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SHEAR WAVE PROPAGATION AND SHEAR DEFORMATION IN SUBSURFACE MATERIALS

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ABSTRACT
The deformational chacteristic of seismic shear waves which propagate through the earth's body in Afikpo, Nigeria has been studied. The modulus of elastic deformation considered was the rigidity or shear modulus. The shear wavesutiliszed in the study were generated from a mechanical source. The corresponding ground motions were received by S – wave geophones. The seismograph used was a 3 – channel digital type with model number MOD. S79. Afikpo is situated within latitude 5^0 52' – 5^0 57'N and longitude 7^0 52'– $7^0$58'E. It has an area of about 5okm^2. Refraction seismic surveys were carried out with the shear waves in three locations within the study area. The result shows that the average shear wave velocity of rock layers in Afikpo are 250m/s and 483m/s for the first and second layers respectively.These gave mean values of shear modulus as 1.2 x 10^8 N/m^2 and 7.2 x 10^8 N/m^2 for the first and the second layers respectively.

KEYWORDS: Seismic, Geophones, Seismograph, Refraction.

INTRODUCTION

A Seismic disturbance is transmitted by periodic elastic displacements of the particles of a material medium. This condition however does not apply close to the seismic source. In or near an earthquake focus or the shot point of a controlled explosion, the medium is permanently destroyed and the deformation is inelastic. (Lowrie, 1997).

If the propagating seismic wave has travelled some distance away from its source, its amplitude decreases and the medium under goes deformation to permit its passage. When an explosion occurs at a point near the surface of a homogenous medium, part of the energy propagates through the body of the medium as body waves while the rest propagates along the free surface as surface waves.

The progress of the seismic wave, copressional (P) or shear (S) is determined by the advancement of the wave front. Shear deformation occurs in subsurface structures due to the passage of the shear waves. When shear waves propagate in an elastic solid, the motion of individual particles is always perpendicular to the direction of wave propagation. And the

velocity, $V_s$of the wave is given by: $V_s = \sqrt{\frac{«}{°}}$

where μ is a modulus of elasticity called shear modulus and ρ is the density of the material medium (Dobrin 1976).

The propagation characteristics of seismic shear waves and the consequent deformation suffered by subsurface materials has been studied in afikpo (Lat. 5^0 52'– 57'N and Long.7^0 52'– 58' E),with the use of the seismic refraction method.

Okwueze (1991) carried out a seismic refraction survey around $6^0$19'N and $8^0$39'E within the Ezeaku shale formation in Ikom, Nigeria.The Ezeaku shale formation passes laterally into the Amasiri sandstone facies in the present Afikpo region. He found out that while the P-wave clearly defined 3 – layers, the number of layers defined by S-wave was not very obvious. The S-wave however, delineated a 2m thick top layer with a velocity of 330m/s overlying a 1000m/s second layer. The value of the shear modulus he obtained were 0.2 x 10^{10}N/m^2 and 2.4 x 10^{10}N/m^2 for the first and second layers respectively.

MATERIALS AND METHOD

MATERIALS

The major equipment used in this study is a portable MOD. S79 three – channel digital type signal enhancement seismograph. This instrument is powered by an in-built 12V accumulator with an operating time of about 30hours. Some other components required in the instrumentation besides the siesmograph include an aluminium striking plate and a 9kg sledgehammer both of which make up the shear wave source. A 10Hz electromagnetic type shear wave geophone was the detector used.

METHOD

Seismic refraction surveys were conducted in three locations in the study area .In each location, shear waves were generated by striking a rectangular- shaped metallic plate. The plate was fixed vertically to the ground but the striking of it with the sledgehammer was done in the horizontal sense. Te shear waves generated propagate through the earth and the corresponding ground motions were detected by shear wave geophones implanted on the ground along the profile line. Up to 12 geophones could be connected to the geophone cable used but only ground response from the first three geophones from the seismic source were recorded in the seismograph at each impact of sledgehammer and the metal plate. The metal was buried to a depth of 5cm in the ground. This was to ensure deeper penetration of the seismic energy when the plate is struck with the sledgehammer and for better coupling. These ismograph recorded arrival times T(milliseconds) of the signal from the shot point while the shot-detector distances X(m) were marked out/measured with a surveyor's tape.

RESULTS AND DISCUSSION

RESULTS

The arrival times, T(milliseconds) of the refracted shear waves and the corresponding distances X(m) of geophones from the source in each of the three locations were plotted graphically as shown in Figs. (1-3) below.

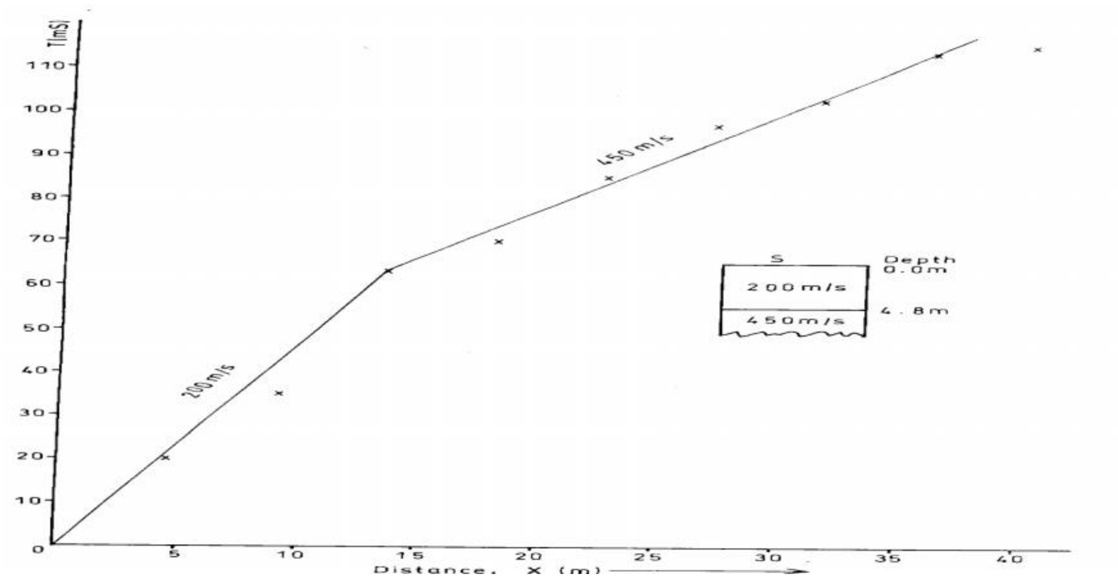

Fig. 1: S-wave (T-X) plot and the equivalent geoseismic layers at location 1.

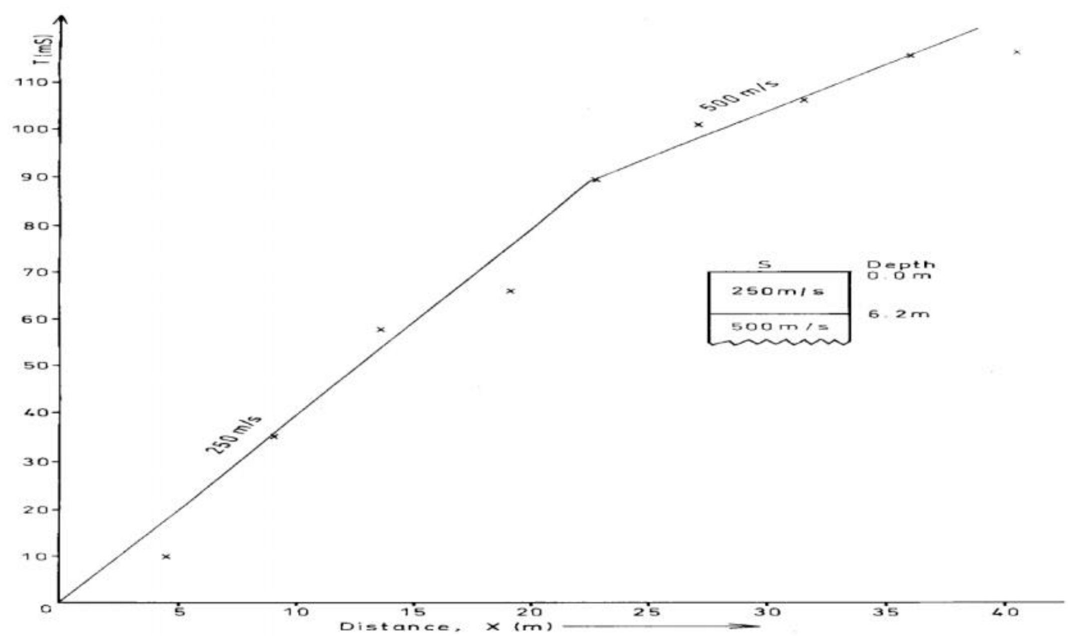

Fig. 2: S-wave (T-X) plot and the equivalent geoseismic layers at location 2.

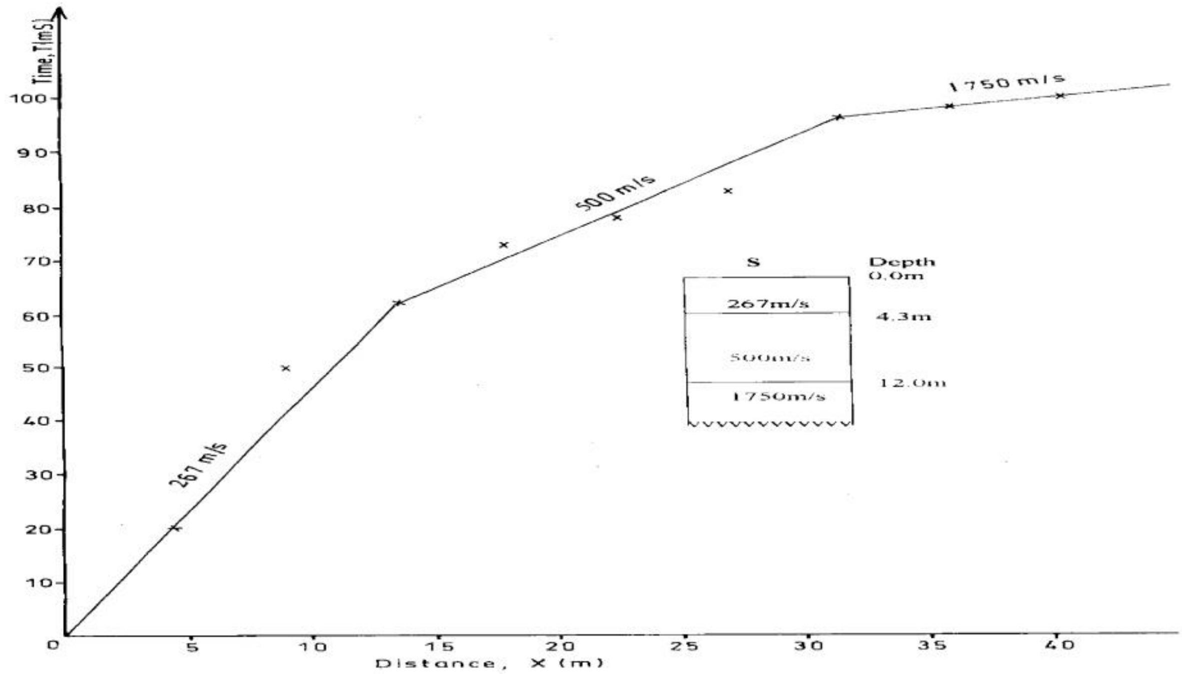

Fig. 3: S-wave (T-X) plot and the equivalent geoseismic layers at location 3.

DISCUSSIONS

Looking at the (T – X) curvesof Figs. 1 – 3, two of the spreads show a 2-layer case while the third show a 3-layer case.

In Fig. 1, the S-wave delineated a 4.8m thick top layer with a velocity of 200m/s overlying a 450m/s second layer. These gave mean values of shear modulus, μ as $1.3x10^8 N/m^2$ and $5.4x10^8$ N/m^2 for the first and second layersrespectively.

In Fig. 2, a two-layer case was also observed with velocities of the first and second layers as 250m/s and 500m/s respectively giving μ-values as $1.7x10^8$ N/m^2 and $6.7x10^8$ N/m^2 accordingly. The thickness of the upper layer was 6.2m.

In Fig. 3, a three– layer case is revealed although the third layer defined by the waves was not very obvious. The shear wave velocities of the three layers from top to bottom were 267m/s, 500m/s and 1750m/s respectively. These gave mean values of shear modulus,μ as 0.7 x $10^8 N/m^2$ and 9.6 x $10^8 N/m^2$. The thickness of the first two layers from the earth's surface were 4.3m and 12.0m respectively.

CONCLUSION

Shear waves were observed to propagate through the body of the earth in the study area as they travelled from source to receiver. This was evidenced by records of arrival times of the signals by the seismograph. It is also obvious that underlying materials in the study area had suffered shear deformation as the waves propagate through them.The evidence of this, is the significant values of shear modulus (μ) which were determined for each of the delineated layers in the analysis.No liquid subsratum was detected in the survey since shear waves cannot propagate in liquids where μ = 0. From the analysis, the average values of the shear wave velocities in Afikpo for the first and second layers are 250m/s and 483m/s respectively. The average values of shear modulus (μ) are 1.2 x $10^8 N/m^2$ and 7.2 x $10^8 N/m^2$ for the first and second layers respectively. The mean thickness of the topmost layer in the study area is 4.6m.

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