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SHEAR COMPRESIONAL WAVE VELOCITY MODEL FOR OML 29 IN THE NIGER DELTA

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ABSTRACT

A study of shear compressional velocity was carried out in OML 29 of the Niger delta. Compressional and shear wave velocity increases with depth for both Sand and Shale beds. Shear wave velocity is a function of Compressional wave velocity, but Compressional wave velocity is not necessarily a function of Shear wave velocity. Shear - Compressional velocity linear trend is higher in sandy than in shaly formations for all wells studied. The Shear-Compressional velocity model for the lithological variation of the study area is given as, $V_S = 0.7968V_P + 3.9228$

INTRODUCTION

Velocity is an important petrophysical parameter used for oil-field optimization or other geophysical evaluations, to determine and predict horizons, faults, facies, unconformities, stratigraphic boundaries, geologic structures, fluid contents, etc. Knowledge of velocity at any depth is important in the recognition of reflectors and refractors with dip or plane horizontal beds. Amonieah *et al* (2007) used the concept of Velocity to determine weathered layers in the Niger Delta. As sound waves encounter a medium of different elastic properties and density, compressional and shear waves are generated. The compressional waves travel parallel to its particle displacement, P-waves propagate through solids, liquids, and gaseous media.

In practice, shear wave data have proven to have little or no information thus, the rock physicist enhance the usefulness of shear wave data by combining it with other rock related properties such as acoustic impedance, elastic impedance, Lame elastic constant, shear modulus etc. Shear wave velocities are measured directly from sonic well logs, core data laboratory analysis or predicted from compressional wave velocity data, Osman (2010).

Bassiouni (1994) has observed that geophysical well logs provide a better representation of in-situ conditions in a lithological unit than laboratory measurements because they sample a finite volume of rock around the well and provide a continuous record with depth rather than discrete sample points. Laboratory measurements have a number of setbacks. A large number of samples must be measured to adequately characterize the stratigraphic section; the rock properties determined in laboratory measurements must still be modified to apply to in-situ conditions and; some lithologies, mostly in shales, may be altered in the drilling and cutting recovery stage so that laboratory measurements contain systematic errors (Pickett, 1963).

The objective of well logging is to measure the physical properties of the undisturbed rocks and the fluid content. Logging parameters computed from these logs are radioactivity, electron density, porosity, sonic transit time and lithology. The Limitations of shear wave information includes; Rock stiffness, fluid compressibility, Density, Target Depth, Signal-to-noise Acquisition and Processing.

Shear wave analysis have significance in the analysis of Amplitude Versus Offset and impedance for the successful detection of hydrocarbon, also for reservoir characterization, as well as, distinguish between pressure and saturation changes in 4D seismic data. Again it is used to obtain Images in gassy sediments where P-waves are attenuated; furthermore shear wave splitting provides the most reliable seismic indicator of reservoir fractures, (Castagna *et al*, 1985).

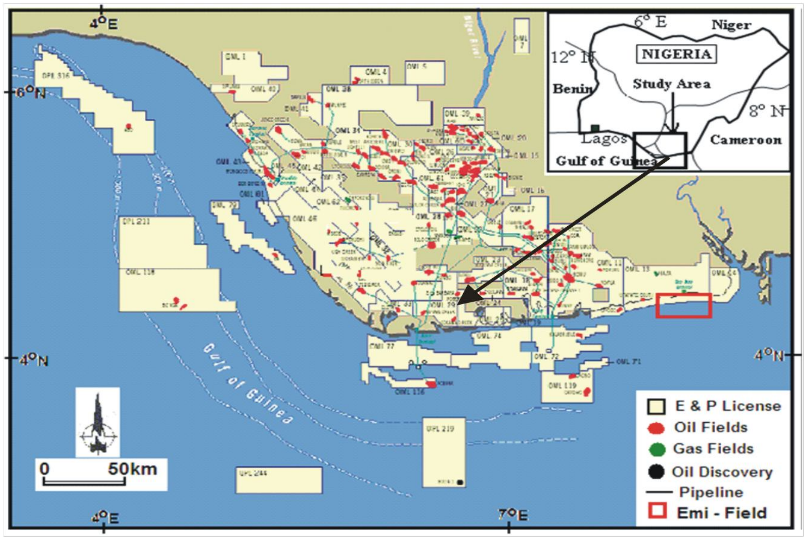

Fig. 1.0: Niger Delta showing the study Area (adapted from: Whiteman, 1982)

GEOLOGY OF THE NIGER DELTA

The Niger Delta is located between latitudes 3° - 6°N and longitude 5° - 8°E (Fig. 1). From apex to coast the sub-aerial portion stretches more than 300km, covering an area of 75,000km^2. The Niger Delta started to evolve in the early tertiary times when classic rivers input increased (Doust and Omatsola, 1989). Eventually the Delta prograded over the subsiding continental oceanic lithospheric transition zone, and during the Oligocene, spread onto oceanic crust of the gulf of guinea. Sediments were supplied from weathering flanks of out-cropping continental basement through the Benue -Niger drainage system. The Niger Delta is an active sedimentary basin at present and has since the Paleocene times prograded a distance of more than 250km from the Benin and Calabar flanks to the present delta front.

Details of the stratigraphic sequence of the Niger Delta has been documented by several studies including; Short and Stauble (1967), Shannon and Naylor (1989), Doust and Omatsola (1990), these and many others have interpreted the Niger Delta as being a river dominated Delta, the post Oligocene delta is typical for a wave dominated delta with well developed shore-face sands, beach ridges, tidal channels, mangrove and fresh water delta covering area of over 70,000km^2 and the sedimentary structure is composed of a complex regressive classic sequence reaching a total stratigraphic thickness of 30,000ft. Three lithostratigraphic units have been recognized in the subsurface of the Niger Delta. These are from the oldest to the youngest, the Akata, Agbada and Benin formations.

Numerous previous works have shown that *Vp/Vs* values are a good indicator of lithology. *Vp/Vs* in mixed lithologies vary linearly between the limits of *Vp/Vs* for the end members (Nations, 1974: Kithas, 1976; Eastwood and Castagna, 1983; Rafavich *et al.*, 1984; Wilkens, 1984: Castagna *et al.*, 1985; Miller and Stewart, 1990). *Vp/Vs* values for different lithologies determined by Pickett (1963) and others are as follows: 2.0 – 2.5 for coal; 2.0 – 3.0 for shale; 1.9 for limestone; 1.8 for dolomite; 1.7 for calcareous sandstone; and 1.6 for clean sandstone (Potter and Foltinek, 1997).

Pickett (1963) popularized the use of the ratio of Compressional to shear wave velocities as a lithological indicator.

Wyllie *et al* (1958) also recorded compressional to shear wave velocity ratio and lithology using well log studies, he predicted shear and compressional wave velocity relationship from shear-compressional velocity plot gotten from laboratory ultrasonic data for both shale and sandstone to be as in equation 1;

$$V_S = (0.7936 * V_P) - 0.7868 \qquad 1$$

Castagna *et al*. (1985) predicted shear and Compressional wave velocity relationship for both shale and sandstone from shear-Compressional velocity plot gotten from in situ data as given in equation 2.

$$V_S = (0.8621 * V_P) - 1.1724 \qquad 2$$

Castagna *et al* (1985) suggested that if the lithology is well known, then one might fine-tune a slight difference between shear wave velocity predicted from Compressional wave velocity for sandstone, shale, Dolomite and limestone formations using least-square fit of superimposed laboratory ultrasonic and in situ data. These expressions are presented in equations 3 to 6;

$$V_S = (0.80416 * V_P) - 0.85588 \text{ (Sand beds)} \qquad 3$$
$$V_S = (0.76969 * V_P) - 0.86735 \text{ (Shale beds)} \qquad 4$$
$$V_S = -(0.58321 * V_P) - 0.07775 \text{ (Dolomite)} \qquad 5$$
$$V_S = -0.05508 * {V_P}^2 + (1.01677 * V_P) - 1.03049 \text{ (Limestone)} \qquad 6$$

METHODOLOGY

In this work, we have used the Castagna *et al* (1985) models to estimate the Shear velocities. This is because they superimposed both laboratory ultrasonic data and in situ data measurements which provided reliable results. Sonic and Gamma ray logs were used in this study for three deep petroleum wells within OML 29 of the Niger Delta.

The compressional wave velocities were determination from the sonic interval transit time, which were read off from the logs at every 30ft depth, for both shale and sandstone formations, via the relation in equation 7, thus;

$$V_P = \frac{1}{\Delta t_{log}} \qquad 7$$

The Shear wave velocity at every 30ft depth was computed from the compressional wave velocity using the relation given in equations 8 and 9;

$$V_S = (0.80416 * V_P) - 0.85588 \quad \text{(Sand beds)} \qquad 8$$
$$V_S = (0.76969 * V_P) - 0.86735 \quad \text{(Shale beds)} \qquad 9$$

RESULTS AND DISCUSSION

From the velocities plotted against depth shown in Figures 2 to 4, it can be shown that, Compressional velocity values varied from 2159m/s to 6767m/s in sandstone units, while in shale units it varied from 2339m/s to 4830m/s. Shear velocity values on the other hand varied from 1736m/s to 5441m/s in sandstone units, while in shale units it varied from 1799m/s to 3717m/s.

The Shear velocity values plotted against depth are shown in Figures 5 to 7. The Shear velocity values also plotted against Compressional velocity values for both sandstone and shale lithologies are shown in Figures 8, 9 and 10.

It is here observed that, Shear - Compressional velocity linear trend is higher in sandy than in shaly formations for all wells studied. The results indicate higher compressional velocities than shear velocities and both velocities increases with increasing depth.

From Figures 8 to 10, the Shear-Compressional velocity model for the lithological variations of the study area is obtained as; $V_S = 0.7968V_P + 3.9228$.

It therefore follows that where Shear velocity data are not available, this model can be useful in their determinations.

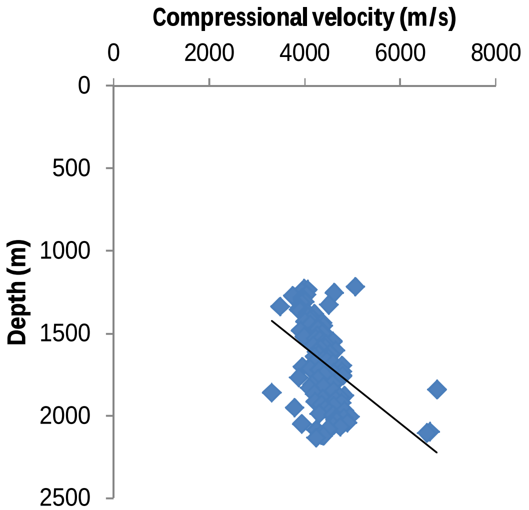

Fig. 2: Depth vs. Compressional Velocity for Well AA 1

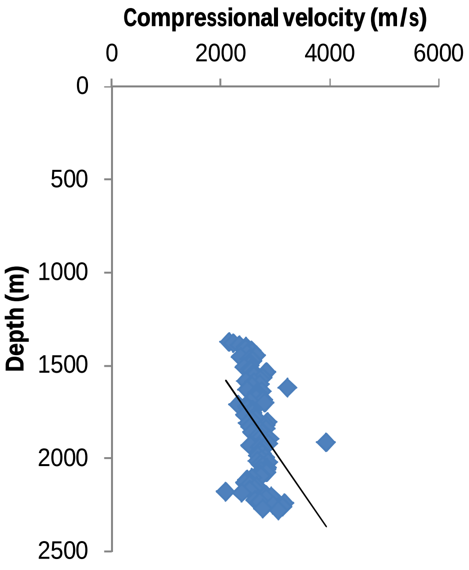

Fig. 3: Depth vs. Compressional Velocity for Well AA2

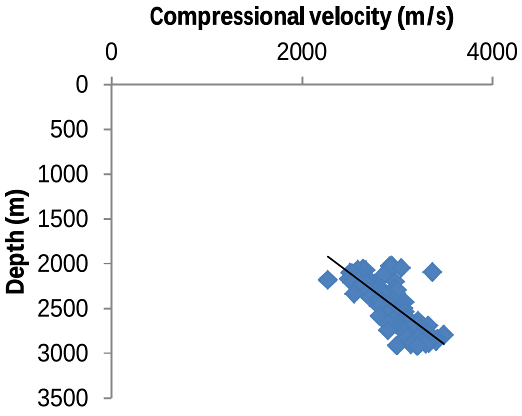

Fig. 4: Depth vs. Compressional Velocity for Well AA 3

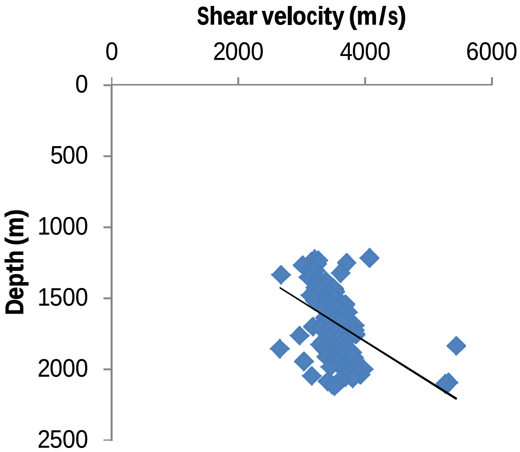

Fig. 5:Depth vs. Shear Velocity for Well AA1

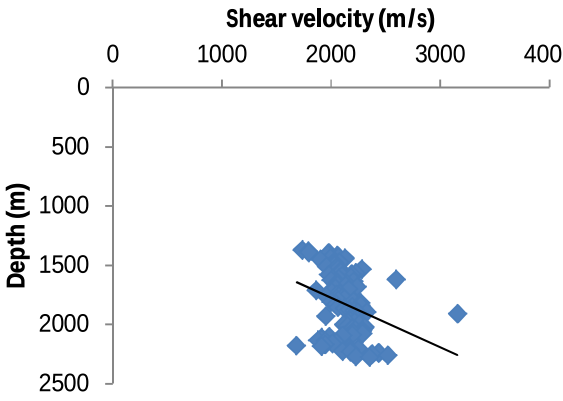

Fig. 6: Depth vs. Shear Velocity for Well AA2

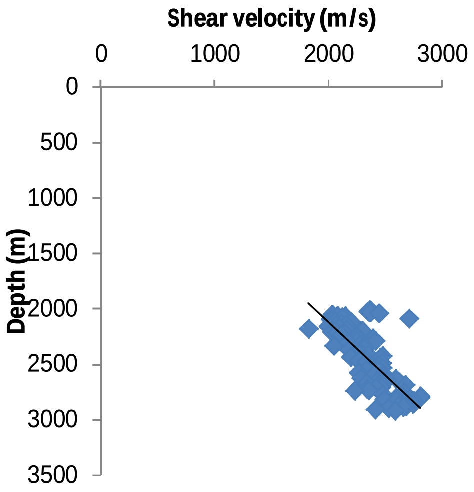

Fig. 7: Depth vs. Shear Velocity for Well AA3

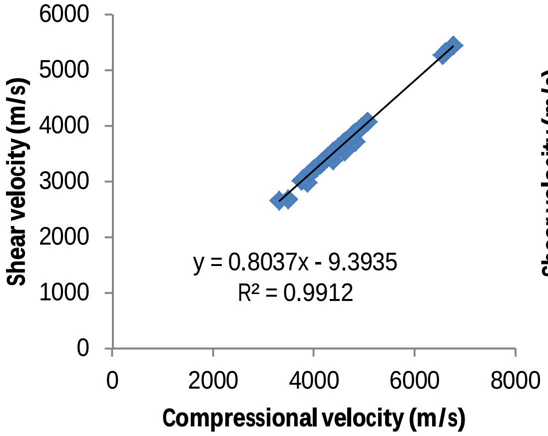

Fig.8.Shear vs. Commpressional Velocity for well AA1

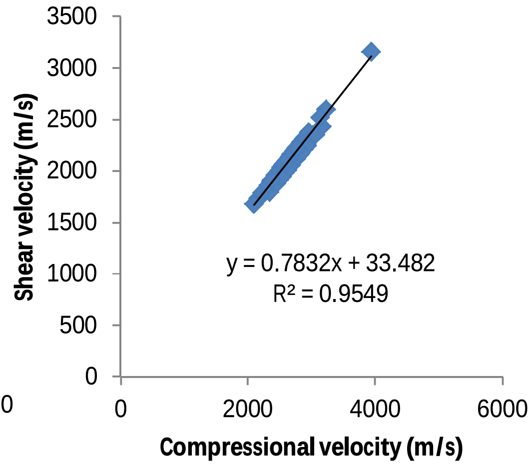

Fig. 9:Shear vs. Commpressional Velocity for Well AA2

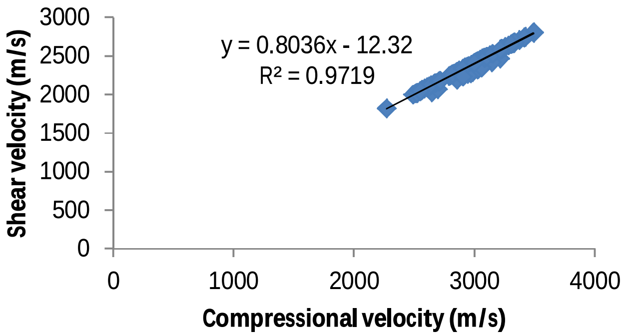

Fig. 10: Shear Velocity vs. Commpressional Velocity for Well AA3

CONCLUSION

From the results of our studies, Compressional and shear wave velocity increases with depth for both Sand and Shale beds. It is here reaffirmed that, Shear wave velocity is necessarily a function of Compressional wave velocity, but Compressional wave velocity is not necessarily a function of Shear wave velocity. Shear - Compressional velocity linear trend is higher in sandy than in shaly formations for all wells studied. The Shear-Compressional velocity model for the lithological variation of the study area has been obtained as; $V_S = 0.7968V_P + 3.9228$.

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