

Integrated Geophysical Investigation of Orile-Oje Archaeological Site, Ogbomosho, Southwest Nigeria.

A.A. Eluyemi, M.Sc.^{1*}; M.O. Olorunfemi, Ph.D.²; and A. Ogunfolakan, M.A., M.Phil.³

¹Centre for Energy Research and Development, Obafemi Awolowo University, Ile-Ife, Nigeria.

²Department of Geology Obafemi Awolowo University, Ile-Ife, Nigeria.

³Natural History Museum, Obafemi Awolowo University, Ile-Ife, Nigeria.

E-mail: aeluyemi@cerd.gov.ng *
mlorunfe@yahoo.co.uk
badadii@yahoo.com

ABSTRACT

An integrated geophysical investigation of Orile-Oje archaeological site in Ogbomosho area, southwest Nigeria was carried out. It was with a view to locating an ancient royal tomb, mapping of ancient iron smelting sites, and any other archaeological features in the ancient town.

Six traverses were established at the Orile-Oje archaeological site at a bearing of 110°. The traverses were marked out at 5 m intervals. Electrical resistivity measurements using dipole-dipole array were carried out along the six traverses while eight Vertical Electrical Soundings (VES) were acquired with ABEM SAS 300 Resistivity Meter along the traverses using the Schlumberger array. Three subsurface geoelectric/geologic layers were delineated. These include lateritic topsoil, weathered layer and the basement bedrock. The inverted dipole-dipole 2-D resistivity structures corroborated the aforementioned sequence. On the 2-D resistivity image along Traverse 3, the suspected ancient tomb is characterized by relatively high resistivity with depth extent of 2 m and lateral extent of about 18 m. between stations 7-18 The slag mound is characterized by relatively high resistivity zone between stations 10-23 (about 26 m on the 2-D resistivity image along Traverse 4) with depth extent of about 1 m. The slag is also characterized by a negative magnetic closure which extended to Traverse 3. Other similar magnetic anomalous zones, suspected to be smelting sites, were also located along Traverses 5 and 6 respectively.

The study concluded that the ancient town of Orile-Oje hosted a suspected ancient royal tomb, several ore smelting sites and two major settlements.

(Keywords: geophysical investigation, archaeological site investigation, Orile-Oje, southwest Nigeria, cultural resources)

INTRODUCTION

Orile-Oje, otherwise known as Igbo-Oje, is an ancient town in the southwestern Nigeria. The ancient town had a central market that linked people from the northern part of the country to the people of the south. Although what led to its collapse was not properly documented, it is suspected that the town might have been displaced as a result of war, chieftaincy dispute, power tussle, or in accordance with an Ifa-oracle (Ogunfolakan, 1994). Presently, there exists at the site relics of the ancient past in several old Baobab trees, relics of collapsed ancient walls, grinding-stones, a suspected ancient iron smelting site, and a suspected ancient tomb of the past Royal Highnesses (Ogunfolakkan, et al., 2006).

Comprehensive recovery of subsurface cultural features cannot be achieved solely by the shovel tests or unit excavation technique of the archaeologist but by detailed geophysical investigation of the subsurface earth. Archaeological-geophysics uses measurements of geophysical properties at the ground surface to create images of the subsurface that can be interpreted by a geophysicist and archaeologist working together to identify subsurface features of cultural origin (William et al. , 2006).

The application of surface geophysical measurements in archaeology is not only capable of delineating the subsurface archaeological artifacts but is also vital in the reconstruction of

the ancient structures of the site under investigation (Lynford and Payne, 1995; Urbini et al., 2007; Geoffrey, 2008 and Di maio et al., 2010). Geophysical application tends to maximize the success of the follow-up archaeological excavation and also provide a non-invasive and cost-effective method of survey (De Young et al., 2000).

In this study, the need to reconstruct the ancient structures as well as the recovery of the archaeological artifacts at the Orile-Oje archaeological site is paramount and for this purpose the electrical resistivity and magnetic methods have been applied. For the fact that the site under investigation is relatively large, the magnetic method is suitable for fast detection of diverse sunken or buried archaeological features. It is possible to identify sections of subsurface linear structures, (enclosures/fencing) or other features such as trenches, channels, terraces, arable-land including areas of discontinuity (entrances, gates) and structures built on stones (houses, wall) and various burnt features (furnaces, mine tailings, smithies, etc.) (Krivanek, 2004). The application of the electrical resistivity and magnetic methods in archaeological site investigation is meant to image the subsurface structures, locate ancient tombs, subsurface metallic confinement such as metallic coffins if any and for the reconstruction of the settlement pattern of the site under investigation.

Location, Extent and Accessibility of the Study Area

Orile-Oje is located along Ijeru-Akunko-Ibadan Road in Ogo-Oluwa Local Government Area of Oyo State (Figure 1). It is situated at the southwestern part of Ogbomoso town, just after the Oje River. The area lies within Eastings 0632556 mE and 0632899 mE and Northings 0891088 mN and 0891436 mN. The average topographic elevation is 305 m above mean sea level. The site is accessible through Ijeru-Akunko-Ibadan Road.

Climate and Vegetation

Orile-Oje is located within the tropical climatic zone that is characterized by two distinct seasons namely: the raining or wet and the dry seasons respectively. The wet season starts from around the months of March/April through to the month of

October even though a little break in rainfall is usually experienced in the month of August. The month of November marks the beginning of the dry season which ends by the end of March.

Temperature is usually high throughout the year with an annual mean of 27°C, Estimates of evapo-transpiration have been made for some stations in the savannah zone of Nigeria and the relative humidity varies from 60 to 80% (Gbadegesin and Akinbola, 1995). The present vegetation of the site is the derived savannah with several baobab trees (Plate 1) (Ogunfolakan et al., 2006). There are other scattered trees all over the place with shrubs and grasses. Millet and cassava cultivation and mango trees are pronounced.

GEOLOGIC SETTING

The area around Ogbomoso is underlain by the Precambrian Basement Complex rocks. The lithological units are quartzite, granite-gneiss and banded gneiss. The quartzites are light colored and may be part of the migmatite-gneiss quartzite complex, mainly composed of quartz. The study area is underlain by granite-gneiss (Figure 2). The granite gneiss are medium to coarse-grained foliated and largely re-crystallized rocks with low quantity of mica and chlorite or other platy minerals. The gneisses display compositional banding where the minerals are arranged into bands of more mafic minerals that are developed under a very high pressure and temperature condition (Afolabi et al., 2010). The constituents of the granite gneisses are quartz, feldspar, with mica and horn blend as accessory minerals. The quartz and the feldspar generally give granite-gneiss its light color which ranges from pinkish to white.

METHODOLOGY

Six traverses were established at the Orile-Oje archaeological site at a bearing of 110° with inter traverse spacing of 50 m except between Traverses 3 and 4 with inter traverse spacing of 22 m. The traverses were marked out at 2 and 5 m intervals (Figure 3).

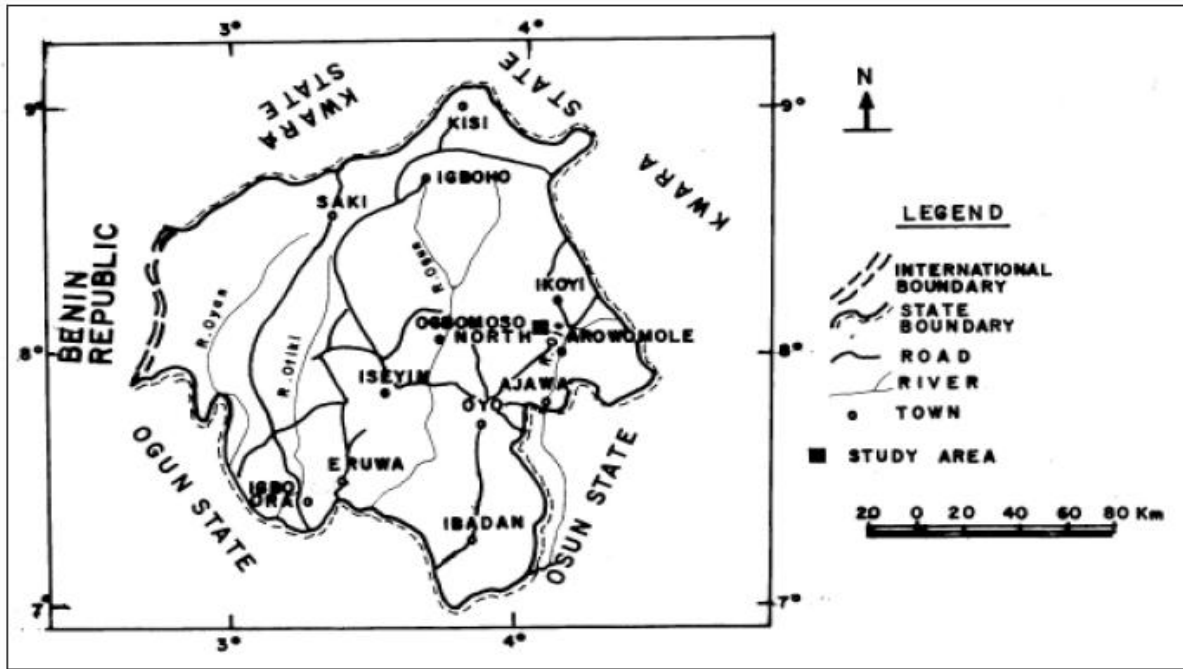


Figure 1: Map of Oyo State Showing the Study Area of Orile-Oje in Ogo Oluwa Local Government Area (after Ogunfolakan et al., 2006).



Plate 1: Photograph of the Investigated Area Showing the Savannah Vegetation of the Area with Baobab Trees.

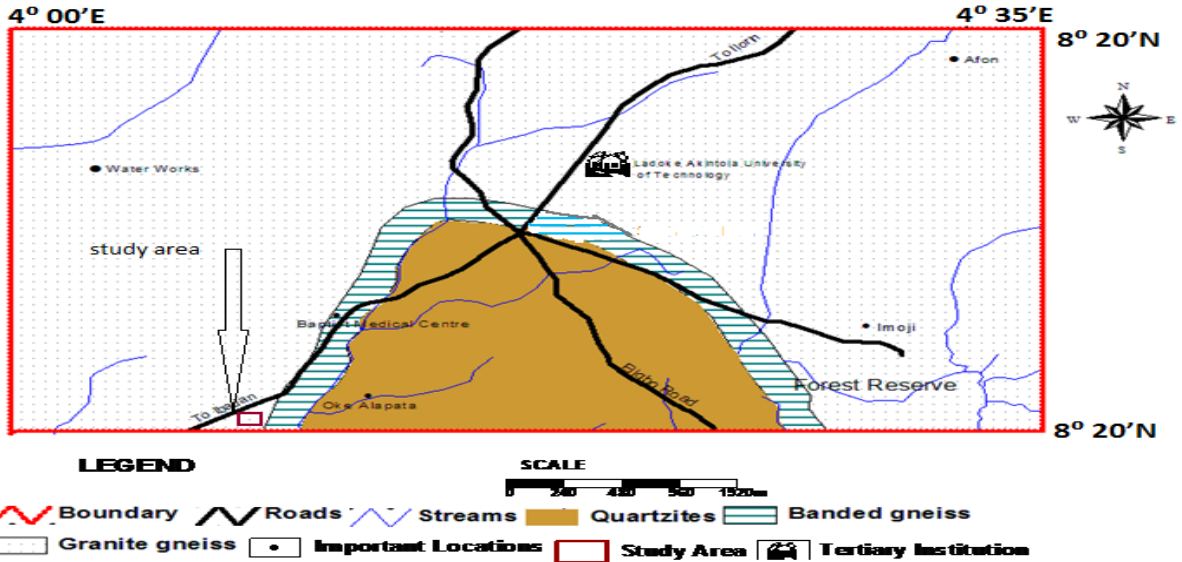


Figure 2: Geological Map of Ogbomosho Showing the Study Area (Modified after Afolabi et al., 2010).

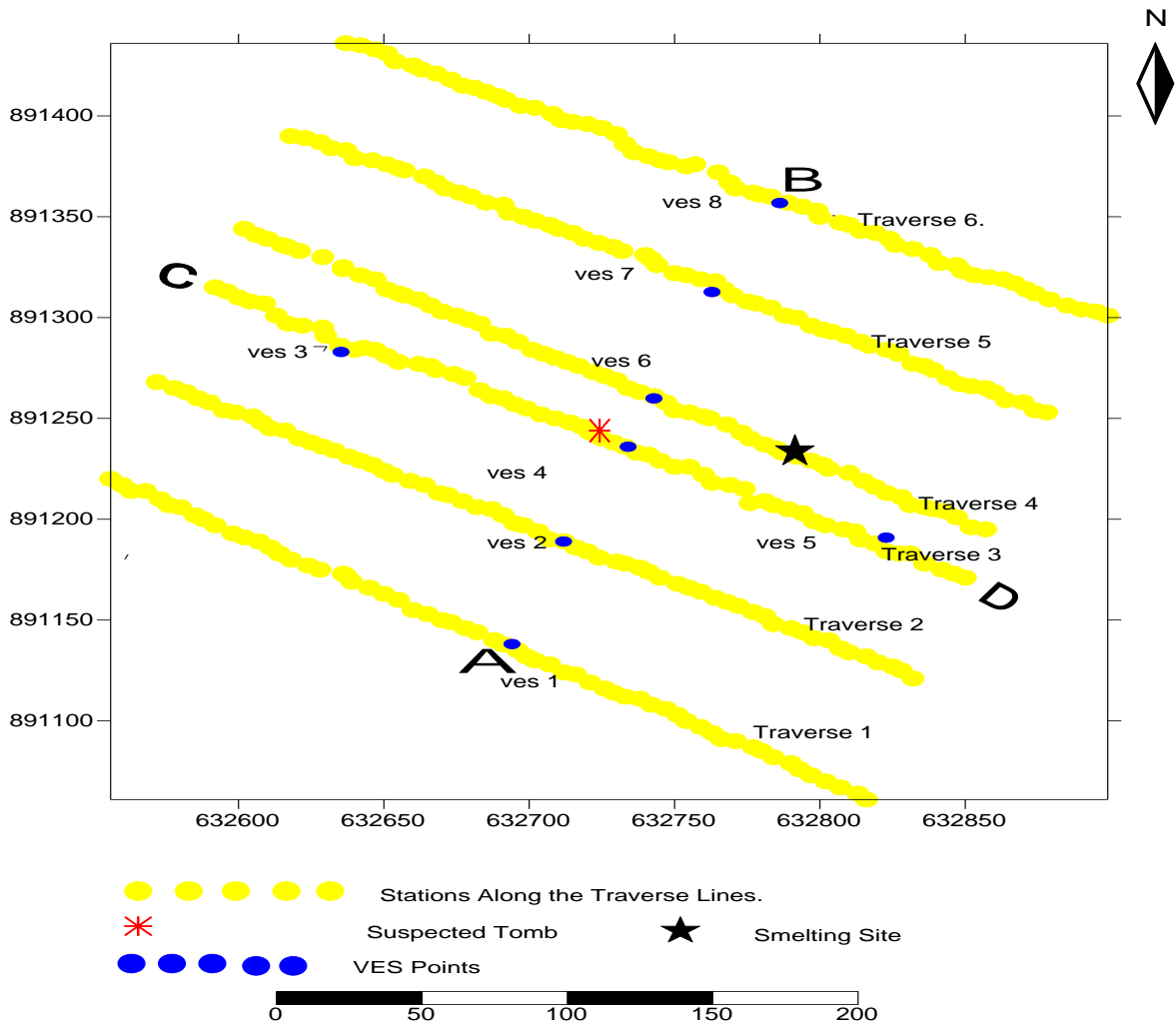


Figure 3: The Geophysical Data Acquisition Map of the Investigated Site.

Electrical resistivity measurements using the dipole-dipole array were carried out along the six traverses for geoelectrical subsurface imaging while eight Vertical Electrical Soundings (VES) were acquired using the Schlumberger array with maximum half-current electrode spacing (AB/2) of 100 m for subsurface sequence delineation. The dipole-dipole data sets were presented as pseudosections along individual traverse lines and subsequently inverted using the DIPRO software.

The VES data were presented as depth sounding curves. The VES data interpretation involved the partial curve matching and 1-D computer assisted forward modeling with the RESIST software. The VES interpretation results were used to generate geoelectric sections. Magnetic data sets were acquired along the six traverses at station separation of 5 m using the Proton Precession Magnetometer. The raw magnetic data were corrected for diurnal variations and offset to produce the residual geomagnetic map which was interpreted qualitatively

RESULTS AND DISCUSSION

This study was guided by two principal archaeological leads. The first one is a suspected ancient tomb of royal highnesses presumably located between stations 28 and 32 with centre between stations 30 and 31 along Traverse 3 (see Figure 3). This feature is identified by a prominent isolated ant mound. The second one is a mound of slag of what is suspected to be indicative of an ore smelting site located around stations 45-47 along Traverse 4. It is also guided by an understanding that the near surface of an inhabited ancient site will be relatively more compacted due to human activities than the adjoining areas and hence will display relatively high resistivity images.

The Electrical Resistivity Method: Vertical Electrical Sounding

The observed Vertical Electrical Sounding (VES) curves are the H-type and are characterized by three lithological layers (Figure 4). The interpretation results of the VES curves are shown in Table 1. The subsurface sequence is composed of lateritic topsoil, weathered basement and the fresh basement bedrock.

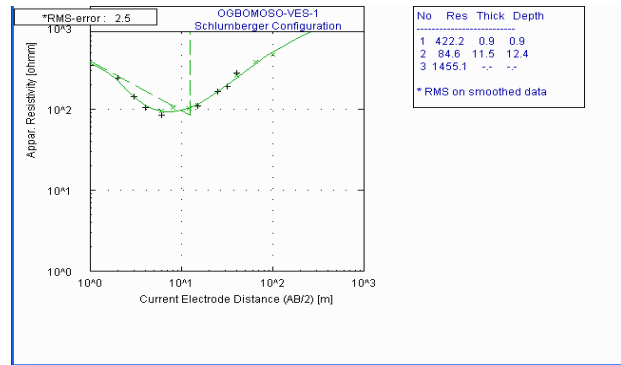


Figure 4: Typical H-Type VES Curve Obtained at Orile-Oje Locality.

Table 1: Vertical Electrical Sounding Interpretation Results at Orile-Oje Archaeological Site.

| VES Number | Depth (m) // Resistivity (Ohm-m) | Type Curve. |
|------------|----------------------------------|-------------|
| 1 | 0.9/12.15//450/113/1520 | H |
| 2 | 1.5/11.3//360/90/810 | H |
| 3 | 0.85/6.80//450/193/1400 | H |
| 4 | 1.9/7.22//250/63/490 | H |
| 5 | 0.34/5.52//420/84/560 | H |
| 6 | 1.75/6.65//215/43/450 | H |
| 7 | 0.63/4.28//500/71/1235 | H |
| 8 | 0.7/5.53//700/99/810 | H |

Geoelectric Sections

2-D geoelectric sections were prepared from the VES interpretation results-one along a SSW-NNE direction while the second section was drawn along a WNW-ESE direction. Both sections define the subsurface lithologies. The geoelectric section A-B (Figure 5) delineates three geoelectric/geologic subsurface layers. These include the topsoil, weathered layer and the basement bedrock. The lateritic topsoil has resistivities and thicknesses that range from 227-630 Ω m and 0.7-1.9 m, respectively. The weathered layer is composed of clay with layer resistivities and thicknesses of 35-85 Ω m and 4.5-11.5 m, respectively. The basement bedrock has layer resistivity of between 498 and 1455 Ω m and depth to the bedrock of 4.3-12.4 m.

The overburden thickens toward the SSW direction. The geoelectric section C-D (Figure 6) reveals three geoelectric/geologic layers.

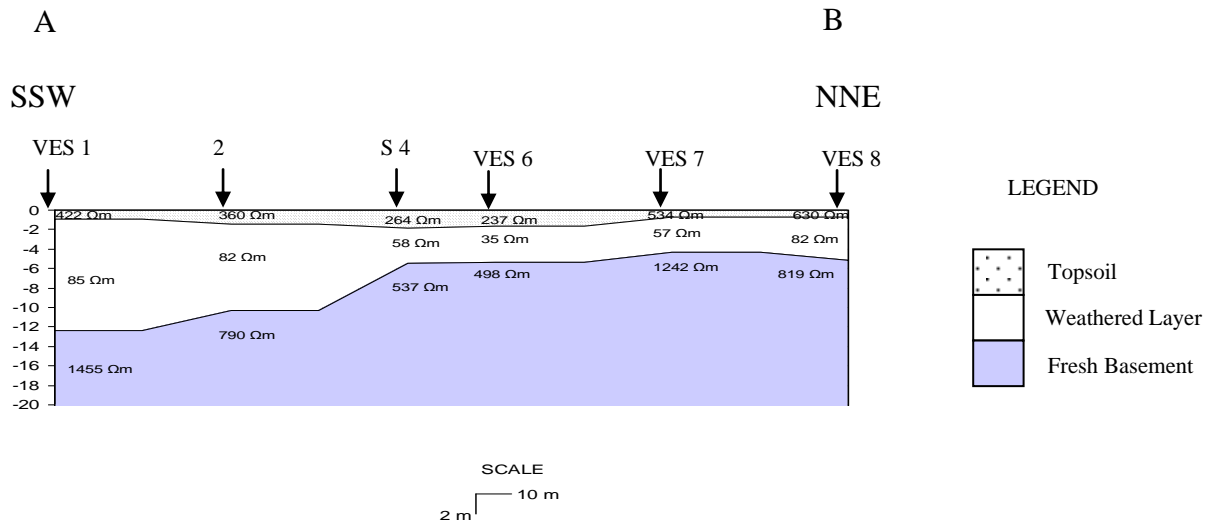


Figure 5: Goelectric Section (A-B) at Orile-Oje Locality.

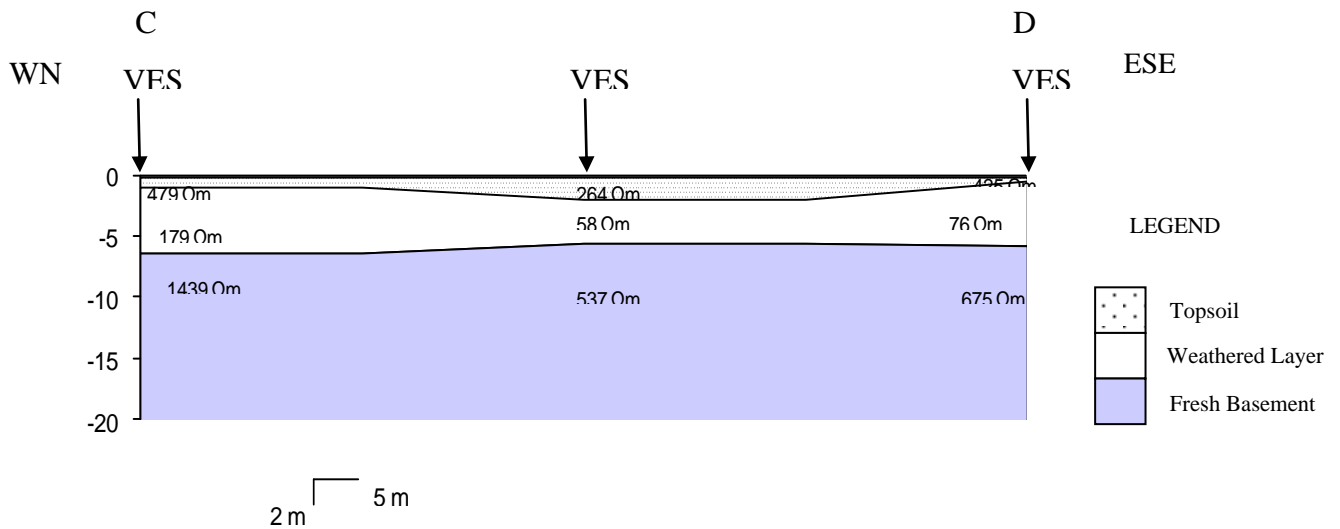


Figure 6: Goelectric Section (C-D) at Orile-Oje Locality.

The topsoil is composed of laterite with resistivities and thicknesses that range from 264-479 Ωm and 0.4-1.9 m, respectively. The weathered layer is composed of clay/sandy clay with resistivities and thicknesses that range from 58-179 Ωm and 3.6-5.4 m, respectively. The basement bedrock has layer resistivity values that range from 537-1439 Ωm and depth to the bedrock of 5.5-6.3 m. Both geoelectric sections show a site with thin to moderately thick overburden and a clayey weathered layer with generally lateritic and moderately high resistivity topsoil

Dipole-Dipole Imaging

The 2-D resistivity structures (subsurface images) generated with dipole length of 5 m beneath all the traverses and most especially the constrained Traverses 3 and 4 show no discernible anomaly over the suspected tomb (Figures 7 and 9) and slag mound along the two traverses, respectively. This was suspected to be due to the large dipole length adopted. Both traverses were subsequently re-ran within the suspected anomalous zones with shorter dipole length of 2 m and optimum depth of investigation of 2.73 m based on Roy and Apparao, 1971 depth equation, for maximum expansion factor $n=5$ (Figures 8 and 10).

Figure 8 shows the short dipole length subsurface resistivity image beneath the suspected ancient tomb. The suspected centre of the tomb is located between Stations 12 and 13. The resistivity structure imaged the subsurface up to a depth of about 2.5 m. The suspected ancient tomb site is characterized by relatively high resistivity image, as expected. It shows that the feature is about 2 m (about 6.6 ft) deep which is typical of depth of graves in Yoruba land. It also shows that the tomb is about 18 m (59 ft) long. It is suspected that the tomb may have hosted a set of royal highnesses possibly buried with the palace attendants (the emewas) as was tradition in the ancient past.

The inverted resistivity structure along Traverse 4 (Figure 9) identifies three subsurface layers. The thin topsoil displays variable resistivity of less than 418 Ωm with yellowish brown to green color band. The weathered layer is characterized by relatively low resistivity of 13-180 Ωm with green/yellow color band. The basement bedrock third layer displays reddish

brown/purple color band with relatively high resistivity of between 418 and 1320 Ωm . The depth to the basement bedrock interface varies from < 2.5 m to > 5.0 m. The interface is uneven with relatively thick (>5.0 m) over burden between Stations 30-37 (see VES 6 in Figure 5) and between Stations 53 and 56.

Another archaeological feature—a slag mound was identified between Stations 46-47 of Figure 9. This feature shows no discernible resistivity image and hence could not be differentiated from the low resistivity weathered layer. This is suspected to be due to the near-surface nature of the feature which the relatively large dipole length (of 5 m) may not have been able to delineate. A dipole-dipole profiling with a dipole length of 2 m was carried out between Stations 41 and 51 (50 m) (Figure 9). Figure 10 (iii) displays the resistivity image beneath the suspected feature. The near surface suspected slag mound is characterized by relatively high resistivity and a depth extent of about 1 m. The high resistivity zone could be up to 26 m wide.

Resistivity Map

An apparent resistivity map was generated from the dipole-dipole data for expansion factor $n=1$, with dipole length of 5 m. (Figure 11). This is the resistivity map generated for theoretical depth values of 2.9 m, using Roy and Apparao, 1971 depth equation for dipole-dipole array. The resistivity map has contour pattern with alternating high and low resistivity closures elongated along a NNE-SSW direction. The most prominent high resistivity closure in reddish brown/yellow color is located on the western flank followed by a relatively low resistivity closure (in green/light green color) and another high resistivity closure flank by low resistivity zone.

The alternation of the high and low resistivity closures could be interpreted to indicate undulating bedrock topography with near-surface basement bedrock beneath the resistively high resistivity zone and deeper basement beneath the low resistivity zone. However a geoelectric section (C-D) constructed across these resistivity structures (see Figure 6) along Traverse 3 shows a relatively uniform overburden thickness and hence a relatively flat basement relief (noting that the surface topography of the survey site is flat).

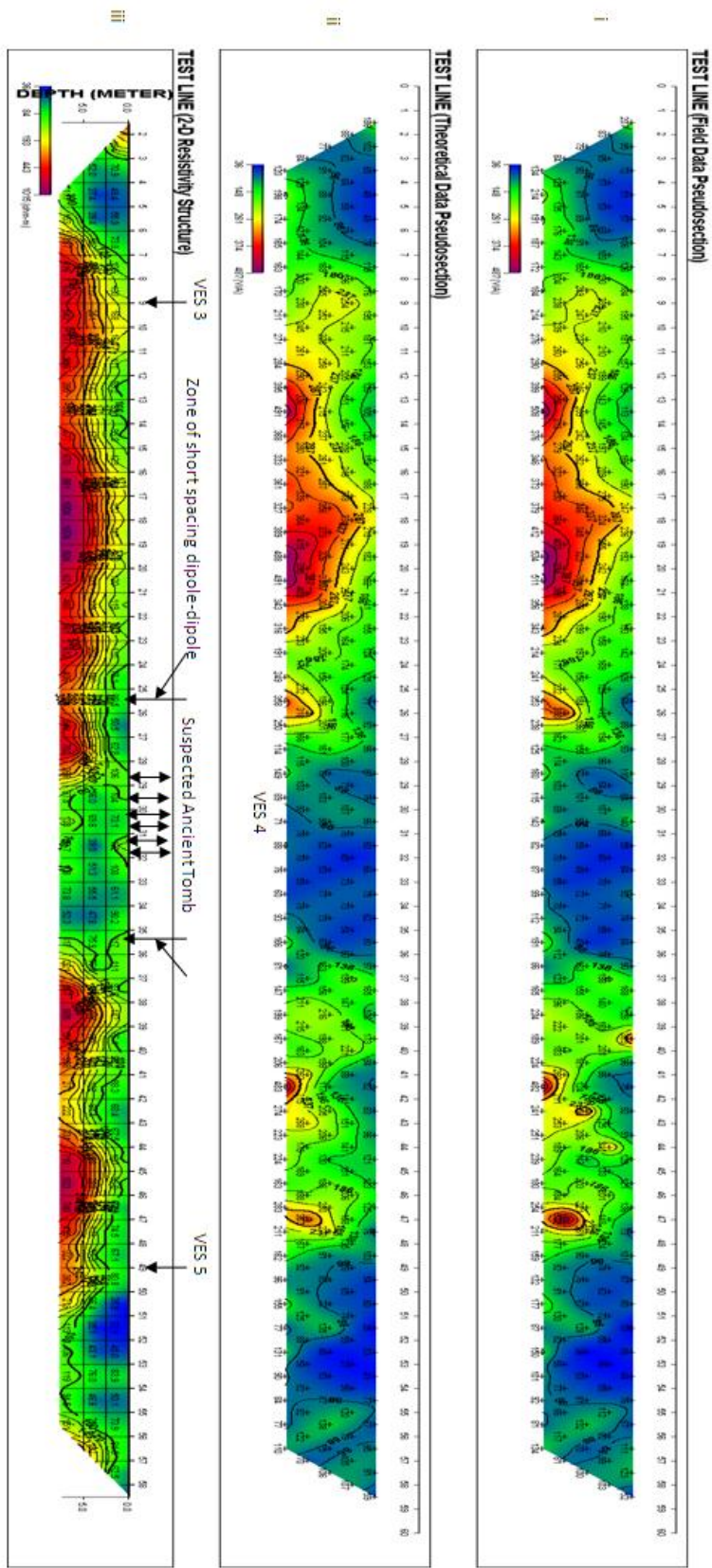


Figure 7: 2-D (i) Observed Pseudo-Section (ii) Theoretical Pseudo Section and (iii) Resistivity Structure along Traverse Three.

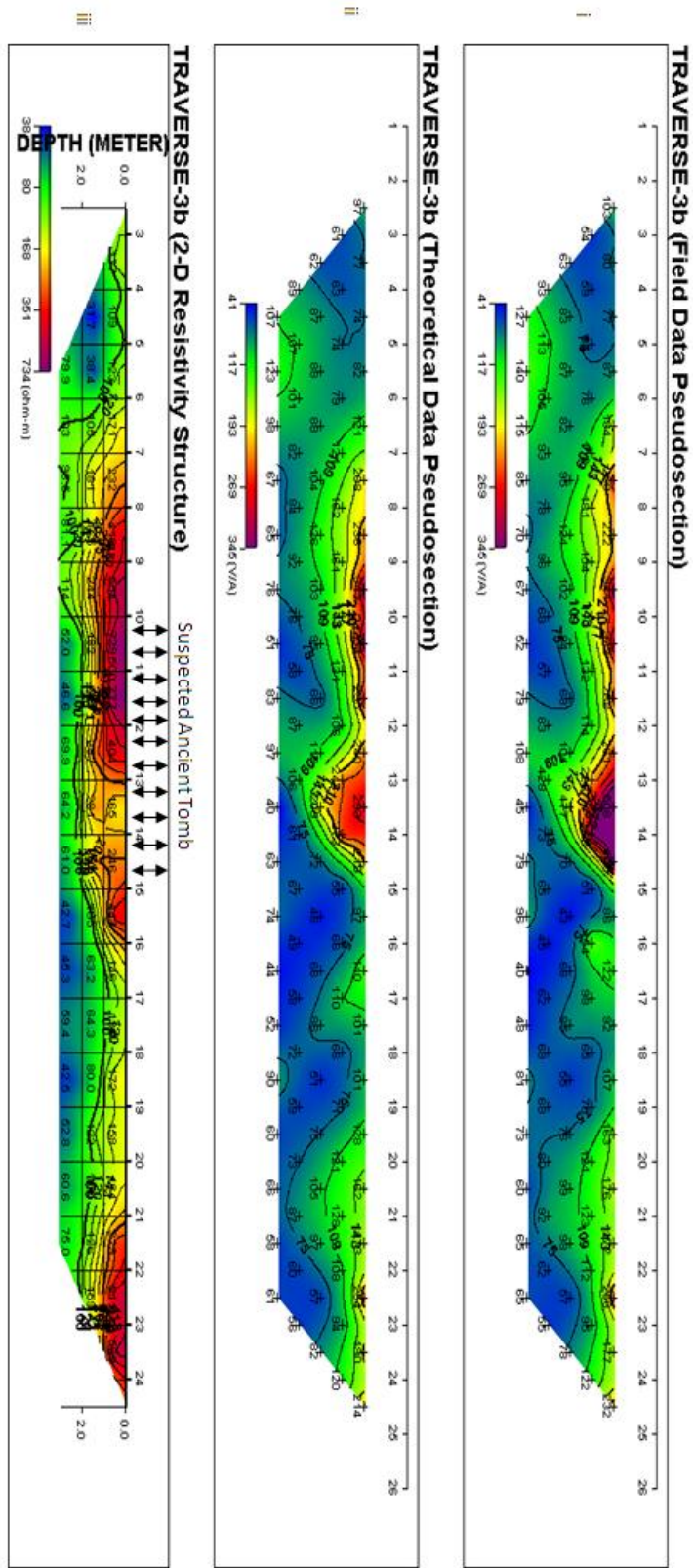


Figure 8: 2-D (i) Observed Pseudo-Section (ii) Theoretical Pseudo Section and (iii) Resistivity Structure along Traverse Three.

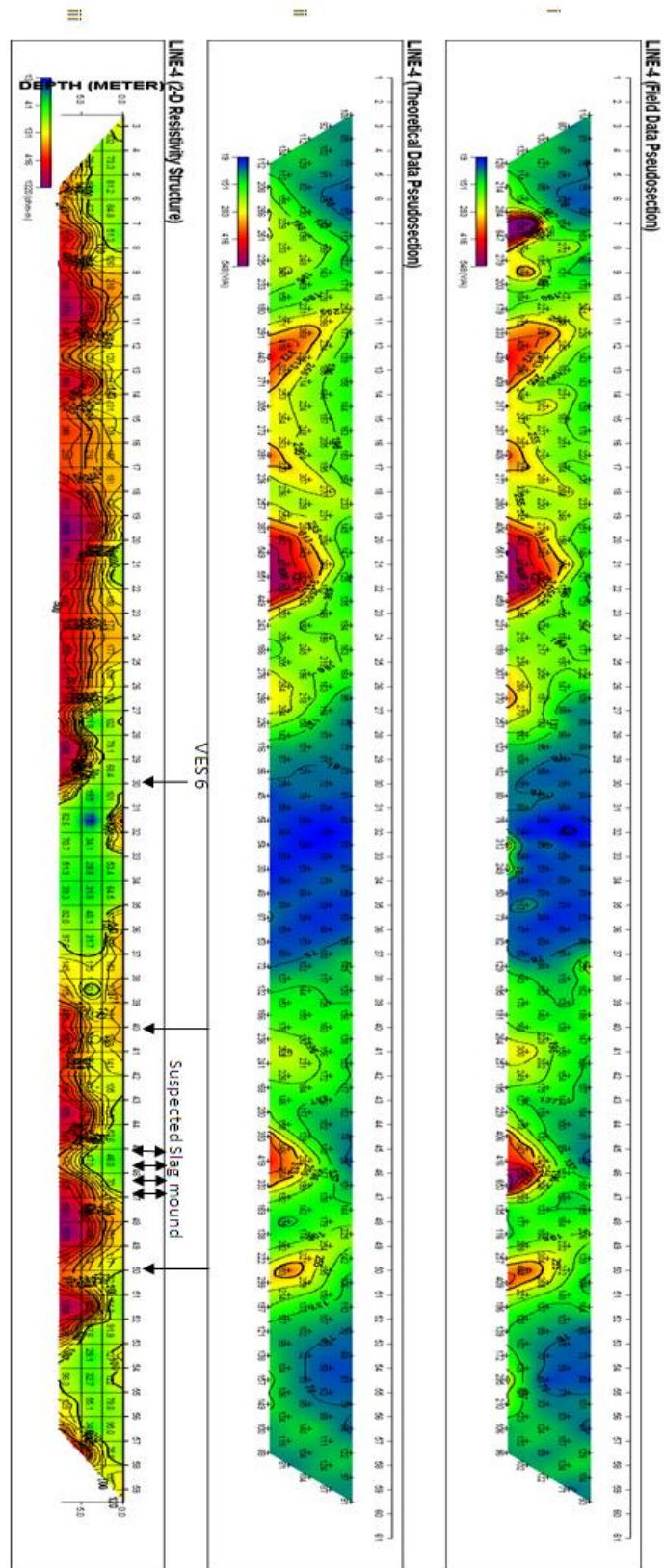


Figure 9:2-D (i) Observed Pseudo-Section (ii) Theoretical Pseudo Section and (iii) Resistivity Structure along Traverse Four.

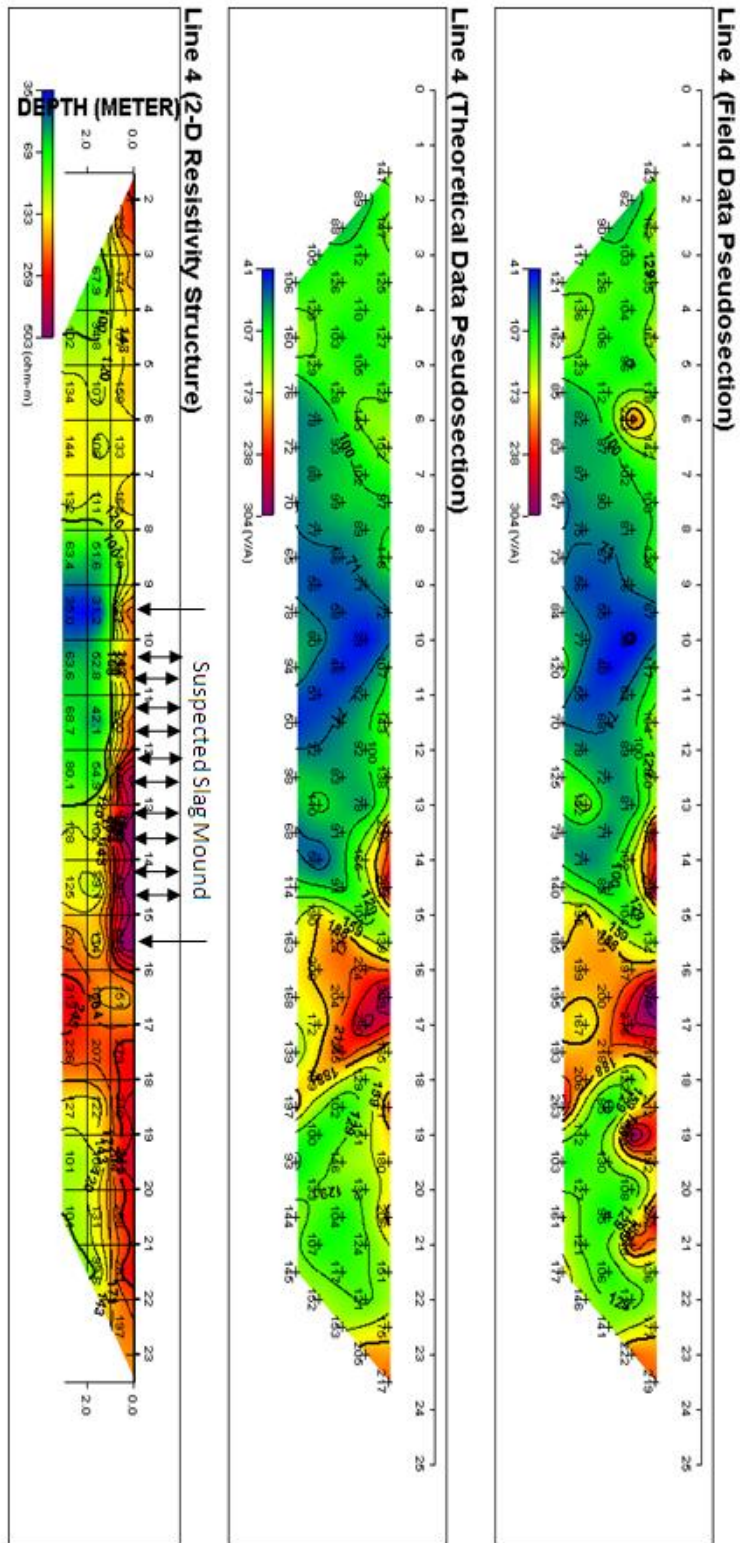


Figure 10: 2-D (i) Observed Pseudo-Section (ii) Theoretical Pseudo Section and (iii) Resistivity Structures along Traverse Four.

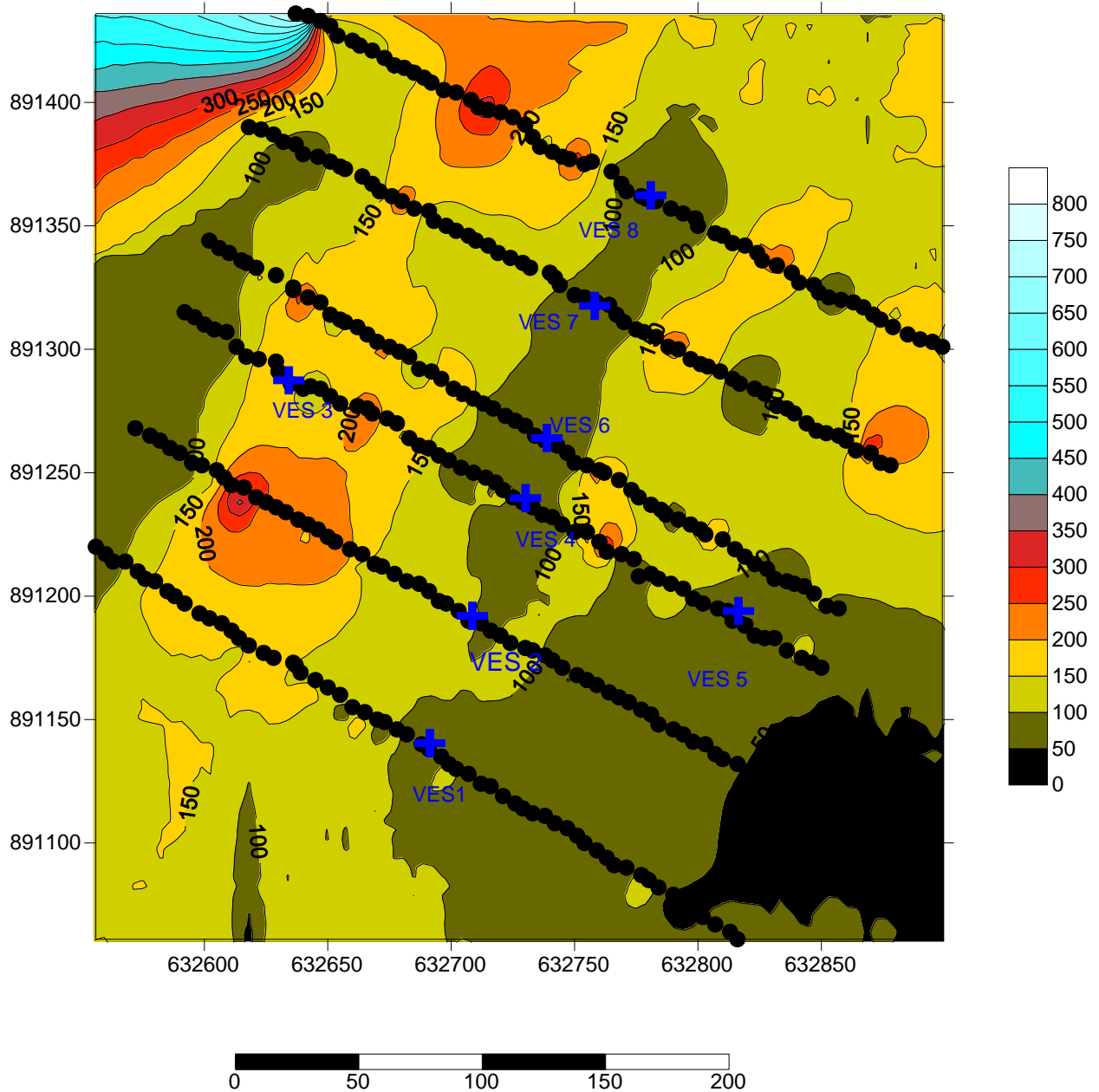


Figure 11: Electrical Resistivity Map for Expansion Factor $n=1$ at Theoretical Depth Level of 1.9 m.

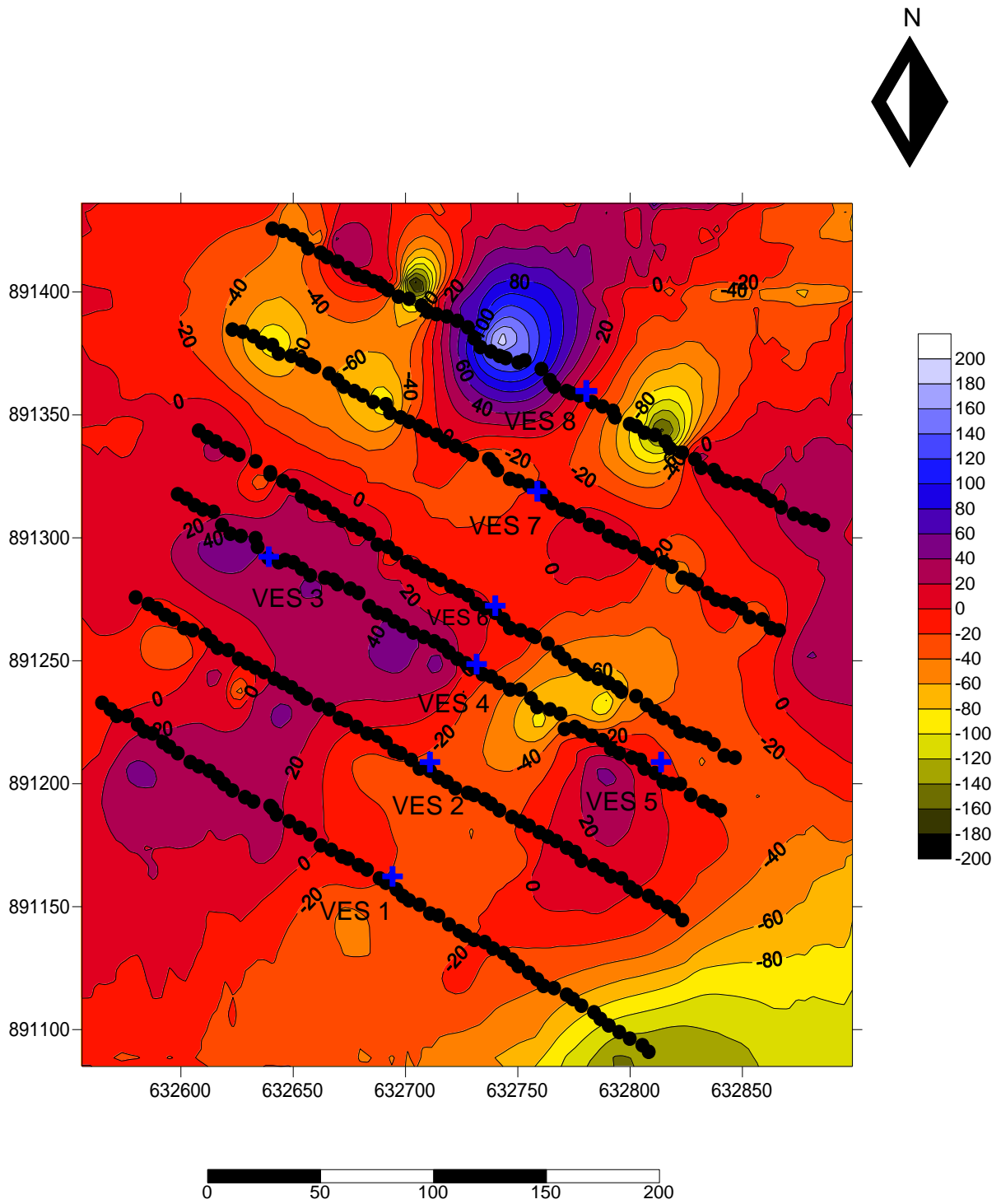


Figure 12: Residual Magnetic Anomaly Map of Orile-Oje Archaeological Site.

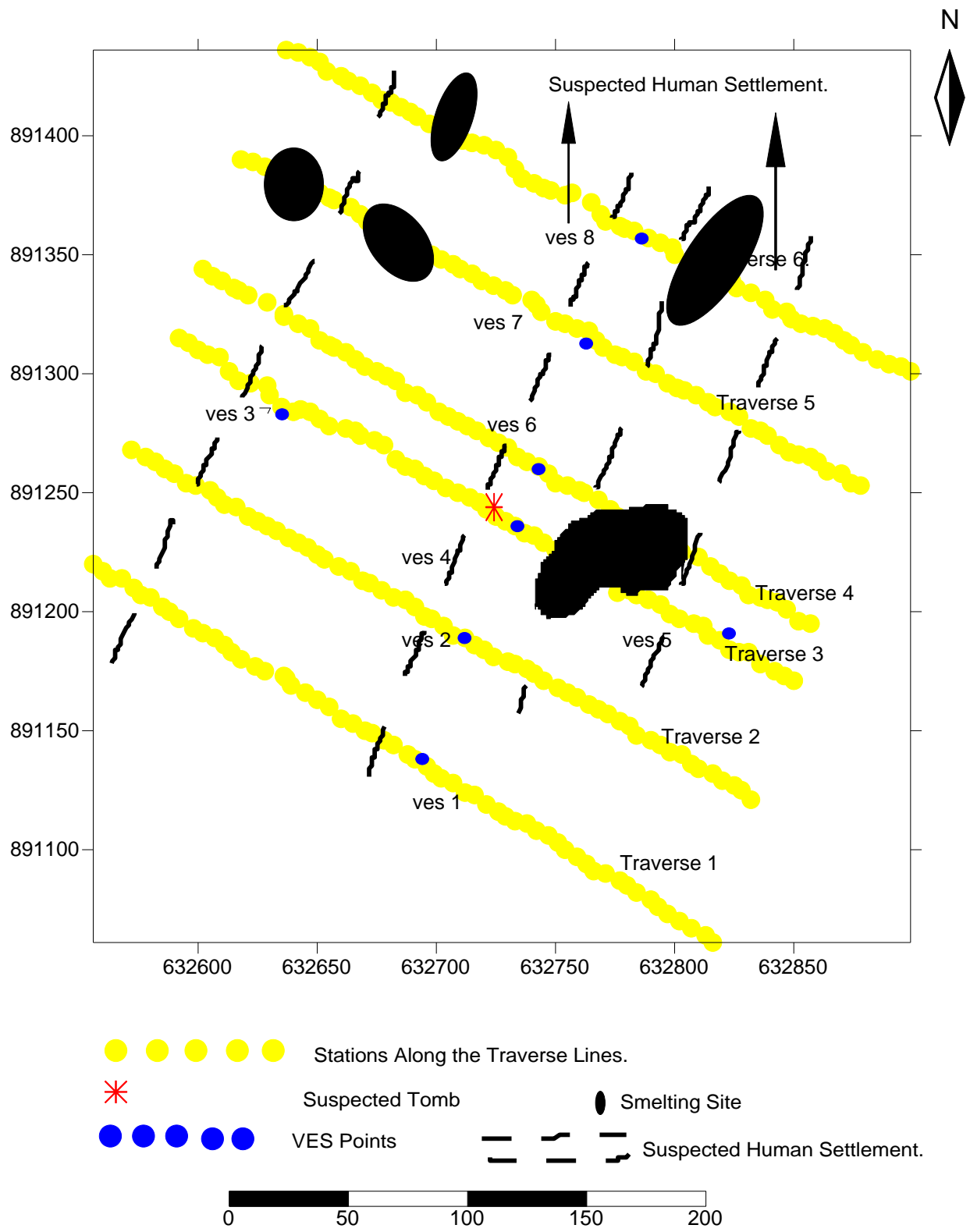


Figure 13: Archaeological Map of Orile-Oje Locality.

The resistivity distribution can therefore not be explained in terms of the basement bedrock relief. An alternative interpretation could be made in terms of human activities at the ancient site. An area subjected to human activities will experience relatively high degree of near and sub-soil compaction, lower porosity and consequently high resistivity. It is therefore suspected that the high resistivity closure may be indicative of human settlements.

The suspected ancient tomb is located on a relatively low resistivity closure zone while the slag mound is located on a resistivity high as observed on the 2-D vertical image (Figure 10).

The low resistivity closure obtained beneath the high resistivity suspected ancient tomb (Figure 8) may be due to the fact that the depth level (1.9 m) of the shallowest of the resistivity map (Figure 11) is virtually beneath the bottom of the suspected tomb and within the low resistivity weathered layer.

Magnetic Map

In a typical low magnetic latitude (close to the magnetic equator) like the Orile-Oje locality, a typical magnetic dyke-like body is characterized by a magnetic low (negative polarity) flanked on both side by low amplitude positive peaks. Such anomalous zones can be identified at the extreme north (NW and NE) and south central part.

The south central negative magnetic closure is located at the southeastern part of Traverses TR 3 and TR 4. This anomalous zone is located on the slag mound which was identified along Traverse 4 but which the magnetic map (Figure 12) shows extend to Traverse 3. The magnetic map also corroborates the 2-D resistivity image (Figure 10) which indicates that the slag mound is much wider than its surface expression and could be up to 25 m wide along Traverses 3 and 4. The anomalous zones along Traverses 5 and 6 may need to be pitted for verification. They could also be ancient smelting centers. Both the suspected human settlements and the ancient tomb do not give any discernible magnetic anomalies. This could mean that the caskets of the royal highnesses may not have been made of metallic objects.

Figure 13 shows the archaeological map of Orile-Oje developed from results of site inspection and geophysical investigation

CONCLUSIONS

The following conclusions can be drawn based on the interpretation results of the electrical resistivity and magnetic surveys of the Orile-Oje archaeological site:

(i) The suspected ancient tomb site is characterized by relatively high resistivity image and estimated depth extend of about 2 m (6.6 ft) and lateral extent of about 18 m. It is suspected that the tomb might have hosted sets of royal highnesses possibly buried with the palace attendants (the emewas).

(ii) A slag mound from a suspected ore smelting site along Traverse 4 was characterized by relatively high resistivity image and a depth and lateral extents of about 1 and 26 m respectively. The site is also characterized by a negative magnetic closure which extend to Traverse 3. Other similar magnetic anomalous zones suspected to be smelting site were also located along Traverses 5 and 6.

(iii) The site is characterized by alternating high and low resistivity contour pattern elongated along a NNE-SSW direction. The high resistivity zones are suspected to be ancient human settlements which could have been compacted by human activities leading to high resistivity. Two prominent suspected human settlements were delineated. The identified negative (low) magnetic closures are located within the identified human settlements. This may confirm that the low magnetic closures identified along Traverses 5 and 6 but without surface expression may actually be smelting sites.

REFERENCES

1. Afolabi, O.A., Abimbola, A.F., and Kolawole, L.L. 2001. "Preliminary Study of the Geology and Structural Trends of Ogbomoso Township, Southwest Nigeria. Science Focus". (In press).
2. De Young, S., Aaron, S., and Angela, H. 2000. "Applications of Field Geophysics within the Habitation Area of a Slave Village at Marshall's Pen, Mandeville, Jamaica."

www.keckgeology.org/files/pdf/Symvol/13th/Jamaica/deyoung_et_al.pdf

3. Di Maio, R., Fedi, M., Lamanna, M., Grimaldi, M., and Pappalardo, U. 2010. "The Contribution of Geophysical Prospecting in the Reconstruction of the Buried Ancient Environment of the House and Marcus Fasius Rufus (Pompeii, Italy)". *Archaeological Prospection*. 17(4):259-775.
4. Gbadegesin, A. and Akinbola, G.E. 1995. "Reference Soil of the Southern Guinea Savanna of Southwestern Nigeria (Oyo State)". Soil Brief Nigeria, 7, University of Ibadan and ISRIC, Wageningen. pp13.
5. Geoffrey, J. 2008. "Geophysical Mapping of Historic Cemeteries". *Technical Briefs in Historical Archaeology*. 3:25-38.
6. Krivanek, R. 2004. "Geophysical Survey in the Archaeologically Uninvestigated Part of Czech Opidda". *Antiquity*. 78(302).
7. Lynford, N. and Payne, A. 1991. "Report on Geophysical Survey Ancient Monuments". Laboratory Report Number: 118/93.
8. Ogunfolakan, A. 1994. "Archaeological Survey of Osun North East of Osun State, Nigeria". M.Sc. Thesis, University of Ibadan, Ibadan, Nigeria.
9. Ogunfolakan, A., Tubosun, B., and Aleru, J.O. 2006. "Archeological Survey of Igbo Oje near Ogbomoso, Oyo State, Nigeria; A Preliminary Report". *Nyame Akuma*. 65:47-55.
10. Roy, A. and Apparao, A. 1971. "Depth of Investigation in Direct Current Resistivity Prospecting". *Geophysics*. 36:943-959.
11. Urbini, S., Bonini, D., Cafarella, L., Chiavucci, P. and Marchetti, M. 2007. "Fast Geophysical Prospecting Applied to Archaeology Results at (Villa Ai Cavallacci) (Albino Laziale, Rome) Site". www.annalsofgeophysics.eu/index.php/annals/articles/view/4430
12. William, J., Johnson, P.G., and Donald, W.J. 2006. "Application of Geophysics to North American Prehistoric Sites". *European Association of Geophysicists*. 24:97-102.

ABOUT THE AUTHORS

Eluyemi, A.A., is a Junior Research Fellow at Centre For Energy Research and Development, Obafemi Awolowo University Ile-Ife. He is preparing for his Ph.D. program.

Martins O. Olorunfemi, is a Professor of Applied Geophysics in the Department of Geology, Obafemi Awolowo University, Ile-Ife. He holds a Ph.D. degree in Geological Sciences (Applied Geophysics) of the University of Birmingham, England. He researches in groundwater, environmental, mineral and engineering geophysics.

Adisa, A., is a Historical Archaeologist. He researches in Yoruba Urban Archaeology focusing on war, conflicts and displacement. He is currently the Director, Natural History Museum, Obafemi Awolowo University, Ile-Ife, Nigeria.

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