 2(b) (Pit 2)

This locus is characterized by a dyke-like magnetic anomaly/low resistivity closure and is suspected of hosting anthropogenic (metallic) object(s) beneath the contemporary sawdust dump site (Figs. 12 and

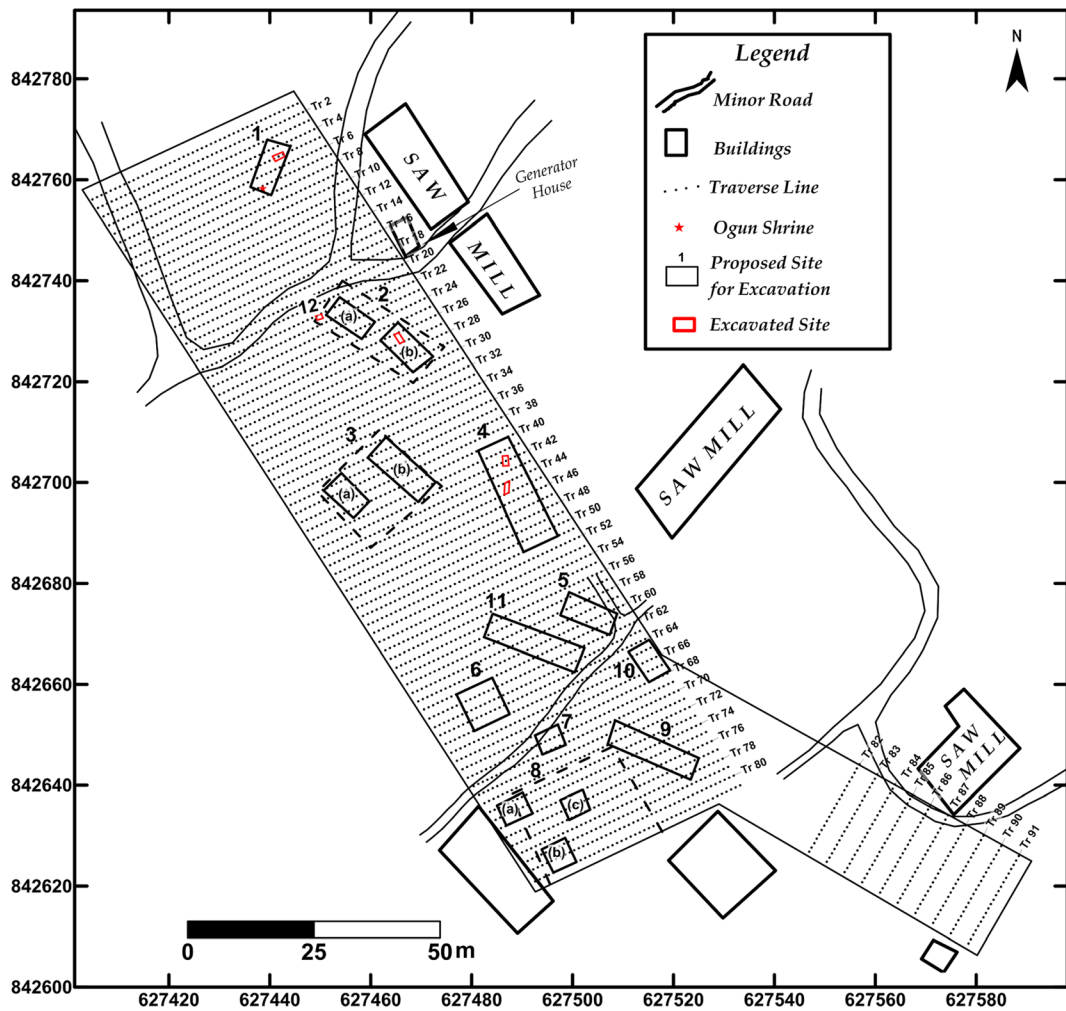


Fig. 12 Proposed and excavated archaeological units at Igbo Oritaa

13). The excavated pit (2 × 1 m) has cultural deposits down to 1.0 m. The unit yielded many contemporary metallic objects such as corroded nails, metal ring, metal blade, a copper-alloy object (possibly a bronze), and a piece of iron slag (Fig. 14) buried beneath an ash deposit derived from the burnt sawdust from the adjoining lumber yard. The observed dyke-like magnetic anomaly was derived from the metallic objects, while the low resistivity was caused by the conductive sawdust ash.

Locus 4 (Pits 3 and 4)

This anomalous zone is elongated (about 22 m long), with the characteristic magnetic low (–ve)/high

resistivity closure suspected to be a collapsed structure (see Fig. 12). Two units (pits 3 and 4) were excavated within the zone, each with a dimension of 2 × 1 m. The cultural deposits are 1.5 m in depth. Pit 3 yielded many potsherds, animal bones, cowries, a flute, metal blade and knives, glass and bone beads, and snail/oyster shells (Fig. 14). The enhanced magnetic susceptibility of the fired clay (in the form of potsherds) and metal objects must have accounted for the observed magnetic low (–ve), while the dry and low porosity potsherds, bones, and snail shells could have been responsible for the observed high resistivity. The excavations at pit 3 revealed the remains of a structure corroborating the inference of a collapsed building from the geophysical survey.

**Table 1** Geophysical characteristics of sites recommended for follow-up archaeological excavation and finds

S/ N	Magnetic zone (block)/ resistivity closures	Magnetic/resistivity characteristics	Suspected archaeological object/feature	Archaeological finds
1	L; 2	Magnetic low (–ve)/high resistivity closure	Suspected Ogun Shrine/collapsed structure	Animal bone fragments, metal blade and ring, ceramic, potsherds, snail shell, iron slag, human premolar
2	C	Typical dyke anomaly (+ve/–ve)/low resistivity closure	Anthropogenic (metallic) object beneath saw dust dump site	Contemporary metal objects such as blade, ring, corroded nails, iron slag, copper alloy object
3	N	Magnetic lows (–ve)/low resistivity closures	Anthropogenic (metallic) objects responsible for two prominent low magnetic anomalies	N/E
4	O, E; 7	Magnetic low (–ve)/high resistivity elongated closure	Collapsed structure or tomb?	Potsherds, animal bones, cowries, flute, metal blade, glass and bone beads, snail/oyster shells, and remains of building foundation
5	S	Magnetic low (–ve)/high resistivity elongated closure	Mound (collapse structure or tomb)	N/E
6	H; 8/9	Magnetic low (–ve)/high resistivity circular closure	Collapsed structures?	N/E
7	J	Typical dyke anomaly (+ve/–ve)/high resistivity circular closure	Collapsed structure?	N/E
8	P; 10/13/14	Magnetic low (–ve)/high resistivity circular closures	Collapsed structures	N/E
9	T; 15	Magnetic low (–ve)/high resistivity elongated closure	Mound of tomb or collapsed structure	N/E
10	12	Magnetic low (–ve)/high resistivity circular closure	Collapsed structure	N/E
11	Q	Magnetic low (+ve/–ve)/linearly elongated low resistivity zone	Trench	N/E
12	Control site	No distinct magnetic or resistivity anomaly	No archaeological or anthropogenic object suspected	No object found

N/E not excavated

### Control Site (Pit 5)

In order to check the effectiveness of the geophysical characteristics as indicators of archaeological deposits, a site that has no distinct geophysical anomaly (one with background magnetic and resistivity effects) and no visible archaeological remains was selected for control excavation (Fig. 13). The 1 × 1-m test pit (P5) was excavated to a depth of 1.0 m. The test unit did not yield any archaeological material and is therefore consistent with the results of the geophysical survey.

### Stratigraphic Description

We will use pit 1 to illustrate the typical stratigraphic profile of Igbo Oritaa. Six strata were identified as shown in Fig. 15. The strata/levels, depths, soil profile, sherd count, and frequency of the other artifacts are highlighted in Table 2. In all, 6,906 potsherds were retrieved from this pit, including two complete pots from stratum 3 where 1,243 potsherds were also recorded. From the downward continuation magnetic map (see Fig.

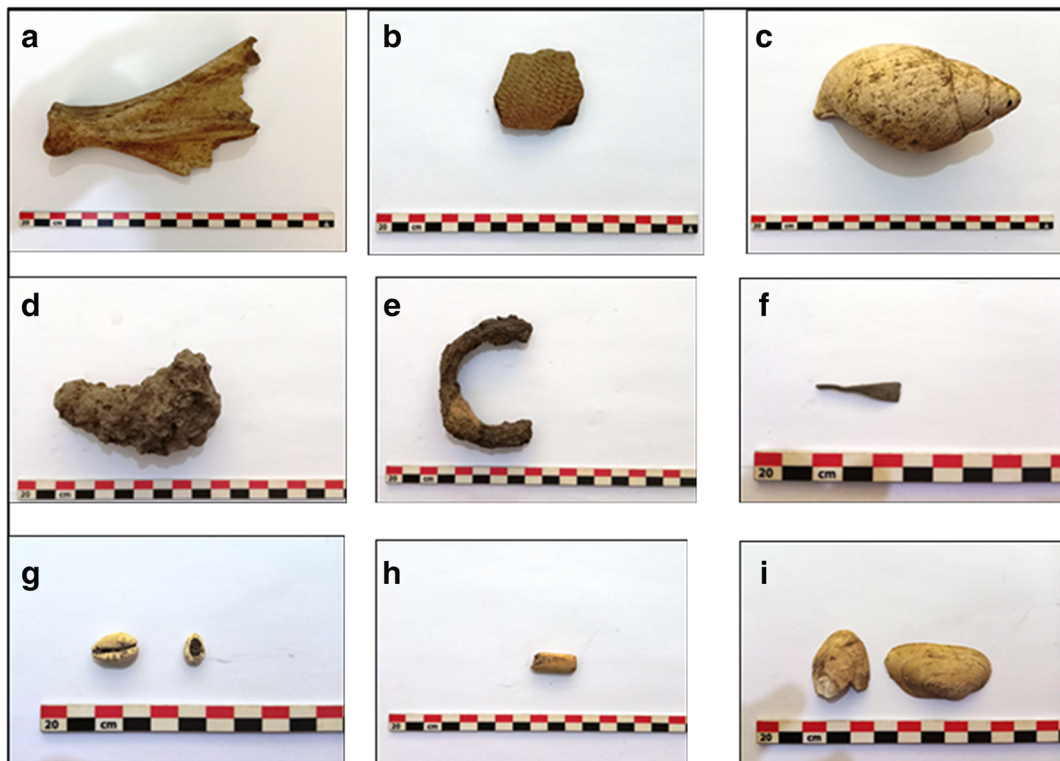


**Fig. 13** Aerial photograph of Igbo Oritaa, showing the excavated units and other features

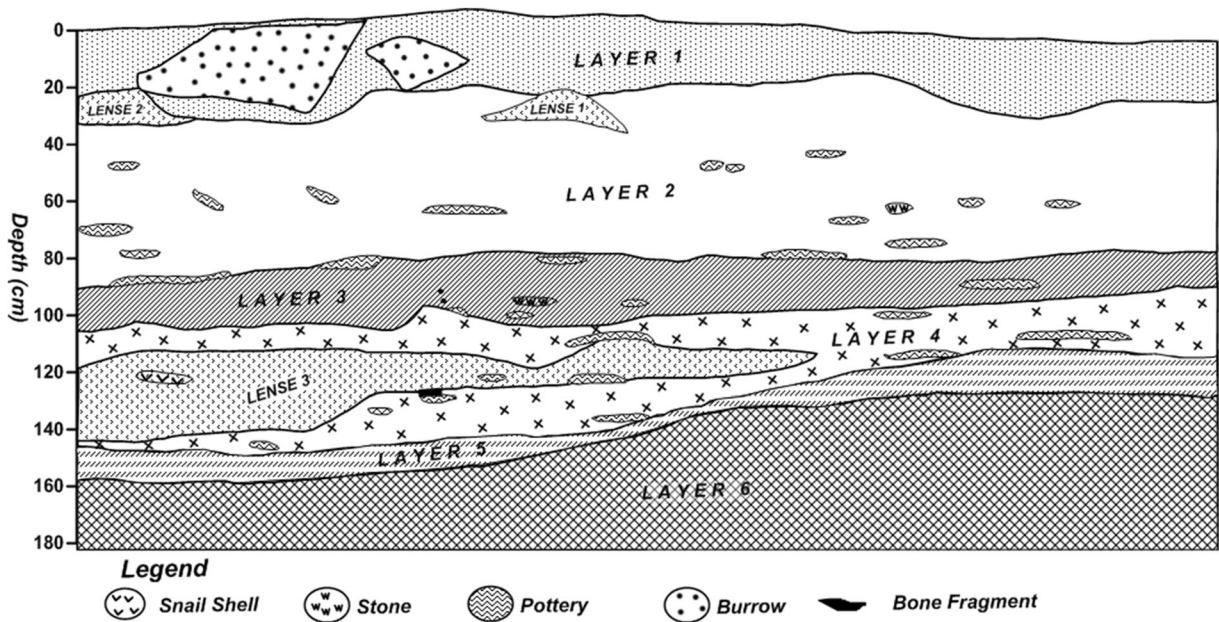
5), the most viable cultural layer was expected to be within the upper 1.5 m, and based on the depth sliced resistivity and weighted average resistivity maps, we expected the concentration of artifacts to be in the 0.25–0.75-m depth levels (Fig. 11a). Our excavations revealed the continuation of archaeological deposits down to 1.55 m, while the largest concentration of potsherds (3,832) was retrieved at depths 0.15–0.90 m. The large number of potsherds with relatively high magnetic susceptibilities due to thermal effect, accounted for the negative magnetic anomaly over most of the site, which is located in low magnetic latitude. There is therefore a very significant correlation between the results of the geophysical investigations and the archaeological finds at Igbo Oritaa.

### Conclusion

Integrated geophysical investigation of the ancient settlement of Igbo Oritaa was carried out to identify



**Fig. 14** Selected archaeological finds: **a** bone fragment, **b** potsherd, **c** snail shell, **d** iron slag, **e** metal ring, **f** copper alloy object, **g** cowries, **h** flute, and **i** oyster shell



**Fig. 15** Pit 1 northern wall stratigraphic section

subsurface archaeological artifacts and features as a guide for the excavation and preservation programs of the site. The study involved magnetic profiling and 1D and 2D subsurface imaging with the electrical resistivity method. Magnetic and resistivity attributes of magnetic lows (negative amplitude) with high resistivity, magnetic lows with low resistivity, and typical thin dyke magnetic anomalies were used

to identify potential areas of archaeological deposits. From the results of this geophysical survey, 11 loci were proposed for further investigation, and three of these (loci 1, 2, and 4) were excavated. The four test pits that constituted the excavations yielded a diverse range of artifacts, ranging from potsherds to bones, snail shells, cowries, metallic objects, and the remains of a building foundation. The maximum

**Table 2** Stratigraphic description and finds recovered from pit 1

Stratum/level	Depth (cm)	Soil profile	No. of sherds	Other artifacts
Upper layer		Burnt sawdust ash	—	—
1	0–30	Powdery dry sandy soil with rootlets	137	Animal bones, palm kernels, lithic materials, and charcoal
2	15–90	Fairly loose/powdery dry sandy-silt with stone inclusions (2.5 YR, 5/2 weak reddish brown)	3,832	Animal bones, oyster shell, metallic object (blade), and charcoal
3	80–105	Loose and powdery soil with stone inclusion, warm casts, and rootlets (5 YR, 5/3, reddish brown)	1,243	Animal bones and charcoal
4	90–150	Loose sandy-silt with rootlets and stone inclusion (5 YR, 2.5/1 black)	842	Several fauna
5	115–155	Friable/fairly powdery sandy-silt with stone inclusion (2–5 YR, 3/1 dark-reddish gray)	850	Animal bones and lithic materials
6	125–180	Fairly soft/powdery/friable silty-sand with stone inclusion (5 YR, 4/2 dark-reddish gray)	2	



**Fig. 16** Sheds over pits 1, 3, and 4



depth of archaeological deposits was 1.55 m, consistent with the 1.5 m predicted from the geophysical survey. The integration of the magnetic and resistivity maps therefore gave geophysical signatures that accurately predict buried artifacts.

The survey area is a small fraction of the ancient Igbo Oritaa settlement most of which is now being used for timber production. The present study is therefore limited to a minimally disturbed parcel of land in the larger settlement area (Fig. 13). However, in spite of the space limitation, the geophysical investigation enabled a targeted and more precise survey, and the results were validated by excavations establishing that Igbo Oritaa was indeed an ancient settlement. Considering the importance of the site in the memory, tradition, and identity of the Iwo community, we have established the scientific basis for pursuing preservation efforts at the site.

The excavation process was used to sensitize the curious public on the need to preserve the Igbo Oritaa as a heritage site. The study gave the leaders of the community a scientific basis to secure a section of the site for preservation and it boosted the claims of the oral traditions that the site is an ancestral homeland of Iwo people. In continuation of the sensitization effort, we intend to carry out on-site exhibition of the artifacts recovered from the excavation. Toward achieving this goal, three of the excavated pits (pits 1, 3, and 4) were left open and a shed has been constructed over them (Fig. 16). The traditional leaders of Iwo are now in conversation on the logistics and feasibility of relocating the sawmill to another site in order to survey and legally secure most of the area as a heritage site, and develop a comprehensive archaeological research and preservation plan for the future.

**Acknowledgments** The authors are grateful the paramount ruler, His Royal Majesty, Oba Abdulrasheed Adewale Akanbi, the Oluwo of Iwo who, through the Iwo Historical and Cultural Association (IHCA), invited us to carry out archaeological research in Igbo Oritaa. Messrs. T. K. Fadare and E. A. Adewale participated in the geophysical data acquisition. The authors are also grateful to the two anonymous reviewers whose comments have helped us improve the quality of the manuscript.

**Funding Information** We thank the Iwo Historical and Cultural Association for financing the geophysical investigation, archaeological excavations, and site preservation effort.

#### Compliance with Ethical Standards

**Conflict of Interest** The authors declare that they have no conflict of interest.

#### References

- Akinjogbin, I. A. (1992). *The cradle of a race: Ife from the beginning to 1980*. Port Harcourt: Sunray Publications.
- Arthur, J. W., Curtis, M. C., Arthur, K. J. W., Coltorti, M., Pieruccini, P., Lesur, J., Fuller, D., Lucas, L., Conyers, L., Stock, J., Stretton, S., & Tyko, R. H. (2019). The transition from hunting–gathering to food production in the Gamo Highlands of southern Ethiopia. *African Archaeological Review*, 36(1), 5–65.
- Atkinson, R. J. C. (1952). Methodes electriques de prospection en archéologie. In A. Laming (Ed.), *La découverte du passé* (pp. 59–70). Paris: Picard.
- Ekinci, Y. L., Balkaya, C., Seren, A., Kaya, M. A., & Lightfoot, C. S. (2014). Geomagnetic and geoelectrical prospection for buried archaeological remains on the Upper City of Amorium: A Byzantine city in midwestern Turkey. *Journal of Geophysical Engineering*, 11(1), 1–17.
- Eluyemi, A. A., Olorunfemi, M. O., & Ogunfolakan, M. A. (2012). Integrated geophysical investigation of Orile-Oje archaeological site, Ogbomosho, Southwest Nigeria. *The Pacific Journal of Science and Technology*, 13(1), 615–630.
- Fleisher, J., & Sulas, F. (2015). Deciphering public spaces in urban contexts: Geophysical survey, multi-element soil analysis, and artifact distributions at the 15th–16th-century AD

- Swahili settlement of Songo Mnara, Tanzania. *Journal of Archaeological Science*, 55, 55–70.
- Gaffney, C. (2008). Detecting trends in the prediction of the buried past: A review of geophysical techniques in archaeology. *Archaeometry*, 50(2), 313–336.
- Gaffney, C., Hughes, G., & Gater, J. (2005). Geophysical surveys at King Lobengula's palace KoBulawayo, Zimbabwe. *Archaeological Prospection*, 12, 31–49.
- Geological Survey of Nigeria (1974). Iwo Sheet 60, 1:25,000 geological map.
- Iloje, N. P. (1981). *A new geography of Nigeria (New Revised Edition)*. Lagos: Longman Nig. Ltd.
- Ladipo, O., & Amoo, A. (2017). Iwoland and its untapped tourism potentials. Unpublished manuscript, 4pp.
- Leucci, G., & Greco, F. (2012). 3D ERT survey to reconstruct archaeological features in the subsoil of the "Spirito Santo" Church Ruins at the site of Occhiola (Sicily, Italy). *Archaeology*, 1(1), 1–6.
- Magnavita, C. (2016). Contributions of archaeological geophysics to field research in Sub-Saharan Africa: Past, present, future. *Azania: Archaeological Research in Africa*, 51(1), 115–141.
- Magnavita, S. (2017). First geophysical exploration in the tumuli zone of central Senegal: A multidimensional approach. *Azania: Archaeological Research in Africa*, 52(1), 100–122.
- Magnavita, C., Breunig, P., Ameje, J., & Posselt, M. (2006). Zilum: A mid-first millennium BC fortified settlement near Lake Chad. *Journal of African Archaeology*, 4, 153–169.
- Novo, A., Vincent, M. L., & Levy, T. E. (2012). Geophysical surveys at Khirbat Faynan, an ancient mound site in southern Jordan. *International Journal of Geophysics*, 2012, 1–8. <https://doi.org/10.1155/2012/432823>.
- Ogundiran, A. (2002). *Archaeology and history in Ilare District (Central Yorubaland, Nigeria), 1200-1900. Cambridge monograph in African archaeology no. 55*. London: Archaeopress.
- Olorunfemi, M. O., Ogunfolakan, B. A., Chouin, G. L., Oni, A. G., Okunubi, M. O., & Akinwumiju, S. A. (2015). Integrated geophysical investigation of Yemoo Groove archaeological site in Ile-Ife, Osun State, southwest Nigeria. *IFE Journal of Science*, 17(3), 553–563.
- Oni, A. G. (2018). *Integrated geophysical investigation of Ijoja archaeological site, Oke-Ako, southwestern Nigeria. Ph.D. thesis*. Ile-Ife: Obafemi Awolowo University.
- Oyeyemi, K. D., Oladunjoye, M. A., Aizebeokhai, A. P., Ajekigbe, P. G., & Ogunfolakan, B. A. (2015). Integrated geophysical investigations for imaging archaeological structure in ancient town of Ile-Ife, Nigeria. *Asian Journal of Information Technology*, 4(7), 246–252.
- Pitt-Rivers, A. (1898). *Excavations in Cranborne Chase, near Rushmore, on the borders of Dorset and Wilts* (pp. 1880–1896). London: Harrison and Sons.
- Rahaman, M. A. (1989). Review of the basement geology of south-western Nigeria. In C. A. Kogbe (Ed.), *Geology of Nigeria* (2nd Revised ed., pp. 39–56). RockView: Jos.
- Vanic, M., & Rajovic, B. (2014). Geophysical survey at the archaeological remains of the Medieval Orthodox Church in Valjevo, western Serbia; student field camp case study. *SEG Technical Program Expanded Abstracts*, pp. 2114–2118. Society of Exploration Geophysicists Annual Meeting, Denver. <https://doi.org/10.1190/segam2014-0466>.
- Young, C. T., & Droege, D. R. (1986). Archaeological application of resistivity and magnetic methods at Fort Wilking State Park, Michigan. *Geophysics*, 51(3), 568–575.

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.