Application of Geophysical and Geotechnical Methods to Determine the Geotechnical Characteristics of a Reclaimed Land*

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Abstract

Near-surface seismic refraction method and electrical resistivity methods were used to characterize the subsurface of a site reclaimed from water bodies, in order to determine the depth to the most competent layer for construction purposes. Nine seismic refraction profiles were surveyed and the data was interpreted using SeisImager software package. Also, twelve vertical electrical soundings were carried out and the acquired data was interpreted using WinResist computer package. The seismic refraction method delineated three layers while the electrical resistivity method revealed between four and five geoelectric layers. The result of the seismic refraction method showed that the third layer is the most competent layer having the highest elastic moduli. Furthermore, the resistivity method revealed that the third geoelectric layer is the most competent having resistivity ranging between 23.3 and 1107.2 Ωm. It was also discovered that the depth to the most competent layer is between 7 m and 18 m in the subsurface. It was concluded that piling will be the most appropriate foundation for any building in the study area.

Introduction

The rising number of casualties reported as a result of building collapse has necessitated that all measures must be employed to ascertain the safety of man and his property. Often times when a building collapses various factors are considered as the cause, such as the sub-standard nature of the building materials, age of the building, lack of experience of the contractors among others. The factor least considered as the cause of building failure is the condition of the soil layer on which the building is placed (Hunt, 2005; Oyedele and Okoh, 2011). Land reclaimed from water bodies are known to contain certain geological formations which are mechanically unstable and as a result can result in building failures if engineering structures are sited on it (Ayolabi et al., 2012). This is because these areas are composed of impermeable soil layers such as clay or peat and as a result, they are naturally flooded.

In order to ensure a proper foundation system for buildings within this type of area, adequate information about the subsurface is necessary. At this point, a comprehensive subsurface investigation can be planned and this will require adequate geophysical and geotechnical methods (Hunt, 2005). As a result, our predictions for a given location must be based on identification of the local geology, interpretation of the land forms of the area, and the application of the characteristics of the various soil deposits and rock formations. Geophysical techniques study the contrast in the physical properties of the different units in the subsurface such as velocity, electrical resistivity, (conductivity), acoustic properties, subsurface geology, and the environmental conditions (Akintoriwa and Adesoji, 2009; Coker et al., 2013) and they can provide some of the information required to delineate those materials in the subsurface space such as the overburden thickness, horizontal and vertical lithologic extents, depth to water table, fault zones (Oyedele and Olorode, 2010).

Geotechnical investigations are carried out as a ground truthing investigation to assist in accurate interpretation of geophysical data. It is often done by using intrusive methods which normally extend to a total depth of less than several hundred feet or more where necessary. The most widely used geotechnical investigation methods are the light cable percussion boring test, static and dynamic penetration tests are the cone penetration test (CPT) and the standard penetration test (SPT) (Baldi et al., 1995; Akintorinwa and Adesoji, 2009). The present study is aimed at determining the geotechnical characteristics of the subsurface soil in the study area, using both electrical resistivity and seismic refraction methods in order to determine its competence for construction purposes.

Geology and Location of the Study Area

The site investigated is within the Eti-Osa local government area of Lagos State, southwestern Nigeria (Figure 1). The area is a gentle sloping, low-lying elevation with respect to the sea level. The site is wholly on land and flooded at the time of investigation. The Site is waterlogged due to water-in-flow from the lagoon. The site is bounded by the Lagoon at the rear. The entire neighbourhood is mostly undergoing rapid development. The Nigeria coastal zone lies within the tropical climate area which has two seasons: the rainy season and the dry season. The rainy season is usually between April and November, while the dry season is between December and March (Akintorinwa and Adesoji, 2009). The area is located between latitude 6° 26'N and 6° 32'N and Longitude 3° 35'E and 3° 45'E. The area lies within the alluvial deposits of southwestern Nigeria basin, which is an integral part of the Dahomeyan Embayment (Figure 2).

Materials and Methods

Electrical resistivity Method

In this study, an ABEM Terrameter (SAS 1000/4000 model) was used for the electrical resistivity study with electrode spread varying between 1-260 m where there were no constraints. Twelve (12) Vertical electrical soundings were carried out using Schlumberger array configuration. The VES data obtained were analysed by plotting the apparent resistivity values against the half current electrode spacing (AB/2) on a log-log graph. The plots were then compared to standard curves or models to determine the number of layers, the layer thicknesses, depths and their true resistvities. A computer iterative software WinResist was used for their interpretation. This method was used to obtain information on the lithology of the area of study and their geoelectric parameters such as the thickness of each layer and layer resistivity.

Seismic Refraction Method

Seismic refraction was carried out in the study area, using a 24-Channel ABEM Terraloc Mark 6 seismogram. The seismic refraction was carried out along the traverses marked out for the resistivity method to allow for easy comparison of the results obtained by the two methods. The energy source used was a 15 kg hammer and geophone spacing of 2 m was used. Shots were carried out at the following points: at the offset distance which is 2 m to the first geophone, between the 6th and 7th geophones, between the 12th and 13th geophones, between the 18th and 19th geophones, and 2 m after the 24th geophones which are termed the offset, quarter spread, mid-spread, three quarter spread, and off-end shots respectively. The purpose of these multiple shots along a traverse is to obtain adequate coverage of the refractor surface and to provide adequate lateral resolution (Reynolds, 1998). The seismic waves generated by this shot travelled down and along different refractor boundaries, only the refracted energies are detected by the geophones (Abidin et al., 2012). The seismic data acquired were interpreted using SeisImager software. The essence of employing this method is to obtain information on the depth to the most competent layer in the subsurface and to determine the strength and competence of each subsurface layer for construction purposes.

Results and Discussion/Conclusion

The results showed that the subsurface is heterogeneous all through the study area. The electrical resistivity methods revealed four to five geoelectric layers in the study area and their lithologies are: loose dry sand, wet sand, sandy clay, sand, and clay/peat. These geomaterials preferred for construction purposes are sand and sandy clay because of their high shear strength and low compressibility potential. These geologic formation were found at a depth range of about 3 m – 20 m across the study area. Different curve types were obtained which ranges from HK, KQ, QH, KH, AK, K, HA, KQH, and KHK (Figure 3). The curve type characterises an area dominated with water retaining geomaterials (Adepelumi et al., 2009).

The seismic refraction method delineated three layers at the study site (Figure 4). The values of the p-wave velocity for each layer was used to determine all the elastic parameters. The first layer is dry soil, while the second layer is saturated, and the third layer contained some impermeable materials which are suspected to be stiff clay as depicted from the geology of the study area. This may be the reason the study area is always logged with water and it takes a long time for it to drain. The third layer all across the study area is the most competent because it has the highest density, which ranges between 1.8367 kg/m^3 and 2.3559 kg/m^3. Also, this layer has the highest Young's modulus ranging between 1.42 GPa and 25.30 GPa. Obviously, the third layer is stronger than the first two layers. Furthermore, the bulk modulus of the third layer lies in the range of 0.99 GPa and 15.94 GPa. The shear modulus also ranges between 0.57 GPa and 10.24 GPa. The Poisson's ratio for the third layer is 0.23 with an error margin of $\pm 0.12 \times 10^{-4}$. This showed that the geomaterials possess the tendency of compressibility. From the above, it was discovered that the most competent layer lies between the depth of 7 m and 18 m.

Geophysical investigations were carried at the study site in order to determine the geotechnical characteristics of the subsurface for construction purposes. The electrical resistivity method revealed that the materials with good geotechnical properties lies between the third and the fourth layers. The seismic refraction result obtained showed that the depth to the most competent layer lies between 7 m and 18. There is an agreement between the results of the electrical resistivity and seismic refraction survey. Therefore, some form of arrangement must be made to

transfer the weight of the building on the surface to the most competent layer at the subsurface. Otherwise, any civil engineering construction at the surface will sink and eventually collapse if proper pile foundation is not done.

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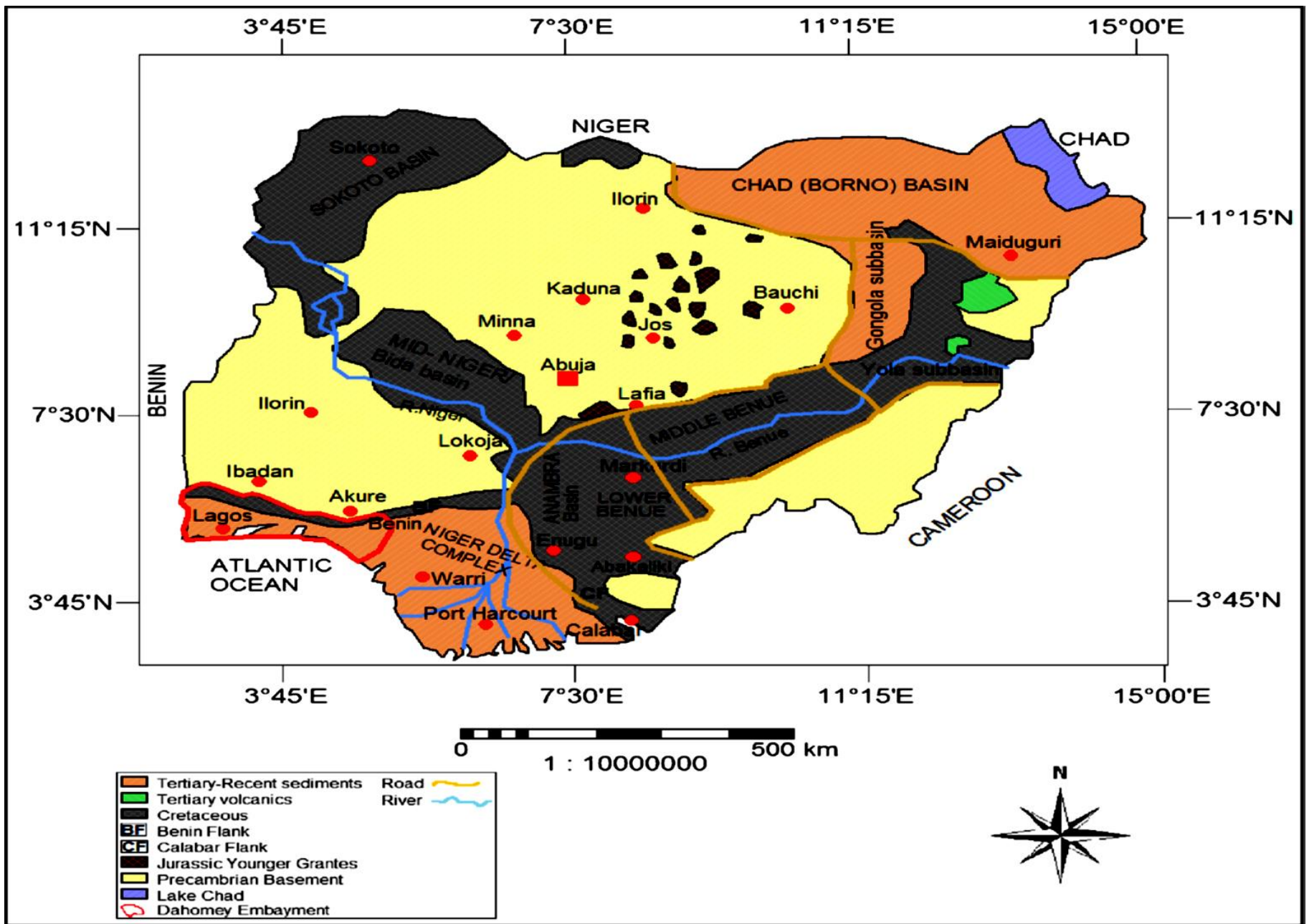
WinResist, 2004, WinResist Version 1.0.

Figure 1. A sketch of the geological map of Nigeria.

OYO   STATE

REPUBLIC OF BENIN

Study area
Recent Alluvium
Coastal plain sands
Oshosun formation
Ilaro formation
Ewekoro formation
Abeokuta formation
Basement complex

N

LAGOS   STATE
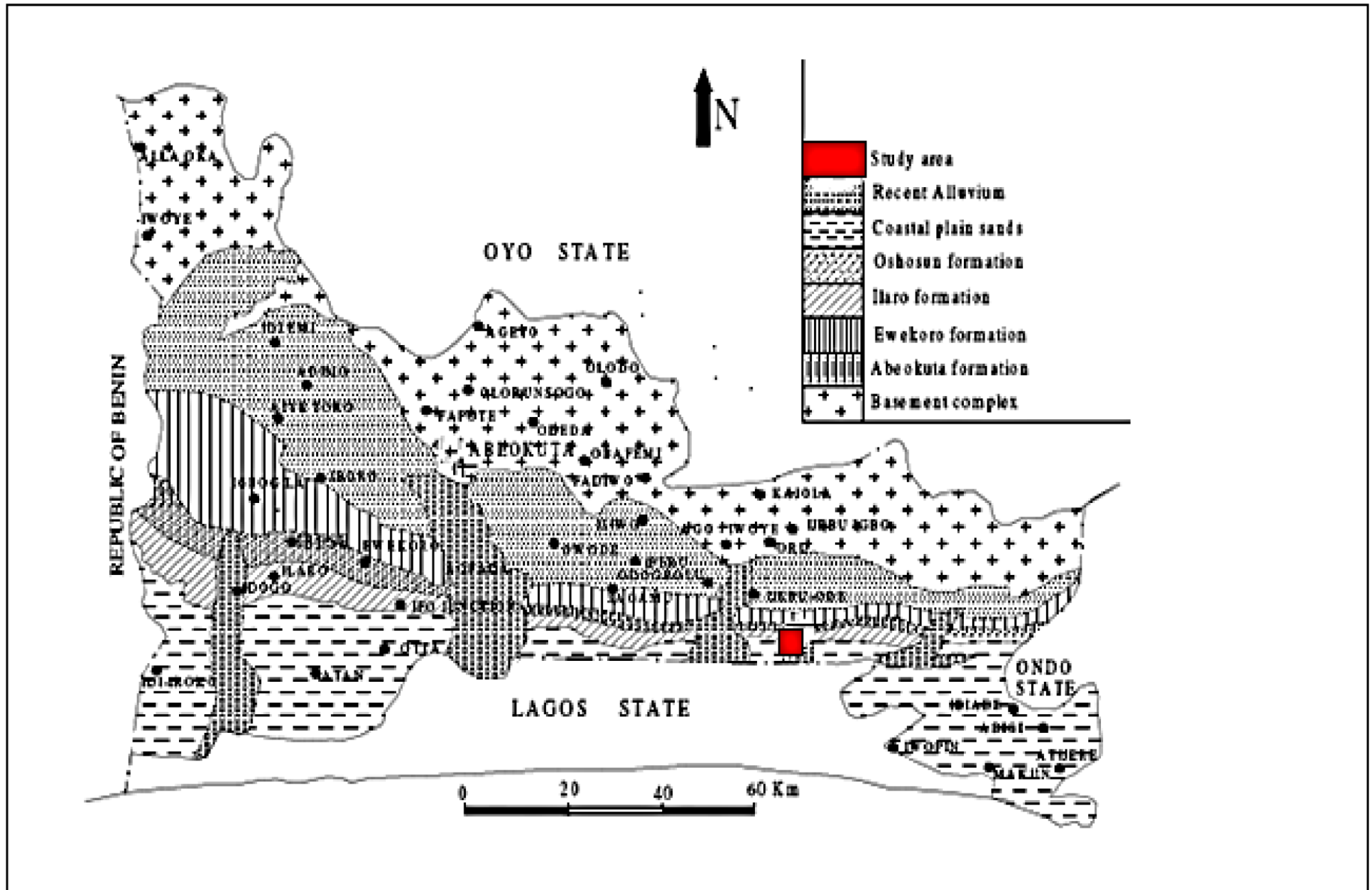
ONDO STATE

0   20   40   60 Km

Figure 2. Geological map of the Nigerian part of the Dahomey Basin. (Modified after Badmus and Olatinsu, 2009).
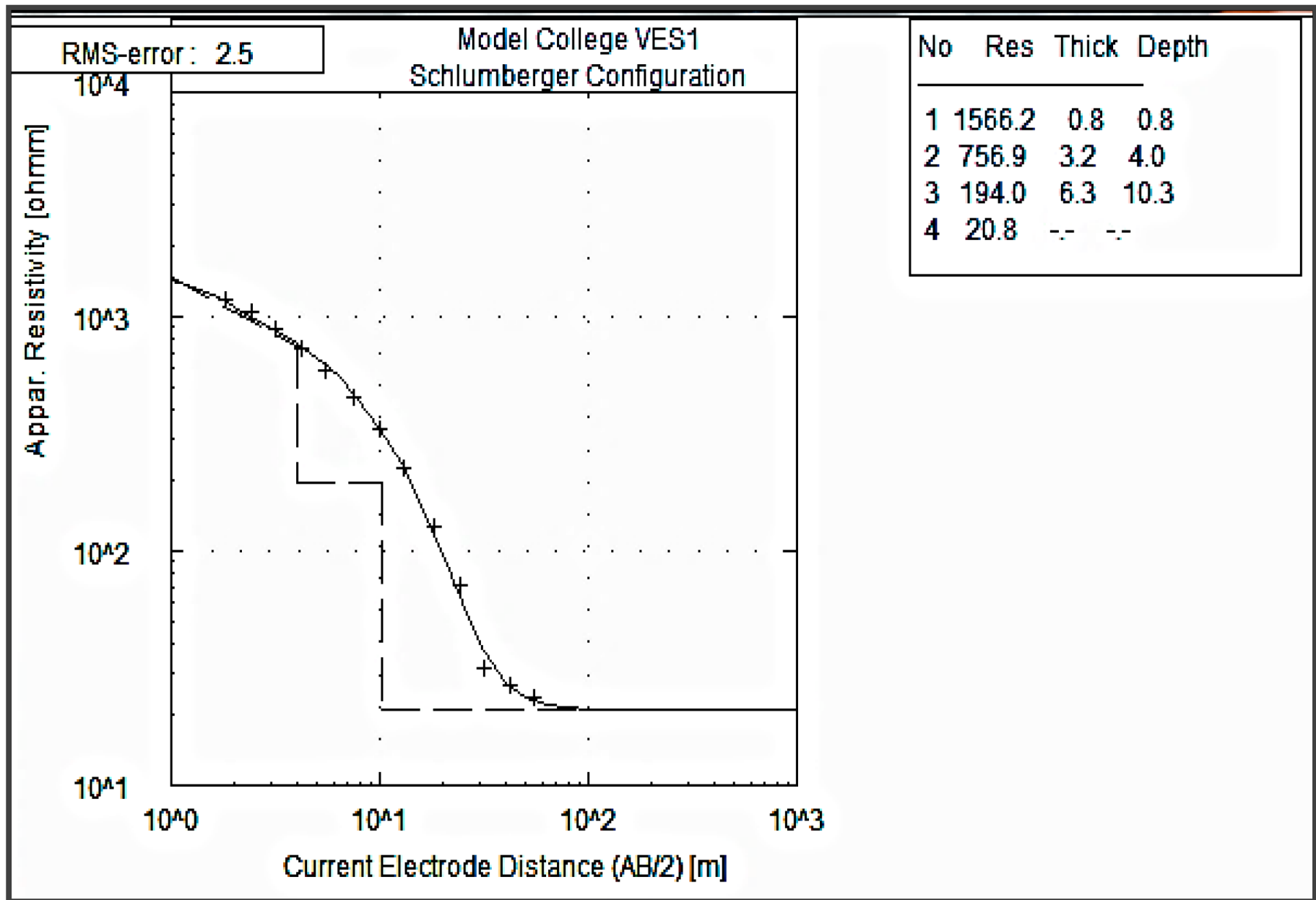
Figure 3. Sounding curve and geoelectric parameters for VES 1.
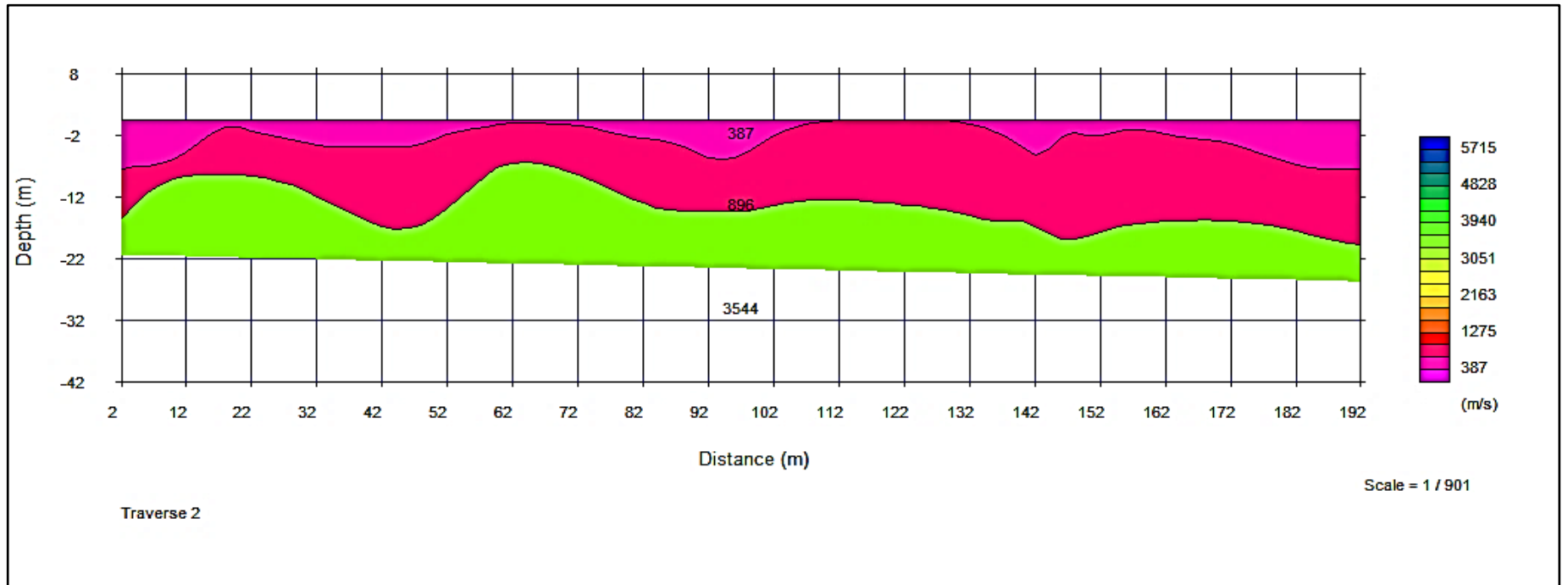
Figure 4. 2D seismic refraction sections indicating the number of layers, their velocities, and the depth of investigation for Traverse 1.