IOSR Journal of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 7, Issue 6 Ver. I (Nov. - Dec. 2015), PP 15-18
www.iosrjournals

Detection of Low-Speed Layer (Lvl) In Seismic Refraction Survey Using Combined Geophysical Methods

Agha S.O.
Department of Industrial Physics, Ebonyi State University, Abakaliki, Nigeria.

Abstract: *A combination of two geophysical methods not only helps to enhance the accuracy of results but also helps to detect the presence of a low velocity layer which cannot be detected by refraction shooting alone. The Direct Current resistivity method was combined with the seismic refraction method to infer the lithology of Nnodo (Latitude 6.30^0 - 6.32^0N and Longitude 8.10^0 - 8.12^0E), Nigeria, during which a low-velocity layer was encountered. The major instruments used were the signal enhancement seismograph and the ABEM terrameter. The seismic refraction method revealed three layers of the earth from its surface with velocities 300m/s, 1200m/s and 2100m/s which were interpreted as dry/loose sand, saturated sand and limestone respectively. The resistivity method however, revealed five geoelectric layers with resistivity values 957 Ωm,363 Ωm,1033 Ωm,489 Ωm and 135 Ωm which were interpreted as dry soil, saturated sand, sandy clay, limestone and shale respectively. A comparison of the two results showed that the third layer from the surface at Nnodo interpreted as probably sandy clay(from the resistivity survey) was not detected in the seismic refraction survey. This was suspected to be a low-velocity layer with a velocity of about 600m/s. Hence the layer of limestone according to the seismic result is the fourth layer of the study area and not the third.The actual lithology of the third layer which the seismic refraction method could not detect is sandy clay. This was evident from the resistivity result. The lithologic sequence of the study area from the earth's surface is therefore dry soil, saturated sand, sandy clay, limestone and fractured shale(wet).*
Keywords: *lithology, refraction, resistivity, seismograph, terrameter.*

I. Introduction

In a multilayered earth, it is generally expected that the seismic velocity to each sub surface layer would be greater than that of the layer overlying it, (Kearey,1991). However in practice, this is not always the case as there has been situation where a low velocity layer underlies a high speed bed. According to Dobrin (1976), if any bed in a sequence of strata has a lower speed than the one above it, it will not be detectable by refraction shooting at all, because the rays entering such a bed from above are deflected in the downward direction and then can never travel horizontally through the layer. Conversely there will be no segment of inverse slope on the time distance curve. The presence of such an undetected low-speed layer will result in the computation of erroneous depth to all interfaces below it if only observed segments are used in the calculations (Dobrin, 1976). A low-velocity layer therefore is a layer of the subsurface overlain by a high- speed bed.

As an illustration, consider the 4-layer case shown in Fig. 1. in which the topmost bed with speed V_0 is underlain by a low speed bed V_1 which in turn overlies successively higher-speed beds V_2 and V_3 respectively. That is $V_1 < V_2 < V_3 < V_4$. The T-X refraction graph is shown in Fig. 2.

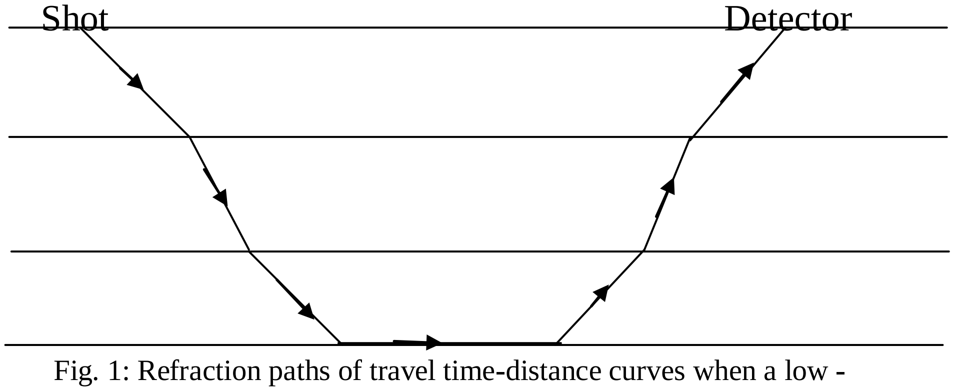

Fig. 1: Refraction paths of travel time-distance curves when a low - velocity layer V_1 lies below a higher- speed layer, $V_2 > V_3 > V_4$

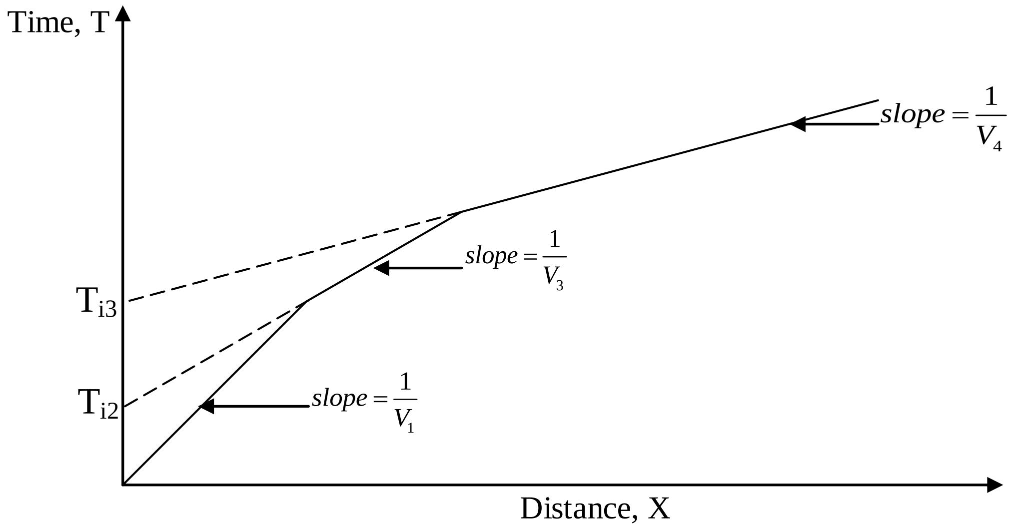

Fig. 2: Time distance graph of a four layer case seismic refraction survey, were the second layer with velocity v_2 was undetected.

Fig.2 shows the slope of the signals with speed, V_1, V_2 V_3. The low velocity layer V_1 did not show on the graph and thus cannot be detected by the seismic refraction method.

According to Stacy(1992), it is not possible to detect the existence of a low speed seismic layer with seismic data alone. The presence of such a layer can however be detected by integrated geophysical method.

Integrated geophysical surveys, including the seismic refraction method and the direct current(d.c) resistivity method were carried out at Nnodo, Nigeria with the aim of inferring the lithology of the area. Nnodo lies within Latitude $6.30^0 – 6.32^0$N and Longitude $8.10^0 – 8.12^0$E. It has an area of about 20km^2. No known geophysical survey has been previously carried out at Nnodo. But some geo-surveys have been carried out in nearby towns to it. Agha et al (2010) carried out a seismic refraction survey at Mgbom(lat. $5.80^{0\,-}$ 5.90^0N and long.7.88^0 – 7.98^0E). Their aim was to estimate the elastic constants of subsurface rocks of the area which included the Young's modulus, E, the bulk modulus K, and the shear modulus, μ. The refraction paths of both compressional and shear waves were utilised in the investigation using a 3-channel seismograph and its accessories. The result showed that the first and second layers from the earth's surface at Mgbom have Poisson's ratio of 0.13 and 0.23 respectively, giving $\mu -$ values of 1.7 x 10^8N/m^2 and 2.4 x 10^8N/m^2 and K-values of 2.5 x 10^8N/m^2 and 6.9 x 10^8N/m^2 and E-values as 5.6 x 10^8 and 11.2 x 10^8N/m^2 respectively. The result indicates that Mgbom rocks have desirable elastic properties suitable for construction works. Agha and Nnabo(2013) carried out a d.c resistivity survey at Nkwegu(20km south of Nnodo) aimed at deducing the lithology of the area. They used ABEM terrammeter(SAS 300C). The result of their investigation showed that the average resistivity and thickness of the earth layers in the study area from the surface are 917.64Ωm and 1.3m for the first layer; 138.89Ωm and 8.8m for the second layer; 480.82Ωm and 17.9m for the third layer and 65.96Ωm and 21.5m for the fourth layer respectively. The result indicates that the first four layers of Nkwegu are made up of lateritic overburden, wet feruginised clay, fissile dry shale and consolidated wet shale accordingly.

II. Materials And Method

Materials: The materials used in the seismic refraction survey include a 3-channel seismograph, P-wave detectors and cable, sledge hammer and metal plate (as wave source) and a global positioning system (GPS). For the resistivity survey, an ABEM terrameter (SAS 300C) current and potential electrode pairs, cables, pegs and a twine.

Method: Both the seismic survey and the resistivity survey were run along the same profile lines one after the other at three different locations within the study area. The shot-detector spacing in the refraction survey was 4.5m while the traverse length was 60m. In the resistivity survey, Schlumberger electrode configuration was used and vertical electrode sounding was carried out.

III. Results And Discussion

Results: Sample results from the study area are shown in Fig. 3 and Fig. 4.

Discussion: Three subsurface layers were obvious from the T-X plot of refraction data shown in Fig. 3. These layers had compressional(P)-wave velocities of 300m/s, 1200m/s and 2100m/s and were interpreted as dry/loose sand, saturated sand and limestone deposits respectively. From the resistivity curve of Fig. 4, five geoelectric layers were revealed with apparent resistivities of 957Ωm, 363 Ωm, 1033 Ωm, 489 Ωm and 136 Ωm respectively. These were interpreted to be made up of dry soil, saturated sand, sandy clay, limestone and fractured shale(wet) for the first five layers respectively. The seismic velocities of dry sand, saturated sand, sandy clay, limestone and saturated shale are about 300m/s, 1500m/s, 600m/s, 2000m/s and 2800m/s respectively(Grant and West,1965; Dobrin, 1976). Since seismic velocity increases generally with depth, there is a velocity inversion at the third layer – the sandy clay layer. This 600m/s layer is therefore a low-velocity layer which the seismic refraction method could not detect.

IV. Conclusion

In the light of the fore-going discussion, we conclude that(i)the first two layers of Nnodo, the study area consists of dry soil and saturated sand respectively (ii) there is a low-velocity layer(LVL) at Nnodo (iii) this layer(the LVL) was not detectable by refraction shooting as we can see from travel-time versus offset seismic refraction curve. (iv) the low-velocity layer is the third layer of the area and is probably sandy clay in composition (v) the fourth and fifth layers of the study area are probably made up of limestone and shale respectively.

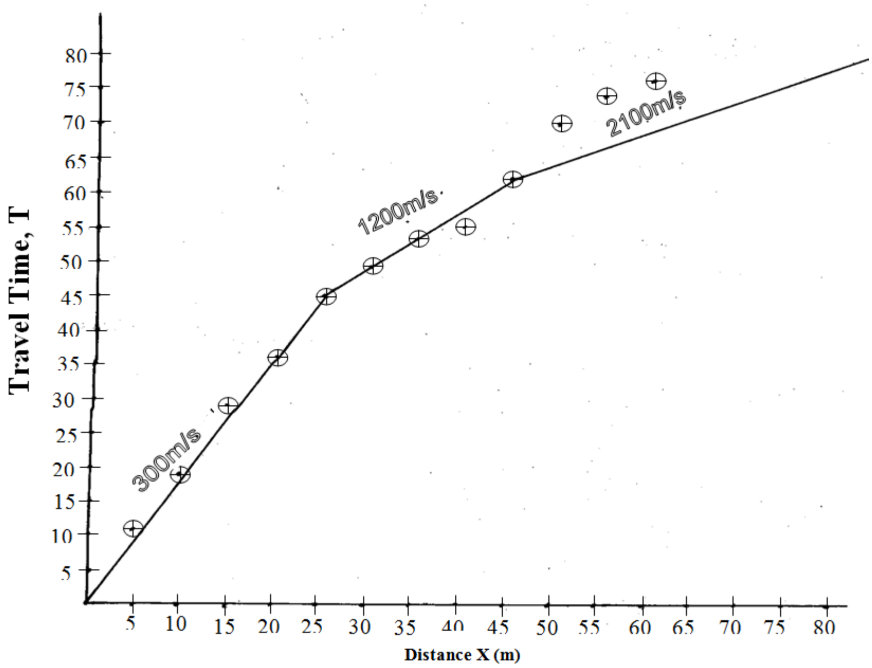

Fig. 3: T-X plot of Seismic refraction data obtained from the study area.

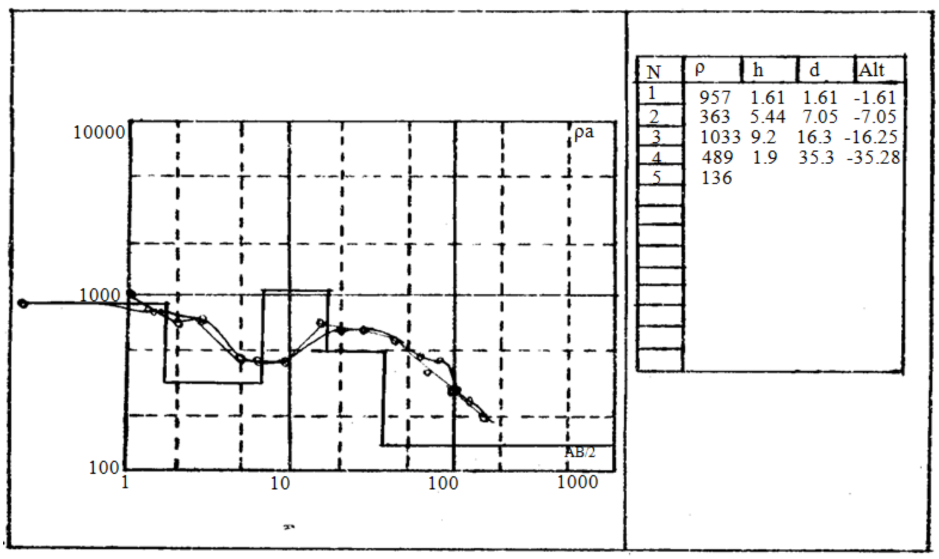

Fig. 4: VES curve of resistivity data obtained along the same profile

References

[1]. Agha S.O. and Nnabo P. N.(2013). Lithologic deduction from resistivity studies in Nkwegu, Nigeria. Journal of the Nigerian Association of Mathematical Physics, 25, Pp. 183-186.

[2]. Agha S. O., Idenyi, N. E. And Umahi, A. E.(2010). Estimation of the elastic constants of subsurface rocks at Mgbom, Nigeria by the seismic refraction method. Journal of Applied and Natural Sciences, 5(1), Pp. 56-59.

[3]. Agha S.O. (2014) : Ground water exploration and exploitation in parts of Abakaliki, Nigeria. Journal of National Association of Mathematical physics (NAMP). Vol. 26(1)pp.

[4]. Agha S.O.(2014b): Compressional wave propagation and deformations in rocks. Journal of national association of mathematical physics. Vol. 26(1)pp

[5]. Dobrin, M.B. (1976). Introduction to geophysical prospecting (3rdedition) Mc Graw-Hill, Book Company Japan. Pp. 300-302.

[6]. Grant, F.S. and West G. F.(1965).Interpretation Theory in Applied Geophyisics. McGraw-Hill Book company, New York.

[7]. Kearey, P. and Brooks, M. (1991). An introduction to Geophysical exploration (2nd edition). Blackwell scientific publications, Cambridge, U.S.A.

[8]. Lowrie, W.(1997). Fundamentals of Geophysics. Cambridge University press, Cambridge, Britain.

[9]. Okwueze,E.E.(1988).Mapping Bedrock Surface and Lithology with the Seismic Refraction Method in Basement Area. Physics, 26, pp 33-40.

[10]. Stacey,F.D.(1992).Physics of the earth.Brookfield,Brisbane,Australia.

[11]. Telford, W.M, Geldart, L.P. and Sheriff, R.E. (1976). Applied Geophysics. Cambridge University Press New York.