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Delineating the Proper Shooting Medium for Seismic Reflection Survey in the Greater Ughelli Depobelt, Niger Delta

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Abstract

The proper shooting medium for seismic reflection survey was delineated in a prospect within the Greater Ughelli Depobelt of the Niger Delta using a sample density of 37 Uphole surveys. This prospect is characterized by river tributaries with large and extensive column of sand bars lining the entire length of river banks, creeks, rain forests and flooded plains which pose difficult challenges in placing shots in the proper medium. Thickness and velocity of these unconsolidated weathered layer materials were computed. Graphical analysis using the UDISYS Software to plot the surface corrected first-break times, Ts (msec) against hydrophone offsets (m) showed a dominant 1-weathered layer model. The results reveal that the weathered layer velocity ranges between 209 and 593 m/s while the velocity within the consolidated layer ranges between 1131 and 1987 m/s. The weathered layer thickness ranges from 3.2 to 6.8 m with the prospect average of 4.7 m. These results suggest that, where possible, Pattern-shot types should be located at depths of about 7.0 m in the North-Eastern part, 5.5 m in the South-Eastern part and 3.5 m in the Western and East-Central parts. These depths are below the weathered layer where signals travel at velocities devoid of time delays during 3D/4D seismic surveys in this area. This has the advantage of cancellation of ground roll (surface noise) during acquisition thereby focussing all the seismic energy in the vertical direction and by-passing thus minimizing the spurious effects of the low velocity weathered layer during acquisition and initial processing of field data.

Keywords: Uphole; Thickness; Velocity; Greater Ughelli Depobelt; Niger Delta

Introduction

Determining the proper shooting medium for seismic reflection data acquisition in the Greater Ughelli Depobelt characterized by river tributaries, creeks and tropical rain forests and other logistic hindrances is one of the challenges for seismic exploration within this area. A good shooting medium is such that the energy source is properly placed and the generated acoustic wave controlled to reach the desired subsurface depth for oil and gas exploration. But choosing a shooting medium in this area with large and extensive column of sand bars lining the entire length of river banks and flooded plains is very difficult because of the aerated, highly loose, and unconsolidated (usually with fluid in the pore spaces) rock materials lying along the shooting profiles.

According to Alaminiokuma and Amonieah [1], these highly loose and unconsolidated rock materials cause high absorption of seismic energy resulting in poor seismic records from shots, time delays to rays thus shifting reflection events out of their true relationships, large velocity contrasts sharply bending seismic rays into near-vertical travel path, high impedance contrast making it an excellent reflector of multiples, high amplitude of reflection resulting in false indications of significant structural relief features among others making it difficult to pin-point the hydrocarbon location.

Consequently, it becomes very indispensable to choose a proper medium for locating the energy source. Uphole survey and investigation for charge and depth are essential to finding this shooting medium. The Uphole method provides the most direct measure of the near-surface [2]. Studies by Uko, et al., Eze, et al., Amonieah et al. Enikanselu, Osagie, Alaminiokuma, et al. [3-6] among others have shown that the information about the near-surface velocities, depths and thicknesses of the layers in the vertical direction can be delineated by this method. The method also provides lithological information of the near-subsurface at the point of drilling through cuttings. The first-break amplitudes when properly studied identify the high velocity medium. The Uphole survey, when conducted at close intervals in

a stable area, deciphers the proper depth for the source of energy to be placed. The energy generated from such depth is good in terms of frequency contents and capable of travelling to sufficiently longer distances minimizing the problem of ground rolls [7].

Physiography of the Study Area

The survey area is characterized by River tributaries, flooded plains creeks and tropical rain forests. The vegetation in the prospect varies from light vegetation and grass lands in the western and central parts to flooded plains and tropical rain forests in the eastern part. The prospect is subject to heavy flooding and erosion in the wet season. The Lyesse River runs through the central part, dividing the prospect into approximately into two halves and River Uromi, a tributary of River Niger aligning almost parallel with the prospect on the northern part while River Niger bounds the prospect on the east.

Location and Geology of the Study Area

The study area lies within the Greater Ughelli Depobelt of the Niger Delta (Figure 1) and covers a surface area of about 4.00 by 3.75 km². The prospect covers four Local Government Areas in Delta State, Nigeria namely: Aniocha South, Ndokwa East, Oshimili North and Oshimili South and bounded by Anambra, Edo and Enugu in the North-East, West and far North respectively.

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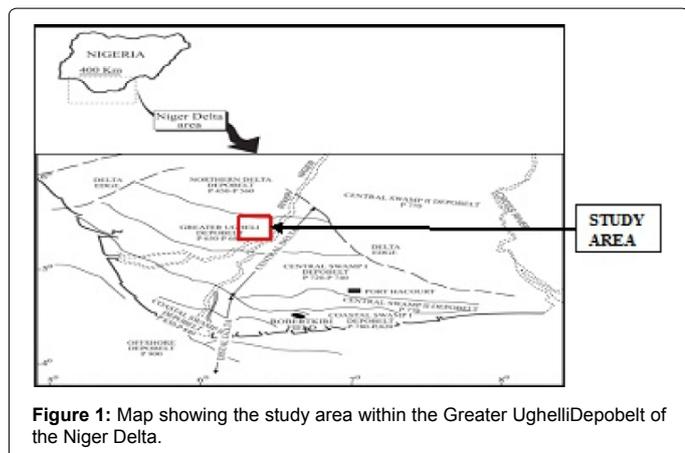
Figure 1: Map showing the study area within the Greater UghelliDepobelt of the Niger Delta.
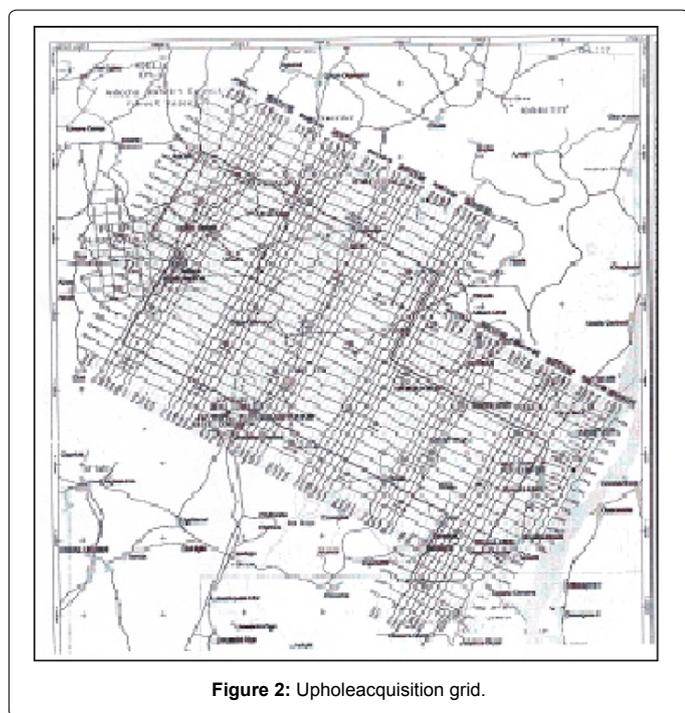

Figure 2: Upholeacquisition grid.

The formation/lithology in the prospect is predominantly of clayey to sand formation. However, at areas close to the River Niger and other large water bodies, the soil formation is sandy with large and extensive column of sand bars lining the entire length of the river bank.

Field Operations and Equipment

A total number of 37 Uphole locations in a grid specification of 4.0×3.75.km^2 were drilled and logged (Figure 2). Thirty of the Uphole locations were drilled to 66 m and logged to 60 m, five were drilled to 60 m and logged to 50 m, one drilled to 55 m and logged to 47 m while one was drilled to 50 m and logged to 40 m due to hard formation encountered at such locations. The holes were aligned to True Vertical Depth (TVD) with PVC casing immediately drilling was completed to maintain formation strength. Uphole locations UPH01, UPH02, UPH03, and UPH04 were moved to new positions as their original shot points could not be drilled due to River Niger Sand Bank while UPH22, UPH24 and UPH25–UPH33 were moved due to community, swamp and hard rock formations respectively but near the originally designed

grid. A shot hole 2.0 m deep and 2.0 m away from the recording hole was drilled to bury the charges. Drilling was by semi-manual, engine powered rotary method. Drilling mud was formulated from drilling chemicals (bentonite and EZ mud) to provide hole stability and transportation of cuttings to surface.

The 2.0 m depth shot hole was loaded with detonators varying from 1 to 10 caps down depending on the depth of the sensors and the quality of the first-breaks. The hydrophone harness was lowered into the cased hole filled with water to the required depth and properly secured to a peg to maintain stability. The following calibrated depths: 60 m, 50 m, 40 m, 30, 25 m, 20 m, 15 m, 10 m, 5 m, 3 m, 1 m, and 0 m were employed for data acquisition as described in Figure 3. Shots are fired from the blaster which provides the required voltage discharge to trigger the detonators. The blasting unit provides the field time signal simultaneously with the firing pulse to the caps. The generated signal was fed back into the recorder (GEOMETRICS STRATAVISOR NZ11) seismograph connected to the harness which records the arrival time sequence. After every successful shot, the hydrophone harness is raised to the next calibrated depth. This procedure is repeated till the last depth is logged.

Data Processing/Analysis

The Uphole survey data were processed by manually and automatically picking the first-breaks from the recorded traces. The arrival time (T_m) read from the monitor are corrected for offset and shot depths using the formula:

$$T_c = T_m * \frac{d_c}{\left(\sqrt{offset^2 + d_c^2}\right)} \tag{1}$$
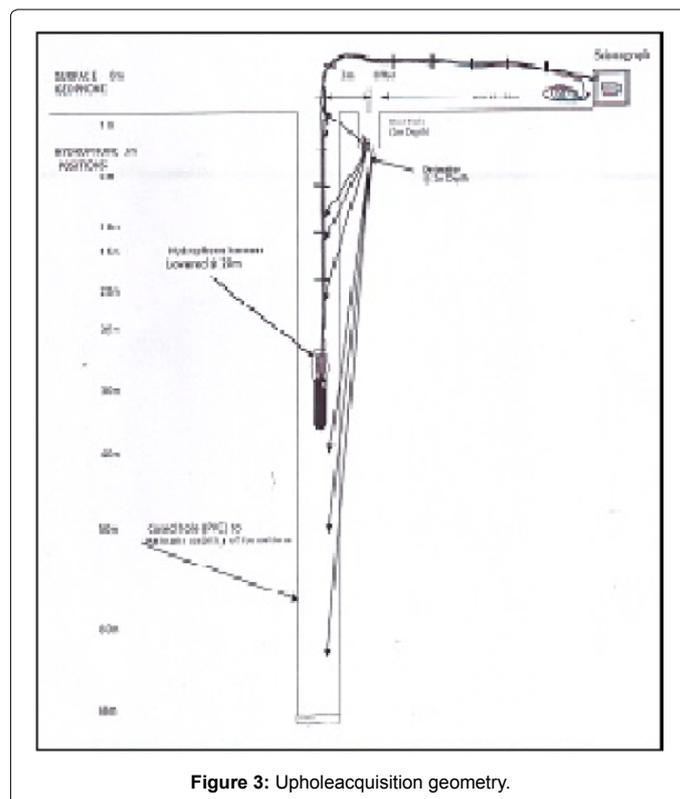
Where T_c=Offset corrected time

Figure 3: Upholeacquisition geometry.

T_m =Raw Pick Time

d_c (Corrected Depth)=Depth (receiver)–Depth (Source) (2)

The time is finally corrected or reduced to surface using:

T_s (surface corrected time)=T_c–T_c (O) (3)

Where T_c (O)=Offset corrected time at the surface

Table 1 shows a typical Raw Pick Time and the corrected Time.

The first-breaks times are plotted against depths (Figure 4) and interpreted using UDISYS Uphole data analysis software to calculate the thickness and velocity of the weathered layer and the velocity of the consolidated layer by the following equations:

i. Slopes were calculated by: $Slope = \dfrac{\Delta t}{\Delta Z}(s/m)$ (4)

ii. Velocities were computed by: $V = \dfrac{1}{slope} = \dfrac{\Delta Z}{\Delta t}(m/s)$ (5)

Where: Δt =change in time, ΔZ =change in depth

iii. Thickness, Z was deduced from the point of intersection of two layers to the depth axis.

Results

Table 2 is a summary of the interpretations of the Uphole data obtained for the near-surface within the prospect.

Figure 5 is a contour showing the various ranges of thickness of the weathered layer while Table 3 shows their positions of low and high within the prospect.

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)	7	6	5	7	10.5	13.5	16	19.5	22	27	32	37
Tc(ms)	-4.9	-2.7	2.2	5.8	10.2	13.3	15.9	19.4	21.9	27	32	37

Table 1: Typical Raw Pick and Corrected Times.

UPH No.	Elevation	Northing	Easting	Weathered Layer Thickness (m)	Velocity (m/s)	Consolidated Layer Velocity (m/s)
1	16.6	203522.8	466182.1	5.2	415	1804
2	15.3	206770.1	468058.7	4.4	237	1851
3	15.04	210017.6	459932.5	4.1	261	1987
4	15.9	213264.8	471808.4	4.7	210	1810
5	14.9	214867.3	471102.6	5	414	1660
6	15.9	211618	467161.8	4.4	341	1691
7	15.6	208367.5	465288.1	5.6	384	1728
8	15	205021	463412.6	5.5	450	1711
9	14.5	201872.3	461536.7	5.3	334	1721
10	15.6	207144	459959.6	5	425	1712
11	15.7	210391.3	461832.9	4.2	316	1463
12	17.6	213641.9	463712.5	6.8	444	1967
13	16.7	216886.9	465583.5	4.7	383	1596
14	15.5	218887.1	462120	4.7	474	1694
15	14.8	215636	460249.1	4.7	452	1737
16	13.6	212392.2	458369.7	4.3	382	1712
17	12.9	209145.6	456493.4	5	396	1801
18	19.1	211143.2	453033.4	4.2	392	1737
19	14.7	213392.4	456636.9	4.5	336	1943
20	15.3	217639.6	456781.5	4.5	570	1690
21	16.4	220888.6	458657.2	3.1	380	1895
22	16.1	222435.2	460474.1	3.7	375	1898
23	16.6	226164.4	357067.4	3.5	539	1856
24	21.8	222287.2	456231.6	4.4	303	1914
25	19.8	219840.4	452970.4	4.2	360	1689
26	17.4	215990.3	452134.9	4.5	278	1775
27	18.1	213344.4	449221.1	3.7	540	1746
28	18.3	215193.4	447517.6	3.1	381	1778
29	16.4	217792.4	449017.6	5..0	593	1726
30	20.5	220189.5	450863.4	3.8	237	1889
31	44.8	224536.7	451352.4	5.4	301	1413
32	81	229432.9	451352.8	5.1	245	1131
33	86.2	229484.9	459766.5	6.7	239	1203
34	51.6	227286.1	447571.8	6.5	311	1387
35	47.1	223900.6	446539.9	4.6	209	1429
36	43.1	220892.2	444513.5	4.5	212	1482
37	25.8	216944.4	442986.4	4	233	1804
Regional Average				4.7	360.9	1703.5

Table 2: Summary of the Interpretations of the Uphole data.
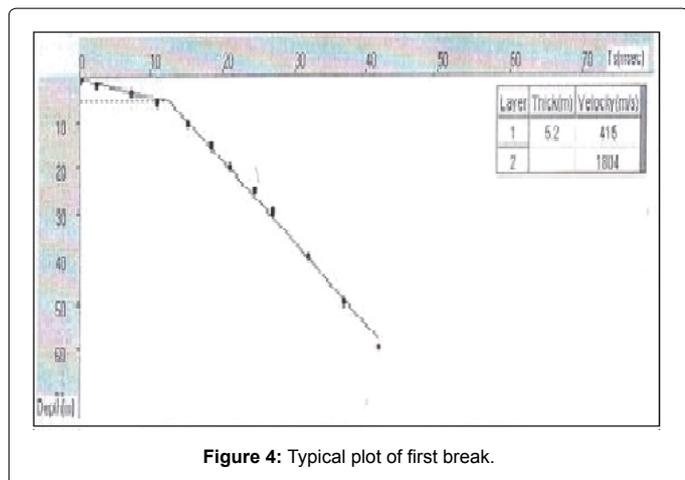
Figure 4: Typical plot of first break.

Figure 5: Contour map.

UPH No.	Elevation (M)	Northing	Easting	Weathered Layer		Consolidated Layer
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37	25.8	216944.4	442986.4	4	233	1804
Regional Average				4.7	360.9	1703.5

Table 3: Weathered Layered Thicknes Range in Different Parts.
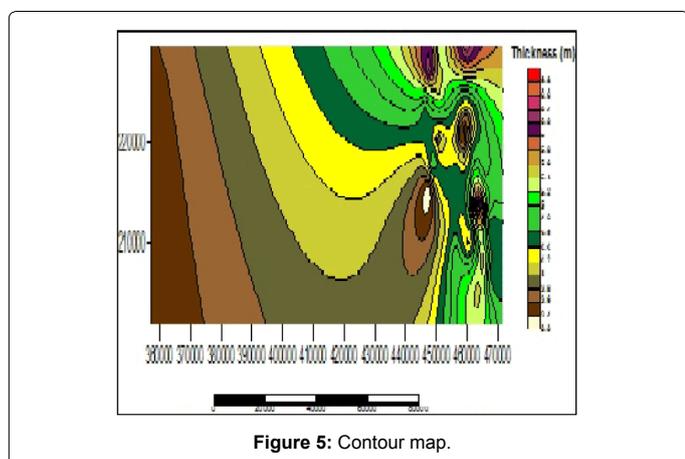
The overall result shows a dominant 1-weathered layer model within the prospect. Based on the sample density of 37 Uphole points, the weathered layer is observed to be thicker in the North-Eastern part with a value of 6.8 m, thin and thinnest in the Western and East-Central parts of the prospect with values of 3.4 m and 3.2 m respectively. The average refractor consolidated layer velocity is computed to be 1703.5 m/s. The Eastern part of the prospect falls within the areas close to the River Niger and other large water bodies, the soil formation is sandy with large and extensive columns of sand bars lining the entire length of the river bank while the entire western part of the prospect falls within the Benin formation with predominantly pebbly to coarse-grained sandstones with intercalation of shale beds. The average thickness of the weathered layer to the refractor consolidated layer is evaluated to be 4.7 m with an average weathered layer velocity of 360.9 m/s.

Conclusion and Recommendation

The varying weathered layer thickness of the different parts of the prospect suggests that, where possible as according to Alaminiokuma and Ogagarue, 2013 [8], Pattern-shot types should be located at depths of about 7.0 m in the North-Eastern part, 5.5 m South-Eastern part and 3.5 m in the Western and East-Central parts below the weathered layer where signals travel at velocities devoid of time delays during 3D/4D seismic surveys in this area. This has the advantage of ground roll cancellation of (surface noise) during acquisition thereby focussing all the seismic energy in the vertical direction and by-passing thus minimizing the spurious effects of the low velocity weathered layer during acquisition and initial processing of field data.

The presence of large and extensive column of sand bars lining the entire length of the river bank and flooded plains observed within the area around the River Niger accounts for the relatively low velocities profile in the eastern part of the survey area. The varying low weathered layer thicknesses observed within the vicinity of the River Niger sand bank in the north-eastern through the south-eastern east-central portions indicate the presence of loose unconsolidated and aerated soil materials which may lead to high absorption of seismic energy. This general variation in the thickness of the weathered layer may, if not considered, lead to false indications of significant structural features.

It is therefore recommended that further research be conducted with more integrated data control points (Uphole and LVL Refraction data) to draw a conclusion on the near-surface structural properties.

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