LOW VELOCITY LAYER MAPPING USING SEISMIC REFRACTION TECHNIQUE IN 'A' FIELD, ETCHE, RIVERS STATE, NIGERIA

Adiela, U.P[1] . Emudianughe, J [2] . Akomolafe, M.T [3].

[1]Department of Petroleum Engineering, Nigerian Agip Oil Company, Port Harcourt

[2] Department of Earth Science, Federal University of Petroleum Resources, Effurun, Nigeria.

[3] Department of Geology, University of Port-Harcourt, Rivers State, Nigeria.

Abstract: This study shows how blind zones (Low Velocity Layers) can be determined from uphole seismic refraction in field "A" Niger Delta. The charge depth was 15ft (5m) in order to remove the effect of the low velocity surface layer and reduces all reflection times to a common height datum. T-X curve showing Travel Time versus Offset Distance was plotted using GNUPLOT Iteration softwares. The velocities of the layers are V_1= 444.4(m/s), V_2= 606.06(m/s) and V_3= 1904.76(m/s) with thicknesses of H_1= 0.326m (1.070ft), H_2= 2.238m (7.343ft). Blind zone was observed between layer 2 and layer 4 with a thickness Z= 2.677m (8.783ft) which was calculated using the Nomograph (Maillet and Bazerque, 1931).

Keywords: Seismic; Refraction, Blind Zones; Nomograph; Layers; Niger-Delta.

INTRODUCTION:

Seismic refraction method is widely used to delineate the low-velocity weathered layers for computation of statics corrections that are applied to the main reflection data. In addition it is considered as a valuable tool for near-surface geophysics and engineering, such as delineation of bedrock or basement and determining the engineering properties of ground. The seismic refraction method requires that the earth materials increase in seismic velocity as depth increases (Dix, 1955). The analysis of refraction data becomes more complicated when the materials contain layers that dip or are discontinuous. For shallow application in which low velocity layer are encountered within a few meters or tens of meters below the Earth's surface, the increasing-velocity requirement is a severe constraint. The applicability of seismic refraction profiling for the detection of velocity inversion known as low-velocity layer (LVL) was investigated in 'A' field in Etche, Rivers State, Nigeria. The investigation was carried out at latitude 5^{o}24'E and longitude 7^{0}32'N. This study seek to show that refraction method is a vast tool in studying the subsurface geologic characteristics of the area, to delineate the layer parameters and map low velocity (Blind Zones) layers in over burden, and their thickness.

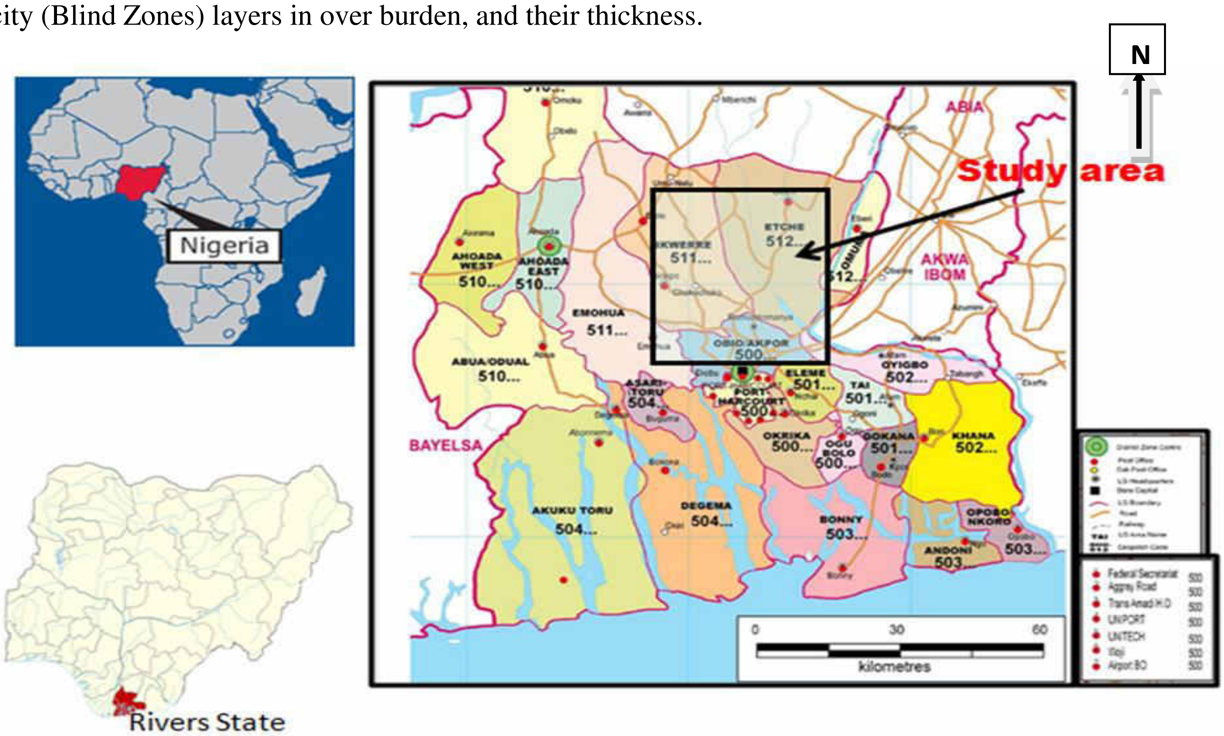

Figure 1: Map showing the location of the study area.

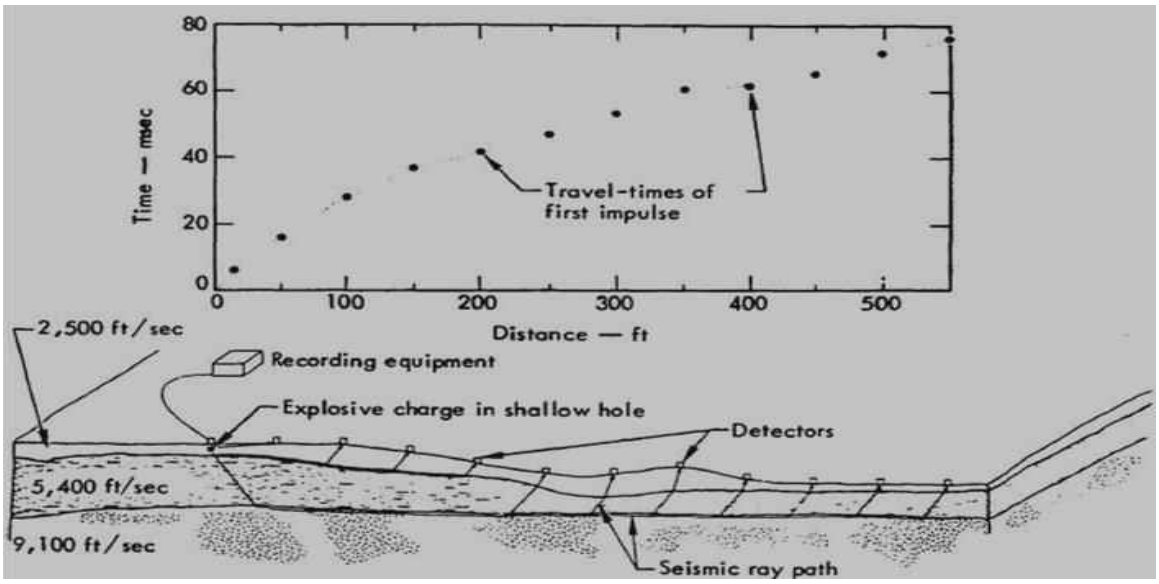

Figure 2: Schematic of seismic refraction survey

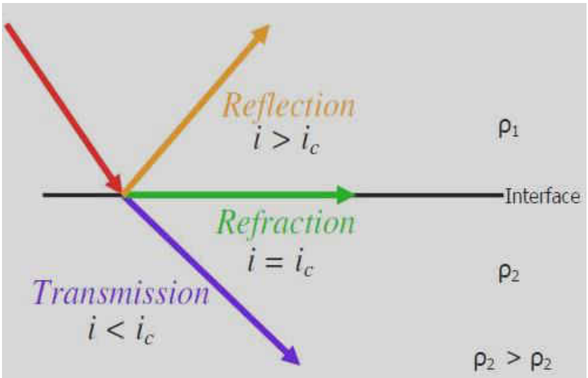

Figure 3: Mode of propagation of seismic waves within the earth layers.

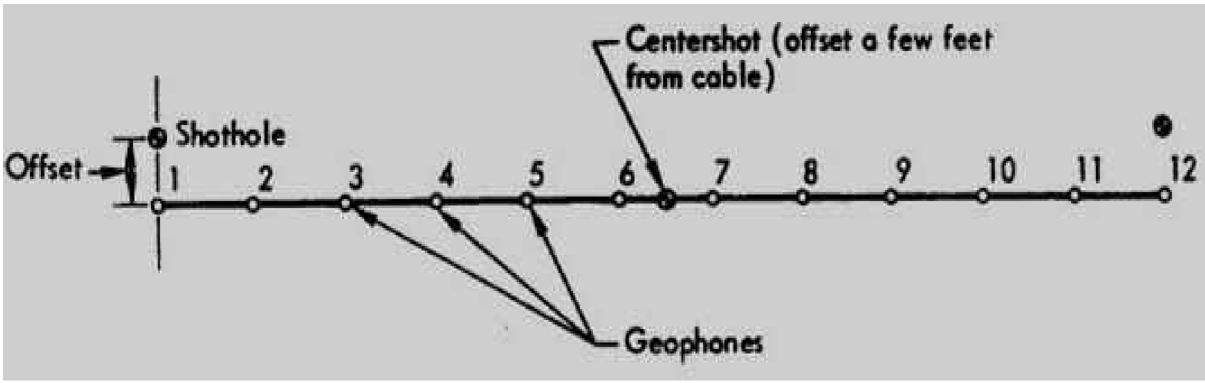

Figure 4: Seismic Refraction Data Acquisition

METHODOLOGY:

In this study, seismic refraction data from grid 5594/1961 ETCHE, Rivers State, Nigeria was analyzed for velocity variation which represents different geometry with different characteristics. Interpretation of the offset geophone data was done through the following procedures;

- Plotting of the T-X plot using iteration software such as GNUPLOT.
- Determination of velocity of layers, from the slope of each segment in the T-X plot.
- Computing layer thickness of each layer from their characteristics velocity.
- Analysis of velocity contrast between layers to check for the possible existence of a low velocity layer (LVL), not detected by the T-X plot of first arrivals.

- Determination of thickness of the LVL (if present) using the Nomograph table (Soske 1959; Maillet and Bazerque 1931; Leet 1938; Green 1962; Domalski 1956). For the study, data from the uphole survey and short spread refraction methods were used. Uphole surveys are the most direct measures of near surface properties (Knox, 1967, Rogers, 1981). The uphole method has the advantage of further resolving thin beds (hidden layers, thus making interpretation less problematic. Shots were fired at varying depths in a deep drilled hole; arrival times to detectors spread on the surface near the shot hole were recorded. In measuring these arrival times, the first breaks were picked as consistently as possible.

The algorithm for uphole survey has been designed as followed:

Step 1: Input values for T (ms) axis and Z (m) axis respectively.
Step 2: Plot the points scatter for T (ms) on the vertical axis against Z (m) on the horizontal axis.
Step 3: Identify the number of layers (lines on graph) plotted.
Step 4: Draw the lines of best fit for T-Z graph
Step 5: Determine the layers thicknesses (depths) and compute layers velocities. Step 6: Display T-Z plot, layers thicknesses and velocities.
Step 7: Stop.

Using GNUPLOT, the arrival times were plotted against their corresponding depths, thus giving the time-depth plot. The time-depth plot allows interpretation and evaluation of the velocity, blind zone, thickness respectively. The data sets used consist of corrected first breaks at 5m and 10m charge depth respectively. For each channel at every shot, 15 shots were taken and arrival times were normalized by subtracting pre-trigger time from first breaks.

RESULT AND ANALYSIS:

The base map for the field is shown in Figure 4.1. The corrected first breaks and their Geophone offset are shown in Tale 4.1 and 4.2 respectively. The T-X plot for charge depth 15ft is shown in figure 4.2 a sharp contrast between the second and third layer. This suggests that there is an intermediate layer or (thin beds) sandwiched between these two layers not revealed in the T-X curve due to insufficient velocity contrast or thickness there.

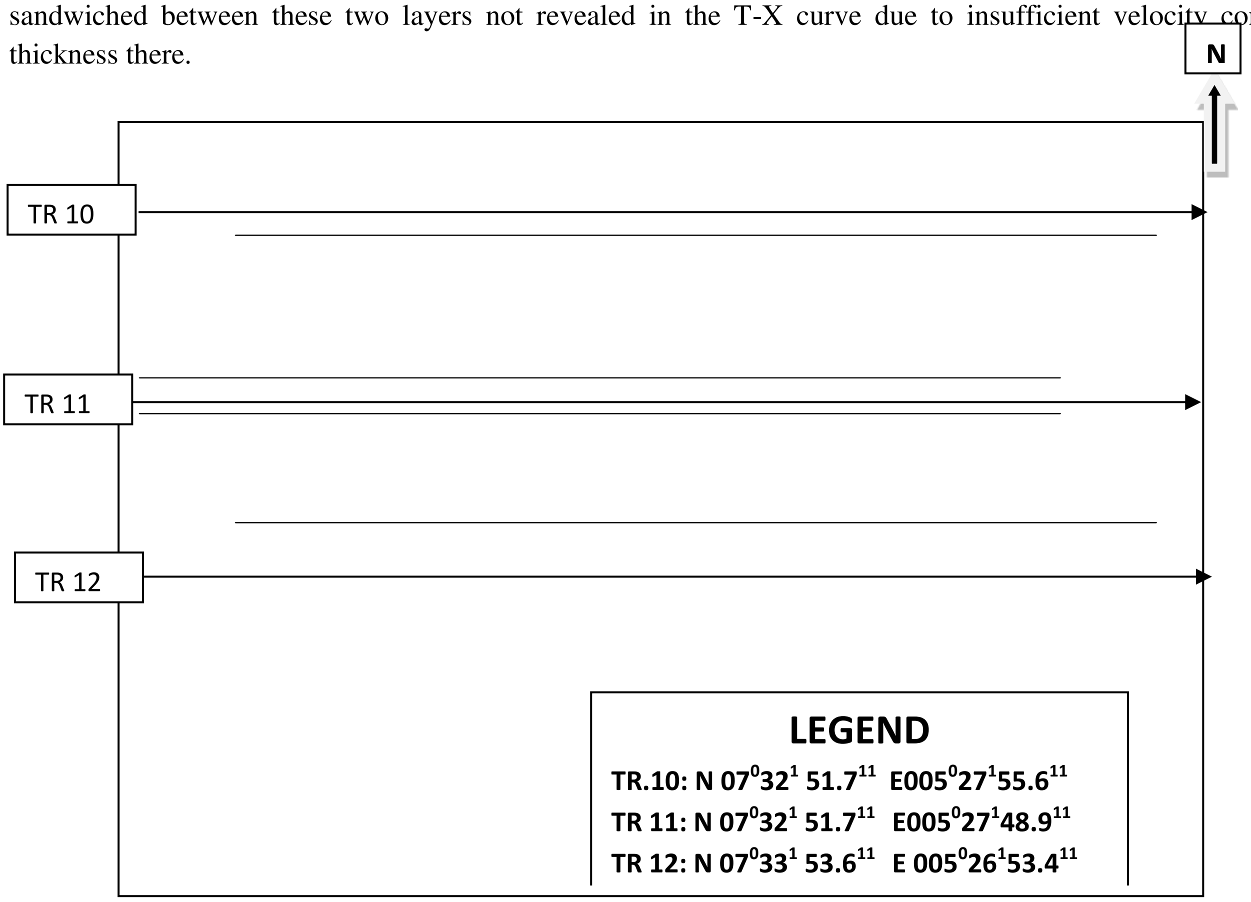

Figure 5: Base map of the study area.

Data Presentation

SEISMIC REFRACTION DATA

INSTRUMENT: ABEM Terraloc Mark 6 Seismograph

LOCATION: Etche, Rivers State, Nigeria.

CHARGE DEPTH: 15ft

No of shots	Geophone Offset (m)	Pick up time for 15ft (5m) charge depth (msec)
1	1	5
2	3	9.5
3	5	14
4	10	22
5	15	30.5
6	20	37.5
7	25	41.5
8	30	44
9	40	49.5
10	50	55
11	60	60.5
12	70	65

Table 1: Corrected first breaks for Geophone offset at 15ft charge depth.

Time distance Curve.

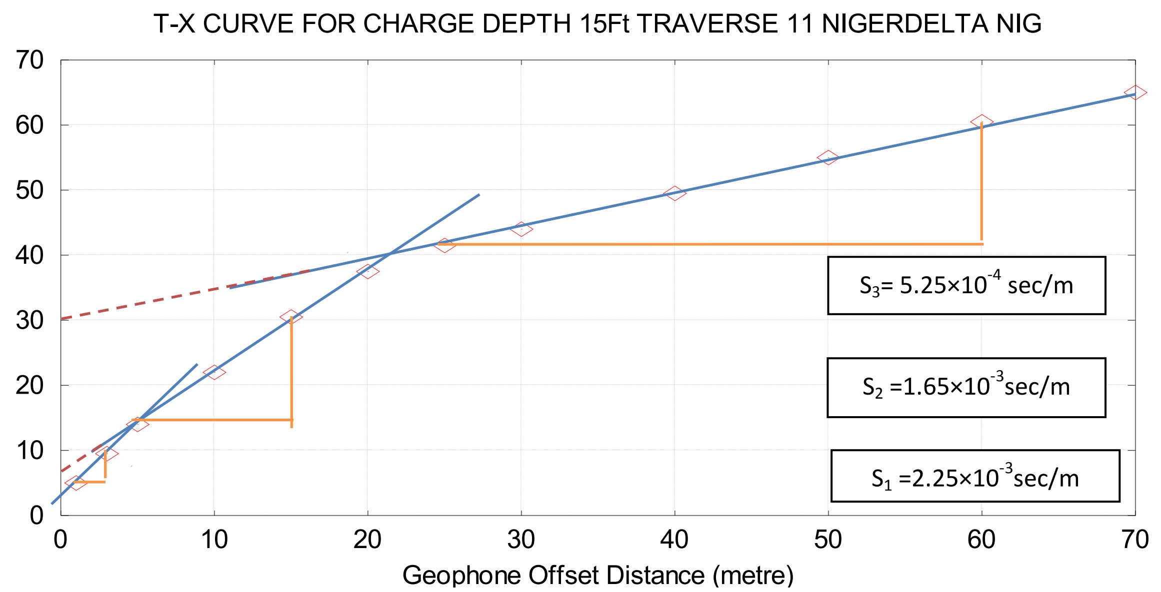

Figure 6: T-X curve for charge depth 15ft, Traverse 11, Niger-Delta.

Layer	Velocity(m/sec)	T intercepts(msec)
1	444.4	2
2	606.06	7
3(LVL Intermediate bed)	?	?
4	1904.76	30

Table 2: Result of the interpretation of the T-X curve above, showing the various layers and their velocities

From the T-X plot shown in figure 6, there is increase in velocity, which is expected from the theory of seismic refraction studies where velocity increase progressively with depth **(V1<V2<V3<V4),** for a four layers earth case. Between layer 2 and 4, the velocity contrast is too far (606.06m/sec-1904.76m/sec) compared to layer 1 and 2, these observation suggests that there is a possible existence of a Blind (LVL zone) between layers 2 & 4, which is not detected on the T-X curve shown in figure 6 above; (Soske, 1959).

Computing Maximum Thickness of the Suspected Low velocity zone (LVL).

The thickness of the suspected hidden Zone (LVL) was computed to ascertain the maximum thickness it would have and still not be manifested by first arrivals on the time-distance curve shown in figure 6. This was computed using a method proposed by (Soske, 1959; Maillet and Bazerque, 1931; Leet, 1938; Green, 1962; Domalski, 1956).

Using the Intercept time equation given as;

$$\text{H} = \frac{Ti}{2}\frac{VoV1}{\sqrt{V1^2 - Vo^2}}$$

Where Ho(max)(Ft) = Maximum thickness of the layer that directly Overlies the hidden layer of interest; Ho(max) is obtained by ignoring the possibility that an intermediate zone exists, Ti is the intercept time of this layer obtained from the T-X curve above, V0, V1 are the characteristics velocities of the layers overlying & underlying the hidden layer respectively.

Using these assumptions, thickness of the first layer.

$$\text{H1} = \frac{0.002}{2}\frac{444.4 \times 606.06}{\sqrt{1904.76^2 + 606.06^2}} = 0.326\text{m} \sim 1.070\text{ft}$$

The maximum thickness of the second layer ignoring the possibility that an intermediate zone exists is given by:

$$Ho(max) = \frac{0.007}{2}\frac{606.06 \times 1904.76}{\sqrt{1904.76^2 - 606.06^2}} = 2.238\text{m} \sim 7.343\text{ft.}$$

- If an Intermediate zone exists between layers with velocities 606.06m/sec, and 1904.76m/sec, its velocity will probably have an intermediate value between these two velocities, we can assume a value of velocity of this intermediate zone such that it should be greater than 606.06m/sec (that overlies it) but far less than 1904.76m/sec (that underlies it) resulting to its inability to be detected by first arrivals. From these assumptions, the probable velocity of the Intermediate zone assumed is about 945.5m/sec.

- We determined α12, α23, and α13, given as;

$$\alpha 12 = \sin^{-1}\frac{444.4}{606.06} = 47.16^{o}$$

$$\alpha 23 = \sin^{-1}\frac{606.06}{1904.76} = 18.55^{o}$$

$$\alpha 13 = \sin^{-1}\frac{444.4}{1904.76} = 13.49^{o}$$

- Using the Nomograph table shown below, we determine the approximate value of R, which is found from the intersection point of α12 = 47.16° & α23 = 18.55°, and interpolating between the R lines (Maillet and Bazerque, 1931). R is approximately equal to 1.35. Also we find the value of S defined as;

$$S = \frac{\tan\alpha 23}{\tan\alpha 13} = \frac{0.3356}{0.2399} = 1.3989$$

- So the maximum thickness Z(max) of the Intermediate zone was determined using the equation;

$$Z\,(\max) = \frac{\mathrm{RS}}{\mathrm{R+S}}\mathrm{Ho(max)} = \frac{1.35\times 1.3989}{1.35+1.3989}2.238 = 1.538m = 5.046ft$$

• Also Ho (min), the minimum thickness of the Overlying layer to the Intermediate zone is determined using;

$$Ho(min) = \frac{\mathrm{Z(max)}}{\mathrm{R}} = \frac{1.538}{1.35} = 1.139m = 3.737ft$$

Therefore the Maximum undetectable thickness of the Hidden layer (LVL) is 1.538m (5.046ft) and the combined average thickness of the two layers (Overlying and Hidden) ranges from a minimum of 2.238m = 7.343ft. (No intermediate zone) up to a maximum of 2.677m = 8.783ft.

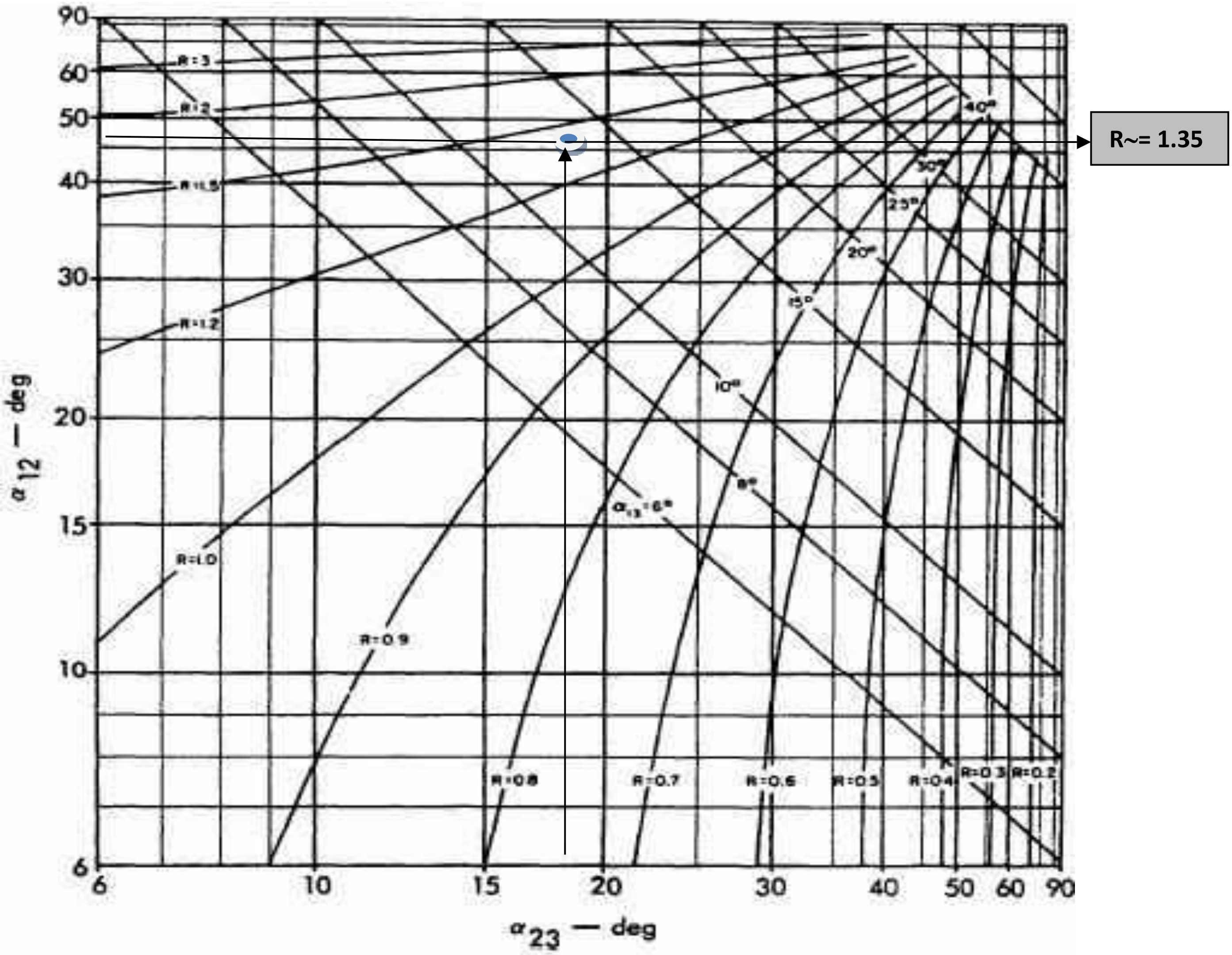

Figure 7: Nomograph used in determination of thickness of possible hidden layer, Maillet and Bazerque, 1931).

Interpretation

From the analysis and result obtained it shows that there is an Intermediate zone "Hidden Layer", sandwiched between the 606.06m/sec and 1904.76m/sec layer. The hidden layer has to be at least 2.677m (8.782ft) in order that refractions from it are recorded as first arrivals.

CONCLUSION:

The following conclusions were drawn:

(a) The Nomograph table proves useful for determination of the thickness of a Low velocity layer, where it is suspected to exist.

(b) The result indicates that the Blind zone needs to be about 2.677m =8.782ft thick for its refractions to be recorded as first arrivals on the geophone units.

(c) This technique is useful as a quality control check, which is valuable in seismic reflection data acquisition projects, were it is required investigate deep subsurface reflectors, kilometers away from the earth, to mapping complex geologic environments such as marginal field and deep waters.

REFERENCES:

1. Barthelmes, A.J.,: Application of continuous profiling to refraction shooting, Geophysics, Vol. 11: 24-42.
2. Catchings, R.D., and Mooney, W.D., (1938). Crustal structure of the Columbia plateau: Evidence for continental rifting, Journal of Geophysical research 93, 459-474. (1946).
3. Dix, C.H.,: Seismic velocities from surface measurements, Geophysics, Vol. 16, pp.192-206. (1995).
4. Dobrin, M. B.,: Introduction to Geophysical Prospecting (McGraw-Hill, New York). (1960).
5. Domalsk, W.,: "Some Problems of Shallow Refraction Investigations;" Geophysical Prospect. Vol. 4, 140-166. (1956).
6. Faust, L.Y., : Seismic velocity as a fraction of depth geologic time, Geophysics, Vol. 16, pp. 192-206(1951)..
7. Green, R., : "The Hidden Layer Problem". Geophysical. Prospect. Vol. 10, 166-177.
8. Hales, F.W., : An Accurate Graphical method for Interpreting seismic Refraction Lines, Geophysics prospect, 6, 285-294. (1962). (1958).
9. Hawkins, L.V., : "The Reciprocal Method of Routine Shallow Seismic Refraction Investigations," Geophysics 26, 806-819. (1961).
10. Leet, I.D., : Practical Seismology and Seismic prospecting. Appleton Century-Crofts Inc, New York. (1938).
11. Maillet, S., and Barzeque, M., : Seismic studies of the earth's Crust in continents, I:Evidence for a low-velocity zone in the upper part of the Lithosphere. Geophysical Journal of the Royal Astronomical society 10, 525-538. (1931).
12. Ogagarue, D.O., : Comparative Study of the Offset- Geophone and down-deep hydrophone seismic refraction survey with application to the Niger Delta Basin, University press, Nigeria. (2007).
13. Press, F and Dobrin, M.B., : Seismic wave studies over a high speed surface layer, Geophysics 21., 285-298. (1956).
14. Slotnick, H.M., : A graphical method for the interpretation of refraction profile data. Geophysics, Vol 15: 163-180. (1950).
15. Soske, J.L., : "The Blind Zone Problem in Engineering Geophysics", Geophysics 24, 359-365. (1959).
16. Tewari, H.C., Dixit, M.M. and Murty, P.R.K., : Use of travel time skips in refraction analysis to delineate velocity inversion, Geophysics prospecting 43, 793-804. (1957).
17. Tarrant, L.H., : A Rapid Method of determining the form of a seismic Refractor from line profile Results, Geophysics prospecting 4, 131-139. (1956).
18. Telford, W.M., Geldert, L.P, Sheriff, R.E. and Keys, D.A., : Applied Geophysics, University Press, England. (1990).
19. Wyrobek, S.M., : Application of delay and intercept times in the interpretation of multilayer time-distance curves. Geophysics prospecting, vol 4: 112-130. (1956).
20. Whiteley, R.J, and Greenhalgh, S.A., : Velocity inversion and the shallow seismic refraction method. Geophysics Exploration 17, 125-141. (1990).