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Electrical Resistivity and Seismic Refraction Methods of Investigating a Landslide Area: A Case Study of Elu Community, Abia State, Nigeria

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ABSTRACT

This study was carried out to investigate the subsurface structure in a landslide area in a community in Ohafia Abia State, using geophysical data obtained from the subsurface formation of the area. A total of seven stations comprising of three vertical electrical sounding (VES) using Schlumberger electrode configuration and four electrical resistivity profiling (2D) using Wenner array configuration were occupied. Resistivity data were acquired using the Abem terrameter (AGI single R8). The data were smoothened and analyzed using Schlumberger computer automatic iterative software. In the same line seismic critically refracted data were acquired using 12-channel ABEM Terraloc MK III digital seismometer and processed with the Reflexw software into 2D velocity depth models. A two-layer model was delineated by the velocity profile with a range of 338 m/s and 4356 m/s for the entire depth of probe. Results of resistivity model show 6 constrained geo-electric layers covering a total depth of 55.0 m with low resistivity values for the top soil. Increase in resistivity with depth observed in the study indicates increase in compaction and solidification with depth in the subsurface as layers alternates. The resistivity of most of the formation layers are averagely high suggesting a high degree of void spaces inside the rock material. This might have resulted from high erosional activities in the area that gave rise to landslides. Also, the formation lithology for the area is mainly sand/sandstone from the top soil to the survey depth, suggesting non protective or absence of highly compacted clay materials that are more resistant to erosion associated with heavy rainfall in the area.

***Keywords*:** Landslide, Electrical resistivity, Layers, seismic velocity, Elu

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1. INTRODUCTION

Geophysical methods of investigation involves the measurement of fields associated with changes in physical properties; density, magnetic susceptibility, electrical conductivity, elasticity, and radioactivity in the near-surface and subsurface of the earth. Changes in physical properties, both in vertical and lateral direction may indicate discontinuities, or anomalies in subsurface materials that govern failure processes. Geophysical properties like electrical resistivity and seismic velocity are affected by geologic formation, degree of fracture, weathering and soil water content. Geophysical methods have been widely applied in the search for hydrocarbon, mineral, and ground water exploration, glacier, and landslide studies, engineering site investigations, even in environmental studies for mapping variation in pore-fluid conductivity to indicate pollution plumes within ground water (Reynolds, 1997).

The electrical resistivity method employs an artificial source of current introduced into the ground through a pair of electrodes and the measurement of potential difference between other two electrodes in the vicinity of current flow. Oladele et al. (2015) used electrical resistivity profiling (2-D) using Wenner array method on five profiles of length 180m each to characterize the shallow subsurface electrical properties. The survey which was aimed delineating features that gave rise to structural instability which led to the cracking and sinking of some buildings in the area revealed the presence of anomalous low resistivity, interpreted as clayey materials in the stratigraphic setup. Another study carried out at Obot Ekpo South-South Nigeria, shows that subsurface electrical resistivity tomography can be applied in various forms of environmental, geotechnical, geological, seismic tectonic and hydrogeological studies since resistivity of subsurface materials depend on various geological parameters (Lapenna et al., 2003; Drahor et al., 2006; Grandjean et al., 2006; Akpan et al., 2009; 2013; Heincke et al., 2010; Arango-Galvánet al., 2011; Chambers et al., 2011; Okoyeh et al., 2013).

This study utilizes electrical resistivity and seismic refraction methods to evaluate the subsurface geology of Elu Community in Abia State Nigeria which has recently been engulfed with landslides (Fig. 1) that was attributed to heavy rainfall. The approach adopted is to characterize the shallow subsurface material electrical properties and strength that may have led to landslide in the area.

2. GEOLOGIC SETTING OF THE AREA

Ohafia Local Government Area is located in Abia State, Nigeria; the region shares common boundaries with Bende Local Government area, Afikpo South Local Government Area, Arochukwu Local Government Area and Cross River State. The Ohafia region is found within latitudes 5º30’ and 5º45’ North and Longitudes 7º45’ to 7º55’ East (Fig. 2). Average annual rainfall of the area varies from 2000 mm to 2400 mm, with maximum peaks in the months of July and September. Relative humidity is over 70% within the Area (John et al., 2015).

In the general stratigraphic section of South-Eastern Nigeria, Ohafia region is situated in the Ajali Sandstone which is part of the Anambra Basin. The fluvio-deltaic sandstones of the Ajali and Owelli Formations constitute lateral equivalents that lie on the Mamu Formation. Enugu and the Nkporo shales represent the brackish marsh and fossiliferous pro-delta facies of the Late Campanian-Early Maastrichtian depositional cycle (Reijers and Nwajide, 1997; Obaje, 2009).

Fig. 1. Some landslide sites in the Study Area

The Ajali Formation consists of alternating sandstones, shale, sandy shale and grey mudstones at various horizons, the beddings usually irregular especially where sandstones and shale alternate in about equal proportions. The break from loamy soil to sandy soil is very easy once deforestation takes place; soils deprived of their vegetative cover are very susceptible to erosion. According to Awalla and Ezeh (2004) the Ajali sandstone is a major clastic formation of campanian-Maastrichian age in Anambra Basin, southern Nigeria. The sandstones have a high incidence of quartz and feldspar pebbles.

Fig. 2. Map of the Study Area

3. MATERIALS AND METHODS

The geophysical method of investigation applied in this study is the 2D electrical resistivity imaging technology which is a combination of Vertical electrical sounding using the Schlumberger and resistivity profile measurements using Wenner arrays techniques. It has been used to identify the discontinuity between landslides material and bedrock (Jongmans and Garambois, 2017).

Four sounding stations were occupied and resistivity data were acquired using the Abem Terrameter (AGI single R8) and other accessories. In this configuration, current (I) is fed into the ground using two current electrodes A and B placed at a maximum spread of 200 m and the resultant medium resistance were measured between two potential electrodes M and N placed at a fixed distance until the voltage reading became too low.

The resistivity of the soil surrounding the current electrodes were obtained and the apparent resistivity and thickness of the various geo-electric layers were then estimated using Advanced Geosciences Incorporation (AGI) computer iterative EarthImager 2D software and Schlumberger analysis version. This involves inversion of direct current resistivity field data to produce the electrical resistivity distribution of the formation under the survey line. The horizontal and vertical subsurface cross sections from the 2D inversion of resistivity data is shown in Figures 3 – 5 and Table 1.

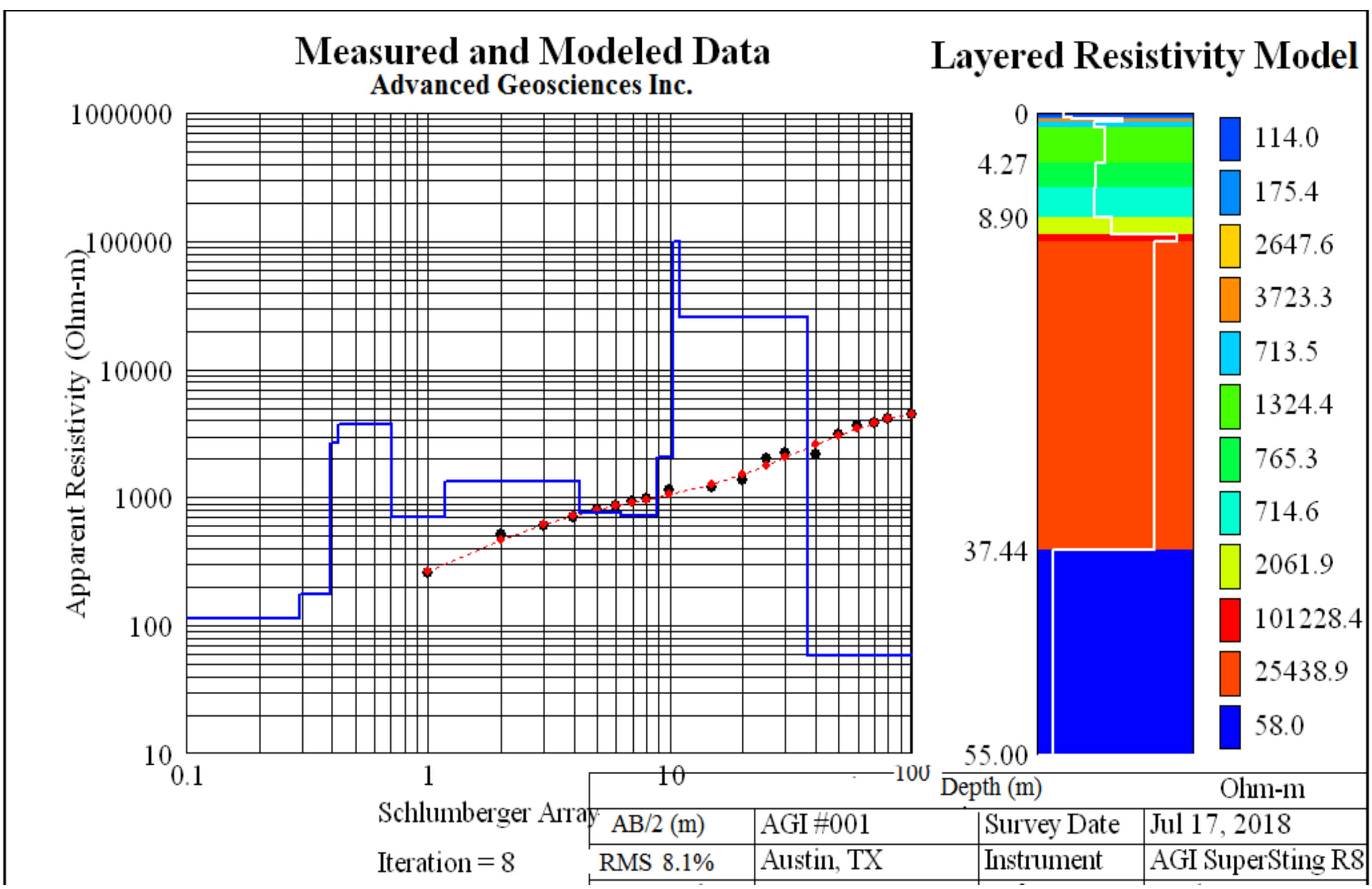

Fig. 3. Geoelctric model layers of Profile 1.

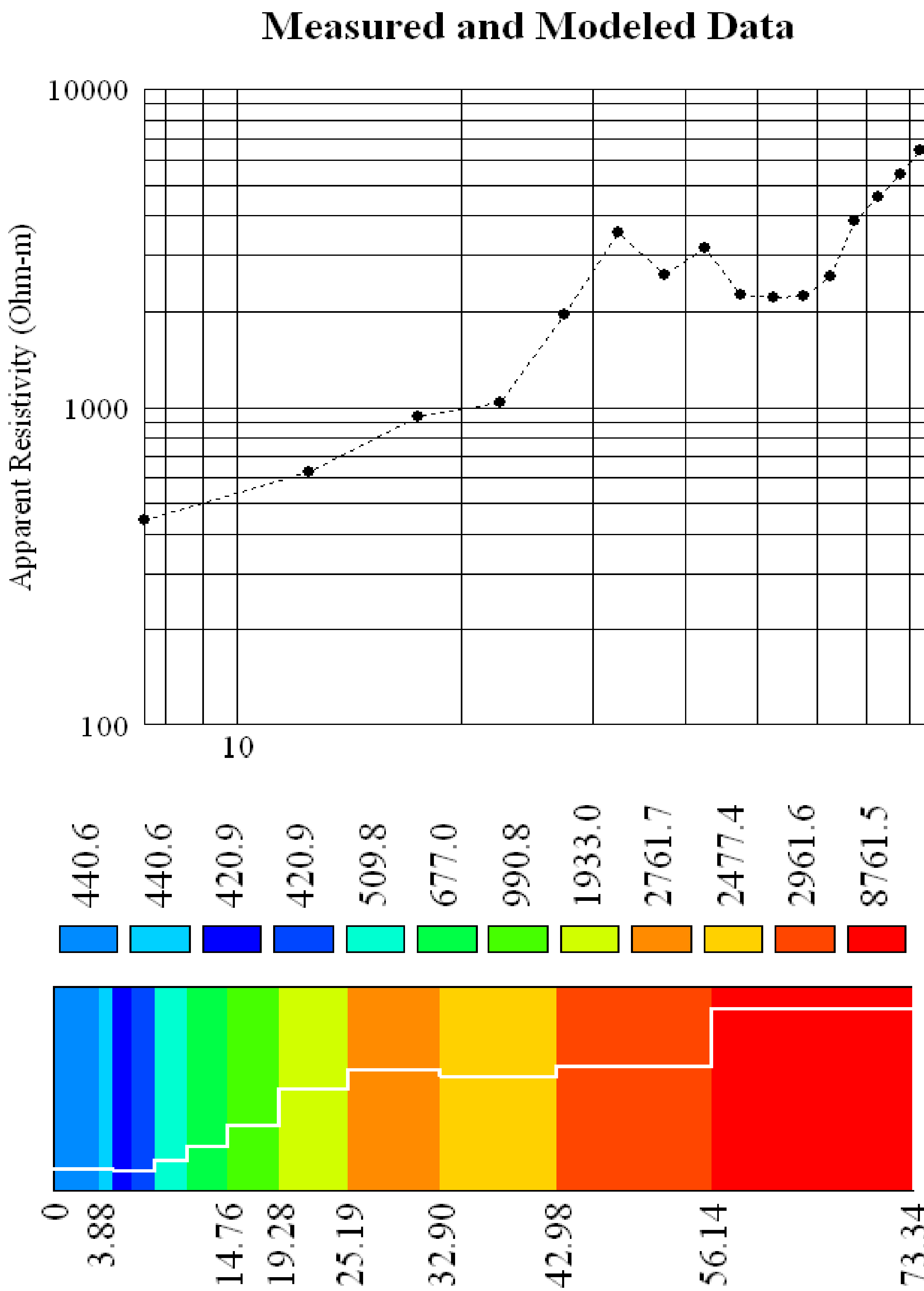

Fig. 4. Wenner Array Modeled data for Profile 1.

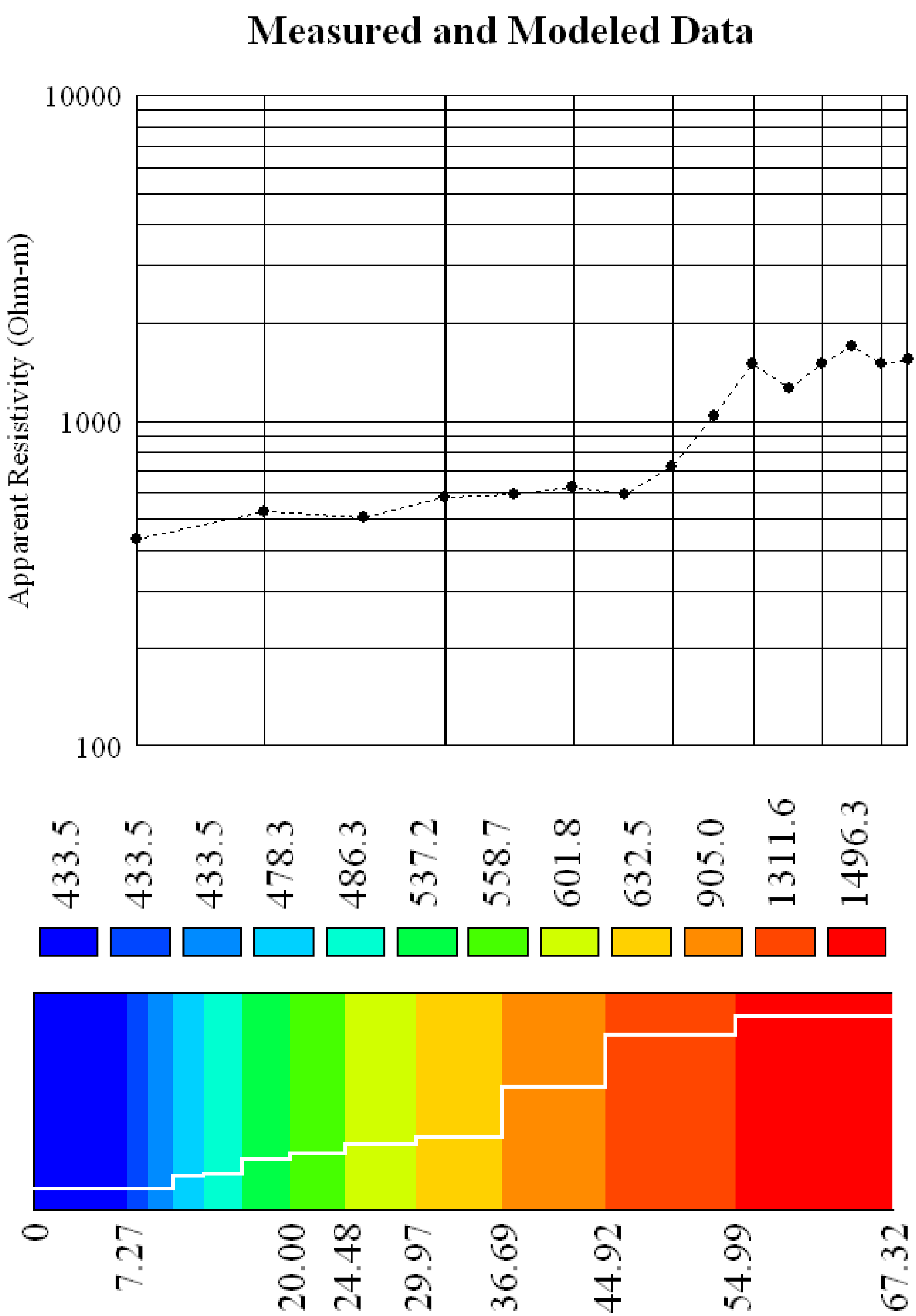

Fig. 5. Wenner Array Modeled data for Profile 2.

Table 1. Lithology of Profile-1 constrained from Geo-electric data

Layers	Apparent resistivity (Ωm)	Bottom depth (m)	Inferred Lithology
1	713.50	1.170	Topsoil
2	1324.35	4.270	Conglomerate
3	714.57	8.902	Sandstone
4	101228.36	10.952	Sandstone
5	25438.90	37.442	Conglomerate
6	58.00	∞	Indefinable

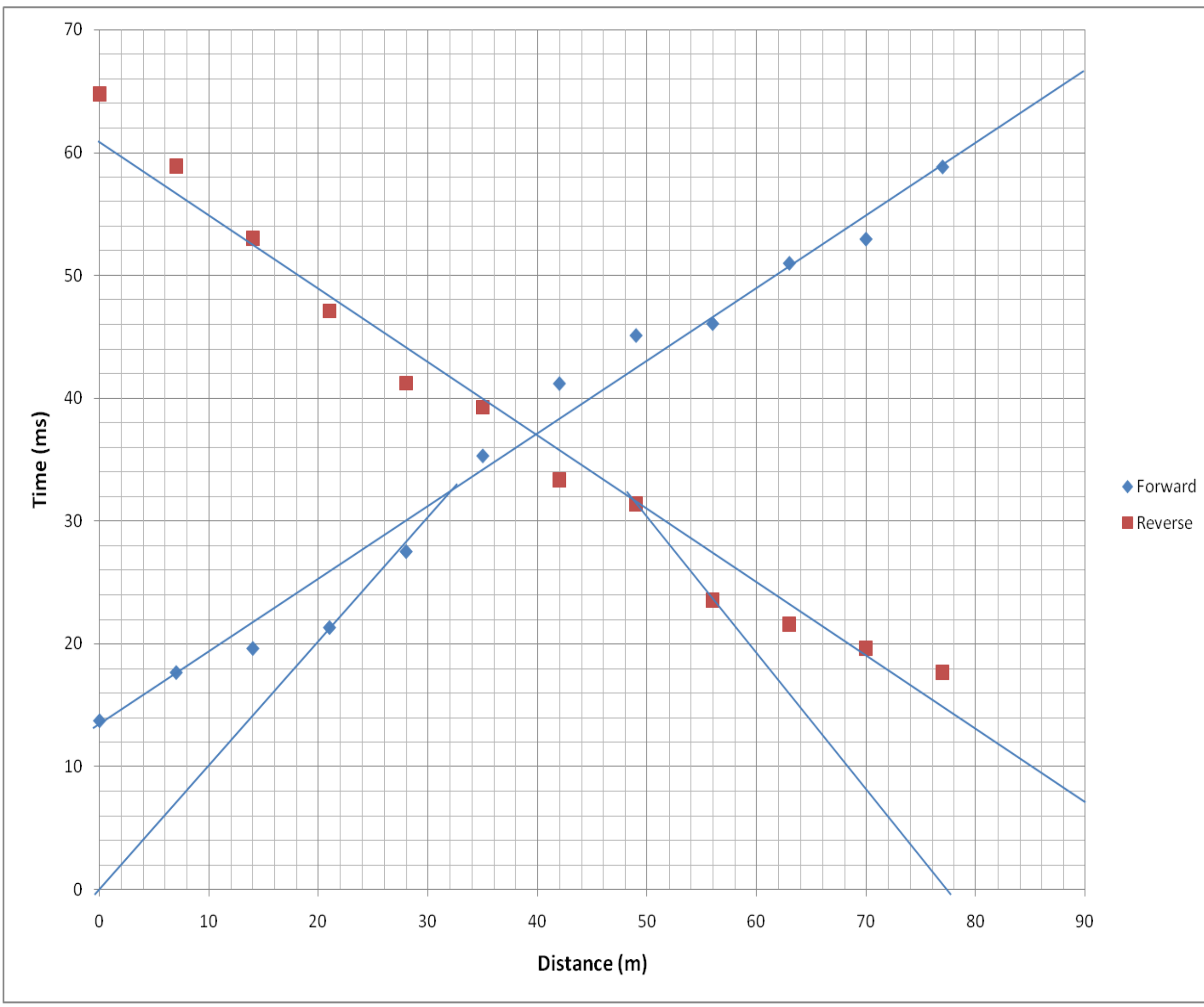

Fig. 6. Time-Distance graph of the Forward and Reversed shots for Profile 1.

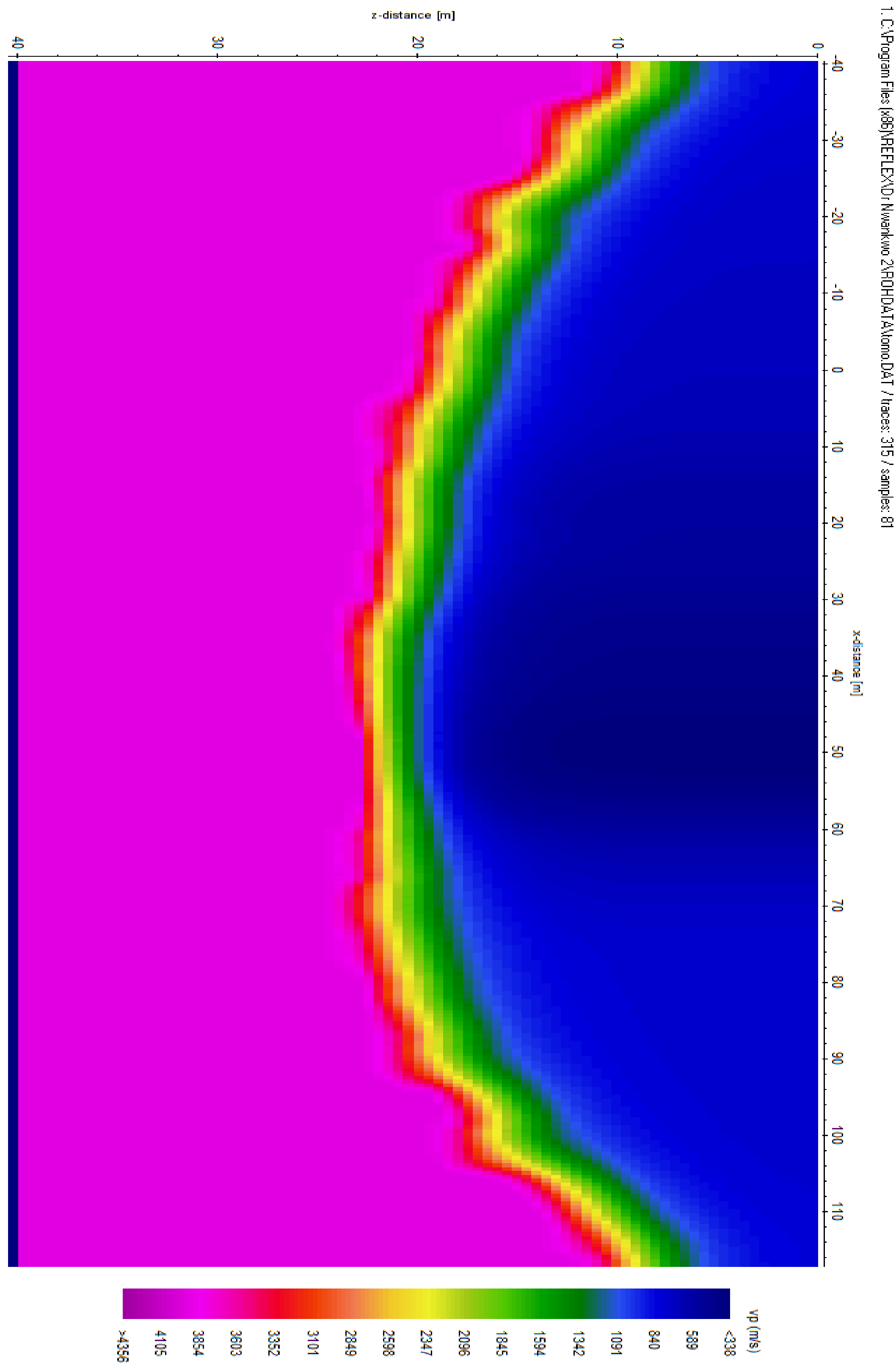

Fig. 7. Tomography model of velocity distribution along the first Profile

For seismic survey, the study was conducted by utilizing a 6 Kg sledge hammer, geophones were used as detector and 12 channel Terraloc ABEM MK III digital seismograph were used to record the seismic signal. The seismic shooting was done in the forward and reversed direction. The geophones were spaced 10 m apart while offset of 23.5 m was maintained before the first and after the last geophone groups. The recorded data were corrected for amplitude loss and the picked first break arrival times were processed and interpreted using Reflex-2D window-based software. The conventional intercept and reciprocal method for forward and reversed shots was used to give qualitative interpretation for all the stations data (Fig. 6).

4. DISCUSSION OF RESULTS

The result of resistivity model revealed multi-geologic layers constrained to 6 layers and resistivity covering a total depth of 55 m vertically and a maximum of 73.34 m along the horizontal axis. The resistivity increases from the top soil (weathered layer) with depth, with values characteristics of coastal plain sand. Zones of relatively low resistivities are described to contain clayey, silty, sandy materials, and moisture contents. Resistivity and velocity increase with depth depict compaction and solidification with depth in the subsurface as layers alternates. The high thickness of the weathered layer and lithology type as revealed in this study suggest that the area may be prone to landslide if other punitive measures are not put in place. Thus, areas overlain with sands are prone to erosion menace than areas overlain with clay, since clays are sticky and stiff.

The tomography model clearly isolated the consolidated from the unconsolidated (weathered) layer (Fig. 7). The model shows that weathered layer velocity varies from 338 m/s to 1000 m/s. The weathered layer thickness is 6.09 m at the beginning, 19.80 m at the middle, and 6.02 m at the end. The following layer has p-wave velocity varying from 1000 m/s to 2000 m/s with thickness of 2.3 m at the beginning, 2.0 m at the middle and 2.9 m at the end. The velocity of the third layer varies from 2000 m/s to 4356 m/s at depths where the second layer stopped.

Similarly, qualitative interpretation of the travel times versus geophone station plots delineates two-layer case with an average first arrival time to recording stations of 33.17 ms for the three profile lines surveyed.

5. CONCLUSIONS

The result of resistivity model in this study reveal multi geologic layers that is constrained to 6 layers. The weathered layer velocity varies from 338 m/s to 1000 m/s with a maximum thickness of 19.80 m. Such thickness of weathered layer which lithology is mainly sand/sandstone from resistivity inversion model is an indication that the area is prone to erosion activities.

The resistivity of most of the formation layers are averagely high suggesting a high degree of void spaces inside the rock material. Also, the formation lithology for the area is mainly sand/sandstone from the topsoil to the survey depth, suggesting non protective/highly compacted layers that can withstand the erosions associated with heavy rainfall in the area.

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