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APPLICATION OF THE UPHOLE SEISMIC DATA IN THE DETERMINATION OF THE WEATHERED LAYER PROFILE IN EAST-CENTRAL NIGER DELTA NIGERIA

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ABSTRACT

A total of 10 uphole data was acquired and analyzed from a seismic prospecting area of the East-Central Niger Delta, Nigeria. The thickness and velocity of the low velocity layer (LVL) was determined. Refraction statics was computed automatically from first break picks using CGG's SDITR interactive programme. The seismic data section with and without static correction were discussed. Normal move out correction was applied to the data collected using CGG's automated VELCOM programme. An interpretation of the data, carried out using the time-depth plots, shows that the thickness of the low velocity weathered layer is variable between 3.0m to 20.5m with an average of 6.7m. The velocity of the weathering layer ranges between 482m/s and 1147m/s with an average of 836.2m/s, while the velocity of the sub-weathering layer varies between 1601m/s and 1832m/s with an average of 1701.3. The knowledge of this weathering structure can be applied in oil and ground water exploration. Also this structure could be used by groups interested in civil engineering.

KEYWORDS: Low velocity layer, uphole, statics correction, normal move out correction, seismic refraction.

INTRODUCTION

A low velocity layer computation, refraction statics and normal move out correction was carried out with seismic data from a seismic prospecting area of the Niger Delta, Nigeria. The study area (Figure 1) is the Imo River 4D prospect in Niger Delta, it lies between latitude 04° 55' 17" and 05° 02' 53" and longitude 07° 03' 11" and 07° 14' 20". The importance of the weathering layer and sub-weathering layer velocities and thickness of the weathering layer in static and normal move out corrections has been highlighted by Uko et al (1992), Adam and Milkereit (1997), Osho and Adetola (1998), Eze et al (2003) and Enikanselu (2008). The need for the determination of these parameters and corrections is necessary in order to remove additional, unwanted and variable time delays present in the recorded data, which can distort the geologic structure picture and degrade the quality of the stacked seismic section and to obtain a high-resolution section which can be used for stratigraphic interpretation (Marsden, 1993).

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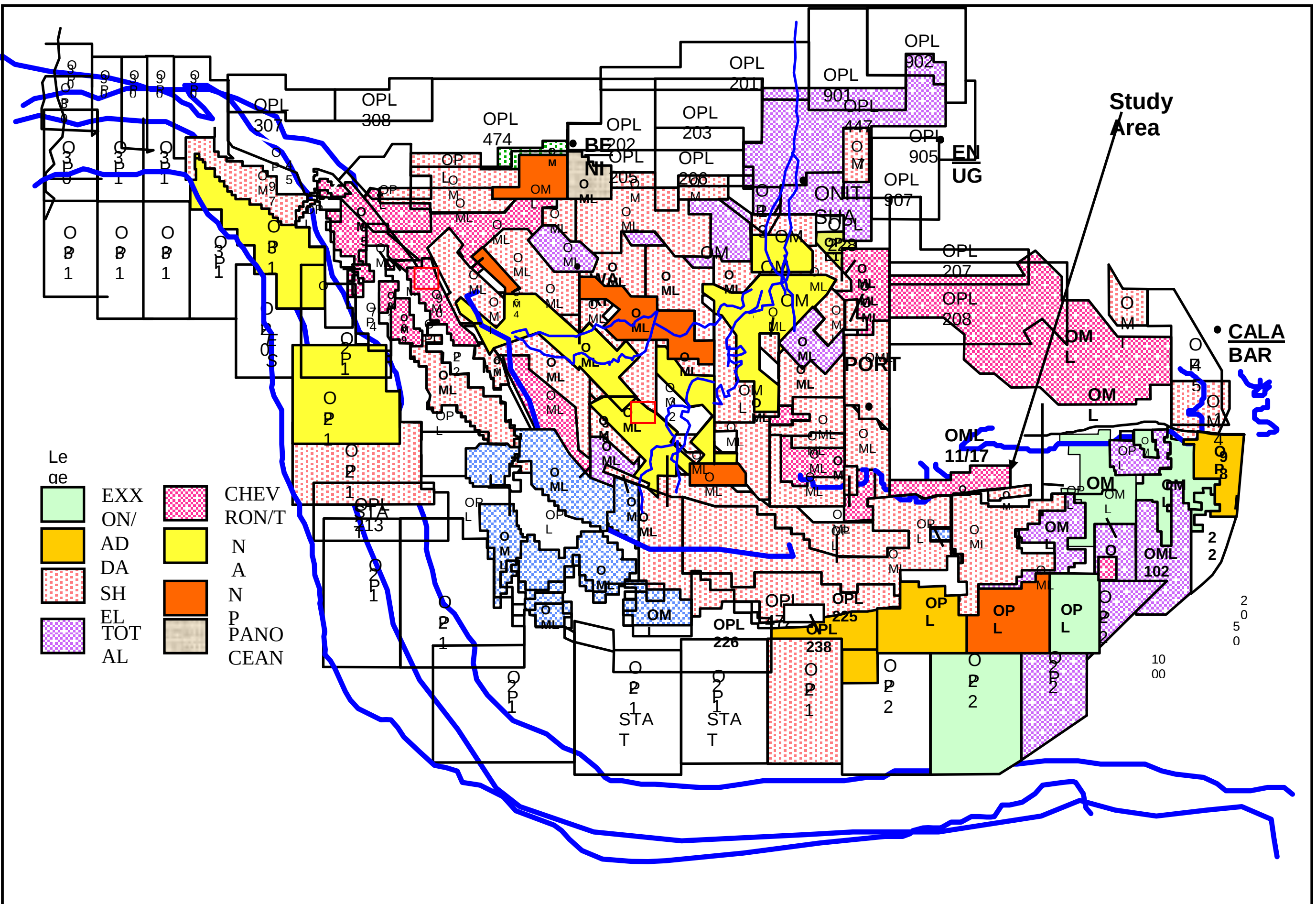

Fig. 1: OML Map Showing the Study Area.

GEOLOGY OF THE NIGER DELTA

The Niger Delta extends from the Benin flank in the west to the Calabar flank in the East, a distance of about 350km, and from Apex of the Delta at Abo to the Coastline, which is about 150km. The Niger Delta is located between the longitude $4^{o} – 9^{o}$ E and latitude $4^{o} – 6^{o}$ N. Sedimentological and faunal data suggest that the modern Niger Delta has a configuration similar to that of a typical delta model. Three major sedimentary formations make up the present day Niger Delta. These are the Benin, the Agbada and the Akata formations. The geology of Niger Delta has been described by many investigators (Reyment, 1965; Short and Stauble, 1967).

The Benin formation consists of coarse-grained, poorly sorted, sub-angular to well rounded and bear lignite streaks. It is over 90% sandstone with shale intercalations. It is a continental deposit of upper deltaic depositional environment. Hematite and Fieldspars are common (Able white, 1985). Typical outcrops of the Benin formation can be seen around Benin, Onitsha and Owerri (Uko et al, 1992). The thickness of the formation varies from very thin at its present day depositional limits of about 200 – 4000m (Short and Stauable, 1967). The Agbada formation overlies the Akata and consists of alternations of sands, sandstones and siltstones.

The Agbada sands constitute the main hydrocarbon reservoirs of the Delta (Able White, 1985). The thickness of the formation varies significantly but the average thickness is more than 400m. It is the time equivalent of the Ogwashi-Asaba-Ameki formation further north.

The Akata formation is the lowest unit of the Niger Delta sequence. It is composed of marine shales with local sandy and silty beds thought to have been laid down as turbidities and continental slope channels fills. The age of the Akata formation ranges from the Oligocene to recent (Reyment, 1965; Kogbe, 1976). Its thickness varies from 576m to about 6060m.

THEORY

The uphole survey provides the most direct measure of the thickness and vertical velocity of the weathered layer. This consists of drilling a hole and firing charges separately at different depths in the hole and receiving the seismic energy at a fixed distance on the surface. The arrival times and charges depths are plotted. The slope of the first line yields the velocity of the weathered layer, the slope of the second line yields the velocity of the sub-weathered layer. The point of the velocity break yields the thickness of the layer.

Refraction Statics: Correction for the weathered layer is done using the first breaks of a certain shot (refracted energy), a model can be constructed for the weathered layer (velocities and depth). Refraction interpretation based on generalized linear inversion (Hampson and Russell, 1984) is adopted in this approach, an input model is designed and theoretical first-break travel times are computed. The model is then perturbed iteratively until the computed and observed traveltimes match according to some squared error criterion.

Normal Moveout (NMO), is the difference between the two-way time at a given offset and the two-way zero offset time. The reflections are aligned using the correct velocity, such that the events are horizontally. Then all the separate traces are stacked (summed). The travel time curve of the reflections for different offset between source and receiver is calculated using.

$$t_x^2 = t_0^2 + \frac{X^2}{V^2} \qquad (1)$$

From this formula the NMO – correction can be derived and is given by

$$\Delta t_{NMO} = t_x - t_0 \qquad (2)$$

But $$t_x = \left[\left(t_0^2 + \frac{X^2}{V^2}\right)\right]^{1/2} \qquad (3)$$

Where x is the offset between the source and receiver positions, v is the velocity of the medium above the reflecting surface, and $t_o$is the reflection time at offset (o), t(x) is the reflection time at offset (x).
The NMO – correction is also called a Dynamic correction.

MATERIALS AND METHODS

Ten (10) uphole data comprising the shot points, Geophone position and measured time Tm (Raw pick time) from the area was acquired from CGG with permission from Shell Petroleum Development Company, Eastern Division. The data were accessed and worked on to obtain Offset correction time (Tc), Surface corrected time (Ts), to achieve this, the following corrections were applied to the raw data.

(i) Corrected depth (Dc) = Depth (receiver) – Depth (source)

(ii) Offset corrected time (Tc) = Tm *(Dc/Offset^2 + Dc^2)^{½}

(iii) Surface corrected time (Ts) = Tc – Tc (o)
Where Tc (o) = Offset corrected time at the surface.

Travel time curves were plotted with the data collected. The velocity of the low velocity layer (LVL), v_1 and the sub-weathered velocity V_2 were computed using the slope method. The calculation of the thickness was based on the equation given by Dobrin, 1976.

$$Z = \frac{t_1 V_1 V_2}{(V_2^2 - V_1^2)^{1/2}} \qquad (4)$$

Where Z = Vertical thickness, V_1 and V_2 = Velocity of the weathering and sub-weathering layers respectively, ti – intercept time.

The refraction statics was computed automatically from first break picks using CGG's SDITR interactive programme. The first step of this sequence was the computation of field statics, from ground surface to the datum plane, depending on the elevation, the shot depth, the thickness and the Velocity of the weathering layer, and the replacement Velocity. Tests were performed to determine the Velocity of the refractor and its offset range. Finally, LMO corrected data were input in CGG's interactive application SDITR, to compute on a swath basis the refraction statics.

Normal move out correction was applied to the data collected using CGG's automated VELCOM Programme. The correct stacking velocities were determined using Constant Velocity Stack (CVS) method. In the CMP gather it is assumed that the RMS Velocity has a constant specified value throughout the raypath (McQuillin, 1984). The RMS Velocity was applied to the CMP gather to correct for NMO. Stacking Velocities were picked directly from Constant – Velocity Stack (CVS) panel by choosing the Velocity that yields the best stack response at a selected event time. The velocity analysis were done at regular but widely separated intervals along the seismic reflection line to ensure that the stacking is undertaken properly.

RESULTS AND DISCUSSION

Table 1 is a summary of the uphole result. The results obtained showed that the thickness of the low velocity weathered layer is variable from 3.0m to 20.5m with an average of 6.7m. This indicates the necessity of correcting for this layer during seismic reflection exploration. The velocity of the low velocity layer ranges between 482m/s and 1147m/s with an average of 836.2m/s. While the Velocity of the sub-weathering layer ranges between 1601m/s and 1832m/s with an average of 1701.3m/s. These marginal variations in these near surface seismic velocity is indicative of the high degree of homogeneity of the layer and underscores the possibility of a smooth statics behaviour in case of any seismic reflection data likely to be acquired in the study area.

A representative time-depth plot obtained at one of the survey lines is shown in Figure 2. The travel times were used to calculate both the thickness and the velocity of the underlying layer.

Figure 3, is traces showing first break picking. The program automatically picks the best events of the section, in a given window. The picking is made on given numbers of cross-lines and in-lines. Reliable picking was ensured by applying linear move out (LMO) to the data. Once picking is done, the LMO correction is reversed. The first break picks associated with the refracted and arrival times are then used in an inversion scheme to estimate the near surface parameters.

Figure 4, is a test in-line with and without refraction statics, it shows there is much improvement on the quality of the seismic section and general time – shift on the data after statics application compared to the section without statics. Also the section with statics is more aligned, strong and continuous especially from 1200ms to 2200ms portion of the seismic section. Figure 5, is the Velcom gather before NMO correction. Figure 6, is the Velcom gather after NMO correction. The alignment of reflections indicate that a good velocity analysis was done and that stacking velocities used were good. Here, the event flattens as the velocity increases with depth.

TABLE 1: A SUMMARY OF UPHOLE RESULTS

UPHOLE	**LOCATION**		**ELEVATION (M)**	**TS (MS)**		
NO				**Thickness (m)**	**Velocity (m/s)**	
	Easting	**Northing**		**Layer 1**	**Layer 1**	**Layer2**
Line 1	**499549.7**	**54855.2**	**0.92**	**3.8**	**1147**	**1657**
2	**500127.2**	**60033.5**	**1.22**	**11.3**	**482**	**1748**
3	**497449.5**	**64855.0**	**1.94**	**5.2**	**819**	**1720**
4	**499549.9**	**68354.9**	**1.28**	**4.3**	**927**	**1693**
5	**493947.2**	**56355.4**	**1.64**	**5.7**	**933**	**1754**
6	**494298.5**	**61355.7**	**1.44**	**3.5**	**977**	**1693**
7	**493897.9**	**65356.0**	**1.62**	**3.0**	**637**	**1601**
8	**489048.8**	**54855.0**	**1.70**	**4.6**	**870**	**1634**
9	**490799.4**	**59853.3**	**1.05**	**4.6**	**870**	**1681**
10	**490799.6**	**64654.4**	**1.40**	**20.5**	**700**	**1832**
Average				6.7	836.2	1701.3

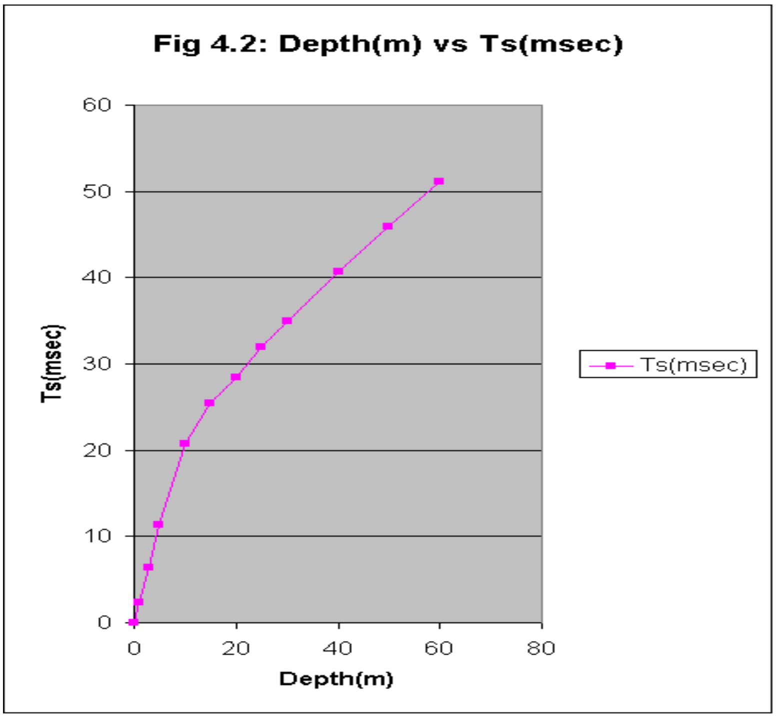

Fig. 2: Depth (m) vsTs (msec)

Layer	**Thick(m)**	**Velocity(m/s)**
1	**11.3**	**482**
2		**1748**

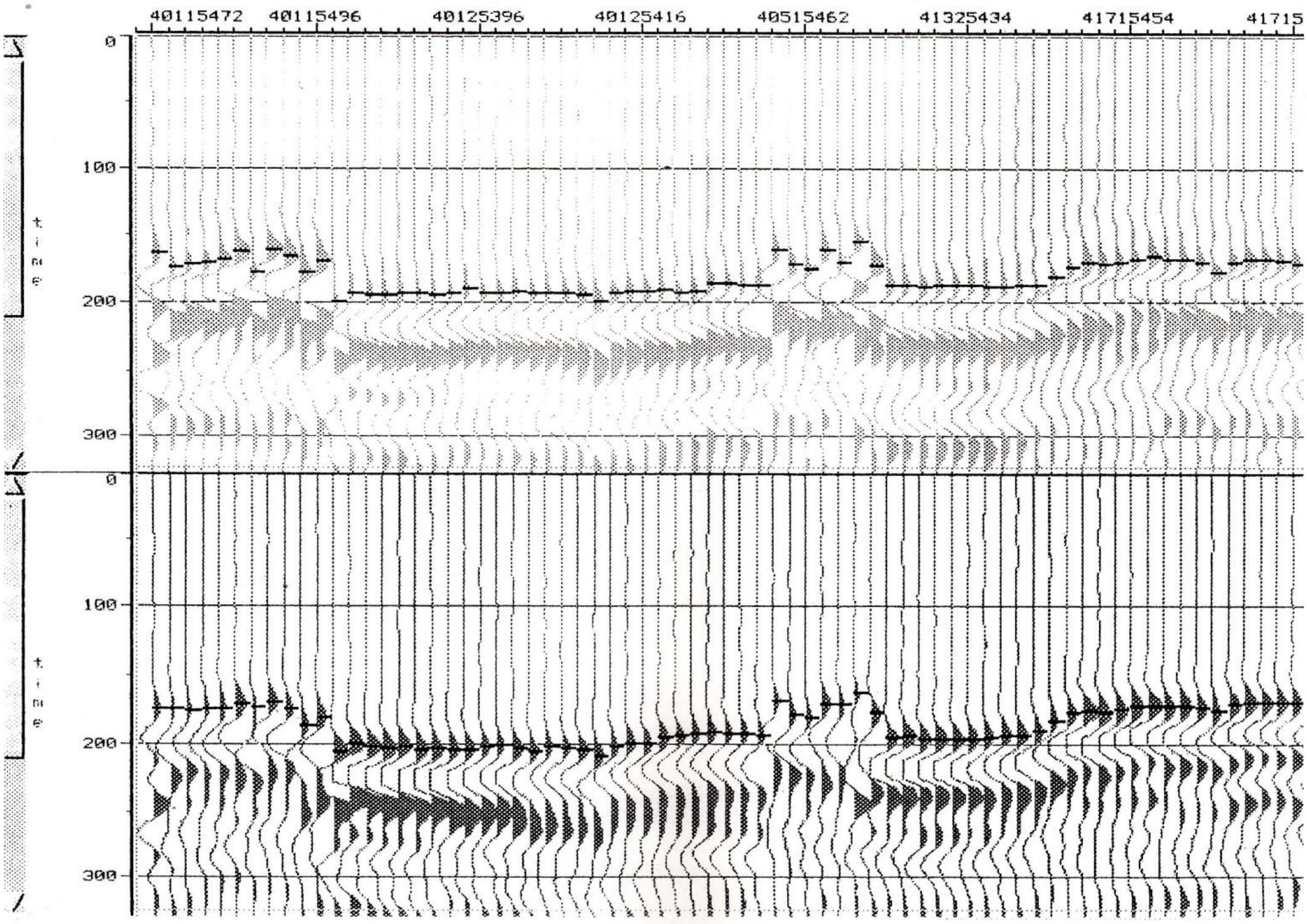

Fig.3. Traces showing first break picking.

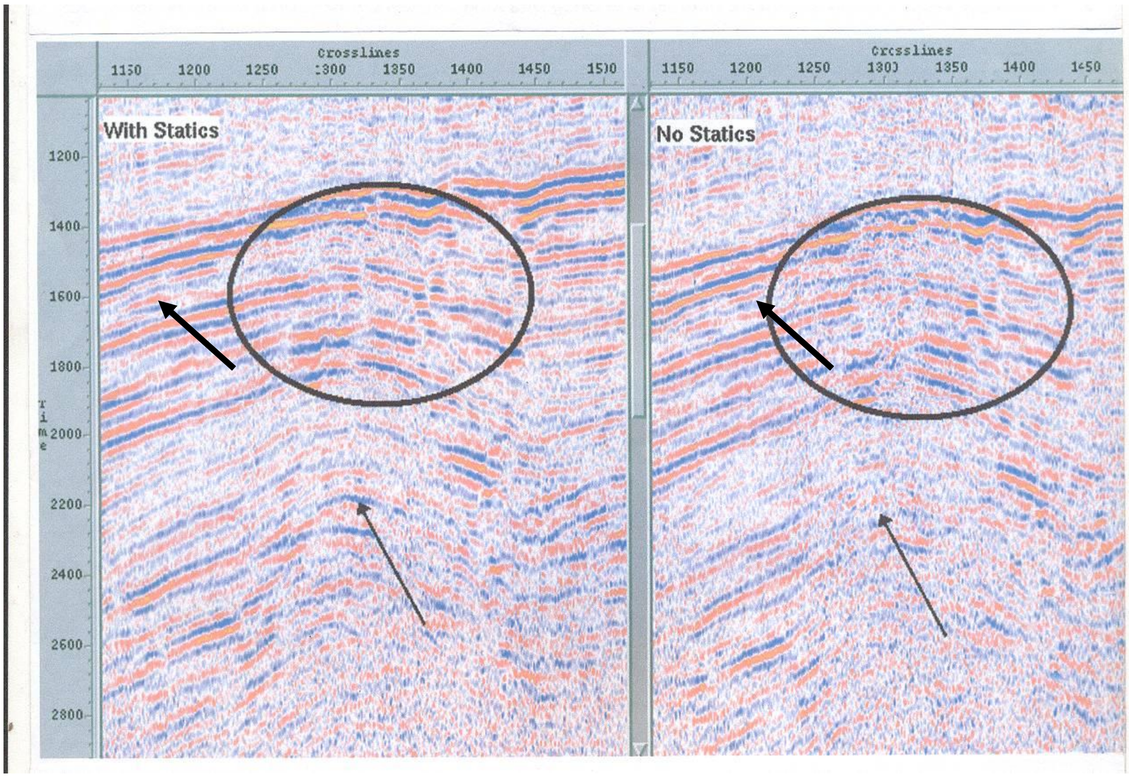

Fig. 4. ATEST IN-INLINE WITH AND WITHOUT REFRACTION STATIC
Note better event continuity in the marked area and general time-shift on the data after statics application.

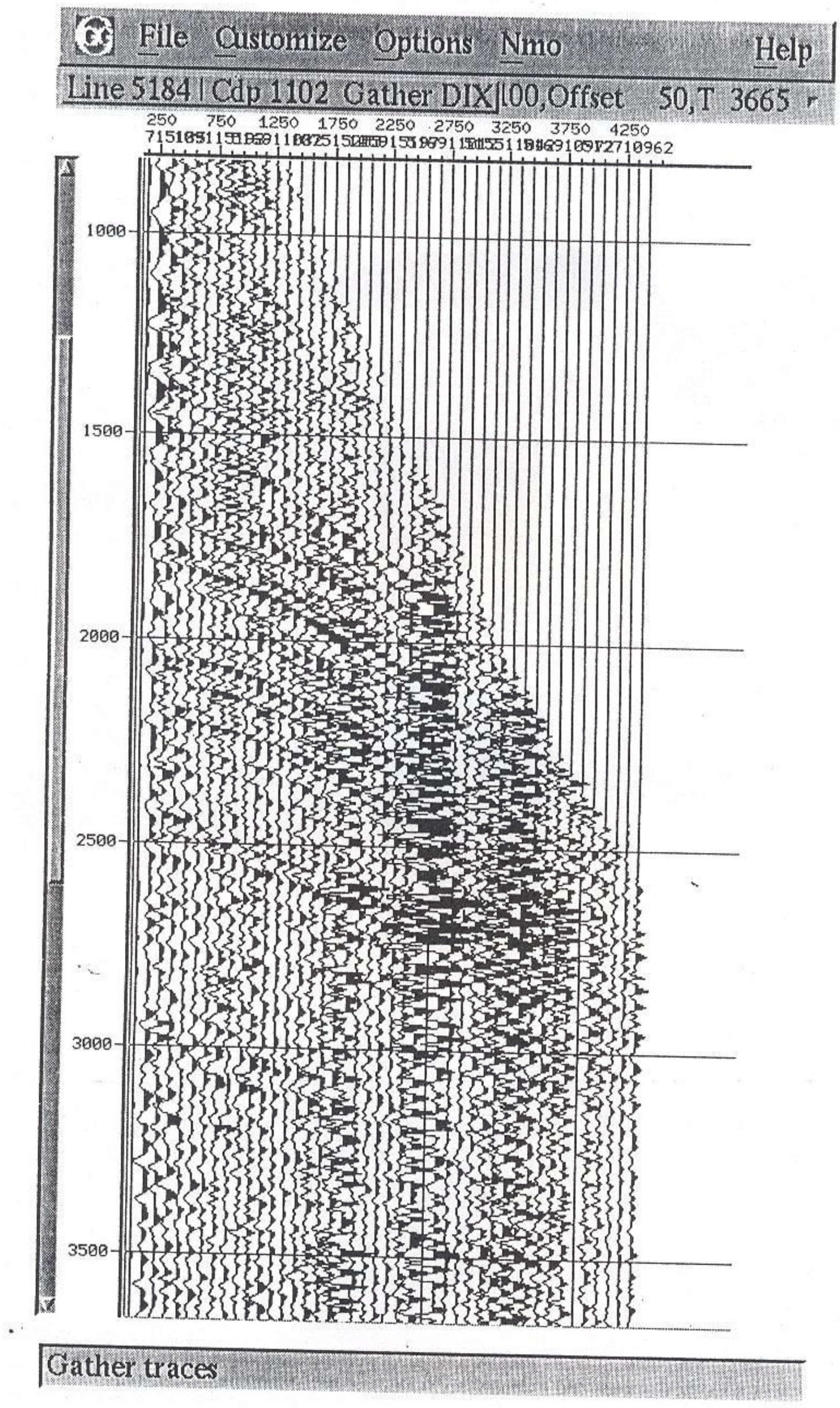

Fig. 5. Velcom gather b/f NMO correction

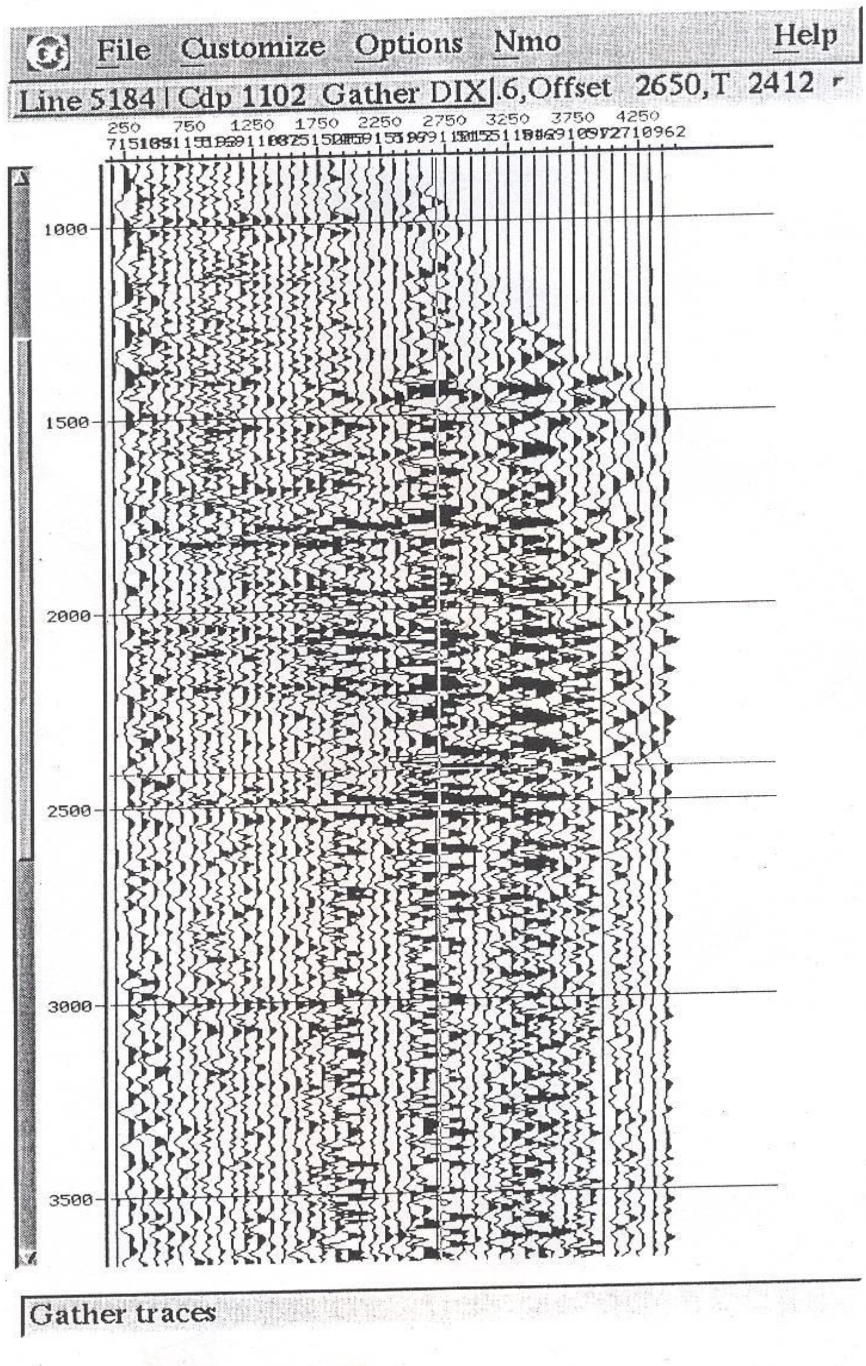

Fig. 6. Velcom gather after NMO correction

CONCLUSION

From the results, it can be seen that the weathering thickness, weathering Velocity and sub-weathering Velocity vary greatly in the study area. The thickness varies from 3.0m to 20.5m and the weathering Velocity varies from 482m/s to 1147m/s. While the Velocity of the sub-weathering layer ranges between 1601m/s and 1832m/s, this result agrees with earlier findings by Uko et al (1992), Eze et al (2003), Telford et al (1976), Coffen (1986) and Enikanselu(2008). The information obtained from this study is extremely important in the determination of time delays needed for static corrections during seismic reflection data processing. This is because of the need to know the depth of the base of weathering layer before a seismic reflection survey, which helps to locate the energy source at appropriate depth so as to reduce the ground roll that will interfere with the seismic reflection data. Besides that, the energy transmitted into surface can be maximized by placing the source below the weathered layer. The need for static correction also leads to improved quality and subsequent processing steps, which in turn, impact the integrity, quality and resolution of the imaged section as seen in this work.

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REFERENCES

Ablewhite, P., (Ed), 1985. Outline of Niger Delta geology. Well Evaluation Conference, Nigeria. 51 – 55.

Adam, E and Milkereit, B., 1997. A fast method for accurately determining 3 – D refraction static corrections. Geophysics, Soc. Of Expl. Geophysics. 65, 1890 – 1189.

Coffen, J. A., 1986. Seismic Exploration Fundamentals; Pennwell Books, Tulsa, Ok. 235.

Dobrin, M. B., 1976. Introduction to geophysical prospecting McGraw-Hill Book Co.

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. 9, (2): 537-545.

Eze, C. L., Okwueze, E. E., Uko, E. D., 2003. The Velocity thickness characteristics of the Mangrove Swamp LVL, South Central Niger Delta *Nigeria Global Journal* 9, 369 – 374.

Hampson, D and Russel, B., 1984. First break interpretation using generalized linear inversion: J. Can. Soc. Expl. Geophys., 20 No. 01, 40 – 54.

Marsden, D., 1993. Static Corrections – a review, Part 1. The Leading Edge 12, 43 – 49.

McQuillin, R. Becon, M. Barclay., 1984. An Introduction to Seismic Interpretation. Graham and Trotman, London. 372.

Reyment, R. A., 1965. Aspect of the Geology of Nigeria: IbadanUniversity Press, Ibadan, Nigeria. 125

Short, K. C and Stauble, A. J., 1967. Outline of Geology of NigeriaDelta. AAPG Bulletin 51, 761 – 779.

Telford, W. M., Geldart, L. P., Sheriff, P. E and Keys, D. A., 1978. Applied Geophysics, CambridgeUniversity Press, London. 472.

Uko, E. D., Ekine, A. S., Ebeniro, J. O and Ofoegbu, C. O., 1992. Weathering Structure of the East – Central Niger Delta, Nigeria: *Geophysics* 57, 1228 – 1233.

Osho, O.O and Adetola, B. A., 1998. Effects of Statics in the ChadBasin. Book of abstract, Nigerian Association of Petroleum Explorationist 16th Annual International Conference.