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Estimation of Dipping Angles of Refracting Interfaces

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Abstract: *The dipping angles of refracting interfaces at Afikpo, Nigeria have been estimated. The seismic refraction method was used. Compressional waves were utilized. The instrumentation includes a seismograph and its accessories. Three layers of the subsurface were revealed by the waves with two refractors, first and second from the earth's surface obvious. The average velocities of the layers were from the surface,413ms^{-1} ,1139ms^{-1} and 2287ms^{-1}.The dipping angle of the first refracting interface to the second was estimated to be 11° while the dipping angle of the second refracting interface to third was 12°.*

Key words: *Dip, Interface, geophone, head wave, refractor.*

I. Introduction

The Refracting interface between two beds can either be horizontal or inclined. Most times, it is practically not horizontal. When the top surface of a refracting bed is not horizontal, errors would be introduced into velocity and depth results if the layers are assumed to be flat. If a refractor is suspected to be dipping, the true velocities of the layers and the dip of the horizon can be obtained by shooting a second complementary profile in the opposite direction (Lowie, 1997).

Let us consider a refractor that dips at an angle,α (Fig. I). If shot points P and Q are at the extremes of a geophone cable, along which geophones are interconnected, the ray PMNQ from the short, P will strike the boundary at critical angle, i_c at M and then travel as a head wave with speed V_2 along the dipping interface while the other ray emerging at N would reach a geophone at the end of the profile at Q. At the reverse shooting, the ray from the short point at Q gets to a geophone at P following the same path but in the opposite direction. The t-x plot for the up-dip shot differs from that of the down dip (Dobrin, 1976). We define d_p as the perpendicular distance from the shot, P to the interface at point R_1 and d_Q as that from shot Q to point, R_2. The travel time to distance, x for the down-dip is evidently.

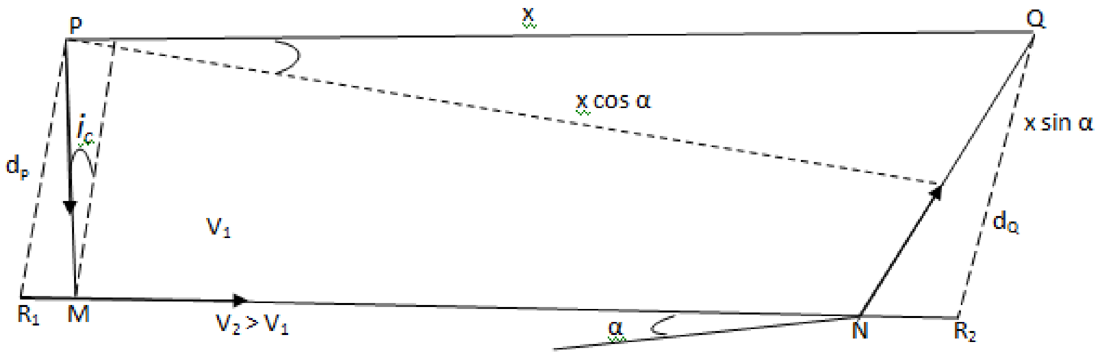

Fig 1: Dipping Refractors

$$t_d = \frac{PM + NQ}{V_1} + \frac{MN}{V_2} \quad \ldots\ldots (1)$$

It could geometrically been shown from Fig.1 that:

$$t_d = \frac{x \sin i_c \cos \propto}{V_1} + \frac{x \cos\, i_c\, \sin \propto}{V_1} + \frac{2d_p \cos\, i_c}{V_1} \quad \ldots\ldots (2)$$

Hence,

$$t_d = \frac{x}{V_1} \sin\, (i_c + \propto) + tid \quad \ldots\ldots (3)$$

$$tid = \frac{2dp}{V_1} \cos\, i_c \quad \ldots\ldots (4)$$

where t_{id} is intercept time for the down – dip shot. Similarly it could be shown that the travel time for the up-dip is given by:

$$t_u = \frac{x}{V_1} \sin\, (i_c - \propto) + t_{iu} \quad \ldots\ldots (5)$$

where t_{iu} is the intercept time for the up-dip (Lowrie, 1997) shot and

$$t_{iu} = \frac{2dQ}{V_1} \cos i_c \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . (6)$$

The refraction paths of compressional body waves were used to locate the presence of dipping interfaces and to estimate the dip angles of the beds in Afikpo, Nigeria, through the seismc refraction method. Afikpo is located within latitudes
5^0 52^1-5^0 57^1N and longitudes $7^0 52^1$-$7^0 58^1$E. It has an area of about 49km^2.

Some geophysical investigations have been carried out in the study area. Agha, *et al.,* (2006) used the seismic refraction method at Afikpo to assess the strength of earth materials in the area for construction works. The elastic parameters they estimated include positions ratio,ν, bulk modulus,k, shear modulus,μ and young's modulus,E. Their result showed that the first two layers of the area had Poisson's ratio values of 0.16 and 0.23 respectively which gave mean values of μ as 0.4 and 3.4 x 10^9 N/m^2, of K as 0.07 and 1.5 x 10^{10} N/m^2 and of E as 0.8 and 9.5 x 10^9 N/m^2 for the first and second layers respectively.

Odii et al (2014) mapped near surface intrusives in Abakiliki using compressional waves. The seismic refraction method was employed.The average P-waves velocity and depth in the study area according to their result were 425m /s and 5.9m respectively for the first layer(probably sandy clay), 833m/s and 14.6m for the second layer(probably loose sand)and 3750m/s and an undetermined depth for the third layer (an intrusive hard rock).They suggested hence that the sources of the hard rocks excavated and crushed in Abakiliki, are intrusions that have occurred at the subsurface.

II. Materials And Method

The materials used in this work comprises an MOD S79 signal enhancement seismograph, primary (p) wave geophones and cable, hammer/plate pair as seismic source, and hammer cable. The seismic refraction method was carried out which involved the use of the over listed materials for profiling. Both forward and reverse profiles were run in three different locations chosen within the study aera. The offsets (x) and corresponding travel-times (Tms) were recorded in each of the
Locations in both the forward, F and complementary shootings/reverse shootings, R.

III. Result And Discussion

The time taken for the waves to travel from shot to the geophones, T(ms) for both the forward shooting (T_F) and the revere shooting, (T_R) were plotted against geophone distances (x) from shot points. Fig. 2 is a typical T-X plot from the area.

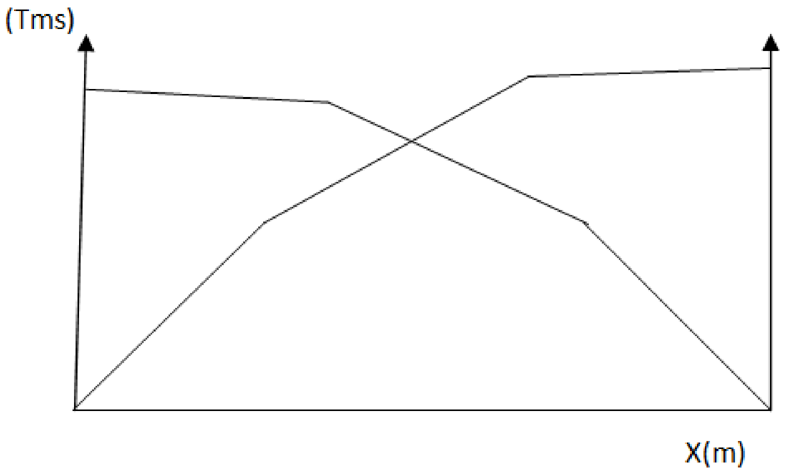

Fig 1: Refraction curves for P-waves at location 2

The values of the true velocities, V estimated for each of the subsurface layers delineated by the waves and the dip angles, α of the inclined refractors encountered are presented in Table 2.

Table 2: Velocities of layers and dip angles of interfaces in various locations of the study area.

Location	Vp$_1$ m/s	Vp$_2$ m/s	Vp$_3$ m/s	Dip angle,**α** (^{0})	
				α$_1$	**α**$_2$
1	306	592	1790	4°	5°
2	625	1800		12°	11°
3	308	1025	2600	6°	8°

IV. Discussion:

From. Table 1, it is observed that 3 layers were revealed by the waves in each location. At location I, the true velocities evaluated were 306m/s, 592m/s and 1790m/s which were interpreted to be probably loose sand, sandy clay and clay stone. The dips of the first and second layers to the second and third interfaces were estimated as 4° and 5° respectively.

At location 2, the true velocities were 625m/s, 1800m/s and 2470m/s which were translated to mean sandy soil, clay and a consolidated layer. The dip angles of the first and second layers were 12° and 11° respectively. At location 3 where the velocities were 308m/s, 1025m/s and 2600m/s for the first three layers from the earth's surface and which were interpreted as sand, sandy clay and claystone,the first and second layers were dipping at 6° and 8° to the second and third interfaces respectively.

V. Conclusion

From the above analysis and discussion, the following conclusion can be drawn:

i. The P – waves revealed 3 layers in each of the location in the study area.
ii. Two refractors were obvious in each location; the first refractor being the interface between the topmost/first layer and the second layer and the second refractor the interface between the second and the third layers from the earth's surface.
iii. Non of the refractors were flat-laying or horizontal. Each one was inclined.
iv The angle of dip varied from location to location
v. The angle of inclination or dip angle was however nearly constant for a given location.
vi. The average value of the dip angles was estimated to be 11° for the first interface and 12° for the second interface.

It is hereby recommended that better energy source of seismic wave be used by future researchers in replacement of the hammer source whose low output could not penetrate much into the subsurface.This will not only confirm the result of this work but would also enable the estimation of dips for deeper layers / refractors.

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