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Seismic Interpretation and Petrophysical Analysis for Evaluation of Ataga Field, Onshore Niger Delta, Nigeria

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ABSTRACT: The majority of geophysical survey in hydrocarbon exploration and production sector is driven by the ability to describe reservoirs. This research is aimed at describing the interpretation and petrophysical analysis of the reservoirs in Ataga field Niger Delta using a combination of seismic and well-log data. The Ataga Field in the Niger Delta was subjected to 3-D seismic interpretation and petrophysical study to perform comprehensive structural interpretation, prospect evaluation, and volumetric calculation. Two reservoir windows "1" and "2" were identified and correlated from four wells ATA 10, ATA 11, ATA 5 and ATA 7. Detailed evaluation was done on well ATA 11 since it is the only well that has sufficient data for both qualitative and quantitative interpretation. Structural interpretation for inline 5731 revealed fifteen faults on the seismic vertical section through ATA 11, most of which are antithetic faults while the rest are synthetic faults. Top and base of each reservoir window was delineated from the well. Result of the petrophysical assessment of reservoir A, B and C for ATA 11 revealed that the porosity values range from (24 - 29) % which are indicative of very good to excellent porosity value according to Rider (1996). While the permeability values range from (1887-2582) mD were obtained from the three reservioir A, B and C of ATA 11 which depict very good to excellent reservoir units. Since, .all of the wells were discovered to have hydrocarbon-bearing reservoir formations (sandstones), the integration of structural interpretation and well logs have successfully revealed that the reservoirs are mostly oil-bearing zones.

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With multiple world-class oil finds, the Niger Delta area has a history of generating substantial hydrocarbons. The Niger Delta is one of Africa's most producing basins, with six depobelts (OPEC 2017). Thick sedimentary deposits and significant geologic features have been maintained in the basin, making it ideal for petroleum creation, migration, and entrapment from the onshore to the continental shelf and deep-water terrains. It is the largest basin on the West African continental coast, and it is home to some of the world's most productive deltaic oil and gas fields. It has been verified and estimated that recoverable reserves of around 37,452 million barrels of oil (OPEC, 2017) and 5.1 trillion cubic metres of gas resources could be found in Niger Delta hydrocarbon province (Akindeji, 2018). tFrom prospect evaluation to field development, an oil and gas field goes through several stages. The initial stage of the process is prospect evaluation, which has the least quantity of information and thus the most uncertainty (Fajana, *et al*, 2019; Emujakporue, *et al*., 2012). Seismic and well-log data are also commonly employed to map the subsurface in petroleum exploration. Seismic profiles offer a nearly continuous lateral image of the subsurface, whereas well-logs provide precise vertical resolution of the geology at

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the borehole (Singh, *et al*., 1997). Seismic profiles can resolve structural and strinatigraphic changes from reflection event arrival times and amplitudes with a high degree of precision. Reflection seismic interpretation has involved the examination of seismic properties for more than two decades. Seismic features can help with structural and stratigraphic interpretation, as well as give suggestions regarding formation type and fluid content estimation, at the same time while providing complete reservoir characterization. The vertical resolution of the subsurface is constrained by the bandwidth of seismic data. For detecting subtle traps, high-frequency data is required. Furthermore, anomalous seismic occurrences cannot be explained solely in terms of geology variables. In both regards, well-logs can aid in the interpretation of seismic profiles, as they can unequivocally offer a high-resolution estimate of many important geologic variables at the borehole level. As a result, combining well-log and seismic data to map subsurface structural and stratigraphic plays would yield a high level of accuracy. It will also provide information on the volume of reservoir hydrocarbons, which can be used in exploration and wellbore planning (Barde, *et al*., 2002; Adejobi and Olayinka, 1997). Time is often used to record the main geophysical seismic data. Meaningful interpretation, on the other hand, requires a thorough presentation. The main goal of geophysical seismic interpretation is to create contour seismic maps that indicate the two-way time to a reflector as determined by the seismic sections. A seismic time-depth conversion technique must be used to transform this time map into a depth map. The average velocity information from well-logs and check shot data is typically used in the depth conversion process. The combination of geology and 3D seismic data could help solve some of the issues with recognizing facies and structural elements (Alao, *et al*., 2013a; Singh, *et al.*, 1997). Similarly, Aizebeokhai and Olayinka (2011) believe that the integration of seismic and well data interpretations is required for qualitative evaluation of hydrocarbon resources. Several academics have researched hydrocarbon exploration. In a similar vein, Adeoye and Enikanselu (2009) found that combining log-derived reservoir properties with seismic data and structural interpretation allows an interpretation team to quantify subsurface hydrocarbon accumulations, generate prospects and leads, classify petroleum resources, determine the probability of success, rank resources, plan future wells, reduce exploration and drilling risks, and increase the success rate for drillable prospects. When 3D seismic data is combined with well log data, Onayemi and Oladele (2014) established that a powerful tool for evaluating the structural framework and estimating a field's reserves is generated. As a result, utilizing an integrated technique of seismic data and a well log approach. The objective of this paper is to describe the interpretation and petrophysical analysis of the reservoirs in Ataga field at onshore Niger Delta, Nigeria using a combination of seismic and well-log data.

METHODS AND METHODS

Materials used for this study are well-logs suites, 3D seismic data, base maps, and the check shot data of selected wells within the study area, and work flow chart for this study is illustrated in Fig. 1.

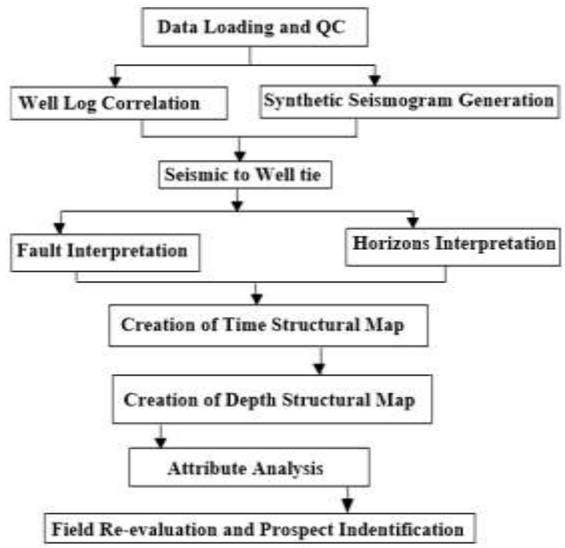

Fig.1. Workflow chart for the study.

Well-log Correlation: To differentiate between the two major lithology types (i.e. sand and shale) dominating in the Niger Delta, the litho-stratigraphic correlation was performed using four accessible gamma-ray logs (ATA 5, ATA 7, ATA 10, and ATA 11). The seismic data gathered for this study was interpreted using the PETREL software. In the well and seismic data processing, the following processes were used: data quality check loading, well-log correlation, lithology identification, and hydrocarbon-bearing zone identification.

Seismic data Interpretation: Horizons and faults were identified and mapped as part of the seismic data interpretation. Through seismic to well tie, the reservoir sands identified on the well-logs were traced on the seismic sections. On the seismic sections, this was done to outline the exact position, lateral extent, and shape of the reservoirs. On the inline and cross-line seismic sections, the reservoir tops and bottoms on the logs were traced. On the base map, the times that corresponded to the horizons were chosen and posted. Fault interpretation, horizon interpretation, and finally seismic structural maps were constructed to analyze the geometry of the mapped horizons employed for seismic data interpretation. This was done in order to locate structural traps or closures around fault blocks.

Seismic Attribute Analysis: Channel and deltaic sands, lithology, and hydrocarbon/fluid accumulations can all be identified using surface seismic amplitude data. A thin bed tuning effect and/or fluctuations in net sand in a bed can cause amplitude anomalies (Muhammad, et al., 2015). A post-stack surface seismic feature is the Root Mean Square (RMS) amplitude. The RMS amplitudes are sensitive to sand-bearing depositional systems and aid in the identification of genetically related depositional successions. RMS amplitude maps of this type can lead to the discovery of previously undiscovered prospect leads in an exploration concession. A RMS amplitude map was created within the Niger Delta for this study, as shown in Fig. 7. RMS characteristic was used in this study (Shakhawat, 2020), which is a post-stack attribute that divides the number of samples within the selected windows by the square root of the sum of squared amplitudes.

Table 1: Qualitative Interpretation of Porosity and Permeability Respectively (Rider, 1996, Osisanya et al., 2021)

Porosity Percentage (%)	Qualitative Interpretation	Permeability Values (mD)	Qualitative Interpretation
0 – 5	Negligible	< 10-5	Poor to Fair
5 – 10	Poor	15-50	Moderate
15 – 20	Good	50-250	Good
20 – 25	Very good	250-1000	Very good
Over 30	Excellent	>1000	Excellent

Hydrocarbon Volume Estimation: The area extent of the reservoir is required to calculate the volume of hydrocarbon in place, but due to lack of seismic data, the values obtained will be in barrels per acre (bbl/acre) (Osisanya et al., 2021, Ochoma, et al., 2020). As a result, equation 1 gives the volume of original oil in place (OOIP) for an oil reservoir as shown in equation 1 and 2.

$$OOIP = \{7758 \times h \times \emptyset \times (1 - S_w)\} bbl/\text{acre} \quad 1$$

As proposed by Udegbunam, and Ndukwe, (1988); Ochoma, et al., (2020)

$$STOOIP = \frac{7758 \times h \times \emptyset \times (1 - S_w)}{B_{oi}} \text{ bbl/acre} \quad 2$$

Where B_{oi} = 1.2bbl/STB as proposed by Osisanya et al., 2021

Where h = thickness of the reservoir (in feet); Ø = Effective porosity (in frac.); NTG = Net to Gross ratio (in frac.); S_W = Water saturation (in frac.); B_{oi} = Formation Volume Factor

RESULT AND DISCUSSION

Petro physical Evaluation of Reservoirs: The petro physical evaluation of the reservoir units forms a qualitative approach of interpreting the well logs. The logs were used to determine the petro physical parameters of each reservoir across the wells. All computations were done using relevant equations and the results obtained for the reservoirs from each of the wells are presented.

Well-log interpretation and correlation: Preliminary well log analysis resulted in the identification of a large hydrocarbon bearing reservoir. Fig. 2 depicts the findings of the well-logs correlation that linked the four wells in the survey region. The correlation analysis was conducted using the Gamma-ray, resistivity, and sonic-logs characteristics. These were collected in order to approximate reservoir parameters using log interpretation. The logs were used to identify lithologic units, which were then compared across wells. The lithologic units were found to have a general lateral continuity over the field, as evidenced by stratigraphic trends. All of the wells were discovered to have hydrocarbon-bearing reservoir formations (sandstones). The combination of resistivity, porosity, and density logs demonstrated that the reservoirs are mostly oil-bearing zones.

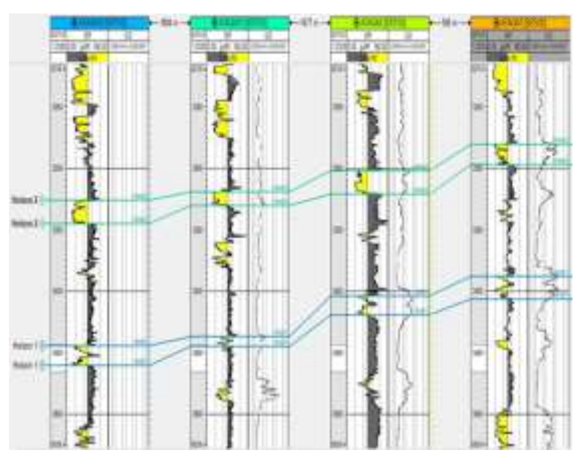

Fig. 2: Well correlation across ATA 10, ATA 11, ATA 5 and ATA 7.

Seismic to well tie interpretation: According to Alao et al. (2013b), seismic to well tie demonstrated that the hydrocarbon-bearing reservoir is linked to a direct hydrocarbon indicator (bright spot) on seismic sections. As illustrated in Fig. 3, the seismic calibration is based on a synthetic seismogram utilizing ATA 11 sonic and density logs with checkshot data from the same well. On the bright point, the horizon selecting process began. The tie was crucial in determining which vistas matched Reservoir B's top and bottom.

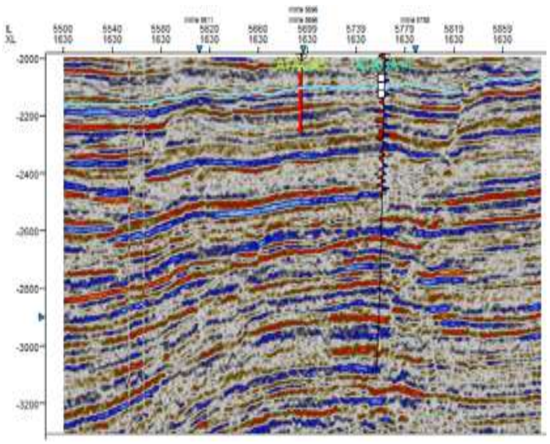

Fig. 3: Seismic section showing synthetic seismogram tying with well ATA 11

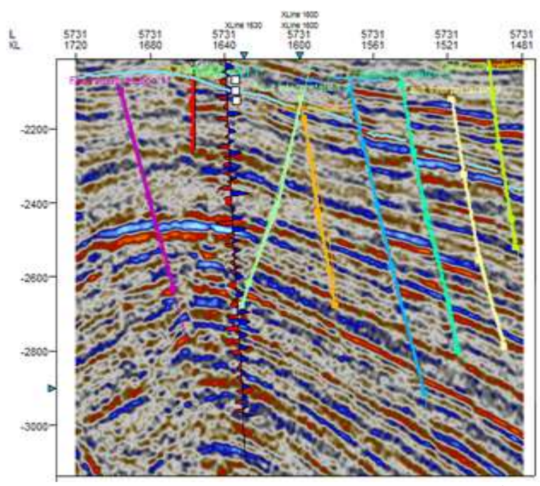

Fig. 4: The vertical section through ATA 11 showing the faults and mapped horizon

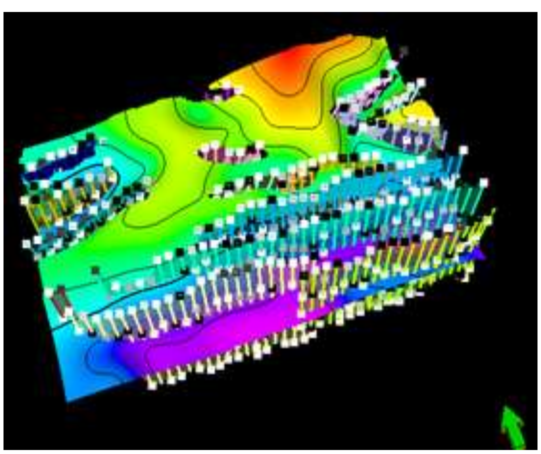

Fig. 5: 3-D window showing the fault interpretation on the structural map

Faults and Horizon Interpretation: As illustrated in Figures 4, 5, and 6, fault mapping was performed on the vertical seismic display across the seismic volume. The top and bottom of the Reservoir B horizon in ATA11 were interpreted and mapped with respect to seismic continuity and well correlation. The majority of the faults were antithetic, whereas the rest were synthetic. There were 39 in-lines in the seismic data and 24 cross lines. A total of 8 faults picked on the inline, 6 faults were synthetic while 2 faults were antithetic. The structural deposition of the mapped horizon substantially favors hydrocarbon accumulation, and the good reservoir parameters collected from the well indicate that the field's economic viability is high.

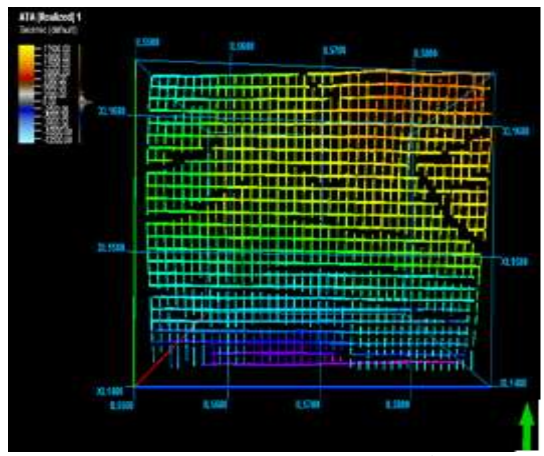

Fig. 6: 3-D window showing the mapped horizons for Reservoir B

Map Generation: As shown in Fig. 7, the structural map depicted the temporal structural map obtained from the mapping of horizons and faults in Reservoir B on the 3-D seismic section.

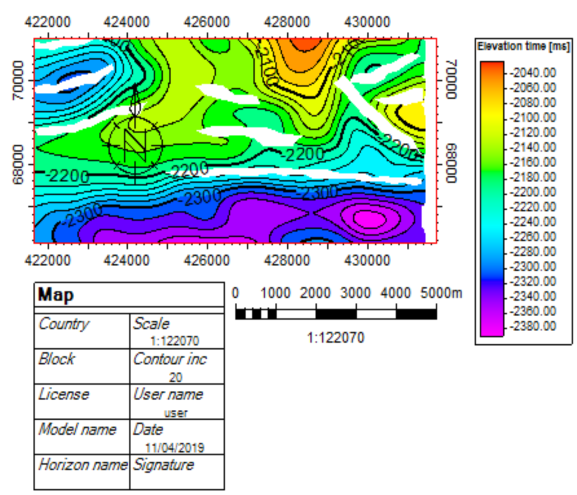

Fig. 7: Time Structural map generated from the mapped horizon of Reservoir B

Seismic Attribute Interpretation: The mapped horizon's Root mean square amplitude exhibited a high amplitude and bright spot area around the structural highs but did not reflect with the well locations, as shown in Fig. 8.

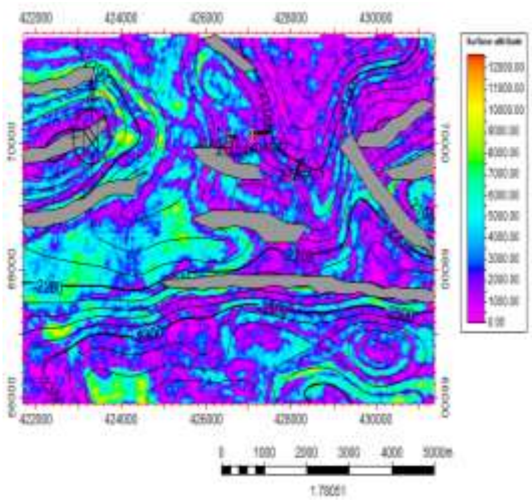

Fig. 8: Amplitude attribute map of Reservoir B

Petrophysical Analysis: The petrophysical characteristics of these reservoir sand bodies indicate that they have good reservoir characteristics. The reservoir A, B, and C sand units were discovered to have porosities ranging from very good to outstanding, as well as high permeability (> 1 darcy) and a high hydrocarbon saturation index, indicating that they have a high ability to host hydrocarbon (Fig. 9, 10, and 11 respectively). According to Osisanya et al., (2021) categorization of porosity, the porosity value obtained across the well within three pay zones gives a very good to excellent rating (table 1). While the high permeability value reported in pay zones implies that the well would allow free flow of fluid within the reservoirs, this is in line with a study conducted by Fajana, et al (2019). The hydrocarbon saturation level indicates that there is a significant proportion of hydrocarbon in the reservoirs compared to the amount of water. Tables 2, 3, and 4 show the petrophysical parameters for ATA 11 well. Reservoir B had a capacity of 221 thousand barrels of oil when it was first discovered.

Prospect Identification: According to Obiadi et al (2012) Futalan et al., (2012); the Akata Shale source rock, which are thick marine shales deposited at the Delta's base in an oxygen-depleted environment, is present in large volume beneath the Agbada Formation (main reservoir unit) and is at least volumetrically sufficient to generate enough hydrocarbon for a world-class province like the Niger Delta (1999). Ekweozor and Okoye, (1980) reported that Total Organic Carbon (TOC) readings for the Akata source rock range from 0.4 % to 14.4 %. The well-logs horizons selected at the top of the plotted reservoirs, and seismic data were used to create a synthetic seismogram. The synthetic seismogram and the seismic data were found to have a strong connection. Throughout the seismic volume, faults marked by abrupt termination and dislocation of the reflection pattern were found and analyzed. The selected horizons were mapped throughout the seismic volume as well. Horizon/structural maps were created for the mapped horizons, and check-shot data was used to convert time to depth. The horizon/structural maps were used to extract the seismic (amplitude) characteristic. The reservoir is characterized by quite large amplitudes in some regions, according to a seismic amplitude attribute map generated from the top of the mapped Reservoir B. As a result, three (3) potentials in the Ataga Field were identified.

Table 2: Showing the calculated petrophysical parameters for Reservoir A

Well	Start MD	GR	Porosity	Vsh	eff Porosity	Sw	F	Swirr	Permeability	Sand Thickness	HV
ATAGA11	3509.03	58.37	0.2542	0.2605	0.2013	0.37919	11.6	0.0073751	2121.712	3.05	73636.94
ATAGA11	3513.61	46.6	0.2923	0.1003	0.2636	0.19384	7.34	0.060458	2582.428	4.21	103850.7

Table 3: Showing the calculated petrophysical parameters for Reservoir B

Well	Start MD	GR	Porosity	Vsh	eff Porosity	Sw	F	Swirr	Permeability	Sand Thickness	HV
ATAGA11	3560	37.31	0.2423	0.0539	0.2305	0.21816	11.06	0.073769	1887.11	12.26	256467.3
ATAGA11	3572.25	27.39	0.2641	0.0061	0.2626	0.26692	9.06	0.06709	2168.842	8.24	184621.1

Table 4: Showing the calculated petrophysical parameters for Reservoir C

Well	Start MD	GR	Porosity	Vsh	eff Porosity	Sw	F	Swirr	Permeability	Sand Thickness	HV
ATAGA11	3597.92	25.79	0.2775	0.0009	0.2747	0.13113	8.25	0.064151	2316.757	5.12	118415.4
ATAGA11	3603.04	35.83	0.2776	0.0511	0.2587	0.4455	8.51	0.0655002	2290.837	9.49	219498

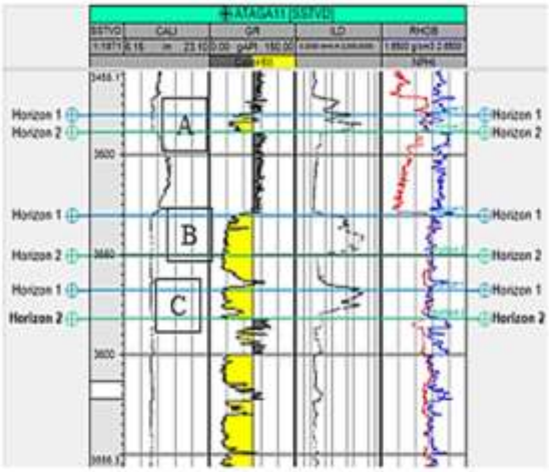

Fig. 9: Well Panel showing Reservoir A, B and C

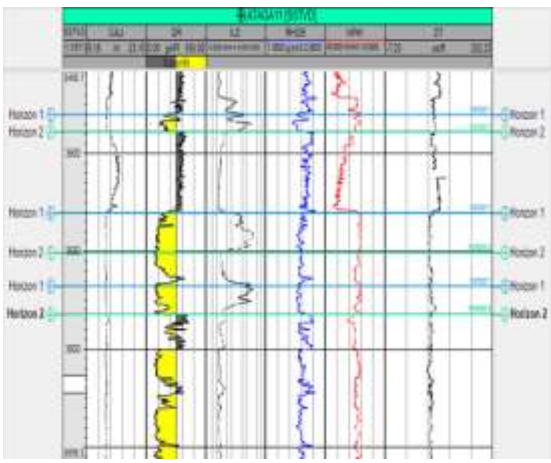

Fig. 10: Well section panel showing logs used for ATA 11 interpretation

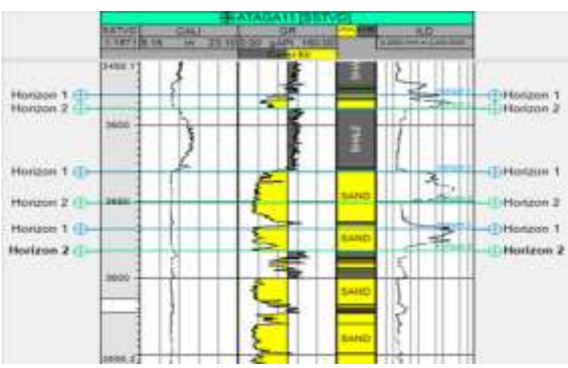

Fig. 11: Well panel showing the Lithofacies and the payzones in ATA1

Conclusion: Well-logs and seismic data were used to evaluate the Ataga Field in the Niger Delta basin. Log suites from wells ATA10, ATA11, ATA5, and ATA7 were used to perform well-log correlation and petrophysical analysis. Reservoir B's petrophysical measurements revealed that it has good reservoir characteristics for hydrocarbon accumulation. In structure and stratigraphic mapping, the combination of seismic data with well-logs has proven to be a helpful and valid tool. Three significant reservoirs were found from the well-log analysis, but only one was interpreted.

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