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VELOCITY-POROSITY RELATIONSHIP IN CLASTIC FORMATIONS A CASE STUDY FROM SOME PARTS OF NIGER DELTA, NIGERIA

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ABTRACT

Velocity-Porosity relationship in some parts of Niger Delta was studiesd with a view to establish the velocity-porosity relationship and the generalized equation(s) that best describe this relationship in clastic formations. Five wireline logs were acquired for the study. Neutron porosity log data was converted to synthetic velocity (V_{TA}) using time-average equation of Wyllie (1956), and the sonic porosity log was converted to sonic velocity (V_{sonic}). The results were presented as velocity-porosity crossplots with the trend line equations and the coefficient of correlation.

The results give a distinct inverse velocity-porosity relationship; *i.e.* velocity decreasing with increasing porosity.

The velocity-porosity relationships established from both sonic log (V_{sonic}) and time-average formulation are best described by polynomial fitting of 2^{nd} order. Two generalized equations of high coefficient of correlation, which can be used to calculate compressional velocity (V_p) from porosity values in clastic formations, were established from these relationship.

KEYWORD: Porosity, Velocity, Compressional, Polynomial and Clastic

INTRODUCTION

Accurate prediction of reservoir quality in clastic formations is, and will continue to be, a key challenge for hydrocarbon exploration and development. In doing this, velocity and porosity are the crucial factors for proper prediction. However, there is need to evaluate the manner in which porosity influences velocity in clastic formations via the study of the velocity-porosity relationship in a way different from the formulation of porosity transforms such as Wood's (1941) relationship, time averaging (Wyllie *et al*; 1956) and Raymer *et al.* (1980) transform. This paper addresses the particular issue of velocity-porosity relationship in clastic formations via;

1 analysis of velocity from sonic log and

2. Velocity formulation from time average equation (Wyllie *et al*; 1956) using porosity values derived from neutron log. The objectives of the study are therefore, to establish the velocity-porosity relationship in clastic formations in some parts of Niger Delta of Nigeria and to establish generalized equation(s) that best describe the velocity-porosity relationship from which the compressional velocity can be calculated using the porosity values.

GEOLOGY OF THE STUDY AREA

The Tertiary Niger Delta (Fig. 1) covers an area between 75000sq. km and 100000sq. km; and is composed of an overall regressive clastic sequence which reaches a maximum thickness of 9000 to 12000m. The thick wedge of Niger Delta sediments consist of three units; Benin, Agbada and Akata Formations (Short and Stauble, 1967).

The Benin Formation consists of continental, massive, highly porous fresh water bearing sandstone and gravel. This formation can be recognized on the basis of its high sand content. The Agbada Formation is a succession of sandstones and shale, it consist of an upper predominantly sandy part with minor shale intercalations and a lower shally part which is thicker than upper sandy part. It is built up of numerous offlap cycles of which the sandy parts constitute the main hydrocarbon reservoirs and shales as the cap rock. The Akata Formation is a shale development consisting of dark grey sandy silt shale with plant remains at the top. It is generally rich in planktonic foraminifer a and is thought to be a major source rock for the hydrocarb ons of the Niger Delta Basin (Weber, 1971).

MATERIALS AND METHOD OF STUDY

The materials used for this work include composite logs of the five wells, named well AA, BB, CC, DD and EE. The data analysis involved the calculation of the compressional velocity (V_{sonic}) from sonic log by taking the reciprocal of the interval transit time (Δt) at an interval of 0.656-1.64m (2 – 5ft). The synthetic velocity (V_{TA}) was calculated by incorporating the digitized porosity values from neutron porosity log to time-average equation (Wyllie, 1956). The velocities were crossplotted with the digitized porosity values, the trend line equations taken and the co-efficients of correlation determined.

RESULTS AND DISCUSSION

The results generated from the data analysis were presented as velocity-porosity crossplot (Figs. 2-7). The crossplo tting of velocity (V_{sonic} and V_{TA}) with porosity (Ø) values gives an inverse velocity-porosity relationship, *i.e.* velocity decreasing with increasing porosity. The velocity-porosity relationship as established by the plotting of sonic velocity (V_{sonic}) against porosity (Ø) is best described by polynomial fitting of 2^{nd} order. The trend line equations given in each of the wells are all in the form; $ax^2 + bx + c$. The results are presented in Table 1. The high degree of coefficient of correlation in each of the wells as shown in the table, documents a good degree of velocity-porosity relations hip as established by the polynomial fitting. However, the relative low degree of coefficient of correlation in well BB may have resulted from other factors, such as intensive fracturing, irregular ties in t he borehole wall and possibly from the presence of high content of free gas (Ansselmetti and Eberli, 1999; Akintorinwa, 2004).

The velocity-porosity relationship as established by the plotting of synthetic velocity (V_{TA}) against porosity (Ø) is also best described by polynomial fitting of 2^{nd} order. The trend line equations given in each of the wells are also in the form; $ax^2 + bx + c$, the results are presented in Table 2. The high

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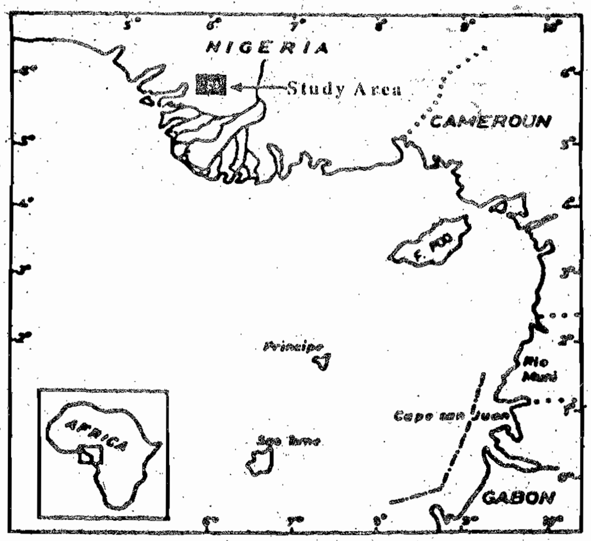

Fig. 1: Location Map of Niger Delta showing the study area

degree of coefficient of correlation in each of the wells also documents a good degree of velocity-porosity relationship as established by the polynomial fitting. Based on this relationship, two generalized equations of high degree of coefficient of correlation:

$V_{TA} = 0.538Ø^2 - 84.78Ø + 5672$

and

$V_{sonic} = -0.7189Ø^2 - 99.336Ø + 5749$

were established, which may be used to calculate compressional velocity from the porosity value.

The crossplotting of the average values of velocity-porosity (Fig. 7), shows that the velocities predicted by time-average equation form an upper envelop of the velocities calculated from the sonic log; *i.e.* at high porosities V_{sonic} can fall below the synthetic velocity V_{TA}, which shows that, time-average equation may overestimate velocities at high porosity (Paillet and Cheng, 1991). Despite the inverse trend with 0.85 coefficient of correlation for polynomial fitting for the crossplotting of the average sonic velocity (V_{sonic}) and porosity (Ø) (Fig. 7), the scattering of velocities at equal porosity can be high. For example at 30% porosity, there is variation in velocity from 2700m/s and 5183m/s (Fig. 7), which make prediction of velocity solely from porosity values unreliable. This could be from the fact that, there is no unique velocity-porosity relationship in sedimentary formations, due to other factors affecting velocity other than porosity (Ansselmetti and Eberli, 1999). In log studies, this pattern of velocity scattering is usually attributed to vugs and fractures (Schlumberger, 1972). Brie *et al.* (1985) pointed out that the velocity scattering at equal porosity is controlled by pore geometry rather than geological secondary porosity formed after deposition.

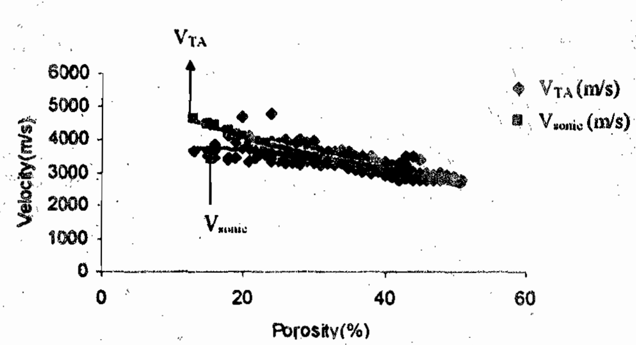

Fig. 2: Velocity-Porosity Crossplot (Well AA)

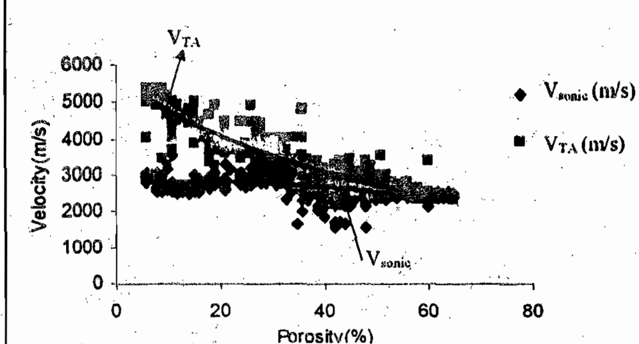

Fig. 3: Velocity-Porosity Crossplot (Well BB)

Table 1: Table of values as established by the polynomial fitting from the sonic velocity (V_{sonic}) in each of the wells.

Well	a	b	c	R
AA	-0.6465	10.472	3748	0.87
BB	-0.1947	4.7596	2820	0.54
CC	-0.352	-0.4418	3520	0.77
DD	-0.0525	-29.443	4522	0.81
EE	-2.387	-175.01	6321	0.91
Average	-0.7189	-99.336	5749	0.85

Table 2: Table of values as established by the polynomial fitting from the synthetic velocity (V_{TA}) in each of the wells.

Well	a	b	c	R
AA	0.6666	-99.309	5676	0.9998
BB	0.543	-83.051	5552	0.94
CC	0.6048	-87.08	5606	0.9998
DD	0.6749	-92.122	5694	0.9998
EE	1.047	-1.114	6028	0.9990
Average	0.538	-84.78	5672	0.9998

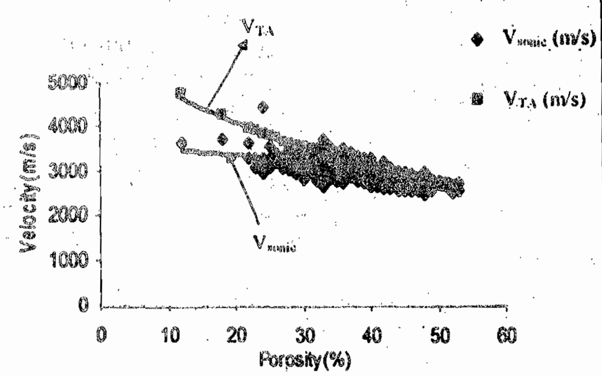

Fig. 4: Velocity-Porosity Crossplot (Well CC)

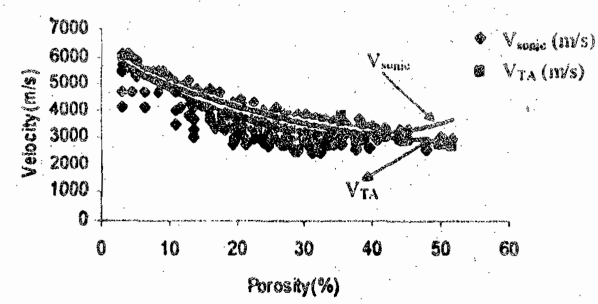

Fig. 6: Velocity-Porosity Crossplot (Well EE)

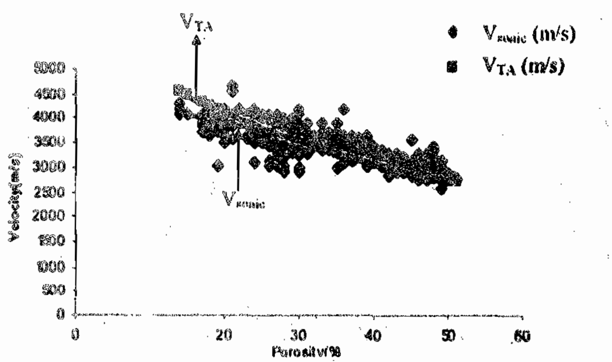

Fig. 5: Velocity-Porosity Crossplot (Well DD)

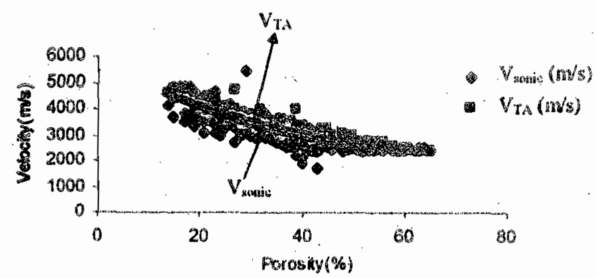

Fig. 7: Average Velocity-Porosity Crossplot (Well AA, BB, CC, DD and EE)

CONCLUSION

A wireline study on five wells in the Niger Delta has allowed the study of the velocity-porosity relationship. The results showed a wide range of velocity and porosity distribution with a distinct inverse velocity-porosity relationship; *i.e.* velocity decreasing with increasing porosity. Two equations of high coefficient of correlation were established from this relationship, which are:

$V_{TA} = 0.538Ø^2 - 84.78Ø + 5672$

and

$V_{sonic} = - 0.7189Ø^2 - 99.336Ø + 5749$

The former equation was modified for porosity value ranges between 15 and 65%, since equation formulated from the time-average equation will overestimate velocity at high porosity (Paillet and Cheng, 1991), based on this equation $V_{TA} = 0.538Ø^2 - 84.78Ø + 5672$ will be more appropriate for these ranges of porosity values. All the equations show that velocity-porosity relationship from sonic log and time-average equation formulation are best describedby polynomial equation of 2nd order in the form $ax^2 + bx + c$ and, the higher the order of the equation, the more the accuracy of the velocity calculated from these equations will be. However, the three equations can be assumed as generalized equations for the calculation of compressional velocity from the porosity value in the clastic formation. These equations are not applicable for porosity greater than 70%.

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