Reservoir Charaterization and Petrophysical Analysis of “PFD” Field, Niger Delta, Using Well Log and 3D Seismic Data

B. M. Ata-Ebirieng, A. R. C. Amakiri, I. Tamunobereton-ari, O. A. Davies

Abstract— This research focuses on the reservoir characterization and petrophysical analysis of interpreted 3D seismic and well log data. Three dimensional (3D) seismic data, and a suite of two geophysical well logs from two wells located on the PFD field, Niger Delta were analyzed using Petrel software. Well log correlation led to the identification of two sandstone reservoirs with potential to hold hydrocarbon lying at depths of 10945-11115ft and 11570-11935ft within the two analysed wells. However, readings from resistivity logs showed that the deepest reservoir has the most potential to be hydrocarbon bearing, hence analysis was carried out for this reservoir alone. To ensure that the reservoir was laterally continuous, a synthetic seismogram was developed to aid tying the well data to the seismic data. The reservoir of interest was shown to be continuous across the field of study. Upon further analysis, certain petrophysical measures were analysed. These petrophysical measures included fractional volume of shale, fractional effective porosity, fractional water saturation and fractional hydrocarbon saturation. Estimated values of fractional volume of shale, fractional effective porosity, fractional water saturation and fractional hydrocarbon saturation had values ranging between 0.04-0.53, 0.04-0.30, 0.17-1.00, and 0.00-0.83 respectively. The reservoir of interest was therefore thought of as having the potential to bear hydrocarbon.

Index Terms— Hydrocarbon Saturation, Petrophysical, Porosity, Seismic, Shale, Water Saturation, Well Logs.

◆

1 INTRODUCTION

Formation evaluation generally is aimed at determining the petrophysical parameters and gross volume inside hydrocarbon bearing reservoirs [1]. Porosity, permeability, net-to-gross, water saturation, hydrocarbon saturation, and volume of shale are the predominant petrophysical properties of reservoir rocks and they have an essential force on hydrocarbon reservoirs evaluation and characterization [2]. The petrophysical properties are used for hydrocarbon reserve estimation and therefore need meditative attention. Reservoir characterization is the combination of different data to describe the reservoir properties of interest in inter-well locations.

Reservoir Characterization generally determine the gross volume within the trap that has the potential to hold hydrocarbons. The knowledge of reservoir characterization and volumetric analysis is an important factor in quantifying producible hydrocarbon [3]. Precisely, reservoir characterization can be carried out using well logs especially using gamma ray and resistivity logs [4]. The need to thoroughly evaluate prospects so as to determine optimal production strategies and also minimize risk that may be associated with hydrocarbon exploration has driven the development of an array of techniques which attempt to propagate log properties. One of such techniques in use is the deterministic and linear physical relationship between log properties and the corresponding seismic response of subsurface rock units (Muslim and Moses, 2011). Well logs interpretation can be used in obtaining vital information and required properties, since a complete coring and core analysis of the entire pay zone is impractical.

Reservoir characterization is a very critical step in exploration and development phases of a prospect and combines multi-disciplinary results of different analysis to reduce risk and enhance understanding of reservoirs. This involves the use of empirical formula to estimate the reservoir parameters such as volume of shale, formation factor, porosity, water saturation, permeability, hydrocarbon saturation etc. Estimates of such reservoir parameters will help to determine if a reservoir is exploitable [5, 6, 7].

Egbai and Aigbogun [8] used mathematical modelling method of petrophysical parameters to characterize reservoirs in Kwale area of Delta state, Nigeria. They concluded that most reservoirs in the wells are gas bearing zones with hydrocarbon saturation ranging from 74.18% to 94.64% with high resistivity values.

Reservoir characterization and formation evaluation of some parts of Niger delta using 3-D seismic and well log data was carried out by Abe and Olowokere [9]. Only one reservoir was delineated across the wells. The result of this analysis has proved that the integration of attribute analysis with structural

---

- *Mr. B. M. Ata-Ebirieng is currently pursuing a master’s degree program in Applied Geophysics from Rivers State University, Port Harcourt, Nigeria.*
- *Dr. A. R. C. Amakiri is currently a lecturer in the department of Physics, Rivers State University, Port Harcourt, Nigeria.*
- *Dr. I. Tamunobereton-ari is currently a lecturer in the department of Physics, Rivers State University, Port Harcourt, Nigeria.*
- *Dr. O. A. Davies is currently a lecturer in the department of Physics, Rivers State University, Port Harcourt, Nigeria.*

interpretation is a reliable and efficient way of carrying out formation evaluation and reservoir characterization. It has also enhanced hydrocarbon exploration for optimal well placement and reserve estimation.

A suite of geophysical wire-line logs from an oil field in Niger Delta have been successfully examined and analyzed by Abraham-Adejumo [10] for the purpose of Well correlation and petrophysical analysis of "Rickie" field onshore Niger Delta. Litho-stratigraphic correlation sections of four wells (R1, R2, R3 and R4) depict that the subsurface stratigraphy is that of sand – shale inter-bedding. Three prominent hydrocarbon bearing reservoirs located at depths of 2,943 m, 3,248 m and 3935 m were identified and mapped. Petrophysical parameters of the reservoirs which included porosity, hydrocarbon saturation, volume of shale, formation resistivity and formation factor were also computed for 'Rickie' oil filed.

Petrophysical and structural analysis of 'maiti' field, Niger Delta, using well logs and 3-D seismic data was carried out by Adewoye *et. al.* [11]. In this work, well logs, check shot and 3-D seismic data have been evaluated to delineate oil bearing sand reservoirs, to determine the petrophysical parameters and to analyses the geologic structures within 'Maiti' field. Three wells were evaluated and three hydrocarbon reservoirs were delineated as R1, R2, and R3. From the result it was deduced that reservoir R1 is the most prolific reservoir while R2 is the least prolific. The structural analysis shows a fault assisted anticlinal structure known as structural trap within 'Maiti' field, Niger Delta, Nigeria.

Amigun and Bakare [12] carried out reservoir evaluation of "Danna" field Niger Delta Using petrophysical analysis and 3D seismic interpretation. The petrophysical analysis carried out on the sand bodies indicates three sand units that are hydrocarbon bearing reservoirs. Time and depth structural maps were generated from 34 seismic data to study the field's subsurface structures serving as traps to hydrocarbon and estimate the prospect area of the reservoirs in acres. From the analysis of the well and seismic data, the gas reserve was estimated to be 225,997 bbl/ft3 while the oil reserve for the three reservoirs is computed as 6,566,089.09 bbl/acre, 14,006,716 bbl/acre and 42,746, 580 bbl/acre respectively.

Amigun and Odole [13] used petrophysical properties to evaluate wells for reservoir characterization of 'SEYI' oil field (Niger-Delta). The analysis of the different petrophysical parameters indicate the presence of hydrocarbon in all the reservoirs. Computed petrophysical parameters across the reservoirs gave porosity as ranging from 0.22 to 0.31; permeability 881.58 md to 14425.01 md and average hydrocarbon saturation of 41.44%, 20.29%, 30.82%, 37.92%, 51.20%, 91.97% and 85.11% for reservoir A, B, C, D, E, F and G respectively. These results together with the determined movable hydrocarbon index (MHI) values (0.05 to 0.75) of the reservoir units suggest high hydrocarbon potential and a reservoir System whose performance is considered satisfactory for hydrocarbon production. Ihianle et al. (2013) used three dimensional seismic/well logs to carry out the structural interpretation over 'X – Y' field in the Niger Delta area of Nigeria. The seismic section and structure map revealed fault assisted closures at the center of the field, which correspond to the crest of rollover anticlines and which served as the trapping medium. The estimated volume of hydrocarbon in place within the interval ranging from 3,909.06m (12,825ft) to 4,053.84m (13,300ft) was calculated as 289,227,007 bbl (37,281acre-ft) of oil. The study showed the feasibility of integrating borehole data and structural map in mapping reservoir fluid boundaries towards calculating the volume of hydrocarbon in place.

Adeoti *et. al.* [14] described the structural style and reservoir distribution in deep-water Niger Delta using data from well logs and 3D seismic. The results from the seismic interpretation and 35 well log data showed that in the inner fold and thrust belt synthesis of the structural province is characterized by complex; broad scale thrust cored anticlines and imbricates structures that are widely spaced. This spacing creates accommodation space for reservoir development. The analysis of the transition zone reveals that the structural province is typified by large areas of little or no formation. From the findings, it was inferred that shallow reservoirs have higher porosity and permeability than reservoirs that are emplaced deeper stratigraphically.

Integrated 3D seismic and petrophysical data was employed by Edigbue *et. al.* [15] to evaluate hydrocarbon of 'Keke' field in the Niger Delta. Two sand units (S1 and S2) which existed between 9127ft and 11152ft were correlated and mapped using gamma ray log. The results obtained from the analysis of this field shows that the trapping mechanisms and the petrophysical parameters in 'Keke' field are favourable for hydrocarbon accumulation.

The objective of this study is to characterize the reservoirs identified in the study area and carry out detailed petrophysical analysis

2 MATERIALS AND METHODS

2.1 Dataset

The data set employed for this work are Well log (Well 1 and Well 7) and 3D seismic data. The suite of well logs consists of gamma ray, resistivity, density and neutron logs of two exploratory wells while the seismic data set comprises of both inline and cross line sections. The data were obtained from Shell Petroleum Development Company, Nigeria. The software package used for the analysis of data is Schlumberger Petrel 2014.1.

2.2 Method

Interpretation of the well-logs and seismic data were done using Schlumberger's Petrel "seismic-to-simulation" interpretation software. The software was used to carry out details of well log analysis, seismic data interpretation, synthetic seismogram generation, map construction and several 2D and 3D graphic presentations of the results.

Permeable zones (sands) were differentiated from non-permeable zones using GR, and Neutron/Density logs. Based on this, tops and bases of Reservoir sands were delineating in all the two wells. Hydrocarbon-bearing intervals were discriminated from water-bearing intervals using the resistivity logs (especially deep resistivity).

Well log correlation was done with the integration of

Gamma Ray, Resistivity, Neutron and Density logs. Various hydrocarbon bearing reservoirs were identified and correlated in the two wells.

The seismic datasets available for this study were loaded into Petrel 2014.1 and the quality check to make the most use of the information provided. Check shot data were used to correct for anomalies from the sonic log, which was then employed to produce a synthetic seismogram that was then used to create a seimic-to-well tie, providing special correlation, according to Qin and Fu [16], of the reservoir unit of interest.

The horizon that was mapped across both crossline and inline are used with fault polygon to generate time structure maps for the top and base of the reservoirs. The available checkshot data were used for converting the time structural map to depth structural map. The checkshot data are utilize for reservoir tops in the PFD field. The area extent of the reservoirs is determined from the depth structural maps.

Faults were mapped in PFD. Horizons were selected and mapped following detailed seismic analysis. They were mapped on the in-lines and crosslines across the study area. These mapped surfaces depict the geometrical configuration of the stratigraphic surfaces displayed as seismic density grids. The density grids of the horizons were used to generate the time surface maps, which gave the representation of the subsurface geology.

Petrophysical analysis were carried out to evaluate the quality of the reservoir parameters. Volumetric calculations were done to determine the volume of recoverable hydrocarbon within the field.

2.2.1 Evaluation of Petrophysical Parameters

Certain petrophysical parameters were evaluated to aid in the characterization of the delineated reservoirs.

2.2.1.1 Shale Volume Estimation (V_{Sh})

Shale volumes were evaluated using both gamma ray and neutron/density curves.

Estimating the gamma ray index is the initial step taken in a bid to calculate the volume of shale in any given fiormation. According to Schlumberger [17],

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

The volume of shale is a very important parameter in reservoir evaluation. It is expressed as shown in the Larionov [18] equation expressed in equation 2. Larionov method was chosen as an estimating tool in this case since it provides relatively acceptable estimates for Tertiary Niger Delta rocks [19]. According to Larionov.

$$V_{Sh} = 0.083 \times (2^{(3.7 \times I_{GR})} - 1) \tag{2}$$

Where;

I_{GR}= Gamma ray index

V_{Sh}= Volume of shale

GR_{log}= Gamma ray log reading in the formation of interest

GR_{min}= Minimum gamma ray reading (clean sand or carbonate)

GR_{max}= Maximum gamma ray reading (shale)

2.2.1.2 Porosity Estimates

The determination of porosity is paramount because it determines the ultimate volume of a rock type that can contain hydrocarbons. The value and distribution of porosity, along with permeability and water saturation, are the parameters that dictate reservoir development and production plans [20].

The effective porosity was then deduced by introducing shale volume into the equation, since most of the reservoirs in the Niger Delta is an intercalation of sandstone and shale [6, 21].

$$\phi_T = \frac{\rho_{matrix} - \rho_{bulk}}{\rho_{matrix} - \rho_{fluid}} \tag{3}$$

$$\phi_{Sh} = \frac{\rho_{matrix} - \rho_{shale}}{\rho_{matrix} - \rho_{fluid}} \tag{4}$$

$$\phi_e = \phi_T - (\phi_{Sh} \times V_{Sh}) \tag{5}$$

Where;

ρ_{matrix}= Matrix density (2.65gcm^{-3} for sandstone)

ρ_{fluid}= Fluid density (Density log readuing in a zone of 100% water saturation

ρ_{bulk}= Density log reading in the zone of interest

ϕ_T = Total porosity in the zone of interest

ϕ_{Sh}= Total porosity in shale

ϕ_e= Effective porosity in the zone of interest

2.2.1.3 Water Saturation Estimates

In order to estimate water saturation, formation water resistivity (R_w) needs to be estimated. R_w is usually estimated in a clean water-bearing interval (water leg) using deep resistivity reading, $S_w = 1$ and the computed porosity (ϕ). However, deep resistivity (R_t) and ϕ (porosity) may vary widely within the water-bearing zone making it difficult to get single values of R_t and ϕ. For this reason, a double logarithmic plot of R_t against ϕ is generally used to estimate R_w. R_w is the intersection on the R_t axis of a best fit line produced from the plot. The plot is commonly referred to as "Picket plot". In this study, a Picket plot was used in estimating R_w from water-bearing interval. Therefore, S_w was then estimated using the computed R_w and ϕ via Archie's equation; local correction factor or tortuosity factor (a) of 1 was assumed; saturation exponent (n) of 2 was also assumed; and cementation exponent (m). These values commonly apply to reservoirs in this field [22].

Effective water saturation was estimated using the modified Simandoux equation, which has been shown to provide relatively good estimates for shaley-sands [23] like those in a typical Niger Delta reservoir, by taking cognizance of volume of shale (V_{Sh}). The equations used are highlighted below:

$$S_w = \frac{aR_w}{2\phi^m}\left[\sqrt{\left(\frac{V_{Sh}}{R_{Sh}}\right)^2 + \frac{4\phi^m}{aR_wR_t}} - \frac{V_{Sh}}{R_{Sh}}\right] \tag{6}$$

2.2.1.4 Hydrocarbon Saturation Estimates

Assuming that hydrocarbon or water were the only fluids present in the pore space of the delineated reservoir rock [24], hydrocarbon saturation (S_H) was obtained from equation 7

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

3 RESULTS

The results obtained for this research are shown below;

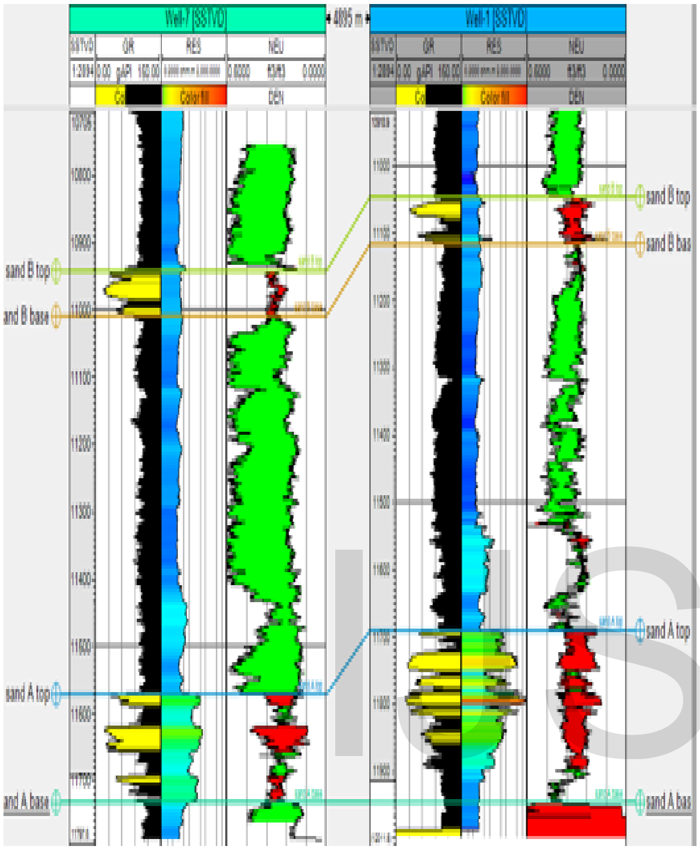

Fig. 1: Well Log Correlation Showing 2 Reservoir Sand

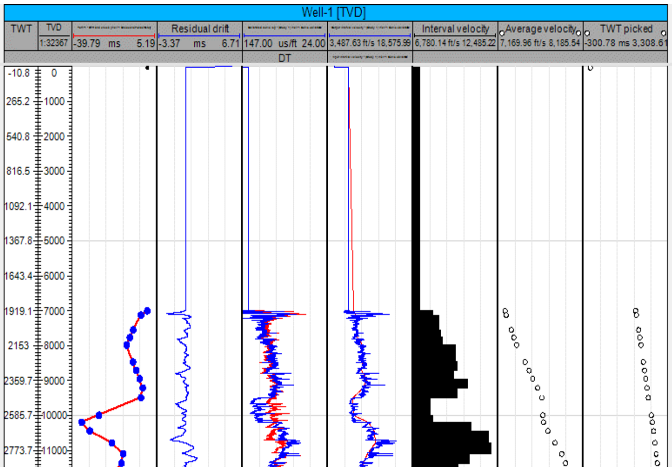

Fig. 2: Sonic Log Calibration using Check Shots

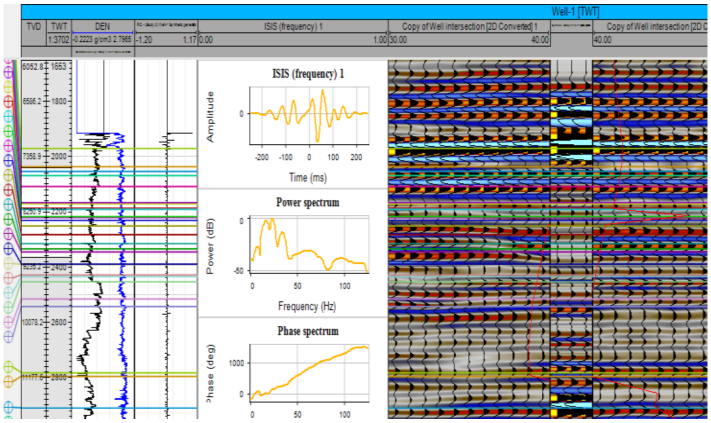

Fig. 3: Synthetic Seismogram

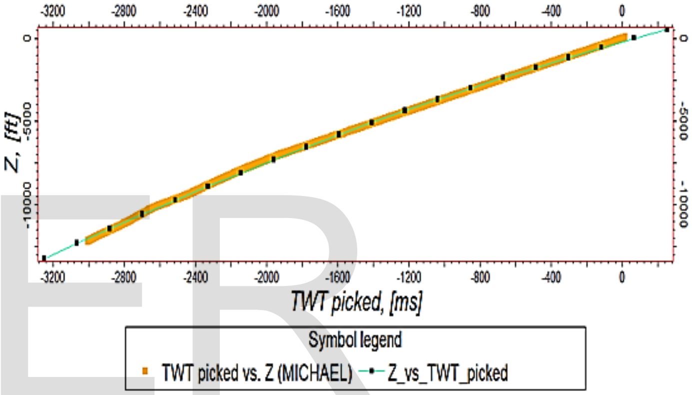

Fig. 4: Time-Depth Relationship

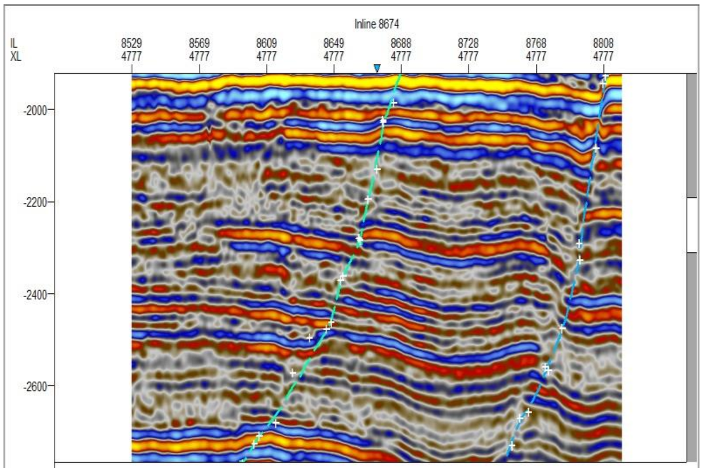

Fig. 5; Modelled Faults and Collapsed Crestal Structure (Crossline) in PFD Field

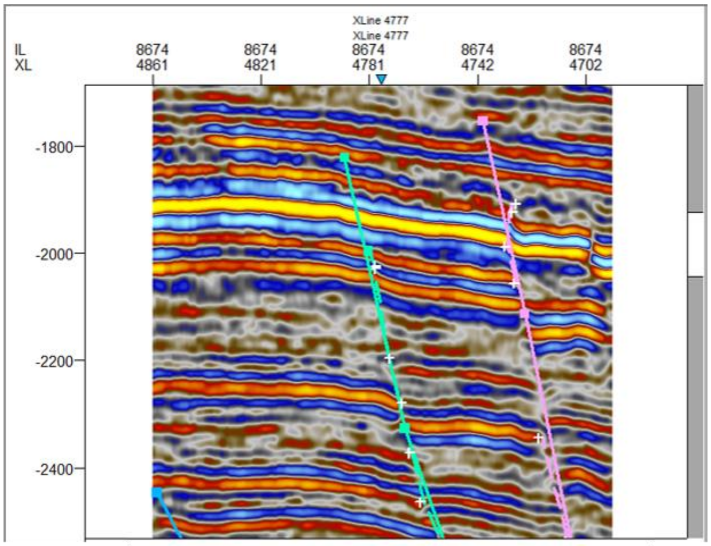

Fig. 6: Modelled Faults and Collapsed Crestal Structure (Inline) in PFD Field

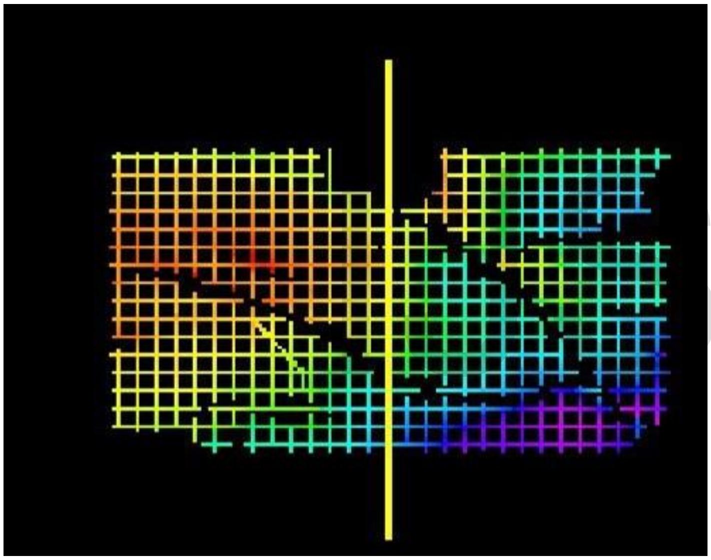

Fig. 7: Modelled Seismic Grids Showing Interpreted horizons and Faults

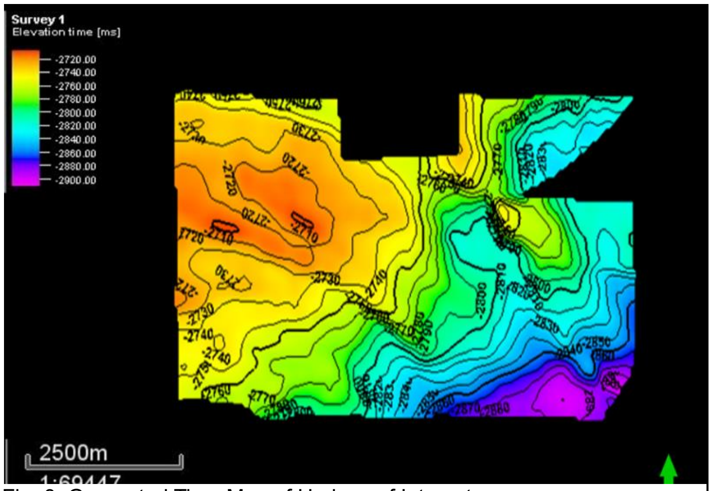

Fig. 8: Generated Time Map of Horizon of Interest

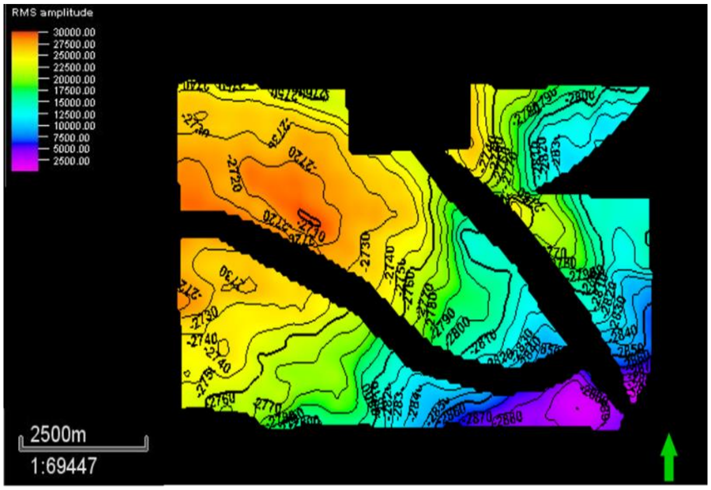

Fig. 9: Generated Time Map of Horizon of Interest

Table 1: Petrophysical Parameters of PFD Field

Wells	Volume of Shale (Fractional)	Effective Porosity (Fractional)	Water Saturation (Fractional)	Hydrocarbon Saturation (Fractional)
Well 1	0.01 – 0.53	0.08 – 0.30	0.17 – 1.00	0.00 – 0.83
Well 7	0.02 - 0.47	0.04 - 0.20	0.27 - 1.00	0.00 -0.73

4 DISCUSSIONS

Data from well log and 3D seismic have been analysed during this study to characterize and carry out a petrophysical analysis within the field of study. Well log correlation, Fig. 1, led to the identification of 2 sandstone potential hydrocarbon reservoirs at 10945-11115ft and 11570-11935ft. Upon further investigation, the resistivity log revealed that the deepest reservoir is more likely to be hydrocarbon bearing due to the high resistivity reading [25].

Synthetic seismogram was generated using WELL 1. The generated synthetic seismogram (Fig.3) showed a near perfect tie with over 90% confidence limit between the generated synthetics and the original seismic. The reservoir tops corresponded to positive amplitudes and is represented by the peaks, while the reservoir bases corresponded to negative amplitudes.

Identification of prominent features such as major and minor faults and horizons were found on the seismic section's interpretation (Fig. 5 & 6). The Faults were mapped in the inline and crossline directions. Seismic reflections which corresponded to top of main reservoir sands are also identified on seismic data for mapping.

The synthetic seismogram led to the development of a time-depth relation (Fig. 4) that was used to convert the generated time map (Fig. 8) to a depth map (Fig. 9). The reservoir of interest was shown to be continuous across the field of study.

Petrophysical parameters were calculated for the deepest correlated reservoir unit for two study wells (WELL 1, WELL 7). The reservoir parameters estimated include volume of shale, fractional effective porosity, fractional water saturation and fractional hydrocarbon saturation. The range of these estimated properties is shown in Table 1, with values depicting those of a typical Niger Delta reservoir rock [6, 26, 27].

5 CONCLUSIONS

Well log and 3D seismic data were analysed to characterize and make estimates of petrophysical parameters in a field in the Niger Delta region. Petrophysical parameters estimated included fractional volume of shale, fractional effective porosity, fractional water saturation and fractional hydrocarbon saturation. The following conclusions were arrived at;

i. The reservoir rock of interest existed at depths of 11570-11935ft.
ii. This reservoir rock is continuous, with major and minor faults across the field of study.
iii. A fraction, estimated to have a range between 0.04-0.53, of the reservoir rock was made up of shale as indicated by the estimated volume of of shale.
iv. A fraction, estimated to have a range between 0.04-0.30, of the reservoir rock was made up of void spaces as indicated by the estimated effective porosity.
v. A fraction, estimated to have a range between 0.17-1.00, of these void spaces were occupied by water as indicted by the estimated water saturation.
vi. And finally, a fraction, estimated to have a range between 0.00-0.83, of these void spaces were potentially occupied by hydrocarbon as indicted by the estimated hydrocarbon saturation.

REFERENCES

[1] Darling, T., *Well logging and formation evaluation*. 2005: Elsevier.

[2] Nwiyor, P.S., E.D. Uko, I. Tamunoberetonari, A.R.C. Amakiri, and O.A. Davies, *Wireline Log Petrophysical Characterization of Selected Reservoirs in Zeta field, Niger Delta, Nigeria.* International Journal of Scientific and Research Publications, 2021. 11(10): p. 82-87.

[3] Worthington, P.F. and L. Cosentino, *The role of cut-offs in integrated reservoir studies.* SPE Reservoir Evaluation, Engineering and Technology Journal, 2005. 8(04): p. 276-290.

[4] Asquith, G.B., D. Krygowski, and C.R. Gibson, *Basic well log analysis*. Vol. 16. 2004: American association of petroleum geologists Tulsa, OK.

[5] Okwoli, E., D. Obiora, O. Adewoye, J. Chukudebelu, and P. Ezema, *Reservoir Characterization and Volumetric Analysis of " LONA" Field, Niger Delta, using 3-D Seismic and Well Log Data.* Petroleum & Coal, 2015. 57(2): p. 108-119.

[6] Davies, O.A., C. Israel-Cookey, E.D. Uko, and M.A. Alabraba, *Reservoir Capacity and Injectivity Characterization for Carbon Dioxide (CO_2) Geo-Sequestration in the Niger Delta.* International Journal of Research and Innovation in Applied Science, 2020. 5(10): p. 19-26.

[7] Davies, O.A., C. Israel-Cookey, D.H. Davies, and P.S. Nwiyor, *Permeability Modelling of a Sandstone Reservoir in Parts of the Niger Delta.* Asian Journal of Applied Science and Technology, 2019. 3(3): p. 73-89.

[8] Egbai, J.C. and C.O. Aigbogun, *Mathematical Modelling of Petrophysical Parameters for Reservoir Characterization using Well Log Data.* Advancement in Applied Science Research, 2012. 3(2): p. 656-670.

[9] Abe, S. and M. Olowokere, *Reservoir Characterization and Formation Evaluation of Some Part of Niger Delta Using 3D Seismic and Well Log Data.* Research Journal in Engineering and Applied Sciences, 2013. 2(4): p. 304-307.

[10] Abraham-Adejumo, R. M., *Well correlation and Petrophysical analysis, a case study of "Rickie" field onshore Niger Delta.* The International Journal of Engineering and Science, 2013. 2(12): p. 94-99.

[11] Adewoye, O., J. Amigun, E. Okwoli, A.J.P. Cyril, and Coal, *Petrophysical and structural analysis of maiti field, Niger Delta, using well logs and 3-D seismic data.* Petroleum & Coal, 2013. 55(4): p. 302-310.

[12] Amigun, J. and N. Bakare, *Reservoir evaluation of "Danna" field Niger delta using petrophysical analysis and 3D seismic interpretation.* Petroleum & Coal, 2013. 55(2): p. 119-127.

[13] Amigun, J.O. and O.A. Odole, *Petrophysical properties evaluation for reservoir characterisation of Seyi oil field (Niger-Delta).* International Journal of Innovation and Applied Studies, 2013. 3(3): p. 756-773.

[14] Adeoti, L., N. Onyekachi, O. Olatinsu, J. Fatoba, and M. Bello, *Static reservoir modeling using well log and 3-D seismic data in a KN field, offshore Niger Delta, Nigeria.* International Journal of Geosciences, 2014. 5: p. 93-106.

[15] Edigbue, P., A. Komolafe, A. Adesida, and O. Itamuko, *Hydrocarbon reservoir characterization of 'Keke'field, NIGER Delta using 3-D seismic and petrophysical data.* American Journal of Scientific and Industrial Research, 2014. 5(2): p. 73-80.

[16] Qin, N. and L.-Y. Fu, *Reliability measurement of joint seismic inversion based on seismic-to-well correlation.* Exploration Geophysics, 2013. 44(2): p. 87-103.

[17] Schlumberger, *Log Interpretation*. Vol II: Applications. 1974, Houston: Schlumberger Well Services, Inc.

[18] Larionov, V., *Borehole Radiometry*. Nedra, Moscow, 1969. 127: p. 813.

[19] Oyedele, K., T. Omeru, O. Ogbe, W. Ifarajimi, and J. Oni, *Reservoir Characterization and Volumetric Analysis of Roan Field, Niger Delta, Nigeria.* Tropical Journal of Applied Natural Sciences, 2019. 2(3): p. 18-30.

[20] Seyyedattar, M., S. Zendehboudi, and S. Butt, *Technical and non-technical challenges of development of offshore petroleum reservoirs: Characterization and production.* Natural Resources Research, 2020. 29(3): p. 2147-2189.

[21] Short, K. and A. Stauble, *Outline of geology of Niger Delta.* AAPG bulletin, 1967. 51(5): p. 761-779.

[22] Davies, O.A., D.H. Davies, and P.A. Ngeri, *Comparative Analysis of Porosity Estimates in a Sandstone Reservoir: The Niger Delta as Case Study*. Journal of Scientific and Engineering Research, 2018. 5(11): p. 102-111.

[23] Shahrina, R.J.R.K., A. Sideka, A. Agia, R. Junina, M.Z. Jaafara, and H. Ariffinc, *Comparison of Water Saturation Models Based on Well Logging Data: A Case Study of MX Field in Malay Basin.* Jurnal Kejuruteraan, 2022. 34(1): p. 101-108.

[24] Dandekar, A.Y., *Petroleum reservoir rock and fluid properties*. 2013: CRC press.

[25] Horsfall, O.I., D.H. Davies, and O.A. Davies, Hydrocarbon Reservoir Characterization Using Well Log in Niger Delta Basin of Nigeria. Interternational Academy of Science, Engineering and Technology (IJANS), 2015. 4(5): p. 55-64.

[26] Akpan, M.O., M.U. Udoh, A. Avwunudiogba, and D.O. Iyang,

Depositional environment and petrophysical characteristics of "XY" reservoir sands, Niger Delta, Nigeria. International Journal of research for science and computational engineering, 2016. 2: p. 108-115.

[27] Eze, M., A. Mode, and C. Ugbor, Formation evaluation of X7 field in the Niger Delta: evidence from Petrophysical data. Niger Delta, Nigeria. Journal of Applied Geology and Geophysics, 2013.