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THE VELOCITY - THICKNESS CHARACTERISTICS OF THE MANGROVE SWAMP LOW VELOCITY LAYER (LVL), SOUTH CENTRAL NIGER DELTA, NIGERIA.

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ABSTRACT

A total of 14 upholes were shot in the Mangrove Swamp of the Niger Delta of Nigeria. The aim of the survey was to determine the thickness and velocity of the low velocity layer (LVL). The velocities and thickness of the layers were computed from the reciprocals of the slopes of the straight-line segments using the FACE Static computer program. Results obtained showed a variation in the thickness of the weathering layer from 2.0m to 5.7m with an average of 3.40m. The variation was random and did not show any trend. The velocity of the low velocity layer ranges between 295ms^{-1} and 727ms^{-1} with an average of 562.7 ms^{-1} while the velocity of the sub-weathering layer ranges between 1502 ms^{-1} and 1918 ms^{-1} with an average of 1716 ms^{-1}. These data are important in seismic static corrections and in geotechnical engineering.

Key words: Thickness, Velocity, Low velocity layer, Uphole

Introduction

A low velocity layer survey was carried in the mangrove area of the Niger Delta to determine the thickness and velocity of the LVL and also the velocity regime of the underlying bed. The study area is bounded by longitudes 6° 55′ E and 7° 14′ E and latitudes 4° 29′ and 4° 57′ N. This is equivalent to about 2000 km^2 land area (Figure 1). The importance of weathering layer and subweathering layer velocities and thickness of the weathering layer in static corrections and in the mapping of the deep structures has been highlighted by Uko et al (992), Osho and Adetola (1998) and Cordsen (2000). Direct waves from LVL interfere with amplitude and phase artifacts in 3-D surveys, causing deleterious effects on the acquired data. Hence the need to determine these parameters accurately in order to apply the necessary corrections in all seismic surveys.

Geology of the Niger Delta

The three main sedimentary formations making up the modern Niger Delta are the Benin, Agbada and Akata Formations representing the topset, delta slope, and the prodelta clay of a typical delta model respectively. The stratigraphy and paleontology of the Niger Delta have been examined in details by Reyment (1965), Short and Stauble (1967), Aseez (1976), Merki (1970).

The Benin Formation is a sequence of over 90% sand and contains only a few shale intercalation. The sand and sandstones are coarse to fine grained, poorly sorted, subangular to well rounded and bear lignite streaks. The thickness of the formation varies from very thin at its present day depositional limits to about 200 – 4000 m (Short and Stauble, 1967)

The Agbada Formation occurs in the subsurface of the entire delta area and may be continuous with the Ogwashi – Asaba and Ameki Formations. It is a paralic sequence divisible into upper and lower units. The upper unit consists predominantly of sandstones with minor shale intercalations while the lower unit is composed mostly of shales. The average thickness of the formation is about 400 m.

The lowermost unit of the Niger Delta sequence, the Akata Formation, is a uniform marine shale unit but contains sandy and silty bars, which are thought to have been laid down as turbidities and continental slope channel fills. The thickness of the formation ranges between 700 and 7000 m (Merki, 1970).

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Table 1. A Summary of Uphole Results of the Mangrove Swamp

Uphole No.	Location		Elevation	Thickness (m)	Velocity (m/s)	
	Easting	Northing	(m)	Layer 1	Layer 1	Layer 2
B01	491225.3	69754.3	0.20	4.3	295	1504
B02	494725.0	70355.3	0.30	4.7	443	1502
B03	491224.3	73952.2	0.10	4.3	443	1502
B04	495724.8	73955.5	0.20	2.6	442	1567
B05	490245.6	77330.2	0.40	5.7	657	1756
B06	490249.2	81730.1	0.30	4.0	538	1918
B07	490726.8	85952.3	-0.50	2.0	544	1505
B08	493736.7	85954.3	-0.10	5.2	636	1800
B09	495724.7	84754.2	-0.10	2.4	457	1794
B10	494737.5	83556.3	-1.50	2.0	727	1873
B11	496225.1	83554.2	0.20	2.0	863	1889
B12	494727.7	81154.8	-0.10	3.0	765	1893
B13	495228.7	78153.3	0.10	2.0	719	1691
B14	495724.8	73995.5	0.30	3.5	349	1833
Average			-0.06	3.4	562.7	1716

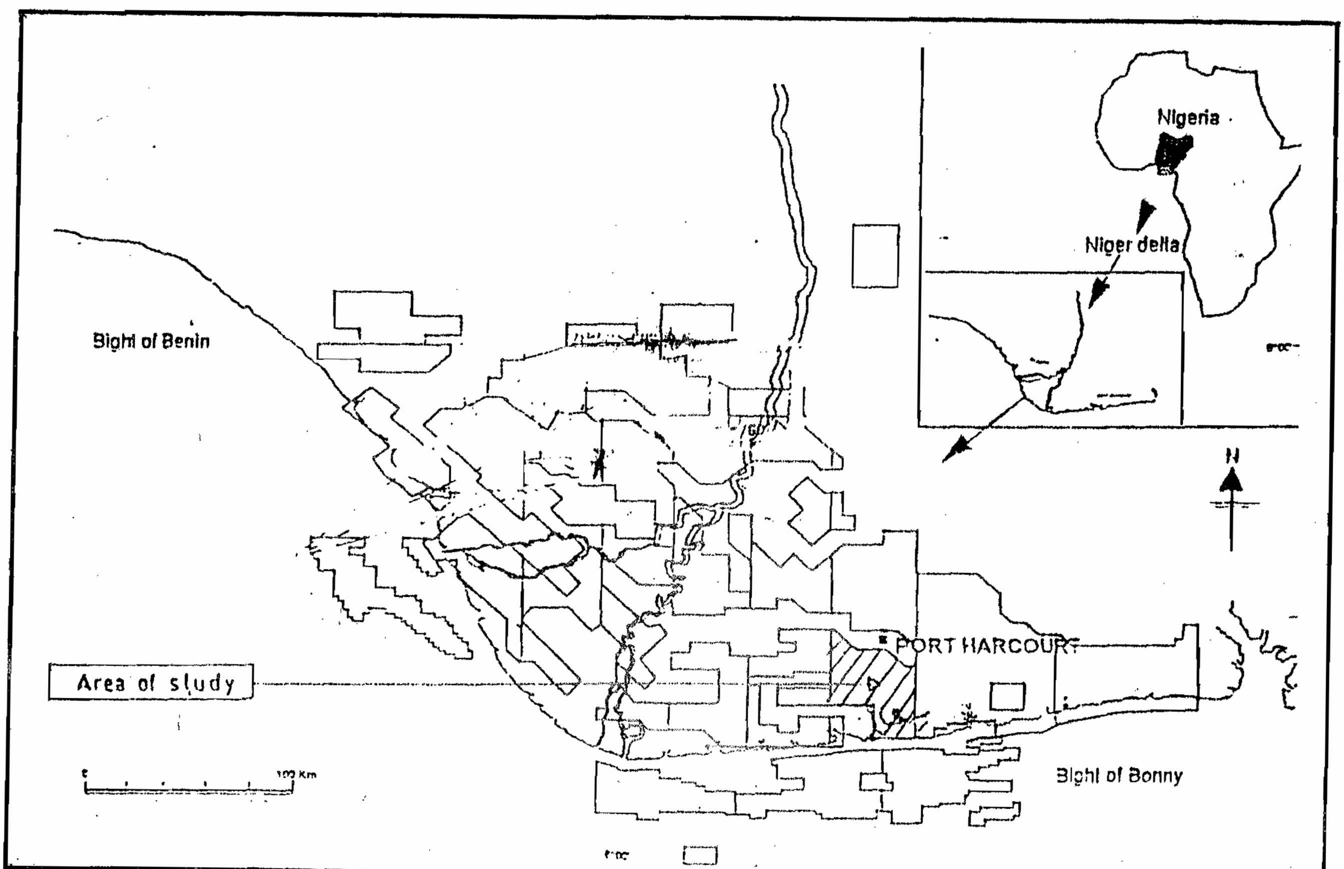

Figure 1. Map of the Niger Delta showing the study area

The topsoil of the mangrove swamp area consists of black muddy clays frequently submerged in the waters of the periodic high tides. Lithologic logs obtained from uphole drillings during this study reveal that the clays continue to an average depth of about 15 m. Beyond this depth to the 60 m maximum depth of the uphole drillings, the clay is underlain by white fine sand, which grade gradually into gravely sand.

Theory

The basic uphole survey consists of firing some shots at different depths in a hole and receiving the generated seismic energy at a fixed distance on the surface. The time taken by the direct waves and the head waves to travel directly to the receiver or to the refracting interface and back to the receiver along the interface can be used to calculate the velocity and thickness of the low velocity layer and the thickness of the underlying infinite layer. In the uphole survey the seismic wave energy reaching the receivers are those traveling through a slant path after they have been partially refracted.

The direct wave, will begin to interfere with primary reflection events at an offset X_{direc} and moveout time t_{NMO} where

$$X_{direct} = V_{VLV} \times ((T_{nmo} + t_{mute}) \quad (1)$$

and

$$(T_{nmo} = t^2 + X_{direct}^2/V^2)^{½} \quad (2)$$

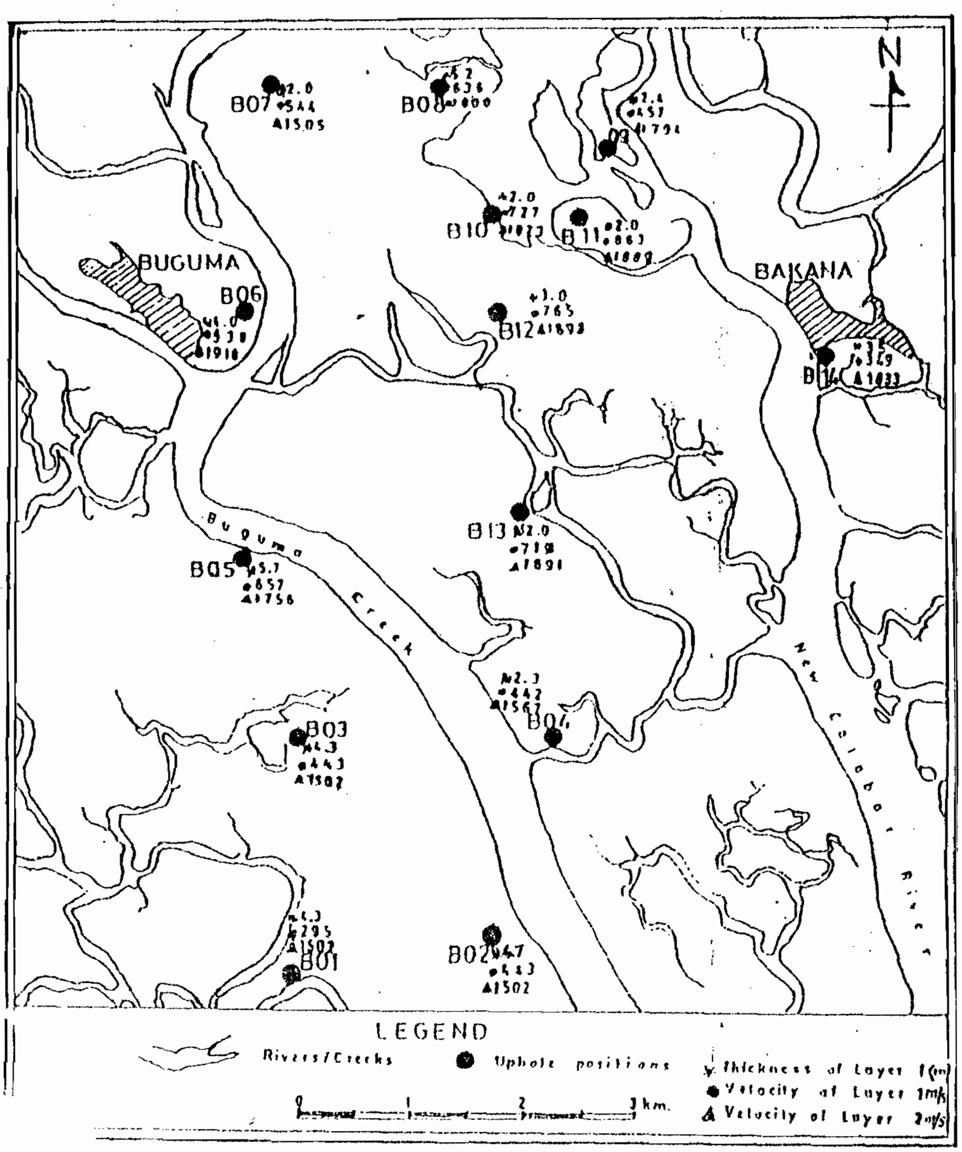

Figure 2. Uphole location map

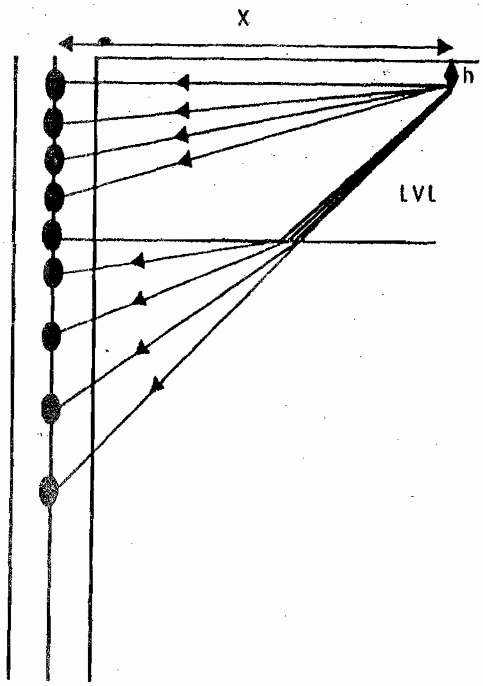

Figure 3. A sketch of the uphole arrangement

where V_{LVL} is the velocity of the material between source and receiver, V is the root-mean-square velocity to the primary event (target), t is the travel time and t_{mute} is a small mute zone that is effectively the width of the direct arrival wave interference.

Method

A total of 14 uphole locations were recorded (Figure 2). The holes were each 60m deep while the source depth was 1.5m. The source consisted of detonators only. The downhole tool is a 24-channel hydrophone cable. The first six receivers from the ground surface were placed at intervals of 1m and the rest at 3m intervals (Figure 3). The closer receiver spacing near the surface was to ensure that the velocity of the weathering layer was adequately recorded for accurate velocity and thickness calculations. The recording unit was OYO seismograph. Figure 4 is a typical uphole monitor from the Mangrove Swamp area.

For a source depth of 1.5 m, an offset of 5 m and a source depth of 1.5 m, the vertical velocity t_v, corrected for the source depth is

$$t_v = \frac{t_s(h-1.5)}{\left(\left(\frac{5h-7.5}{h}\right)^2 + (h-1.5)^2\right)^{1/2}} \quad (3)$$

where h is the respective receiver depths.

The velocities of the layers were computed automatically from the reciprocals of the slopes of the straight-line segments. The thicknesses were computed automatically from the FACE program based on the thickness equation

$$Z = \frac{t_i V_1 V_2}{\left(V_2^2 - V_1^2\right)^{1/2}} \quad (4)$$

where Z = vertical thickness, V_1 and V_2 = velocity of the weathering and subweathering layers respectively, t_i = intercept time

A Representative time-depth plot and the lithologic logs are shown in Figure 5. The FACE Statics Package, used in the processing and interpreting of these data is a collection of computer utility programmes for evaluating uphole and refraction data, and is used in computing the field static values for each station. The weathering geometry/trace sort option of the package was used to assign uphole shooting geometry to header, sort the data traces and create the Green Mountain database files so that screen aided picking could be used when required, to select the first beak times.

Results
Table 1 is a summary of the results.

The weathered layer consists of clay, which extends into the underlying layer by as much as 20.00m in some cases as shown in the lithologic log. The clay is always underlain by fine-grained sand, which shows a downward coarsening in some places.

Within the swamp area the velocity of the weathering layer shows a very significant variation ranging from 295.00ms^{-1} to as much as 863.00ms^{-1}. The average velocity of the weathering layer from the fourteen measurements is 563.00ms^{-1}. The underlying layer velocity ranges from 1502.00ms^{-1} to 1983.00ms^{-1} with an average value of 1716ms^{-1} for the fourteen measurements. The elevation values shows that the mangrove area is a low-lying area sometimes below mean sea level. This low elevation may have accounted for the very low

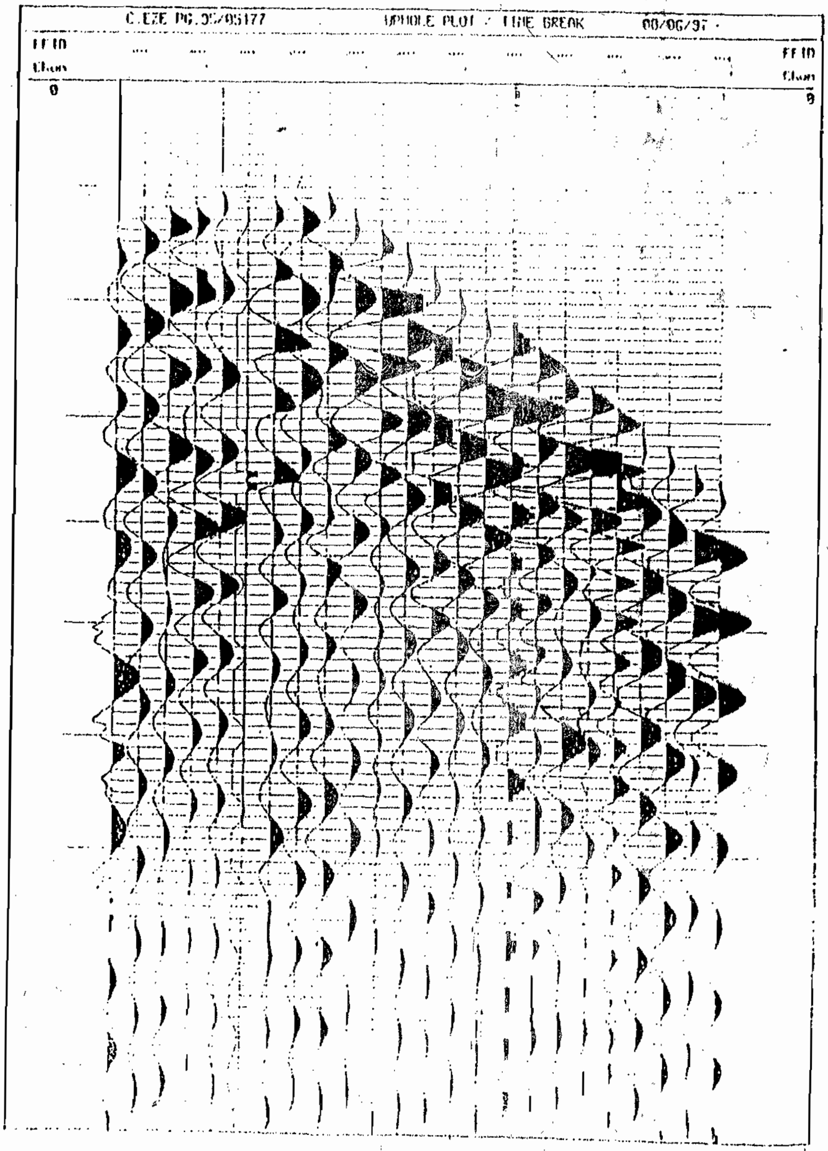

Figure 4. A typical uphole monitor from the study area

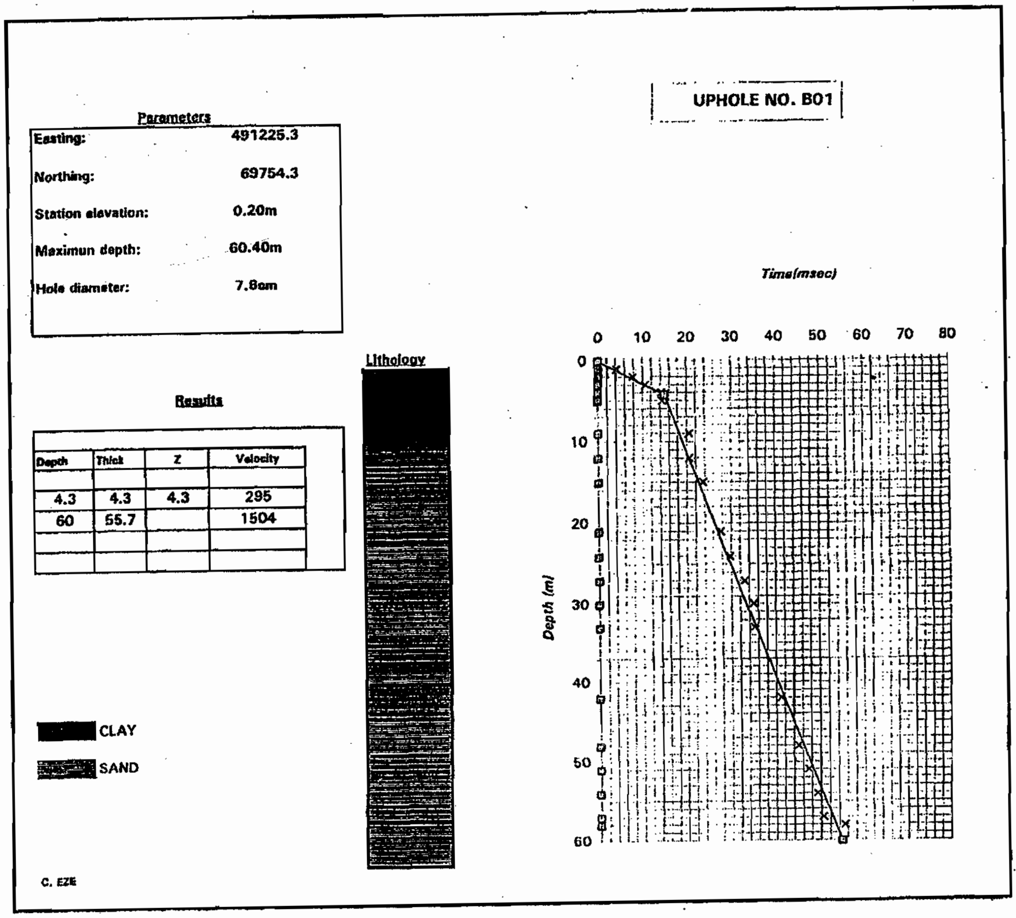

Figure 5. A typical depth-time graph from the study area

average LVL thickness of 3.4m compared to an average of 20.0m reported by Uko, et al (1992) from the east-central part of the same Niger Delta.

Conclusions

The interpreted data show a significant variation in the weathered velocity and thickness in the area, varying between 2.0m and 5.7m and between and 295.0ms^{-1} and 863.0ms^{-1} respectively. These results explain the necessity for consistent and accurate static correction of seismic reflected data in the area. There are indications of lateral variations in velocity and thickness of the weathering layer. A more detailed survey will be required to determine the direction of the variation.

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