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*Full Length Research Paper*

# Geophysical mapping of the occurrence of shallow oil sands in Idiopopo at Okitipupa area, South-western Nigeria

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**Oil sands are known to be an alternate source of energy and of great economic value. To map the occurrence of shallow oil sand deposits in Idiopopo, Okitipupa area in Ondo state southwestern Nigeria, vertical electric sounding (VES) in 11 stations along 3 profiles were carried out using the Schlumberger configuration. Apparent resistivity value obtained ranged from (135.7 ± 0.05) ohm-m to (4592.6 ± 0.05) ohm-m. The resistivity curves obtained for each VES location were interpreted using partial curve-matching and computer iterated techniques and it revealed the presence of 4 and 5 geo-electric layers. Interpretation of the geo-electric parameters obtained indicates the possible presence of oil sand in the fourth layer of VES 8 with a resistivity value of 164.9 ohm-m at a depth of about (16.50 ± 0.05) m and thickness of (39.03 ± 0.05) m. Also, VES locations 5 to 8 (profile one) all indicate the possible presence of oil sands in the fifth layers with a resistivity value of less than (725.0 ± 0.05) ohm-m at a mean depth of (39.05 ± 0.05) m. However, due to the depth of probe more information about these layers could not be ascertained. It is recommended that further geophysical survey techniques like VES with increased electrode spacing and/or 2D resistivity method should be employed to effectively map the oil sands especially along profile one.**

**Key words:** Geo-electric, oil sand, Idiopopo, South-western Nigeria, vertical electric sounding, resistivity.

## INTRODUCTION

Oil sands formerly known as tar sands are composed of bitumen, mineral matter which includes clay or sand and water. The bitumen also referred to as heavy oil constitutes an important energy resource that must be rigorously treated in order to convert it to an upgraded crude oil before it can be used in refineries to produce gasoline and other fuels. Thus oil sand is economically valuable and important to the community in particular and the nation in general, such as Nigeria, as a source of revenue. The by-product of the bitumen can be useful domestically; pitch a by-product of bitumen can be used as a smokeless, domestic charcoal/coal briquette. It is also a useful material for petroleum and allied industries. Nigeria is known to have enormous reserves of oil sands within a belt that cut across Ogun, Ondo and Edo states, covering a distance of approximately 10 km. Enu (1985) described the nature and occurrence of the Nigerian oil sand and remarked that it is made up of sand (84%), bitumen (17%), clay (2%) and water (4%). He also studied the porosity of tar sand using quite a number of techniques and observed that the porosity of tar sand ranges from 16 to 35%. Heavy oils are generally found in younger reservoirs, which includes Pleistocene, Pliocene and Miocene as well as in older Cretaceous, Mississipian and Devonian formations (Satinder and Larry, 2008). Ekweozor and Nwachukwu (1989) carried out a geo-chemical investigation of tar sand and source rock evaluation of interbedded shale to determine its primary origin and identify the causative factor for its transformation to the asphatic residues found today in sandstone outcrops. They concluded that the oil in oil sands was sourced by down dipping carbonaceous rocks of possibly early to middle cretaceous age and the conventional oil water later watershed and bio-transformed as a result of encountering meteoric water laden with micro-organism during its up dip migration. Geophysical techniques have been used extensively for mineral resources exploration, although the type of mineral sought after would inform the

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type of geophysical prospecting technique to be employed. As oil sands occur at shallow depth (Satinder and Larry, 2008) of less than 1000 m (De-Hua and Jiajin, 2008); geo-electric methods have been used successfully in oil sand detection, since it is an efficient method for delineating shallow layered sequences or vertical discontinuities involving change in resistivity. The significant thickness relative to depth as well as the very high resistivity contrast with the host geology (Bauman, 2005) contributes to the success of geo-electric techniques in oil sands detection. Examples are in the application of electromagnetic airborne techniques (Cristall et al., 2004) and electrical resistivity tomography (Kellet and Maris, 2005) in finding best deposits. 1-D resistivity survey has also been employed in direct detection of Alberta hydrocarbons (Bauman, 2005) and Nigerian oil sand (Ako et. al., 1983). Hence, this study employed the vertical electric sounding (VES) technique of geophysical survey to map the oil sand deposits in Idiopopo, Okitipupa local government area of Ondo state of Southwestern geopolitical zone in Nigeria.

## Physiographical and geology setting of the area

The study area, Idiopopo, in Okitipupa local government area of Ondo state, Nigeria is located along the oil sand belt and lies between latitudes N 06°388591 and N 06°39348[1] and longitudes E 04°357831 and E 04°35924[1] (Figure 1). Idiopopo is located at the outskirt of the town, some kilometers away from a nearby village called Idiobilayo. Roads leading to Idiopopo were unmotorable. Idiopopo falls within the tropical rain forest and woodland belt in Nigeria. It has a thick forestation made up of palm trees, scrubs, bamboo trees, etc. As a result of continuous humid climate of the equatorial rainforest; tall and slender trees many of which have stilt roots including palm trees, rubber trees and cocoa trees are the main vegetation found in this area.

The geology of the study area falls under the Dahomey sedimentary basin. Omatsola and Adegoke (1981) studied the tectonic evolution and stratigraphy of the Dahomey basin in which they subdivided the sequence into stratigraphic units namely Ise formation, Afowo formation and Araromi formation based on the lithostratigraphic study of some boreholes from the area. The Ise formation lying uncomfortably on the basement consists of alternating sands and clay units. The Afowo formation is bituminous and lies on the Ise formation. It consists of alternating sands and shales units. The youngest formation, the Araromi formation is mostly marine shale with thin limestone bands.

## MATERIALS AND METHODS

### Theory of methodology

Geophysical method of subsurface investigation is known to provide a relatively rapid and cost-effective means of deriving large area information coverage of subsurface geology. It involves the use of various survey techniques which includes electrical resistivity technique. In electrical resistivity survey technique, artificial generated electric currents are put into the ground and the resulting potential differences are measured at the surface by means of electrodes. Since the current is measured as well, it is possible to determine an effective or apparent resistivity of the subsurface. 2 electrodes are used to supply a controlled electrical current to the ground, such that the lines of current flow adapt to the sub-surface resistivity pattern so that the potential difference between equipotential surfaces can be measured where they intersect the ground surface using a second pair of electrodes. The large contrast in resistivity between ore bodies and their host rocks is exploited in electrical resistivity prospecting, especially for minerals as they are good conductors. 2 main procedures are employed in electrical resistivity surveys, vertical electric sounding (VES) and constant separation traversing (CST). VES gives the resistivity variation with depth while CST gives the lateral variation of resistivity. For VES, the current and potential electrodes are maintained at the same relative spacing and the whole spread is progressively expanded about a fixed point. The apparent resistivity of the subsurface is thus obtained using the appropriate geometric factor.

### Methodology

For this study, the vertical electric sounding (VES) technique was employed using the Schlumberger configuration. 11 VES points which fall along 3 profiles, were taken across the study area with a maximum half electrode spacing of (AB/2) of 120.00 m, using the junior Syscal Iris Terrameter. The apparent resistivity obtained was then plotted against the corresponding half electrode spacing(AB/2) on a bi-logarithimic paper. Partial curve matching of the data yielded geo-electric parameters which were then used as starting model parameters for the computer aided iteration. The computer iteration, pseudo-section and cross-section of each profile were generated using WinGlink [TM] version 1.62 software, which also enabled smoothening of the data.

## RESULTS AND DISCUSSIONS

The pseudosections obtained show the variation of the apparent resistivity across each of the profile (Figures 2, 4 and 6) in the study area. Interpretation of the resistivity curves obtained revealed the presence of 5 geo-electric layers in all VES positions except in VES positions 3, 4 and 10 with 4 layers. The geo-electric parameters obtained for each VES location are presented in Table 1.

## Profile 1

This profile runs in the east-west direction and has VES locations 5, 6, 7 and 8 along it. The pseudo-section and cross-section of the profile is given in Figures 2 and 3 respectively. The apparent resistivity variation to a depth of about 100.00 m is shown, revealing an increase in apparent resistivity value to the east of the profile, with a resistivity of above 1021 Ωm between 15.00 to 50.00 m depth at a length of between 440 and 450 m along the profile (Figure 2). The cross-section which is obtained using the iterated values reveals that the profile is above sea-level. With the highest elevated point being VES 7,

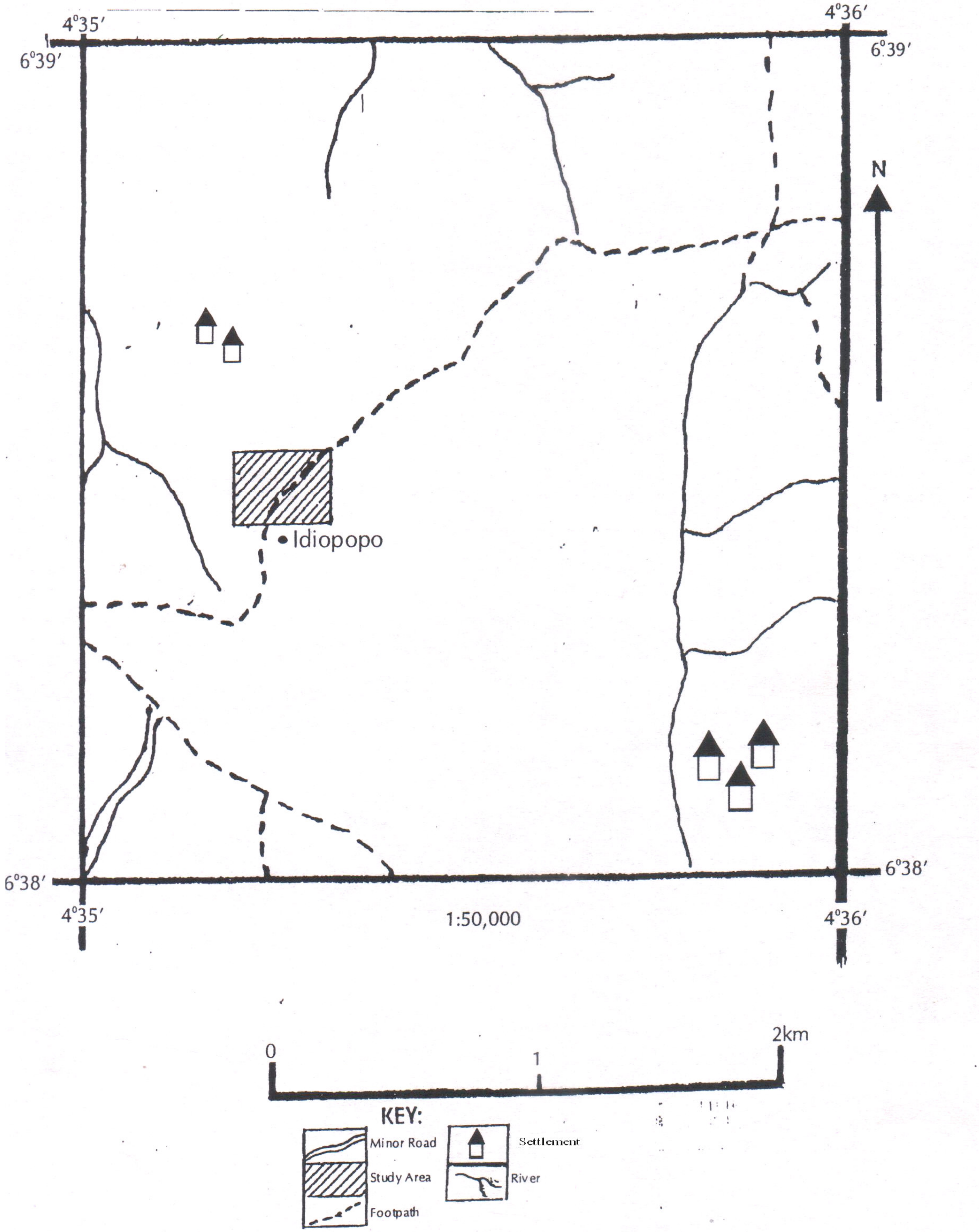


**Figure 1**: Location map of the study area

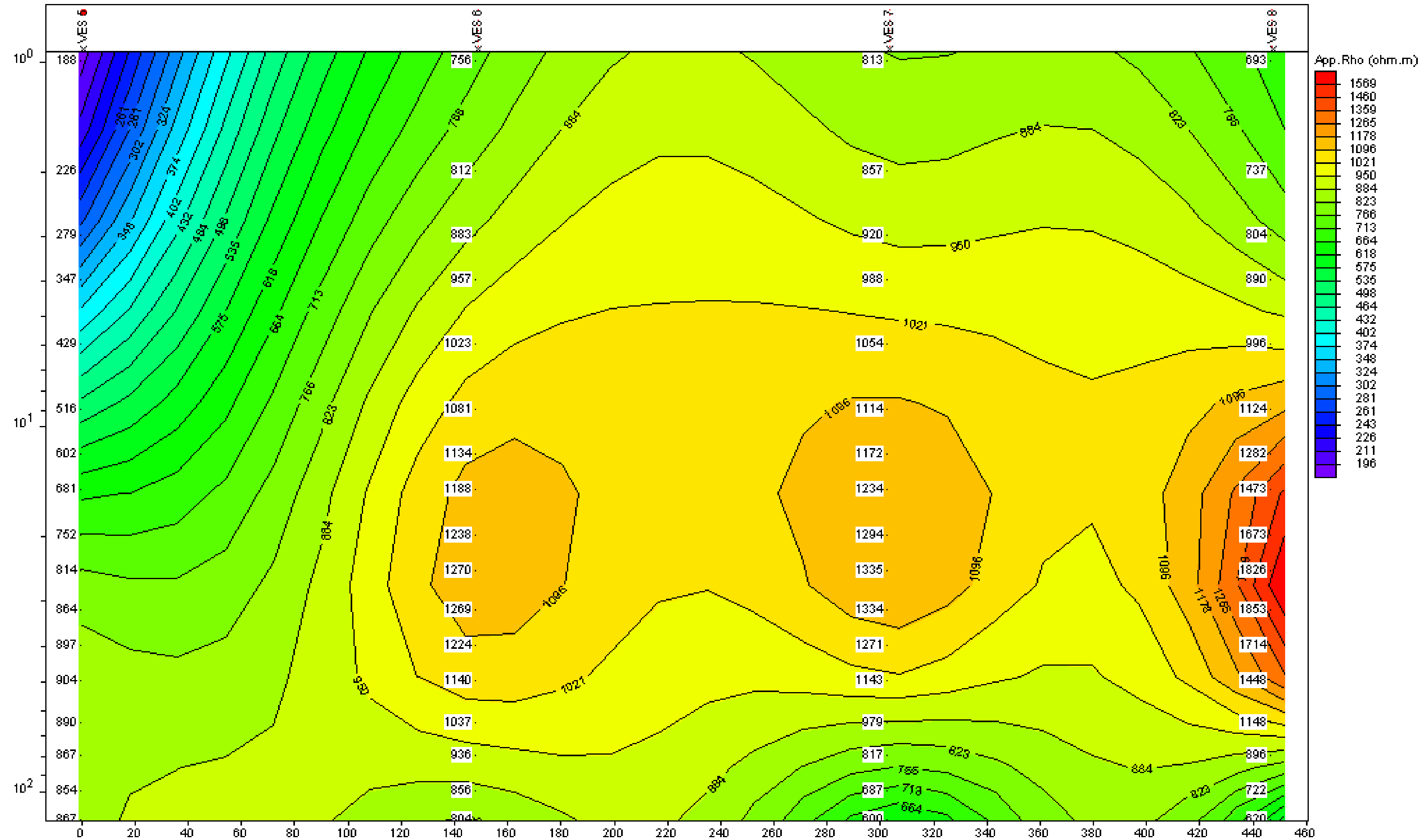


**Figure 2:** Pseudo-section of Profile 1 (E-W direction)

the computer aided iteration revealed that the VES stations on this profile all have 5 layers (Table 1) which is also have 5 layers with resistivity value of less than 725.00 Ωm at a mean depth of 39.05 m. However, VES 8 is seen to have a resistivity value of 164.94 Ωm and a thickness

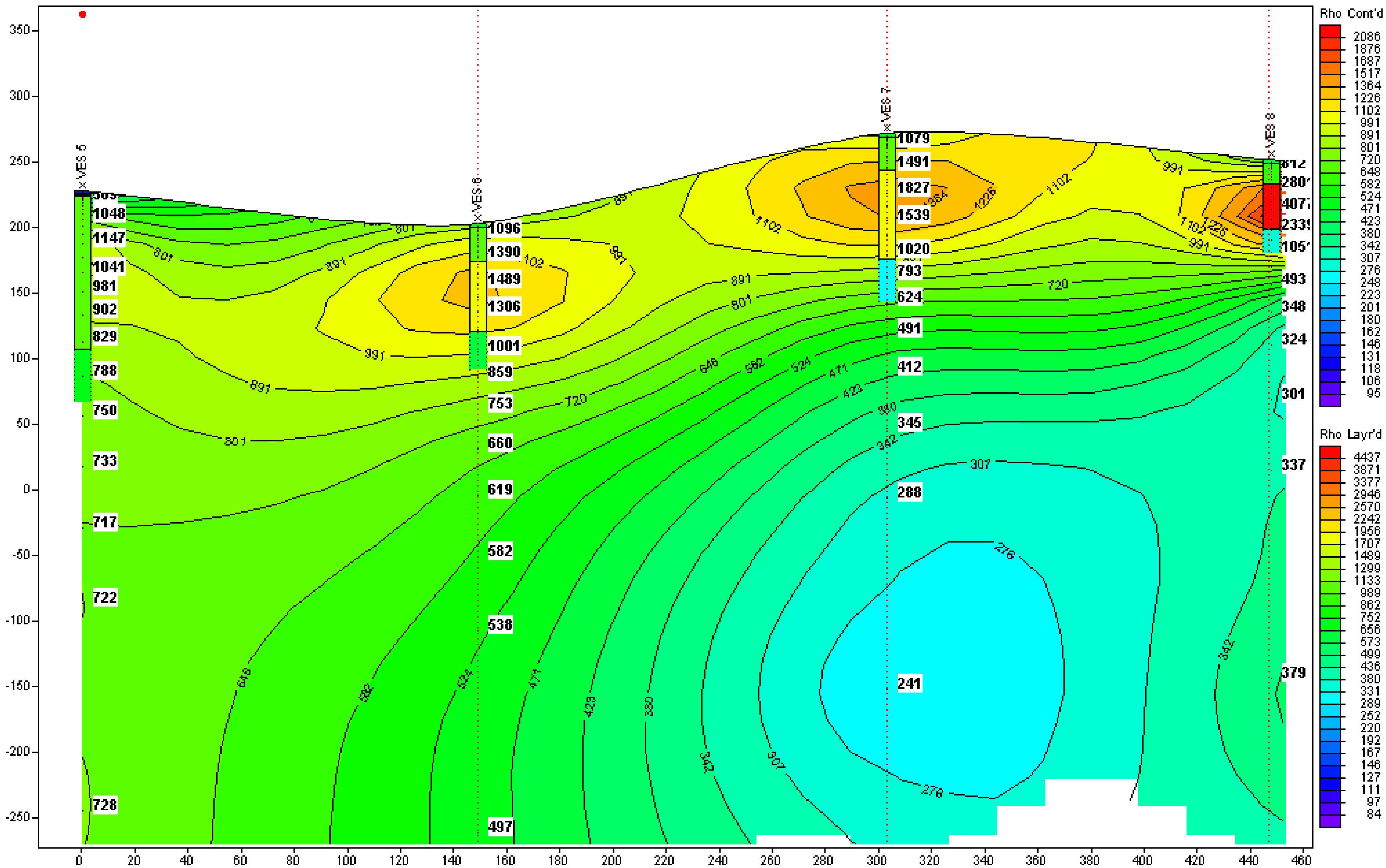


**Figure 3**: Cross-section of Profile 1 (E-W direction).

of 39.03 m. This is pictured in the interpolated plot of the cross section which shows a region of low resistivity in the western part of the cross-section.

**Profile 2**

This includes VES 1, 2, 3 and 4, running in the SW-NE direction. The pseudo-section (Figure 4) reveals a general increase of apparent resistivity with depth. The cross-section (Figure 5) shows

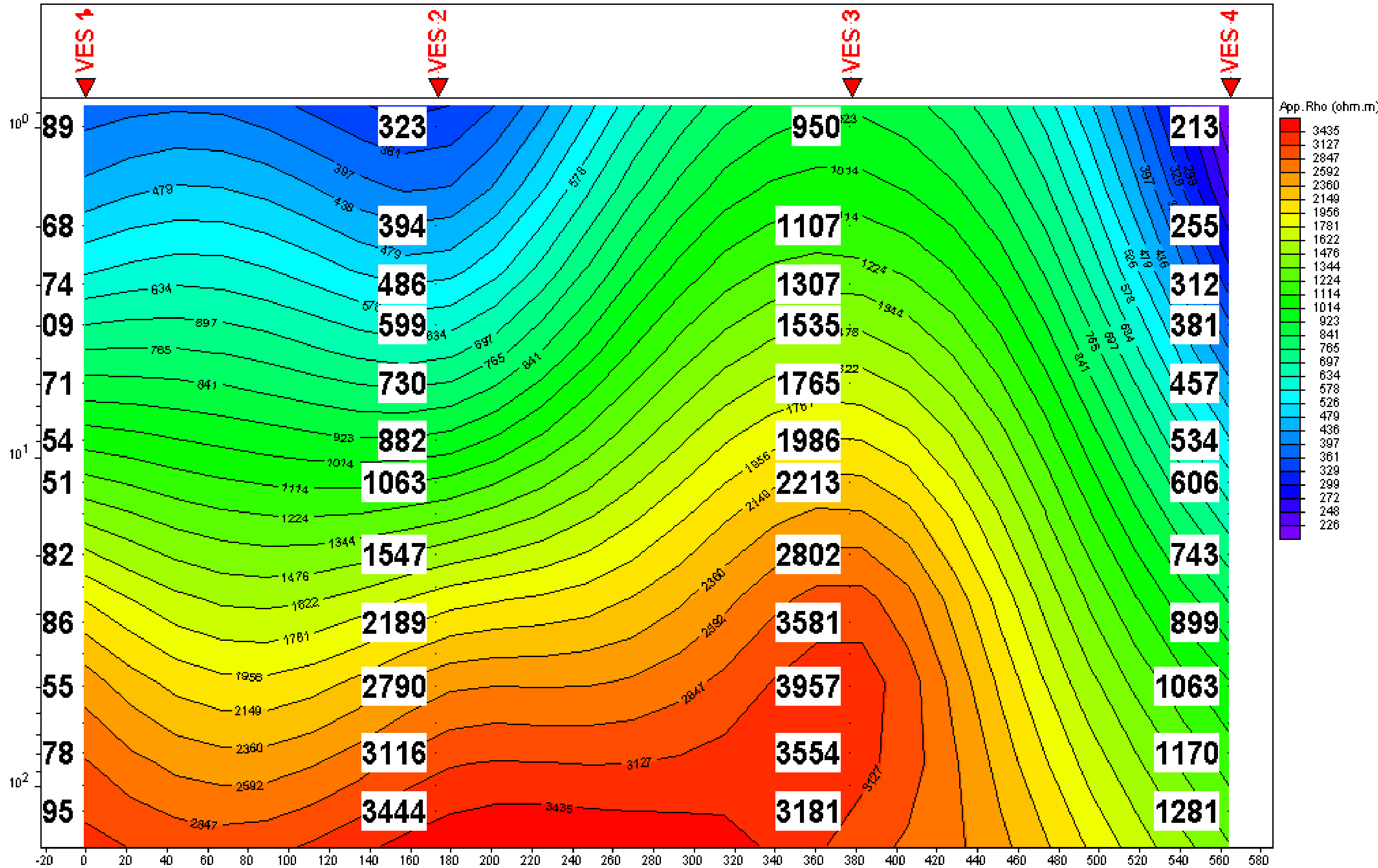


**Figure 4:** Pseudo-Section of Profile 2 (SW-NE direction)

that the profile is dipping to the north-east. The general trend of the resistivity along this profile is relatively high but is reducing towards the north-eastern part of the profile (VES4).

**Profile 3**

VES 11, 10 and 9 fall along this profile which runs in the west-east direction. The pseudo-section (Figure 6) shows a relatively low resistivity value across the profile, except at the low extreme to east of the profile. The cross-section (Figure 7) also reflects a region of increase resistivity to the

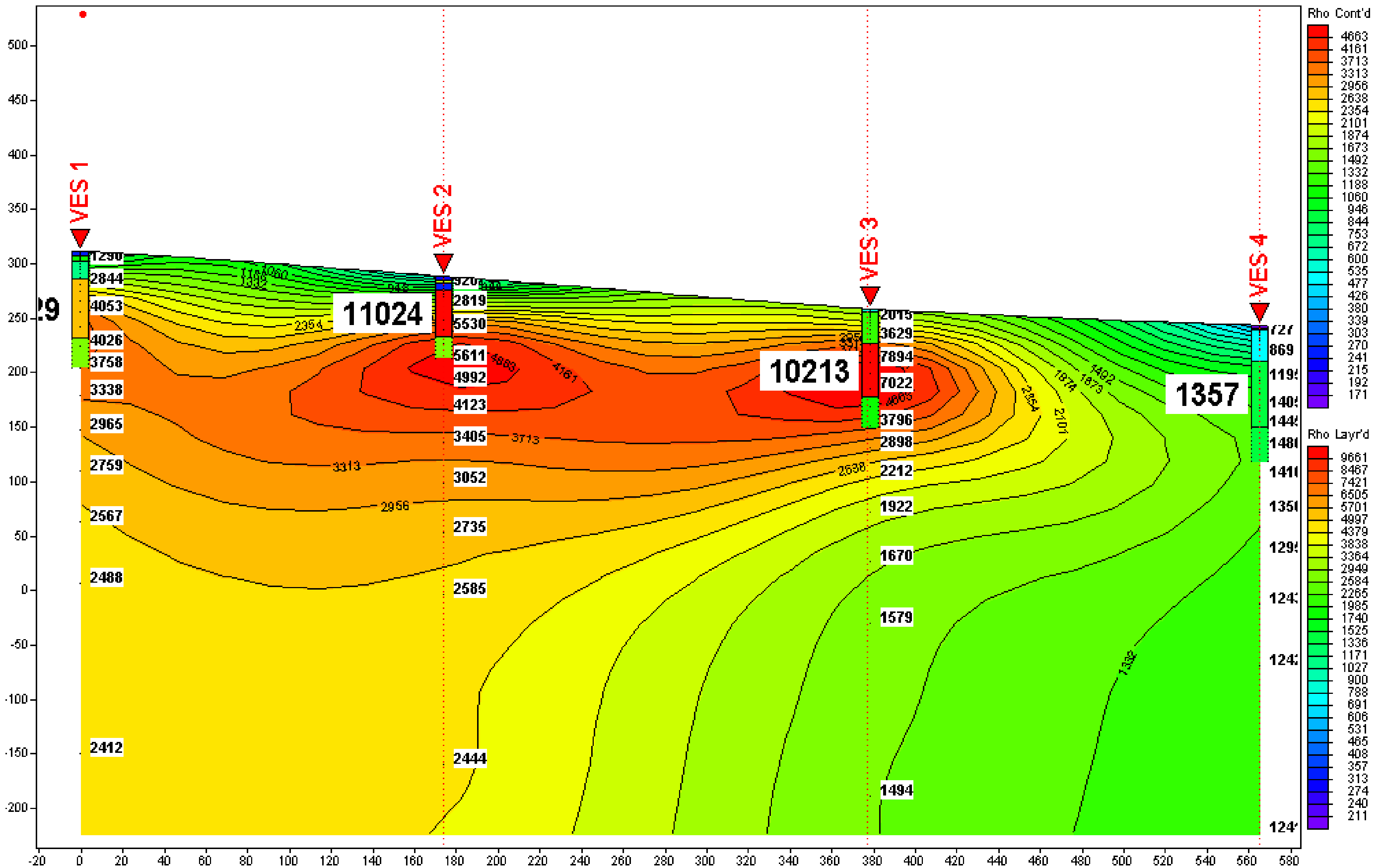


**Figure 5:** Cross-section of Profile 2 (SW-NE direction).

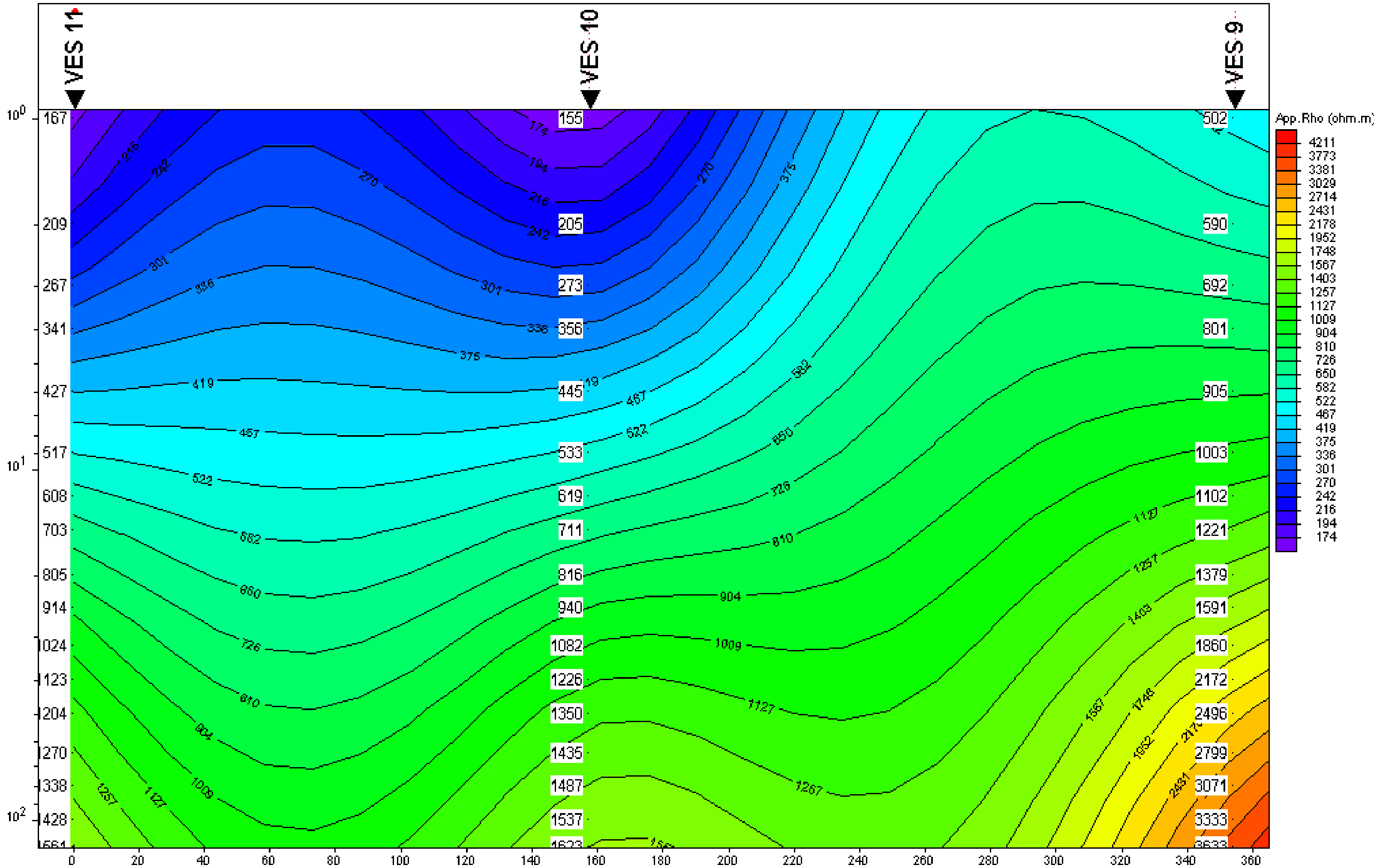


**Figure 6:** Pseudo-section of Profile 3 (W-E direction)

east of the profile, but with a discontinuity in the interpolation.

Generally, it is expected that the effect of bitumen saturation conductivity of various types of rocks should be negative, that is, conductivity should decrease considerably resulting in increased resistivity value (McConnell and Glenn, 2008; Bauman, 2005). However, this has not been the situation for Nigeria oil sand deposits; as bitumen saturation seems to have the same effect as water with considerable content of dissolve deposits. This is probably because the oil sands

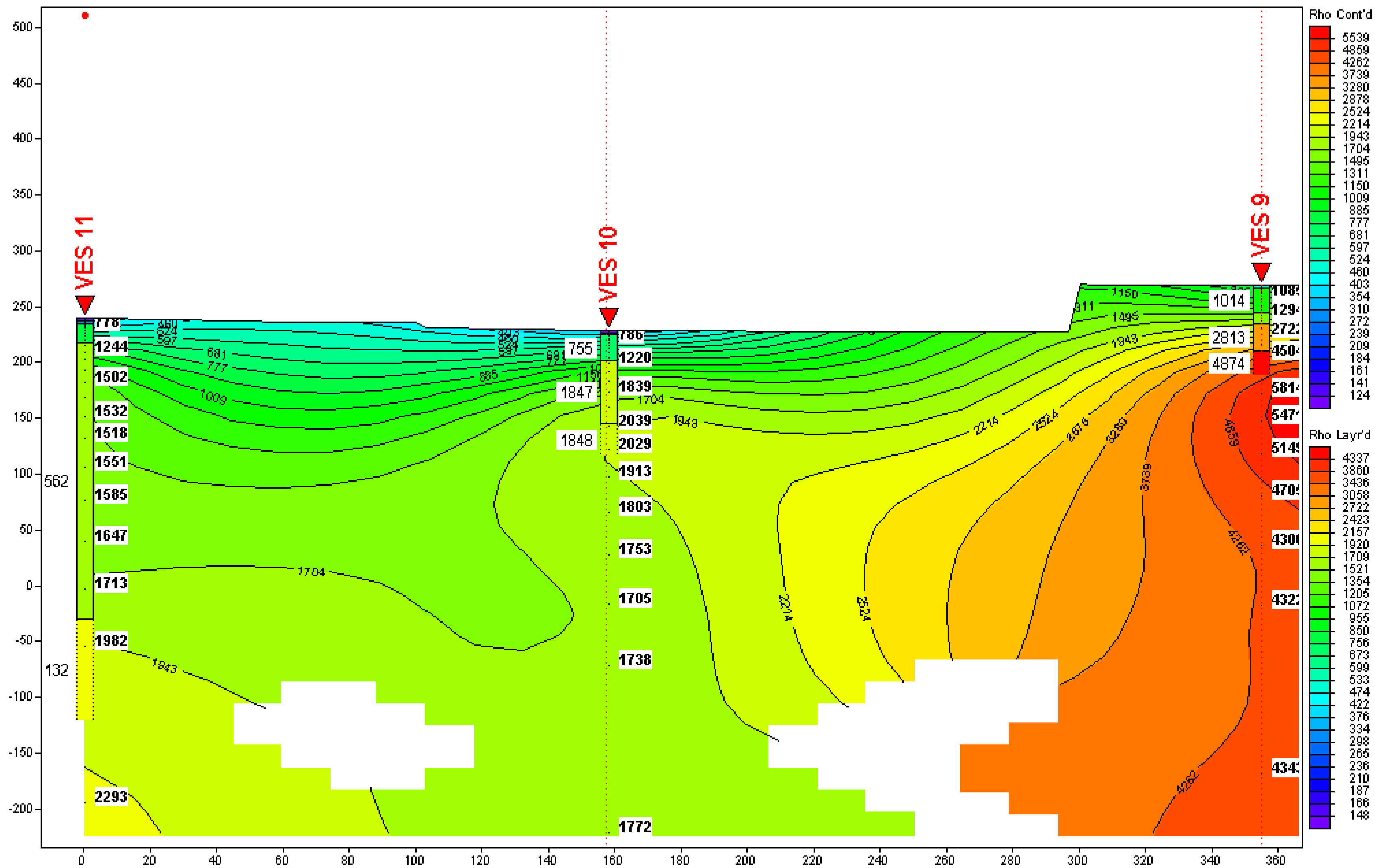


**Figure 7:** Cross-section of Profile 3 (E-W direction)

defined a resistivity limit of less than 100 Ωm for Nigerian oil sands. Researches on Nigeria oil sands shows they are very similar to those of Athabasca are water wet (Adegoke et al., 1981). Investigations carried out by Ako et al. (1983) tentatively(Canada) and that the physical and che-

**Table 1.** Geo-electric parameters.

| VES No. | Layers | Resistivity (ohm-m) | Thickness (m) ± 0.05 | Depth (m) ± 0.05 |
|---|---|---|---|---|
| 01 | 1 | 352.53 | 1.39 | 1.39 |
| | 2 | 1963.52 | 1.47 | 2.86 |
| | 3 | 1162.64 | 5.02 | 7.88 |
| | 4 | 5269.41 | 16.37 | 24.25 |
| | 5 | 2631.53 | - | |
| 02 | 1 | 296.18 | 1.30 | 1.30 |
| | 2 | 3494.80 | 0.68 | 1.98 |
| | 3 | 333.47 | 1.97 | 3.95 |
| | 4 | 11023.77 | 13.00 | 16.95 |
| | 5 | 2627.24 | - | |
| 03 | 1 | 793.85 | 0.92 | 0.92 |
| | 2 | 2103.95 | 8.79 | 9.71 |
| | 3 | 10213.07 | 15.02 | 24.73 |
| | 4 | 1807.70 | - | |
| 04 | 1 | 185.77 | 0.86 | 0.86 |
| | 2 | 216.49 | 0.35 | 1.21 |
| | 3 | 712.59 | 8.75 | 9.96 |
| | 4 | 1358.03 | - | |
| 05 | 1 | 141.38 | 0.48 | 0.48 |
| | 2 | 282.11 | 0.45 | 0.93 |
| | 3 | 74.21 | 0.29 | 1.22 |
| | 4 | 1008.17 | 35.48 | 36.70 |
| | 5 | 724.00 | - | |
| 06 | 1 | 719.99 | 0.93 | 0.93 |
| | 2 | 1075.78 | 3.05 | 3.98 |
| | 3 | 1416.57 | 14.95 | 18.93 |
| | 4 | 1133.13 | 14.05 | 32.98 |
| | 5 | 679.27 | - | |
| 07 | 1 | 755.62 | 0.93 | 0.93 |
| | 2 | 1137.61 | 6.30 | 7.23 |
| | 3 | 1749.16 | 11.37 | 18.6 |
| | 4 | 1246.66 | 12.40 | 31.00 |
| | 5 | 491.33 | - | |
| 08 | 1 | 629.73 | 0.80 | 0.80 |
| | 2 | 948.67 | 5.25 | 6.05 |
| | 3 | 5537.47 | 10.46 | 16.51 |
| | 4 | 164.94 | 39.03 | 55.54 |
| | 5 | 635.36 | - | |
| 09 | 1 | 478.27 | 0.98 | 0.98 |
| | 2 | 1014.00 | 6.71 | 7.69 |

**Table 1.** Contd.

| | | | | |
|---|---|---|---|---|
| | 3 | 1456.74 | 3.12 | 10.81 |
| | 4 | 2813.26 | 7.42 | 18.23 |
| | 5 | 4873.90 | - | |
| 10 | 1 | 132.43 | 0.77 | 0.77 |
| | 2 | 2.54 | 0.51 | 1.28 |
| | 3 | 755.43 | 7.07 | 8.35 |
| | 4 | 1846.66 | - | |
| 11 | 1 | 146.52 | 0.87 | 0.87 |
| | 2 | 318.63 | 0.72 | 1.59 |
| | 3 | 846.55 | 5.26 | 6.85 |
| | 4 | 1561.86 | 75.40 | 82.25 |
| | 5 | 2131.74 | - | |

mical properties of tar sand of southwestern Nigeria compare favorably with those of Anthabasca in Canada but however with higher bitumen and asphaltic content (Dada, 2005). Typical resistivity value for oil rich sands of Athabasca ranges from about 110 to 1800 ohm-m. With these deductions, it is therefore valid to conclude that areas which fall within theses range of values are indications of bitumen saturation.

## Conclusion and Recommendation

From the data analysis, profile 1 revealed a low resistivity value of 164.9 Ωm at a depth greater than 10.46 m with a thickness of 39.03m in the fourth layer of VES 8. This is indicative of a possible bitumen saturated zone.

Resistivity value of less than 750 Ωm was also obtained at the fifth layers of VES 5 to VES 7 and the fourth and fifth layers of VES 8 with the cross-section of this profile indicating a region of low resistivity towards the Western part of the profile. This is further indicative of possible bitumen saturation across the profile but at different depths and concentration. It is therefore recommended that further geophysical survey techniques like VES with increased electrode spacing and/or 2D resistivity method should be employed to effectively map the oil sand especially along profile one. To complement the geophysical survey, further geological investigations should be carried out as well as a detailed drilling programme in the study area.

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## REFERENCES

Adegoke OS, Enu EI, Ajayi TR, Ako BD, Omatsola ME, Afonja AA (1981). Tar Sand a New Energy Raw Mater. in Nigeria Proceeding Symposium on New Energy Raw Material. karlovy, pages pp.17 -22.

Ako BD, Alabi AO, Adekoe OS, Enu EI (1983). Application of Resistivity Sounding in the Exploration for Nigeria Tar Sand, Energy and Exploitation © Graham and Trotman Limited 2(2): 155-164

Bauman P (2005). 2-D Resistivity Surveying for Hydrocarbon-A Primer. CSEG Recorder, April , pp.25-33.

Cristall J, Farquharson C, Oldenburg D (2004). Airborne Electromagnetic Inversion Applied to Oil Sand: Expanded Abstract, Can. Soc. Expl. Geophysics. Annual Meeting as cited by Douglas R. Schmitt in Heavy and Bituminous Oils: Can Alberta Save the World*?* Preview, October 2005. 25p.

Dada SS (2005). Bitumen Development Programme for Nig. In: Proceedings of the Workshop on Mineral Resources Development and Management in Lagos state Training Workshop. August 8-10. 19 p.

De-Hua, Jiajin Liu (2008). Seismic Properties of Heavy Oils Measured data; The Leading Edge, Sept. 27(9): 1108-1114.

Ekweozor CM, Nwachukwu JI (1989).The origin of Tar Sand of Southwestern Nigeria. Nigerian Association of Petroleum Explorationist B. 4(2): 82-94.

Enu EI (1985).Textural Characteristics of Nig. Tar Sands. Sedimetary Geol. 44: 65 – 81.

Kellet RL, Marvis V (2005). Imaging Electrically Resistive oil Sand Channels in North East Alberta, Canada, as cited by Douglas R. Schmitt in Heavy and Bituminous Oils: Can Alberta Save the World*?* Preview, Oct. 25p.

McConnell D, Glen T (2008). Athabasca oil sands Exploration and Development Investigation using the Helicopter-Borne Transient Electromagnetic Techni, Back to Exploration-2008 CSPG CWLS Convention. pp. 701-705

Omatsola ME, Adegoke OS (1981).Tectonic evolution and Cretaceous Stratigraphy of Dahomey Basin Nigeria. J. Min. Geol. 1: 44 – 48.

Satinder C, Larry Lines (2008). Introduction to this Special Section: Heavy oil. The Leading Edge, Sept. 27(9): 1104-1106.