International Journal of Development and Sustainability
Online ISSN: 2186-8662 – www.isdsnet.com/ijds
Volume 2 Number 1 (2013): Pages 131-139
ISDS Article ID: IJDS12091002

Study of near-surface layers of Omerelu area using low velocity layer (LVL) method

Olumide Oyewale Ajani [1*], Joseph Ademola Fajemiroye [2], Olutayo Adekunle Odumosu [3]

[1] *Department of Physics and Solar Energy, Bowen University, Iwo, Osun State, Nigeria*
[2] *Department of Physics (Radiation Laboratory), University of Ibadan, Ibadan, Nigeria*
[3] *Exploration Unit, United Geophysical Company, Warri, Delta State. Nigeria*

Abstract

It is important that we have good knowledge of the soil type so as to appreciate the enormous resources we are stepping on. It is more compelling for oil explorationists to know more as this will go a long way to determine the success or failure of search for minerals. Seismic methods give a good overview of a wide area though they involve greater logistics and operational requirements than some other geophysical methods. The purpose of present study is to determine the depth of the weathered layer and velocities of near-surface layers over the investigated area. Twelve sample points were picked with a grid system spread over a perimeter of approximately 4km x 4km. The in-house UpSphere computer program was utilised to analyse and display result in a way that makes final interpretation very easy. This program actually removed the burden of plotting the graphs and the contour maps manually. The depth of weathered layer in the study area varies between 12m and 13m. The velocities of the weathered layer and the consolidated layer vary between 500 m/s – 550 m/s and 1790 m/s – 1875 m/s respectively. Also the dip is in the north east – south west direction.

Keywords: Weathered layer, Contour maps, Seismic methods, UpShere program

Cite this paper as: Ajani, O.O., Fajemiroye, J.A. and Odumosu, O.A. (2013), "Study of near-surface layers of Omerelu area using low velocity layer (LVL) method", *International Journal of Development and Sustainability,* Vol. 2 No. 1, pp. 131-139.

* Corresponding author. *E-mail address:* aj_ani2000@yahoo.com

1. Introduction

Seismology is a venerable science with a long history (Lorie, 1997). Its principles is basically based on Generation of a signal at a time that is known exactly and for the resulting seismic waves travel through the sub-surface media and be refracted or reflected back to the surface where the resulting signals are detected and also recorded. The time difference between the source being triggered and the arrival of the seismic waves (which are propagated as either body waves or surface waves) is used to determine the nature of the subsurface layers. Systematic recording and subsequent data processing allows detailed analysis of the seismic waveforms to be performed. Information gathered from developed seismograms are then used to develop images of the sub-surface structures which in turn enables proper understanding of the physical properties of the materials present in such area of investigation.

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 of the Earth's surface, the increasing-velocity requirement is a severe constraint. A difficult situation might occur when a low-velocity layer underlies a layer with high velocity e.g. sand underlying a clayey material (Faust, 1951). Another complicated situation occurs when the seismic wave goes through a blind zone (i.e. where a layer is too thin to appear as a first arrival on a seismogram). These two situations can lead to erroneous results. Other abnormally encountered is the case of lateral velocity changes over small distances and abrupt termination of geologic beds.

1.1. Background theory

If the Earth is imagined to have a multi-layered structure with numerous thin horizontal layers, each characterized by a constant seismic velocity, which increases progressively with increasing depth(Chaubey,1990). A seismic ray that leaves the surface with angle i_1 will be refracted at each interface until it is refracted critically. The ray that finally returns to the surface will have an emergence angle equal to i_1. Snell's law applies to each successive refraction, for example, at the top surface of the nth layer, which has a velocity V_n.

$$\frac{Sin\,i_1}{V_1} = \frac{Sin\,i_2}{V_2} = \ldots\ldots\ldots. = \frac{Sin\,i_n}{V_n} = p = constant \qquad (1)$$

where p is the ray parameter. If V_m is the velocity of the deepest layer, along whose surface the ray is eventually critically refracted ($Sin\ i_m = 1$), then the value of p must be equal to $1/V_m$.

As the number of layers increases and the thickness of each layer decreases, the situation is approached in which the velocity increases constantly with increasing depth. Each ray then has a smoothly curved path. If the vertical increase of velocity is linear with depth, the curved rays are circular arcs (Telford, 1990).

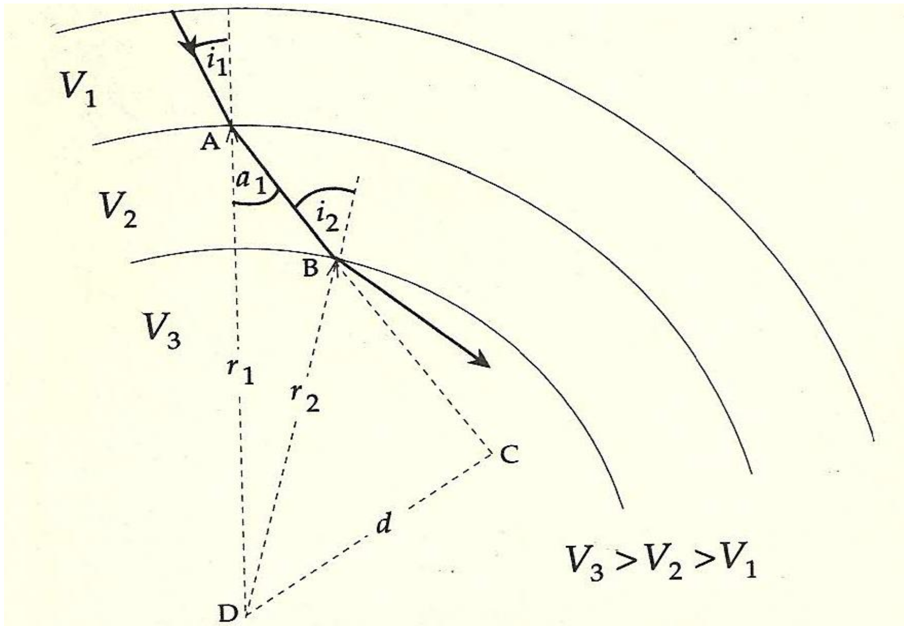

Figure 1. Refraction of a seismic ray in a spherically layered earth, in which the seismic velocity is constant in each layer and the layer velocity increases with depth.

The passage of seismic body waves through a layered spherical earth can be treated to a first approximation by representing the vertical (radial) velocity structure by sub-dividing the Earth into concentric shells, each with a faster body wave velocity than the shell above it (Marion,1992). Snell's law of refraction applies to the interface between each pair of shells. For example, at point A, we write,

$$\frac{Sin\, i_1}{V_1} = \frac{Sin\, a_1}{V_2} \tag{2}$$

Multiplying both sides by r_1 gives

$$\frac{r_1 sin\, i_1}{V_1} = \frac{r_1 sin\, a_1}{V_2} \tag{3}$$

In triangles ACD and BCD, respectively, we have

$$d = r_1 sin a_1 = r_2 sin i_2 \tag{4}$$

Combining equations (2), (3) and (4),

$$\frac{r_1 \sin i_1}{V_1} = \frac{r_2 \sin i_2}{V_2} = \cdots = \frac{r_n \sin i_n}{V_n} = constant = p\ (ray\ parameter) \quad (5)$$

2. Methodology

2.1. Location/geology of study area

Geographically, the study area lies between latitude 05^0 08'N and 05^0 13'N and longitude 06^0 51'E and 06^0 58'E. It is situated in the River State part of the Niger Delta, Nigeria. Some of the relatively large urban settlements around study area are Omerelu, Apani, Ubima, Umuapu, Isu-Etche, and Rison palm plantation.

The vegetation of the area of operation is mainly farm land, palm plantation, thick bush and rubber plantation. The study was carried out during the rainy season. The humidity was high at this period.

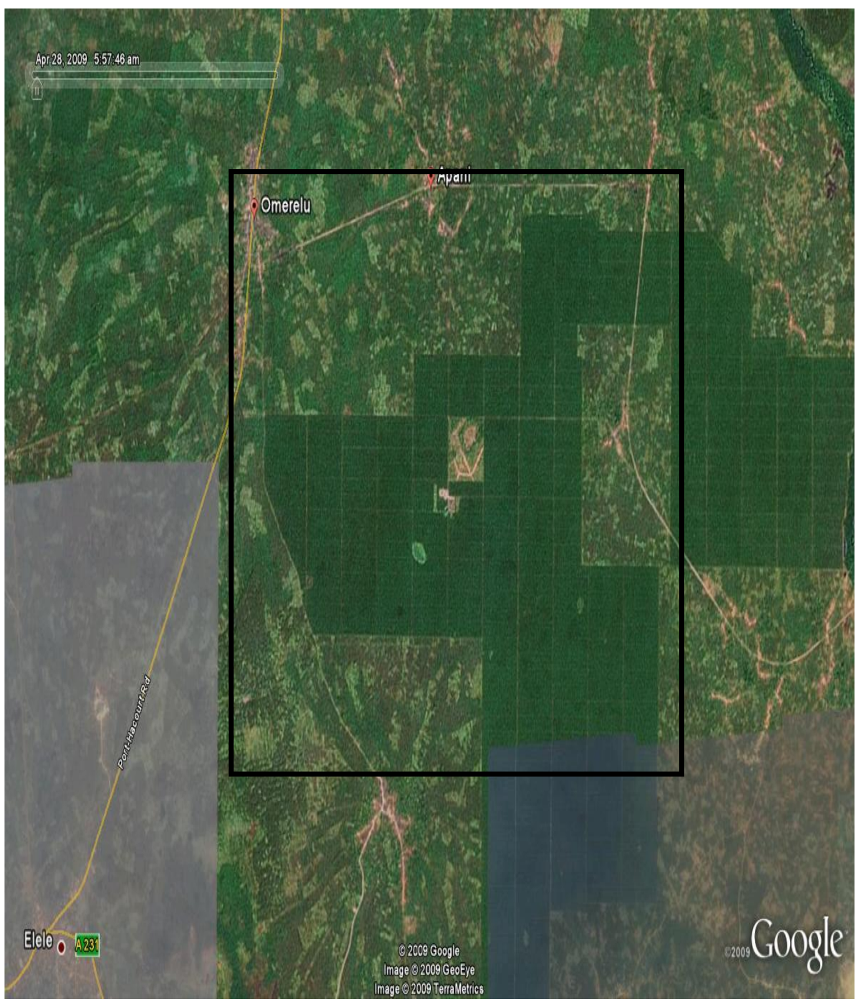

Figure 2. Aerial map of study area

The Tertiary lithostratigraphic sequence of the Niger delta consists in ascending order, of the Akata, Agbada, and Benin Formations, which make up an overall regressive elastic sequence about 30,000 - 39,000 ft (9,000 – 12,000m) thick (Enikanselu, 2008).

2.1.1. Akata formation

The marine Akata Formation is a continuous shale unit, which in most places is under-compacted and may contain lenses of abnormally high pressured siltstone or fine-grained sandstone. It represents the prodelta facies; most wells drilled in the Niger delta failed to penetrate the base of the formation (Ogagarue, 2007).

It grades into overlying Agbada formation. It is rich in microfauna. The age of the formation ranges from Eocene to Recent. It has a thickness of over 1,300 metres (Wright, 1976).

2.1.2. Agbada formation

The Agbada Formation directly overlies the Akata formation. This formation has been described by Reyment (1965) and Wyllie (1956) among others. It is a sequence of sand and sandstones bodies alternating with shales. The formation consists of an upper unit in which the Shale intercalations are relatively thin and a lower unit in which the shale units become increasingly prominent at depth. The formation is rich in microfauna at the base and become sparsely fossiliferous or barren in the upper part. The alternations of sands, sandstones and shale are due to local transgressions and regressions. The Agbada formation is deposited in an active environment. It is up to 3000 metres thick and ranges in age from Ecoene to Holocene (Okwueze, 2011).

2.1.3. The Benin formation:

The topmost unit of the Niger delta is the Benin Formation. The formation is predominantly sandy i.e. over ninety percent sands and sandstones, with a few shale intercalations which becomes more abundant towards the base. The sands and sandstones are coarse grained and pebbly, locally fine grained, poorly sorted, sub-angular to well rounded and bears lignitic streaks and wood fragments. The formation was deposited in a continental upper deltaic environment. Benin Formation is interrupted by the Afam clay member in the Eastern part of the country. The formation generally exceeds 2000 metres in thickness and ranges in age from Miocene Recent. Total thickness of sediments in the Niger delta may be much as 12,000 metres (Wyllie, 1956).

2.2. Field operations

The field operation was carried out with the LVL/UH crew of an existing geophysical crew working in an area covering Omerelu in the south to Ihiagwa in the north. A GPS seismic instrument station was used to take the coordinates and elevation of each point. When drilling, 3m steel casing was used to make 1m holes. The drilling method involved hitting the ground to cut the soil and picking the casing up to put aside the cuttings. This process is repeated several times until the required depth of about 1m is achieved. The LVL comes in after drilling with OYO McSeis 160M and 12- jug geophone string. The instrument is used to initiate the dynamite while the signal is received by the jugs and passed to the instrument for recording. The drilled hole is loaded with 0.5kg dynamite with detonator and firing line attached to connect the dynamite to the instrument for initiation of shot. The 12 jugs are stretched over 90m. Two holes are drilled at both ends of the laid geophone string.

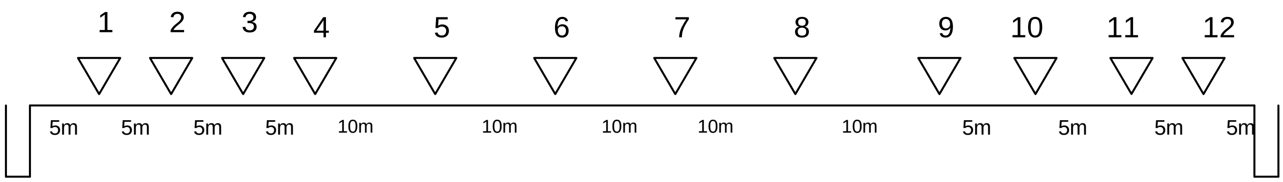

Figure 3. Lay –out of seismograms along the field lines

After the data acquisition the data was transferred for further analysis and interpretation which included plotting of graphs and contour maps and entry into database for subsequent use during data processing.

Some geophysicists prefer to put their shot depth below the weathered layer to optimize signal-to-noise ratio (Mishra, 1998). However, for the crew in consideration all shots were taken within the weathered layer for safety and environmental reasons.

3. Results

3.1. Processing of result

The low velocity layer data was processed using software developed by Seismologists. Brief summary of the software and its use are as described below. The current version of the Upsphere software as at the time of this study was version 1.4. The development of the software started from version 1 then subsequently we have versions 1.1, 1.2, 1.3 before this present version 1.4. The development is always arising because of desire to make the software simpler, more user-friendly and with increased capabilities.

The first and the main template has entries where the general description of the study, each data set identification number, depth of shot, the coordinates of the study area, etc can be typed in. It also has fields to input offset for each receiver deployed and capability to accept or read data from the recording instrument through another program written by Seismologists. It has fields where soil type observed during drilling can be entered.

After entering the data into the fields, the data is then plotted. It shows the points on the graph and the break-point for each data set is defined after observation and then re-plotted to now display lines of best-fit for various layers. The Upsphere program has ability to plot and display as much as 4 layers. The entire processing takes place in a short while (therefore in case of poor data acquisition from the field another acquisition can be planned immediately).

At this point the subsurface velocities and weathering depth are displayed by the program. This process is repeated for each data set. Finally, the complete plot for the area under study is saved in a file in the program and sent to Mapview option to create the contour maps. Subsequently interpretation follows with the map or data acquired.

Seismic refraction data recorded and analysed is further treated with the Upsphere program to produce contour maps (Figures 16 – 19) to clearly display velocity and depth variations over the area under study. This makes it easier to apply the result for final use.

Geometry verification carried out in the field reduces the normal processing time drastically. Geometry verification checks that the source and receiver positions attributed to every shot record are correct (Figure 21). One error typically encountered in geometry verification is a mistake in the identification of shot-point location. This can occur when the source is at the wrong location or if the location is mis-surveyed. It can also occur if receiver locations are mis-surveyed or if the wrong receivers are active. These mistakes can be detected quickly by applying some simple processing at the base camp, after the day's acquisition. The process is called Linear Moveout (LMO). LMO compares arrival times recorded for a given source-receiver geometry to those expected for the same geometry, assuming a constant velocity subsurface. If the source and receivers are in the right places, the LMO process yields seismic traces with first arrivals aligned in time. Any other pattern of first arrivals indicates a mistake in the source-receiver geometry.

Linear Moveout (LMO) Flow:

- Input near traces, trace length 1000ms
- Select the first trace from each cable
- Apply zero band pass filter
    - Low cut frequency: 4Hz
    - Low cutoff slope: 24dB/octave
- Input final P1/90 UKOOA and generate SPS format geometry database
- Geometry update – add positional information in the seismic trace header
- Super sample traces to 1 ms to improve moveout resolution
- Apply trace balancing to normalize RMS amplitudes to 2000
- Apply low cut filter 4Hz, 24dB/oct slope
- Shift data to 50ms to make allowance for the direct arrival
- Perform Linear Moveout Analysis using 1830 m/s

4. Conclusion

The velocity result is used to determine the soil type based on the known physical properties of various soil types. The velocity result is also applied during data quality control by Seismologists. This process is known as Linear Moveout (LMO). Basically, the velocities obtained from the study are applied to correct for offset difference for the receivers during data acquisition.

Civil engineers and construction experts use the result among under fundamentals to determine the soil type and position of foundation for structures to be erected.

Subsoil conditions are examined using test carried out by Geoscientists to determine the physical and chemical properties of the subsurface layers. The extent of the test depends on the building type and site conditions. Engineers dealing with soil mechanics devised a simple classification system that will tell the engineer the properties of a given soil. The unified soil classification system is based on identifying soils according to their textural and plasticity qualities and of their grouping with respect to behaviour. Soils are usually found in nature as mixtures with varying proportion of particles of different sizes, each of these components contribute to the soil moisture.

Soil is classified on the basis of:

- Percentage of gravel, sand and fines
- Shape of grain
- Plasticity and compressibility characteristics

Coarse sand (200 – 1000 m/s) are soils which comprise of gravel and sand and contain a wide variety of particles. These are most suitable for foundations when well drained and well confined. Generally, the greater the PI (Plasticity index/Cohesiveness) the greater the potential for shrinkage and swelling usually characteristic of clay like soils. This type is not desirable for foundation bearing except it is well compacted.

Depth of weathering, environmental and accessibility concerns determine the depth of shot. As a practice in Niger Delta region, shallow holes are used. However, in relatively virgin areas where there has been no much data, shot depth are placed below the weathering layer – in the case of area of study below 13m – to optimize the signal-to-noise ratio. To determine the depth of weathering in such virgin areas, low velocity layer study is carried out prior to production drilling and recording to ascertain the depth of weathering and direct the drilling team to drill below the weathering layer.

References

Chaubey, A.K. (1990), Seismic Reflection and Refraction Methods. Cambridge University press, England.

Dix, C.H. (1955), "Seismic velocities from surface measurements", *Geophysics*, Vol. 20, pp. 68 - 86.

Dobrin, M.B. (1985), Introduction to geophysical prospecting. McGraw-Hill Book Co, Inc., New York.

Enikanselu, P.A. (2008), “Geophysical Seismic Refraction and Uphole Survey Analysis of weathered Layer Characteristics in the “Mono” Field, North Western Niger Delta, Nigeria” in *Proceedings of National Workshop on Geophysical Seismic Analysis*, Delta State Nigeria, pp. 1 – 7.

Faust, L.Y. (1951), “Seismic velocity as a fraction of depth geologic time”, *Geophysics*, Vol. 16, pp. 192 – 206.

Lowrie W. (1997), *Fundamentals of Geophysics* , Cambridge University Press, England, pp 145 – 147, 83 – 98.

Marion, D. (1992), “Compressional velocity and porosity in sand-clay mixture”. *Geophysics*, Vol. 57, pp. 554 – 563.

Mishra G. (1998), Soil Investigation & Foundation Types. University Press Ltd, Nigeria, pp. 1 – 8.

Ogagarue, D.O. (2007), “Comparative Study of the offset – geophone and down – deep hydrophone seismic refraction survey with application to the Niger Delta Basin”, University press. Nigeria.

Okwueze E. (2011), “Petroleum System: Niger Delta Province, Nigeria, Cameroon, and Equatorial, Africa” *Shell Intensive Training Programme (Geophysics: Seismic methodslectures),* Shell Petroleum Development Company, Nigeria.

Reyment, R.A., (1965), Aspects of the Geology of Nigeria. University Press Ltd. Nigeria.

Sheriff, R.E and Geldart, L.P., (1993), *Exploration seismology*, Cambridge University Press, England.

Telford, W.M., Geldart, L.P., Sheriff, R.E., and Keys, D.A. (1990). *Applied Geophysics*, University press, England.

Wright, J.B. (1976), Origin of the Benue Trough: A critical review in Geology of Nigeria. Elizabethan publication Company, Nigeria.

Wyllie, M.R.J., Gregory, A.R. and Gardner, L.W. (1956), “Elastic wave velocities in heterogeneous and porous media”, *Geophysics,* Vol. 21, pp. 41 – 70.