CARD International Journal of Science and Advanced Innovative Research (IJSAIR)
ISSN: 2536-7315 (Print) 2536-7323 (Online)
Volume 2, Number 2, June 2017
http://www.casirmediapublishing.com

A Study of the Weathering Layer using Uphole Method of Seismic Refraction Survey in Obayantor and Environs, Edo State, Nigeria

[1]Omoruyi, S. O.; [2]Ebahili, E. O. & [3]Selong, U, E.

[1,2]Department of Geology, University of Benin, Benin City, Nigeria
[3]Department of Geology, University of Calabar, Calabar, Nigeria
Email: ebahili789@yahoo.com
Corresponding Author: Ebahili, E. O.

ABSTRACT

This study is aimed at using uphole method of seismic refraction survey to investigate the thickness of the weathering layer as well as the velocity regimes of the weathering, unconsolidated and consolidated layers in meter/second (m/s). This was accomplished by using the information on the thickness of the weathering layer obtained from the uphole survey to plan depth parameter for high frequency seismic waves (shots) as it applies to 3-D seismic reflection survey and also carryout static corrections, geometry error (linear move-out) correction and migration as it applies to 3-D seismic processing. The study was carried out in Obayantor between Oredo and Ikpoba Okha Local Government Areas, Edo State. The field equipment set-up in uphole method of seismic refraction survey consisted of a calibrated hydrophone harness with marine rope in a well bore filled with water, a recording equipment called OYO Mc Seis version 3.0, a Master-Slave controlled blaster, a printer and a field battery to power the equipment was used. While, the processing and interpretation software was UDYSIS. Fifteen uphole locations were acquired in this study with identity, A,B,C,D,E,F,G,H,I,J,K,L,M,N and O at different locations throughout the study area. Rotary drilling method was used to drill to depths of 63m to 66m and logging was at 60m, 50m, 40m, 30m, 25m, 20m, 15m, 10m, 5m, 3m, 1m and 0m. The lithologies of the formations showed mainly sand and clay. From this study, the weathering layer velocity obtained ranged between 318m/s to 606m/s with an average value of 449m/s. This shows low velocity with which seismic waves are propagated. The thickness obtained for the weathering layer ranged between 4.2m to 10.9m with average value of 7m. The velocity of the unconsolidated layer obtained ranged between 151m/s to 1220m/s with an average value of 1017m/s. The thickness of the unconsolidated layer ranged between 4.2m to 22.2m with an average value of 16m. The value of the velocity obtained for the consolidated layer ranged between 1528m/s to 1950m/s with an average value of 1714m/s.

Keywords: Uphole, Weathered Layer, Hydrophones, Seismic Refraction, consolidated layer

INTRODUCTION

Uphole method of seismic refraction survey is a field technique, which uses hydrophones as receivers in a well bore filled with water. The energy source where seismic waves are generated is a shot hole which normally ranges between 1m to 2m depending on whether it is a swampy terrain or dry ground below the subsurface at an offset distance of 2m from the well bore. The seismic refraction method is based on the measurement of the travel time of seismic waves refracted at the interfaces between subsurface layers of different velocity (Ayolabi, *et al.,* 2009). Weathering layer of the substratum refers to the shallow surface layer composed of weathered materials such as soil, sand, gravel etc, which are unconsolidated (loose) materials. These layers are often characterized by low seismic velocities, hence the common name LVL (Low Velocity Layer). Base of weathering can be described as the boundary between the weathered layer and consolidated layer (Kolawole, *et al.,* 2012). Various study on the weathering layer of the Niger Delta has been done, among these works were those done by Adesanya, *et al.,* 2013, who delineated the weathering layer of the Niger delta and obtained an average value for the thickness and velocity to be 4m and 466m/s respectively. They obtained an average value for the velocity of the consolidated layer to be 1746m/s.

Geophysical properties of the shallow layers of the earth of the Niger delta have been investigated and reported by various workers using field techniques such as uphole, downhole and LVL (Low Velocity Layer) methods of refraction survey. Results of data interpretation obtained from Escravos indicate that the velocity of the weathered layer ranged between 454 and 533 m/s with an average value of 495 m/s. The results also revealed that the depth of the weathered layer ranged between 2.91 and 4.41 m with an average value of 3.68 m (Anomohanran, 2013). Results of data interpretation obtained from the "Mono" field, onshore NW Niger delta revealed that the thickness of the weathered layer is fairly uniformly thin in the area, ranging from 3.50m around the western and eastern flanks to 5.30m at the north central location with a regional average of 4.4 m. The average weathered layer compressional wave velocity was about 525 m/s; ranging from 300 m/s to 750 m/s around the north west and south eastern flanks and central portion of the study area respectively. The underlying consolidated layer has an average velocity of about 1800 m/s adjudged sufficiently competent to withstand engineering structures (Enikanselu, 2008). Igbokwe *et al.*, (2011) obtained an average value for the regional thickness for the weathering layer of the Niger delta to be 18.15m and velocity to be 1092m/s. The study area is Obayantor and environs in Oredo and Ikpoba Okha Local Government Areas of Edo State. It lies in the western part of the Niger Delta Basin (Fig. 1). It is situated between latitude "06 03'00" and 06" 11' 00" North of the equator and between longitude 05" 31' 00" and 05" 40' 00" East of Greenwich meridian.

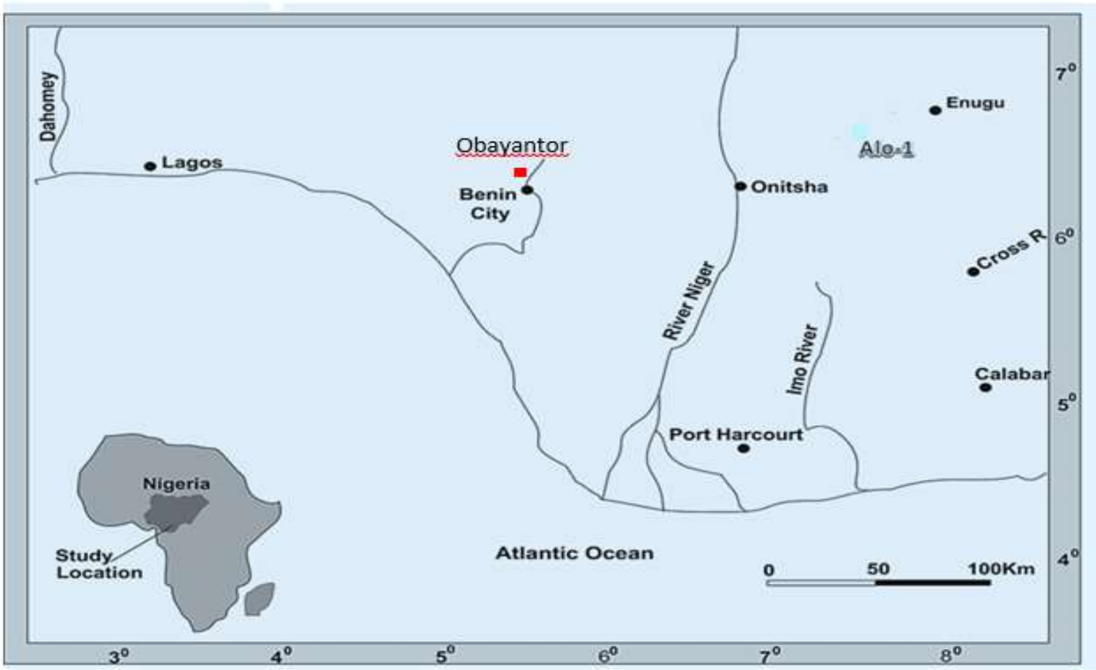


Figure 1: Map showing location of study area

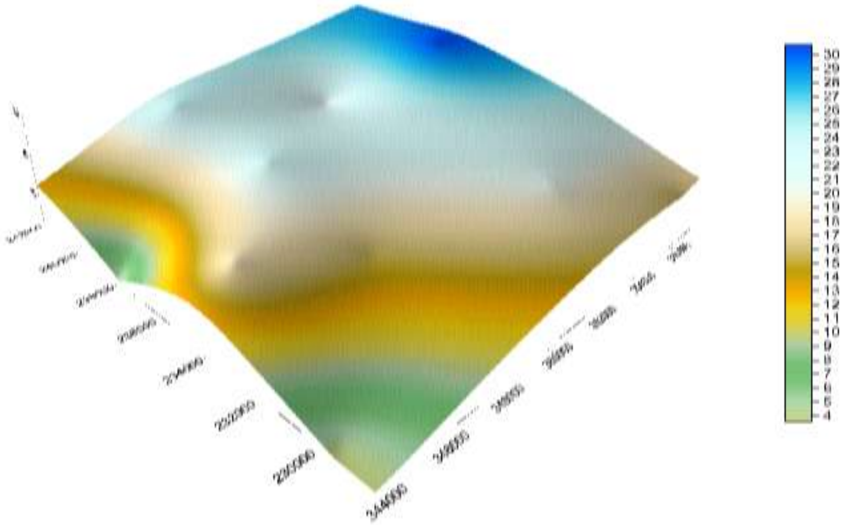


Figure 2: Elevation map of study area

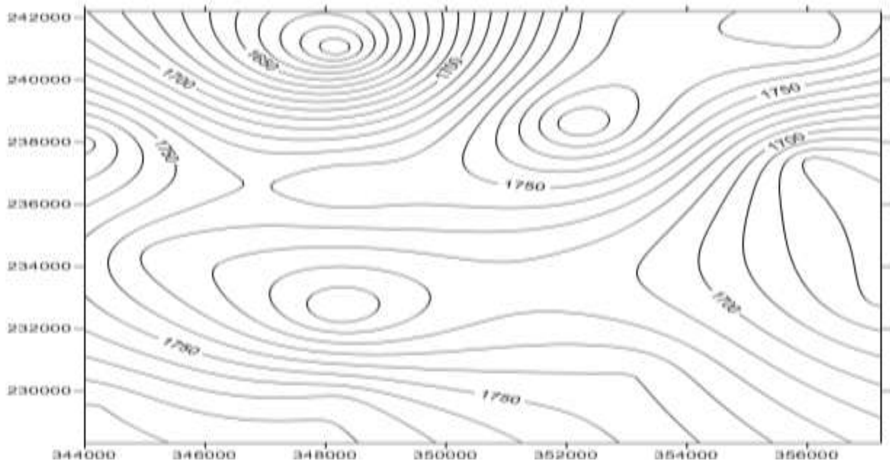


Figure 3: Contour map of study area

Geology of the Niger Delta Basin

Lithostratigraphy

Outcrop sediments in the Northern reaches of the Niger Delta Basin, range in age from Eocene to recent. The Eocene outcrops occur south of the Benin Flank and the basinal areas in the Northern fringe of the delta. The Recent outcrops are the present coastlines. Surface evidence of Oligocene and Miocene deposits are limited and much of the age determination is uncertain. The approximate surface boundaries of the Eocene-Recent sediments have been indicated in Hosper, (1965).

The Niger Delta Basin stratigraphy shows a typical off-lap sequence broadly divided into three main chronostratigraphic units, (Short and Stauble, 1967), comprising time equivalents proximal-to-distal prograding facies. These units comprise the bottom set Akata Formation, composed mainly of deep marine shales, which range in age from Eocene to Recent and deposited in deep marine environment. The Agbada Formation conformably overlies the Akata Formation, comprising alternating sequence of sands and shales and its age ranges from Eocene to Recent. The topmost Benin Formation is predominantly sandy and was deposited in continental environment, ranging in age from Early Miocene to Recent (Whiteman, 1982). The ages of these three formations are diachronous.

MATERIALS AND METHODS

The materials used included: recording instrument Mc Seis-Seismograph version 3.0, blaster unit, marine rope 100m length, geophones, metal weight, plastic clips, firing line plus connecting cables, two 12 volts dry cell battery, other materials are plotter paper rolls, masking tapes, bulldog tapes, cutter knife, venture tapes and hand napkin.

Acquisition Method (Procedure)

The uphole survey consist of the Mc Seis seismograph which is the recording equipment, it is connected to the harness containing the hydrophones. The electrical blasting device, the Master Slave Controlled blaster is also connected to the Mc Seis and the battery powers both devices. In every uphole location, a hole was drilled to 63m to 66m depth at an intersection point between source and receiver lines using rotary method and the hole flushed continuously for about 20 minutes and cased with pvc casings to enhance stability for smooth and effective loading. The explosive in the shot hole is exploded at about 63m by a detonator connected by means of wire to the blasting machine. Ditch cutting samples were collected at every 4m-depth interval. The ditch cuttings were described as seen on the field by physical examination and classified based on Wentworth grade scale.

Lithology logs were made based on the ditch cuttings samples collected at the 4m-depth interval.

To maintain formation strength once the drilling is completed, the drilling crew pulled out and evacuated their drilling equipment from shot point thereby making the location free for logging. The Uphole supervisor will then setup the instrument at a safe distance away from the shot hole while the uphole assistant and other Up-hole men load the drilled hole with explosive down to the required depth. A detonator is inserted into the dynamite and extended by means of wire connected to the blaster on the surface. The blaster is used to detonate the explosive. After the initial setup of equipment and safety procedure consideration, the firing command is sent from the blaster unit, which would provide required voltage discharge needed to trigger the detonator, which in turn explodes the dynamite (energy source). The blasting unit normally produces a field time signal, which precedes the explosion of the dynamite. This signal is fed back and recorded into the instrument to produce the arrival time sequence. Once a shot is successfully taken, it is recorded by the Mc Seis instrument and the output data would be printed out in hardcopy. A total of 12 hydrophones stations are logged at the different depth intervals from the surface earth (0m) down to 60m at the bottom of the wellbore filled with water.

Uphole field sheets were used to log details of the uphole location, depth of logging, explosive used, source and receiver lines and lithology log. Preliminary check is carried out at the uphole location to assess arrival times (first breaks) picked to ascertain immediately the quality of the uphole data acquired in the field. The following calibrated depths of 60m, 50m, 40m, 30m, 25m, 20m, 15m, 10m, 5m, 3m, 1m and 0m, were used for data acquisition. Instrument test carried out at 0m on the ground level to check and confirm that the uphole equipment was in good condition.

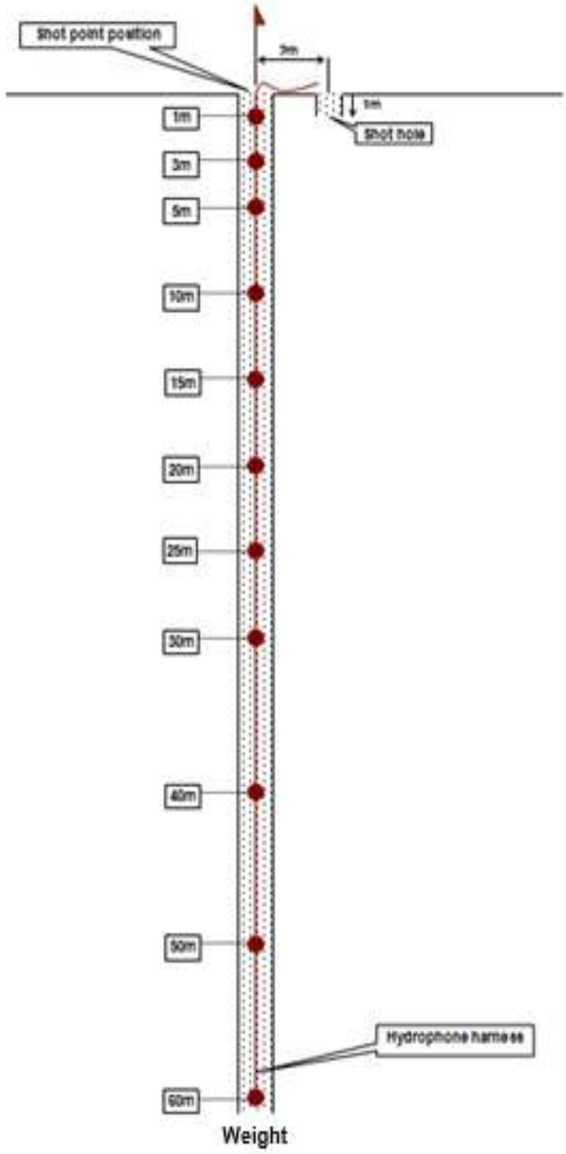


Figure 4: Uphole schematic diagram showing an array of hydrophones

RESULTS AND DISCUSSION

The results for the 15-uphole points acquired are contained in table 1. Some of the logging sheets are contained in table 2 and table 3. The interpretation software used in this survey for the 15-uphole points acquired is contained in Fig. 4 to Fig. 5. UDYSIS, the China National Petroleum Company designed software for uphole processing and interpretation was used in this survey. The comprehensive data set for the 15-uphole points acquired is contained in table 2 below.

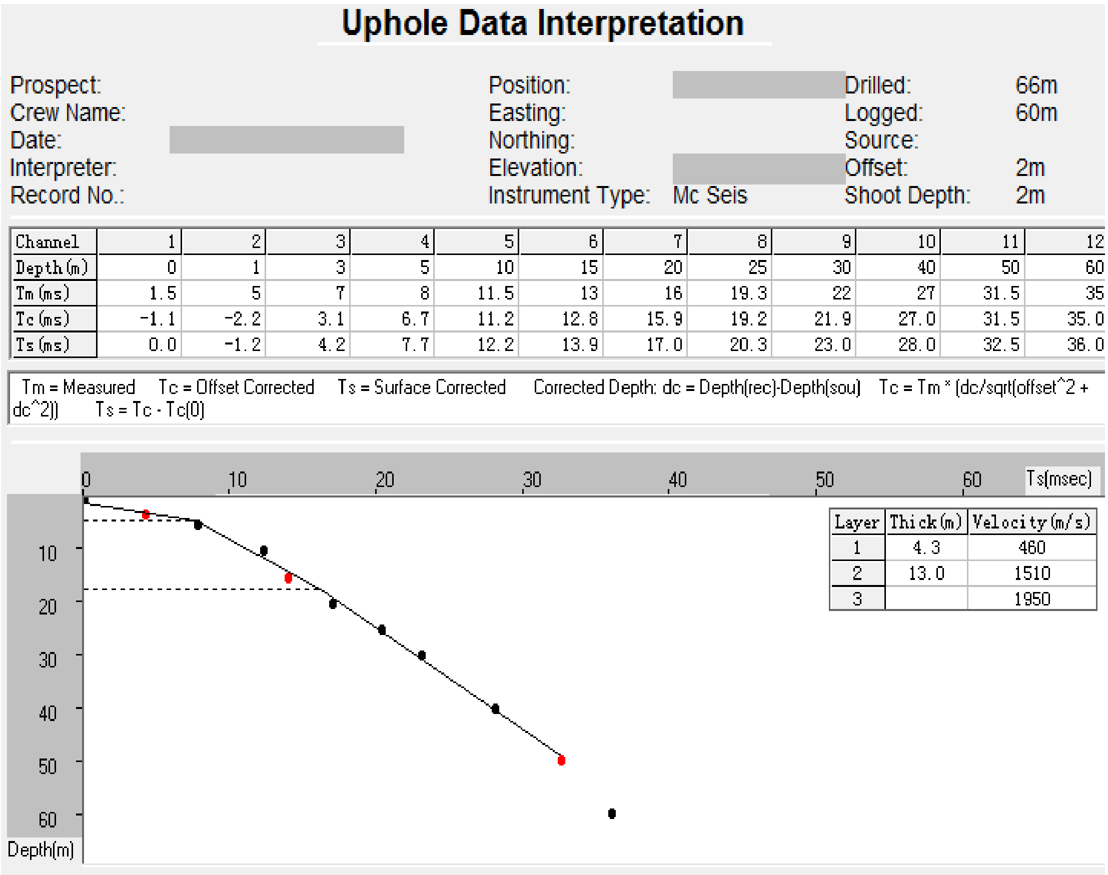
Table 1: Summary of data set obtained in the study area

S/N	Uphole ID	Location Co-ordinate Easting	Location Co-ordinate Northing	Elevation	Velocity (m/s) Vo Layer I	Velocity (m/s) Vu Layer II	Velocity (m/s) Vc Layer III	Distance (m) Do D1	Distance (m) Du D2	Distance (m) Dc D1+ D2
1	A	318199.7	227880.8	3.9	460	151	1950	4.3	13.0	17.3
2	B	318194.2	227881.4	3.5	351	1136	1701	8.3	4.2	12.5
3	C	318192.5	227889.1	3.6	318	1220	1841	5.7	14.1	19.8
4	D	318189.7	227878.5	3.7	503	767	1678	10.9	14.2	15.1
5	E	318194.2	227885.1	3.8	325	1190	1601	6.3	15.1	21.4
6	F	318191.0	227889.0	3.6	394	-	1726	10.2	7.4	17.6
7	G	318192.3	227882.4	3.7	371	1136	1570	6.1	17.1	23.2
8	H	318189.2	227889.1	3.5	591	833	1695	6.3	16.8	16.8
9	I	318197.0	227886.5	3.8	423	971	1754	5.0	22.2	27.2
10	J	318191.0	227885.0	3.7	463	967	1528	5.5	19.5	25
11	K	318191.0	227980.5	3.9	442	883	1626	4.5	18.4	14.9
12	L	318188.6	227790.4	3.5	498	872	1754	4.9	19.7	24.6
13	M	318196.8	227889.7	3.7	606	878	1817	8.2	17.3	25.5
14	N	318199.6	227880.4	3.5	423	934	1785	4.2	21.6	25.8
15	O	318189.9	227897.0	3.6	569	943	1686	6.8	21.3	21.3
Total					6737	14240	25712	97.2	241.9	308
Average Approximate Value					449	1017	1714	7	16	20.5

V_o = Layer I = Velocity of the weathering layer in m/s
V_u = Layer II = Velocity of unconsolidated layer in m/s
V_c = Layer I1I = Velocity of consolidated layer in m/s
D_o = D_1 = Total Thickness (depth) of the weathering layer in meters
D_2 = Total Thickness (depth) of unconsolidated layer from base of the weathering layer in meters
D_c = (D_1 + D_2) = Depth of consolidated layer from earth surface (om) in meters

Table 2: logging sheet for location A Uphole

Recording Instrument Used:		Mc Seis-SX 24 XP				Easting: 318199.7		
Drilled Depth:		66m				Northing: 227880.5		
Offset Distance:		2m				Elevation: 3.9m		
Energy Source depth:		2m						
File No.	Hydro Phone Depth (m)	No. of Channels	Caps Used (Pcs)	Cap Wire Length (m)	Dynamite Used (kg)	First Break (Milli Sec)	Lithology	Description
1	60	12	-	75	2	35		Sand (medium)
2	50		-			31.5		Sand (coarse)
3	40		-			27		Sand (medium)
4	30		-			22		Sand (coarse)
5	25		-			19.3		Sand (fine)
6	20		-			16		Sandy Clay
7	15		-			13		Sandy Clay
8	10		-			11.5		Sandy Clay
9	5		-			8		Sandy Clay
10	3		-			7		Sandy Clay
11	1		-			8		Clay
12	0		-			11		Sand (fine)



Channel	1	2	3	4	5	6	7	8	9	10	11	12
Depth(m)	0	1	3	5	10	15	20	25	30	40	50	60
Tm(ms)	1.5	5	7	8	11.5	13	16	19.3	22	27	31.5	35
Tc(ms)	-1.1	-2.2	3.1	6.7	11.2	12.8	15.9	19.2	21.9	27.0	31.5	35.0
Ts(ms)	0.0	-1.2	4.2	7.7	12.2	13.9	17.0	20.3	23.0	28.0	32.5	36.0

Layer	Thick(m)	Velocity(m/s)
1	4.3	460
2	13.0	1510
3		1950

Figure 5: Plot and Interpretation for Uphole A

Table 3: logging sheet for location B Uphole

Recording Instrument Used:	Mc Seis-SX 24 XP	Easting:	318199.7
Drilled Depth:	66m	Northing:	227880.5
Offset Distance:	2m	Elevation:	3.9m
Energy Source depth:	2m		

File No.	Hydro Phone Depth (m)	No. of Channels	Caps Used (Pcs)	Cap Wire Length (m)	Dynamite Used (kg)	First Break (Milli Sec)	Lithology	Description
1	60		-			48		Sand (medium)
2	50		-			40		Sand (coarse)
3	40		-			36		Sand (medium)
4	30		-			32		Sand (coarse)
5	25		-			28		Sand (fine)
6	20	12	-	75	2	25		Sandy Clay
7	15		-			22		Sandy Clay
8	10		-			19		Sandy Clay
9	5		-			16		Sandy Clay
10	3		-			10		Sandy Clay
11	1		-			7		Clay
12	0		-			2		Sand (fine)

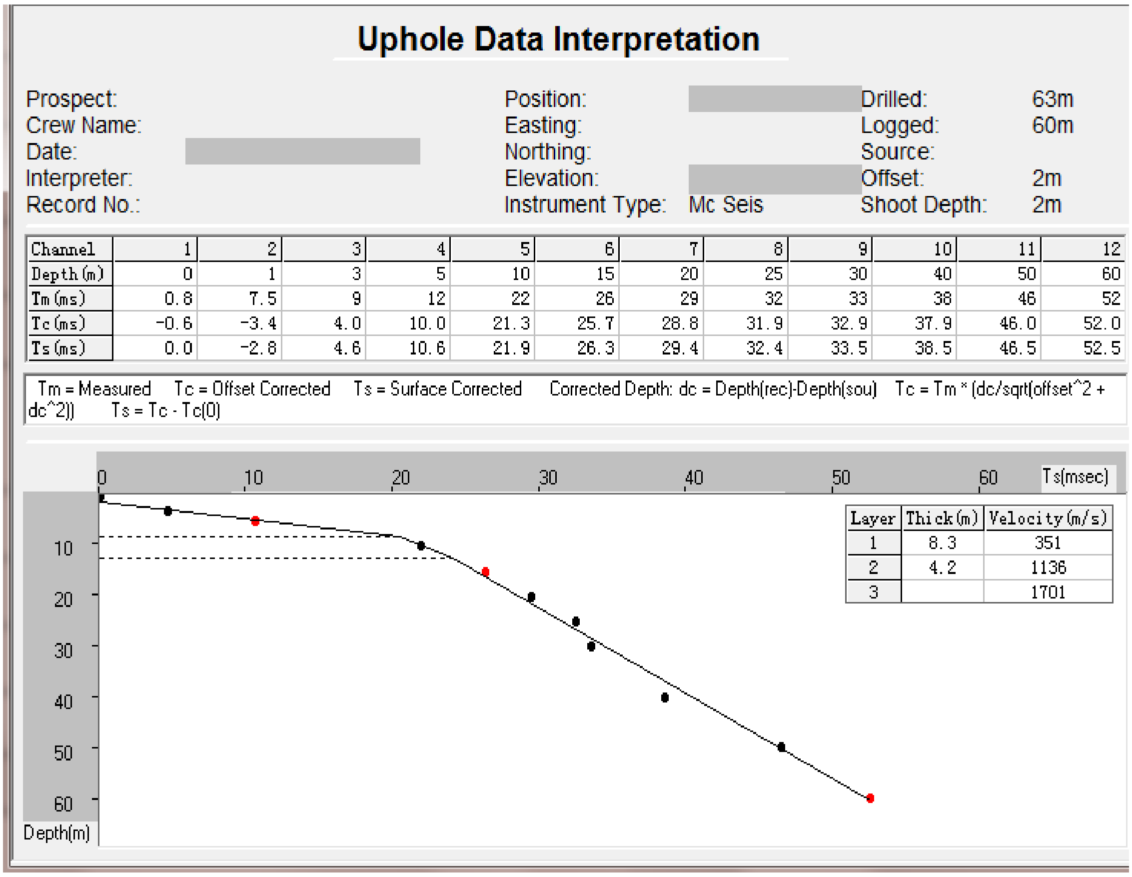


Figure 6: Plot and Interpretation for Uphole B

Table 4: Logging Sheet for Location C Uphole

Recording Instrument Used:		Mc Seis-SX 24 XP				Easting: 318199.7		
Drilled Depth:		66m				Northing: 227880.5		
Offset Distance:		2m				Elevation: 3.9m		
Energy Source depth:		2m						
File No.	Hydro Phone Depth (m)	No. of Channels	Caps Used (Pcs)	Cap Wire Length (m)	Dynamite Used (kg)	First Break (Milli Sec)	Lithology	Description
1	60	12	-	75	2	46		Sand (medium)
2	50		-			42		Sand (coarse)
3	40		-			37.5		Sand (medium)
4	30		-			33		Sand (coarse)
5	25		-			28		Sand (fine)
6	20		-			26		Sandy Clay
7	15		-			22		Sandy Clay
8	10		-			18		Sandy Clay
9	5		-			14		Sandy Clay
10	3		-			10		Sandy Clay
11	1		-			7		Clay
12	0		-			1.6		Sand (fine)

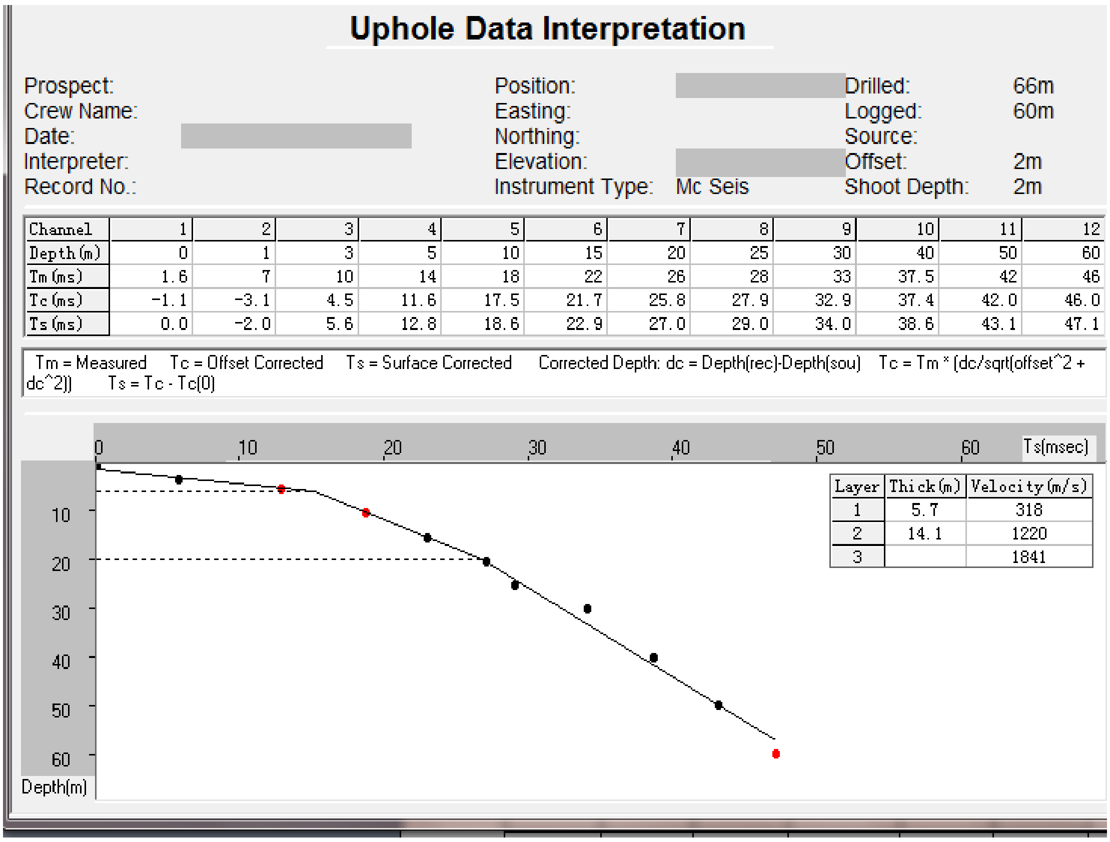


Figure 7: Plot and Interpretation for Uphole C

Table 5: logging sheet for location D uphole

Recording Instrument Used:	Mc Seis-SX 24 XP	Easting:	318199.7
Drilled Depth:	66m	Northing:	227880.5
Offset Distance:	2m	Elevation:	3.9m
Energy Source depth:	2m		

File No.	Hydro Phone Depth (m)	No. of Channels	Caps Used (Pcs)	Cap Wire Length (m)	Dynamite Used (kg)	First Break (Milli Sec)	Lithology	Description
1	60		-			50		Sand (coarse)
2	50		-			45		Sand (medium)
3	40		-			41		Sand (medium)
4	30		-			33		Sand (coarse)
5	25		-			30		Sand (fine)
6	20	12	-	75	2	27		Sandy Clay
7	15		-			24		Sandy Clay
8	10		-			19		Sandy Clay
9	5		-			13		Sandy Clay
10	3		-			6		Clay
11	1		-			5		Clay
12	0		-			1.4		Sand (fine)

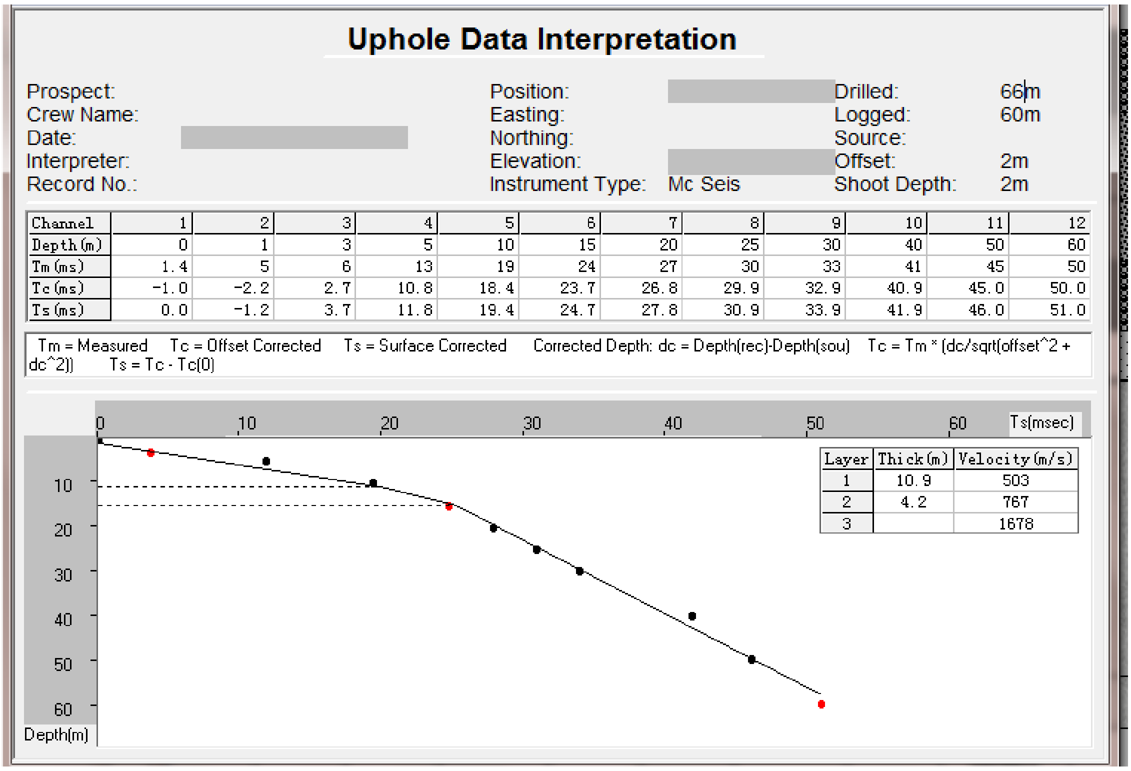
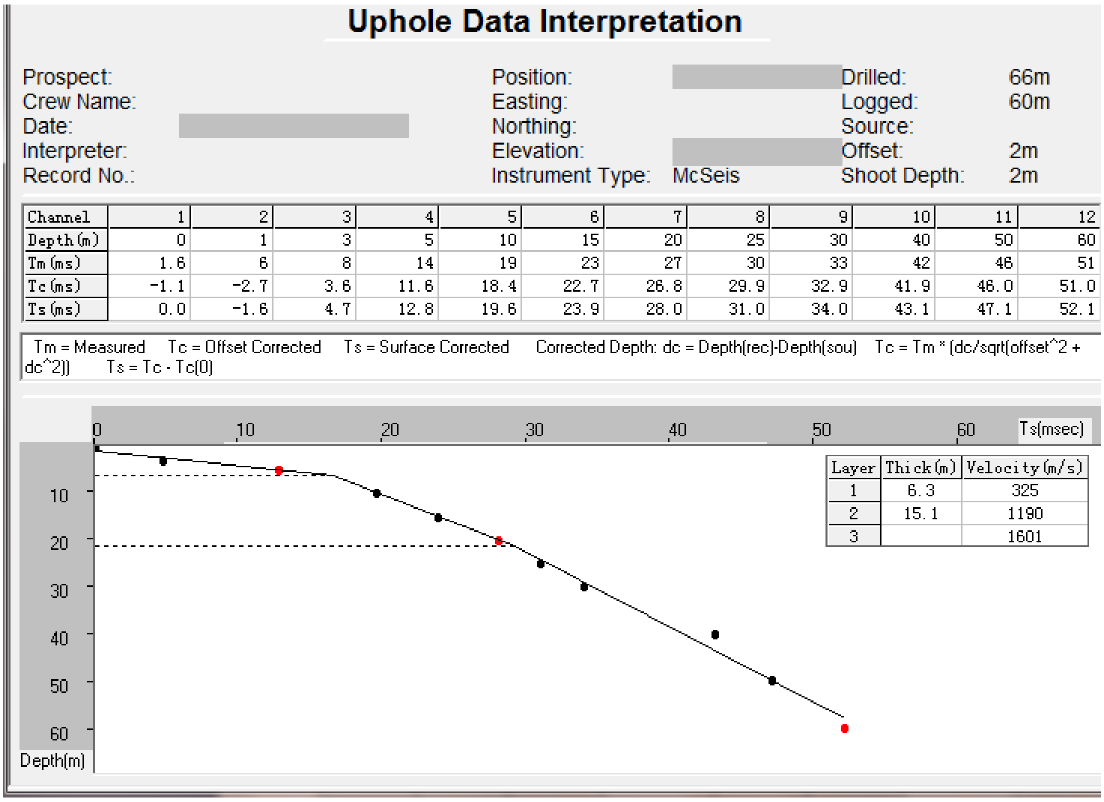


Figure 8: Plot and Interpretation for Uphole D

Table 6: logging sheet for location E uphole

Recording Instrument Used:		Mc Seis-SX 24 XP				Easting: 318199.7		
Drilled Depth:		66m				Northing: 227880.5		
Offset Distance:		2m				Elevation: 3.9m		
Energy Source depth:		2m						
File No.	Hydro Phone Depth (m)	No. of Channels	Caps Used (Pcs)	Cap Wire Length (m)	Dynamite Used (kg)	First Break (Milli Sec)	Lithology	Description
1	60	12	-	75	2	51		Sand (coarse)
2	50		-			46		Sand (medium)
3	40		-			42		Sand (medium)
4	30		-			33		Sand (coarse)
5	25		-			29		Sand (fine)
6	20		-			26		Sandy Clay
7	15		-			24		Sandy Clay
8	10		-			19		Sandy Clay
9	5		-			14		Sandy Clay
10	3		-			8		Sandy Clay
11	1		-			5		Clay
12	0		-			1.3		Sand (fine)



Channel	1	2	3	4	5	6	7	8	9	10	11	12
Depth (m)	0	1	3	5	10	15	20	25	30	40	50	60
Tm (ms)	1.6	6	8	14	19	23	27	30	33	42	46	51
Tc (ms)	-1.1	-2.7	3.6	11.6	18.4	22.7	26.8	29.9	32.9	41.9	46.0	51.0
Ts (ms)	0.0	-1.6	4.7	12.8	19.6	23.9	28.0	31.0	34.0	43.1	47.1	52.1

Layer	Thick (m)	Velocity (m/s)
1	6.3	325
2	15.1	1190
3		1601

Figure 9: Plot and Interpretation for Uphole E

The summary of the 15-uphole points acquired shows 3 velocity regimes, each velocity regime corresponding to a given layer with same value of velocity in m/s for that particular layer.

The first velocity regime, which corresponds to layer I range in value from 318m/s to 606mls with an average value of 449m/s for all 15 uphole points. This layer delineates the weathering layer or LVL (low velocity layer) in the study area. And the thickness ranges from 4.2m to 10.9m with an average value of 7m. In this layer, seismic waves are propagated at low velocities resulting to low frequency seismic waves (shots) with high amplitudes. In this layer, seismic waves are always associated with ground rolls and surface waves, which often mask seismic shots undesirably. Hence in terms of subsurface resolution of structural and stratigraphic features this layer or velocity regime is not desirable.

The low velocity with which the seismic waves travel through the formations in this layer is due to the loose and uncompacted nature of the grains making up the formations. In a typical 3-D seismic reflection survey, this layer is not suitable for use as depth parameter. Weathering processes are still actively going on in this layer, the signal–to–noise ratio is low, and this often leads to poor resolution of the subsurface geology. The second velocity regime corresponds to the second layer in the study area and it ranges in velocity from 767m/s to 1510m/s with an average value of 1017m/s. The thickness of this layer ranged in value from 12.5m to 27.2m with an average value of 20.5m. This layer below the weathering layer, is unconsolidated though the degree of compaction is greater than the weathering layer. The signal–to–noise ratio in this layer is higher than that obtained from the weathering layer and is used as depth parameter in pattern shots in 3-D seismic reflection survey. This layer helps to delineate the onset of the consolidated layer at the depth it interfaces with the third layer.

The third velocity regime corresponds to the third layer in the study area. The velocity value in this layer ranged from 1528m/s to 1950m/s with an average value of 1714m/s. The depth of the top of this layer is 20.5m from the earth surface given its approximate value in the study area for all 15 uphole points acquired. This layer corresponds to the consolidated layer. The high velocity value of this layer is due to its consolidated and compacted nature. Seismic waves are propagated in this layer fastest compared to the layers above it. In this layer the signal–to–noise ratio is high and problems of ground rolls and surface waves masking reflected waves in 3-D seismic reflection survey are eliminated. Ground roll is a form of dispersive, low frequency, high amplitude noise that obscures useful information seismic exploration. Ground roll removal is an essential part of land seismic data processing.

The need to delineate the consolidated layer is crucial in present day petroleum exploration in the oil and gas industry. It is used to plan depth parameter in single deep holes (SDH) in modern 3-D seismic reflection survey and it is used for static correction purposes. Hence it's overall input as an indirect tool in structural and stratigraphic resolution of the subsurface geology. The sum of D1, which corresponds to distance of the weathering layer, and D2, which corresponds to the distance of the unconsolidated layer, corresponds to the depth where the consolidated layer begins. Static corrections are applied to seismic data to compensate for the effects of variations in elevation, weathering velocity, weathering thickness or reference to a datum. The objective is to determine the reflection arrival times which would have been observed in all measurements had it been made on a flat plane with no weathering or low velocity material present. These corrections are based on uphole data, refraction first break or event smoothing.

CONCLUSION

From the values obtained from the analysis carried out in this study as contained in table 2, it has been clearly shown that the uphole method of seismic refraction survey is central to 3-D seismic reflection survey and as a result plays a key role in petroleum exploration in the oil and gas industry. The uphole method of seismic refraction survey was used to delineate the velocities of the weathering layer, the unconsolidated and consolidated layers respectively. The velocity regimes obtained from this study that correspond to the three layers obtained with increasing velocity from layer one to layer three also help to establish the geologic fact and principle that compaction and consolidation increase with increase in depth into the subsurface from the earth surface.

Static corrections as it applies to processing in 3-D seismic reflection was made possible with the information on the consolidated layer obtained from uphole method of seismic refraction survey. Seismic data acquired on land need to have the effects of changes in ground surface elevation removed the potential effects of changes in thickness and velocity of the overburden, low-velocity weathered rock and aeolian dunes.

Short-period statics occur within the length of the spread, whereas long-period statics are associated with lateral variations that are longer than the length of the spread.Geometry error correction is also achieved from the information obtained on the consolidated layer during Linear-Move-Out (LMO) correction in 3D seismic reflection survey during processing. To migrate seismic data, processors need to know or be able to estimate the subsurface velocity field. The accuracy of any result obtained from the implementation of any migration algorithm would depend on the accuracy of the velocity model used.

From this work, it has been proved beyond doubt that uphole method of seismic refraction survey is an invaluable tool in petroleum exploration as it applies to the acquisition of 3-D seismic reflection survey which currently is a mainstay in the oil and gas industry all over the world, and as such it is strongly recommended that it should be carried out in any project or prospect before actual shooting of any 3-D seismic reflection survey.

REFERENCES

Anomohanran, O., 2013. Geophysical Investigation of Groundwater Potential in Ukelegbe, Nigeria, *Journal of Applied Sciences,* vol. 13(1), pp. 119-125.

Ayolabi, E. A., Adeoti, L., Oshinlaja, N. A., Adeosun, I. O. and Idowu, O. I., 2009. Seismic Refraction and Resistivity Studies of Part of Igbogbo Township, Southwest Nigeria. Journal of Scientific Research Development, vol. 11, pp. 42-61.

Enikanselu, P. A., 2008. Geophysical Seismic Refraction and Uphole Survey Analysis of Weathered Layer Characteristics in the Mono Field, North Western Niger Delta, Nigeria. *Pacific Journal of Science and Technology,* vol. 9(2), pp. 537-545.

Hospers, J., 1965. Gravity Field and Structure of the Niger Delta, Nigeria, West Africa. *Geological Society of American Bulletin,* vol. 76, pp. 407-422.

Igbokwe, M. U. and Ohaegbuchu, H. E., 2011. Investigation into the Weathering Layer Using Uphole Method of Seismic Refraction. *Journal of Geological Mineral Research,* vol. 3, pp. 73-86.

Kolawole, F., Okoro, C. and Olaleye, O. P., 2012. Downhole Refraction Survey in Niger Delta Basin: A 3-layer Model. *ARPN Journal of Earth Sciences,* vol. 1(2), pp. 67-79.

Short, K. C. and Stauble, A. J., 1967. Outline of Geology of Niger Delta. *American Association of Petroleum Geologists Bulletin,* vol. 51(5), pp. 761-779.

Whiteman, A. J., 1982. Nigeria. Its Petroleum Geology, Resources and Potential. Graham and Trotman, London, 39p.