Petroleum and Coal

Article Open Access

Weathered Layer Characterization of Ohaji-Egbema and Environs, South Eastern Nigeria, Using Up hole Refraction Surveys

O. Ajayi, A. I. Opara, C. A. Ahiarakwem, O. C. Okeke, V. I. Fagorite

Department of Geology, Federal University of Technology, PMB 1526 Owerri, Nigeria

Received January 24, 2020; Accepted April 22, 2020

Abstract

Increasing structural failures and the collapse of engineering structures as well as poor seismic data acquisition in the study area is the result of poor understanding of the characteristics/attributes of the weathered layer. To have a deep understanding of the weathered layer of Ohaji-Egbema area, twelve(12) Uphole refraction seismic survey was conducted using Seistronix seismograph with 32 channels with the specific objective of characterizing the weathered layer. The UpShere software was used to pick the first break, process and interpret the data. The results of the refraction seismic survey conducted in the study area revealed spatial variations in the depths of the weathered layer which ranged from 4.8m to 25m with a value of 10.74m, while the weathered layer velocity ranged from 346m/s to 767m/s with a mean value of 447.58m/s. The results revealed two (2) zones with distinct high weathered layer depths of 25m and 17.7m respectively. These high weathered layer depths are believed to be associated with the incidences of foundation failure and the collapse of engineering structures which generally occurs if soil improvement mechanisms are not put in place. Also, reflection seismic data acquired from the study area especially waves passing through this uncompacted and loose layer will lead to a high volume of poor seismic data. It is therefore recommended that before erecting engineering structures within these zones with high weathered layer depth, special foundation treatment is required, for other zones with moderate weathering depths between 4.8m to 10.3m, a foundation depth of 10.5m should be ensured before erecting engineering structures while a 35m - 40m depth hole would be appropriate for better seismic reflection data quality.

Keywords: *Weathered layer; Low-velocity layer; Foundation failure; Uphole seismic; Seismic data acquisition.*

1. Introduction

The weathered layer otherwise known as the low-velocity layer is the topmost layer of the Earth's surface which is characterized by very low velocities compared to those of the near-surface consolidated layers. This layer is usually made up of loose unconsolidated sedimentary materials. Velocities within the low-velocity layer (LVL) vary both vertically and laterally with the large disparity in the velocities between the low-velocity layer and the underlying strata causing problems in the acquisition of reflection seismic data. This is because very small changes in the thicknesses of the weathered layer usually makes large differences in the arrival times of the seismic reflections which lead to the imaging of false geologic structures [1].

This layer effectively slows down the propagation of seismic waves through the earth and hence increases their travel times. This can lead to erroneous predictions of depths of geological structures. In seismic reflection work, one very important method in eliminating this problem is the application of static corrections which corrects for the effects of the low-velocity layer and the varying surficial elevations. But before static corrections can be determined and applied, the LVL characteristics which include velocity, thickness of the LVL, and its elevation must be known and thus incorporated into the processing programme of seismic reflection data [2]. The effects of the low-velocity layer on the seismic reflection data quality have been documented by previous studies [1,3]. Adeoti *et al.* [3] also stated that recent advancement in seismic technology has shown that the single deep hole (SDH) charge method gives a better resolution and mirroring of deeper reflector than the pattern holes charge method owing to the elimination of attenuation effects of low-velocity (weathered layer). However, the occurrence of weak seismic shots is still common due to little or no deep understanding of the effect of the weathered layer on the quality seismic data.

Uphole seismic refraction survey is widely used in the determination of the thickness and velocity of the weathered layer. Ogagarue [4] pointed out that shots taken in these layers tend to be of low frequencies because the layer is capable of absorbing higher frequency signals and releasing lower frequency ones. The views expressed by Ogagarue [4] have been further proven by some recent studies including the studies by Opara [1]. Since the higher frequency signals give the subsurface information required, it is appropriate that shots are taken below this unconsolidated layer to acquire good quality data. The uphole and downhole seismic refraction studies are the most important and commonly used techniques for studying the features of the low-velocity layer. These two techniques are used in delineating and characterizing the near-surface velocities, depths, and thickness of the layers in the vertical direction [3].

According to Nwosu *et al.* [6], the application of geophysical methods for the determination of rock/soil conditions for geotechnical and civil engineering construction has increased rapidly in recent time. This is due to the fact that subsurface characteristics are very important inputs to guarantee the stability of the foundation of civil engineering structures such as high rise buildings, dams, and highways [6]. Since nearly all engineering structures erected on the earth surface have their sub-structures supported by soil, therefore it is important to have adequate knowledge of the nature and characteristics of the soils supporting the sub-structures for structural integrity, safety and durability of the proposed structures. Foundation evaluation of a new site is necessary so as to provide subsurface that normally assist civil engineers in the design and sitting of foundations of civil engineering structures [7]. Conventionally, geotechnical methods usually used by the civil engineers in assessing the strength of the materials for the support of engineering structures are costly, time consuming and not fully effective as they might not give adequate spatial coverage and their deficiency in giving a good depth of investigation. Therefore, it is imperative to complement the conventional methods with cost effective, non-evasive geophysical data like the Uphole Seismic Reflection data [8-10]. Engineering geophysics gives detailed information on the degree of competence of the subsoil in foundation engineering [11]. Careful geophysical studies that are supported by improved geotechnical techniques therefore yield very favorable results even in the case of highly problematic areas [12].

Therefore, the application of the Uphole seismic refraction in characterizing the weathered layer is a veritable tool in making decisions especially in the determination of the drill depth and charge depths before the commencement of any seismic reflection operation [4]. It is also very important in determining the foundations of high rising engineering structures below the unconsolidated layer. The objectives of this study therefore are to determine the velocity variations of the low-velocity and consolidated layers of the study area, and obtain information about the thickness of the low-velocity layer which will help in foundation studies for the design and construction of roads, bridges, high-rise buildings, and dams in addition to reflection seismic data acquisition and processing.

2. Geological setting of the study area

Ohaji-Egbema has an estimated area of 890 square kilometer and a population of 182,538 at 2006 census. The local council lies in the South-Western part of Imo State. It shares common boundaries with Owerri in the East, Oguta Local Government area in North and Ogba/Egbema/Ndoni in Rivers State in the South-West. It lies within latitudes 5°18' 49.65" - 5° 24' 30" N & Longitudes 6°49'28.24"-6°52'40.77"E(Fig.1).

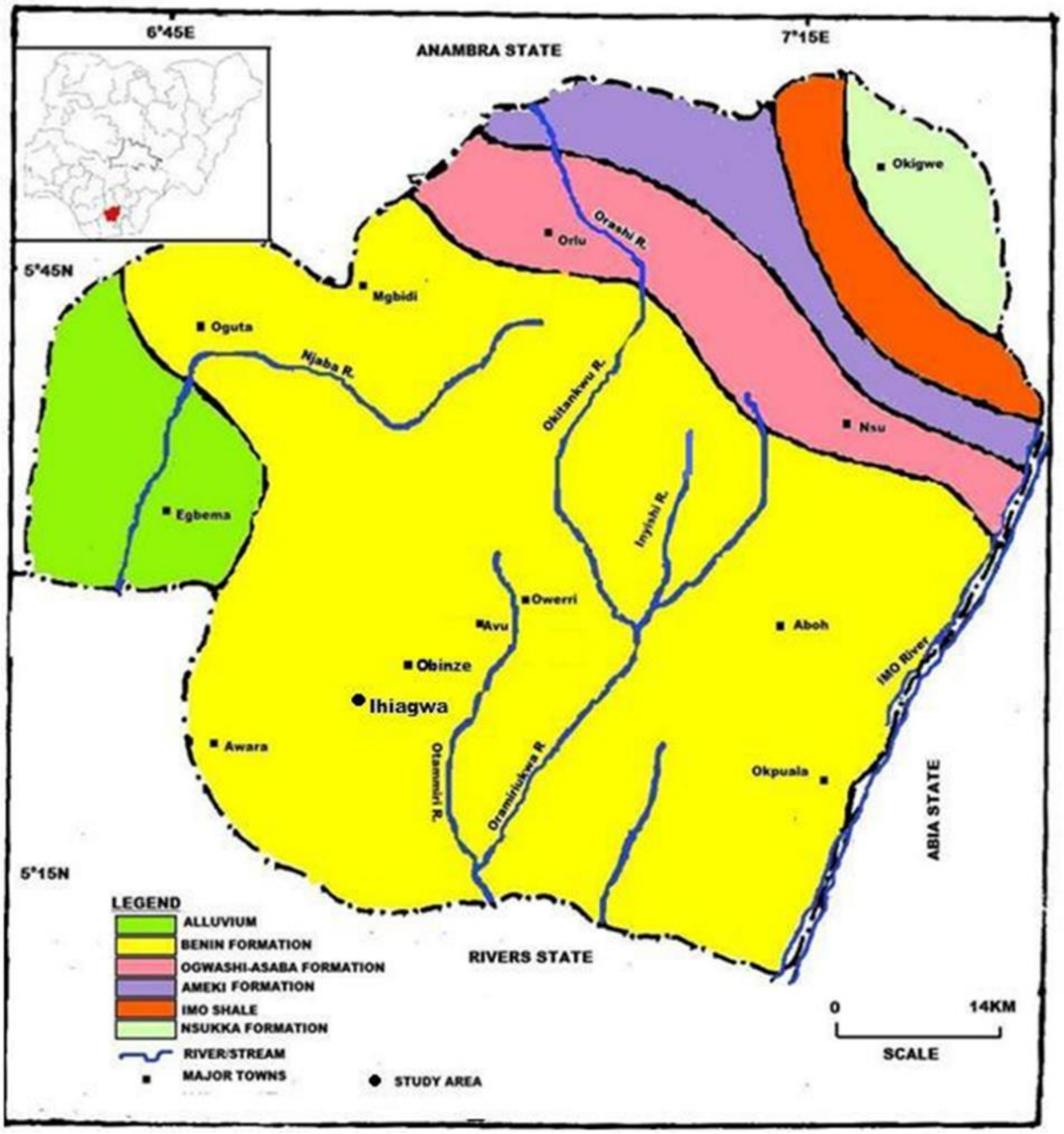

Fig. 1. Imo State Map showing Ohaji-Egbema

The study area as shown in Fig. 2 & 3 is located within the Niger Delta basin. Litho-stratigraphically, the Niger Delta is divided into three pronounced units which include the Benin Formation which is made up of mainly the coastal plain sands, the Agbada Formation (reservoir sands) and the Akata Formation (source rock) which is made up of the overpressured ductile shales [14]. The study area is underlain by the Benin Formation which consists of sands, sandstone, gravel, with clays occurring in lenses. This sandstone formation has high porosity of about 30-40% and high permeability of between 1-2 darcys [15]. The study area is situated in the humid tropics with a total mean annual rainfall of about 250 mm and an annual temperature range of 26-30^{0}C. The landscape of the area is a low-lying plain with almost no portion of the study area exceeding 60m above the sea level. The vegetation of the study area is that of the rain-forest which is characterized high amount and intensity of rainfall associated with rich flora and fauna. The study area is underlain by tertiary sediments with the soils derived from coastal plains sands of the Benin Formation [14,16]. A geologic section across the area from northwest(NW) to the Southeast(SE) shows that the upper 300m of the formation consists of thick sandy units which grade into clayey sand with gentle dip seawards [17]. The sand units are coarse-grained, poorly sorted, and with lenses of fine-grained sands. Further studies by Reyment [18] pointed out that the mode and environment of deposition of the Benin Formation is mixed continental.

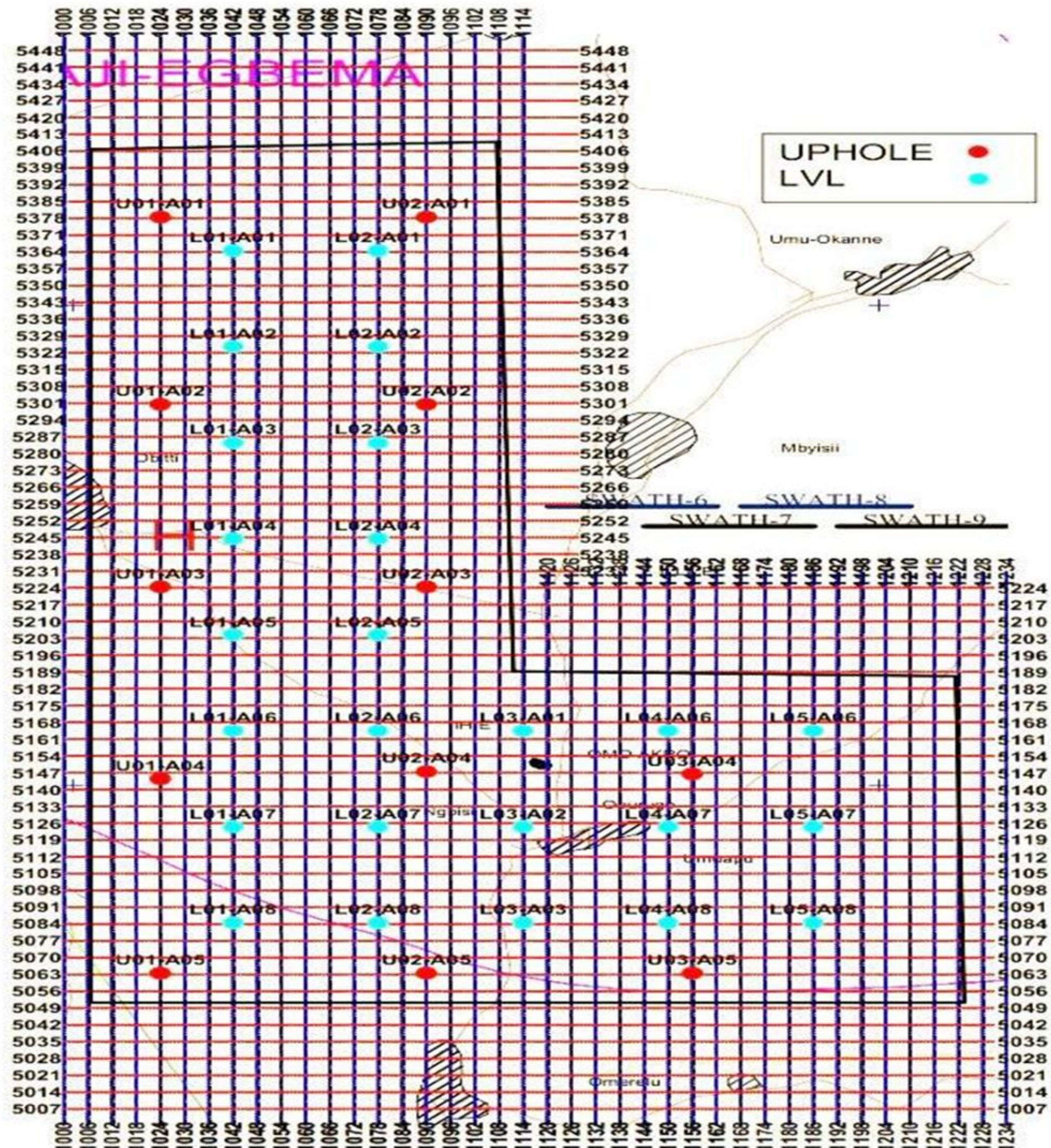

Fig. 2. Prospect map of the study Area (Source: United geophysical Nig. Ltd)

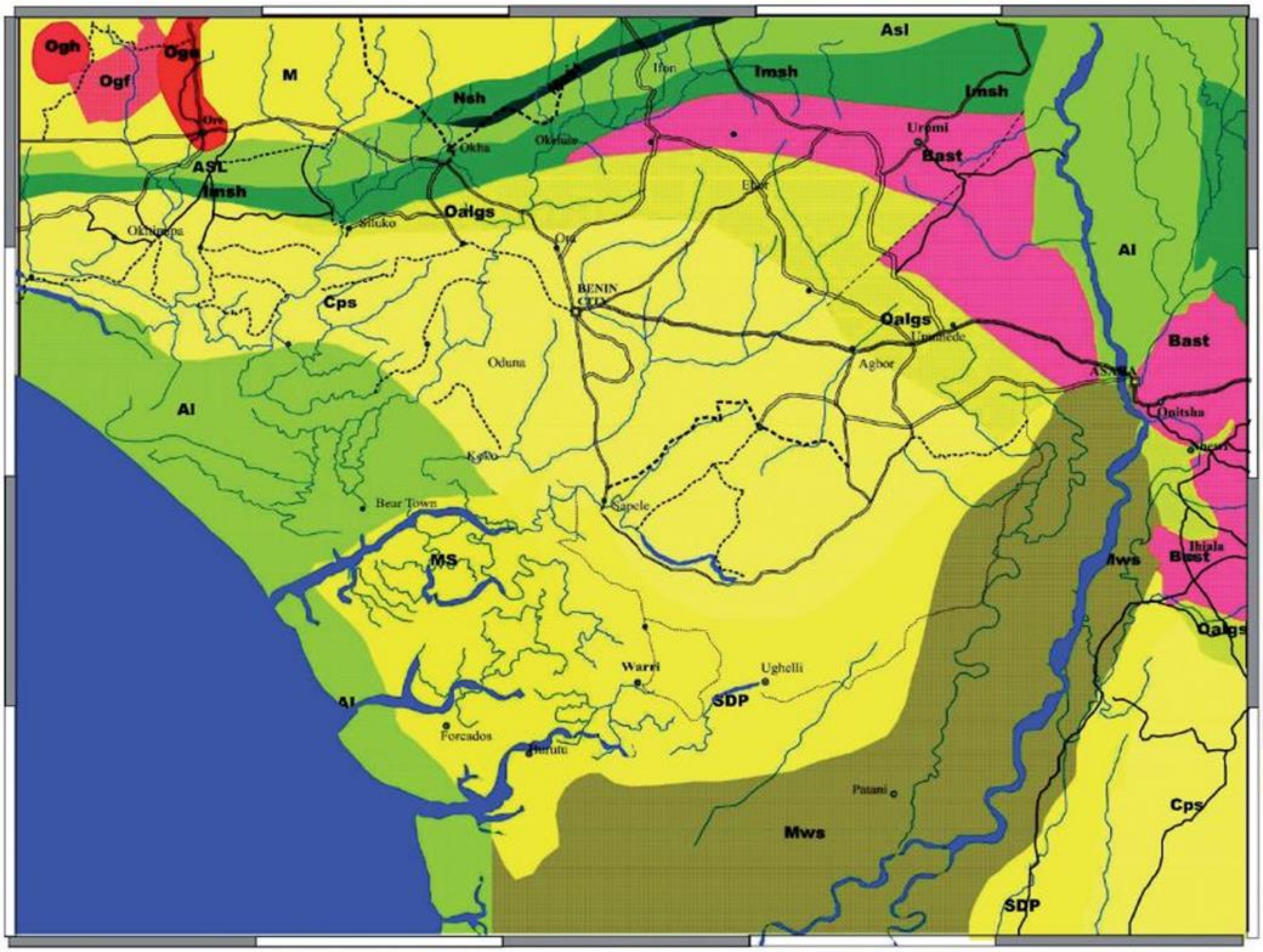

Fig. 3. Geologic map of Niger Delta Basin [13]

3. Methodology

3.1. Theory

The seismic refraction technique is based on the refraction of seismic energy at the interfaces between subsurface/geological layers of different velocity. The seismic refraction method uses very similar equipment to seismic reflection, typically utilizing hydrophones in an array, and a seismic source (shot). The schematic diagram (Figure 4a) illustrates the path of seismic waves propagation from the source at the surface. Some of the seismic energy travels along the surface in the form of direct waves. However, when a seismic wave encounters an interface between two different soil or rock layers, a portion of the energy is reflected and the remainder will propagate through the layer boundary at a refracted angle. At a critical angle of incidence, the wave is critically refracted and will travel parallel to the interface at the speed of the underlying layer. Energy from this critically refracted wave returns to the surface in the form of a head-wave, which may arrive at the more distant geophones before the direct wave. By picking the time of the first arrival of seismic energy at each geophone/hydrophone, a plot of the travel-time against distances along the survey line can be generated. This type of graph is shown in Figure 4b. The gradients of the lines in this type of plot are related to the seismic velocity of the subsurface layers. The final output is a velocity/depth profile for the refractors shown in the Figure 4b.

The gradients of the lines in this type of plot are related to the seismic velocity of the subsurface layers. The final output is a velocity/depth profile for the refractors as shown.

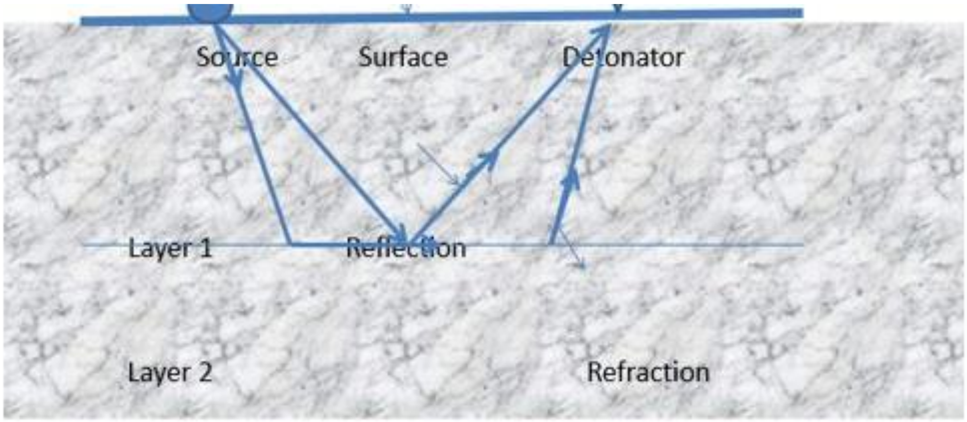

Fig. 4a. A typical plot of travel- time against distance

On a plot of T versus x, this is the equation of a straight line and has the slope 1/V1 and which intercepts the T axis (x=0) at a time boundaries survey.

$$T = \frac{x}{V_1} + \frac{2z\sqrt{V_1^2 - V_0^2}}{V_1 V_0} \qquad (1)$$

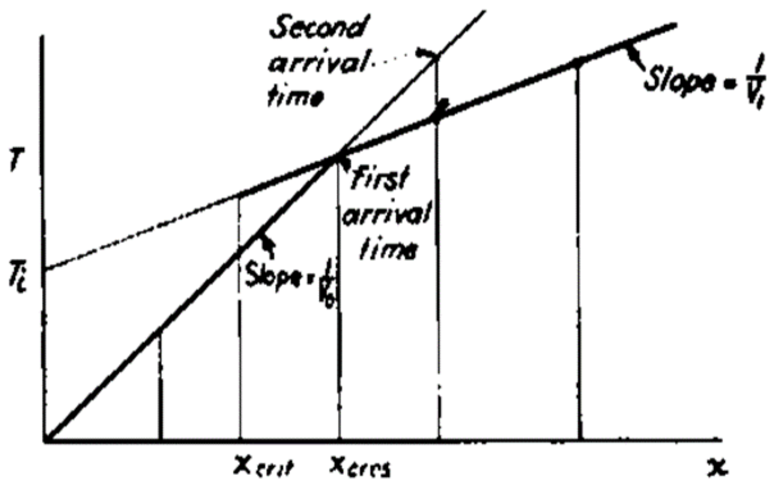

Fig 4b. Schematic diagram illustrating the path of seismic waves

$$T_i = \frac{2z\sqrt{V_1^2 - V_0^2}}{V_1 V_0} \qquad (2)$$

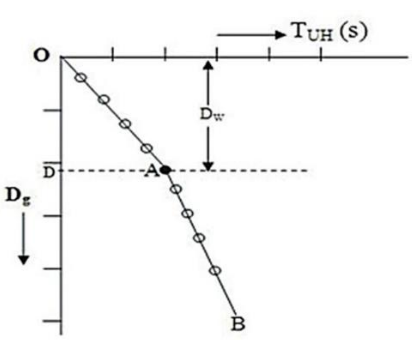

Fig 4c. A Typical uphole plot

This analysis of depth and velocity determination can be carried out for any number of layers. Similarly, the velocities of the weathered layer, the bedrock and thickness of the weathered layer (VW, DW, and VB) can be deduced from the uphole survey data (Figure 4c). Here the reciprocal of the slopes of the segments OA and AB equals VW and VB respectively, while OD is the thickness of the weathered layer, where D is the base of the LVL. The uphole data information usually serve as control to the surface refraction data and is often more reliable [11].

4. Materials and methods

The equipment used in this study comprise of seistronix seismograph, blaster, laptop computer as workstation or Mini platform, detonator; to generate seismic waves and calibrated hydrophones (Fig 5). Twelve (12) uphole datas were acquired from the area of study through United Geophysical Nigeria Ltd (UGNL).Borehole depths of 65m were drilled and logged at 60m. Flushing method of drilling was used to acquire the boreholes specified depths. Drills cuttings were collected at interval depths of 3m. The drills cuttings were used to log the downhole lithological vertical profile.

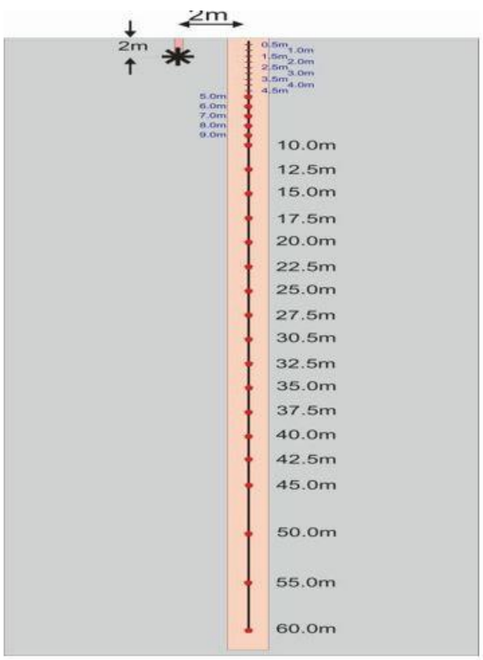

Fig. 5 Schematic diagram showing hydrophones design array

An energy source hole of 2m deep was drilled 2m away from the recording hole. Four cap-wires were connected in series to generate seismic waves. The cap-wires were buried at 2m depths and connected to the blaster at every borehole drilled. A downhole hydrophone calibrated at logging depths of 0m, 1.0m, 2.0m, 2.5m, 3.0m, 3.5m, 4.0m, 4.5m, 5.0m, 6.0m, 7.0m, 8.0m, 10.0m, 12.5m, 15.0m, 17.5m, 20.0m, 22.5m, 25.0m, 27.5m, 30.5m, 32.5m, 35.0m, 37.5m, 40.0m, 42.5m, 45.0m, 50.0m, 55.0m and 60.0m (Fig. 5) was inserted into each downhole point.

The seistronix seismograph has 32 channels, the acquired data was processed and interpreted using Upshere software; to pick the first break of each downhole trace. Then on each data acquired, a plot of time against each hydrophone position was made and travel-time versus depth curves for the borehole was generated. The information from the above curves were used in generating thickness and velocities contour maps and the model for the weathered and consolidated layers with the aid of Surfer 12 software.

Table 1. Summary of uphole data for two layers model parameters

s/n	Uphole number	Eastings	Northings	Elevation (m)	Depth weathered (m)	Velocity weathered (m/s)	Velocity consolidated (m/s)
1	52241024	486081.7	144134.5	43.3	11.1	402	1732
2	51471024	486082.3	140284.1	40.4	5.6	346	1324
3	53011024	486081.9	147983.8	45.3	17.7	579	1845
4	50631024	486080.9	136083.9	39.2	6.1	373	1339
5	53781024	486081.3	151834.2	47.1	25	767	1869
6	52241090	489378.2	144134.2	45.1	8.3	359	1418
7	50631090	489379.6	136083.7	38.8	10.3	380	1534
8	51471090	489390.1	140285.8	41.1	12.1	417	1881
9	53781090	489380.9	151833.5	52.1	4.8	445	2047
10	5301090	489381.1	147983.9	48.1	6.7	526	1756
11	51471156	492680.2	140284.6	41.9	12.1	417	1881
12	50631156	492679.8	136083.4	40.33	9.4	360	1475
average				43.56	10.74	447.58	1675.08

5. Results, interpretation and discussion

5.1. Presentation of results

Table 1 shows the complete results of the Uphole survey analyses in the study area. A total of twelve Uphole points were logged. A detailed quantitative interpretation of the twelve points using the Time-Depth graph was done. A two-layer geologic model was obtained from the overall results. The travel-time versus depth curves for some of the Uphole shots at points 1, 2, 4, and 5 are shown in Figs.6, 7,8, and 9. The results of the study revealed that the weathering thickness in the study area ranged from 4.8m to 25m with a regional average of 10.74m. Similarly, the weathering velocities varied from 346m/s to 767m/s with an average value of 447.58m/s, while the consolidated layer velocities ranged from 1324m/s to 2047m/s with a regional average of 1675m/s.

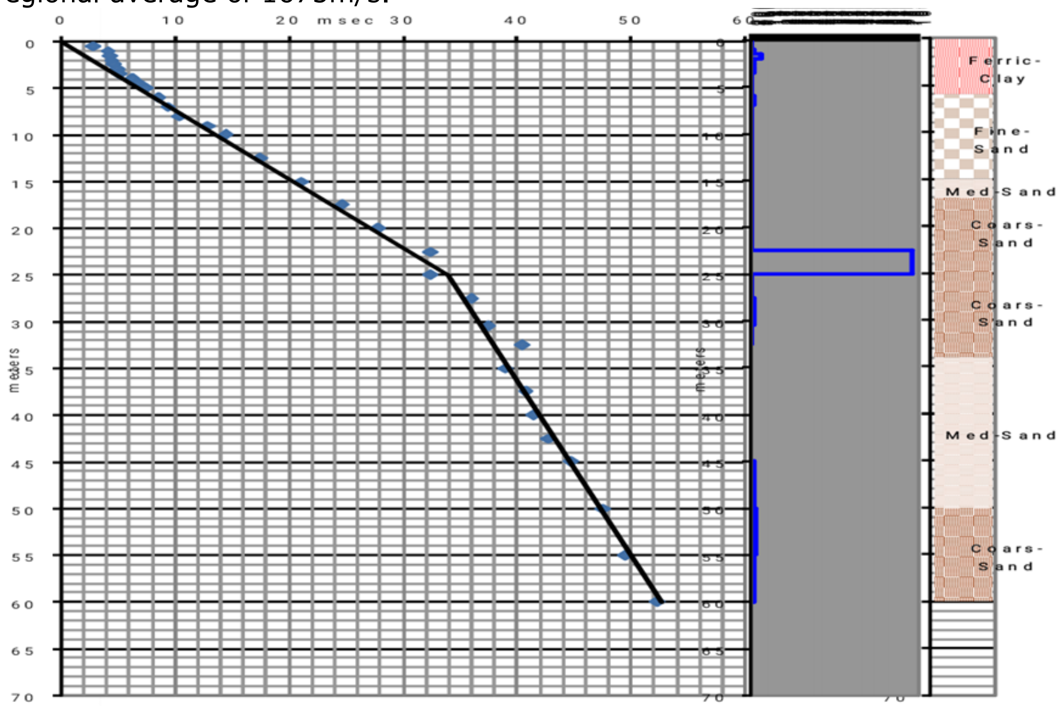

Fig. 6. Distance-time graph of the Up hole shot at Point 1

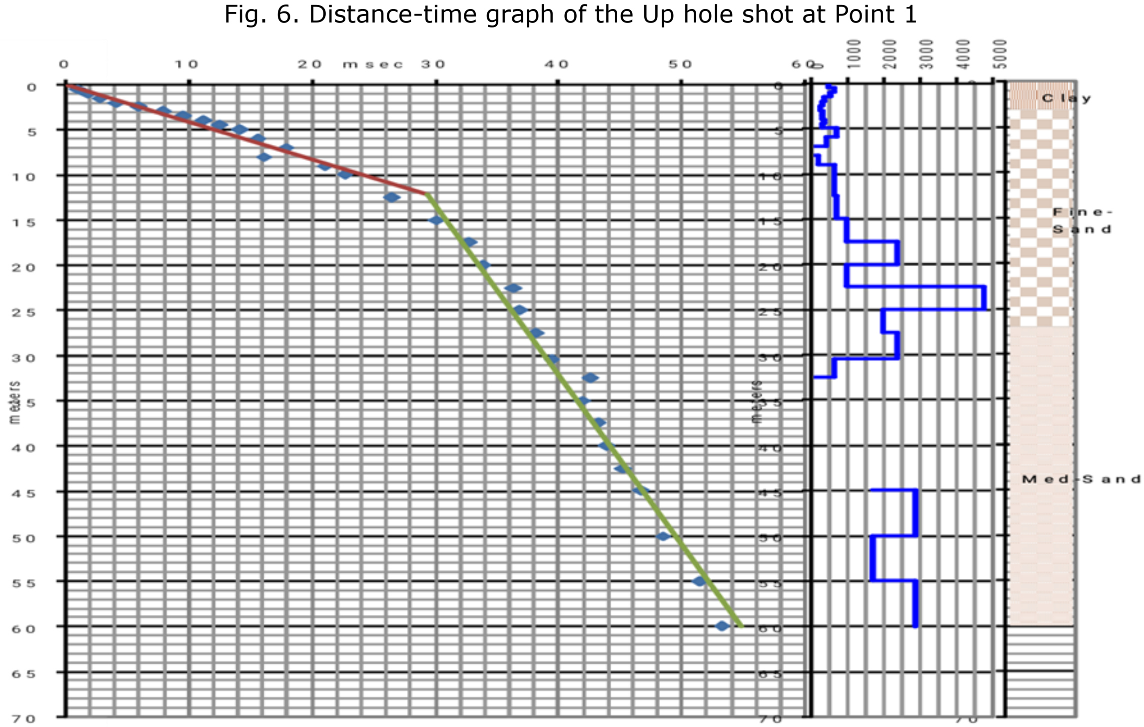

Fig. 7. Distance-time graph of the Up hole Shot at Point 2

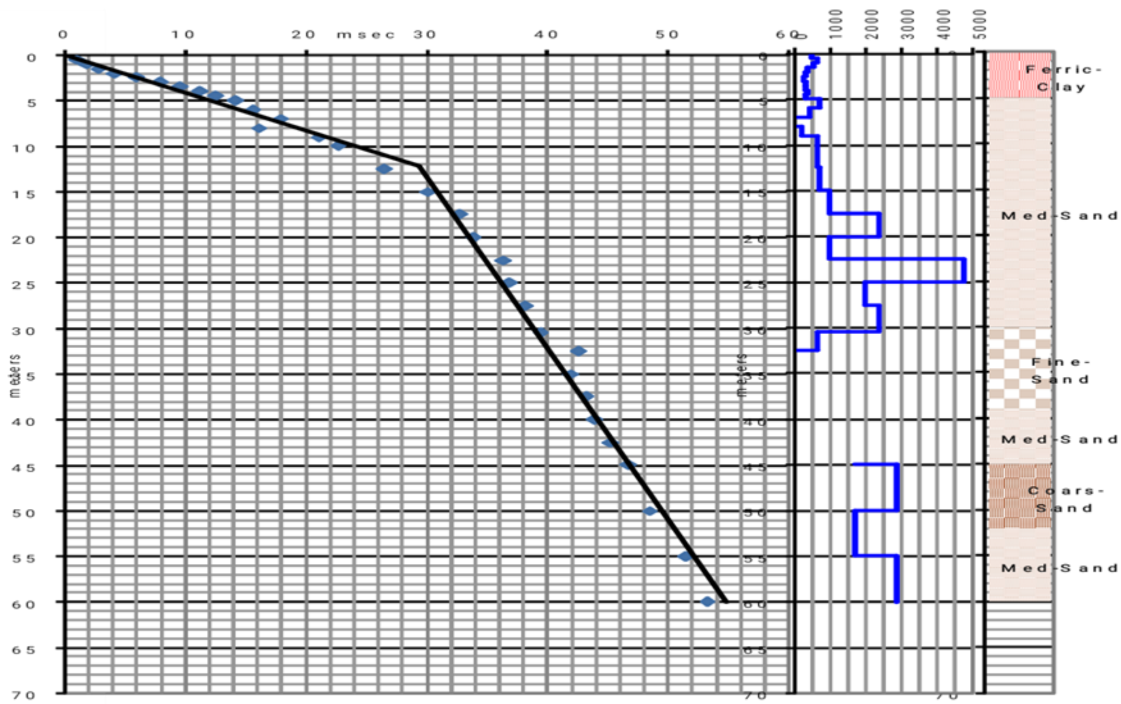

Fig. 8. Distance-time graph of the Uphole Shot at Point 4

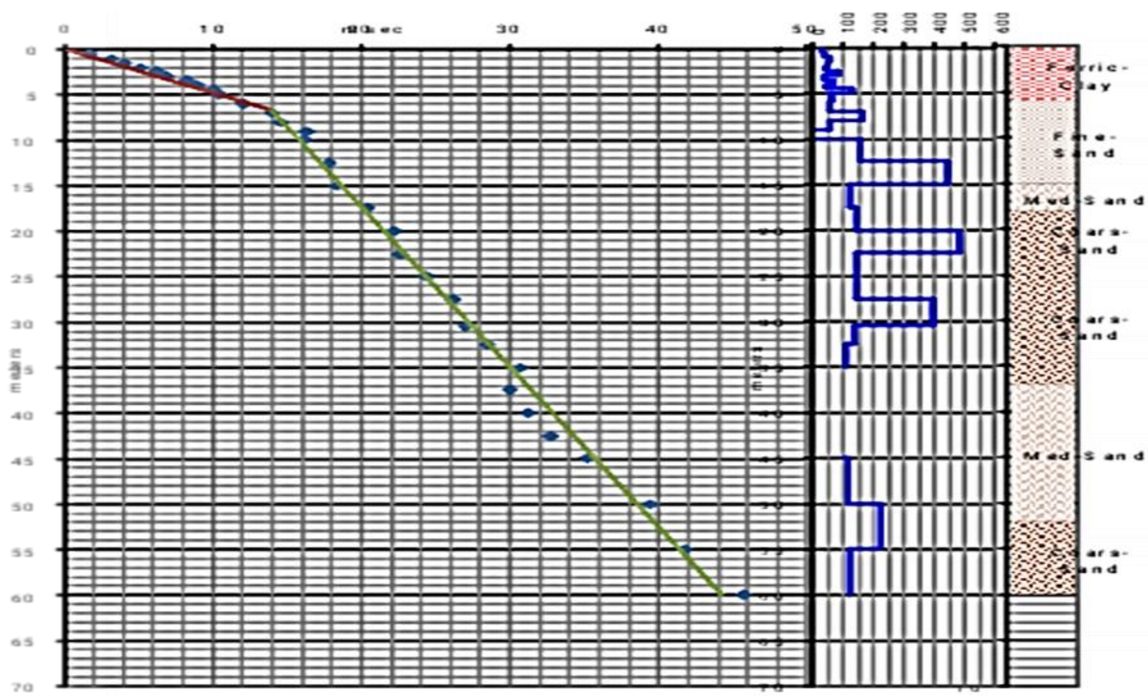

Fig. 9. Distance-time graph of Up hole Shot at Point 5

The velocities of the weathered and consolidated layers, the thickness of the low-velocity layer, and the surface elevation of the study area are presented as contour maps generated using Surfer 12 software in Fig. 10, 11, 12 and 13. Similarly, the cross-sectional plots of the elevation, layer velocity and thickness of the weathered layer are presented in Fig. 14a-c. From the plots, the two-layer geologic models are also revealed and are in agreement with the results as shown in Table 1.

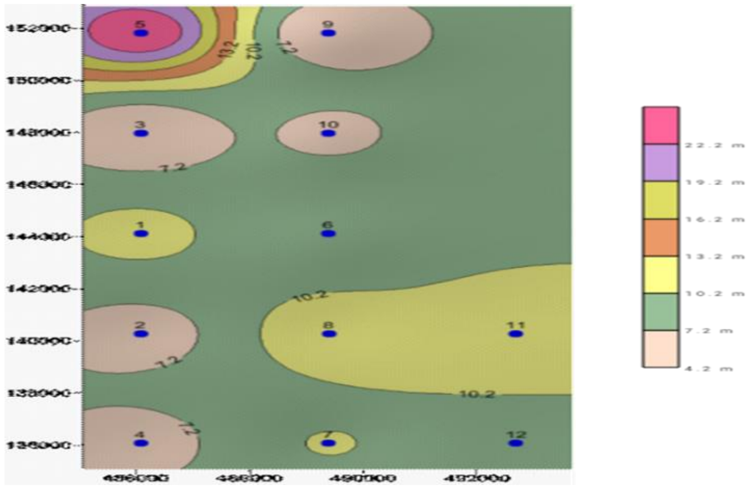

Fig. 10. Weathered Layer Thickness Contour Map

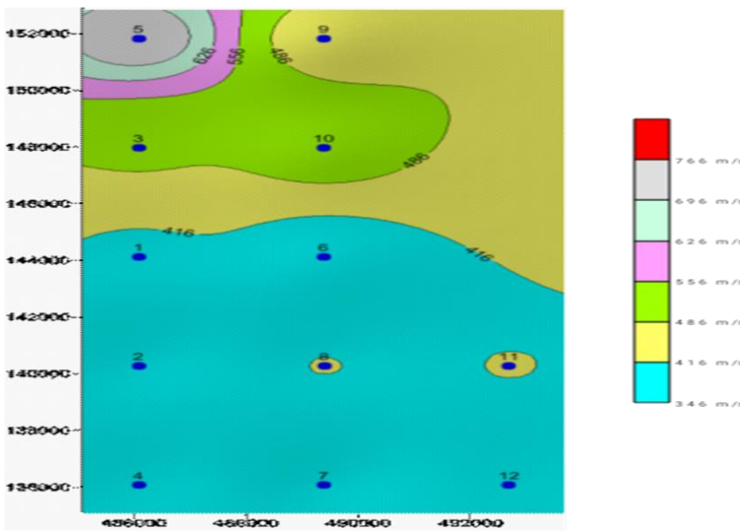

Fig. 11. Low-Velocity Layer1 (Weathering Layer) Contour Map

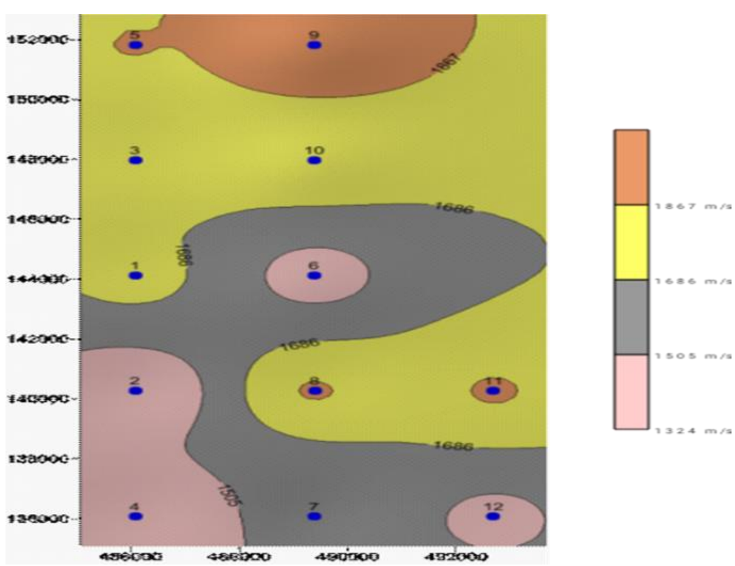

Fig. 12. Consolidated Layer Velocity Contour Map

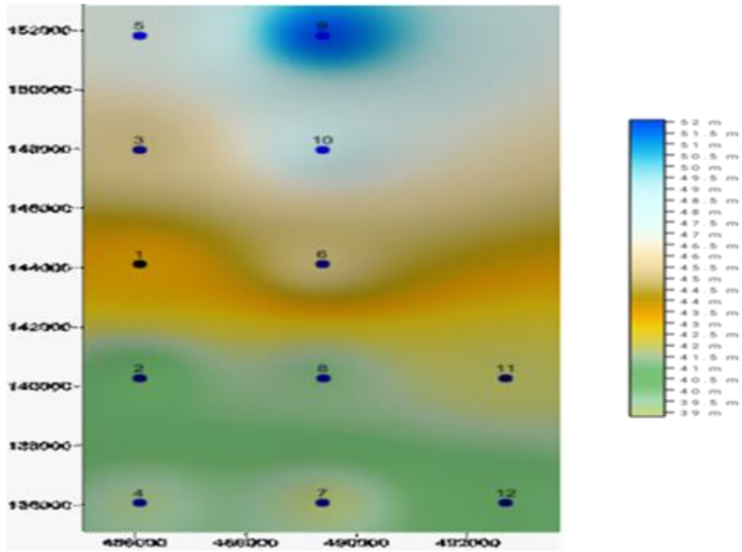

Fig. 13. Elevation Contour Map

5.2. Interpretation and discussion

An analysis of the cross sectional diagram as shown in Fig.14 revealed that the porous and permeable sand bodies are underlying the topsoil around Uphole U01-A01 and U01-A02 of the study area as indicated by the high weathered layer thickness or low-velocity layer depth recorded in that area. Porous rocks have a greater ability to hold water and this results in low seismic velocity and explains why seismic wave velocity is markedly attenuated in some areas around the Niger Delta [1]. Also, slightly compacted sand materials underlie the topsoil of the rest of the Uphole points (U01-A03, U01-A04, U01-A05, U02-A01, U02-A02, U02-A03, U02-A04, U02-A05, U03-A04, and U03-A05) of the study area. These slightly compacted sand materials is the reason for the moderate weathering velocity and low weathering thickness recorded in this area compared to Uphole points U01-A01 and U01-A02 as shown in the the prospect map(Fig.2). The consolidated layers of Uphole points U01-A04, U01-A05, U03-A03, and U03-A05 of the study area are believed to be less compacted. This is evident in the less consolidated layer velocity observed in this area compared to other areas. Care must be taken while carrying out a seismic shooting in the area because of these characteristics [1]. Generally, the results of the refraction seismic survey in this study revealed variations in the depths of the weathering layers which ranged from 4.8m to 25m with an average depth value of 10.74m and weathering velocity which ranged from 346m/s to 767m/s with an average weathering velocity of 447.58m/s.

Finally, the consolidated layer velocity ranged from 1,324m/s to 2,047m/s with an average value of 1675.08m/s. The range of velocities for the weathered and consolidated layers obtained in this study are in agreement with the findings obtained from previous study carried out in the Niger Delta [1,3,19-20]. Studies by Asry *et al.* [21] revealed that the velocities of the weathered and consolidated layers are respectively in the range of between 450 and 900m/s and between 1600 and 2000m/s respectively with the weathered layer having a regional average thickness of approximately 6m. Results of the study by Uko *et al.* [20] in the southeast Niger delta revealed an average weathered layer velocity of 500m/s and an average consolidated layer velocity of 1736m/s. Similarly, Ofomala [19] in his study in the Southern Niger Delta estimated the velocity of the weathered layer in the area to be between 250m/s and 800m/s while the study by Alaminiokuma and Amonieah [22] in North- central Niger delta estimated the weathered layer velocity to vary between 119m/s to 941m/s. Studies by Opara *et al.* [1] revealed that the velocity of the low -velocity layer ranged between 144 and 996m/s with a regional average of 407m/s while the thickness of the low velocity layer varied between 3.0 and 9.6m with a mean value of 5.0m.

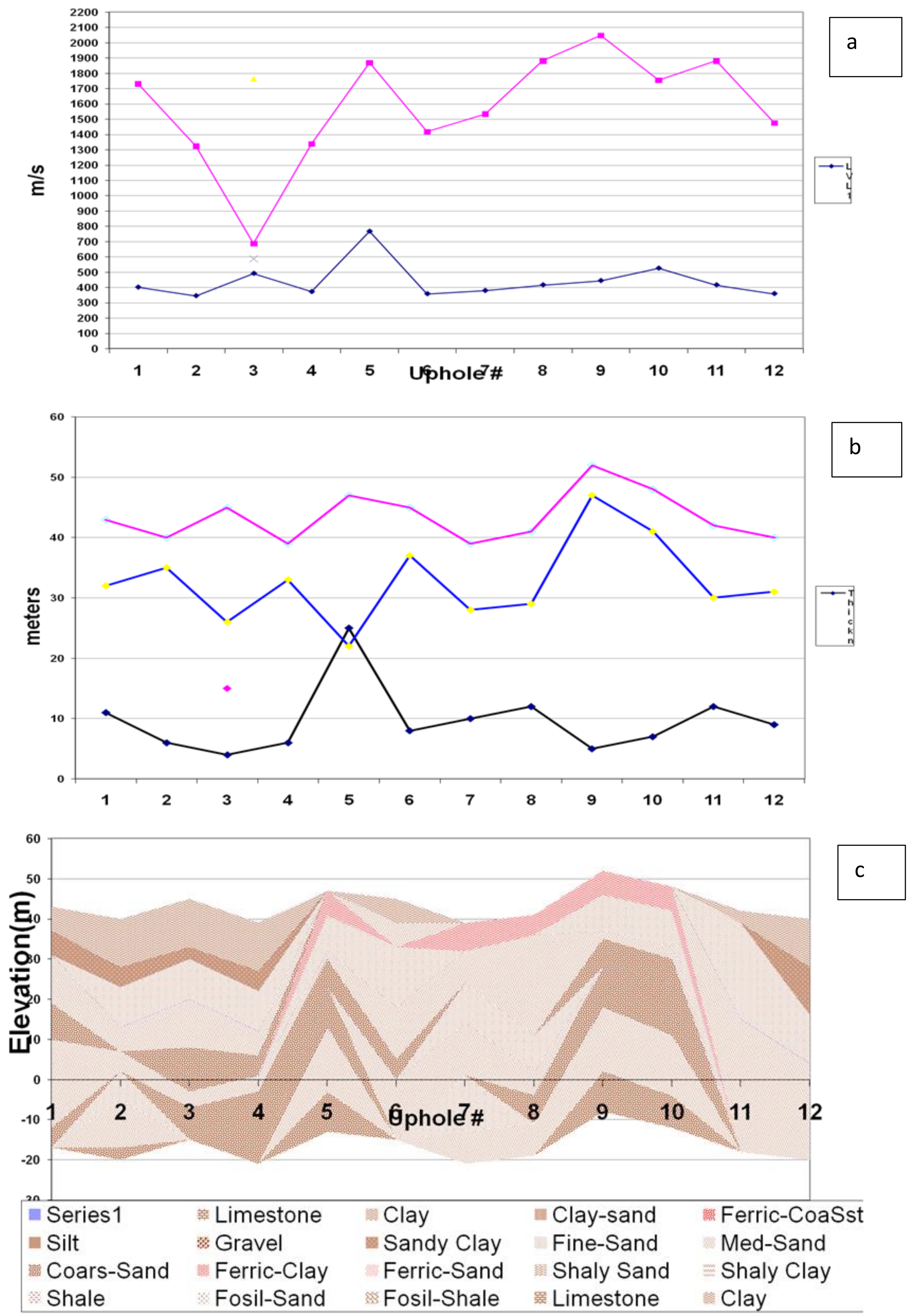

Fig. 14. Cross-sectional plots of the study area showing Up hole Shot points 1 to 12: (a) Cross section showing seismic velocity across the study area (b) Cross section showing elevation across the study area(c) Cross section showing lithology across the study are

Also, the velocity of the consolidated layer was observed to be between 1449-1812m/s with an average value of1738m/s. Opara *et al.* [1] further recommended that shots for reflection seismic survey in the area should be located at a minimum depth of 9.6m in the area to eliminate the effects associated with the low velocity layer. These findings therefore shows that the velocity of the weathered layer obtained in this study is practically within the range obtained from previous study.

6. Conclusion and recommendation

Detailed up hole refraction seismic survey of the study area revealed that the depths of the weathered layer ranged from 4.8m to 25m with a value of 10.74m, while the weathered layer velocity ranged from 346m/s to 767m/s with a mean value of 447.58m/s. The analysis of the result of the Uphole data revealed two (2) zones with distinct high weathered layer depths of 25m and 17.7m respectively. In conclusion, the downhole survey revealed a two-layer geologic model for weathering thickness and velocity. Hence, the downhole seismic method is a very useful technique in studying subsurface characteristics of a given area for application in engineering foundation studies by site civil engineers. Its application in reflection seismic data acquisition and processing by geologists, geophysicists, and seismologists are well known to be reliable. Also, the information provided by the study can be used to infer the presence of subsurface structures in the study area [4] and depths below the weathered layer that is most suitable for the acquisition of good quality seismic data in the area.

It is therefore recommended that;

1. That for the Zones(U01-A01 and U01-A02) with deep weathered layer depths of 25m and 17.7m, road construction or building of engineering structures require specific foundation treatment (soil improvement) before erecting any civil structures as most foundation failures of roads and other engineering structures within this area are attributed to this zones.
2. Other zones (U01-A03, U01-A04, U01-A05, U02-A01, U02-A02, U02-A03, U02-A04, U02-A05, U03-A04, and U03-A05) with moderate weathering depths between 4.8m to 10.3m require a minimum foundation depth of 10.5m to ensure stable foundations for engineering structures.
3. A 35m to 40m depth hole would be appropriate for better quality seismic data in this area of study.
4. A detailed geophysical study and characterization of the study area of study is therefore recommended.

Acknowledgements

The authors extend profound gratitude to the Management of United Geophysical Nigeria Ltd, for providing the enabling environment during the entire period of the data acquisition and Interpretation. The support of the Management of Federal University of Technology Owerri is also highly appreciated.

References

[1] Opara AI, Agoha CC, Okereke CN, Adiela UP, Onwubuariri CN, Okpono JO, and Nosiri OP. Low Velocity Layer Characterization in the Niger Delta:Implications for Seismic Reflection Data Quality. Journal geological society of India, 2017; 90. 187-195.

[2] Uko ET, Emudianughe JE, Eze CL Comparison of the Characteristics of Low Velocity Layer (LVL) in the Mangrove Swamp and in the Upper Flood Plain Environments in the Niger Delta, using Seismic Refraction Methods. J. Geol. Geophys., 2016; 5: 248.

[3] Agoha CC, Opara AI, Okereke CN, Onwubuariri CN, Emberga TT, Inyang GE, Ugwuegbu IE, and Chilaka JC. Weathered Layer Determination and Its Effects on Engineering Structures: Case Study of Parts of the Niger Delta. World Jcurves of Environmental Engineering, 2015; 3(2): 40-51.

[4] Adeoti KSI, Adesanya O, Olodu U, and Bello MA. Application of Uphole Seismic Refraction Survey for Subsurface investigation: A Case Study of Liso Field, Niger Delta, Nigeria. World Applied Sciences Journal, 2013; ISSN 1818-4952.

[5] Ogagarue DO. Comparative study of the offset geophone and down dip hydrophone Seismic refraction survey with application to the Niger delta basin, Nigeria; Pacific Journal of Science and Technology, 2007; 8(1): 49-58.

[6] Nwosu LI, and Emujakporue GO. Computer processed interpretation of Geophysical Logs of an Oil Field Niger Delta Sedimentary Basin, Onshore Nigeria. Journal of Geography, Environment and Earth Science International, 2016; 8(4): 1-19.
[7] Omoyoloye NA, Oladapo MI, and Adeoye OO. Engineering Geophysical study of Adagbakuja Newtown Development, South Western Nigerian. Journal of Earth Science, 2008; 2(2): 55-63.
[8] Olorunfemi MO, Ojo JS, and Ojelabi EA. Geophysical site investigation of the premises of Idu Flow station. Nigeria Agip company (NAOC) Limited. (for multipurpose oil services company limited, Port Harcourt). Technical report 2002.
[9] Akintorinwa OJ, and Adesoji JI. Application of Geophysical and geotechnical investigations in Engineering site Evaluation. International Journal of Physical Sciences, 2009; 4 (8): 443-454.
[10] Akintorinwa OJ, and Adeusi FA. Integration of Geophysical and Geotechnical Investigations for a proposed lecture Room complex at the Federal University of Technology, Akure, SW, Nigeria. Ozean Journal of Applied Sciences, 2009; 2(3): 241-254.
[11] Ofomola MO, Adia, KAN, Olagunju GM, and Ako BD. Integrated Geophysical methods for post foundational studies, Obanla staff Quarters of the Federal University of Technology, Akure, Nigeria. Pacific Journal of Science and Technology, 2009; 10(2): 93-111.
[12] Offordile ME. The occurrence of of exploration on groundwater in Nigeria Basement rocks. Nigeria journal of Mining and Geology, 1983; 20: 131-146.
[13] Opara AI, Onuoha KM, Anowai C, Onu NN, and Mbah RO. Geopressure and Trap Integrity Predictions from 3-D Seismic Data: Case Study of the Greater Ughelli Depobelt, Niger Delta. Oil & Gas Science and Technology – Rev. IFP Energies Nouvelles, 2013; 68(2): 383-396.
[14] Weber KJ, and Daukoru EM. Petroleum Geology of the Niger Delta: Proceedings of the ninth World Petroleum Congress, Volume 2, Geology: London 1975, Applied Science Publishers.
[15] Onyeagocha AC. Petrography and Depositional environment of the Benin Formation , Nigeria. Journal of Minning and Geology, 1980; 17(1): 147-151.
[16] Ejedawe JE. Patterns of incidence of oil reserves in Niger Delta Basin. AAPG Bulletin, 1981; 65(9): 1574-1585.
[17] Short KC, and Stäuble AJ. Outline of the geology of Niger Delta, AAPG Bulletin, 1967; 51: 761-779. 257-67.
[18] Reyment RA. Aspect of the Geology of Nigeria: Ibadan University Press, Ibadan 1965, Nigeria, 125.
[19] Ofomola MO. Uphole Seismic refraction survey for low velocity layer determination over Yom Field, South East Niger Delta. Journal of Engineering and Applied Sciences, 2011; 6 (4): 231-236.
[20] Uko ED, Tamunobereton-ari I, Omubo-Pepple VB. Comparison of Compressional wave Velocity depth Profiles from Surface and Downhole Detectors in the Near Surface in the Southeast Niger Delta, Nigeria. International Journal of Asian Social Science, 2012; 2(6): 869-880
[21] Asry Z, Abdul RS, Wan ZY, Jasni Y. Geoelectrical Resistivity Imaging and Refraction Seismic Investigations at Sg.Udang, Melaka. Amer. Jour. Engg. Appld. Sci., 2012; 5(1): 93-97.
[22] Alaminiokuma GI, Amonieah J. Near Surface structural model for enhanced Seismic data acquisition and processing in North central Niger Delta. Amer. Jour. Sci. Indus. Res., 2012; 3: 252-262.

To whom correspondence should be addressed: Dr. O. Ajayi, Department of Geology, Federal University of Technology, PMB 1526 Owerri, Nigeria E-mail: oajayi873@gmail.com