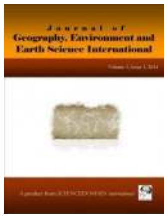

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Integrated Reservoir Characterization of "XOX" Field in the Southern Niger Delta, Nigeria

Aigbedion Isaac[1*] and Dawodu Francis[1]

[1]Ambrose Alli University, Ekpoma, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

3D seismic sections, composite well logs and check-shot data were used for four wells in this study. The wells were drilled to the depths of (i) 1627-2541 m, (ii) 1726-2804 m, (iii) 1788-2994 m and (iv) 1955-3409 m. All data were loaded in the petrel software. The in-line (dip) is 1281 and cross-line (strike) 5382 covering a total area of 164,019 m^2 with a line spacing of 25 m. Five hydrocarbon producing reservoirs (A_1, A_2, A_3, A_4, and A_5) were identified. Well-to-seismic tie revealed that hydrocarbon bearing reservoirs were associated with direct hydrocarbon indicator. Five horizons were studied and four faults mapped for the purpose of carrying out 3-D subsurface structural interpretation. The study showed that the 'XOX'-field bears a considerable amount of 129,931,627.6 million square cubic feet (MMSCF) of gas in-place and about 173,579,727.3 million barrels (MMBSTB) of oil reserve which could be exploited for commercial purpose.

Keywords: Seismic; well logs; hydrocarbon; Niger Delta; reservoir.

**Corresponding author: E-mail: isaacaigbedion@yahoo.com;*

1. INTRODUCTION

The bulk of the hydrocarbon encountered in the Niger Delta has been mostly within a depth range of 4,000 ft to 12,000 ft (about 1,200 m to 3,650 m) since the search for oil began in 1914 [1]. The Niger Delta province contains only one identified petroleum system [2]. This system is referred to as the tertiary Niger Delta (Akata-Agbada), petroleum system.

The Niger Delta-Nigeria has been a consistently sand- rich system throughout its Cenozoic period as a result, reservoir quality is always of secondary concern in exploration, even in the more distal parts of depobelts. The objectives of reservoir characterization are to integrate geophysical information with geologic information and petroleum-engineering information to solve development and production problems [3]. Most sedimentary rocks are composed of grains, with voids (pore space) between them. The pore space that remains from what was present at deposition is primary porosity. The connections between pore space can be destroyed by cementation or other forms of daigenesis. Fractures sometimes provide connections between pore spaces.

Information about reservoir rocks typically is obtained from samples (such as cores, sidewall plugs, or samples brought up with the returning drilling mud) or from logs of physical measurements made in boreholes [4].

The objectives of this study are to make detailed use of seismic and well log data to delineate the reservoir units in the wells of study in the Niger Delta – Nigeria, and to evaluate hydrocarbon potentiality.

1.1 Geology of the Study Area

The study area is located onshore of the Niger Delta-Nigeria, covers an area of 75,000 km^2. It is bounded to the North by the Anambra basin and Abakaliki anticlinorium and in the south by the Gulf of Guinea (Fig. 1). It is however, bounded to the west and northwest by the West African shield which terminates at the Benin hinge line, and to the east by the Calabar hinge line. The Niger Delta basin to date is the most prolific and economic sedimentary basin in Nigeria by virtue of the size of petroleum accumulation discovered and produced as well as the spatial distribution of the petroleum resources to the onshore continental shelf through deep water terrain [5].

Intensive exploration efforts over the last 35 years in and around the Niger Delta has led to a succession of significant discoveries, notably the Bonga, Agbami/Ekoli and Akpo discoveries in Nigeria and zafiro and Alba in Equatorial Guinea [6].

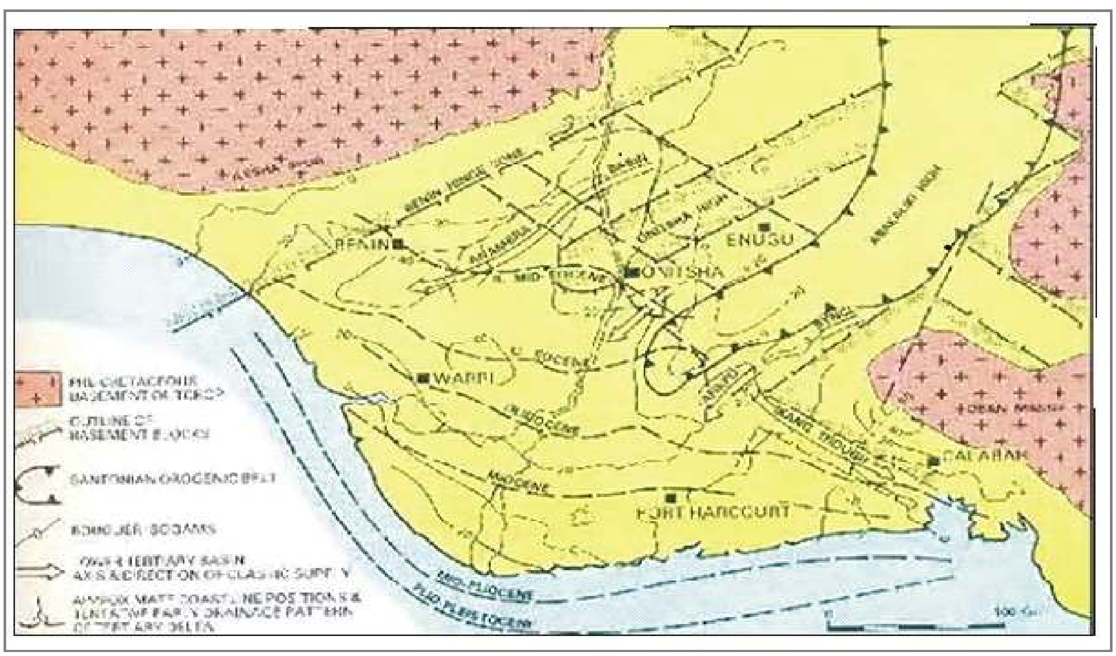

Fig. 1. Geologic map of Niger Delta [5]

2. MATERIALS AND METHODS

The two methods that would be used in this study are seismic reflection and well logging. The well logs used were those of caliper, gamma ray, resistivity, neutron, density and porosity. Five sand bodies were correlated across the Four wells. All the data were loaded into petrel software workstation. The study was performed using petrel 3Dimensional (3D) seismic

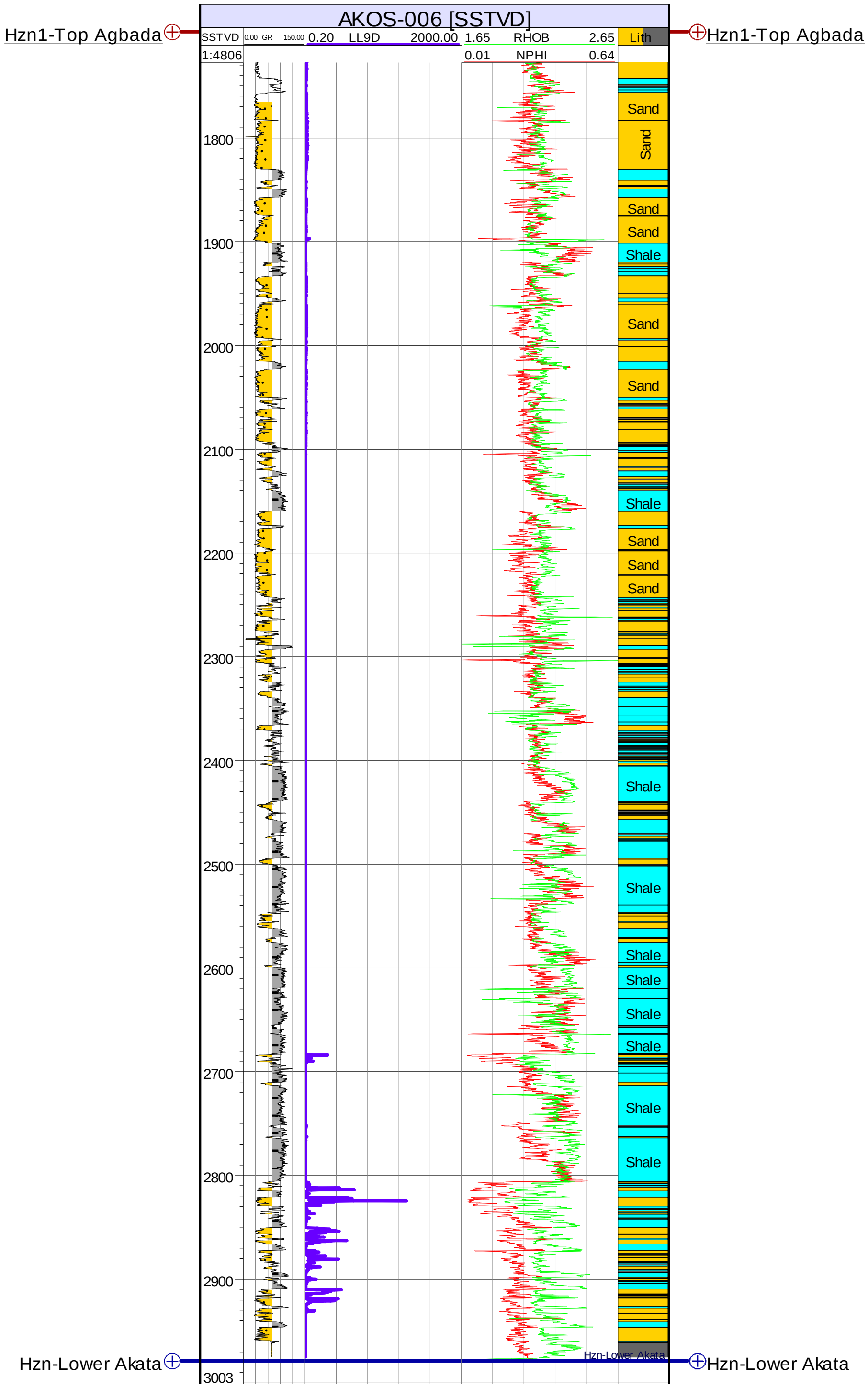

Fig. 2. A composite log showing the resistivity and neutron-density cross plot

interpretation modules. The cross-line (strike) and the in-line (dip) and the well logs were provided by Shell Petroleum Development Company Limited, Nigeria.

Five hydrocarbon bearing sands were identified on the log and labelled sand M-01 and sand M-02. Depth structure maps were generated for these horizons, first by posting the faults on the base map and then mapping the horizons using contour interval of 20 ms. Petrophysical parameters of the reservoirs derived from the log (Fig. 2) which includes:

(i) Volume of shale: This was derived from the gamma ray log first by determining the gamma ray index I_{GR} [7].

$$I_{GR} = \frac{(GR_{log} - GR_{min})}{(GR_{max} - GR_{min})} \tag{1}$$

where I_{GR} = gamma ray index; GR_{log} = gamma ray reading of the formation; GR_{min} = minimum gamma ray reading (sand baseline); GR_{max} = maximum gamma ray reading (Shale baseline).

For the purpose of this research work, volume of shale for tertiary rocks was used:

$$V_{sh} = 0.083\,(2^{(3.7 \times IGR)} - 1) \tag{2}$$

(ii) Net-to-gross ratio (NTG): This is the proportion of clean sand to shale within a reservoir unit. The gross sand is the whole thickness of the reservoir; the non-net sand is the shaly sequences within the whole reservoir thickness.

The net sand is thus obtained by subtracting the non-net sand from the gross sand. The Net-to-gross ratio reflects the quality of the sands as potential reservoirs. The higher the NTG value, the better the quality of the sand.

$$NTG = \frac{\text{Net sand}}{\text{Gross sand}} \tag{3}$$

where Net sand = gross sand-shaly intervals

(iii) Total porosity ($Ø_T$): This was calculated from density porosity log using the equation:

$$Ø_T = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f} \tag{4}$$

where

ρ_{ma} = matrix density = 2.65 g/cc for sandstone (reference), ρ_b = bulk density which is taken to be 1 for gas and 0.87 for oil (reference).

(iv) Effective porosity: This corresponds to the interconnected pores in the formation. The sum of the two porosity types (residual and effective) is usually referred to as the total porosity.

$$Ø_{eff} = Ø_{total} - (Ø\,sh \times Vsh) \tag{5}$$

where

$Ø_{eff}$ = effective porosity, $Ø_{total}$ = total porosity, $Øsh$ = log reading in a shale zone, Vsh = volume of shale.

(v) Water and hydrocarbon saturation: Water and hydrocarbon saturation are very much related. In this research project, water saturation was derived using Archie's equation for water saturation in uninvaded zone [8].

$$R_t = aR_w / Ø^m S_w^n \tag{6}$$

$$Sh = 1 - S_w \tag{7}$$

where S_w = water saturation; R_w = resistivity in the water log (i.e. resistivity of formation water);

Rt = true formation resistivity derived from the deep induction resistivity log; Ø = porosity.

n = saturation exponent usually taken as 2.0; m = cementation factor; a = tortuosity.

(vi) Irreducible water saturation: It is sometimes referred to as critical water saturation. It defines the maximum water saturation that a formation with a given permeability and porosity can retain without producing water.

$$S_w = \left[\frac{F}{2000}\right]^{\frac{1}{2}}$$

where

F = 0.81 (in sand stone reservoirs), (8)

and F = formation factor

(vii) Bulk volume of water (BVW): This is the product of water saturation and porosity corrected for shale [9]:

$$BVW = SW \times Øe \quad (9)$$

where BVW = bulk volume of water, SW = water saturation; Øe = effective porosity.

(viii) Permeability: This is a measure of the ease with which a fluid (gas, oil or water) flows through connecting pore spaces of reservoir rock. It is very pertinent in predicting the rate of production from a reservoir.

$$K = 0.136\ (Ø^{4.4}/Swirr^{2}) \quad [10] \quad (10)$$

where K = permeability in millidarcy; Ø = porosity; Swirr = irreducible water saturation.

3. RESULTS AND DISCUSSION

The Benin Formation shows little presence of hydrocarbon but not of economical scale. The well logs revealed five (5) hydrocarbon-bearing sandstone reservoirs (*A1*, *A2*, *A3 A4* and *A5*) which were visible from the gamma ray logs and the neutron – density logs after defining the base lines and cut off (Fig. 2). One approach is the use of the gamma ray log for determining the amount of shaliness of a formation and for picking tops [11] from well logs in the ''XOX'' field, in the Southern Niger Delta Basin. Emphasizing on the use of well logs in correlating seismic data when picking horizons and tops [12] in the study of the tertiary lithostratigraphy of the Southern Niger Delta revealed that the producing intervals are composed of sandstone [13].

From the analysis, specifically the resistivity and gamma ray logs, five hydrocarbon bearing reservoir zones namely; A1, A2, A3, A4, and A5 were identified across all the wells encountered at depths ranging from 1627 m to 4093 m (Tables 1 and 2).

Four wells (Figs. 3 and 4) indicate high prospect of gas at reservoir one (A1) and two (A2) between depth 1627 m to 2804 m. From the plot, the fluids in the reservoirs are gas, oil and water. The gas – oil contact (GOC) occurred at a depth of 1177 m, the oil – water contact (OWC) occurred at a depth of 1617 m and reservoir A5 indicates 83% of water Formation high above cut – off of 60% between depth 2188 m to 4093 m. From the Well log, it was observed that reservoirs A1 to A4 are hydrocarbon filled while reservoirs A5 is water filled (Figs. 3 and 4).

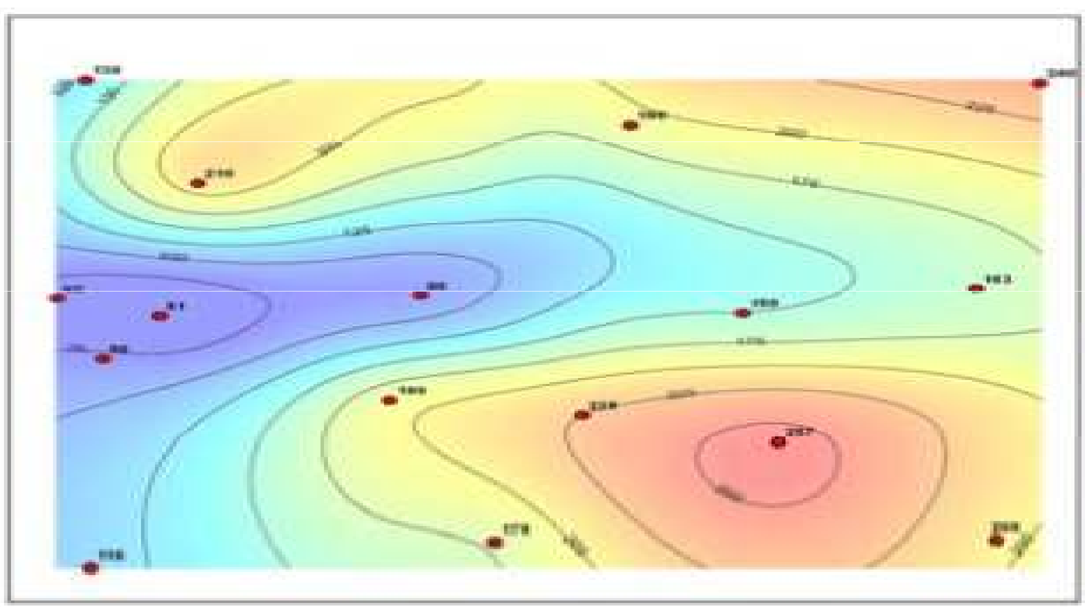

Fig. 3. Isopach thickness of the entire reservoirs view in 3D surface map

Table 1. Summary result of petrophysical log parameters estimated in well_006

Sand units	Depth interval (m)	GR_{log} (API)	I_{GR}	LLD (Ωm)	Gross (m)	Net (m)	N/G %	Φ%	K (md)	PHIE (dec)	F	Swir %	Sw%	Vsh%	Sh%
A1	1697– 1830	33	0.22	42.9	133	108	81	31.28	1760	0.34	9.89	8.58	56.84	12.5	43.16
A2	1858 – 1901	28	0.18	36.3	43	34	79	37.17	1420	0.35	11.37	7.13	59.11	15.5	40.89
A3	1933 – 2119	44	0.25	66.0	186	27	15	39.84	952	0.33	15.22	6.76	61.52	9.0	38.48
A4	2160 – 2339	43	0.21	66.0	179	39	21	36.19	1303	0.31	10.57	7.2	59.53	14.5	40.47
A5	2820 – 2959	48	0.19	619.5	139	82	59	35.03	21206	0.30	12.64	14.57	56.48	16.0	43.52

Table 2. Summary of the petrophysical parameters for all reservoirs across six wells in 'X' field

Reservoir sand units	Depth interval (m)	Average gross thickness (m)	Average net thickness (m)	Average N/G(dec)	Average porosity ϕ%	PHIE (dec)	Average permeability k(md)	Average water saturation (Sw)%	Average hydrocarbon saturation (Sh)%	Remark
A1	1627-2541	457	66	0.14	27.11	0.29	989	56.80	43.2	Hydrocarbon
A2	1726-2804	539	80	0.15	22.09	0.33	799	55.90	44.1	Hydrocarbon
A3	1788-2994	603	78	0.13	30.01	0.31	891	58.79	41.21	Hydrocarbon
A4	1955-3405	725	58	0.08	25.31	0.24	223	54.87	45.13	Hydrocarbon
A5	2188-4093	953	44	0.05	26.30	0.28	334	82.76	17.24	Water/Shaly
All zones	1629 – 4093	3277	326	0.55	130.82	1.45	3236	309.12	190.88	

Table 3. Average summary of some petrophysical parameters for all reservoirs across six wells

Reservoirs	Depth interval (m)	$Ø_T$	V_{sh}	R_w(Ω)	BVW (dec)
A1	1627 – 2541	0.56	9.22	0.224	0.57
A2	1726 - 2804	0.55	11.01	0.222	0.56
A3	1788 - 2994	0.61	14.11	0.223	0.59
A4	1955 - 3405	0.49	22.13	0.213	0.55
A5	2188 – 4093	0.45	34.05	0.254	0.83

Table 4. Net reservoir and net pay zone with their fluid contents across wells

	Zone intervals		Net reservoir				Net pay zone		Fluid
Zone name	Top ft (m)	Base ft (m)	Gross (ft)	Net (ft)	N/G (dec)	ϕ%	(Sw)%	(Sh)%	Remark
A1	5337.9(1627)	8336.6(2541)	1500.8	216.5	0.1443	27.11	56.80	43.2	Gas oil contact
A2	5662.7(1726)	9199.5(2804)	1768.3	262.5	0.1483	22.09	55.90	44.1	Gas oil contact
A3	5899.1(1788)	9822.8(2994)	1978.3	255.9	0.1294	30.01	58.79	41.21	Oil water contact
A4	6414.0(1955)	11171.(3405)	2378.6	190.3	0.080	25.31	54.87	45.13	Oil water contact
A5	7178.5(2188)	13428.(4093)	3126.6	144.4	0.046	26.30	82.76	17.24	Water contact

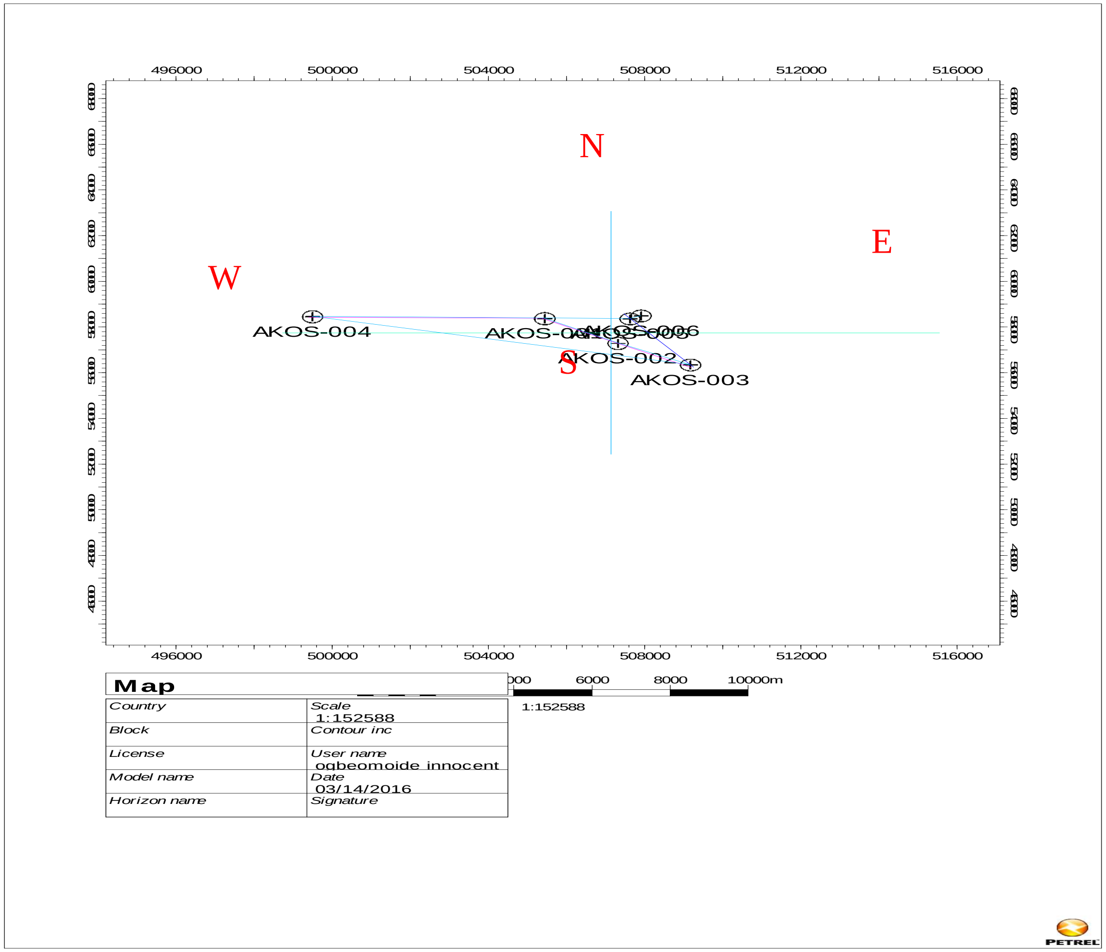

Fig. 4. 3D Map window showing the well location on petrel

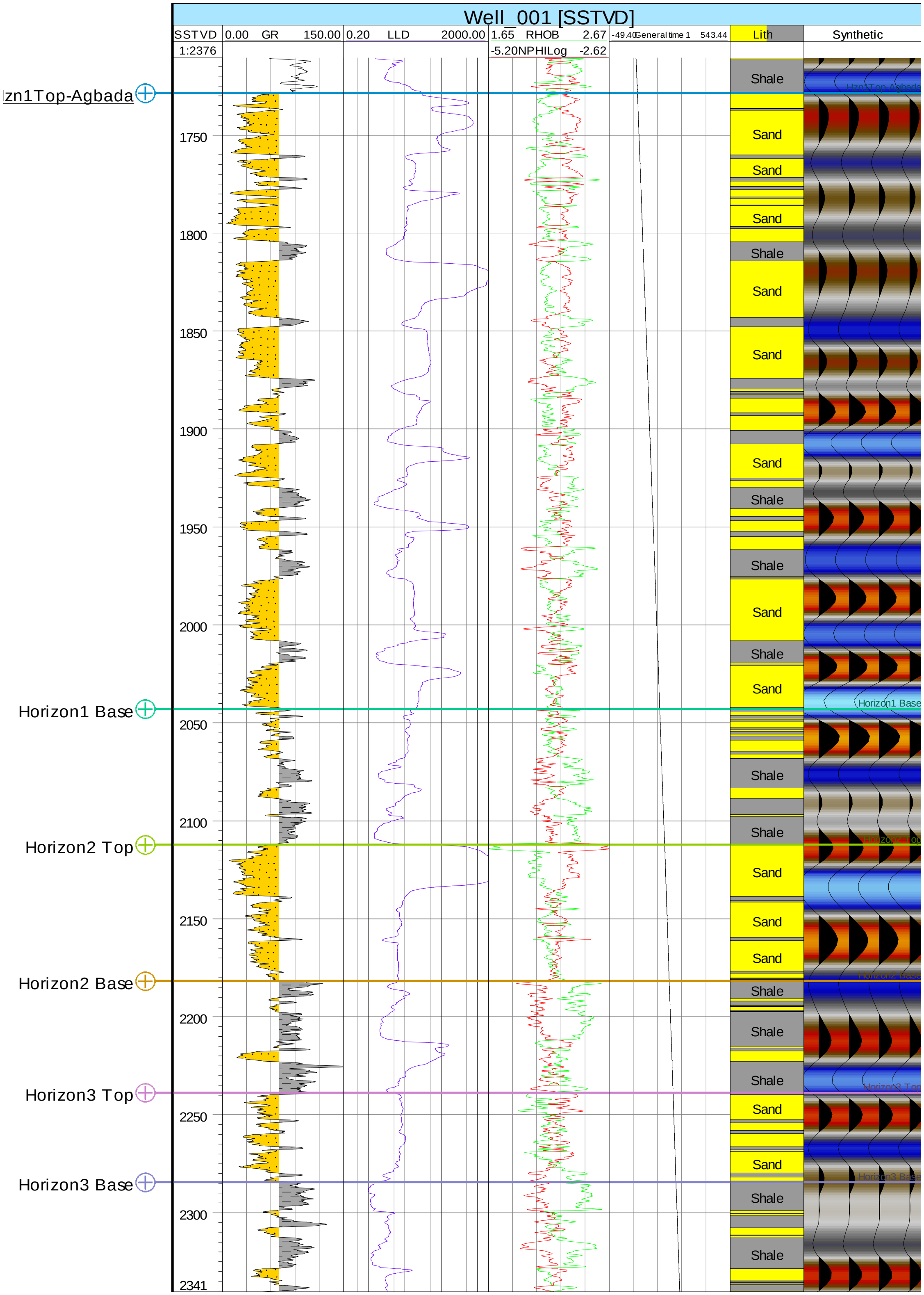

Fig. 5. Seismic-well-tie synthetic

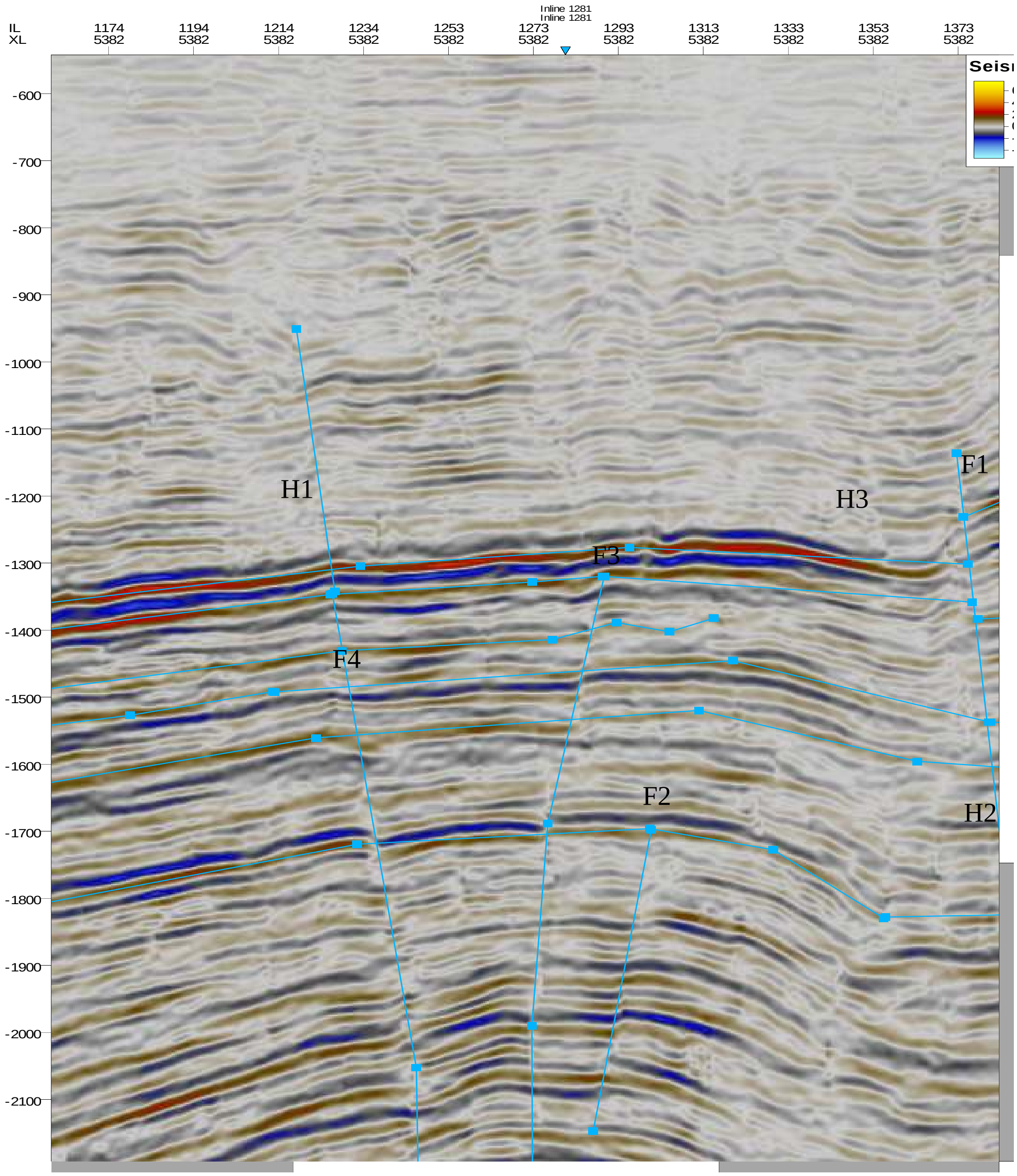

Fig. 6. Typical seismic section (Inline 1281), showing horizons and faults

4. CONCLUSIONS

The delineation and mapping of hydrocarbon-bearing reservoirs from surface seismic sections and well logs within the depth interval of 5344.49 ft (1629 m) and 13428.48 ft (4093 m) was carried out for the 3-D structural interpretation and evaluation of petrophysical parameters in the area of study.

From well log analysis, five hydrocarbon-producing reservoirs (A1, A2, A3, A4 and A5) were identified. Well-to-seismic tie revealed that hydrocarbon bearing reservoirs were associated with direct hydrocarbon indicators (Bright spots and dim spots) on the seismic sections. Five horizons were studied and four faults mapped for the purpose of carrying out 3-D subsurface structural interpretation. Finally, the study has shown that 'XOX' field evaluated petrophysical parameters are excellent for commercial oil/ gas exploitation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Aigbedion I, Iyayi SE. An appraisal of the Abura field. International Journal of Physical Sciences. 2006;2:093-100.
2. Doust H, Omatsola E. Niger Delta: In Edwards JD, Santogrossi PA, eds. Divergent/Passive Margin Basins. American Association of Petroleum Geologists Bulletin Memoir. 1990;48:201-328.
3. Oyedele KF, Ogagarue DO, Mohammed DU. Integration of 3D seismic and well log data in the optimal reservoir characterization of EMI field, offshore Niger Delta oil province, Nigeria. American Journal of Scientific and Industrial Research. 2013;4:11-12.
4. Sheriff RE. Fundamental of reservoir geophysics. Society of Exploration Geophysicists. 2010;20-40.
5. Nwachukwu JI, Chukwurah PI. Organic matter of Agbada formation, Niger Delta, Nigeria. American Association of Petroleum Geologists Bulletin. 1986;70:48-55.
6. Ameloko, Owoseni J. Reservoir characterization of 'X' field in the Niger Delta area using seismic and petrophysical data; 2015.
7. Schlumberger. Log interpretation I – principles. Houston: Schlumberger Ltd. 1974;30-38.
8. Archie GE. The electrical resistivity log as an aid in determining some Reservoir characteristics. Pet. Tech. 1952;5:34.
9. Adepelumi AA, Alao OA, Kutemi TF. Reservoir characterization and evaluation of depositional trend of the Gombe sandstone, Southern Chad Basin, Nigeria. Journal of Petroleum and Gas Engineering. 2011;2:11-131.
10. Asquith G, Krygowski D. Basic well log analysis. AAPG Methods in Exploration Series. 2004;6:16.
11. Arzuman S. 3-D structural and seismic stratigraphic interpretation of the Gauasare-Misoa interval. VLE 196 Area, Block V, Lamar Field, Lake Maracaibo, Venezuela. Master's Thesis, Texas A & M University, USA; 2002.
12. Cosentino L. Integrated reservoir studies. Editions Technip, Paris, France. 2001;25-84.
13. Evamy BD, Haremboure J, Kamerling P, Knaap WA, Molloy FA, Rowlands PH. Hydrocarbon habitat of tertiary Niger Delta. American Association of Petroleum Geologists Bulletin. 1978;62:277-279.

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