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Integrated Prospectivity Evaluation of XYZ Field Coastal-Swamp Depobelt Niger-Delta Basin Nigeria

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ABSTRACT

Five studies were conducted on the “XYZ” field to understand its reservoir properties, structural settings, and hydrocarbon-in-place. Petrophysical parameters were calculated using appropriate equations and wireline logs. 3D seismic fault models were created. A stacking pattern of the reservoir sand bodies was interpreted from a gamma-ray motif. The reservoir surface area was deduced using hydrocarbon indicators and seismic amplitude change. A seismic inline section corresponding with the reservoir zone was used for the seismic facie studies. Reservoir R1 has net-thickness of 111.71m and 117.09m, N/G ratio of 76% and 85%, effective porosity of 25% and 28%, hydrocarbon saturation of 44% and 40%, permeability of 14md and 16md, and Formation factor of 156.32 and 13.77 in well “XYZ-03” and “XYZ-05” respectively. Three-ways and two-ways fault-dependent closures with an anticlinal stratigraphic closure were delineated towards the western and middle parts of the field. Reservoir R1 generally shows an aggrading stacking pattern. R1 associated with wells "XYZ-03" and “XYZ-05” has hydrocarbon volume of 272,293.40m^3 (1,712,674 bbl) and 193, 502.93m^3 (1,217,097 bbl) respectively. Seismic facies showed continuous reservoir sand bodies. The field is endowed with moderate to good multiple reservoirs, and effective fault and stratigraphic closures, which support economically considerable hydrocarbon volume.

Keywords: Closures; Faults; Petrophysics; Prospectivity; Reservoir; Seismic facies; Stacking pattern.

1. Introduction

Correct determination of reservoir characteristics and properties through structural analysis of the subsurface geology, and delineation of the quantity and economic worth of hydrocarbon in prospect are some of the major challenges facing oil-producing industries. These problems span across the issue of types of closure, reservoir units, reservoir stratigraphy, sedimentology, and reservoir volumetric (hydrocarbon potentials) among others. These mentioned problems and more related ones were what this research aimed to solve in the study of the “XYZ” field. This involved the integration of 3D seismic and well log data, to evaluate the field reservoirs’ petrophysical characteristics, stratigraphy, structural properties, and reservoir volumetric capacity. This avail improved understanding of hydrocarbon potential and economic value of the oil field.

“XYZ” field is located in the Niger Delta Oil province, the southern part of Nigeria, precisely at the coastal swamp depobelt of the basin. The Niger Delta is situated in the Gulf of Guinea between longitude 5 ^{0}E -8 ^{0}E and latitude 4 ^{0}N and 9 ^{0}N. It has an approximated area of 300,000 km^2, and its sediments amount to a volume of 500,000 km^3 (Turtle et al., 1999; Hospers, 1965). The structural configuration of the study area entails a large simple rollover structure (Danwazan et al., 2023; Damuth, 1994; Edigbue et al., 2014). The sedimentation type within the area is paralic sand and shale sequence (Diab et al., 2022). The shale sequence becomes more prevalent downward between 1930 m and 2050 m sub-sea (Onyekuru et al., 2012). The study area is shown diagrammatically in the base map shown in Figure 1.

The Lithostratigraphy of the Niger Delta is divided into three major formations, which include Akata, Agbada, and Benin formation (Short & Stäuble, 1967). The Akata Formation makes the base of the Niger Delta sequence and the formation consists of hemipelagic, pelagic, and prodelta shale deposited in marine environments (Amodu et al., 2022; Stacher, 1995). The Agbada Formation comprises a paralic sequence of interbedded sandstones deposited in

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prograding transitional or coastal environments, and shales, which were prodelta to hemipelagic in origin. The Agbada Formation is Eocene to Recent in age about 3,500 m thick. The Benin Formation is the last laid formation in the Niger Delta lithostratigraphical arrangement, serving as the cap for other formations (Akata and Agbada) (Short & Stäuble, 1967). The formation overlays the Agbada formation. The Benin Formation is mainly arenaceous and consists of marginal marine to continental sandstones deposited in fluvial to coastal environments.

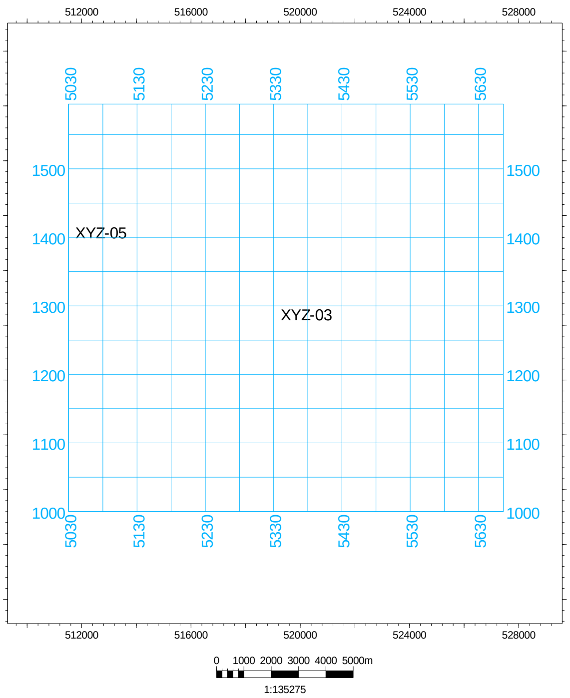

Figure 1. Base map of the XYZ field

Sandstone and unconsolidated sands predominantly serve as the source of petroleum in the Agbada Formation (Osokpor & Ogbe, 2023). Characteristics of the reservoirs in the Agbada Formation are controlled by the depositional environment and by depth of burial. Known reservoir rocks are Eocene to Pliocene in age, and are often stacked, ranging in thickness from less than 15 m to 10 % having greater than 45 m thickness (Evamy et al., 1978). The thicker reservoir probably represents composite bodies of stacked channels (Doust and Omatsola, 1990). The lateral variation in reservoir thickness is strongly controlled by growth faults.

Structural traps are the most commonly known traps in Niger Delta fields, although stratigraphic traps are also common (Mercier et al., 2023). The structural traps developed during the syn-sedimentary deformation of the Agbada paralic sequence. The interbedded shale within the Agbada Formation constitutes the primary seal rock in the Niger Delta. The shale provides three types of seal system; clay smears along faults, interbedded sealing units against which reservoir sands are juxtaposed due to faulting, and vertical seals.

2. Methodology

2.1. Well correlation

Reservoirs were correlated across the wells using gamma and resistivity log signatures. The determination of a suitable sand body for hydrocarbon accumulation leads to the evaluation of petrophysical properties such as porosity, permeability, water saturation, gross reservoir thickness, net reservoir thickness, volume of shale, formation factor, and bulk volume water. This was carried out by using the appropriate wireline logs and equations, e.g. porosity was determined from density and sonic log, while water saturation was calculated from resistivity log using Archie's equation (Asquith et al., 2004).

2.2. Structural Interpretation

Structural interpretation was done using the reservoir tops and base horizons except in reservoir-R2 in which only top depth was used. The depth of the horizons of the reservoirs in the well was located on the seismic section using check shot data to locate the time correspondence of the depth of the various well horizons on the seismic section, which is usually in TWT. Thereafter, the corresponding seismic horizons were picked manually across both the inlines and crosslines of the seismic section to produce time structure maps (isochrones map), depth structure maps, and isochrones surface models for each horizon. The depth structure maps were produced from the isochrones map using velocity information derived from the check shot data. (Ihianle et al., 2013; Tang et al., 2023).

2.3. Reservoir volumetric evaluation

Reservoir volumetric evaluation was based on the results obtained from reservoir characterization and 3D structural study of the field, which helped in identifying areas of high possibility of hydrocarbon accumulation. In the volumetric study, concentration was laid on reservoir-R1 as reservoir-R2 has limited data (Figure 2). Seismic information was adopted to determine the area of hydrocarbon accumulation by applying the principle of direct hydrocarbon indicators (i.e. bright and dim spot), which was used to estimate the reservoir boundary as a point of reflection amplitude contrast due to changes in material phase between shale, formation water and hydrocarbon (Figure 3). The surface area of the reservoir boundary was calculated using the square grid method, Eq. (1); each grid equals 100 square meters.

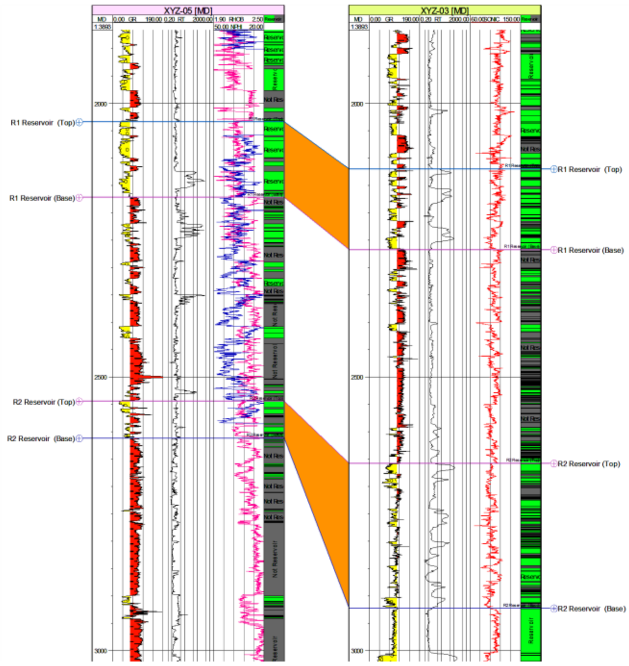

Figure 2. Well log section showing the position of the two reservoirs

The estimated volume of hydrocarbon in reservoir-R1 in the subsurface (hydrocarbon in place) was calculated using Eq. (2) by inputting the computed results obtained from petrophysical evaluation and reservoir surface area determination.

This technique is further described by Aigbedion and Aigbedion (2011) and, Fagbemigun et al. (2021).

$$[(1/2\ \ Incomplete\ cell) + (Complete\ cell)] \times 100\ m\text{^}2 \qquad (1)$$

$$HCIP = A_x\, h_x\, (N / G)_x\, \Phi e_x\, (1 - S_w) \qquad (2)$$

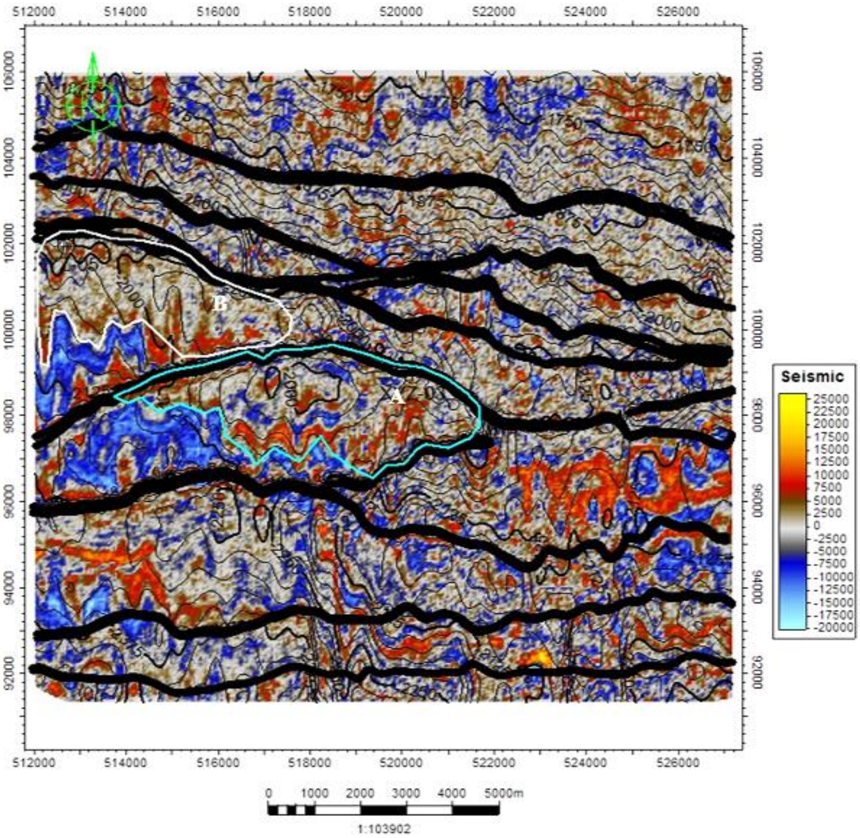

Figure 3. Reflection amplitude map for reservoir "R1"

2.4. Depositional environment studies

The study of the depositional environment of sand bodies and facies changes within reservoir-R1 was carried out using gamma ray log signature as described by Omoboriowo et al. (2012). The reservoir was divided into layers based on the sand stacking pattern, and the stratigraphy cross-section of the reservoir was studied across the two wells.

2.5. Seismic facies analysis

Seismic facies analysis was done by choosing the 5378-inline section which tally with the location of the reservoirs. The seismic facies were delineated based on signature and continuity. This helped to buttress the depositional history, lithology and mode of formation, lateral continuity of the reservoirs, and the trap/seal system of the field.

This technique is further described by Mitchum et al. (1977).

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3. Results

3.1. Petrophysical studies

Petrophysical data (Table 1 and Table 2) indicated that the reservoirs are moderate to good reservoirs. Reservoir-R1 in “XYZ-05” well has 7 % as the volume of shale, 28 % sonic porosity, 27 % effective porosity, 40 % saturation hydrocarbon, 16 md permeability value, and formation factor of 13.77, serving as the best reservoir among the three studied reservoirs. Reservoir-R1 in “XYZ- 03” well has a volume of shale value of 27 %, 34 % sonic porosity value, 25 % effective porosity, 44 % hydrocarbon saturation, and 14 md permeability values.

These values implied that the reservoir has good quality, but the high formation factor value (156.32) indicates that the reservoir has a low ability to yield its hydrocarbon content. However, with an enhanced well operation process, the level of productivity will be more viable. Furthermore, reservoir-R2 in “XYZ-03” well has the following petrophysical parameters; 22 % volume of shale, 29 % sonic porosity, 23 % effective porosity, and 39 % hydrocarbon saturation, 12 md permeability and formation factor of 17.19. These values indicated that the reservoir is of moderate quality.

However, the thickness of the reservoir is encouraging despite the fair hydrocarbon content and could be considered for further exploration processes (Figure 2).

Table 1. Computed Petrophysical Parameters from XYZ-05 well

Reservoir Name	Top (m)	Bottom (m)	Gross thickness (m)	Net thickness (m)	N/G (%)	V_{sh} (%)	Φ_t (%)	Φ_e (%)	S_w (%)	S_h (%)	K (md)	F
R1	2033.86	2171.83	137.97	117.09	85	7	28	27	60	40	16	13.77

Table 2. Computed Petrophysical Parameters from XYZ-03 well

Reservoir Name	Top (m)	Bottom (m)	Gross thickness (m)	Net thickness (m)	N/G (%)	V_{sh} (%)	Φ_t (%)	Φ_e (%)	S_w (%)	S_h (%)	K (md)	F
R1	2119.82	2267.2	147.38	111.71	76	27	34	25	56	44	14	156.32
R2	2657.85	2922.63	264.78	176.02	66	22	29	23	61	39	12	17.19

3.2. Depositional environment studies

Depositional environment studies indicated that reservoir-R1, studied for hydrocarbon content volume, is a multiple reservoir (Figure 4). Multiple reservoir encourages continuous exploitation process, and thus improve economic viability. The interpretation of the stacking pattern within the reservoir-R1 zone is presented in tabular form in Table 3.

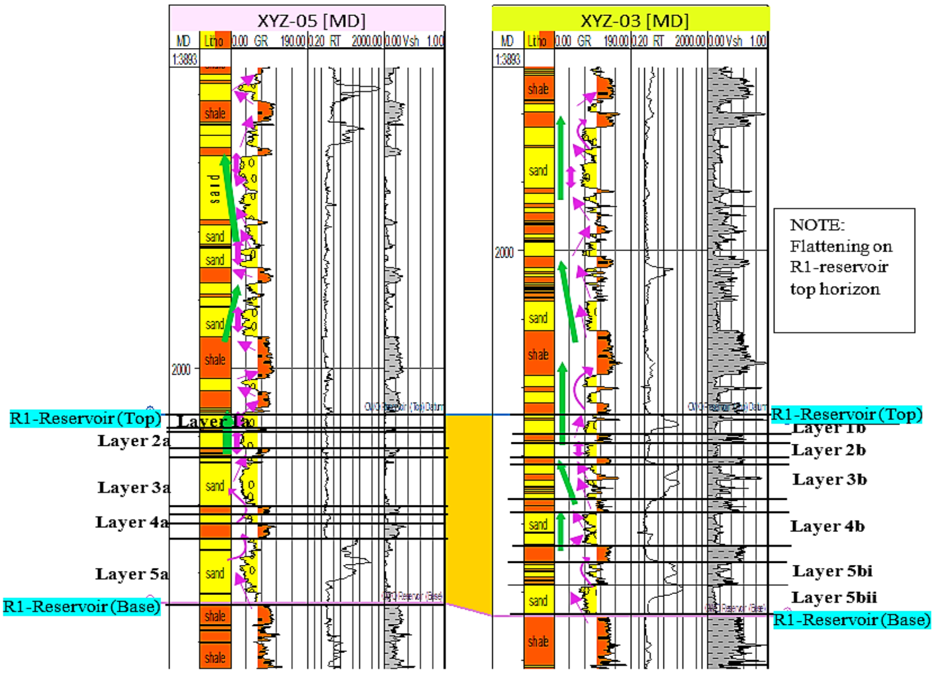

Figure 4. Stacking pattern delineated from Gamma ray log for reservoir "R1"

Table 3. Interpretation of gamma-ray motives within the R1-revoir zone in the two wells

Layers	• Log shape ➢ Stacking pattern	Possible depositional environment	Interpretation/ observations
1a	• Short cylindrical blocky shape ➢ Aggrading stacking	Fluvial/tidal flood plain, fluvial channels, deltaic distributary, and tidal channels.	There is an increase in shalliness toward XYZ0-03 well thus the position of XYZ-03 is nearer to the shoreface
1b	• Bell shape pattern ➢ Retrograding stacking	Shore face – proximal offshore	
2a. /2b.	• Short cylindrical blocky shape ➢ Aggrading stacking	Fluvial/ tidal flood plain, fluvial channels, deltaic distributary and tidal channel	There is an increase in the thickness of shale toward the XYZ-03 well.
3a.	• Symmetrical hourglass/ egg shape ➢ Prograding, aggrading, and retrograding stacking	Tidal flat, tidal channel fill, and shoreface – proximal offshore	Layer 3b shows more shalliness, thus exhibiting a shift in the depositional environment i.e. toward the sea.
3b.	• Saw teeth /serrated shape ➢ Aggrading stacking	Fluvio-deltaic plain, storm-dominated shelf, and distal marine slope	
4a.	• Funnel shape ➢ Prograding stacking	Mouth bar, deltaic front, and shoreface	Layer- 4a is a thin sand body but the thickness of layer 4 increases toward XYZ-03. However, it shows a fairly constant depositional environment across the wells
4b.	• Irregular block shape ➢ Aggrading stacking	Fluvio-deltaic plain, reworked offshore bars, and deltaic front	
5a.	• Symmetrical hourglass ➢ Prodrading, aggrading, and retrograding stacking	Tidal flat-tidal channel fill, shoreface-proximal offshore	Layer-5 splits into two depositional phases in XYZ-03 well, and thus a change in the depositional environment
5bii (lower phase).	• Funnel shape ➢ Prograding stacking	Mouth bars, deltaic front, and shoreface	
5bi (upper phase)	• Short serrated shape ➢ Aggrading stacking	Fluvio-deltaic plain, storm-dominated shelf, and distal marine slope	

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3.3. 3D seismic structural interpretation

3D structural interpretation revealed the general structural settings of the field (Figure 5). Fault-IV is a growth fault formed because of differential loading. Fault-VII is a synthetic fault; fault-VIII is an antithetic fault (indicating a basin-ward direction toward the south). Fault-IV (growth fault) cut across fault-III, which is a normal fault, this fault served as a point of reversal to the throw direction of the remaining faults (from land-ward downthrows to sea-ward downthrows). The remaining notable faults were normal faults, which tended to the seaward direction. These faults include faults I, II, V, VI, and X. The hydrocarbon accumulations were discovered at the fault-enclosed area of the field situated at its central to western side.

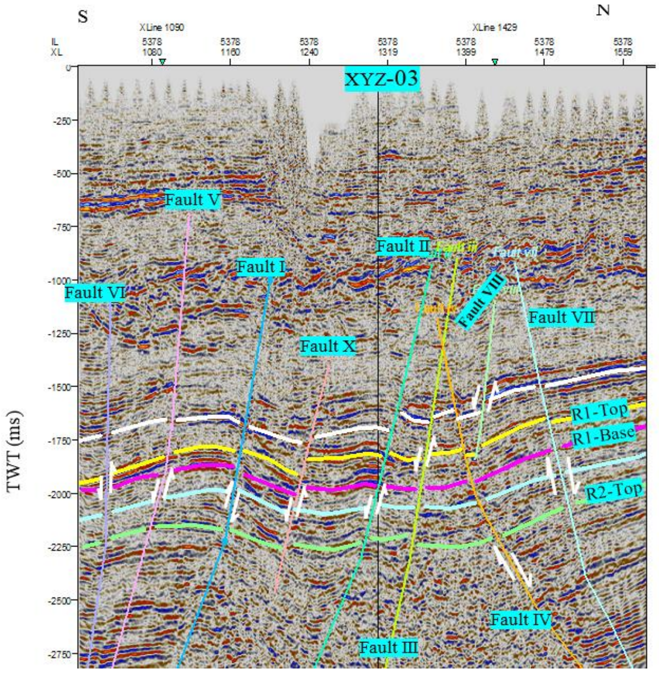

Figure 5. Structural interpretation

3.4. Reservoir volumetric evaluation

Location-A and -B, containing substantial hydrocarbon accumulation were within the depth of 2000 m to 2125 m and 2000 m to 2100 m deep, respectively. Location-A is enclosed by a three (3) way fault closure system while location-B is enclosed by a two (2) way fault closure system and by an anticlinal closure toward the East. The thickness of the reservoir sand body in the locations ranged from 125 m to 200 m as revealed by the isopach map for the reservoir-R1 zone (Figure 6). The thickness indicated a high possibility of a large volume of hydrocarbon accumulation and thus high economic feasibility of extraction processes.

A total area of 22,100 m^2 was calculated for reservoir-R1 studied in Well "XYZ-03" associated with location-A. While the total area of 16,500 m^2 was calculated for reservoir-R1 studied in Well "XYZ-05", associated with location-B. These calculated areas are combined with all other petrophysical parameters presented in Table. 1 was used to determine the volume of the reservoirs. Total volume of 272,293.40 m^3 (*1,712,674 bbl)*) was also calculated for reservoir-R1 associating with "XYZ-03" well at location-A. Likewise, a total volume of 193,502.93 m^3 *(1,217,097 bbl)* was calculated for reservoir-R1 associated with the "XYZ-05" well at location B.

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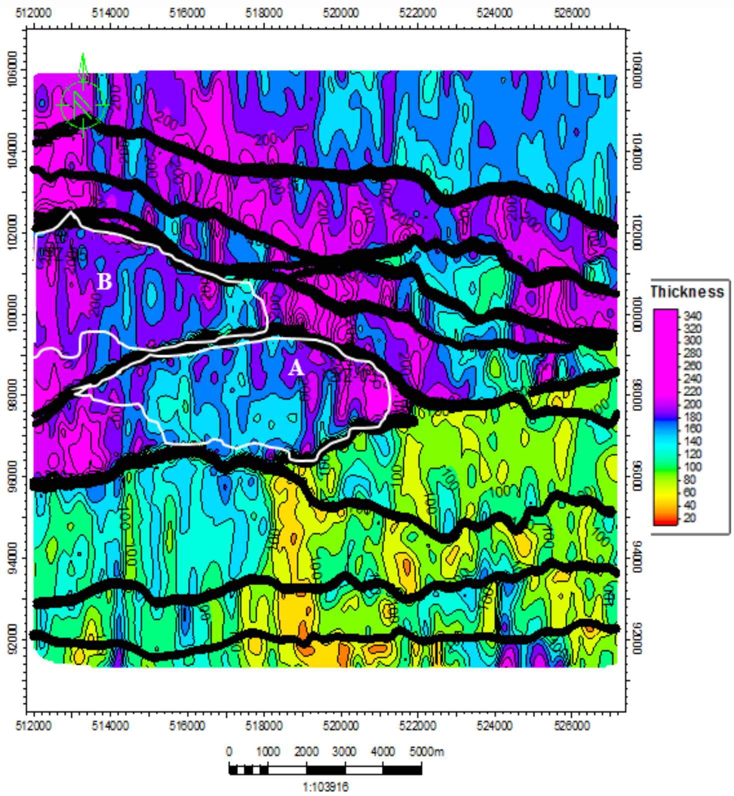

Figure 6. Isopach map of reservoir "R1"

3.5. Seismic facies analysis

Three seismic facies were recognized and denoted SF-I, SF-II, and SF-III (Figure 7). Their characteristics and interpretations are presented in Table 4. SF-I and SF-II were associated with the zone of the evaluated reservoirs (reservoir-R1 and -R2). The properties and nature of the deposit delineated from the study of these two facies supported the lithology contrast that portrays the reservoirs' trapping system, seal system, and lithological continuity that warrant a high volume of hydrocarbon accumulation.

Table 4. Seismic facies Characteristics and Interpretations

Seismic facies	Facies characteristics	Interpretation	Observation
SF-I	High amplitude, moderate to good continuity, parallel to sub-parallel reflection configuration.	Clear vertical alternation of contrasting lithologies Great lateral extent and high volume of sediment deposition	Disturbed by structural truncation
SF-II	Moderate to high amplitude, moderate to low continuity	Moderate to high lithological contrast Mild change in energy level of sedimentation conditions across the field within such facies	Continuity of SF-II is more hampered by structural deformation
SF-III	Moderate to high amplitude chaotic reflection (i.e., discontinuous discordant reflections of variable amplitude and frequency).	Highly distorted internal organization of the deposits, e.g. slumped deposit (in this case), over-pressured shale, volcanic rock, mobile salt deposit, etc.	The chaotic nature of the formation of this facie caused the uplift and faulting of the overlying layers

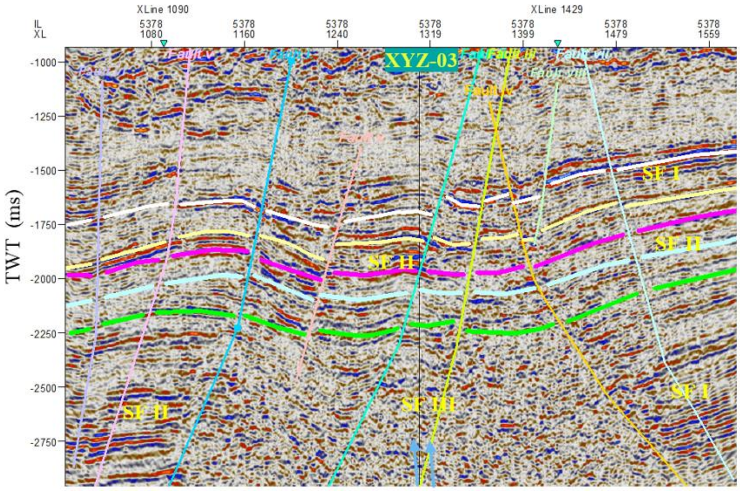

Figure 7. Seismic Facies interpretation

4. Conclusions

Reservoir-R1 associated with well "XYZ-03" has a computed possible Hydrocarbon in Place (HCIP) volume of 272,293.40 m^3 *(1,712,674 bbl),* while reservoir-R1 associated with well "XYZ-05" has 193,502.93 m^3 *(1,217,097 bbl).* This implies that the reservoirs are economically viable. This view is also supported by the presence of an excellent trapping system, which concealed the reservoirs in the two locations.

Reservoir R1 is a multiple reservoir. Thus, the reservoir is divisible into distinct sand bodies. Shalliness increases toward well "XYZ-03", which implies that well "XYZ-03" is closer to the marine depositional environment during the sedimentation process of reservoir-R1 in wells "XYZ-03" and "XYZ-05".

Furthermore, only SF-I and SF-II seismic facies are associated with the zone of reservoir-R1. These seismic facies indicate good lithological contrast and continuity, warranting high hydrocarbon accumulation.

However, the results presented in this study serve as a basis for further studies on the "XYZ" field. This study is not conclusive in itself in determining the final hydrocarbon potential and economic feasibility of the "XYZ" field due to limited data and information.

5. Recommendations

It is recommended that more appraisal wells be dug within the areas marked location-A and -B, for more data to be acquired for appraisal studies.

Likewise, Sedimentological and geochemical studies should be carried out on core samples from the wells to have a better understanding of the reservoir petrophysical properties and purity of the sand bodies.

Finally, further studies should be carried done on depositional environment and facie change by introducing bio-data analysis and age determination.

Declarations

Source of Funding

The study has not received any funds from any organization.

Competing Interests Statement

The authors have declared no competing interests.

Consent for Publication

The authors declare that they consented to the publication of this study.

Authors' Contributions

Both authors took part in literature review, research, and manuscript writing equally.

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Nomenclature

A	surface area of reserovir, m^2
F	formation factor
G	gross thickness, m
h	thickness of the reservoir, m
HCIP	hydrocarbon in place, bbl
K	permeability, millidarcy (md)
N	Net thickness, m
S	average saturation fraction
V	shale volume fraction or percentage

Greek symbols

Φ	porosity fraction

Subscripts

e	effective
h	hydrocarbon
sh	shale
t	total
w	water

References

Aigbedion, I., & Aigbedion, H.O. (2011). Hydrocarbon volumetric analysis using seismic and Borehole data over Umoru Field, Niger Delta-Nigeria. International Journal of Geosciences, 2(2): 179–183. Link: https://citeseerx.ist.

psu.edu/document?repid=rep1&type=pdf&doi=c4db89361835cb000db74d440459ae21ee9a6670.

Amodu, A., Oyetade, O.P., Fadiya, S.L., & Fowora, O. (2022). Sequence stratigraphic analysis and hydrocarbon prospectivity of Amo Field, deep offshore Niger Delta, Nigeria. Energy Geoscience, 3(1): 80–93. doi: https://doi.org/10.1016/j.engeos.2021.11.003.

Asquith, G.B., Krygowski, D., & Gibson, C.R. (2004). Basic well log analysis (Vol. 16). Tulsa: American Association of Petroleum Geologists. Link: https://archives.datapages.com/data/specpubs/method16/me16ch00/images/me16ch00.pdf.

Damuth, J.E. (1994). Neogene gravity tectonics and depositional processes on the deep Niger Delta Continental margin. Marine and Petroleum Geology, 11(3): 320–346. doi: https://doi.org/10.1016/0264-8172(94)90053-1.

Danwazan, J., Egunjobi, K.J., & Akinwande, R.O. (2023). Integrated modeling and reservoir characterization of Ataga Field, Niger Delta Basin, Nigeria. International Journal of Geosciences, 14(05): 450–466. doi: https://doi.org/10.4236/ijg.2023.145024.

Diab, A.I., Sanuade, O., & Radwan, A.E. (2022). An integrated source rock potential, sequence stratigraphy, and petroleum geology of (Agbada-Akata) sediment succession, Niger Delta: Application of well logs aided by 3D seismic and Basin Modeling. Journal of Petroleum Exploration and Production Technology, 13(1): 237–257. doi: https://doi.org/10.1007/s13202-022-01548-4.

Doust H, Omatsola E, (1990) Niger Delta, American Association of Petroleum Geologists Bulletin Memoir. 48: 201–328.

Edigbue, P.I., Komolafe, A.A., Adesida, A.A., & Itamuko, O.J. (2014). Hydrocarbon reservoir characterization of “Keke” field, Niger Delta using 3D seismic and petrophysical data. Standard Global Journal of Geology and Explorational Research, 2(1): 043-052. AJSIR-5-2-73-80-libre.pdf (d1wqtxts1xzle7.cloudfront.net).

Evamy, B.D., Haremboure, J., Kamerling, P., Knaap, W.A., Molloy, F.A., & Rowlands, P.H. (1978). Hydrocarbon habitat of Tertiary Niger Delta. American Association of Petroleum Geologists Bulletin, 62: 1–39. doi: https://doi.org/10.1306/C1EA47ED-16C9-11D7-8645000102C1865D.

Fagbemigun, T.S., Ayuk, M.A., Oyanameh, O.E., Akinrinade, O.J., Amosun, J.O., Sanuade, O.A., Hammed, O.S., & Oyebamiji, A.R. (2021). Hydrocarbon reservoir characterization of “Otan-ile” field, Niger Delta. Journal of Petroleum Exploration and Production Technology, 11(2): 601–615. https://doi.org/10.1007/s13202-020-01069-y.

Hospers J. (1965). Gravity Field and Structure of the Niger Delta, Nigeria, West Africa. GSA Bulletin, 76(4): 407–422. doi: https://doi.org/10.1130/0016-7606(1965)76[407:GFASOT]2.0.CO;2.

Ihianle, O.E., Alile, O.M., Azi, S O., Airen, J.O., & Osuoji, O.U. (2013). Three-dimensional seismic/well logs and structural interpretation over ‘X-Y’field in the Niger Delta area of Nigeria. J. of Science and Tech., 3(2): 47–54.

Mercier, L., Migeon, S., Dall’Asta, M., Praeg, D., Rubino, J.-L., Delhaye-Prat, V., Lafont, F., & Akpi, T. (2023). The rectangular drainage pattern of a submarine canyon controlled by extensional tectonic structures: A case study of the AFAM incision surface (Tortonian, Niger Delta, Nigeria). Marine Geology, 462: 107093. doi: https://doi.org/

10.1016/j.margeo.2023.107093.

Mitchum Jr, R.M., Vail, P.R., & Thompson III, S. (1977). Seismic stratigraphy and global changes of sea level: Part 2. The depositional sequence as a basic unit for stratigraphic analysis: Section 2. Application of seismic reflection configuration to stratigraphic interpretation. Link: https://archives.datapages.com/data/specpubs/seismic1/data/a165/a165/0001/0050/0053.htm.

Omoboriowo, A.O., Chiaghanam, O.I., Chiadikobi, K.C., Oluwajana, O.A., Soronnadi-Ononiwu, C.G., & Ideozu, R.U. (2012). Reservoir characterization of KONGA field, onshore Niger delta, southern Nigeria. International Journal of Emerging Technology, 3: 19–30. Link: https://www.researchgate.net/profile/Kingsley-Chiadikobi-2/publication/336303748_Reservoir_Characterization_of_KONGA_Field_Onshore_Niger_Delta_Southern_Nigeria/links/5d9aa88a299bf1c363fd0023/Reservoir-Characterization-of-KONGA-Field-Onshore-Niger-Delta-Southern-Nigeria.pdf.

Onyekuru, S.O., Ibelegbu, E.C., Iwuagwu, J.C., Essien, A.G., & Akaolisa, C.Z. (2012). Sequence stratigraphic analysis of “XB field”, Central Swamp Depobelt, Niger Delta Basin, Southern Nigeria. International Journal of Geosciences, 03(01): 237–257. doi: https://doi.org/10.4236/ijg.2012.31027.

Osokpor, J., & Ogbe, O.B. (2023). The pattern of organic matter type occurrence and distribution in predicting hydrocarbon source formation: An example from Eocene Niger Delta Basin Shale deposits. Journal of Sedimentary Environments. doi: https://doi.org/10.1007/s43217-023-00146-6.

Short, K.C., & Stäuble, A.J. (1967). Outline of the geology of the Niger Delta. AAPG Bulletin, 51(5): 761–779. doi: https://doi.org/10.1306/5D25C0CF-16C1-11D7-8645000102C1865D.

Stacher, P. (1995). Present understanding of the Niger Delta hydrocarbon habitat. In Geology of deltas Geology of Deltas: Rotterdam, M.N. Oti, and G. Postma, eds., A.A. Balkema, Pages 257–267. http://pascal-francis.inist.fr/vibad/index.php?action=getRecordDetail&idt=6312061.

Tang, X., Yu, Y., Zhang, X., Peng, G., Niu, S., Qiu, X., Lu, M., & He, Y. (2023). Multiphase faults activation in the southwest Huizhou sag, Pearl River mouth basin: Insights from 3D seismic data. Marine and Petroleum Geology, 152: 106257. doi: https://doi.org/10.1016/j.marpetgeo.2023.106257.

Tuttle, M.L., Charpentier, R.R., & Brownfield, M.E. (1999). The Niger Delta Petroleum System: Niger Delta Province, Nigeria, Cameroon, and Equatorial Guinea, Africa. US Department of the Interior, US Geological Survey. researchgate.net/profile/Michael-Brownfield/publication/265273146_The_Niger_Delta_Petroleum_System_Niger_Delta_Province_Nigeria_Cameroon_and_Equatorial_Guinea_Africa/links/570fcfae08ae68dc79096b16/The-Niger-Delta-Petroleum-System-Niger-Delta-Province-Nigeria-Cameroon-and-Equatorial-Guinea-Africa.pdf.