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Geophysical Investigation of Groundwater Potential in Akamkpa Area Cross River State Southern, Nigeria using Refraction Seismic and GPR Methods

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Abstract: Refraction seismic and GPR survey were carried out in Akamkpa area, Cross River State within latitude 5°00'N to 5°48'N and longitude 8°12'E to 9°00'E to delineate aquiferous zones for ground water potentials. The study area is part of Oban Massif Basement complex which is overlain by cretaceous-tertiary sediment of Calabar Flank. The metamorphic rock units in the area are: Phylites, Schists, Gneisses and Amphibolites. These rocks are intruded by pegmatites, granites, granodorite, diorite and dolerite. The refraction seismic survey was done in three (3) traverses with length 1km. From the results obtained, it was observed that the velocities of the first layer in the three (3) traverses varied from 300m/s to 380m/s with depth between 0.5m to 1.8m, this indicated the weathered layer top soil. The second layer velocities varied from 624m/s to 746m/s with depth between 1.8m to 9.8m, lateritic rocks were observed, the third layer velocities varied from 1058m/s to 1204m/s with depth between 5.8m to 18.2m, with sand/sandstone observed. The last layer was made up of granite with velocity up to 1805m/s at depth of 18.2m below. Only four geologic layers were observed. From the GPR survey, profile 1 and 2 showed four distinct geologic layers with average velocities of 8cm/ns, 8cm/ns, 12cm/ns and 16cm/ns respectively and electrical conductivity of 7.75 Ωm^{-1}, 16.2 Ωm^{-1}, 26.5 Ωm^{-1} and 35.5 Ωm^{-1} respectively. Profile 3 indicated three geologic layers with velocities 3cm/ns, 7cm/ns and 13cm/ns respectively. From the study, productive borehole with good drinking water is expected to be within 30m to 50m (100ft-165ft) depth.

Key words: Pegmatites · Granites · Granodorite · Diorite · Dolerite and Conductivity

INTRODUCTION

Akamkpa area is part of Oban Massif basement complex, southern Nigeria. The inhabitants of this area reside in scattered hamlets, villages and small towns. They are mostly farmers; water demand in the area is mainly for domestic and agricultural uses. Majority of the people depend on shallow dug wells and streams which are mostly seasonal. The streams are also generally remote, polluted and hazardous. Most of the natural resources in the Cross River State occur in Akamkpa area [1]. Presently, there exist oil palm and rubber plantations, quarries and holiday resorts. There is also a game reserve manage by the World Wildlife Fund (WWF) and funded by the United Nation in the area. These existing facilities and the need to provide portable water to rural dwellers, therefore, prompted the quest to develop water resources within the area. The work aimed at using a combination of refraction seismic and radar imageries in Akamkpa to delineate aquiferous zones so that productive boreholes can be drilled within the area.

The main objectives and end product of any seismic work is the ability to interpret seismic data in geological terms [2]. In most seismic refraction techniques, the assumption lies on the value of the velocity (V_1) of the section above the refractor. This is because of the heterogenous composition of the superficial deposit which make the overburden velocity rarely constant, [2, 3].

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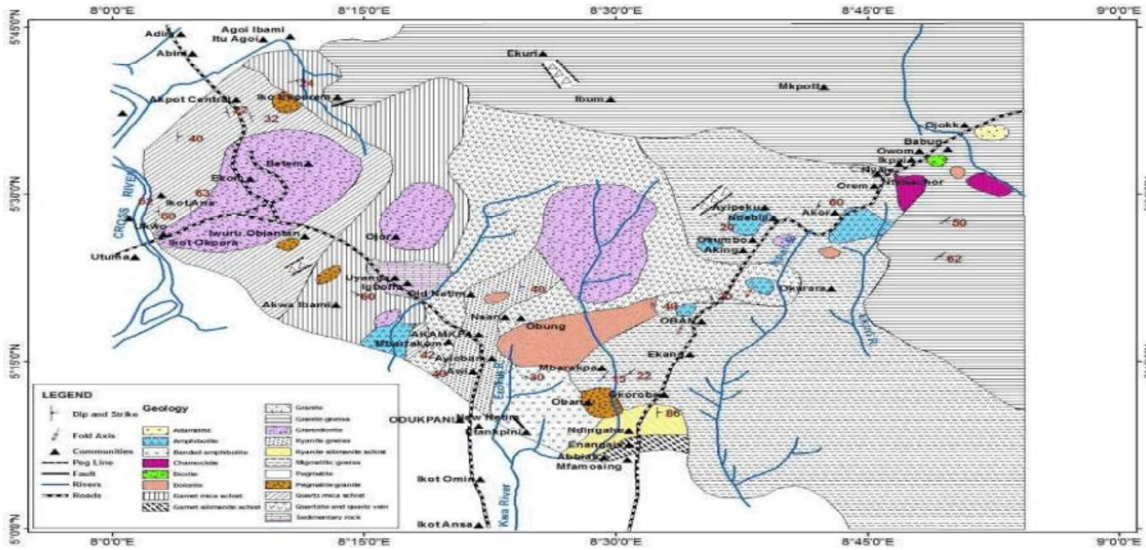


Fig. 1: Geologic Map of Oban Massif

Akamkpa area is part of the Precambrian Oban Massif, which is overlain by cretaceous-Tertiary sediments of the Calabar Flank. The metamorphic rock units in this area are: phylites, schists, gneisses and amphibolites. These rocks are intruded by pegmatites, granites, granodiorites, diorites, tonalites, Monzonites and dolerites [4]. Associated with the rocks are charnokites which occur as enclaves in gneisses and granodiorites (Fig. 1).

These rocks record three phase of tectono-thermal events which have affected the Nigerian basement with the most resent being the Pan-African Orogeny dating about 600±150 Ma ago. The main results of the deformation include fractures, faults, folds and dykes trending N-S, NE-SW and NW-SE directions. Similar trends characterized major lineaments revealed by remote sensing and aeromagnetic interpretation [1].

Methodology: The geophones were laid 2m apart and were connected to geophone cable; a trigger was connected to a 2kg hammer. The geophone cable was then connected to seismogram. When the hammer hits the metal plate, the geophones will give out seismic waves, the seismograph records the signals received from the geophones and were displayed on a computer. The group geophones were used to filter noise, battery was used to power the seismogram. P-waves were generated. Forward and reverse shooting were done. The penetration was not too deep, since hammer shooting was used instead of dynamites. At each shot point the arrival times for each of the geophone were recorded. IXRefraX and Seisimager software was used to analyze the data.

The slopes of the graphs were used to calculate the velocities and the depth to the refractors were calculated using the equations below:

$$Z_1 = \frac{t_1 V_1\ V_2}{\sqrt[2]{V_2^2 - V_1^2}} \quad (1)$$

$$Z_2 = \frac{t_1 V_2\ V_3}{\sqrt[2]{(V_3^2 - V_2^2)}} \quad (2)$$

Seismic velocity information was correlated with rock type and used in identifying subsurface materials. Due to overlapping of velocities for different rocks, the identification of rock type was exclusively on velocity. It can however be used in a small area where range of velocity is small and therefore certain rocks can be identified based on velocity.

The processing of the data is often based on the first arrivals, since it permits accurate interpretation and easy recording of their travel times. The Wyrobek method [5] was used to analyze the data in this study. This uses graphic aids to facilitate the routine computations. Based on the Wyrobek's approach [5] a plot of the travel time (T) versus the detector position of all the receiving stations along each traverse was obtained.

For GPR survey, an electromagnetic micro pulse was emitted into the earth by a transmitting antenna. The electromagnetic waves were propagated into the subsurface and reflected from boundary layers or buried objects (targets) of variable density. The reflected waves were detected by receiving antenna, amplified and processed. The amplified waves were digitally recorded by the digital recorder. GPR measurements were done in three profiles; the measurements were recorded by maintaining a fixed distance between the transmitting antennas and receiving antenna along the survey measurement line. The GPR survey grid was established in each entry area with survey line trending N-E direction. Three survey lines were established each approximately 1000m (1km) long and spaced 1m apart.

Radexplorer 1.4 Software was used on the GPR data processing to show the amplitude maps and rock types. The recommended processing stages were employed; which includes range gain, band-pass filtering, frequency filtering, spectral whitening, background removal, migration, Hilbert transformation, deconvolution, smoothing, stacking and finally, re-sampling of processed digital data to produce the final images [6-8].

The usual final product of GPR mapping involves the presentation of amplitude images that are product of a computer analysis of thousands of reflection “anomalies” [9]. In the GPR method, individual wiggle trace (as seen in Fig 14a & b, 15a & b and 16a & c) are used to produce reflection profiles, which are then re-sampled to generate amplitude slice map (Fig. 14d, 15e and 16b). Each of these processing steps produces important images that must be understood, integrated and analyzed in conjunction during interpretation. The nature of the ground and geological features were defined and understood.

The wiggle traces and profile were used to delineate the lithological units as seen in the radargram plots. The wiggle traces shows the amplitude reflections of the different layers [10]. Wiggle traces/profiles in amplitude slicing methods were used to generate anomalies at vary depths from one horizon within different slices in the ground.

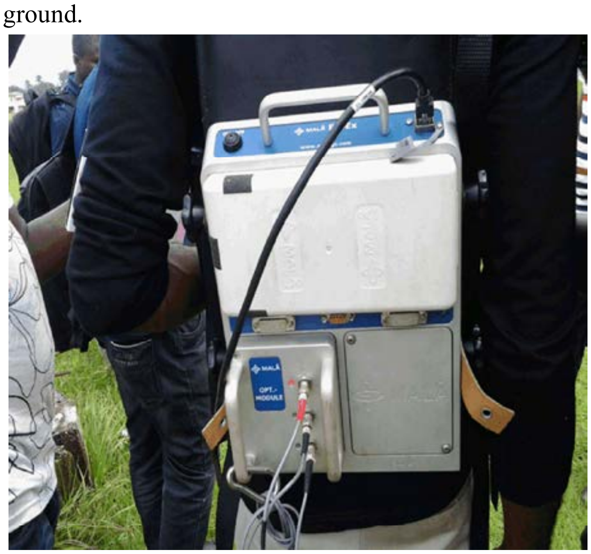


Plate 1: Ground Penetrating Radar Equipment

Plate 2: Transmitter and Receiver Antenna to the Radargram and Monitor (Field Lay Out)

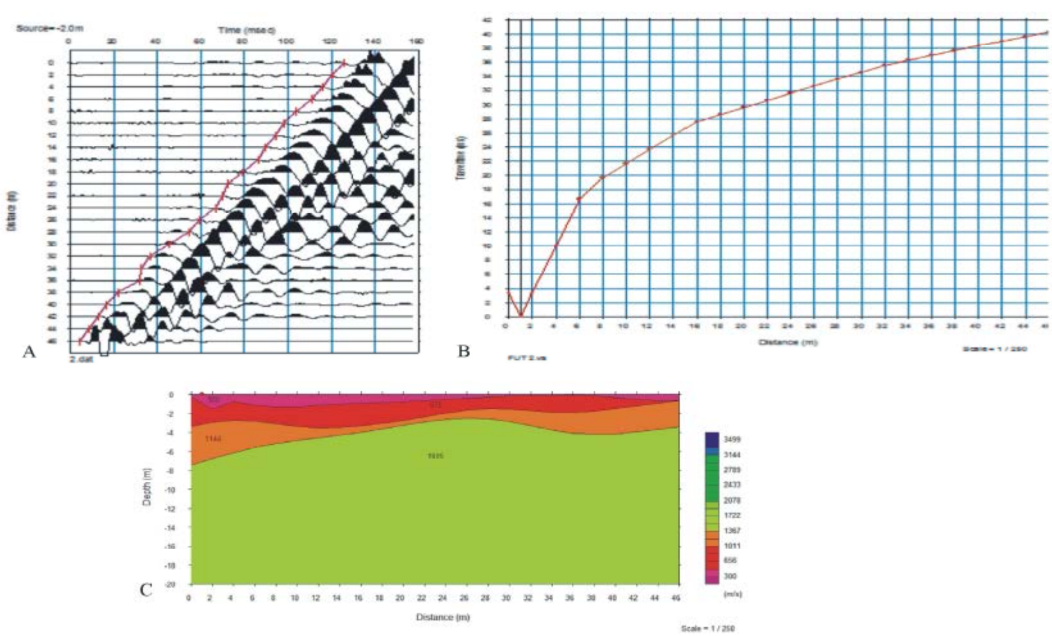
Plate 3: Seismogram Connected to Monitor

Plate 4: Geophone Cables connected to Seismogram

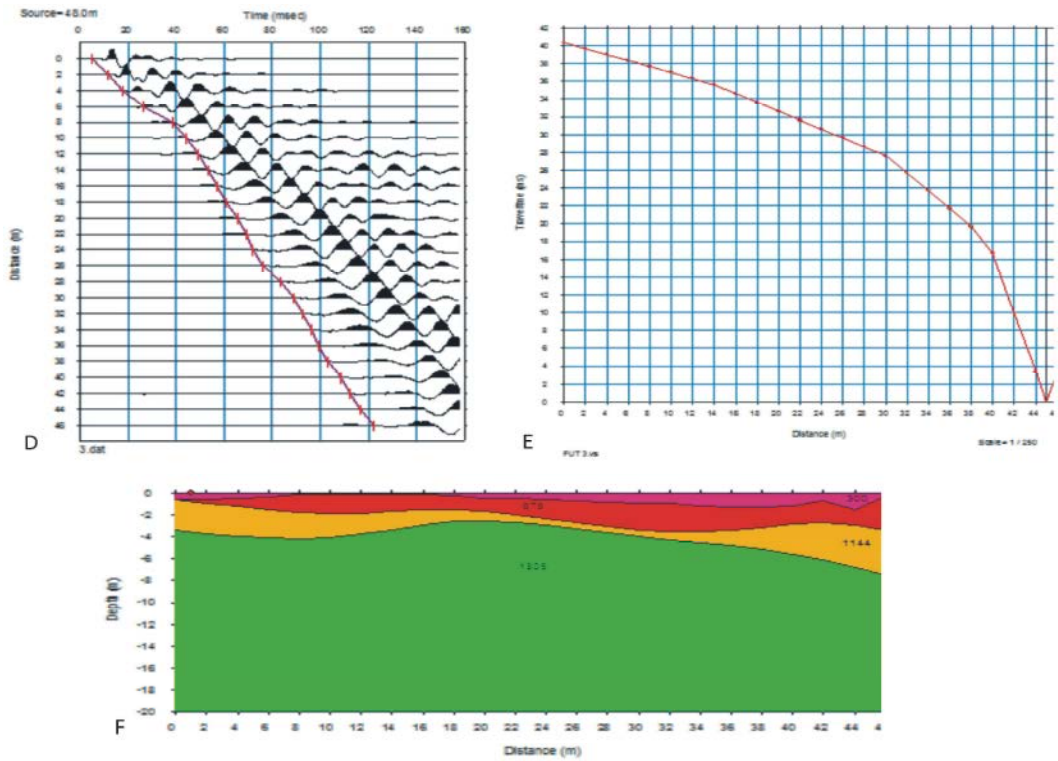
RESULTS

Seismic Refraction: The slope of these graphs were used to obtain the average velocities V_1, V_2, V_3, etc. for both the first layer and the refractors. The intercept time was also determined from the graph. To obtain the depth to refractor at each shot point, the intercept time is divided by two to give the half - intercept time often called the delay time D. Values of the delay time D at each shot point is thus multiplied by an appropriate factor F to obtain the depth.

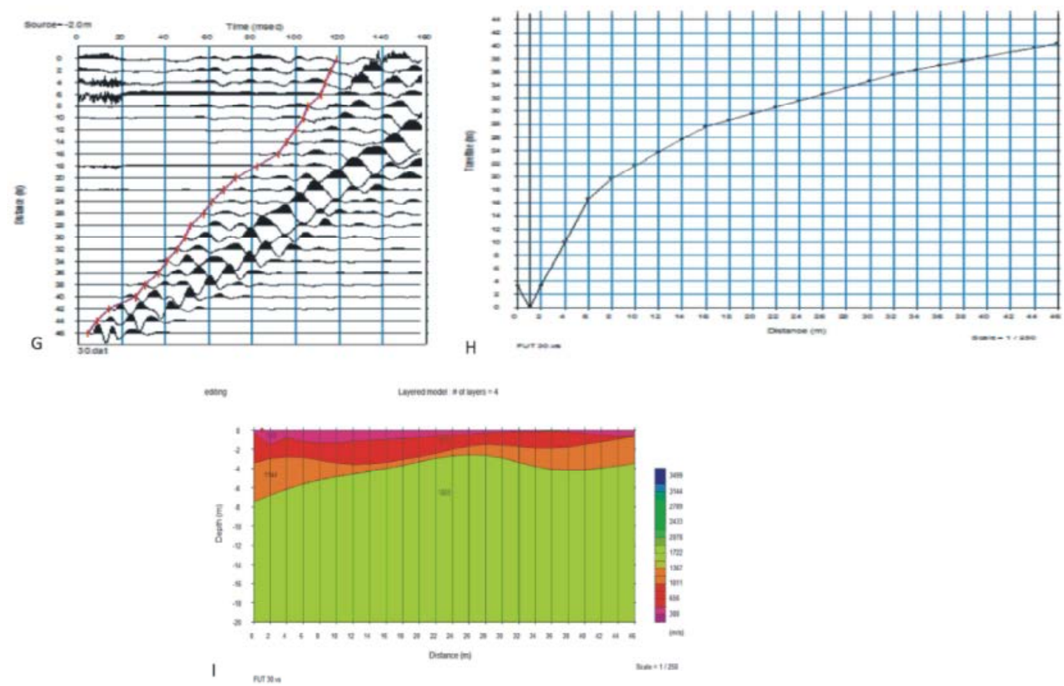
TRAVERSE: 1			TRAVERSE: 2			TRAVERSE: 3	
X(M)	T(ms)F	T(ms)R	X(M)	T (ms)F	T (ms)R	X(M)	T(ms)F
2.00	5.00	125.75	2.00	124.31	118.91	0.00	220.83
4.00	11.72	120.50	4.00	119.57	116.25	5.00	217.28
6.00	17.64	116.25	6.00	117.00	113.75	10.00	216.36
8.00	26.07	111.00	8.00	110.50	111.53	15.00	212.80
10.00	38.84	103.75	10.00	105.87	105.87	20.00	211.35
12.00	43.85	98.50	12.00	101.92	103.50	25.00	205.30
14.00	48.98	94.55	14.00	97.75	100.21	30.00	192.79
16.00	53.46	89.41	16.00	91.25	95.73	35.00	188.31
18.00	56.75	86.51	18.00	86.51	91.91	40.00	175.53
20.00	60.57	79.01	20.00	82.04	82.30	45.00	170.25
22.00	65.71	72.50	22.00	74.53	72.55	50.00	151.70
24.00	69.26	69.75	24.00	72.16	67.16	55.00	138.93
26.00	71.90	67.00	26.00	68.87	61.49	60.00	127.34
28.00	76.11	59.65	28.00	60.57	57.54	65.00	119.83
30.00	83.75	54.65	30.00	57.28	51.35	70.00	109.43
32.00	89.15	45.25	32.00	52.54	48.98	75.00	99.29
34.00	92.50	36.50	34.00	48.32	45.43	80.00	90.99
36.00	96.39	32.25	36.00	43.85	40.55	85.00	80.19
38.00	99.55	31.50	38.00	39.11	36.47	90.00	70.50
40.00	103.00	21.75	40.00	35.81	30.81	95.00	61.23
42.00	108.90	16.50	42.00	31.34	26.60	100.00	52.80
44.00	112.06	13.00	44.00	27.52	13.82	105.00	42.13
46.00	116.27	8.50	46.00	12.64	8.75	110.00	31.73
48.00	122.20	4.00	48.00	8.00	4.00	115.00	11.50



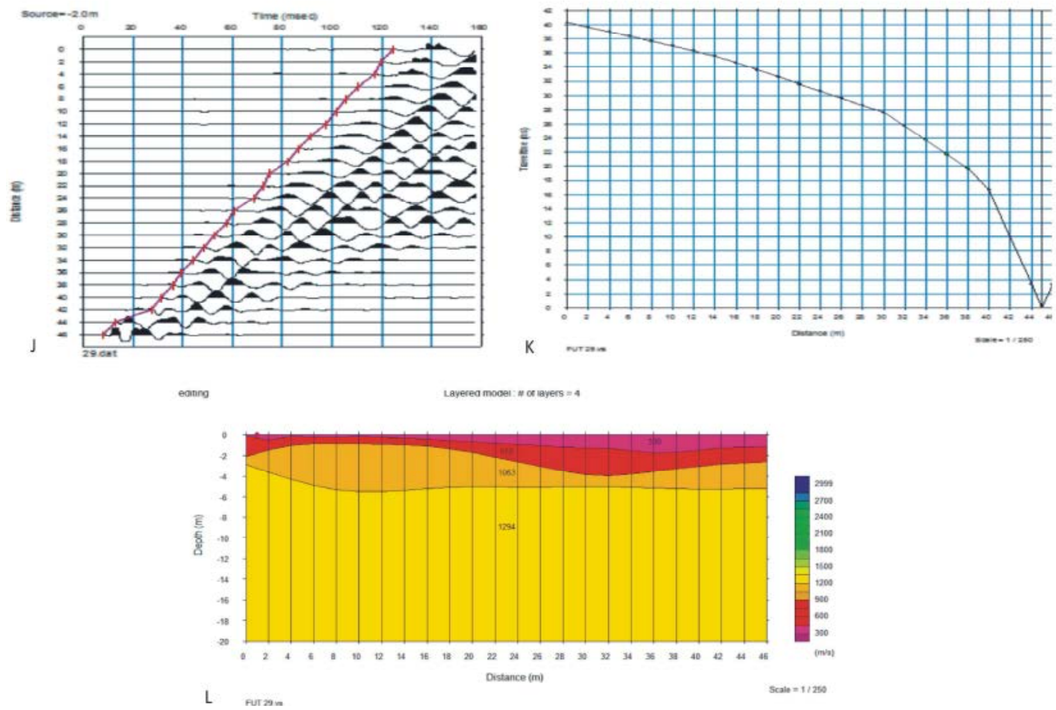
A. Traverse 1 wiggle trace (forward shooting)
B. Traverse 1 data plot (forward shooting)
C. Traverse 1 layer model (forward shooting)



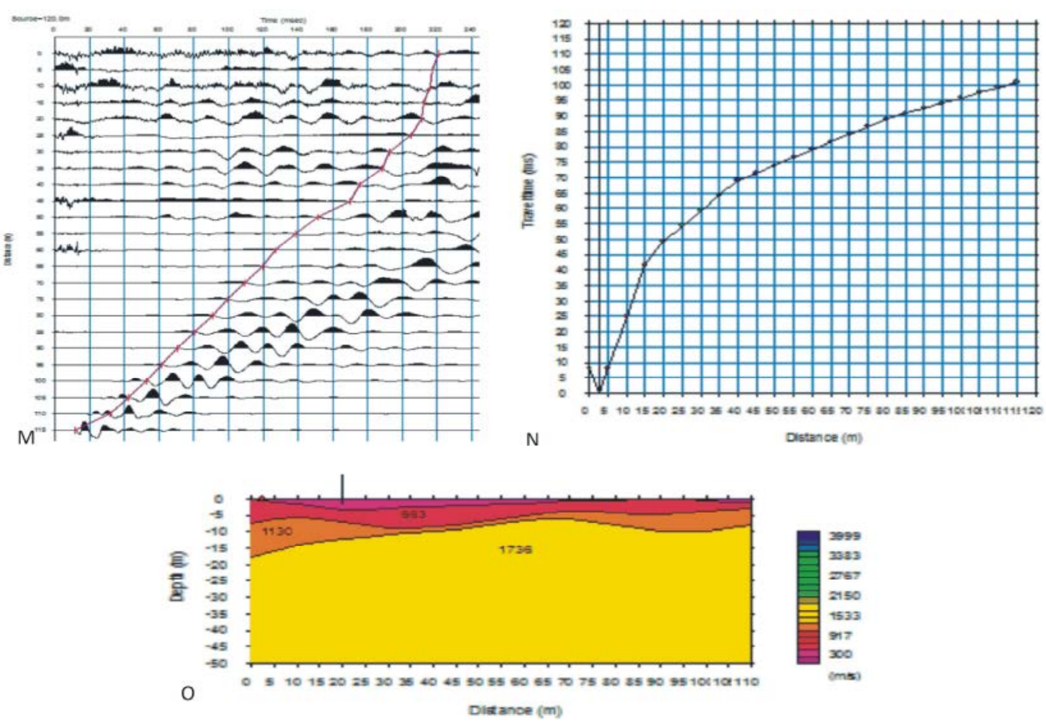
D. Traverse 1 wiggle trace (reverse shooting)
E. Traverse 1 data plot (reverse shooting)
F. Traverse1 layer model (reverse shooting)



G. Traverse 2 wiggle trace (forward shooting)
H. Traverse 2 data plot (forward shooting)
I. Traverse2 layer model (forward shooting)



J. Traverse 2 wiggle trace (reverse shooting)
K. Traverse 2 data plot (reverse shooting)
L. Traverse2 layer model (reverse shooting)



M. Traverse 3 wiggle trace (forward shooting)
N. Traverse 3 data plot (forward shooting)
O. Traverse3 layer model (forward shooting)

However, in this interpretation, by combining the general geology of the area and using standard tables that provides approximate range of velocities of longitudinal seismic waves through some earth materials. A good attempt is made to obtain a reasonable geological structure for the surveyed area.

The time-distance graph was plotted (using Excel package), Fig; B, E, H, K and N were samples of the resulting time-distance graph plotted with data from Fig; A, D, G, J and M. The graphs showed a four layer case as seen in Fig; C, F, I, L and O.

The slopes of the layers were calculated and the inverse of the slopes gave the values for the velocities, the depths to refractors were also calculated using software (IXRefraX and Seisimager).

Based on the values of the velocities obtained, the first layer velocity throughout the entire survey varies between 300m/s - 380m/s with depth between 0.5m - 1.8m. It was observed that the first layer is composed of weathered basement top soil. The second layer velocity varies from 624m/s - 746m/s and was used to obtain the contour map for V_2 as seen in fig. C, F, I, L and O. The velocities were increasing with depth. The characteristics of lateritic rocks were observed at the depth between 1.8m - 9.8m. The velocity values of the third layer vary from 1058m/s - 1204m/s with depth between 5.8m -18.2m. The characteristics of sand and sandstone were observed. The last layer was made up of granite with velocity up to 1805m/s at the depth of 18.2 below. Only four geologic layers were observed throughout the study area.

GPR Survey Result: Each depth that is sliced contains only a portion of the horizon's reflection which appears as individual "anomalies" that are present at discrete depths as seen in Figures below.

From profile 1 and 2; it was observed that the study area were made up of four layers, the top soil, wet sand, dry sand/sandstone and granites respectively with the following velocities; 13cm/ns, 9cm/ns, 6cm/ns and 19cm/ns and electrical conductivity of 5.3 Ωm^{-1}, 11.1 Ωm^{-1}, 25 Ωm^{-1} and 25 Ωm^{-1} respectively in profile 1.

Profile 2, the following velocities were observed; 3cm/ns, 7cm/ns,18cm/ns and 14cm/ns respectively and the electrical conductivity of 10.2 Ωm^{-1}, 21.3 Ωm^{-1}, 28 Ωm^{-1} and 46 Ωm^{-1} respectively.

Profile 3, it was observed that the profile has only three layers namely; wet sand/sandstone, dry sand/ sandstone and granites respectively, with the following velocities 3cm/ns, 7cm/ns and 13cm/ns and the electrical conductivity of 10.6 Ωm^{-1}, 5.2 Ωm^{-1} and 21 Ωm^{-1} respectively.

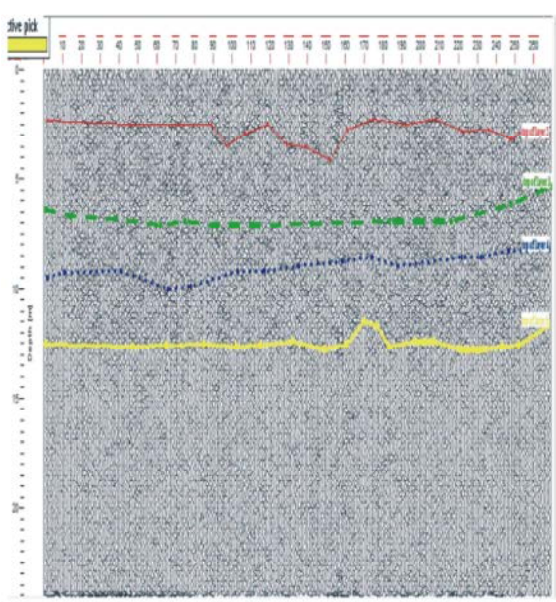


Fig: 14a

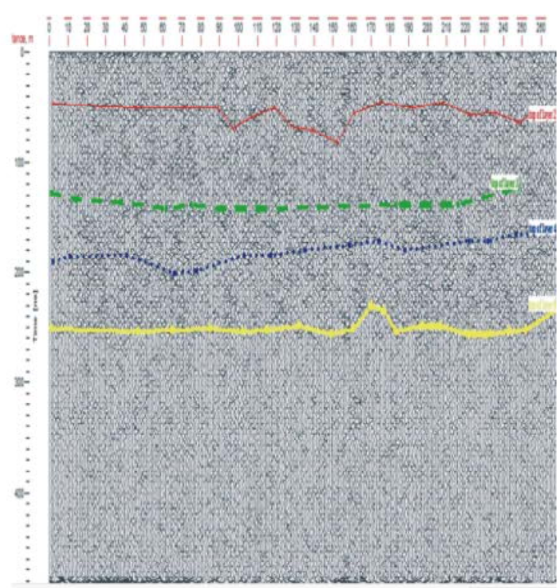


Fig: 14b

Fig. 14a: Wiggles traces plots of distances (m) against depth (m). (100MHz)

Fig. 14b: Wiggles traces plot of distances (m) against time (ns).

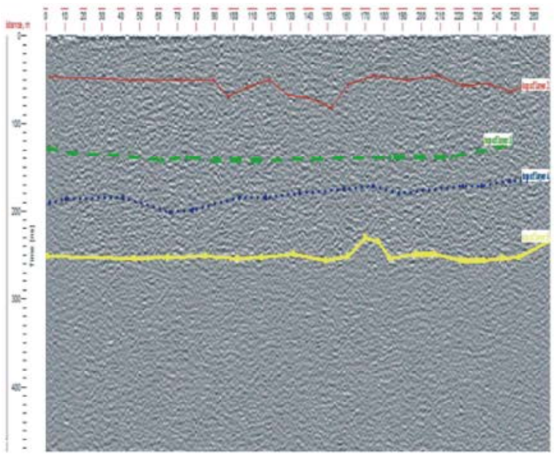


Fig: 14c

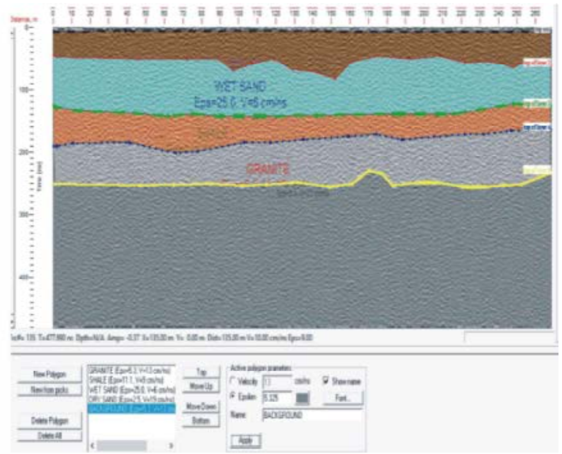


Fig: 14d

Fig. 14c: Radar gram plots of distances (m) against time (ns) in Grayscale
Fig. 14d: Litho Unit of Traverse 1

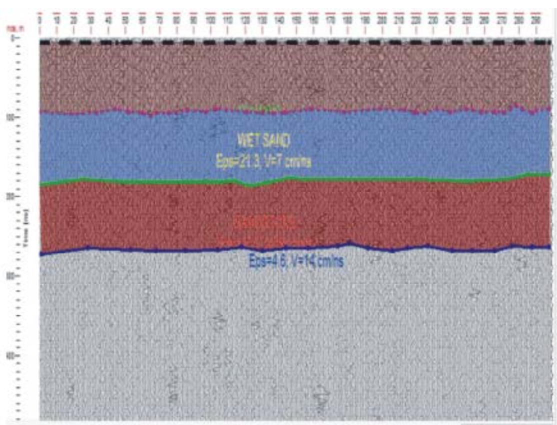


Fig: 15a

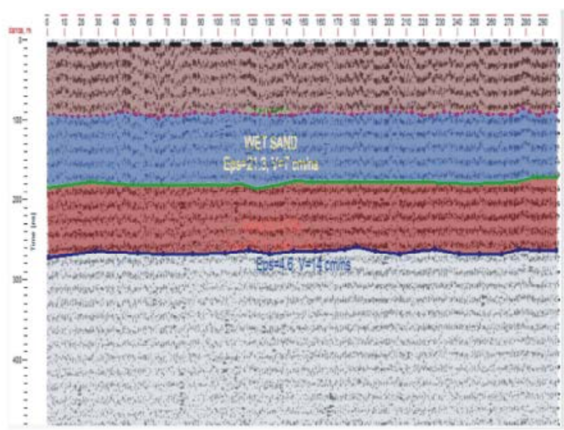


Fig: 15b

Fig. 15a: Wiggles plot of distances (m) against time (ns)
Fig. 15b: Wiggles plot of distances (m) against depth (m)

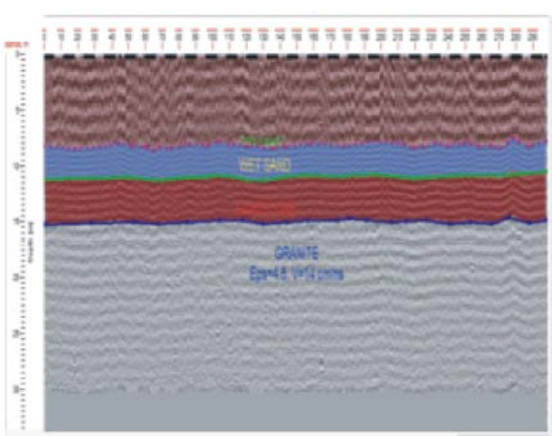


Fig: 15c

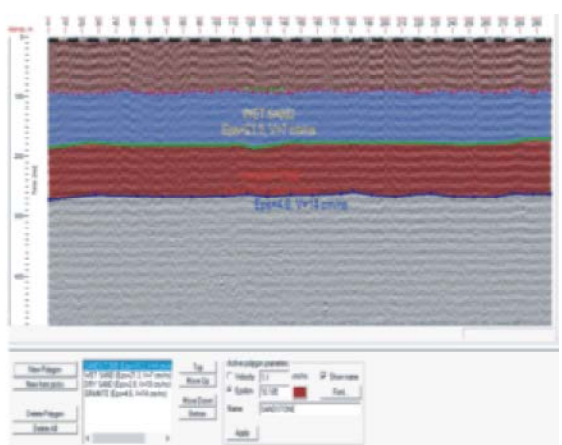


Fig: 15d

Fig. 15c Radargram plot of distance(m) against depth (m) (100MHz)
Fig. 15d Radargram plot of distances (m) against time (ns)

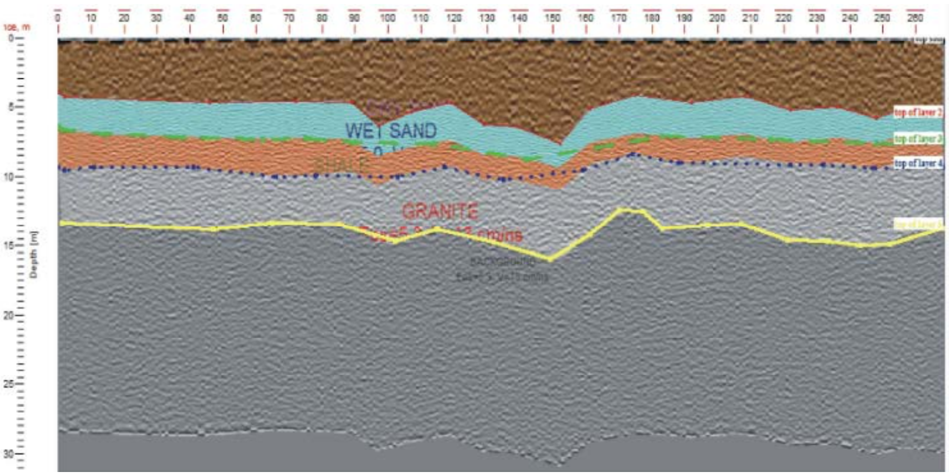


Fig. 15e: Litho Unit of Traverse 2

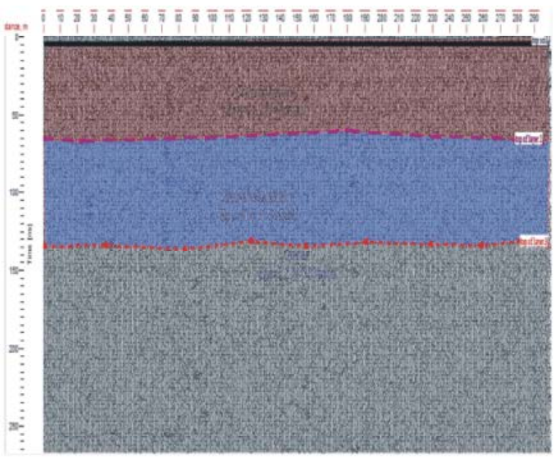


Fig: 16a

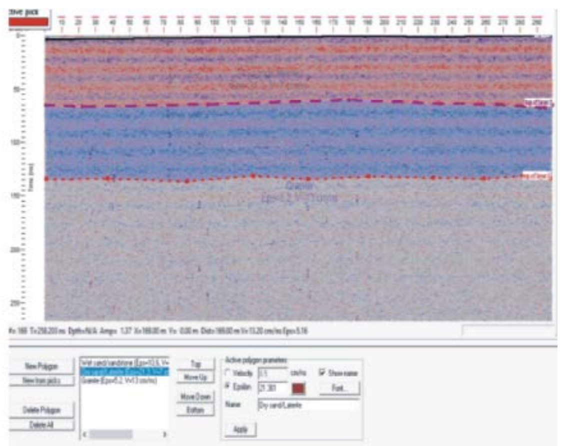


Fig: 16b

Fig. 16a: Wiggles trace plot of distances (m) against time (ns).

Fig. 16b: Litho Unit of Traverse 3

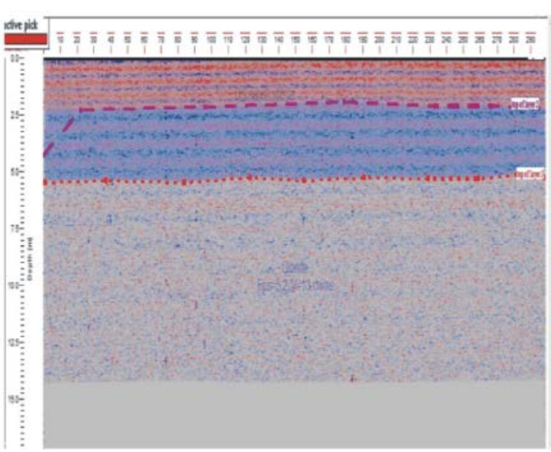


Fig: 16c

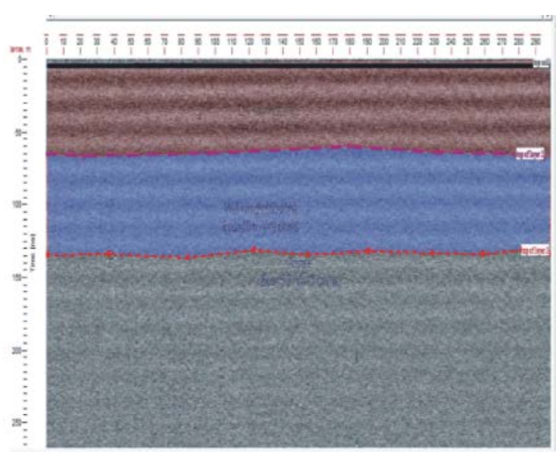


Fig: 16d

Fig. 16c: Radargram plot of distances (m) against depth (m) in colour scale.

Fig. 16d: Radargram plot of distances (m) against time (ns) in grayscale.

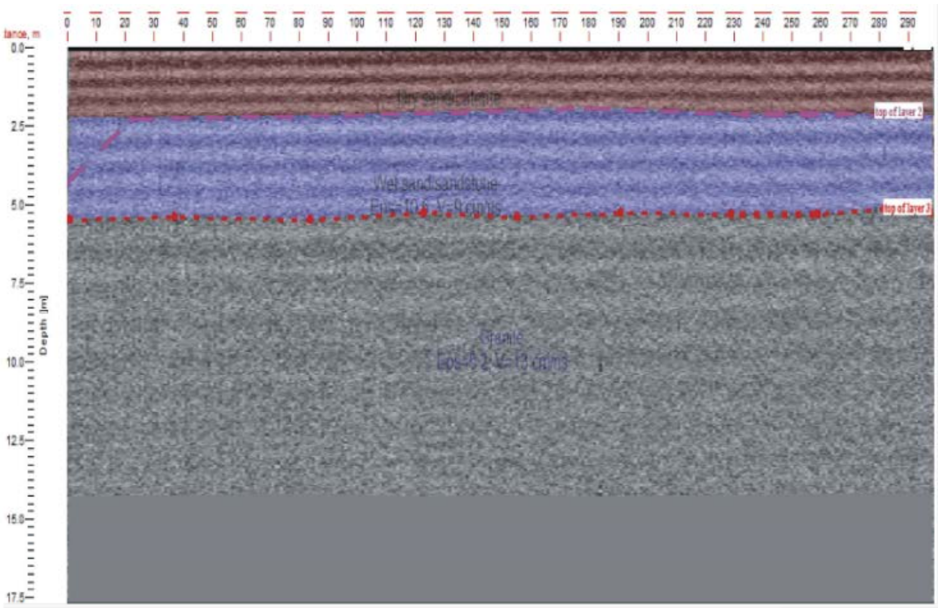


Fig. 16e: Radargram plot of distances (m) against depth (m) in grayscale.

CONCLUSIONS

Refraction seismic and GPR methods have been employed in the study of Akamkpa area for ground water potential. From the study, it has been seen that refraction seismograph is used for shallow subsurface investigation. GPR and refraction seismic have similar principles except that GPR uses electromagnetic energy while seismic method uses acoustic energy.

The depth to water table has also been seen to vary from place to place. Depth to water is between 18.5m to 50m (61ft to 165ft). The study area has good potential for groundwater.

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