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A Combination of Electrical Resistivity and Seismic Refraction Surveys for Ground Water Exploration in Basement Region of Ifon, Ondo State, Nigeria

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Abstract: A geophysical survey employing seismic refraction and vertical electrical soundings were carried out in parts of Ifon town and environs using a 24 channel seismograph and Abem Terrameter model SAS 1000B with inbuilt booster. The VES has a maximum current electrode separation of 700m. The result of the surveys has enabled the delineation of the aquifer system of the area. Four to five distinct geoelectric layers were observed namely clay, sand of various types, gravel and fresh crystallic basement with resistivities varying from 62.1Ωm to 18530.0 Ωm with depth ranging from 1.0m to about 150.3m. The seismic sections show two layers with the first layers showing weathered layers while the second layers shows the fresh crystalline basement. Viable boreholes for good portable water should be sited at locations 2 and 5 (Orin-Oyih River Road II and Orin-Oyih Quarry Site II) having a fine Aquifer at a depth of 41.2m and 31.5m respectively.

Key words: Groundwater potential, Vertical Electrical Sounding (VES), resistivity, seismic refraction, aquifer.

INTRODUCTION

The study area Ifon is a region of Ose Local Government Area of Ondo State located in the western part of Nigeria. If lies between latitude 6^0N to 7^0N and longitude 5^0 E to 6^0 E. Ifon is a juncting town with two axes to Edo State on the East and one to the rest of Ondo State. It lies about midway on the federal highway that connects Akure and Benin City. The Town covers a total area of about 5 squares kilometers and belongs to the rain forest belt. The major problem of this area is its lack of sufficient and safe water supply for domestic and industrial uses.

The study is aimed at determing the general water level of Ifon, the different aquifer layers, the thickness of various aquifer layers, the geoelectric properties, the velocities and the depth of the layers, by interpreting the seismic data acquired and ascertain the hydrogeology of the studied area. The study is basically to give the actual depth of subsurface ground water in the area which will aid the proper sitation of wells and the proper drilling of boreholes in the give area of study.

Vertical electrical techniques was chosen for this study because the equipment is simple, field logistics are easy and straight forward and the analysis of data is economical and less tedious than other methods (Zhody et al. 1974).

Resistivity of ground water varies from 0.2 to over 100 m depending on its ionic concentration and the amount of dissolved solids (Ali et al., 1999). Resistivity of natural water and sediments without clay vary from 1.0 to 1000 m while the resistivity of clay alone vary from 1.0 to 120 m (Zhody et al, 1993).

Seismic refraction in based on Snell's law which governs the refraction of sound or light ray across the boundary between layers of different physical properties. As sound waves travel from a medium of low seismic velocity into a medium of higher seismic velocity, some are refracted towards the lowers velocity medium and some are reflected back into the first medium. The refracted waves arrive at the earth's surface where it can be detected by a geophone which generates an electrical signal and sends the signal to a seismograph (Haeni, 1978).

River Oyih is the source of domestic water need for the inhabitants of the study area. However, this river is polluted by activities of the local farmers especially during the dry season for fermentation of cassava, washing of melon, clothes, passing of feaces resulting in unhygienic nature making it unsafe for drinking and domestic use.

Further reading on this area could be seen from the work of Omosuyi et al; 2008, Oladapo et. al; 2004, Ayolabi, 2005 and Atakpo and Akpoborie, 2008.

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Geology of the Study Area:

The study area, Ifon and environs are made of clastic sediment which forms part of the dahomey basin in south western Nigeria. The area is underlain by ferruginised sandstone, quartz, rich sandstone (non-ferruginised), shale, mudstone, clay stone and sandy shale. This clastic sediment underlies migmatitegneiss basement complex as seen in the base of river channels in this area.

The area is dominated by ferrogenous sandstone which is observe to occur along side some shale mudstones and laterite.

The south western basement complex is one of the three basement complexes in the country, the other two are the north central and the south eastern basement complexes. The south western basement complex of Nigeria lies to the rest west African in late pre-cambrian region to early Paleozoic orogenesis. It extends westward and continues till Ghana. The basement complex like the other two basement complexes has five major group of rocks. These are

1. Migmatite-gneiss complex which comprises biotite and biotite horn blende, gneisses, quartzite and quartz schists.
2. Slightly migmatized to unmigmatized paraschist and meta-igneous rock which include schist, quartzite marbles and calcsilicates rocks.
3. Charnockitic rocks.
4. Older granites which comprises rocks varying in composition from granodiorites to true granites
5. Unmetamorphose dolerite dykes.

Vegetation:

The vegetation of Ifon is of the rain forest. The forest has been drastically reduced due to persistent farming, bush burning, building**,** ship construction and local mining. The area is of rural setting and the inhabitants practice peasant farming. They grow cash crop mostly cocoa and palm produce. Some practice mixed cropping such as yam, cassava, melon, maize, pepper, beans, onions, and vegetables. Some of them engage in fishing as part time job from the river available in the town.

MATERIALS AND METHOD

Resistivity Method:

The electrical resistivity method employed in this study is the Schlumberger array configuration. Electrical prospecting makes use of a variety of principles, each based on some electrical properties or characteristics of the materials in the earth (Egbai and Asokhia, 1998). In this method, measurements were made with increasing separation between the electrodes about the midpoint. The instrument used for data acquisition was the ABEM 1000 SAS Terrameter having an inbuilt booster. This equipment has the ability of computing and displaying the apparent resistivity on the subsurface with the input data of the current electrode AB and potential electrode MN separation. The 5 locations are as follows:-

Orin-Oyih River Road 1 – Location 1
Orin-Oyih River Road 11 - Location 2
Orin-Oyih River Road 111 - Location 3
Orin-Oyih Quarry Site1 -Location 4
Orin-Oyih Quarry Site1 -Location 5

The current electrode spread varied from 1.0m to a maximum of 700.0m.

Seimic Refraction Method:

OYO MC seis-160 equipment was used for the recording of the seismic refraction pulses with a chosen field configuration of twenty-four geophones were planted along a multi-core cable which was then connected to the 24-channel seismic recorder pot of the equipment. The distance within the geophones is 3.0m each.

The sledge hammer was used as the source of energy. The trigger metal and base-metal plate were placed and every connections intact. The seismic refraction pulses were recorded for the forward shots, reverse and split shots.

The observed field data (table 1) were used to produce depth sounding curves. The qualitative interpretation of field sounding curves were subjected to partial curve matching techniques using two layer apparent resistivity curves. The sounding curves were obtained as a result of plotting the apparent resistivity values from the field work against electrode spacing. The results of the curved matched values were iterated using the resist software (Vander Velpen, 1988).

The computer modeling utilized the quantitative interpretation (curve matching) result to obtain the layer resistivities and thicknesses of the subsurface under investigaton. This is shown in table 2.

Table 1: Field Data Obtained with Abem Terrameter 1000 SAS.

S/N	Current Electrode Spread AB/2 (m)	Potential Electrode MN/2	Geometric Factor K	VES1 (App. Resistivity ℓ(m)	VES 11 ℓ(m)	VES 111 ℓ(m)	VES IV ℓ(m)	VES V ℓ(m)
1	1	0.5	6.28	200	410	220	185	864.40
2	2	0.5	25.13	296	386	270	160	716.10
3	3	0.5	56.55	348	371	340	138	531.83
4	4	0.5	100.53	400	330	430	120	394.51
5	6	0.5	226.19	480	250	600	102	260.65
6	6	1.0	113.10	480	250	600	102	260.65
7	9	1.0	254.47	550	222	900	110	221.17
8	12	1.0	452.39	631	218	1180	128	222.83
9	15	1.0	706.86	650	230	1450	149	241.01
10	15	2.0	353.45	650	230	1450	149	241.01
11	25	2.0	981.75	685	320	2200	255	324.18
12	32	2.0	1608.05	575	380	2800	330	384.69
13	40	2.0	2513.57	551	440	3400	400	451.85
14	40	5.0	1005.31	551	440	3400	400	451.85
15	65	5.0	2654.65	528	600	4800	600	644.72
16	100	5.0	6283.19	520	800	6250	800	874.88
17	100	10.0	3141.59	520	800	6250	895	874.88
18	150	10.0	7068.59	550	1000		895	1137.34
19	200	10.0	12566.37	640	1200			
20	200	20.0	6283.19	640	1200			
21	250	20.0	9817.48	750	1400			
22	300	20.0	14137.17	900	1500			
23	350	20.0	19242.26		1600			

Table 2: Summary of Iteration Results.

Location	Ves	Layer	Thickness (M)	Depth (M)	Resistivity Ωm	Lithology	Curve Type
1	I	1	1.0	1.0	189.5	Clayey sand,Fine grain sand,	KA
		2	13.6	14.6	749.5	Silty sand,Coarse grained	
		3	135.8	150.3	468.9	sand	
		4			4457.3		
2	II	1	1.0	1.0	434.2	Silty sand Clayey sand	QA
		2	3.3	4.3	315.9	Clay Fine grain sand	
		3	4.0	8.3	98.6	Coarse grained sand	
		4	32.9	41.2	651.8		
		5			2451.6		
3	III	1	0.9	0.9	213.3	Clayey sand Silty sand	A
		2	1.4	2.3	352.8	Coarse grain sand	
		3	5.1	7.4	2672.8	Gravel sand	
		4	22.9	30.4	14169.6	Fresh crystalline basement	
		5			18530.0		
4	IV	1	1.0	1.0	195.2	Clayey,sand,Clay sand,	QA
		2	2.2	3.1	115.9	Clay,Clayey sand,	
		3	2.7	5.8	62.1	Coarse grained sand	
		4	6.1	11.9	218.0		
		5			2595.3		
5	V	1	1.5	1.5	900.0	Fine grained sand	HA
		2	10.0	11.5	175.0	Clayey sand	
		3	20.0	31.5	800.0	Fine grained sand	
		4			2500.0	Coarse grained sand	

Table 3: Summary of Seismic Refraction Result.

Location	V_1 (ms)	V_2 (m/s)	Z (m)	T(s)$\times 10^{-3}$
1	340.80	1125.95	6.59	36.88
2	408.25	1270.50	6.97	32.33
3	521.08	1003.41	4.30	28.50
4	375.30	1395.85	8.70	21.95

The seismic data obtained from the field were used to plot time-distance (t vs x) graphs. The slopes were obtained from the graphs which are the inverse of the velocities. The intercept times were also determined from the graph as shown in the fig 6. The variables, wave velocities and intercept times were used to calculate the depth (Z) of each layer.

$$z = \frac{t_1 t_1 t_1}{\sqrt[2]{v_2^2 - v_1^2}}$$

where t_1 = intercept time
Z = depth of each layer
V_1 and V_2 = velocities in layers 1 and 2

The results obtained from the computer modeling, seismic refraction as well as their geoelectric sections are presented as shown. Their corresponding curves are equally presented.

The average velocities of the various spread, interpret time, and their corresponding distance were calculated and shown in Table 3.

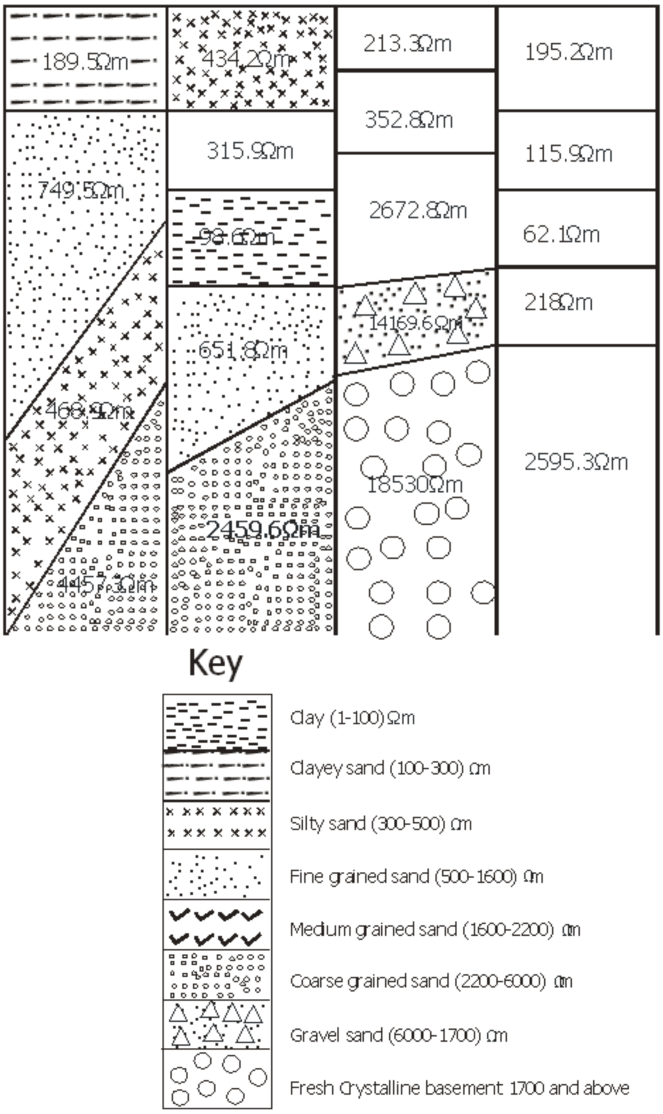


Fig. 1: Geoelectric section of ifon lithology.

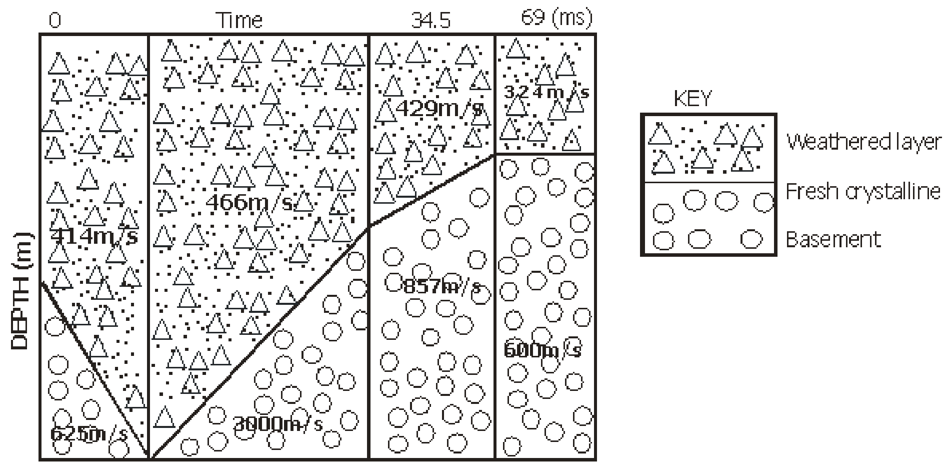


Fig. 2: Seimic section for Orin Oyih River II (Location 2) (Not draw to scale).

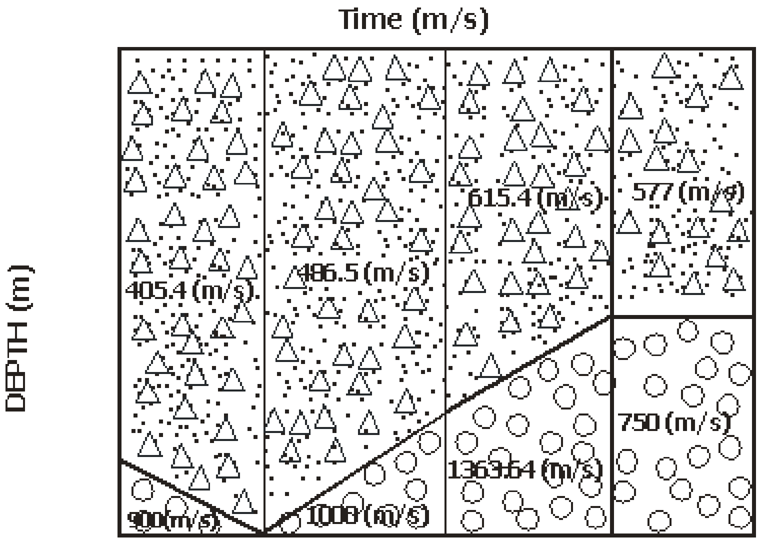


Fig. 3: Seimic section for Orin Oyih Quarry Site I (Loc. 3).

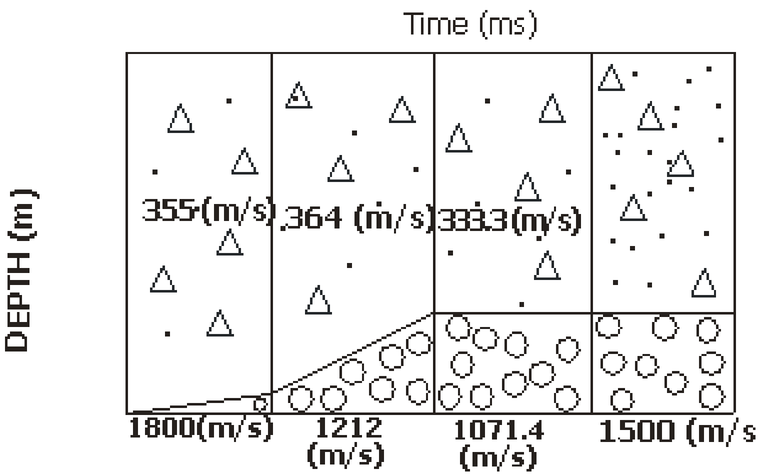


Fig. 4: Seimic section for Orin Oyih River Road III.

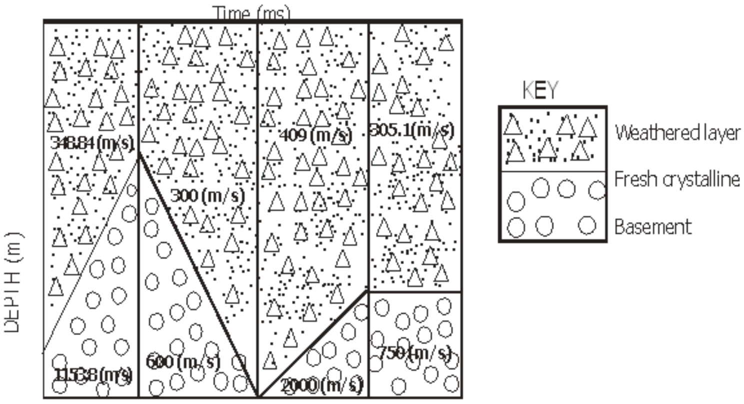
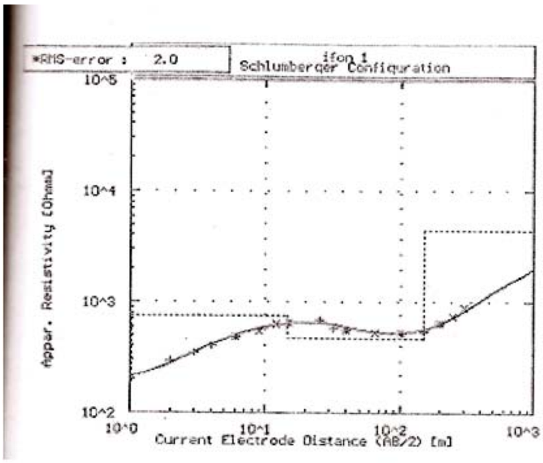
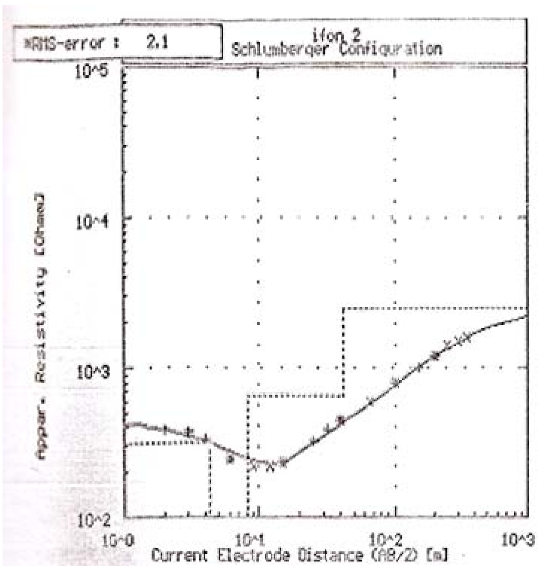


Fig. 5: Seimic section for Orin Oyih River Road I, Ifon.



No	Res	Thick	Depth
1	189.5	1.0	1.0
2	749.5	13.6	14.6
3	468.9	135.8	150.3
4	4457.3	-.-	-.-

* RMS on smoothed data



No	Res	Thick	Depth
1	434.2	1.0	1.0
2	315.9	3.3	4.3
3	98.6	4.0	8.2
4	651.8	32.9	41.2
5	2451.6	-.-	-.-

* RMS on smoothed data

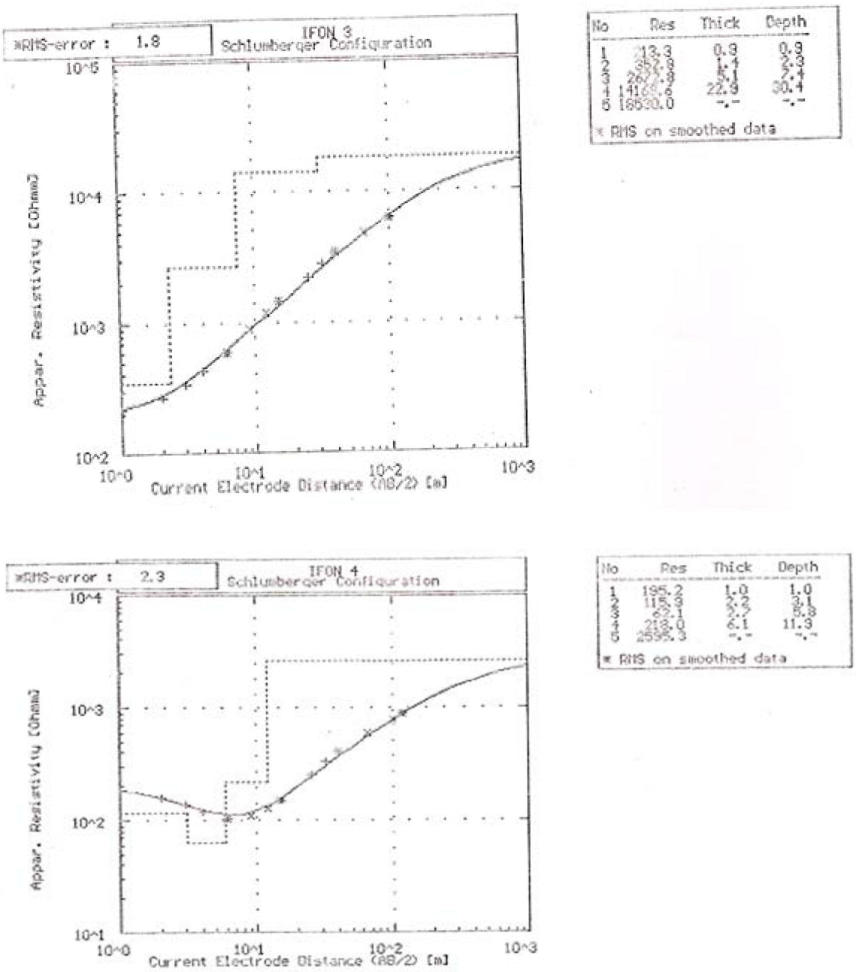


Fig. 6: Typical sounding curves for the four locations.

RESULTS AND DISCUSSION

The interpreted sounding curves (Figure 6) show the resistivity, thickness, layer and curve type for the five VES locations (Table 2). Five VES curves whose layer varies from 4 to 5 were analyzed. The curve are of KA, QA, A, and HA type.

Location 1 has 4 distinct layers having very low resistivity of 468.9Ωm at the third layer. The aquifer in these location has a depth of about 150.3m. The lithology shows silty sand. The water from this location may not be good due to the silty nature of the aquifer. Boreholes within this location contain mineralized water (Selemo et al 1995).

Location 2 is characterized by QA-type curve showing five distinct layers from the geoelectric section. The third layers have a very low resistivity of 98.6Ωm at a depth of 8.2m made of clay. The very fine aquifer is located in the fourth layer having a resistivity of 651.8Ωm made of granied sand at a depth of 41.2m

Location 3 is made of A-type curve showing increasing resistivity. The fifth layer shows a fresh crystalline basement which is a major characteristics of the lithology of Ifon. This location is not good for sitting boreholes.

Location 4 is characterized by AQ-type curve consisting of five layers. The third layer has a resistivity of 62.1Ωm at a depth of 5.8m. This layer is made of clay. The fourth layer has a resistivity of 218.0 m at a depth of 11.8m where the aquifer is located. The aquifer is not a good one because it is within the range of silty sand and as such the water could be mineralized.

Location 5 is of the HA type curve consisting of four layers. This is made of top soil fine grained sand having a resistivity of 900.0Ωm at a depth of 1.50m followed by clay sand whose resistivity is about 175.0Ωm at a depth of 11.5m. The aquifer is within the third layer whose resistivity is 800.0Ωm at a depth of 31.5m.

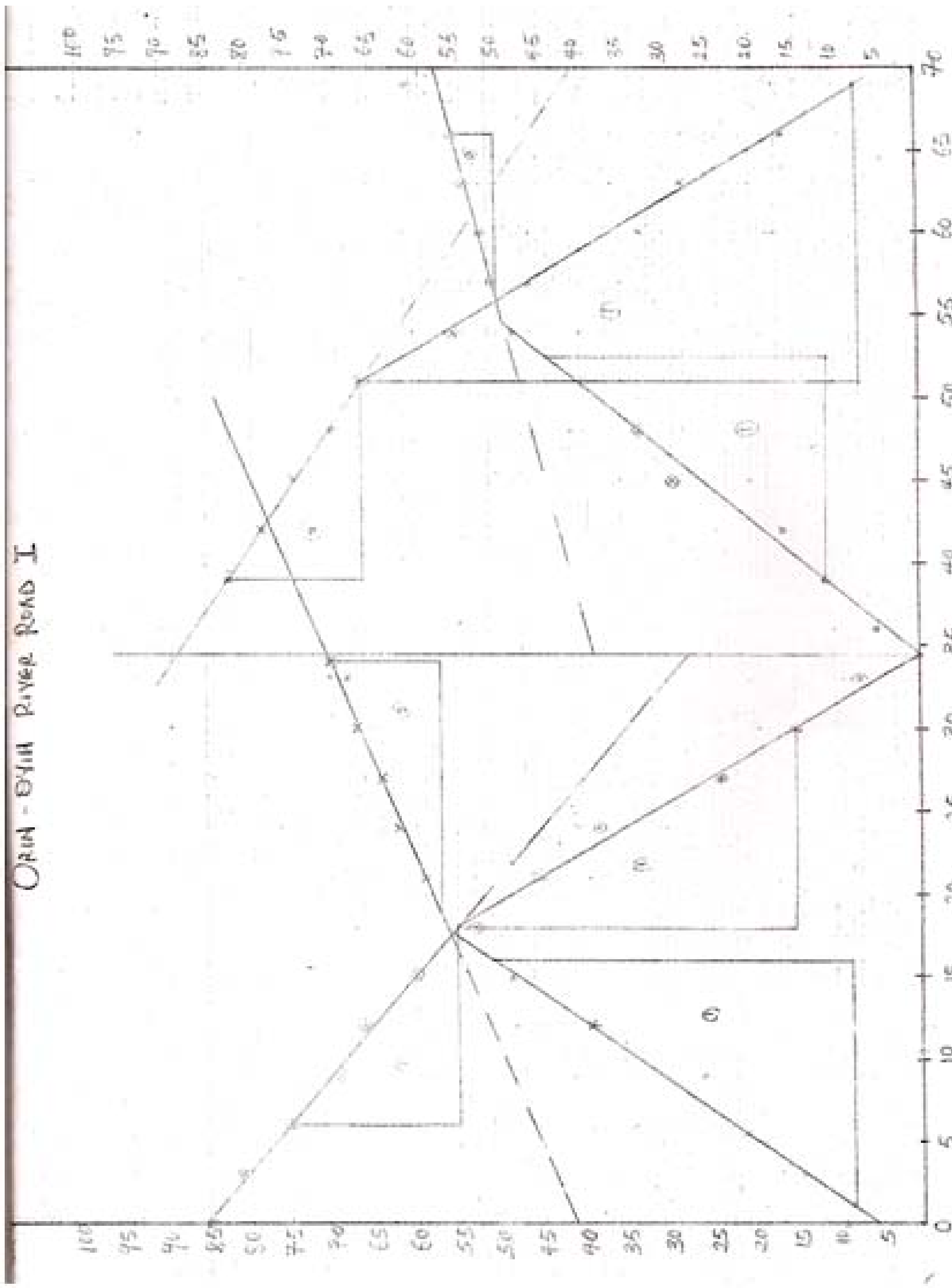


Fig. 7: Time distance graph of seismic refraction of Orin Oyih River Road I, location 1(p8).

The lithology is fine grained sand having good subsurface water.

The seismic sections show two layers with the first layer showing weathered layer, while the second layer shows the fresh crystalline basement. The velocities of the first layer for the four locations (1-4) is within the range of 340.0m/s to 521.08m/s. The second layer has velocities varying within 1003.41m/s to 1395.85m/s. This is as shown in table 3.

Conclusion:

This paper basically describes the use of surface electrical and seismic surveys in delineating the subsurface formation in the basement area of Ifon Community of Ondo State, Nigeria. The results of the surveys have enabled the delineation of the aquifer system of the area. Four to five distinct geoelectric layers

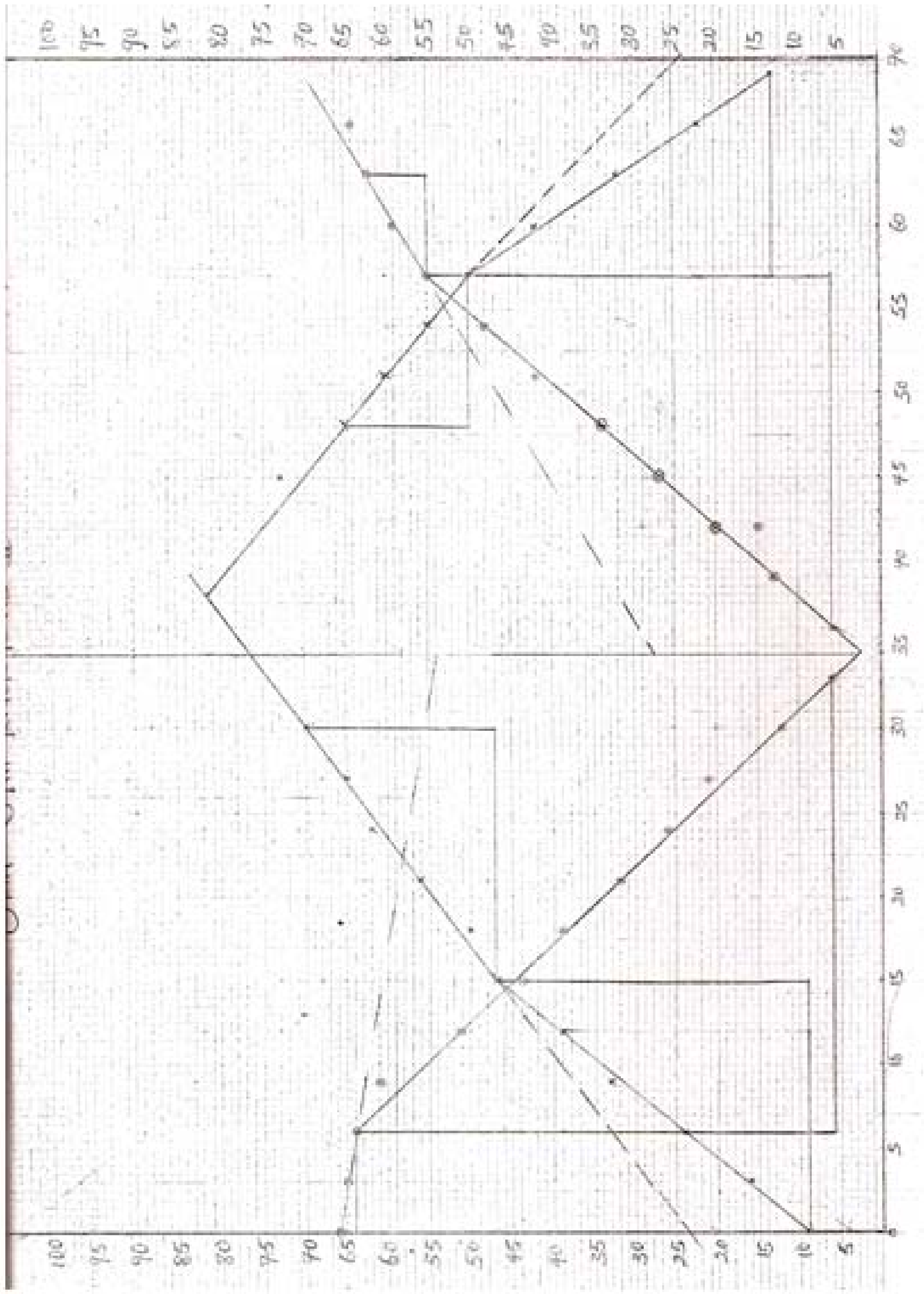


Fig. 8: Time distance graph of seismic refraction of Orin Oyih River Road II, location 2(p9).

were observed namely clay, sand of various types, gravel and fresh crystalline basement with resistivity varying from 62.1Ωm to 18530.0Ωm with depth ranging from 1.0m to about 150.3m. These layers are in agreement with the borehole log and lithology log of the area. A borehole drilled recently in location 2 is in high agreement with the result of VES survey.

From the seismic investigation and VES results, the Orin-Oyih River Road and the quarry site areas contain thick over burden (decomposed rocks), frequent fracture and fault zones which are required for ground water in basement areas. It is reasonable to assume that zones with light thickness of decomposed rocks are due to intense fracturing of the basement having the highest permeability with greater depth where the clay content from the weathered basement in very low. Therefore, it is very important that the boreholes should be drilled down to the fresh bedrock, the depth indicated by the seismic investigation.

Viable boreholes for good portable water should be sited at locations 2 and 5(Orin-Oyih River 11 and Orin-Oyih Quarry Site 11) having a fine aquifers at a depth of 41.2m and 31.5m respectively.

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