Scientia Africana, Vol. 7 (No.2), December 2008; pp 46-53
 ISSN 1118 - 1931

DETERMINATION OF DEPTH TO BEDROCK IN AFIKPO SYNCLINE OF THE BENUE TROUGH NIGERIA, USING SEISMIC REFRACTION METHOD

UGWU, SYLVESTER A.
Department of Geology, University of Port Harcourt
ugwusa@yahoo.com

Received: February, 2008
Accepted: October, 2008

ABSTRACT
A three channel digital signal enhancement Seismograph model S79-3, was used in continuous profiling to determine the depth to bedrock in Afikpo syncline. Afikpo syncline came as a result of instability of accumulated sediments in the Benue trough during the Albian-Turonian tectonic episode. Incessant collapse of building structures in Nigeria compelled us to carry out seismic refraction surreys in the fast developing Ndibe beach. The results of the survey gave a two-layer model. The seismic P-wave velocity of the weak overburden sediment varies from 277-512ms while layer two has a P-wave velocity which ranges from 370-1408ms. The depth to bedrock varies from 2.0 to 3.98m. The depth to the expected Afikpo sandstone in the Ndibe beach area in 3.98m and any engineering structure placed in the Afikpo sandstone will be geotechnical sound. The seismic refraction method has proved to be an indispensable tool used to determine the depth to bedrock.

Key Words: Bedrock, Seismic Refraction, Velocity, Geology

INTRODUCTION
Recently there have been several reported cases of collapsed buildings and other civil engineering structures in the country. There were over twenty-one (21) reported cases of such incidence in 2005 and 2006 years alone (Tell, 2006). On December 8, 2007 a story building collapsed at Abuja (Network news- 4pm Dec. 2007). In each case lives and properties worth huge sums of money were lost. Over 60 people have lost their lives due to collapsed buildings in Lagos alone (A.I.T news 4pm December, 2007). Though there are many factors which when neglected could lead to collapse of buildings such as using substandard materials and design problems but also investigation into the cause of these mishaps had always pointed to incompetent foundation rocks as another major cause of these avoidable and regrettable events.

From Macgregor Collage to the heart of Afikpo town and other elevated parts within the environs the bedrock, the ferruginated Afikpo sandstone, is on the surface. But as one goes down towards the Ndibe beach, the bedrock is covered by thick overburden sediments made up mainly of gravelly sand, sandy clays and siltstones. Development and urbanization are rapidly moving towards the beach hence the need to locate the depth of the covered bedrock within that area. Building contractors in a bid to reduce cost and maximize profit usually avert carrying out soil test, or geophysical investigations to determine the quality of the rock upon which to site the foundation of their buildings. The culture of carrying out geophysical survey before erecting engineering structures appears to be worthless in the eyes of most contractors. At last they end up putting up such foundations on incompetent overburden layers which are not capable of supporting the building. The need to site the foundation of every reasonable engineering structure on the solid foundation is *biblical.*

The objective of this work is to determine the depth to bedrock in some areas within the Afikpo syncline (Fig. 1) using seismic refraction method. Seismic refraction is one of the best geophysical methods used in determining the depth to bedrocks. Many textbooks (Dobrin 1976; Telford et al,1990) and numerous journal articles(Ackerman et al,1986; Haeni.1986, Ivanov et al, 2000a Zhadonov, 2002 Sheehan and Doll,2003; Shlendein et al.,2003; Xia et al.,2005; Ivanov et al., 2006) present the details of seismic refraction theory, problems and limitations.

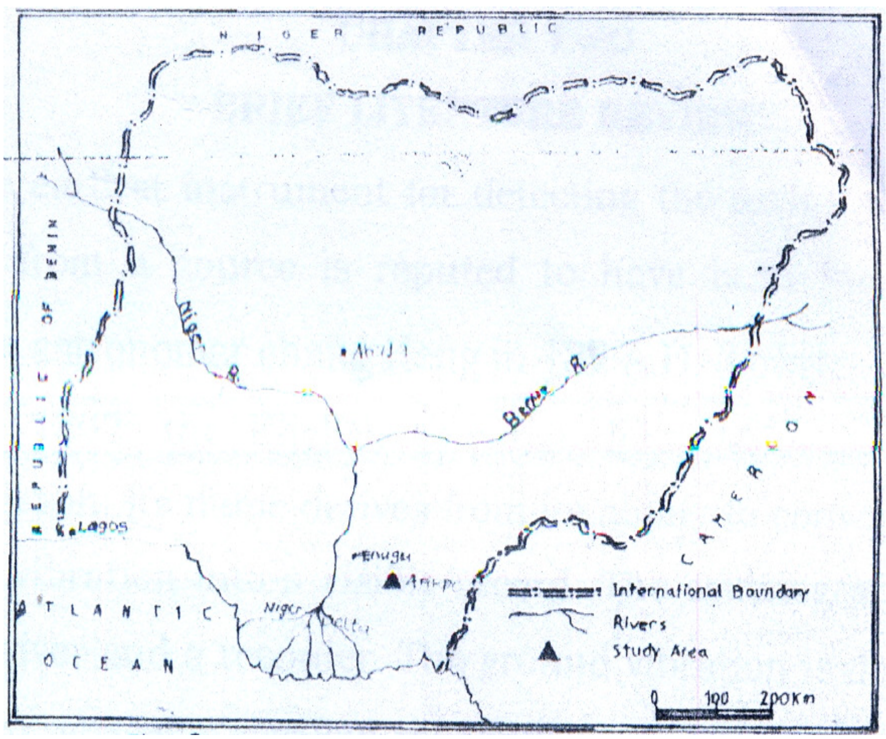

Fig. 1: Map of Nigeria showing the study area.

Some of the published geophysical investigations in the Benue trough are mainly the gravity surveys (Cratchly and Jones, 1965., Artsbachev and Kogbe, 1974., Adighije, 1979., Adighije, 1981b., Ajayi, and Ajakaiye, 1981., Ajakaiye and Burke, 1972). Aeromagnetic anomaly interpretations (Ofoegbu, 1984., Ofoegbu and Onuoha, 1991); resistivity and magnetic surveys (Mamah et al 2000), Spontaneous potential survey (Ugwu, 2006) and resistivity survey (Ugwu, 2007).

BRIEF GEOLOGY OF THE AREA

The Benue trough is a linear stretch of sedimentary basin running from the N.E to S.W and bounded roughly by the basement complex areas in the North and South of the river Benue. This elongate basin is continuous and has been described as the long arm of the Nigerian coastal basin (Reyment, 1965). The Benue trough has a lateral extent of about 250km in the south and consists of the Anambra basin, the Abakaliki Anticlinorium and the Afikpo

syncline. The accumulation of thick sediments in the Benue trough from the Albian to Turonian times led to the development of instability at the base of faulted crustal blocks. This instability culminated in large scale folding with fold axis parallel to the trend of the Benue trough-NE-SW. The lips of the trough began to sag forming the Anambra Basin on the right axis and the Afikpo syncline on the left (Fig.2). The uplifted part of the fold became known as the Abakaliki anticlinorium. The Abakaliki fold belt becomes a positive element to shed sediments and detritus into the depressed platforms of Anambra basin and Afikpo syncline (Hoque and Nwajide, 1989., Olade, 1975., Reyment, 1965, Agumanu, 1986.,) After the Santonian tectonic event and the formation of the Afikpo syncline, marine transgression resumed during the Campanian-Maastritchian erosion in the lower Benue trough with the deposition of the Nkporo Formation first. The Nkporo shale consists dominantly of shale in most parts of the Benue trough but its lateral equivalent in the Afikpo syncline is a sandstone unit called the Afikpo Sandstone composed of quartz arenite (Hoque, 1977). The Nkporo shale is overlain by the Heterolithic Mamu formation comprising of shales, sandstones, siltstones and some coal measures. The Mamu formation is succeeded by the Ajali sandstone.

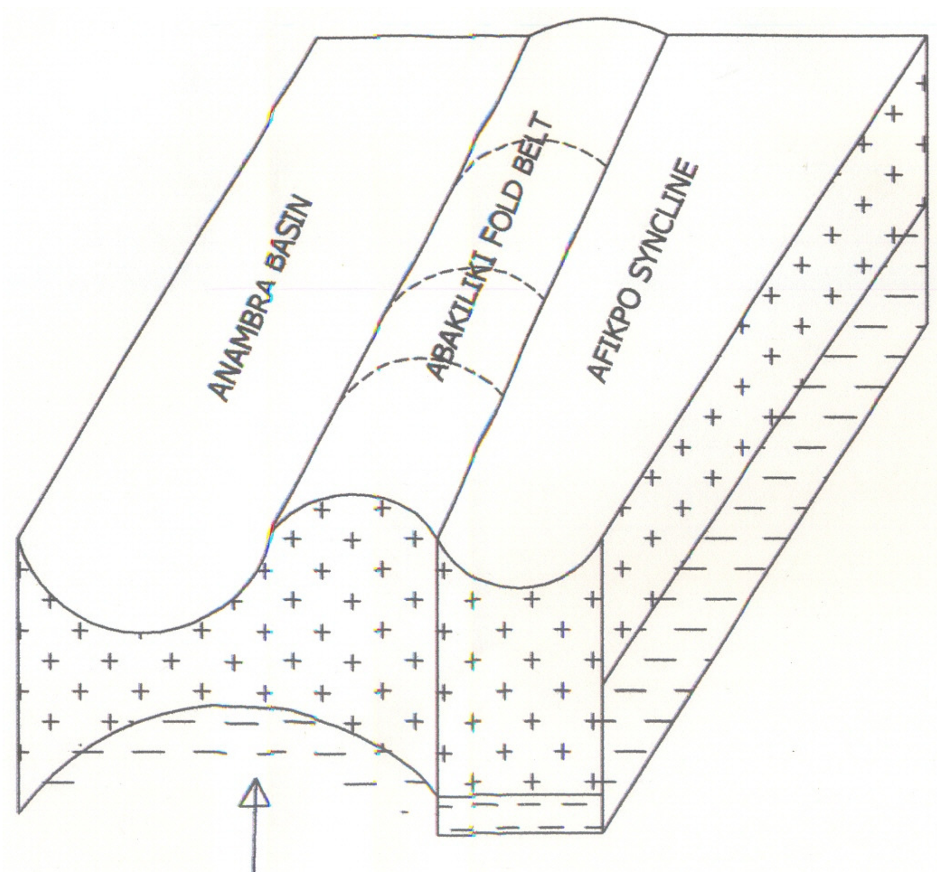

Fig. 2: A Schematic diagram of the Formation of Afikpo Syncline.

METHODOLOGY

The major equipment used included, a three channel digital signal enhancement seismograph, MODS79-3, Geophones (10Hz types), strike plate, a 9kg sledge hammer, a 50m measuring tape, and cables.

DATA ACQUISITION

The survey crew laid out the traverse lines, using the 50m measuring tape which determines the positions of both the shot point and centers of the geophone groups in a continuous profiling. The length of the traverse was 60m with the detectors planted at 5m interval. The trigger geophone was placed close to the strike plate. Seismic waves were generated by striking the sledge hammer on the metal strike plate. These waves were picked up by the geophones and transmitted to the seismograph. The arrival of the waves were recorded and displayed on the screen of the seismograph together with their arrival times in each of the three locations surveyed. Both forward and reversed traverses were taken. The three locations and the directions of the traverse lines were

1) Normadic Primary School Ndibe beach, NE-SW
2) Ohabuike Technical Secondary school Nkpoghoro, NW-SE and
3) Akanu Ibiam Federal polytechnic Uwana Afikpo , NN-SS.

RESULTS

Data Processing/Interpretation

From a series of geophones placed on the ground, the seismic arrival times in milliseconds (ms) versus the shot-to-detector distances in meters were plotted to give a time-distance curve. The arrival times were plotted on the vertical axis (y) while the shot-to-detector distances were plotted on the horizontal axis (x). Figure 3 shows that at distances less than the crossover distance, the sound has traveled directly from the sound source to the detectors. This compressional wave has traveled a known distance in a known time. Therefore the velocity of layer one can be calculated. In the time-distance curve (Fig 3) V_1 is equal to inverse slope of the plotted line or

$$V_1 = \frac{\Delta x(m)}{\Delta y(ms)} \lim_{x \to \infty}$$

Where V_1 = the velocity of sound in layer one

ΔX = change in distance

ΔY = change in time.

From the crossover distance the sound wave that has traveled through layer one then along the interface of the high speed layer (layer two) and refracted back to the surface through layer one, arrives before the wave that has been in the slow layer. When these points are plotted on the time-distance curve, the inverse slope of this segment equals the apparent velocity of layer two. From the time-distance curve; we obtained a two-layer model (fig 3). The depth to the bedrock is calculated using the formula

$$d = \frac{X_c}{2} \sqrt{\frac{v_2 - v_1}{v_2 + v_1}}$$

Where d = depth to bedrock (m)

x_c = crossover distance (ms)

v_1 = velocity in layer one (ms)

v_2 = velocity in layer two (ms)

 ISSN 1118 - 1931

The summary of the results from the three locations are presented in Table 1.

Table I: Summary of the Results

S/N	Location	v_i (ms)	v_2 (ms)	x_c	T (ms)	Depth (m)
1.	Nomadic Pr. Sch. Ndibe	512.0	943	10	11	2.7
2.	Ohabuike Sec. Sch. Nkpoghoro	379.0	1408.0	10.5	20	3.98
3.	Akanu Ibiam Fed. Poly. Uwana Afikpo	277	370	11	30	2.0

The results are compared with the established standard velocities of compressional waves in some rocks (Table II).

Table II: Standard Compressional Velocities in Some Rocks

Rock Type	Standard P-Wave Velocities (ms)
Granite	5520 – 56040
Sandstone	1400 – 4300
Limestone	1700 – 4200
Clay	110 – 2500
Loose Sand	1800
Coarse gravel (wet)	11500 – 16700
Sand with gravel (wet)	690 – 1150
Sand with gravel (dry)	430 – 690
Sandy clay	360 – 430

(Modified from Zblyth and Freitas, 1979).

DISCUSSION

Most inversion based solutions of geophysical problems including refraction travel time problem are non-unique because by their nature these problems consist of a finite number of measured data points that are used to define a continuously varying Earth structure (Ivanov et al., 2005) Non-uniqueness can also result from error in the data This is especially true when the inverse problem is unable, such as when small perturbations in the data(equivalent to the amount of data error) cause large changes in the solution (Ivanov et al., 2006). Nonuniqueness is resolved by using *a priori information* (API) (Zhadonov, 2002) With enough *a priori information* at our disposal we arrived at our result A quick look at Tables I and II and the figures therein respectively showed that in the two-layer model (Figure 3), layer one in all the three locations is made up of dry friable sandy clay and gravelly sand which constitute the loose overburden sediments and the thickness varies from 0.0 – 2.7m.

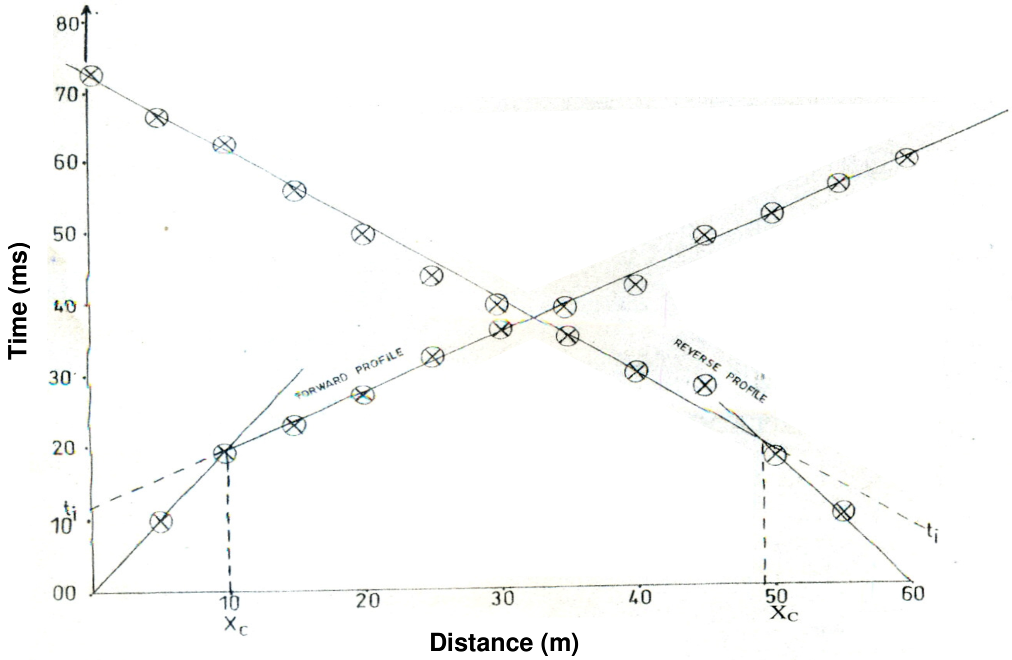

Fig. 3: Time-Distance plot.

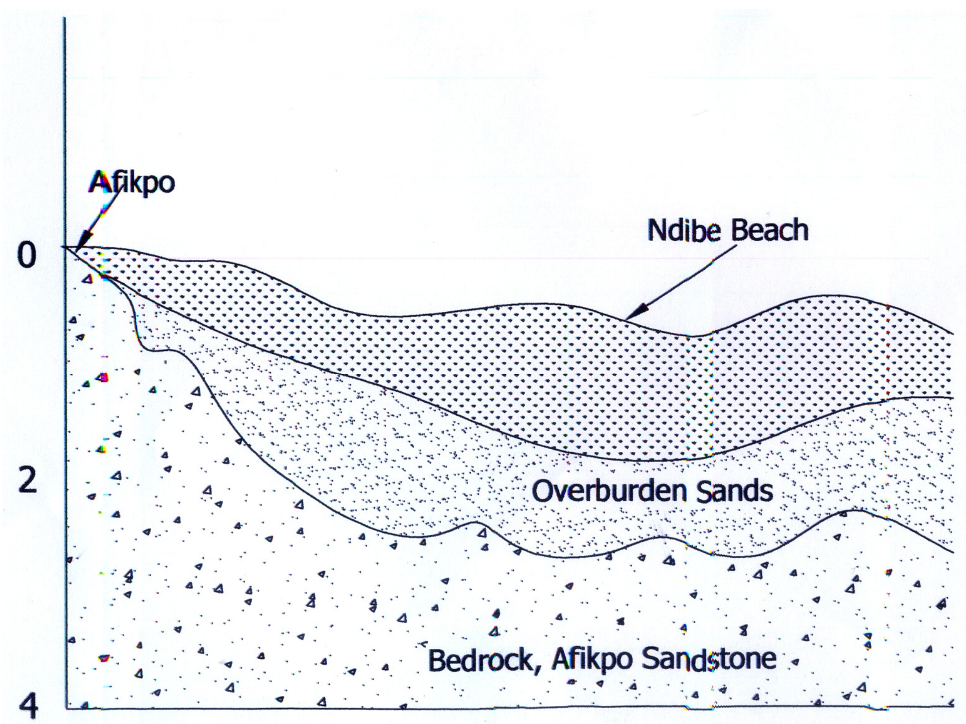

Fig. 4: Bedrock, Afikpo Sandstone.

Layer two in the first and third locations (Normadic Pri. Sch. Ndibe and Akanu Ibiam Fed. Poly.) is made up of compacted gravelly sand and sandy clay lithology starting from 2.0m down. The depth to the expected Afikpo sandstone, within the area, was found at location two – Ohabuike Tech. Sec. Sch. Nkpoghoro, Ndibe beach at 3.98m (Figure 4). The bedrock depths in locations one, three and environs is 2.7m and in location two the depth is 3.98m. The topography of the area contributes to the variations in the bedrock depths. On the average, foundation of up to 3.98m will meet the expected Afikpo sandstone bedrock at the Ndibe beach and will be geotechnicaly sound and safe.

CONCLUSION

To use the refraction results effectively in shallow engineering site investigation, initial geologic information is of great assistance. The seismic refraction method was successfully employed in Afikpo syncline to determine the depths to bedrock. From the three locations surveyed, the average depth to the Afikpo sandstone which constitutes the bedrock is 3.98m. The bedrock has a P-wave velocity of about 370-1408 ms while the overburden weak sediments have P-wave velocity of about 277-512ms. Engineering structures placed on the Afikpo sandstone will be geotechnical safe. The seismic refraction method is an indispensable tool in the hand of an engineering geophysicist, because it can be used to delineate the nature of the subsurface layer as well as in determining the depth to the bedrock (Ukaigwe, 2000).

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