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Subsurface Models of Abitumen-Rich Area near Ode-Irele, Southwestern Nigeria.

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Abstract: *Subsurface geophysical investigation around Looda village, near Ode-Irele was carried out with the principal objective of evaluating the depth to the bituminous sand and its thickness with a view to suggesting better environmentally compatible exploitation technique.Electrical resistivity survey using the Schlumberger array was employed to generate subsurface models. 13 VES points along three (3) traverses were established in the study area with manual curve matching followed by Computer iteration of the vertical electrical sounding (VES) data. A careful study of the results, together with the knowledge of the Stratigraphy of the area was used to develop the subsurface models.Two distinct models were generated. The first model generated is characterised by a thin top soil (less than 1m thick) comprising the overburden underlain by dry sand (1.0m - 4.6m thick) which overlies bituminous sand horizon (6m -19m thick). This horizon is underlain by sandy silty clay. The second model generated is defined by top soil (0.5m -1.8m thick) underlain by bituminous sand horizon (2.5m -14.8m thick) which overlies saturated sand (1.9-11.3m thick). A fairly impervious sandy silty clay layer underlies this aquifer.Huge deposit of heavy oil sand with thickness ranging from about 2.5m to 19.0m was observed between a depth of about 0.5m and 5.4m in the study area. This depth is relatively shallow andcan be exploited preferably by open cast mining. However, precaution must be taken to prevent burst out and contamination of the aquifer sandwiched between the bituminous sand and sandy clay horizons in some locations during exploitation.*

Keywords: *Bituminous sand; Electrical resistivity survey; subsurface model; Aquifer; Open castMining.*

I. Introduction

In a study which entails the mapping of the occurrence of oil sands in Ijebu-Mushin using electrical and ground magnetic geophysical survey, it was revealed that substantial deposit of bituminoussands was present in the Southwestern part of the area (Odunaike, et al, 2010).Also, a geophysical survey carried out by some researchers to show the occurrence of oil sand in Idiobilayo, Okitipupa, southwestern Nigeria, revealed that the bituminous sand occurs in two (2) horizons in the subsurface that is the X and Y horizons (Akinmosin et al, 2013).

Bituminous sands are naturally occurring mixture of sand grains coated with water and bitumen which occupies the pore spaces between the grains. The bitumen is made up of heavier fraction of crude oil of natural origin and it is completely soluble in carbon sulphide. This bitumen finds application as conventional oil, paving and road building material, roofing material of all kinds of building and as undercoat for automobiles and tyre manufacturing industries.

Extensive oil sands with reserves of about 41 billion barrels of oil are known to occur in Cretaceous terrigenous sediments which onlap on the Crystalline Basement complex rocks of Precambrian age within the south western part of Nigeria (Enu, 1985).

These bituminous sands occur along the East-West belt (The Okitipupa ridge) approximately 120km long and 6km wide extending from Ogun, Ondo to Edo states (Enu, 1985); as seepages on farmlands, along road cuts and as surface and near surface impregnated sediments exposed along river banks and at break of slopes.

The bituminous sands were confirmed to be part of the Afowo formation and occur in the subsurface in two predominantly sandy zones separated by an 8m thick oil shale(Enu, 1985)with each oil sand horizon averaging 12m. The lower horizon (Horizon Y) is mostly quartz sand with thickness ranging from 3m – 26m showing an upward fining of grain textures and increased consolidation updip while the upper horizon (Horizon X) has thickness ranging from 10m –22m and comprises sandstone with interbedded shales and siltstones.

Though it occurs in two horizons in the subsurface, the depth of occurrence by different workers varies from one place to another and as such the need arises for detailed geophysical study of individual locations to know its depth of occurrence and provide a baselineinformation that can be used during its exploitation.

This research was aimed at generating geophysical models to deduce the lithological characteristics of the subsurface layers and the bitumen-bearing zone in Looda village near Ode-Irele, Ondo state.

GEOLOGIC SETTING AND LOCATIONOF THE STUDY AREA

The bituminous sand belt in Nigeria lies within the Eastern Dahomey basin with over 2,500m thick Cretaceous and younger sediments which comprises of lithostratigraphic group and different formations (Nwachukwu, et al, 1989). This basin is the eastern flank of Dahomey basin which runs from southeastern Ghana through Togo and the Republic of Benin to southwestern Nigeria.

The basin was believed to have emerged as a result of the separation of the African-South American land masses and the subsequent opening of the South Atlantic Ocean which began with a rifting stage in the Lower Jurassic – Early Cretaceous. This was brought about by basement fracturing which resulted inblock faulting, fragmentation and subsidence of the central Paleozoic basement rocks (Nton, 2001). Consequently, the West African and South American land masses drifted apart, leading to the opening of the South Atlantic Ocean and the basement subsidence which followed, made a RRR (Ridge- Ridge- Ridge) triple junction at the Gulf of Guinea. The three arms of this triple junction include the Gulf of Guinea, the Atlantic Ocean and the Benue trough (Burke,1971).

Overlying directly the Precambrian basement complex rocks in the Eastern Dahomey basin, is the Abeokuta group. Three (3) formations were recognised in the Abeokuta group based on the lithological homogeneity and similarity in origin (Nton, 2001). This includes Ise, Afowo and Araromi Formations. The Abeokuta group is overlain by the Ewekoro Formation, followed by Akinbo Formation, Oshosun Formation (Jones and Hockey, 1964; Nton, 2001), Coastal plain sands and the Recent Alluvium (Figure 1).

The study area lies within the Afowo Formation (Figure 2) of the Abeokuta group (Jones and Hockey, 1964). This Formation comprises of coarse to medium grained sandstone with variable but thick interbeds of shale, siltstone and clay which were deposited in a transitional to marginal marine environments.

The study area, Looda village, near Ode-Irele, Southwestern Nigeria, lies within latitudes N06^{0}38^{1} and N06^{0}41^{1} and longitudes E04^{0}51^{1}and E04^{0}55^{1} and it is drained byone (1) Major River;RiverOluwa flowing from the southwestern part of the area with many distributary channels (Figure 2). It is located within thetropical rain forest and woodland belt of Nigeria and as a result of the continuous humid climate of thistropical 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 area is accessible by major roads and footpaths (Figure 3).

II. Methodology

Geophysical techniques have been used extensively for mineral resources exploration, although the type of mineral sought after would inform the type of geophysical prospecting techniques to be employed.

As bituminous sands occur at shallow depth of less than 1000m; geo-electric methods have been used successfully in its detection (Bauman, 2005; Odunaike, et al, 2010).This is because 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 bituminoussands detection.

In this study, Vertical Electric Sounding (VES), an electrical resistivity tool was employed to probe the subsurface in order to identify the bitumen-bearing horizon and lithological variation. This enabled a 1-dimensional measurement of the variation in subsurface electrical properties with depth. This was achieved by increasing the separation between the two (2) current electrodes about a central point.

Using the Schlumberger configuration, 13 VES points (Figure 3) with minimumelectrode spacing of 100m were taken in the study area along 3 traverses in the North-South directionwith the aid of a Campus Tiger Terrameter. The vertical electrical sounding (VES) data were later presented as depth sounding curves. This was established by plotting apparent resistivity values (pa) against electrode spacing (AB/2) on a bi-log graph paper. The points were then joined together with a smooth curve. Manual curve matching of the data yielded geo-electric parameters such as thickness and the resistivity values of each layer. The subsurface models were then generated from the geo-electric parameters by computer aided iteration softwares;WinResist 1.0.version and SURFER 11.

III. Results And Discussion

The curve types identified are predominantly KQ, HK and KH (Figure 4a, 4b and 4c) curves. The interpretation of the resistivity curves obtained shows that 4 geo-electric layers were present in the subsurface as shown in Table 1.

The results of the interpretation of the geoelectric sections were used to construct two (2) subsurface models along traverses taken in the North-South directions.

The geo-electric sequences for the first model which comprises of VES points 1-7 taken along Traverse 1 (Figure 5), shows a subsurface characterized by top soil, underlain by saturated sand, bitumen-impregnated sand and a sandy clay layer. The resistivity values of the bitumen-bearing layer along this traverse ranges from 318Ωm to 1656Ωm withapproximately 6-19m thickness while the dry sand overlying the bitumen-impregnated layer has resistivity values that ranges from 135Ωm to 5429Ωm with thickness ranging from 1.0 to 4.6m. The high resistivity of the dry sand layer corresponds to the unsaturated zone (Van Overmeeren,1989).

The second subsurface model which comprises of VES points 8-10 and 11-13 taken along two (2) traverses are characterised by top soil, underlain directly by bitumen-impregnated sand, followed by saturated sand and sandy clay layers (Figure 6 and 7). The bitumen-bearing layer range in thickness from 2.5 to 14.8m with resistivity values ranging from922 to 2842Ωm while the saturated sandy layer directly beneath it have resistivity values ranging from 682 to 1262Ωm with thickness ranging from 1.9 to 11.3m.

Regionally, the geoelectric sections of the 2 subsurface models were correlated with borehole log of some wells drilled in Southwestern Nigeria. The boreholes were drilled in Idiobilayo, Southwestern part of Okitipupa in Ondo state. At Idiobilayo, the oil sand horizon was intercepted at depth of 12-21m and 18-30m for the 2 wells; with the oil sand layer having thickness of 9m and 12m respectively (Akinmosin, et al, 2013). This is not farfetched from that obtained in the study area.

IV. Conclusions

Vertical electrical soundings in Looda near Ode-Irele were extensively carried out to generate subsurface models that can serve as baselinedata for its exploitation.

In the study, the resistivity values of the bitumen-bearing layer for the two subsurface models ranges from 318Ωm to 2482Ωm, averaging 1400Ωmwith thickness ranging from 2.5 to 19m and averaging 10.75m.

The depth to bitumen-bearing sand in the study area is very shallow. It ranges from 0.5m to 5.4m. These values are relatively low and it shows that the bituminous sand is almost outcropping in some of the area and thus can be easily exploited owing to the thin overburden that must be removed during its exploitation.

The geoelectric sections obtained showthe apparent resistivity curves across each profile in the study area and it suggests a subsurface geology characterised by alternation of sands and sandy clay occurring at various depth with variable thicknesses.

Also, removal of overburden in areas where saturated sand underlies the bitumen-impregnated layer can lead to "burst out". This is due to the fact that the confined aquifer is under pressure and the removal of the overburden can result in sinking of heavy duty machines and uncontrollable over flooding. Thus, preventive measures are needed during exploitation.

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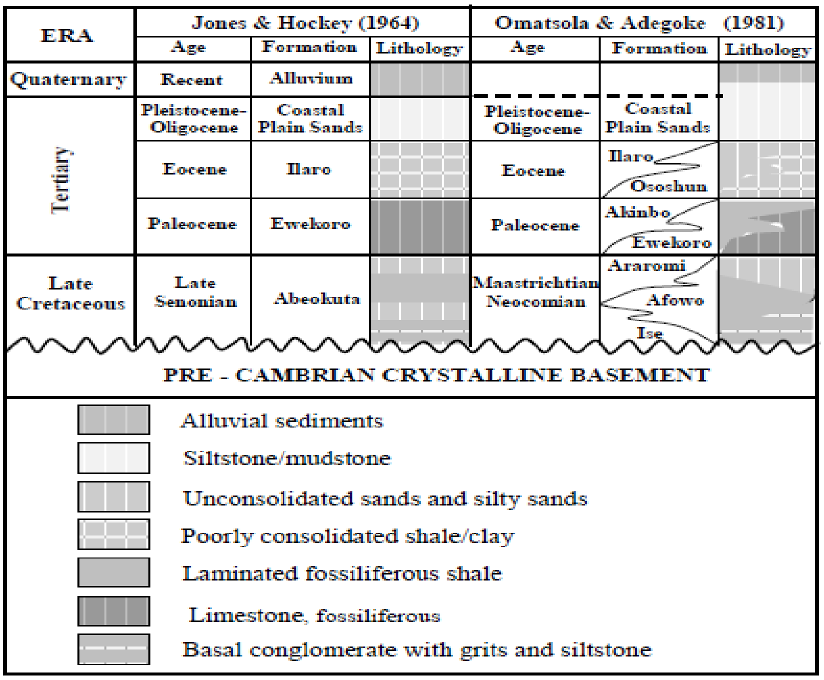

Figure 1: Lithostratigraphic units of the Eastern Dahomey basin

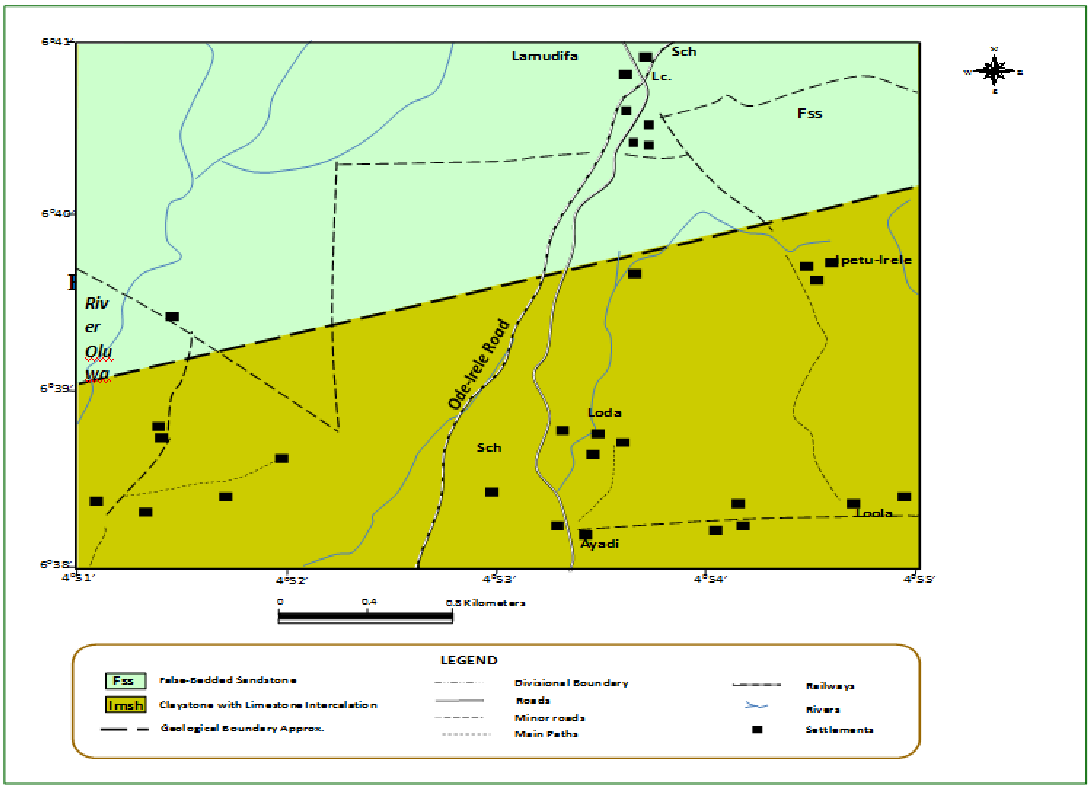

Figure 2: Geological map showing the study area (Loda village)

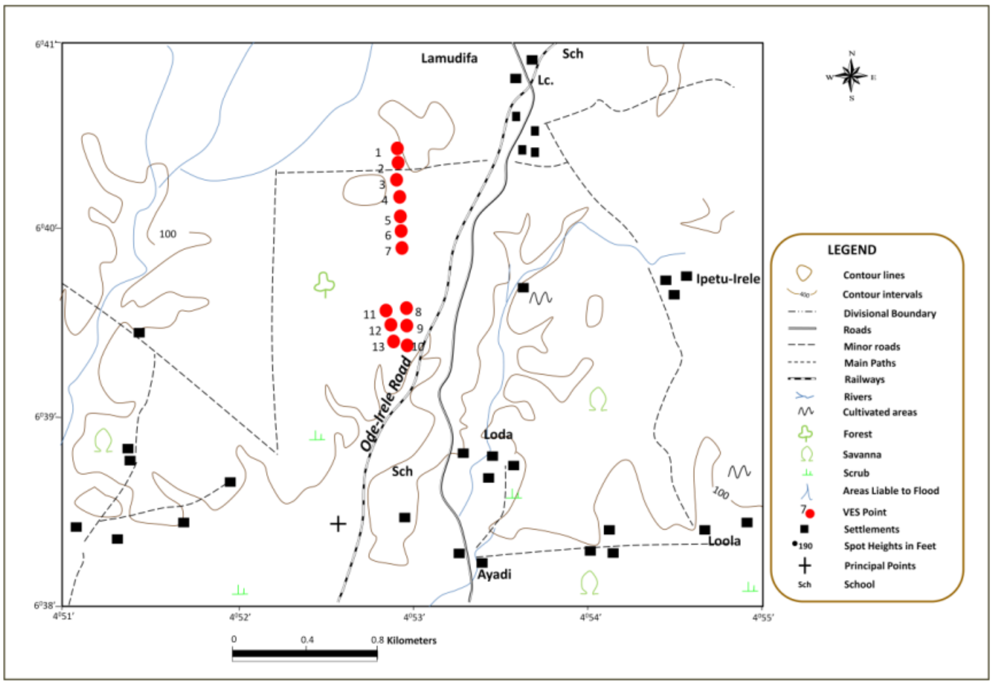

Figure 3: Location map of the study area showing the VES points

Table1. Summary of Geo-electric parameters of VES curve obtained

VES No	**No of Layers**	**Resistivity (Ω-m) $\rho_i/\rho_2/\rho_{n-1}$**	**Curve Type**	**Thickness(m) $h_1/h_2/h_{n-1}$**	**Probable Lithology**
1	4	371/225/898/177	HK	0.8/1/7.7	Topsoil/Sand/Tarsand/Sandyclay
2	4	304/135/1644/48	HK	0.7/1/6.5	Topsoil/Sand/Tarsand/Sandyclay
3	4	995/426/1656/49	HK	0.7/1.8/6.1	Topsoil/Sand/Tarsand/Sandyclay
4	4	822/323/791/80	HK	0.7/1.5/5.6	Topsoil/Sand/Tarsand/Sandyclay
5	4	1148/2932/642/83	KQ	0.8/3.7/13.4	Topsoil/Sand/Tarsand/Sandyclay
6	4	412/2356/386/20	KQ	0.9/3/12.4	Topsoil/Sand/Tarsand/Sandyclay
7	4	174/5429/318/733	KH	0.8/4.6/19.1	Topsoil/Sand/Tarsand/Sand
8	4	735/1614/867/34	KQ	1.8/7.2/6.5	Topsoil/Tarsand/Sand/Sandyclay
9	4	580/2842/1206/95	KQ	0.7/2.5/11.3	Topsoil/Tarsand/Sand/Sandyclay
10	4	283/1599/859/112	KQ	0.9/8.6/1.9	Topsoil/Tarsand/Sand/Sandyclay
11	4	655/922/1262/60	AK	1.1/4.5/3.5	Topsoil/Tarsand/Sand/Sandyclay
12	4	860/1760/790/60	KQ	0.7/3.1/8.3	Topsoil/Tarsand/Sand/Sandyclay
13	4	395/1503/682/21	KQ	0.5/14.8/6.1	Topsoil/Tarsand/Sand/Sandyclay

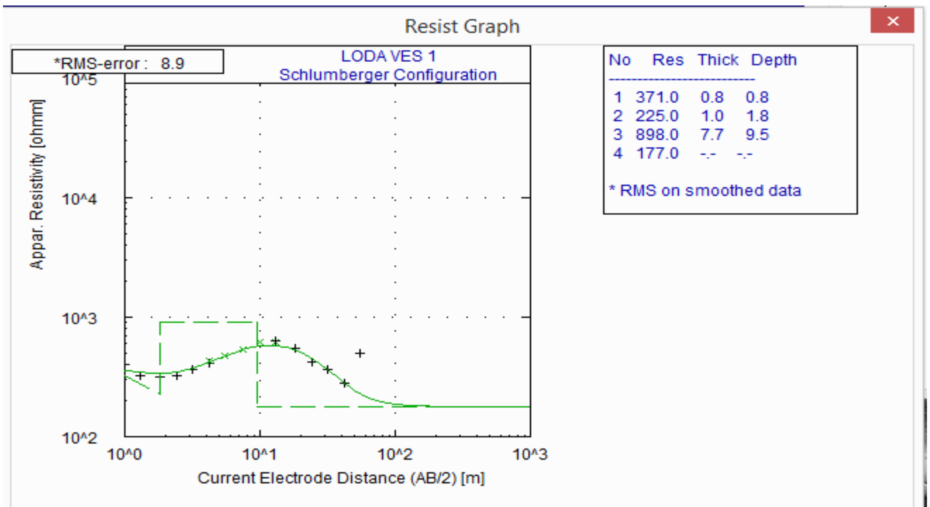

Figure 4a: Typical HK curve-type in the area

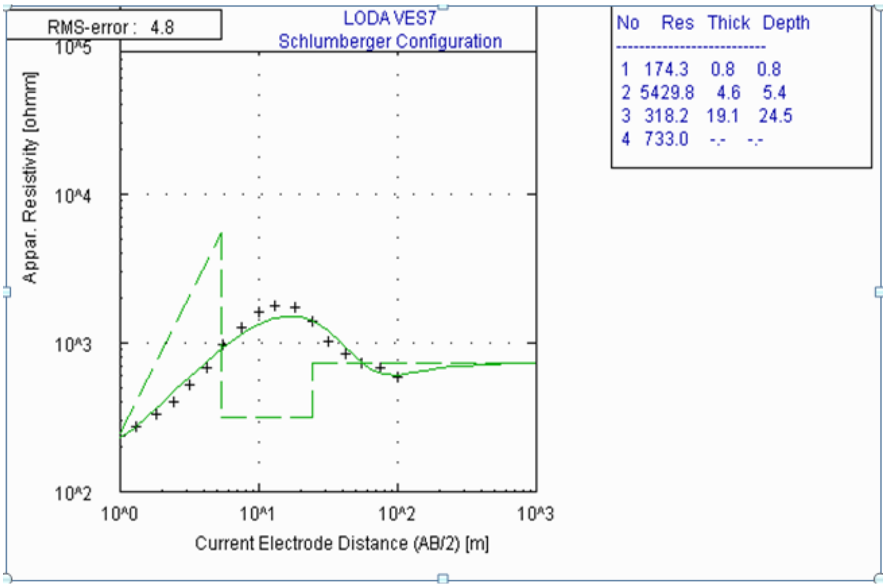

Figure 4b: Typical KH curve-type in the area

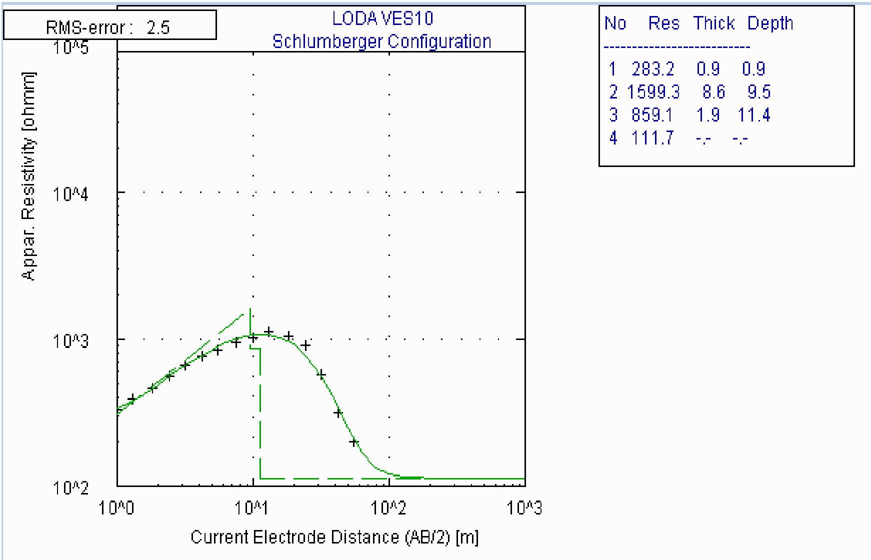

Figure 4c: Typical KQ curve-type in the area

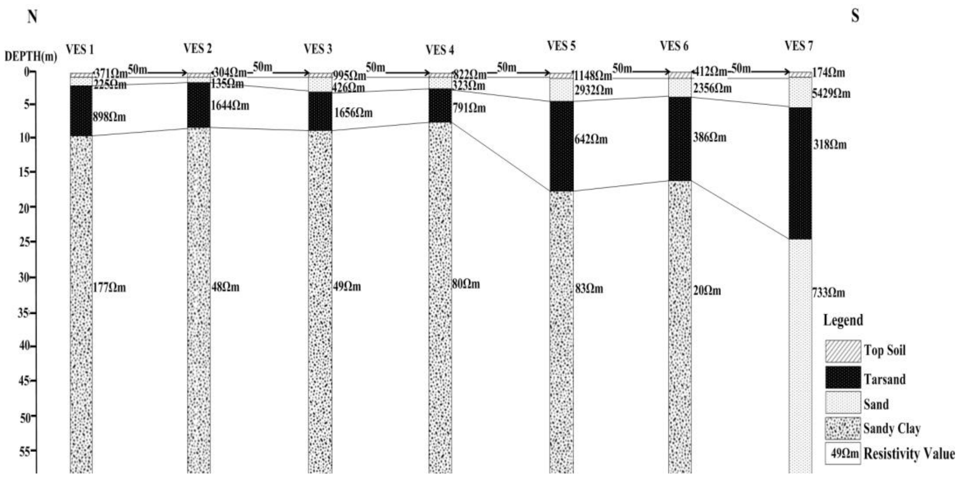

Figure5: Geo-Electric section along Traverse 1 in Looda village

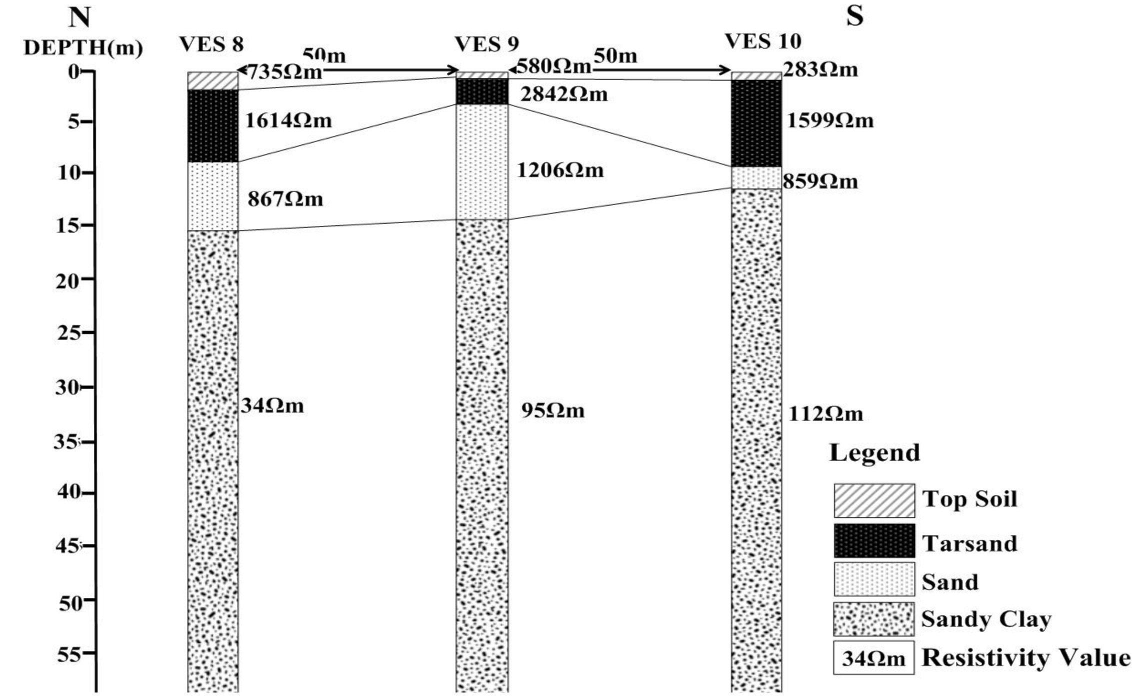

Figure 6: Geo-Electric section along Traverse 2 in Looda village

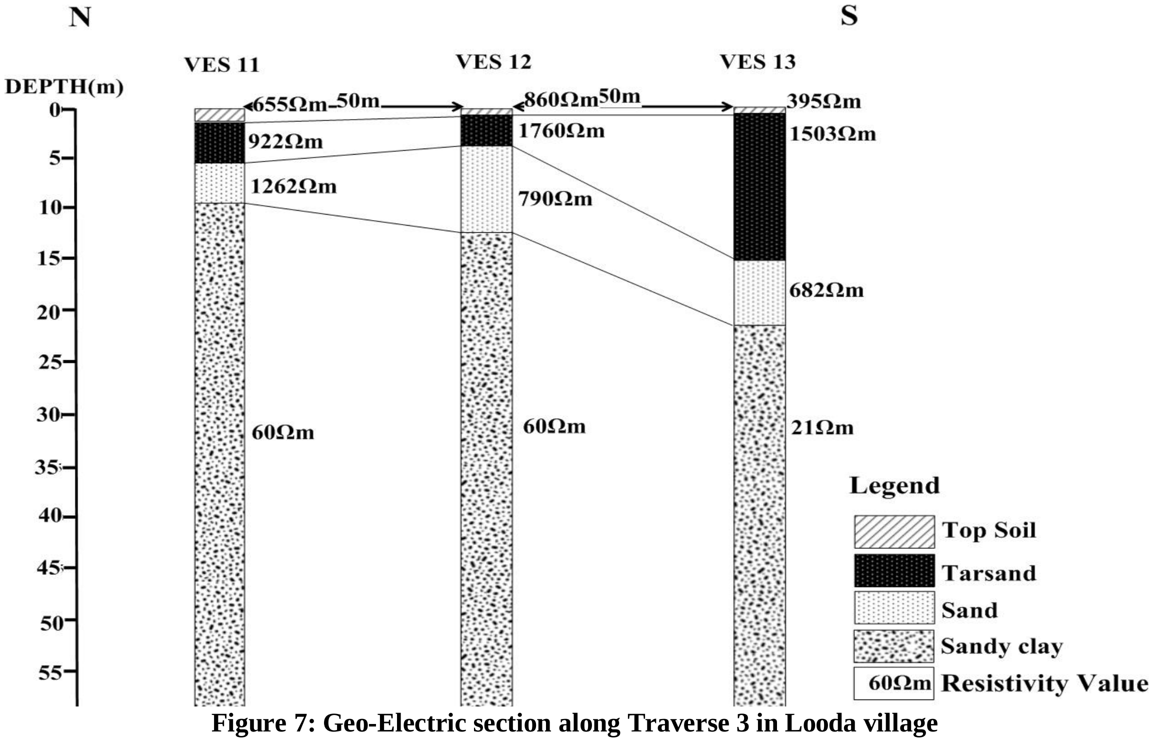

Figure 7: Geo-Electric section along Traverse 3 in Looda village