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Research paper

Reservoir characterization using integrated seismic attributes and petrophysical parameters in an onshore field of Niger delta basin

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Abstract

An integrated approach of reservoir characterization of a field was performed using seismic attributes and petrophysical parameters for the evaluation of subsurface geological features and hydrocarbon potential of an onshore field in Niger Delta Basin. Four reservoir intervals were identified within the field wells based on their position within the stratigraphic column, and the reservoir correlation, which was aided using the principle of uniform horizontality, based on the simple rule that sediments are deposited horizontally and basic understanding of sequence stratigraphy. The study revealed that, the four reservoirs were predominantly sand units intercalated with shale within the reservoir units. The petrophysical evaluation revealed the Net to Gross (NTG) values ranges from 79% to 87% within the reservoir units, while the effective porosity ranges from 17% to 21%, the permeability ranges between 1307mD to 1678mD across the reservoir units, while the water saturation ranges from the lowest of 35% (Reservoir C) to 78% in reservoir D. A total of fifteen faults were interpreted using the seismic data, while the surface maps (Time and depth surface maps) revealed the identified closures which are anticlinal structures that are fault dependent. The characterization of the reservoir was further enhanced using the seismic attributes (structural and stratigraphic) extracted such as Reflection intensity, Sweetness, Variance, Envelope, Instantaneous frequency, Time gain, Trace AGC, Local structural dip, Gradient magnitude and RMS amplitude. The results shows moderate to high sweetness (sweet spots) within the zone of interest, while the Envelope attribute show acoustic impedance contrasts indicating discontinuities, lithology changes and possible present of hydrocarbon (Bright spots). The variances and gradient magnitude enhanced the signal to map out discontinuities caused by faults and fractures which are signature that enabled delineation of the zone. The integrated approach validates the lithology discrimination of the elastic properties from the well logs and its effectiveness in optimizing and proper understanding of the subsurface, thus identifying and unmasking hidden features within the reservoir (probable bypass) in the field. The study has revealed that the integration of seismic attributes with petrophysical parameters is a better characterization method for fluid and lithology discrimination of a field in any given reservoir study.

Keywords: *Bright Spots; Root Mean Square; Reservoir Characterization; Seismic Attributes; Stratigraphic Column.*

1. Introduction

Surviving the current global oil crises, most oil and gas companies needs advance technology for a very careful and thorough evaluation of information obtained from the subsurface; evaluation of such information has gone beyond the use of well logs only but integrating the information analysis of conventional 2-D and 3-D seismic data. The information extracted from seismic data includes various seismic attributes which has proven to be a very useful tools in exploration and development of possible prospects. Seismic attributes extracted/obtained from seismic data have helps to better visualizes and quantify subsurface structures/features for interpretation purposes. Thus, extraction of seismic attributes from seismic data can therefore be said to be a better analysis technique needed to improve the accuracy of interpretations and predictions of hydrocarbon prospects as well as field development.

Seismic attributes allow the geoscientists to interpret faults and channels, recognize depositional environments and unravel structural deformation history. They are also useful in checking the quality of seismic data for artifacts delineation, seismic facies mapping, prospect identification, risk analysis and reservoir characterization. Seismic attributes provide a link between petrophysical properties and seismic data of the reservoir, which are directly or indirectly related to rock properties of the field. Seismic attributes evaluation involves the analysis of the subtle changes in properties of particular subsurface reflections in determination of the rock properties, including fluid content which assist in the creation of different geological models in a faster and reliable way (Taner, 1979). Seismic attributes have emerged to transform subjective and experienced based interpretation process into something less tedious and more objective. The use of seismic attributes has passed through periods of great proliferation and enthusiasm contrasting with moments of disuse and lost in credibility (Azevedo et al., 2012).

Amongst the first seismic attributes developed relative to the 1-D complex seismic trace includes envelope amplitude, instantaneous phase, instantaneous frequency, apparent polarity and acoustic impedance. Other attributes commonly used are coherence, azimuth, dip, instantaneous amplitude, instantaneous bandwidth, AVO and spectral decomposition (Ralph, 2009). For effective seismic attributes analyses, several attributes should be correlated to validate the end results of the feature of interest where the amplitude content within the seismic data effectively provides physical parameters about the subsurface such as acoustic impedance, reflection coefficients, velocities, and absorption effects which supply structural and stratigraphic details or act as direct hydrocarbon indicator (DHIs) (Taner, 1979). Seismic attribute falls into two broad categories which are those that quantify the morphological component of seismic data and those that quantify the reflectivity component of seismic data. The morphological attributes are applied to extract information on reflector dip and azimuth, which are used to determine to faults, channels, fractures, diapirs and carbonate buildups, while the reflectivity attributes extract information on reflector amplitude, waveform and variation with illumination angle, which can, in turn, used to determine subsurface lithology, reservoir thickness, and hydrocarbon prospects. While in the reconnaissance model, 3-D seismic attributes could be applied to delineate structural features and depositional environments. Whereas in reservoir characterization model, 3-D seismic attributes are calibrated against real and simulated well data to evaluate hydrocarbon accumulations and reservoir compartmentalization (Oyeyemi, 2015). This research work was borne out of the fact that there is a need to reduce exploration risk and uncertainties to their barest minimum in the industry, considering the financial cost effects on exploration activities,

2. Structural overview of Niger delta basin

Niger Delta is a large, arcuate delta of the typical, wave- and tidal-dominated type (Doust and Omatsola, 1990). It is located in the Gulf of Guinea on the margin of West Africa, at the southern culmination of the Benue trough and extends from about latitudes 4^0 to 6^0 N and longitudes 3^0 to 9^0 E (Opara et al., 2011). The delta formed at the site of a rift triple junction related to the opening of the southern Atlantic starting in the Late Jurassic and continuing into the Cretaceous as shown in Figure 1 (Tuttle et al., 1999). During the tertiary, it built out into the Atlantic Ocean at the mouth of the Niger-Benue river system, an area of catchment that encompasses more than a million square kilometers of predominantly savannah-covered lowlands (Weber and Daukoru, 1975). It ranks amongst the world's most prolific petroleum producing tertiary deltas that together account for about 5% of the world's oil and gas reserves (Opara et. al., 2011). The evolution of the Niger Delta is predominantly controlled by pre- and syn-sedimentary tectonics (Evamy et. al., 1978), the formations reflect a gross coarsening-upward progradational clastic wedge (Short and Stauble, 1967), which were deposited either in marine, deltaic, and fluvial environments (Weber, 1986), as accumulation of marine sediments in the basin probably commenced in Albian time, after the opening of the South Atlantic Ocean between the African and South American continents (Doust and Omatsola, 1990). The deposition of the three formations occurred in each of the five offlapping siliciclastic sedimentation cycles that comprise the Niger Delta, these cycles (depobelts) are 30-60 kilometers wide, prograde southwestward, 250 kilometers over oceanic crust into the Gulf of Guinea (Stacher, 1995). Five major depobelts are generally recognized which include the Northern, Greater Ughelli, Central Swamp, Coastal Swamp and Offshore depobelts (Figure 2), each with its own sedimentation, deformation, and petroleum history (Steele et. a.l, 2009).

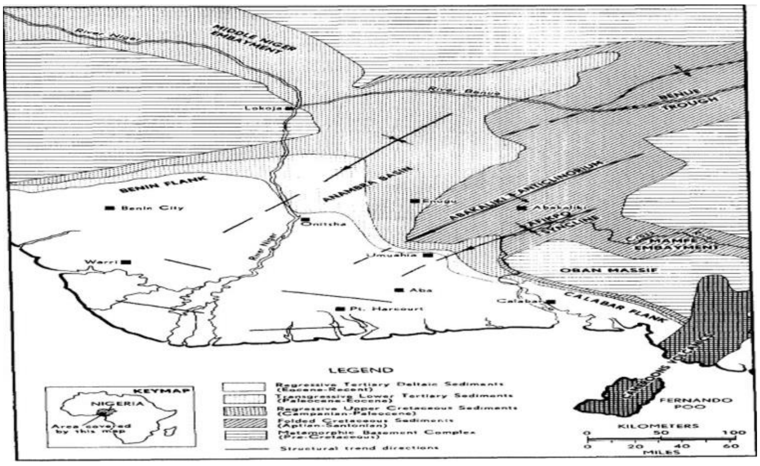

Fig. 1: Structural Units of Niger Delta Area (Short and Stauble, 1967).

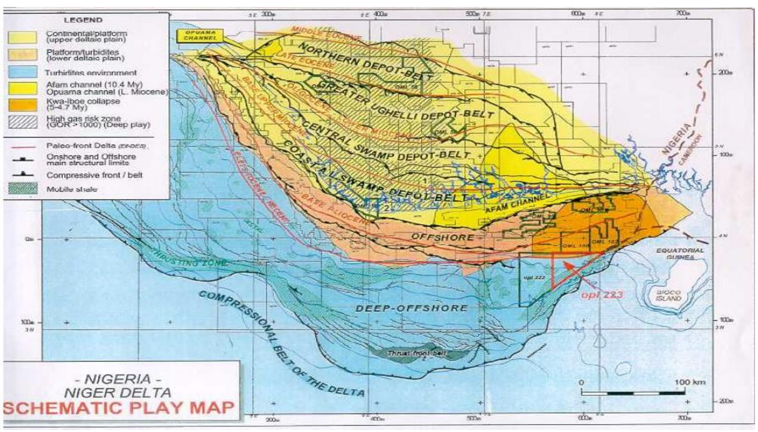

Fig. 2: Map Showing the Niger Delta Depobelts (Steele Et Al., 2009).

3. Location of study area

The study area is located at A-Field, within the onshore area of Niger Delta in Nigeria (Figure 3). The terrain is generally swampy in nature, with river channels and tributaries emptying into the Atlantic Ocean. The Field lies between longitude 6°17"55'E and latitude 4°37"27'N. The Field is located within the Central Swamp Depobelt, Onshore Niger Delta.

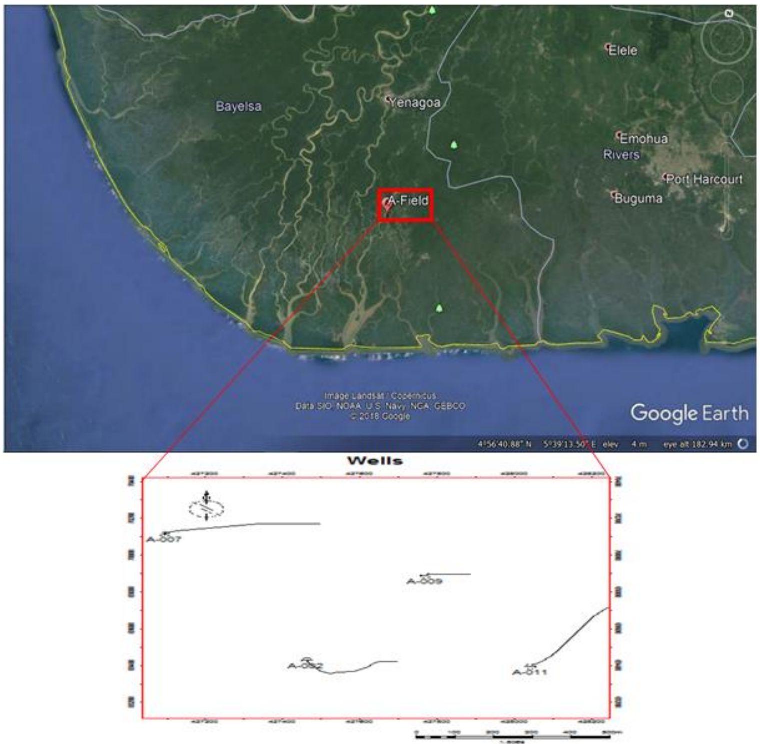

Fig. 3: A Map Showing the Location of the A-Field, Central Swamp Depobelt, Onshore Niger Delta (Source: Google Earth 2018) and the Base Map for A-Field Showing the Distribution of Wells Within the Area.

4. Theoretical background

4.1. Seismic attribute

Seismic attributes are described as the measure of seismic data that helps in visualization or quantification of features of interpretational interest (Marfurt, 2005), they are also seismically derived parameter computed from pre-stack or post-stack data before or after migration (Chambers and Yarus, 2002). Some common attributes are amplitude, phase, frequency, polarity, and velocity from seismic attributes are useful as hydrocarbon indicators whereas acoustic impedance, reflectivity and transmissivity are useful for boundary conditions, hardness, and nature of surfaces while anomalies due to variation in seismic attributes often appear in seismic sections as bright spots, flat spots, and velocity sags. Seismic attributes are significant in defining lithological contrast, bedding continuity, bed spacing and thickness, depositional environment, geologic structures, gross porosity, fluid content, abnormal pressure, temperature, and polarity of seismic (Sheriff, 1980). Structural attributes extracted from seismic helps in picking horizons and faults, while attributes extracted (relating) to log and rock properties help in defining a better petrophysical and facies model, thus reducing uncertainty.

4.1.1. Classification of seismic attributes

4.1.2. Seismic attributes can be classified based on their computational characteristics (walls et al., 2002) as follow

- Physical Attributes- These are attributes computed from complex traces, which are directly related to wave propagation, lithology, and other parameters. Physical attributes can be classified either as pre-stack or post-stack attributes, with each having sub-classes as instantaneous and wavelet attributes. Instantaneous attributes are computed sample by sample and indicate continuous change of attributes along the time and space axis, while wavelet attributes, on the other hand represent characteristics of wavelet and their amplitude spectrum.
- Geometric Attributes- These are attributes computed from reflection configuration and continuity properties of the subsurface such as dip, azimuth and discontinuity.

4.1.3. Seismic attributes properties

- Reflection intensity

The Reflection Intensity attributes is related to the energy in the seismic trace and is computed within a moving window. The formula for Reflection Intensity is:

$$A_{RI(t)} = \sqrt{1/N \sum_{i=-N/2}^{N/2} (f\,(t+k))} \quad (1)$$

It is useful for delineation of amplitude features while retaining the frequency appearance of the original seismic data. Reflection Intensity is also useful for AVO calculations given as

- RMS amplitude

The root mean square of the input data trace f(t). This attribute relates to the energy in the trace and is computed within a moving window.

$$A_{RMS}(t) = \sqrt{1/N \sum_{i=-N/2}^{N/2} [\, f\,(t+k)\,]^2} \quad (2)$$

4.2. Types of attributes

4.2.1. Complex trace attributes: these includes

- Sweetness

Sweetness is a composite seismic attribute used to highlight thick, clean reservoirs, along with hydrocarbons contained within. Mathematically, sweetness is derived by dividing reflection strength (also known as “instantaneous amplitude” or “amplitude envelope”) by the square root of instantaneous frequency.

- Envelope

Envelope, which is also known as reflection strength, instantaneous energy, and magnitude, is defined as the total energy of the seismic trace. In other words, it is the modulus of the seismic trace, which is the real part, and the imaginary part. Mathematically, it is given as:

$$Envelope = [\, f^2(t) + g^2(t)\,]^{1/2} \quad (3)$$

The real part f(t), is our original trace; the imaginary part g(t), is also the Quadrature Amplitude. The attribute clearly shows subtle lithological changes that may not be apparent on the seismic data.

- Instantaneous frequency

Instantaneous Frequency $\omega_c(t)$ is the rate of change of the instantaneous phase. Mathematically expressed as:

$$\omega_{c(t)} = \partial\{\varphi(t)\}/\partial t \quad (4)$$

Instantaneous frequency is independent of phase and amplitude and is useful in indicating reservoir rock properties such as hydrocarbon, fractures zones detection, and changes in thickness and lateral changes in lithology. The instantaneous frequency has an apparent higher resolution on the input data which is useful for mapping subtle changes.

- Instantaneous phase

The Instantaneous phase is the argument of the complex function and it reveals weak and strong events with equal strength. Mathematically, the Instantaneous phase is given as:

$$\varphi(t) = tan^{-1}\,[g(t)/f(t)] \quad (5)$$

4.2.2. Structural attributes: these are that isolate structural variation in the seismic reflection pattern

- Ant tracking

Ant tracking is used in edge enhancement for the identification of faults, fractures, and other linear anomalies within the seismic data volume (Pedersen et.al., 2002).

- Gradient magnitude

The Gradient Magnitude attribute is the length of the 3-component gradient. The gradient is computed using the algorithm for the 1st Derivative but computed for the in-line direction, cross-line direction, and vertical direction. The magnitude is the square root of the sum of the squared for these derivatives.

$$Gradient\ Magnitude = \sqrt{f'(x)2 + f'(y)2 + f'(z)2} \quad (6)$$

The Gradient Magnitude is amplitude sensitive thus can be used to discriminate regions from those with significant reflectivity and signal strength.

- Structural smoothing

This attribute reduces noise without degradation to the fault expression contained in the original data. The structural smoothing can also be used to illuminate flat spots within the seismic volume. The smoothing operator is Gaussian having the expression:

$$h_G(k) = \frac{1}{\sqrt{2\pi\sigma}}\, exp^{\left(-\frac{1}{2}\frac{k^2}{\sigma^2}\right)} \quad (7)$$

Where σ determines the width of the smoothing filter and the degree of the smoothing (Iske and Randen, 2005).

- Variance

The Variance attribute is used to isolate edges from the input data set (Van Bemmel et al., 2000). Variance is also a great stratigraphic attribute, it can really bring out depositional features including reefs, channels, splays, etc. The normalized variance algorithm is computed as:

$$\sigma_t^2 = \frac{\sum_{j=t-L/2}^{j=t+L/2} w_{j-t} \sum_{i=1}^{l} (x_{ij} - x_j)^2}{\sum_{j=t-L/2}^{j=t+L/2} w_{j-t} \sum_{i=1}^{l} (x_{ij})^2} \quad (8)$$

Where x_{ij} is the sample value at the horizontal position, I, and vertical sample, j, w_{j-t} is the vertical smoothing term over a window of length, L.

4.2.3. Stratigraphic attributes

These attributes isolates seismic textures visible in seismic data. These include the structural orientation measurements (chaos and flatness), frequency decompositions (Iso-frequency).

- Chaos

The Chaos attribute maps the "chaoticness" of the local seismic signal within a 3-D window (Iske and Randen, 2005). This chaoticness means how consistent is the orientation estimates based on the principal component method. Areas with low consistency correspond to regions of chaotic signal patterns and can be related to local geologic features; e.g. Faults/discontinuities, reef textures, channel infill et cetera.

- Iso-frequency

The Iso-Frequency component is a patented seismic decomposition method and generates an attribute volume at user-defined frequencies (Pepper and Bemmel, 2011). With the cosine correlation transform (CCT) method, the resulting frequency value is a measure of the contribution for each user-defined frequency within window based on cross-correlation between a cosine wave of that frequency and the auto-correlation of the windowed input seismic data. Thus, the CCT output value is a correlation coefficient measuring the similarity of the auto-correlated seismic data to a known cosine wave signature of a specific frequency. The correlation value range is -1.0 to 1.0, where 1.0 would mean an identical signal, 0.0 means uncorrelated, and a negative value means a polarity difference. The cross-correlation algorithm is defined as:

$$\emptyset_{GH}(\tau) = \frac{\sum_{k=-N}^{N} G(k)H(k+\tau)}{[\sum_{k=-N}^{N} G^2(k)\sum_{k=-N}^{N} H^2(k)]^{1/2}} \quad (9)$$

Where G (k) and H (k) are the signals being cross-correlated, either the windowed seismic trace with itself to generate the auto-correlation, to the cosine function and the windowed seismic auto-correction.

5. Methodology

5.1. Materials and methods

This study was conducted using post stacked 3-D seismic data and well log obtained (recorded) from the field, onshore Niger Delta Area (study area). Some of the available data are the well log suite, which comprises of Gamma ray (GR) logs, Caliper logs, Porosity logs (neutron, density and sonic) and resistivity (shallow and deep) with their well header information, check shot data and well survey deviation data. The seismic data utilized was a processed post-stack 3-D seismic section; its wavelet type is zero phase with SEG reverse polarity having 5577-5850 in-lines and cross-lines 1495-1750, with line spacing of 25 meters. Two major industrial softwares were used for the processing and interpretation.

5.2. Research design and workflow

In achieving the aim of the study, the following outlined procedures/workflow was utilized for the successful completion of the study as shown in Figure 4:

1) Data sourcing, data gathering, and data loading into relevant software.
2) Data quality assurance and quality control.
3) Well logs conditioning (despiking and interpolation).
4) Well correlation.
5) Petrophysical evaluation of reservoirs.
6) Attribute cross plots from well logs
7) Seismic data pre-evaluation and reflective pattern analysis.
8) Seismic Interpretation and seismic extraction
9) Synthetic seismogram generation, well to seismic tie and phase determination.
10) Seismic attributes extraction.
11) Hydrocarbon Prospect evaluation
12) Volumetric evaluation.

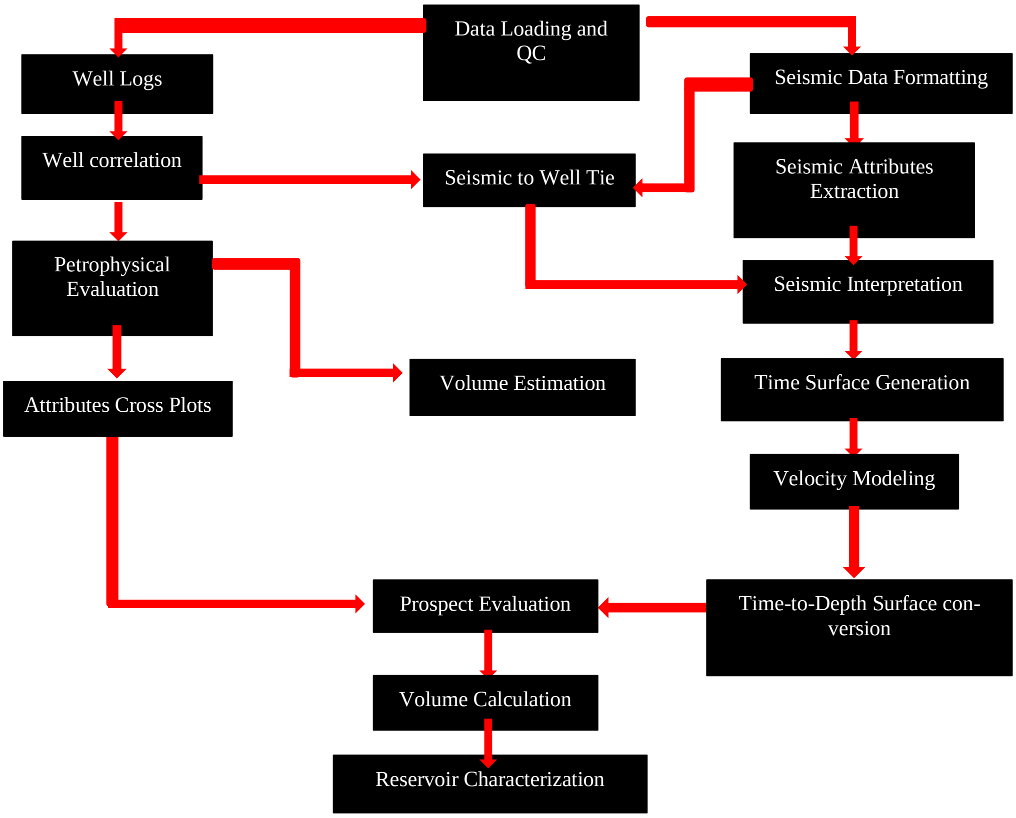

Fig. 4: Workflow Utilized for the Analysis of A-Field.

The data set were quality checked and sorted into acceptable format for the software namely: Petrel™ software was used for data appraisal, well correlation, petrophysical analysis and evaluation, well to seismic tie, seismic analysis and interpretation, seismic attributes extraction and generation of hydrocarbon prospect while the Hampson Russell software was used for lithology evaluation and fluid discrimination respectively.

6. Results and discussion

The results obtained from the study, which include results from the well log evaluation of the selected wells, delineation of the well lithology, correlation of the wells, petrophysical analysis and evaluation of the properties, cross-plot analysis for computing the attributes for fluid discrimination and seismic attributes analysis are presented in the following figures 5-20.

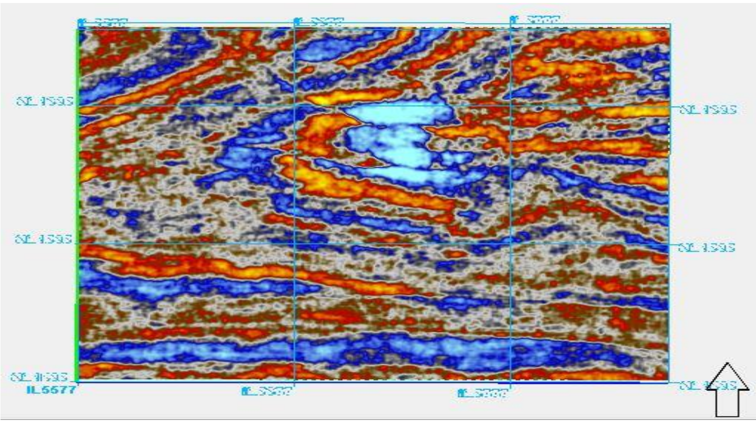

Fig. 5: Original Seismic Data.

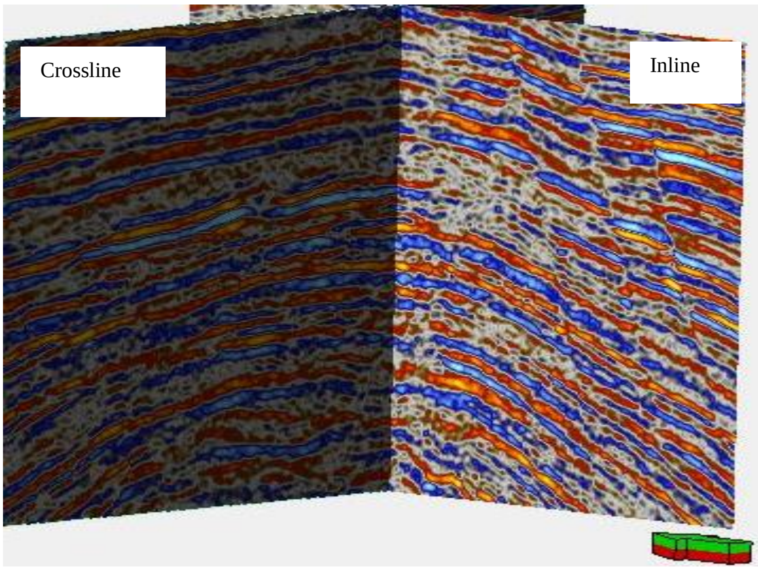

Fig. 6: The In-Line and Cross-Line of the Original Seismic Data Respectively.

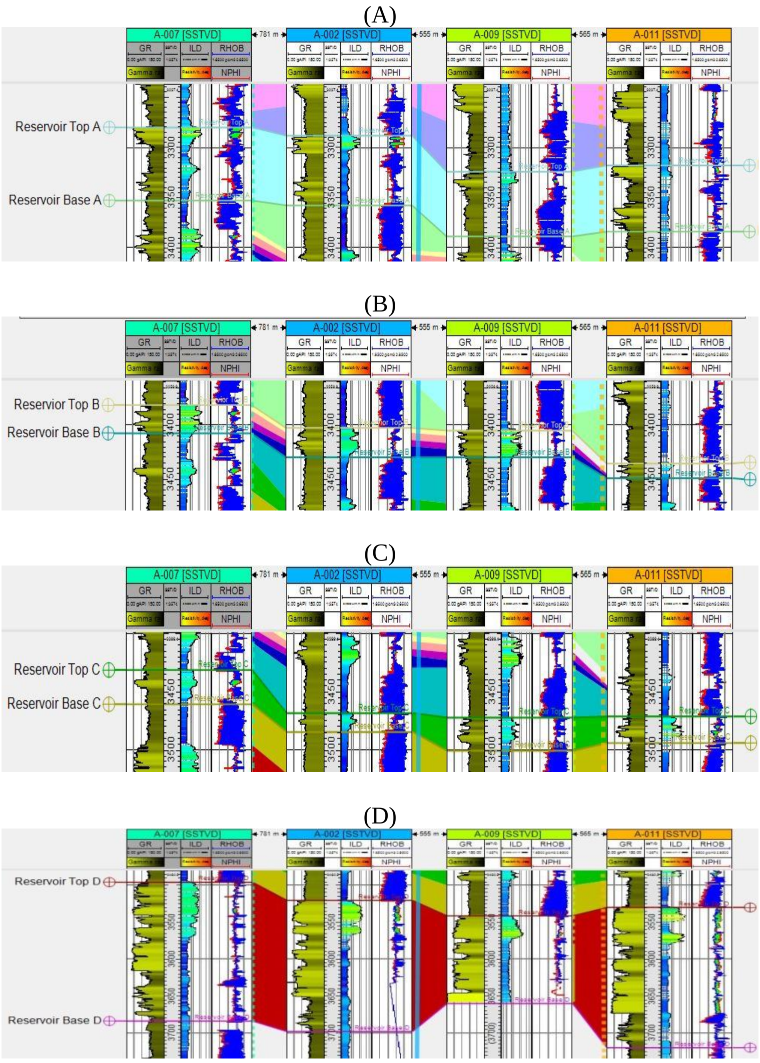

Fig. 7: Lithology Identification of the (A) Reservoirs-A (B) Reservoir-B, (C) Reservoir-C and (D) Reservoir-D within the Four Wells of the Field Used for the Study.

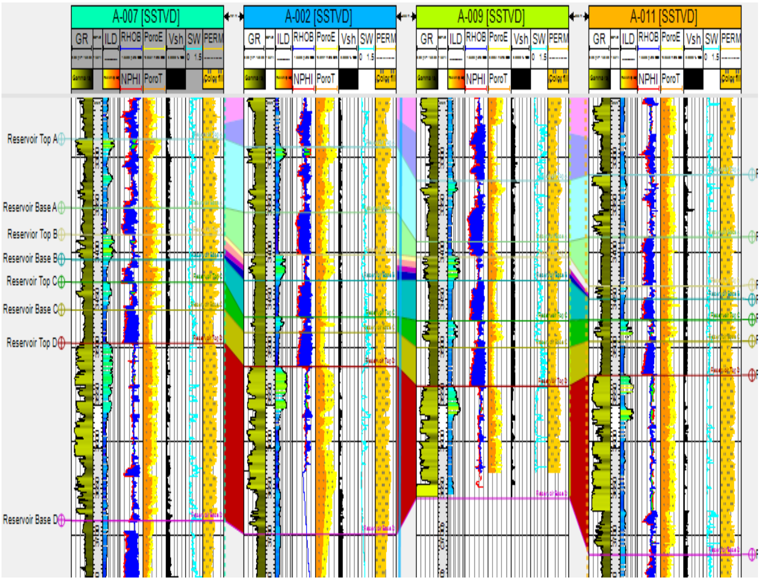

Fig. 8: Correlation of the Wells Showing the Correlated Reservoirs within the Four Wells.

The results identified four lithologic reservoir sand units across the well with depth ranges from 3288m (top) to 3730m (bottom). The reservoir identified were labeled reservoir A, B, C and D. These obtained reservoirs were used for petrophysical evaluation of the reservoir properties, namely Shale Volume, Effective porosity, Permeability, Water and Hydrocarbon saturation as shown in the Figures 9-12, while the obtained values are tabulated in Table 1. The fluid contents in the reservoir sand units were discrimination using the resistivity log.

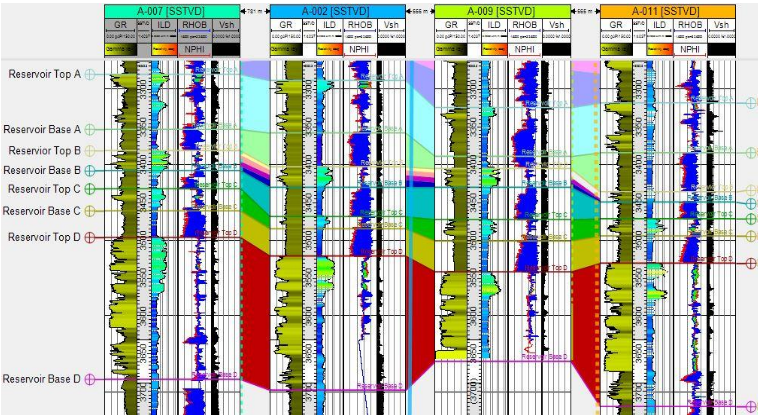

Fig. 9: Shale Volume Values Calculated for the Four Reservoir Intervals and Correlated Across All Four Wells.

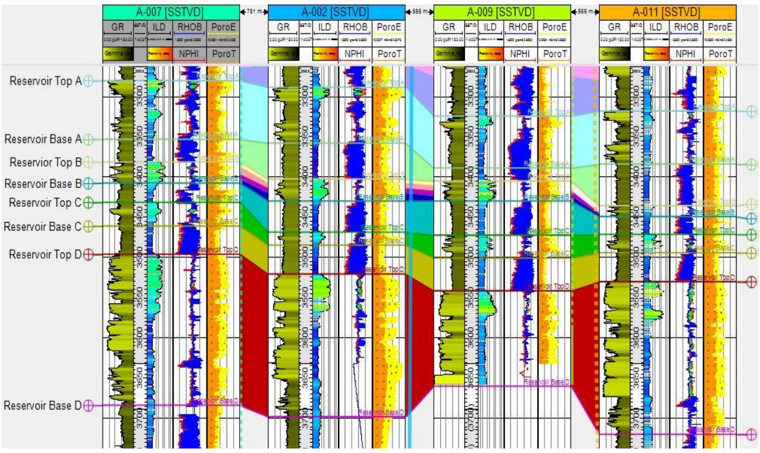

Fig. 10: Porosity Values Calculated for the Four Reservoir Intervals and Correlated Across All Four Wells.

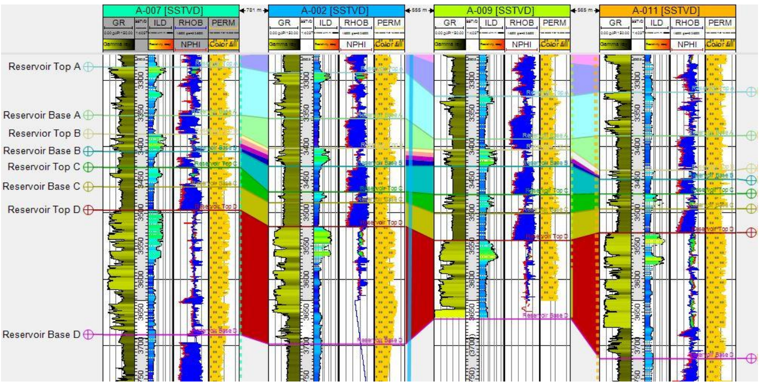

Fig. 11: Permeability Values Calculated for the Four Reservoir Intervals and Correlated Across All Four Wells.

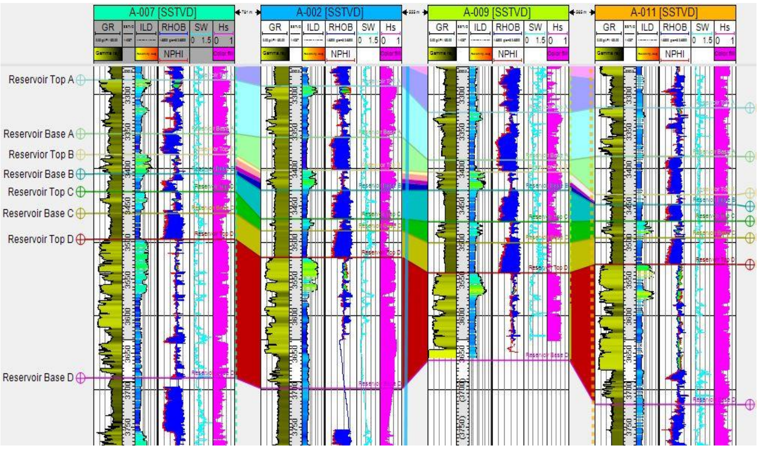

Fig. 12: Hydrocarbon Saturation Calculated for the Four Reservoir Intervals and Correlated Across All Four Wells.

Table 1: Petrophysical Evaluation of the Reservoir Units in the Four Wells in the Field

Wells	Reservoir sands	Top (m)	Base (m)	Gross thickness (m)	Shale volume (%)	Shale volume (m)	Net sand (m)	Net-to Gross (%)	Total Porosity (%)	Effective Porosity (%)	Water saturation (%)	Permeability (mD)	Hydrocarbon saturation (%)	Fluid type
Well-2	A	3289	3358	69	14%	9.66	59.34	86%	22%	20%	59%	1744.303	41%	Oil/water
	B	3402	3431	29	12%	3.48	25.52	88%	19%	17%	56%	1155.55	44%	Oil/water
	C	3469	3485	16	12%	1.92	14.08	88%	13%	11%	82%	691.9105	18%	Oil/Water
	D	3521	3698	177	13%	23.01	153.99	87%	20%	19%	78%	1636.715	22%	Oil/Water
Well-7	A	3280	3352	72	17%	12.24	59.76	83%	24%	22%	42%	1540.439	58%	Oil
	B	3381	3407	26	14%	3.64	22.36	86%	25%	21%	52%	1821.868	48%	Oil/Water
	C	3431	3460	29	13%	3.77	25.23	87%	28%	25%	41%	2019.133	59%	Oil
	D	3496	3684	188	14%	26.32	161.68	86%	26%	22%	82%	2214.002	18%	Oil/Water
Well-9	A	3325	3389	64	23%	14.72	49.28	77%	25%	23%	35%	2037.376	65%	Oil
	B	3404	3430	26	13%	3.38	22.62	87%	19%	17%	66%	1254.444	34%	Oil/Water
	C	3472	3501	29	14%	4.06	24.94	86%	15%	14%	56%	1001.586	28%	Oil/Water
	D	3542	3660	118	13%	15.34	102.66	87%	15%	14%	76%	995.2449	24%	Oil/Water
Well-11	A	3318	3384	66	30%	19.8	46.2	70%	19%	16%	78%	1313.773	22%	Oil/Water
	B	3435	3449	14	15%	2.1	11.9	85%	19%	16%	51%	991.2469	49%	Oil/Water
	C	3471	3494	23	14%	3.22	19.78	86%	29%	24%	44%	2276.725	56%	Oil
	D	3531	3720	189	16%	30.24	158.76	84%	19%	17%	81%	1434.346	19%	Oil/Water

The original seismic volume and the variance attribute were used to enhance the faults traces, a total of 15 faults were interpreted from the seismic data. The faults identified were synthetic (growth faults) and antithetic faults

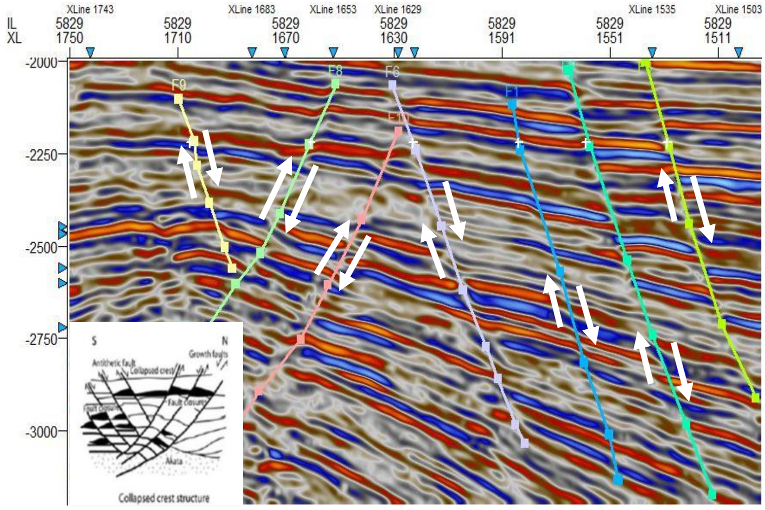

Fig. 13: Seismic Inline -5829 Ms Showing Interpreted Synthetic (F1, F2, F3, F6, F9) and Antithetic (F8, F10) Faults (Inset Figure on Common Fault Types in Niger Delta. Doust and Omatsola, 1990).

7. Seismic attributes assessment

The results shows the used of the different seismic attributes to mapped out discontinuities caused by faults and fractures signature which enabled the delineation of the possible zone of interest and proper characterization of the field. The results for the Instantaneous frequency, Reflection intensity, Sweetness, Variance, Local structure dip, Gradient magnitude, RMS amplitude, Iso-Frequency and Envelope attributes are shown in Figure 17-19.

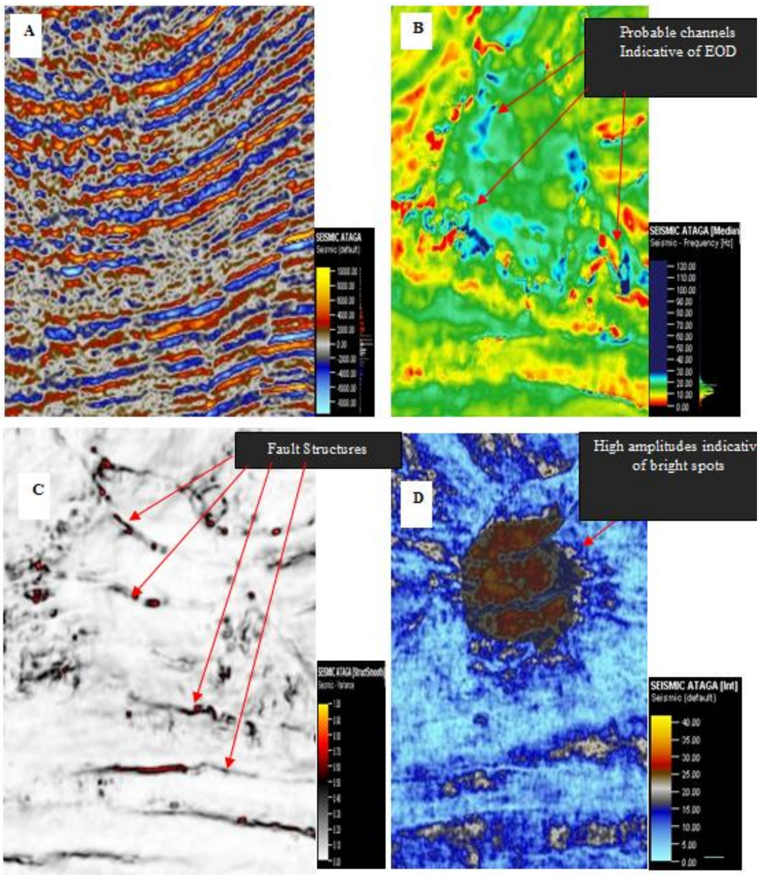

Fig. 17: Seismic Attribute Extracted at Time Slice -2468 Ms of (A) the Original Seismic, (B) the Instantaneous Frequency (C) the Variance Map (D) Reflection Intensity Map.

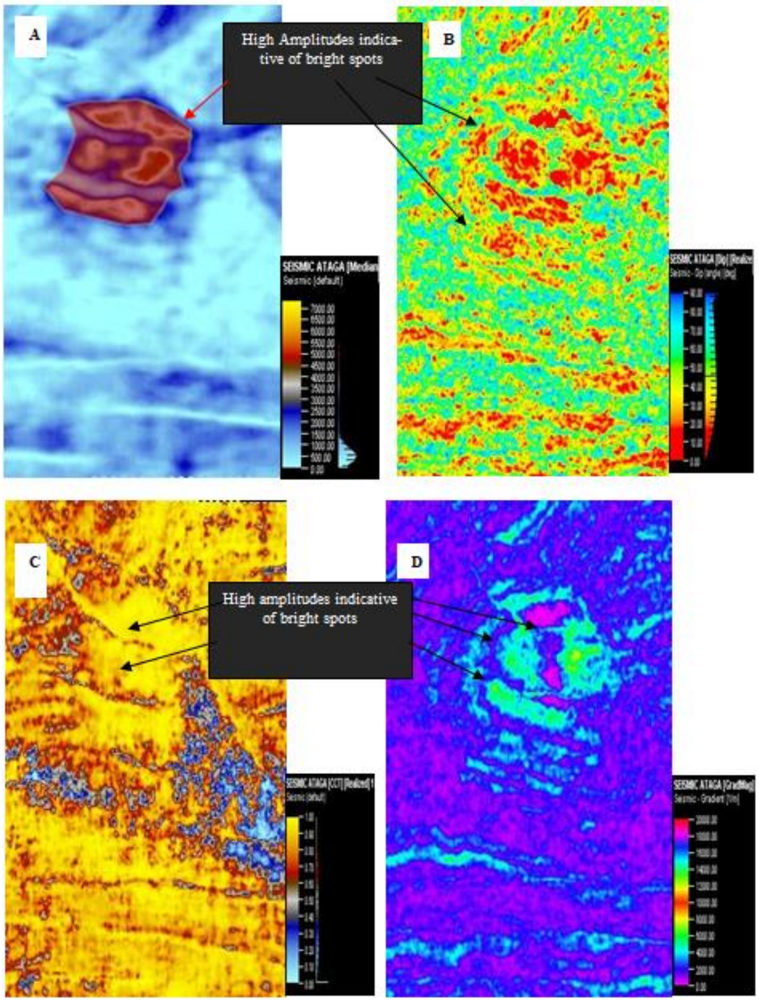

Fig. 18: Seismic Attribute Extracted at Time Slice -2468 Ms (A) Sweetness (B) Local Structural Dip (C) Iso-Frequency (D) Gradient Magnitude.

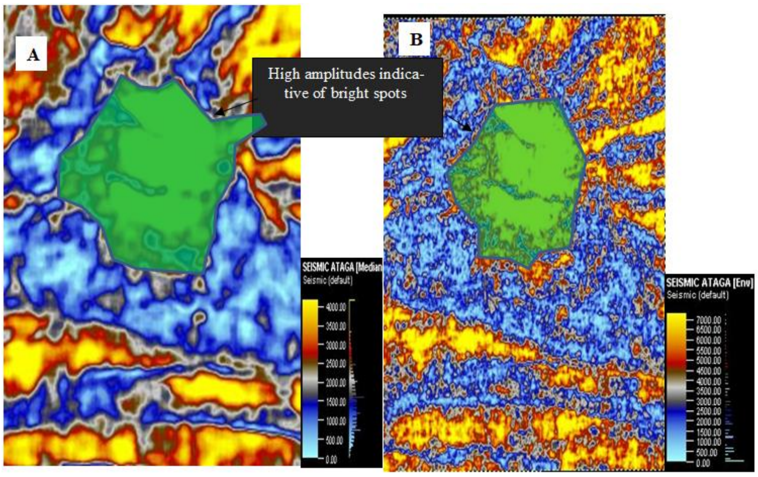

Fig. 19: Seismic Attribute Extracted at Time Slice -2468 Ms (A) Envelope (B) RMS Amplitude.

8. Discussion

8.1. Petrophysical reservoir analyses

8.1.1. Well analysis

The four main reservoir units were identified (namely reservoirs A, B, C and D) across the well (Figure 7 and 8). The reservoir sand units range from about 16m to 177m thickness in Well-002, 26m to 188m thickness in Well-007, 26m to 118m thickness in Well-009 and from 14m to 189m thickness in Well-011 respectively. These reservoir units are generally made up of fairly clean sands, with an average shale volume that ranges from about 12.75% to 18.5%, average total and effective porosity ranging from 18.5% to 25.75% and 16.75% to 22.5% respectively, while the average water saturation ranges from about 54.25% to 68.75%. Reservoirs A and D show signatures depicting block with sharp top and base sequence, reservoirs B show signatures depicting a fining downward with sharp base, while reservoir C show a coarsing upward with sharp top sequences on both ends of the shale beds. Reservoir B was observed to house the cleanest sand unit within the reservoir.

8.1.2. Seismic extraction assessment

The attribute extracted for instantaneous frequency show varying amplitudes ranging from 0 - 120 Hz where the highest amplitude was depicted by dark blue colour indicative of river channels around the area representing the environment of deposition (Figure 17b). The attribute extracted for variance identify fault structures on the seismic data, various faults across the seismic showing major and minor faults depicting structural deformations on the seismic (Figure 17c). Major faults serve as trap mechanisms for the reservoirs in place. While the reflection intensity attribute extracted at -2468 ms identified varying amplitude ranging from 0 – 40, with the highest amplitude indicative of bright spots at the centre of the seismic data (Figure 17d). The attribute extracted for sweetness at -2468 ms identified varying amplitude ranging from 0 – 7000, with the low amplitude ranging from 0 – 4500 while the highest amplitude ranging for 4500 – 7000 ms indicative of bright spots regions on the seismic data (Figure 18a). The local Structural dip attribute extracted from the seismic data identified region of high and low amplitude indicative of structural complexities (Figure 18b), the extracted seismic attributes ranges from 0 -100 where the low amplitudes indicated bright spot regions on the seismic data. The Iso-Frequency attributes were extracted at -2468 ms and varying amplitude ranging from 0.00 – 1.00, were identified with the highest amplitude ranging from 0.60 -1.00 while the lowest amplitude ranges from 0.00 – 0.60 at the centre of the seismic data (Figure 18c). The Gradient Magnitude attribute extracted from the seismic data identified region of high and low amplitude (Figure 18d), the extracted seismic attributes ranges from 0.00 – 20,000.00 where the amplitudes around 14,000.00 – 18,000.00 indicated anomalous amplitude showing bright spot regions on the seismic data. The extracted attribute for envelope at -2468 ms identified varying amplitude ranging from 0.00 – 4000.00, with the low amplitude ranging from 0.00 – 2500.00 while the highest amplitude ranging for 2500.00 – 4000.00 ms indicative of bright spots regions mostly around the centre of the seismic data (Figure 19a). While the RMS amplitude attributes were extracted at -2468 ms and varying amplitude ranging from 0.00 – 7000.00 ms, high amplitude ranging from 4500.00 – 7000.00 ms indicative of bright spot regions were identified while the low amplitude reading ranges from 0.00 – 4500.00 ms from the seismic data (Figure 19b).

9. Conclusion

The study has integrated the results obtained in well logs evaluation, well log correlation, petrophysical analysis, seismic well tie, fault mapping, horizon mapping/interpretation, time surface generation, time to depth conversion, velocity modeling, seismic attribute analysis, to delineate the lithology and discriminate the reservoir fluids in other to characterized our study area, A-Field, onshore Niger Delta . In the reservoir delineation, four lithologic sand reservoirs were identified using gamma ray, resistivity and the cross plot of neutron and density logs. The study has evaluated the following petrophysical parameters for the field as follows, average effective porosity as 18.4%, total porosity estimated to be 20.25%, the average shale volume of 61.75%, average water saturation of 53.5% and permeability of 1508.0425mD respectively, these parameters were used to further quantify the extends of producibility of the four reservoirs. Seismic to well tie was carried out to correlate the well log to the seismic using the checkshot provided for one of the well, while horizons were picked on the events where the well tops of the reservoir cut across the reservoirs and mapped on seismic which was used to model the time and depth surface after velocity modeling. Synthetic and antithetic faults were mapped on seismic with the aid of structural and stratigraphic attributes like variance, chaos, trace AGC, structural smoothing. Instantaneous frequency, sweetness, reflection intensity, RMS amplitude, Iso-frequency, gradient magnitude, envelope, and local structural dip were extracted from the original seismic to analyze anomalous high amplitude areas which identified key prospect areas for hydrocarbon accumulation. Cross plots of computed attributes were used to accurately delineate the lithology and discriminate the fluids, so as to further characterize the existence of fluid and lithology in the reservoir. The qualitative interpretation of seismic attributes in reservoir characterization of A-field has revealed that the integration of seismic attributes with petrophysical parameters is a better characterization method for fluid and lithology discrimination of a field in any given reservoir study. This study has also shown that A-field from this study is not that viable in terms of hydrocarbon prospects within the reservoir intervals because of the high-water saturation and shale volume values, which are not highly economical for production of the field.

Declaration of interests

- The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.
- The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Conflicts of interest

- The author(s) declare(s) that there are no conflicts of interest regarding the publication of this article.

Data availability statement

The data used for the study is a priority/confidentiality data of the research unit partner, GCube Integrated Services Limited (Oil Servicing Company in Nigeria) and currently saved in the server of the company. The data was released for their interns, who are former students of the University and members of the Research unit. Request for availability can only be granted with permission from the Company Director, which might also require the approval of the National Regulatory Authority if the need arise

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