Mapping of Near-Surface Intrusives in Abakaliki: A Seismic Refraction Method.

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ABSTRACT

Compressional (P) waves were utilized to map near-surface intrusives in Abakaliki, Nigeria. The Seismic Refraction Method was employed. The purpose of this study is to show that mineral deposits abound in Abakaliki. These mineral deposits like rocks can be harnessed for the social-economic development of the state. Abakaliki has a sedimentary geology and is located in South-Eastern Nigeria within latitudes $6^0 15'$ - $6^0 20'$ N and longitudes $8^0 5'$ - $8^0 10'$ E.

The equipment used was sledge hammer, a three-channel seismograph, geophones and geophone cables, a spade, a tape, and a field umbrella. A transverse length of 60 meters was covered for shooting with geophone spacing of 5 meters. The survey was carried out in three locations within the study area and the P-waves revealed a three-layer case for each of the locations. The results of the study indicated that the average P-wave velocities and depths in the first location were 425m/s and 5.9m for the first layer (probably sandy clay), 833m/s and 14.6m for the second layer (probably loose sand) and 3750m/s for the third layer (an intrusive hard rock) respectively. The average P-wave velocity and depths for the remaining two locations were 862m/s and 6.0m for the first layer (probably loose sand), 1250m/s and 13.0m for the second layer (probably moist clay) and 2500m/s for the third layer (probably limestone), respectively.

The results showed that only in the first location were hard rocks (intrusives) encountered. The result therefore suggests that the sources of the hard rocks excavated and crushed in Abakaliki are intrusions that have occurred at the sub-surface.

(Keywords: velocity, compressional (P) waves, near-surface intrusives, seismic refraction, three-channel seismograph, geophone)

INTRODUCTION

Molten magma, which has erupted from beneath the Earth owing to volcanic activity, sometimes solidifies to form intrusive rocks within the sub-surface. In a sedimentary area, compressional body waves that encounter such rocks (intrusives) usually indicate a significantly higher seismic velocity than the usual sedimentary structures (Lowrie, 1997).

The aim of this work is to map such intrusive rocks in Abakaliki, Nigeria. This is necessary in order to locate and exploit granites and other hard rocks that are useful in engineering constructions. In Abakaliki particularly, these hard rocks are excavated once they are noticed and crushed for building and road constructions. The seismic refraction method, which is very suitable for shallow investigations such as this case, was employed.

The behavior of seismic waves traveling through rocks has been a subject of extensive theoretical and experimental investigations. Such researches have shown that seismic velocities of rocks are strongly related to the rock densities with denser rocks having higher seismic velocities. These relations are well documented in relevant literature (Twiss and Moores, 1992; Telford et al., 1998; Plummer et al., 1999; Okon, 2001; Umanah, 2001; Agwu, 2001; Monroe and Wicander, 2002; Agha, 2002; Milson, 2005; Singh, 2005; and Ikelle and Amundsen, 2005).

Several initial studies (Carpenter et al., 2003; Cramer and Hiltunen, 2004; Sheehan et al., 2005; Hiltunen and Cramer, 2006) indicate that refraction tomography performs well in many situations where traditional refraction techniques fail, such as velocity structures with both lateral and vertical gradients. To gain acceptance and widespread applications, it must be demonstrated that refraction tomography compare well with ground truth information obtained from real test sites (Campbell and Scott, 1991; Moser, 1991 and Scott, 2001).

Other documented literature show the relationship between seismic wave velocity and rock porosity and depth of embedded structures as well as other applications of seismic refraction method (Telford, 1976; Sheriff and Geldart, 1983; Kearey, 1984; Dobrin, 1976; Lowrie, 1997; and Effiong, 2001;).

MATERIALS AND METHODS

Abakaliki has a sedimentary geology and lies between latitudes $6^0 15'$N and $6^0 20'$N and longitudes $8^0 5'$E and $8^0 10'$E. It is located in Ebonyi State, South-eastern Nigeria and has a total surface area of about 81km^2 (Figure 1).

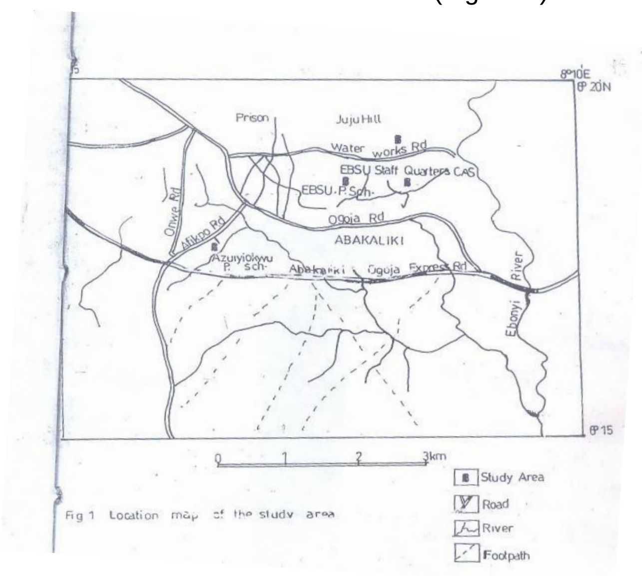

Figure 1: Location Map of the Study Area.

The entire area that lies south of the Benue Trough has three major geologic units: the Albian Asu River Group (Lower Cretaceous), the Turonian Ezeaku Formation and the Nkporo Shale. Each of these geologic units outcrops on the surface and can be seen as one moves from east to west along the study area.

The Albian Asu River Group comprises of an uneven mixture of shales, sandstones, limestones and siltstones in some places. The sediments were deposited during the opening up of the Atlantic and the consequent separation of African and south American continents (Murat, 1970 and Nwachukwu, 1972).

At the southern end, the sediments were later folded along northeast-southwest direction, forming the Abakaliki Anticlinorium.

The Ezeaku Formation is Turonian in age and consists basically of flaggy, dark and calcareous shales, siltstones, sandstones, sandy and shaly limestones and mudstones with frequent facie changes (Peters and Ekwuozor , 1982; Kogbe, 1976). Faults and igneous intrusions are common features in this unit as shown in Figure 2.

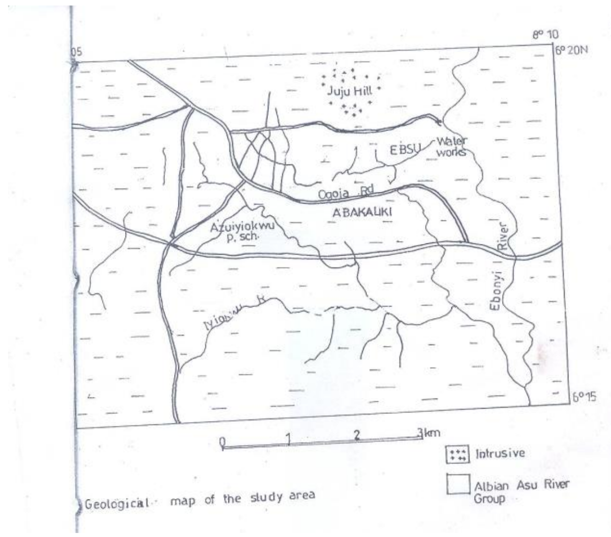

Figure 2: Geological Map of the Study Area.

The Nkporo Shale is the youngest unit of the sequence and is Campanian-Mastrichtian in age. Fissile dark-grey to black carbonaceous shale, interbedded with thin ironstone beds and intercalated with sandstones, is a common feature in this unit. Marls and gypsum are the major components of this formation. It directly underlies the Turonian Ezeaku Formation unconformably.

The area has a dendritic drainage pattern formed by a network of streams and brooks flowing in different directions. Of all these, only the Ebonyi River is perennial although its effluence is usually doubled during the rainy season (Johnson, 1996). It has a tropical rain forest climate made up of two seasons: the wet (April to October) and dry (November to March) seasons.

The survey involved establishing stations in each of the three locations in the study area

(Abakaliki). The three locations are Hope High School, Onwe Road; College of Agricultural Sciences, Ebonyi State University (EBSU) and Girls' High School, Azuiyiokwu.

The equipment used for the field work included the three-channel signal enhancement seismograph, a metal plate, a sledge hammer and cable, P-wave geophones and geophone cables, spade, measuring tape and field umbrella.

Each location in the study area was surveyed, marked and the source point for generating seismic waves was selected. The geophones were firmly placed on the ground in a single profile and spaced 5 meters apart. A small hole was dug to place the metal plate. The sledge hammer was used to hit on the metal plate to give enough energy into the ground to generate primary (longitudinal) seismic waves in the ground.

The vibrations of the ground due to the hitting of the hammer on the metal plate were detected by the geophones as mechanical energy. The geophones, in turn, converted the mechanical energy to electrical signals which traveled through the geophone cables to the seismograph where they were shown as sinusoidal traces and an automatic printout was obtained.

RESULTS AND DISCUSSIONS

The field data which comprised travel times and offset distances were tabulated and graphs of travel times, T(S) against offset distances, X(m) were plotted for each data point. Each data point is made up of a P-wave travel time and an offset. They were all manually plotted. A typical T-X plot for the area is shown in Figure 3.

The graph of the arrival times, T against the offset distances, X of seismic waves that traveled through the ground is a segmented line where each segment represents a particular refractor in the earth's sub-surface. The number of segments in a given T-X plot indicates the number of refractors as well as the number of layers through which the waves traveled. The various layers have different lithologic properties and, consequently, different seismic velocities.

From the Travel Time-Distance curves for the data gathered from each location, each of the spreads showed a three-layer case. The Velocities (V_1, V_2 and V_3) of the three layers of each of the three locations with their corresponding thickness are tabulated in Table 1.

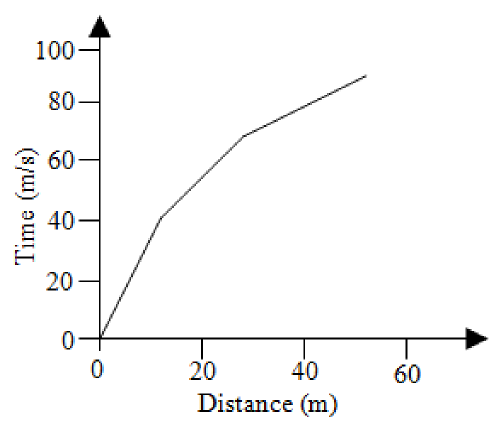

Figure 3: A typical T-X Plot from the Area.

Table 1: The P-Wave Velocities (V) and Thicknesses (Z) of Layers at the Three Locations in Abakaliki.

Location	**V_1(m/s)**	**V_2 (m/s)**	**V_3 (m/s)**	**Z_1 (m)**	**Z_2 (m)**
Hope High School, Onwe Road.	425	833	3750	5.9	14.6
College of Agric. Sciences, EBSU.	862	1250	2500	6.0	13.0
Girls' High School, Azuiyiokwu.	694	833	2500	8.2	14.6

The P-wave velocities and thicknesses in the first location (Hope High School, Onwe Road) were 425m/s and 5.9m for the first layer (probably sandy clay), 833m/s and 14.6m for the second layer (probably loose sand) and 3750m/s for the third layer (probably an intrusive hard rock), respectively.

The P-wave velocities and thicknesses in the second Location (College of Agricultural Sciences, Ebonyi State University) were 862m/s and 6.0m for the first layer (probably loose sand), 1250m/s and 13.0m for the second layer (probably loose sand) and 2500m/s for the third layer (probably limestone) respectively.

The P-wave velocities and thicknesses in the third location (Girl's High School, Azuiyiokwu) were 694m/s and 8.2m for the first layer (probably dry soil), 833m/s and 14.6m for the second layer (probably loose sand) and 2500m/s for the third layer (probably limestone), respectively (Table 1).

Thus, a hard rock (an intrusive) is present in the third layer (with seismic wave velocity of 3750m/s) of the first location (Hope High School, Onwe Road) at a depth of about 20.5m below the surface of the earth. Intrusive hard rocks are absent in the second and third locations of the surveyed area – Abakaliki.

CONCLUSION

Seismic refraction can effectively be used to detect the internal distribution of rock properties within the earth. From the variation of P-wave velocities with depth, the rock types located at different depths can be inferred from seismic refraction survey.

From the results of this work, hard rocks (intrusives) are probably present at Hope High School, Onwe Road, Abakaliki at a depth of about 20.5m below the surface of the earth. These rocks can be used for building/road constructions and can also serve as a source of income for the natives of the locality.

The intrusive hard rocks are probably absent in the second and third locations of the study area. It is therefore recommended that Onwe Road should be exploited for intrusive hard rocks.

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