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Seismic Studies and Velocity Estimation Using Refraction Method

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Abstract: Seismic refraction work was carried out within the premises Ebonyi State university, Abakaliki with the objective of estimating the velocities of subsurface layers. The study area lies within latitude 6°18'N - 6°20'N and longitude 8°05'E- 8°10'E and has an area of about 84km^2. The major instrument used was a 3-channel seismograph with model number MOD. S79. Both compression(P)l and shear(S) waves refraction paths were utilized and analyzed. Three locations in the study area were surveyed. The results obtained shows that the average P-wave velocities for the first, second and third layers of the three locations of the study area are 763m/s, 1748m/s and 2752m/s respectively. These layers were interpreted to be sand with gravel (wet), limestone and sandstone. The average thicknesses of the first two layers were 4.7m and 7.0m respectively. The average value of the S-wave velocities were 367m/s, 1086m/s and 1793m/s respectively,which gave a mean thickness of 5.1m and 8.8m for the first and second layers respectively. The results indicate that the speed with which shear waves propagate through the earth's subsurface layers were less than those of compressional waves.

Key words: Seismic · Geophones · Seismograph · Refraction

INTRODUCTION

Seismic studies is the study of different forms of seismic waves as they propagate by the deformation of rock materials beneath the earth.

It can be defined as the studies done to gather and record patterns of induced shock waves from underlying/underground layers of rocks which are used to create detailed model of the underlying geological structures. Seismic waves are waves created by earthquake, explosions or other controlled sources [1]. There are two methods used in seismic surveying. These are the reflection and the refraction methods.

The seismic refraction method is based on the refraction of seismic energy at the interface between subsurface layers of different velocities. This method uses very similar equipment to reflection surveying, typically utilizing geophones in an array and a seismic source (short point). A part of the seismic energy propagates from the source along the surface. This is the seismic surface wave. The remainder which propagates into the earth as body wave encounters an interface between two different soils or rock layers; a portion of the energy is reflected while the remainder propagates through the layer boundary at a refracted angle. At a critical angle of incidence, the wave is critically refracted and will travel parallel to the interface at the speed of the underlying layer.

The aim of this research work is to determine the velocities of compressional and shear seismic body waves with a view to infer the structural nature of the subsurface layers of Abakaliki, the study area. Knowledge obtained from this work would be useful for both engineering and hydrogeological applications. Agha *et al.* [2] in their study of the propagation of P-waves and S-waves in Afikpo, Nigeria, observed that the velocities of both P and S waves increased with depth of the subsurface layers. They however noted that for a given medium, the P- wave velocity was greater than the corresponding S- wave velocity.

Location and Geology of Study Area: The study area is Ebonyi State University (EBSU), Abakaliki which is situated on the Abakaliki anticlinorium with an area of about 84 square kilometers. Abakaliki is geographically located within longitude 80° 05' E - 80° 10' E and latitude 6° 15' N - 6° 20' N with an altitude of 98m above sea level [3, 4, 5, 6, 7].

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Geologically, the study area is underlain by the Abakaliki formation which is predominantly made of shales. The shale formation belongs to the Asu-River group of the Albian cretaceous sediments. The Asu-River group is middle Albian sediment consisting of very thick marine, dark, grey shales and minor Limestones. The sediments consists of poorly bedded shales known as Abakaliki shales with sandstone and limestone lenses [8, 9, 10].

MATERIALS AND METHODS

Materials: Seismic wave generation, detection and recording as utilized in this study were carried out by the use of the following instruments: sledge hammer, metal plate, P- and S- wave sources, 3-channel seismograph, geophones (P- and S- types), geophone cable and surveyor's tape.

The sledge hammer was used alongside the metal plate and the P-wave and S-wave source to generate the seismic signals.

Method: The locations which were chosen within the study area for the seismic refraction survey include EBSU staff quarters, (Location 1), Pre-degree school of EBSU (Location2) EBSU Post- graduate school (location 3).

The P- wave source was used for both forward and reverse profiling in each location while the S- wave source was used for only forward profiling. In each location and along a given profile line, the S-wave profiling was first carried out before the P-wave profiling. For each type of seismic source laid, corresponding geophones were interspaced along the profile line. The inter-geophone distance was 5m, while the traverse length was 60m. Arrival times of the signals were also recorded at the seismograph as they traveled from source (short point) to receiver (geophones).

RESULTS

Results: The seismic data obtained from the survey which include the arrival times(T) and the Shot-detector distances(X) were graphically analysed by plotting travel time, T(ms) against offset, X.

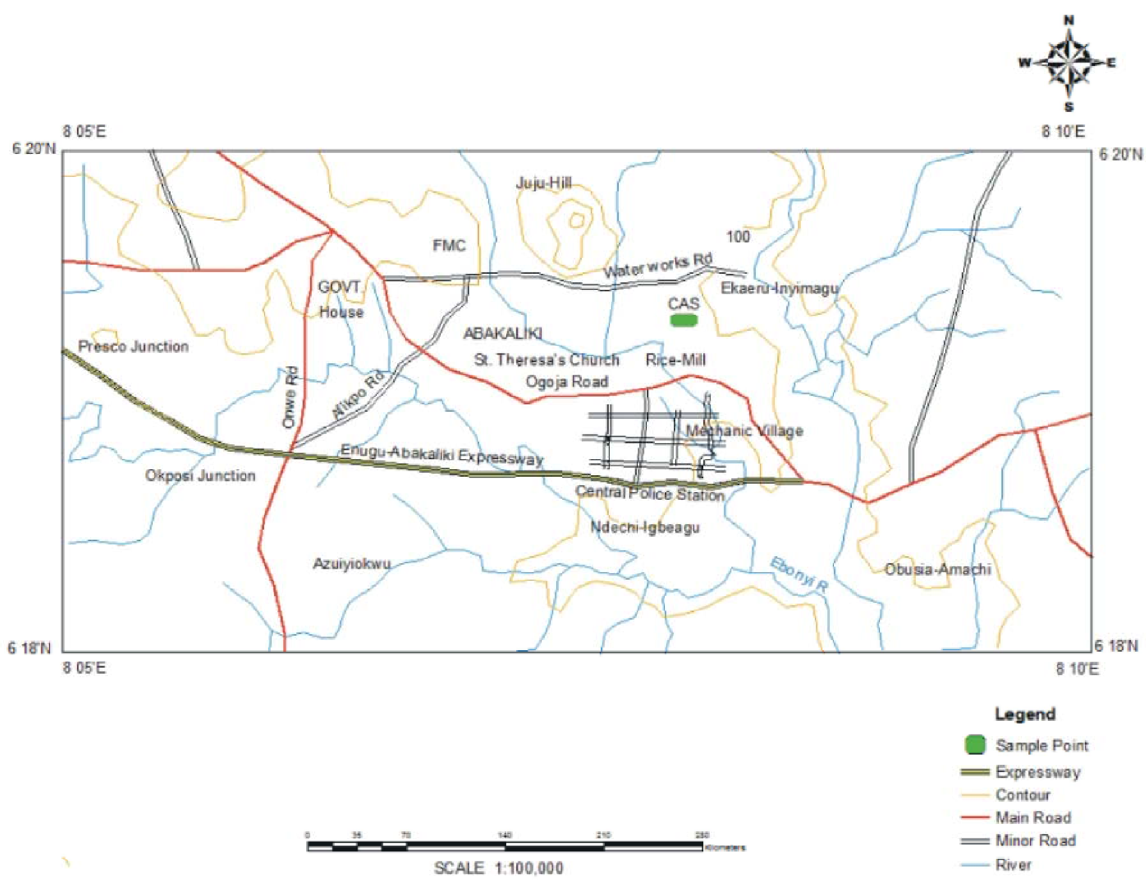

Fig. 1: Location map of the study area

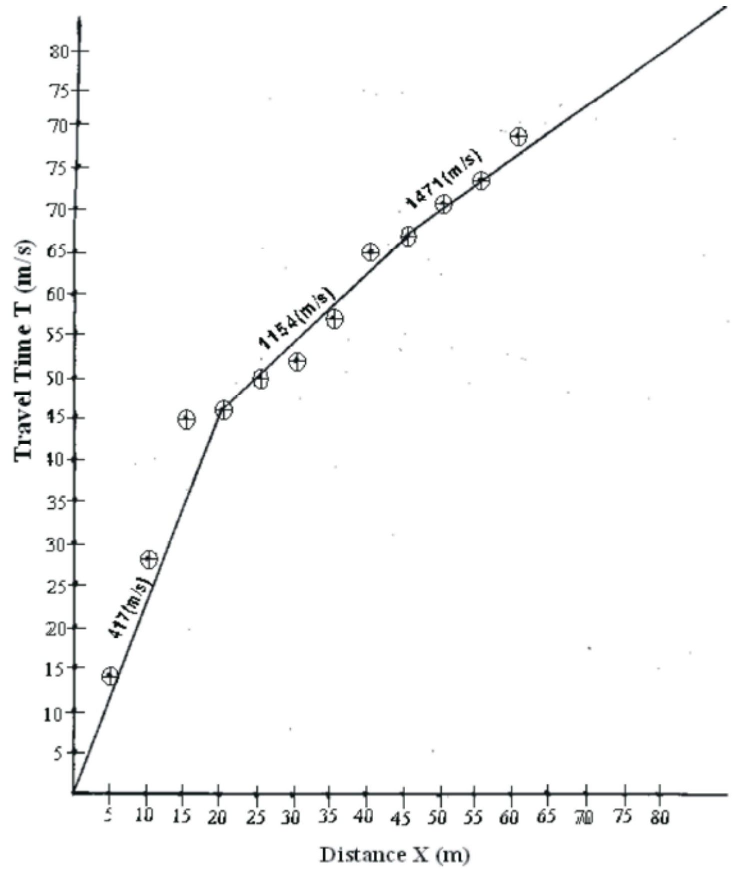

Fig. 1: T-X plot of S-wave data from EBSU Staff Quarters

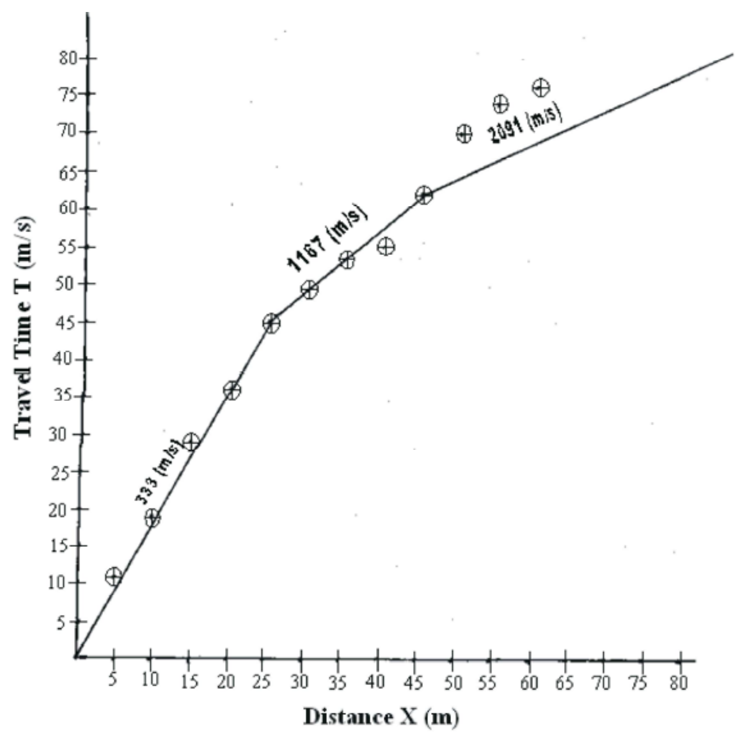

Fig. 2: T-X plot of S-wave data from Pre -Degree School EBSU

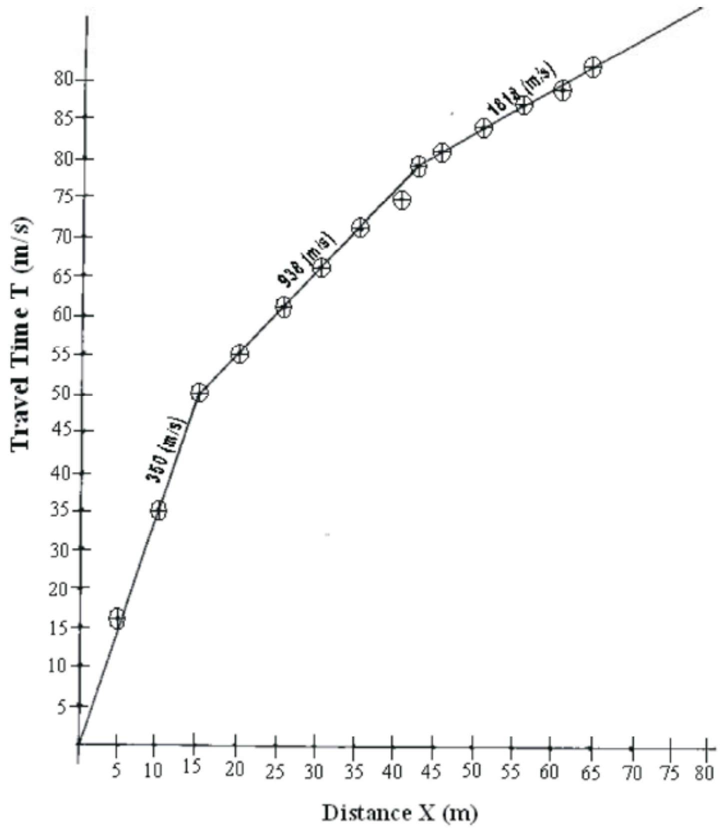

Fig. 3: T-X plot of S-wave data from Postgraduate School EBSU

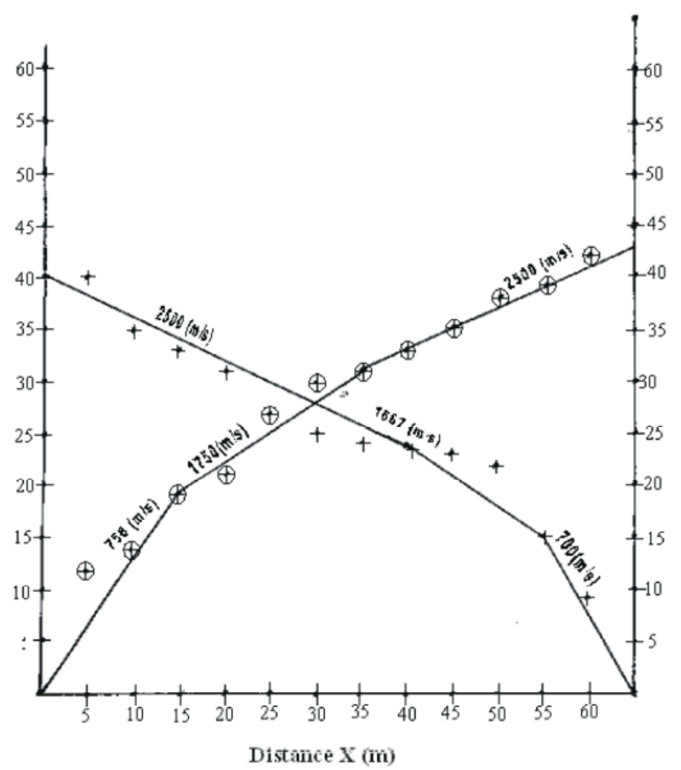

Fig. 4: T-X plot of P-wave data from EBSU Staff Quarters

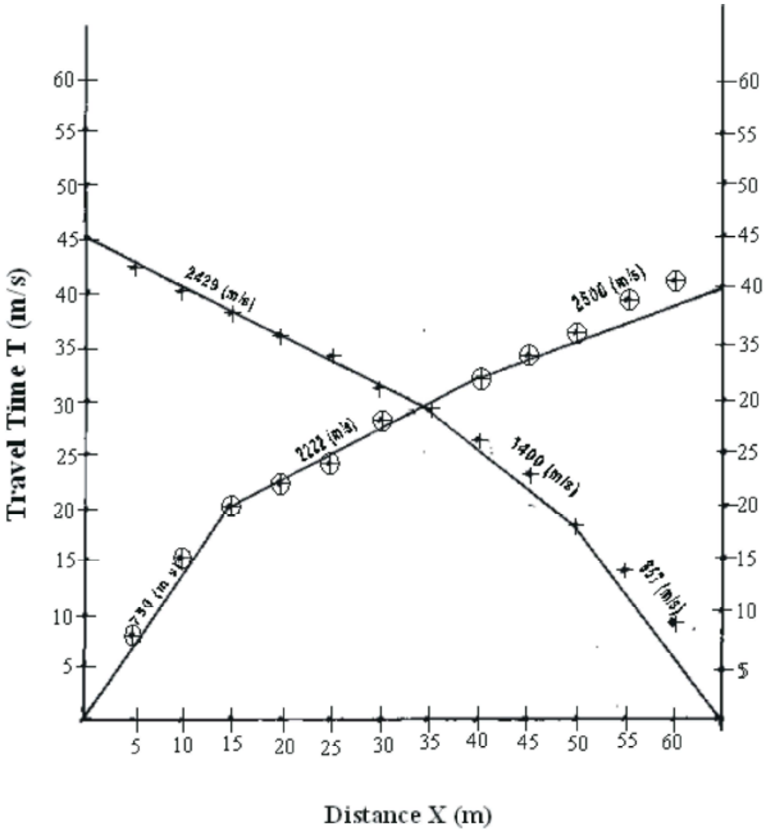

Fig. 5: T-X plot of P-wave data from Pre Degree School EBSU

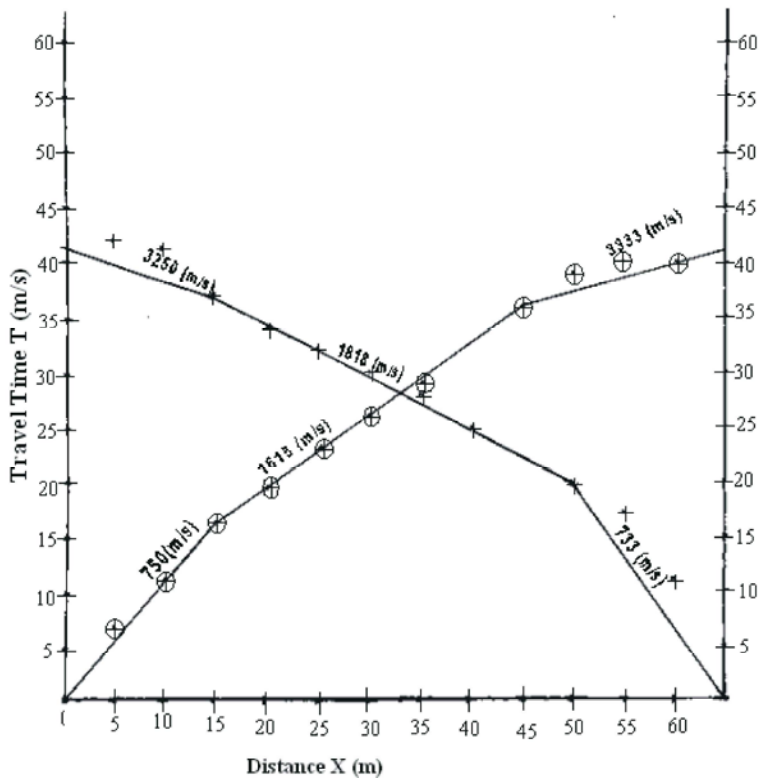

Fig. 6: T-X plot of P-wave data from Postgraduate School EBSU

Table 1: True velocities and thicknesses of layers in various locations of the study area for S-wave

Location	V_1(m/s)	V_2(m/s)	V_3(m/s)	Z_1(m)	Z_2(m)
EBSU Staff Quarters	417	1163	1471	6.9	14.6
Pre- degree School	333	1167	2091	9.3	21.3
Postgraduate School	350	938	1818	5.5	17.4

Table 2: True velocities and thicknesses of layers in various locations of the study area for P-wave

Location	V_1(m/s)	V_2(m/s)	V_3(m/s)	Z_1(m)	Z_2(m)
EBSU Staff Quarters	743	1709	2500	4.8	13.0
Pre-degree School	804	1818	2465	4.3	10.0
Postgraduate School	742	1717	3292	6.2	18.8

Figs. 1-3 show the S - wave T-X plots while Figs. 4-6 show the P- wave T-X plots.

The velocities and thicknesses of the various layers delineated in each of the locations were calculated for both P- and S- waves and are shown in Tables 1 and 8 below respectively.

Interpretation: From the T-X plots of the waves in Figs. 1-6, it is observed that both the P-waves and S-waves revealed a three layer case in each of the locations. The average P- wave velocity for the three locations were 763m/s, 1748m/s and 2752m/s for the first three layers respectively.

These layers were interpreted to be probably sand with gravel (wet), limestone and sandstone from top to bottom respectively. The mean thicknesses of the first and second layers were 5.1m and 8.8m respectively.

The average velocity of the layers delineated by S-Waves in the three locations are 367m/s, 1383m/s and 1793 for the first, second and third layers respectively.

CONCLUSION

From the considerations made with respect to the fore-going analysis and discussion, we conclude that(i) each of the two waves(P and S) reveal three layers of the subsurface(ii) the sources of the two body waves probably have the same strength(iii) the average velocity for the P-wavess in the three locations are 763 m/s, 1748m/s and 2752m/s for the first three layers respectively while those of the S-waves were 367m/s, 1383m/s and 1793m/s for the first, second and third layers respectively which implies that the P-waves propagate with higher velocity into the earth subsurface than the S-waves.

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