Resolution of Uncertainties in Convectional Logs Using 3D Explorer(3DEX) Data Sets: Niger-delta Example, OLU Field

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Abstract: The novel approach of unraveling the potential of bypassed hydrocarbon reservoir in a thinly laminated geology by comparing the petrophysical parameters and computed Stock Oil Initial-In-Place (STOIIP) obtained from conventional log response to that obtainable in high resolution image data sets was carefully initiated. Archie's equation was adopted in the estimation of water saturation. The net-to-gross was estimated directly from the logs. TECHLOG 2.7 Version was used to estimate the petrophysical properties and also to zone the log accordingly for easy assessment and interpretation. The results show that water saturation from 3DEX is lower than that from the conventional method which implies higher hydrocarbon saturation. The STOIIP results reveal a greater enhancement in petrophysical properties of the 3DEX data to that of the wireline, hence gave over 200% increment in reservoir Y3.000 D-08 (3DEX) Block C, over D-08 and C-04 Y3.000 (wireline) within the same Block. Similarly, that of Block C, Z4.000 (3DEX) consisting of well D-08 gave an increment of over 600% when compared with that obtained from Block C, Z4.000 (wireline) consisting of C-04 and D-08. This result reveals that an improved accuracy is assured when 3DEX tool is employed and hence gave a better economics options for production and developmental initiative.

Key words: Reservoir · Water saturation · Wireline · Net-to-Gross · 3D Explorer · Well

INTRODUCTION

The formations in the Niger Delta, Nigeria consist of sands and shales with the former ranging from fluvial(channel) to fluviomarine (Barrier Bar), while the later are generally fluviomarine or lagoonal [1]. Three major lithostratigraphic units have been recognized in the Niger Delta [2-4]. These are Akata, Agbada and Benin formations. The Akata Formation is a shale unit with horizons of sand that occur near the top. It is marine in origin and represents the prodelta facies of the Niger Delta. It is regarded as the major source rock of oil and gas in the Niger Delta. The Agbada Formation overlies the Akata and is represented by a sequence of sandstones and shales. The formation is paralic and represents the delta-front facies of the Niger Delta. The sand is fine to very coarse grained and conglomeratic. The Benin formation is the shallowest part of the sequence and composed of almost entirely of non marine sand. The Olu Field, being part of Niger Delta, is located about 60 km Southwest of Port-Harcourt. The field was discovered in 1960 by the exploration well SB-1. The field is part of the East

west trending Krakama-Awoba-Ekulama-Robertkiri-SB-field microstructure, a large rollover anticline in the hanging wall of the Santa Barbara Boundary fault.

The oil industry has a mandate to provide an increasing supply of hydrocarbon while also enhancing ultimate recovery and increasing cost effectiveness of exploration and productions. In exploration and development, formation evaluation that includes porosity, permeability and water saturation measurements is very important stage in prospecting for reservoir characterization and hydrocarbon reserveS [5]. The porous and permeable layers often form the reservoir or aquifer unit and hydrocarbon reservoir rocks in which water, oil and gas could accumulate in commercial quantity [6]. One of challenges in exploration is the accurate estimation of reserves in potential reservoir formations and the impact of such estimations on project economics. Technologies introduced to meet such challenges, which are already demonstrating economic value, include the 3D Explorer (3DEX) multi-component induction instrument, bore hole imaging tools ((OBMI) EARTH Image, CBIL, FMI,

etc) and the resultant petrophysical analysis of their measurement [7-8].

The superior vertical resolution of micro-resistivity-imaging tools helps petrophysicist answer difficult questions about porosity type and distribution, sand-clay distributions and the correlation and orientation of both full bore and sidewall cores. In some cases, borehole images provide the details to resolve log-quality and log interpretation issues, such as the presence of drilling-induced fractures or laminated sands. In thin-bedded reservoirs, high-resolution borehole images enable petrophysicists and geologists to determine the distribution of high-quality, productive sand, also known as sand-count analysis. Thinner sand beds and shale laminations require higher resolution measurements to fully account for the amount of sand. This micro resistivity technique has significantly improved the industry's ability to calculate total hydrocarbon reserves in thin-bedded reservoirs [9]. Borehole-imaging services include the highest resolution measurements that can be made on wireline today and are used frequently in combination with other tools-such as the Schlumberger Combinable Magnetic Resonance (CMR) and Elemental Capture Spectroscopy tools (ECS) and Elementary Log analysis software (ELAN)-to evaluate reservoir complexities [10].

Therefore, considering a very complex reservoir formation ranging from massive thick sand/shale sequences or layers, characterizing a low pay zone, petrophysical evaluation in such reservoir using a convectional or wireline log usually leads to high shale volume content, low hydrocarbon saturation and incorrect reservoir estimation. Thus, in such exploration, wells potential economic reservoirs may be overlooked or optimal oil saturation may be underestimated due to poor vertical resolution of convection logging tools. Hence, the uncertainties arising using conventional logs in the field from the past study then informed the application of 3D Explorer (3DEX).

MATERIALS AND METHODS

Three (3) well data with conventional log comprises Gamma, Resistivity, Neutron/Density and a well with high-resolution resistivity image log 3D-Explorer (3DEX) and core data were given from Olu Field within Niger-Delta region. For the purpose of this research the wells are A-03, B-04, C-06 and D-08 (with 3DEX). Software (Petrel 2005 version) was employed in the process of generating the area /depth values for each block in each reservoir. Four reservoirs were examined namely, W2.000, X7.000,

Y3.000, Z4.000. The four wells all penetrated through these reservoirs.

The gamma-ray log was used specifically to estimate the Net-To-Gross (N/G) for each reservoir in each well. The gamma-ray log used in C-06 was adjusted using TECHLOG 2.7 in order to enhance its continuity throughout the entire reservoir and lithological identification efficiency. The porosity was obtained from density log as shown in Equation 1. Water saturation from the Archie's equation was determined using Equation 2 while hydrocarbon saturation was estimated from Equation 3. The planimeter was used to estimate the area/depth values for each block within the reservoir, which was used to plot the area/depth map with a view to estimating the Gross Rock Volume (GRV) for all the wells within the block that penetrated through that reservoir. This value was used as an input into the Equations 4 and 5.

$$\varphi_D = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f} \quad (1)$$

$$S_w = \sqrt{\frac{(FR_w)}{R_t}} \quad (2)$$

$$S_h = 1 - S_w \quad (3)$$

$$STOIIP = \frac{GRV \times \dfrac{N}{G} \times \varphi(1 - 5_w)}{B_0} \quad (4)$$

$$HCIP = GRV \times \frac{N}{G} \times \varphi(1 - 5_w) \quad (5)$$

φ_D = Density porosity

S_w = Water Saturation

S_h = hydrocarbon saturation.

R_t = True formation resistivity, Ωm,

Rw = formation water resistivity, Ωm,

F = formation factor = 1 / φ^2 and Where φ = Effective porosity.

B_O = Formation Volume Factor for Oil

STOIIP = T Stock Oil Initial-In-Place

GRV = Gross rock volume

N/G = Net-to-Gross

HCIP = Hydrocarbon in Place

RESULTS AND DISCUSSION

The results of the study are shown in Tables 1-3 respectively and Figure 1. These are subsequently discussed as follows. The effective porosity and oil
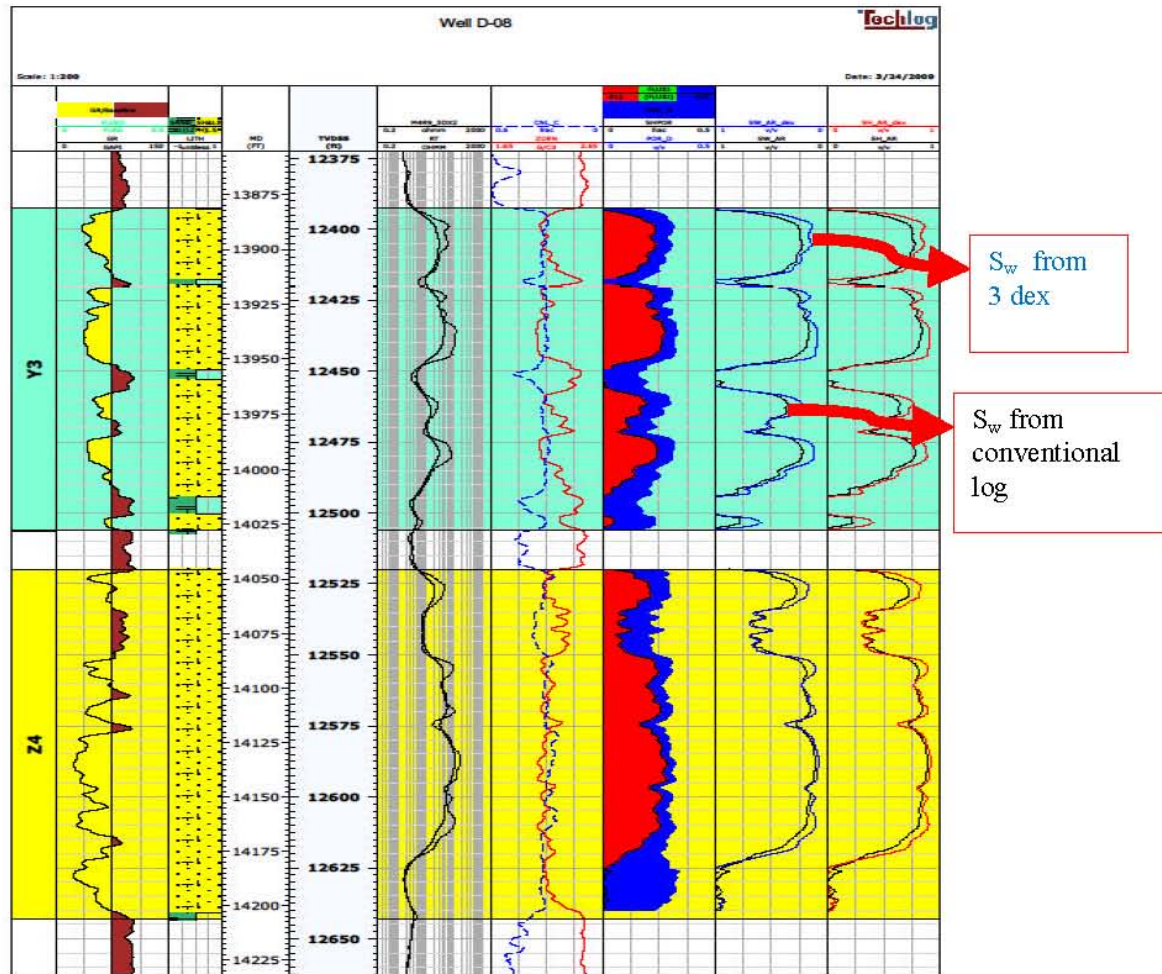
Fig. 1: Well D-08

saturation results determined from D-08 (Y3.000-Z4.000) reservoirs through 3DEX (Table 1) are more accurate than the ones from the same well within the same reservoir by using conventional log tool (Table 2). Therefore, since there is no geological variation between B-04, C-06, D-08 in reservoir K3.000, K4.000 (within the same block), as regards their petrophysical properties, it simply implies that if the 3DEX log were run in these wells, they are likely to produce the same result as seen in the well with 3DEX as against the result from poor resolution of wireline log. The vertical resistivity measured by the 3DEX instrument in D-08 (Y3.000 and Z4.000) is much higher than the traditional horizontal resistivity reading (conventional) as shown in column 6 of Figure 1. Columns 9&10 of Figure 1 show that 3DEX has lower water saturation and higher hydrocarbon saturation than those from wireline log.

The STOIIP results (Table 3) show over 200% increment in reservoir Y3.000 D-08 (3DEX) Block C over

D-08 and B-04 Y3.000 (wireline) within the same Block. Similarly, that of Block C, Z4.000 (3DEX) consisting of well D-08 gave an increment of over 600% when compared with that obtained from BLOCK C, K4.000 (wireline) consisting of B-04 and D-08. Therefore, since there is no geological variation between B-04, C-06, D-08 in reservoir K3.000, K4.000 (within the same block), with respect to their petrophyscal Properties, it simply implies that if the 3DEX log were run in these wells, they are likely to produce the better result as seen in the well with 3DEX compared to ones from wireline log.

Considering the economic aspect, it is quite interesting to note that the use of 3DEX tool in D-08 Y3.000, Block C will yield 1.8millon USD, compared to 0.5millon USD (at the rate of 66.7USD/barrel) in wireline D-08 and B-04, within the same Block. Similarly, the use of 3DEX in D-08 Z4.000, Block C, gave 0.7millon USD over above 98,629.29 USD obtained from B-04, D-08 Z4.000

Table 1: Petrophysical properties (wireline) for the wells reservoirs

PETROPHYSICAL PROPERTIES (WIRELINE)

Wells	Zones	N/G	Porosity (φ)	Water Saturation (S_w),	Hydrocarbon Saturation (S_h),
B-04	X7	0.72	0.24	0.18	0.82
B-04	Y3	0.58	0.19	0.49	0.51
B-04	Z4	0.39	0.18	0.52	0.48
C-06	Y3	0.52	0.19	0.49	0.51
C-06	Z4	0.48	0.12	0.73	0.27
D-08	X7	0.49	0.19	0.83	0.17
D-08	Y3	0.62	0.27	0.38	0.62
D-08	Z4	0.64	0.26	0.30	0.70

Table 2: Petrophysical properties of the Image (3DEX) log data for well 08

PETROPHYSICAL PROPERTIES (3DEX)

Wells	Zones	N/G	Porosity (φ)	Water Saturation (S_w),	Hydrocarbon Saturation (S_h)
D-08	Y3	0.89	0.31	0.01	0.99
D-08	Z4	1	0.3	0.08	0.92

Table 3: Estimation of STOIIP within a specific block

Block	Zone	Well Penetrated	Method Applied	STOIIP
C	Y3	D-04 and D-08	Convectional	8165 MMstb
N	Y3	C-06	Convectional	801 MMstb
C	Y4	D-04 and D-08	Convectional	1478.7 MMstb
N	Y4	C-06	Convectional	644.7 MMstb
C	Y7	B-04 and D-08	Convectional	1666.6 MMscf
C	Y3	D-08	3DEX	28354 MMstb
C	Y4	D-08	3DEX	10642 MMstb

Block C. This implies that a better result (in terms of accuracy) and gain is assured by the use of 3DEX tool.

CONCLUSION

The study shows the efficacy in the application of 3D Explorer (3DEX) Data sets over Convectional Logs in unraveling the potential of bypassed hydrocarbon reservoir in a thinly laminated geological environment. This arose from better effective porosity and oil saturation results from 3DEX than conventional log tool. Also, considering the fact that there is no geological variation between B-04, C-06, D-08 in reservoir K3.000, K4.000 (within the same block), as regards their petrophysical properties, it simply implies that if the 3DEX log were run in these wells, they are likely to produce the same result as seen in the well with 3DEX as against the result from poor resolution of wireline log. Hence, in terms of economic aspect, better gain is assured using 3DEX.

ACKNOWLEDGEMENTS

REFERENCES

1. Aigbedion, I. and S.E. Iyayi, 2007. Formation Evaluation of Oshioka Field Using Geophysical Well Logs. Middle East J. Scientific Res., 2(3-4): 107-110.

2. Short, K.C. and A.J. Stauble, 1967. Outline of the geology of the Niger Delta. American Assocciation of Petroleum Geologists Bulletin, 51: 761-779.

3. Franky, E.J. and E.A. Cordy, 1976. The Niger Delta oil province: recent developments onshore and offshore. Geological Society of American Bulletin, 19: 195-199.

4. Maron, P., 1969. Stratigraphical aspect of the Niger Delta. J. Mining and Geol., 4: 1-3.

5. Jerot, S. and S. Ariffin, 2008. Formation Evaluation:Correlation between Clay volume and porosity Based on the Well Logging data. In the Proceedings of 2008 Scientific Conference III-Universiti Kebansaan Malaysia(UKM), Bangi-Malaysia, pp: 1-9.

6. Enikanselu, P.A. and A. Adekanle, 2008. A Fortran Programme for Computing Formation (Connate) water resistivity from spontaneous potential logs. American-Eurasian J. Scientific Res., 3(2): 172-177.

7. Schlumberger, 1994a. DSI dipole shears sonic imager. Schlumberger education services, 42.

8. Schlumberger, 1994b. FMI fullbore formation microimager. Schlumberger education services, 42.

9. Schlumberger, 2002. Advanced Formation Evaluation Serminar. Lagos, Nigeria, pp: 6-7.

10. Akbar, M., M. Petricola, M. Watfa, M. Badri, M. Charara, A. Boyd, B. Cassell, R. Nurmi, J.P. Delhomme, M. Grace, B. Kenyon and J. Reostenburg, 1995. Classic Interpretation Problems: Evaluating Carbonates. Oilfield Review, 7(1): 38-57.