

Seismic Refraction Profiling For Groundwater in a Basement Terrain: The Case of Akamkpa, Southeast Nigeria.

Fedelis Ushie and Oboho Eminue*
Department of Geosciences, Akwa Ibom State University, P.M.B 1167,Uyo, Nigeria
*E-mail of the corresponding author: obohoeminue@gmail.com

Abstract
Weathering induces secondary porosity on (otherwise) crystalline basement rocks; forming a wide range of regolith. Groundwater accumulates at the base of this regolith and the thicker the regolith, the higher the possibility of locating groundwater occurrence. Nine (9) seismic refraction profiles were survey using the hammer-plate striking system in various parts of Akamkpa with the intent of locating aquifers. The interpretation of the time – distance graph reveal a typical two layer model. The top layer, with mean seismic velocity of 931m/s with thickness between 3.39m and 19.23m from the surface is within the range of velocities for loose and porous material whereas, the lower layer with mean seismic velocity of 2284m/s compares well with those of fissured to fresh (transitional) basement rocks. This shows that the weathered overburden material of the basement complex is thick enough (3.39 – 18.23m) to support shallow to medium depth borehole development in the area.
Keywords: Basement, Porosity, Regolith, Seismic Velocity, Weathering.

1. Introduction

This paper describes a geophysical investigation undertaken in Akamkpa, a predominantly basement area in Cross River State, Nigeria (Figure 1) to explore the groundwater potentials of the area. The geophysical exploration technique used is the seismic refraction method. Seismic refraction has been mostly used in groundwater and contaminated site investigations because of its relative simplicity and adaptability for shallow zone investigations. Groundwater level can be determined as a boundary of acoustic impedance by seismic refraction method (Mooney 1984).

The possibility of using the seismic refraction method is determined by the elastic properties of the near surface layers. The success of the seismic refraction surveys in the determination of the thickness of weathered basement and depths to water table has been very encouraging (Redpath 1973; Spencer 1973; Ushie 2010). The groundwater level can be determined as a boundary of acoustic impedance by seismic refraction method. When the electric properties of near surface sand and clay beds are investigated, a principal obstacle is recognized in applying the method of resistivity measurement to problems water exploration, namely: the dissociated ions of adhesive water, being an electrolyte, in the case of both sand and clay give a relatively good electric conductivity even to the "dry" ground, which will not be significantly altered by the saturation of the pore volume by groundwater (Ajayi 1998). Regardless of several exceptional cases, the groundwater level does not behave as an electric boundary and it cannot be located by the method of resistivity measurement. The possibility of using the seismic refraction method is determined by the elastic properties of the near surface layer.

This study is aimed at locating possible groundwater reservoirs so as to provide clean potable water and reduce reliance on the untreated surface waters in the Akamkpa Basement area. The result of this study will facilitate planning and development of groundwater in the area.

2. Location and Hydrogeology of the Study Area

The study area lies between longitudes 7^0 49^1 and 6^0 56^1N in Cross River State, Nigeria. Geologically, the study area falls within the Oban Basement complex Southeastern Nigeria. It is divisible into three distinct geomorphologic regions each with its different hydrogeological characteristics (Figures. 1 and 2). These include:

- The Basement Complex comprising the Oban Hills and the Obudu Plateau.
- The Cross River Plain and the Ikom Depressio
- The Calabar Coastal Plain.

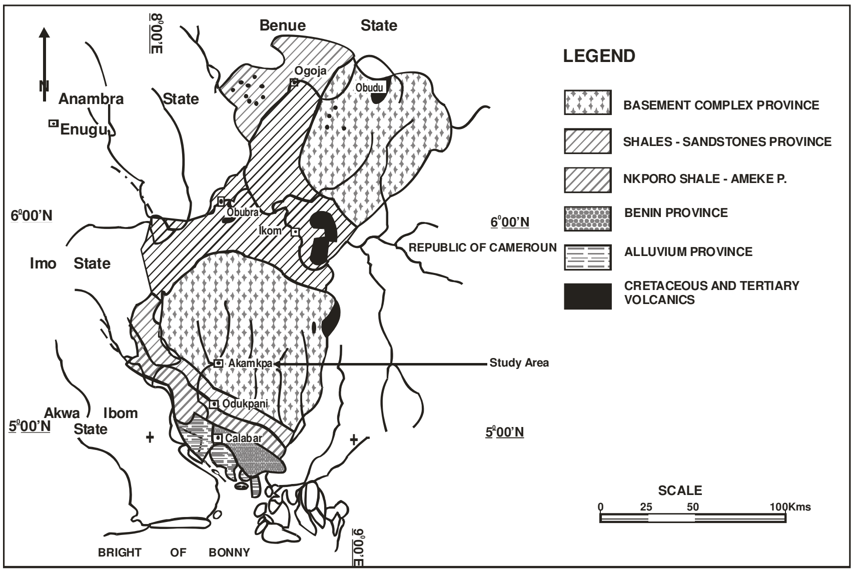

Figure 1. Hydrogeological provinces of Cross River State showing the study

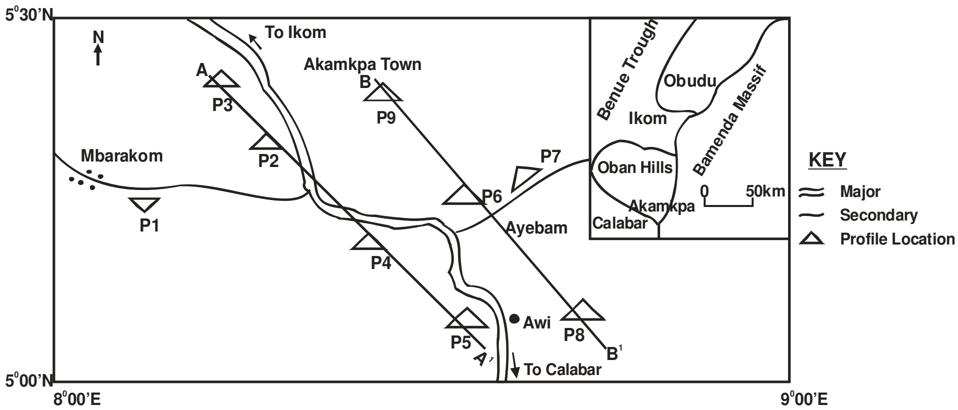

Figure 2. Sketch of local map of study area showing profile location

Ninety percent (90%) of Akamkpa lies in the Oban Basement Complex which contains mostly highly weathered and fractured schist and gneisses with minor intrusive igneous rocks such as granodiorite, diorite, and dolerite (Edet *et at*, 1994).

The most common sources of water in this area are springs, streams and wells. Total annual rainfall in Akamkpa is approximately 1,800mm and increases towards the south to a maximum of 3,100mm.

3. Materials and Methods

The materials used for the data acquisition include; strike plate, sledge hammer, geophones, tape, cables and seismograph. The seismic refraction investigation was carried out using a 12-channel Mark Terraloc MKIII Abem seismograph. The geophones were connected to the seismograph through the geophone cable. Seismic waves were produced by striking the sledge hammer onto the steel plate. Seismic signal was enhanced by stacking 4 to 6 shots until the record showed satisfactory signal-to-noise ratio. Nine seismic refraction profiles have been acquired in the study area. The lengths of the profiles vary between 80 to 120 meters. Forward and reverse seismic shooting were carried out with geophone interval of mostly 10 meters. The refracted seismic waves were recorded by the seismograph (Okwueze 1985).

3.1 Data Presentation and Interpretation

The seismograph is the main result of the field work; it represents the recording of the received signals. The recorded seismic traces reflect the response of the subsurface interfaces. The most important arrivals are the direct and refracted waves which are received by the geophones. Some of the recorded traces have shown certain level of noise and are considered as noisy or bad traces and were deleted from some of the shot records. The first arrival picks and their corresponding distances are taken and tabulated. The first arrival time obtained by each geophone is plotted against the geophone location in each array and the plotted points are best fitted to reflect layers' interfaces and seismic velocities are estimated (Table1).

The data was interpreted using the "Plus-minus" method of interpretation to provide depths to primary refractors beneath the overburden and compressional wave velocity in that refractor. The seismic velocities are calculated from the inverse of the slope of the fitted lines on the time - distance graph (Dobrin 1974; Prasnis 1979).

Two parameters were used to quantify the layer thickness. The first of these is the cross-over distance (X_c) which simply refers to the offset at which the head wave becomes the first arrival (Figure 3). The second commonly used parameter is called the zero offset time (intercept time, T_o). By measuring X_{cros} or T_o, in addition to the seismic velocities of the first and second layers, the thickness of the layers were computed.

In this exercise, layer thicknesses were determined by the intercept time method using the following formula (Equation 1):

$$D = \quad tiV_1V_2 / 2\,(V_2^2 - V_1^2)^{1/2} \qquad (1)$$

Where,

D = Thickness of the first layer

ti = Intercept time on the time axis

V_1 = Velocity in layer 1

V_2 = Velocity in layer 2

Table 1. Field Data

SHORT POINT DISTANCE (M)	ARRIVAL TIME FOR ALL THE PROFILES																	✳ - Not Available
	PROFILE 1		PROFILE 2		PROFILE 3		PROFILE 4		PROFILE 5		PROFILE 6		PROFILE 7		PROFILE 8		PROFILE 9	
	FORWARD PROFILE	REVERSE PROFILE	FORWARD PROFILE	REVERSE PROFILE	FORWARD PROFILE	REVERSE PROFILE	FORWARD PROFILE	REVERSE PROFILE✳	FORWARD PROFILE	REVERSE PROFILE	FORWARD PROFILE	REVERSE PROFILE	FORWARD PROFILE	REVERSE PROFILE	FORWARD PROFILE	REVERSE PROFILE	FORWARD PROFILE	REVERSE PROFILE
5	13	10.1	19.3	22.5	9.9	9.7	3.7		10.8	10.4	10.5	11.2	6.5	8.3	11.4	10.9	9.2	11.6
10	16.4	12	11	10	14.2	11.6	9.5		12.6	15.6	16.4	16.7	16.1	15	22.9	18.6	13.2	14.8
15	26. 7	26.3	25	28.3	16.6	14.2	18.9		19.7	22.4	18.4	19.6	19	19.4	25.1	23.4	17.3	18.2
20	29.2	32.9	32.8	33.8	20.1	18.3	23.1		26.5	30.9	22.5	23.1	24	22.6	36.1	26.5	19.3	22.5
25	34.4	43.6	34.6	48.5	23.1	22.6	35.2		33	35.7	24.6	27.1	30.1	26.7	38.5	29.7	24.7	25.3
30	49.4	46.8	87.6	42.1	24.8	26.2	48.6		37	41.2	25.6	30	31.1	28.3	39.8	31.6	28.1	27.1
35	51.9	50.9	45.7	46.5	28.1	28.6	54.3		46.3	44.6	26.2	31.2	35.6	30	42.3	32.4	31.8	28.4
40	56.9	54.9	46.3	49.6	30.3	29.2	58.5		47.9	46.3	26.8	31.8	37.8	32.6	43.7	33.6	32.2	29.8
45	64	58.3	47.2	52.3	28.1	31.1	65.5		49	48.4	27.8	32.5	39.2	34.8	45.6	35.6	34.6	30.2
50	66	62.4	46.7	54.5	33.9	33	68.4		52.4	51.2	28.4	33.8	41.6	36.5	47.8	37	36.2	31.6
55	69.8	69.4	48.2	56.7	34.3	35.7	72.6		55.6	53.3	30.1	35.2	43.4	38.8	50	40	38.9	32.6
60	70.6	71.2	49.4	58	36.4	37.8	74.8		59.4	56.4	32.3	36.8	45.2	41.6	51.2	42.4	39.6	33.4

Table 2. Summary of Computed Velocities and Depth

PROFILE NO.	AVERAGE VELOCITY (M/S)		DEPTH (M) TO FRESH ROCK (D)
	V_1	V_2	
1	742.75	1527.8	5.94
2	549.3	1937.5	8.59
3	773.8	1534	5.15
4	576.1	786.05	3.39
5	833.3	1315.8	10.8
6	751.9	2916.7	14.5
7	1736.1	4642.85	18.23
8	1339.3	2033	13.3
9	533.4	2804.5	6.52
10	1463.7	333.35	15.49

4. Discussion of Results

Figure 3 shows a typical Time-distance plot and interpreted seismic section of the study area. The figure shows a two-layer model. Generally, velocities of the top layer vary between 333.8 to 1736.3m/s with an average of 850m/s. this low velocity layer is known as the weathered layer. The interpreted results show that the depth to bedrock in the Akamkpa area ranges from 3.39 to 15.49 meters, with an average of 9.60 meters. The compressional velocity computed for the basement varies from 786m/s to 4642m/s (Table 2).

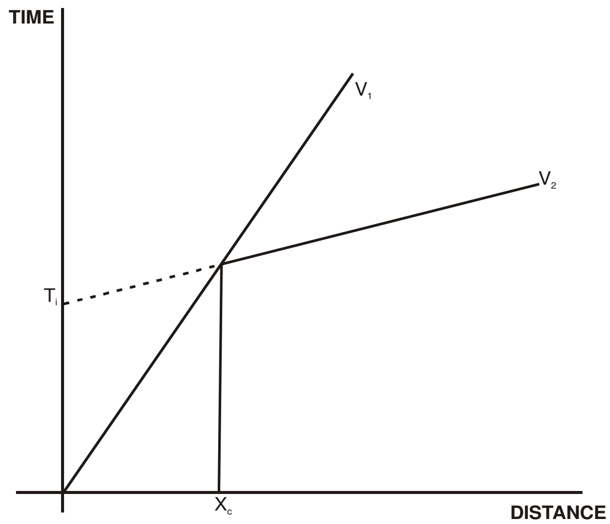

Figure 3. Typical distance-time (Tx) Graph for a 2-layer model.

Although velocities of seismic waves are not a positive indicator of the composition of materials and rock types, they however, could be said to be roughly proportional to the degree of consolidation of the rock. The velocities of the top layer vary between 333.8 to 1736.3m/s.

The variation in depths to refractor in the various sounding points shows the undulatory nature of the subsurface of the fresh basement rock. The thickness of the weather overburden materials seems high enough to support shallow to medium depth borehole development. Figures 4a and 4b show typical sections for AA^I and BB^I profiles respectively across the study area.

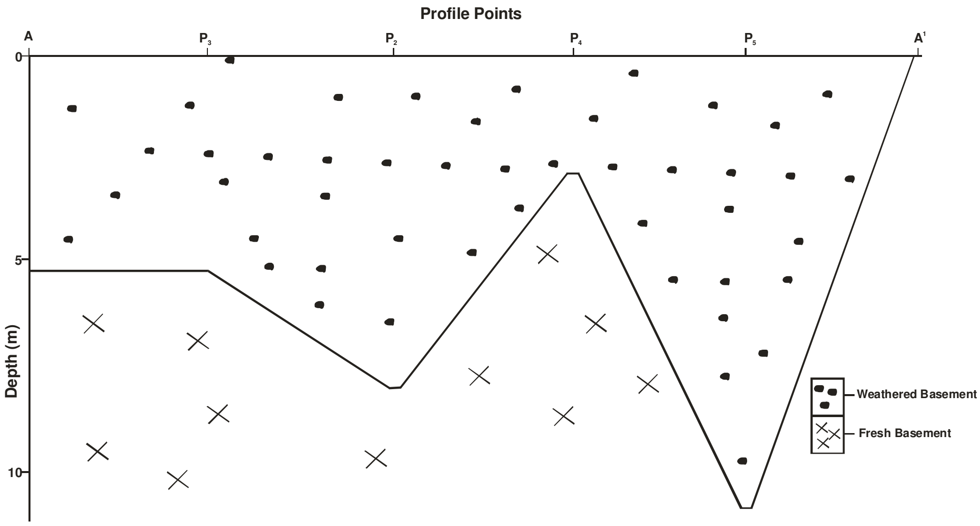

Figure 4a. Typical cross section across the profile AA^1 in the study area.

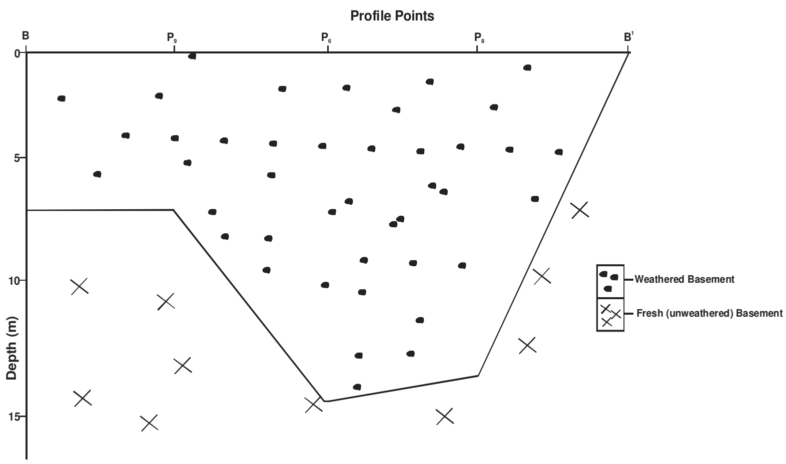

Figure 4b. Typical cross section across the profile BB^1 in the study area.

The result of the seismic interpretation was compared with the water level measurements from existing water boreholes in the area and the result shows that the aquifer depth obtained from the survey is reliable.

5. Conclusion

Seismic refraction has been used to investigate the occurrence of groundwater in Akamkpa area of Cross River State. The obtained measurements in the weathered (top) layer indicate seismic velocities range 333.8 to 1736.3m/s with an average velocity of 786m/s. The computed thicknesses of the overburden aquiferous layer vary between 3.39 to 15.49 meters with an average of 9.60 meters. The result of the study shows that the weathered basement rock is the major aquifer in subsurface.

It is worth mentioning that the seismic refraction method is very reliable depending on the area where it is applied and the hammer-plate striker system is not only reliable but also cheap.

References

Ajayi, D. (1998), "Causes of borehole failure in crystalline rocks of south western Nigeria", *Procedures of first Biennial natural Hydrology Symposium.*466-489.

Dobrin, M. B. (1976), "Introduction to Geophysical prospecting", Mcgraw Hill Inc. U.S.A.

Edet, A. E., Teme, S. C., Okereke C. S., & Esu, E. O., (1994), "Lineament analysis for ground water exploration in the Precambrian Oban Massif and Obudu Plateau South Eastern, Nigeria", *Journal of Mining & Geology* **30,** 87 – 95.

Mooney, B. K., (1984), "Reduction Scheme in Seismic Refraction", Musgrave Company, U.S.A, 322 – 356.

Okwueze, M. N., (1985), "Seismology", Musgrave Company, U.S.A, 232 – 284.

Parasnis, D. C., (1979), "Principles of applied Geophysics", 3rd Ed. Hapman & Hall, New York.

Redpath, M. A., (1973), "Refraction Survey and Deep Supergene Process Calculation", W. H. freeman and Company.

Spencer, A. C., (1973), "Economic Geology" **17**, 312 – 317.

Ushie, F. A., (2010), "Economic Evaluation of lateritic rocks in Obudu Area, Southeastern Nigeria", *Ph.D Thesis.* Nnamdi Azikiwe University Awka, Nigeria

Fidelis Ushie is a senior lecturer in the Department of Geosciences, Akwa Ibom State University, Nigeria. A Corporate Member, Nigerian Mining and Geosciences Society since 2005, He holds a PhD in Economic from Geology Namndi Azikiwe University, Awka, Nigeria in 2010, an MSc in Exploration Geophysics from University of Calabar, Nigeria in 1996. His researches are in the area of exploration geophysics and economic geology.

Oboho Eminue is an Assistant Lecturer in the Department of Geosciences, Akwa Ibom State University, Nigeria. A Corporate Member, Nigerian Geosciences and Mining Society since 2001, Member, Nigerian Association of Hydrogeologist since 2012, He holds an MSc in Engineering Geology/Hydrogeology from University of Calabar, Nigeria in 2004. His research interests are groundwater development and earthwork slopes.