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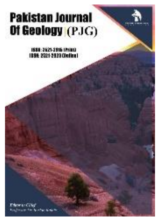


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*RESEARCH ARTICLE*

# RESERVOIR CHARACTERIZATION USING SEISMIC ATTRIBUTES IN W-FIELD, ONSHORE NIGER DELTA

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**ABSTRACT**

Seismic attributes are very useful tools for reservoir characterization and prospect evaluation because they enhance visibility of features that are below the resolution of seismic data. This study utilized seismic attributes such as maximum amplitude, root mean square (RMS), average energy and sweetness for prospect, identification and evaluation in W-Field, onshore Niger Delta using seismic and well data. Three reservoirs were identified (A, B, C) and reservoir C was selected after thorough scrutiny of available well logs, sand thickness and hydrocarbon presence. Faults were enhanced using variance attribute and the result shows that closures on reservoir C surface are associated with collapsed crestal structures bounded by major faults responsible for hydrocarbon trap formation. The RMS and maximum amplitude attribute results shows the higher the RMS value, the brighter the amplitude anomalies, which coincide with the distribution of hydrocarbons in the reservoir and supported by Average energy interpretations. However, the anomalies are brighter and sharper using the Average energy seismic attribute. The result shows moderate to high sweetness zone (sweet spots) reveals bright amplitude anomalies within the zone of interest, indicating high amplitudes and low frequency of hydrocarbon bearing sand zone. Similarly, multitrace coblending (sweetness + variance) conducted on seismic volumes reveals that there is no significant difference in structure and bright amplitude anomalies with those recognized using the surface attributes. Seismic attributes offer complimentary tools to qualitatively and quantitatively characterize stratigraphic and structural features in a field, especially those features below the resolution of seismic data.

**KEYWORDS**

Seismic Attributes; Maximum Amplitude; Root Mean Square; Average Energy; Sweetness

## 1. INTRODUCTION

Reservoir characterization is about describing the rocks and fluids of the reservoir to understand its mechanics, physics, volumes, spatial distributions and flow that ultimately can be expressed in models (Tehrani, 2016). The resulting reservoir models are used to predict and optimize the production of the reservoir. Characterization of a reservoir deals with quantifying its rock and fluid properties, such as the porosity, permeability and hydrocarbon saturation (Nanda, 2016). Reservoir characterization is the study of reservoir properties using geophysical, petrophysical, geologic and engineering disciplines, including and spatial variations and uncertainty analysis of geologic and engineering data (Ma, 2011; Xinghe et al., 2011). There two important aspects of reservoir characterization (1) characterization of petrophysical properties, including fluid saturation, porosity and permeability (2) characterization of the reservoir's geometric features, including depositional facies bodies, structural and stratigraphic controls (Xinghe et al., 2011).

Chopra and Marfurt defines reservoir characterization as the quantitative analysis of seismic data, well logs, and production data to produce a 3D understanding of porosity, thickness, permeability, lithology, fractures, and compartmentalization (Chopra and Marfurt, 2007). Reservoir heterogeneity, and hence flow performance, is primarily controlled by the spatial distribution of depositional facies. Reservoir characterization best practice typically recommends first modelling the depositional facies, and then populating each simulated facies with its corresponding specific porosity and permeability distributions (Sebastien and Levy, 2008). Seismic attributes are the components of the seismic data obtained by mathematical computation (Ismail et al., 2020). They have been used for reservoir characterization, especially since the emergence of 3-D seismic data (Chen and Sidney, 1997; Brown, 2004; Xinghe et al., 2011). Seismic attributes are grouped into two classes: (1) geometric attributes and (2) physical attributes. Geometric attributes such as coherence, ant tracking, curvature, chaos, variance, dip, and azimuth enhance the visibility of the geometrical shape or characteristics of seismic reflectors, while physical attributes such as phase, frequency and amplitude relate to the lithology of the subsurface (Jibrin et al., 2009; Ngeri et al., 2015).

Basically much information hidden from seismic data are extracted by the different seismic attribute to identify prospects, minor and major faults, unconformities, gas zones, gas channels and predicting reservoir properties and their dynamic monitoring which will lead to a better geological and geophysical interpretation (Chen and Sidney, 1997; Brown, 2004; Xinghe et al., 2011; Ismail et al., 2020). However, some researchers affirmed that seismic data information content is incredibly rich in terms of texture, geometry, frequency, and amplitude and there is still much more that can be accomplished (Eastwood, 2002; Ismail et al., 2020).

A group of researchers opined that there are plenty of applications for measurement and analysis of seismic attributes (Ismail et al., 2020). Firstly and very important applications are the detection of direct hydrocarbon indicators (DHI), the geometric attributes that can help to recognize edges of interesting geological features and secondly, physical attributes which are used for lithology and fluid change determination

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(Ismail et al., 2020). A regional reconnaissance interpretation of source, reservoir and seal rock distribution for exploration screening purposes were carried out by some researchers using seismic attribute analysis and depositional elements (Sahoo et al., 2014). Numerous authors have highlighted that seismic attributes are important predictors of reservoir geometries either quantitatively or qualitatively (Hossain, 2019).

Seismic attributes were used to resolve serious interpretational challenges associated with sub-seismic faults and subtle stratigraphic features in order to enhance reservoir characterization (Opara and Osaki, 2018). Likewise, a group of researchers re-evaluated the hydrocarbon prospects in a Niger Delta field so as to identify unharnessed hydrocarbon prospects with the help of seismic attributes (Okeke et al., 2018). The usefulness of seismic attribute analyses in seismic geomorphology studies of the Moragot field, Gulf of Thailand, clearly shows the geometry and spatial distribution of sand bodies, thereby helping in field development planning as well as in reducing exploration risk (Hossain, 2019; Allo et al., 2022). Some researchers analyze high amplitude anomalies using seismic attributes from seismic data for the potential presence of hydrocarbons in Edi field, Niger Delta (Etuk et al., 2020).

Okpoli and Arogunyo used gamma ray, resistivity, neutron and density Logs to identified four lithologies which are sandstone, shaly sandstone, shaly sand and shale for the integration of well logs and seismic attribute analysis in identifying a reservoir in PGS Field onshore Niger Delta, Nigeria (Okpoli and Arogunyo, 2020). One reservoir (G) was picked, identified, and correlated across the four wells named PGS 5, PGS 7, PGS 10 and PGS 11. Ten faults (F1, F2, F3, F4, F5, F6, F7, F8, F9 and F10) were identified and mapped on different inlines with the trace appearing on the corresponding cross lines showing the structural framework of the field (Okpoli and Arogunyo, 2020). While some of these faults extend through the extent of the field known as major regional growth faults (F10, F4 and F5), identified and correlated across the field forming the boundaries to the North and South of the field, a few flank faults appearing on few of the lines and listric crestal faults appearing within the seismic extent (Okpoli and Arogunyo, 2020).

The two major regional faults F10 and F4 and some other faults are dipping to the south away from the direction of sediment supply. Thus, they are both regional faults while some of the other faults are dipping south, southwest, southeast, etc. South dipping crested faults F10, F9 and F4 are important trapping faults responsible for holding the hydrocarbon in wells PGS 5, PGS 7, PGS 10, and PGS 11 has opined (Okpoli and Arogunyo, 2020). Their study shows that the hydrocarbon traps are basically fault assisted. Six horizons were interpreted across the field with both time and depth maps generated for one of the horizons (Okpoli and Arogunyo, 2020). Four attributes (amplitude, variance, acoustic impedance, root mean square) were extracted and displayed by Okpoli and Arogunyo as flattened maps (slice at 1481, 1561, 1640, 1720ms) for each of the interpreted horizons (Okpoli and Arogunyo, 2020). Root mean square (RMS) amplitude, instantaneous frequency and interval average maps were extracted on seismic events with pronounced bright the dim spots.

These maps were used to establish the diagnostic ability of 3D seismic attribute analysis in enhancing seismic interpretation and volumetric estimation of the mid Miocene to Pliocene Agbada Formation reservoirs within the Coastal swamp depobelt, Niger Delta Structures respond to acoustic wave in different ways thus the four attributes extracted were suitable for studying subtle and sub-seismic structures missed by conventional seismic interpretation (Okpoli and Arogunyo, 2020). They concluded that it is more efficient to use seismic attribute mapping and analysis for the interpretation of the 3D seismic data to locate both seismic scale and sub-seismic scale structural and stratigraphic elements. Furthermore, variance attribute map proved to be an appropriate tool to study fault architecture than dip attribute or any other attribute map in the study area. Therefore, to reduce the risk of drilling dry hole, resulting from missed fault by conventional seismic interpretation, seismic attribute analysis can be integrated into the standard practice of hydrocarbon exploration and production company (Okpoli and Arogunyo, 2020).

Seismic attribute analysis for prospect delineation within the Agbada formation of the 'TMB' field, Niger Delta basin was carried out in order to increase volume of production by detecting hydrocarbon prospects that might have been by-pass or not detected within the field since the field has produced reasonable quantity of hydrocarbons in the past within the proven area of the fault block (Allo et al., 2022). Eight reservoirs were identified and correlated across the wells and faults orientations with significant displacement were picked across the field (Allo et al., 2022). Two of the faults mapped were major syn-tectonic growth faults dividing the field into three fault blocks (FB1, FB2 and FB3). Three horizons (Res. E, Res. H and Res. J) were used to generate the time maps, which were converted to depths by a polynomial function from Time- Depth relationship (Allo et al., 2022).

In order to identify new areas with probable hydrocarbons presence in the field, four seismic attributes (Average Energy, Root Mean Square (RMS), Sweetness and Relative Acoustic Impedance (RAI)) were adopted and examined (Allo et al., 2022). One of the Fault Blocks (FB3) was identified as the prospect (area of interest) and it reveals attribute amplitude responses that suggest the presence of hydrocarbon. The result of the extracted attribute from Average energy, RMS and Sweetness attributes showed high amplitudes similar to attributes obtained from areas around Well log locations (proven area) (Allo et al., 2022). The prospect areas conformed to a four-way fault-dependent anticlinal closure exhibiting a vertical stacking pattern of multiple sand levels with likely hydrocarbon saturation, confirmed by normal curves from the attribute's histogram distributions supporting hydrocarbon presence in FB3 (Allo et al., 2022).

The sweetness seismic attribute is a very useful tool for proper description of the depositional environment, reservoir quality and lithofacies discrimination (Zelenika et al., 2018). Sweetness as a rule is used in the delineation of the sand, shale, and sand channels useful to define the vertical continuity and lateral variation also of the targeted interval (Raef et al., 2015). The sweetness seismic attribute is a combination of two attributes (Instantaneous Frequency and Envelope) and it is commonly used to identify seismic features in the seismic data where there is a change in the overall energy signatures (Taner et al., 1979; Hart, 2008). Sweetness has been used to delineate stratigraphic features like channels and it is a very good hydrocarbon indicator (James et al., 2016).

Mathematical, the sweetness seismic attribute is defined as the Instantaneous Amplitude (reflection strength) divided by the square root of Instantaneous Frequency (Hart, 2008). Sweetness is used in the fluvial systems to identify isolated sand bodies since they produce stronger and broader reflections than the surrounding shales (Taner et al., 1979). Sweetness attribute is designed to identify and improves the imaging of sand intervals or bodies that are oil and gas prone places called "sweet spots" (Koson et al., 2014; James et al., 2016). However, it is less suitable in environments with low contrasts in acoustic impedance between sands and shales or where sands and shales are highly interbedded (Taner et al., 1979).

Variance edge attribute is a method that measures the similarity of waveforms or traces adjacent over given lateral and/or vertical windows. So, it can image discontinuity of seismic data related faulting or stratigraphy (Koson et al., 2014). Variance attribute is a very effective tool for delineation faults and channel edges on both horizon slices and vertical seismic profile (Koson et al., 2014). A group of researchers concluded that the variance attribute has proved to help imaging of channels and faults and is also useful in displaying directly the major fault zones, fractures, unconformities and the major sequence boundaries (Pigott et al., 2013; Koson et al., 2014).

RMS amplitude is a powerful attribute that can be used to see the sweeping changes in amplitude character (Al-Masgari et al., 2020). RMS amplitude provides a scaled estimate (magnitude) of the seismic trace values or traces envelope (Koson et al., 2014; Al-Masgari et al., 2020). This can be used to calculate the variations in signal to noise ratios and defining zones of noise, seismic stratigraphic changes or structural patternsChopra and Marfurt, 2007). When a reservoir contains hydrocarbons, it usually has strong amplitudes that can either be positive or negative depending on the polarity and phase of the seismic data. Hence, the maximum amplitude and the root mean square (RMS) seismic attributes are effective tools used to distinguish hydrocarbon presence in a reservoir. The RMS attribute is similar to the maximum amplitude attribute where the high amplitude anomalies coincide with the distribution of hydrocarbons in the reservoir. This RMS attribute is useful to highlight coarser-grained facies, compaction related effects (e.g. in marl and limestone) and unconformities (Koson et al., 2014).

Average energy is a post-stack attribute that computes the sum of the squared amplitudes divided by the number of samples within the specified window used. This provides a measure of reflectivity and allowing the direct hydrocarbon indicators mapping within a zone of interest (Seismic attribute, 2023). The average energy attribute of seismic waves is a measure of seismic reflectivity in the specified time window. Higher energy should correspond to higher amplitude (Johnston, 2010). Lateral variations within seismic events among others are enhanced by average energy attribute. Hence, it is useful for seismic object detection for example, amplitude anomalies, chimney detection, etc. The response energy also characterizes bed thickness and acoustic rock properties (Average energy, 2023). According to Abriel, the average energy attribute to correlate strongly most often with liquid saturation (oil/water vs. gas) due to the strong effect of these reservoir properties on both velocity and density, and energy of seismic reflections are generated at boundaries where the acoustic impedance (the product of velocity and density) changes (Abriel, 2008).

Therefore, it is mostly used in direct hydrocarbon indicators. Generally, the average energy attribute values are not important, and often not cited, because it is the relative value of an attribute along a given interval or horizon that is important (Average energy, 2023). The study aimed at using seismic attributes for characterizing reservoirs in W-Field, Onshore Niger Delta by utilizes well logs and seismic data. Both volume and surface attributes that will be generated in this study includes; variance, root-mean-square amplitude, maximum amplitude, average energy and sweetness attributes. These attributes are used solely for structural interpretation, stratigraphic interpretation and prediction of hydrocarbon presence. Though selecting an appropriate attribute to describe a relevant reservoir property is commonly critical (Chen and Sidney, 1997; Brown, 2004; Xinghe et al., 2011).

## 2. Location of The Study Area

The study area is located in the Niger Delta Basin of Nigeria and named 'W-Field'. It is within the longitudes 6°14′40″E to 6°33′38″E and latitudes 4°50′10″N to 4°58′22″N in the coastal swamp depobelt (Figure 1), onshore Niger Delta. Niger Delta is the largest delta in Africa with a sub-aerial exposure of about 75,000 km$^2$ and a clastic fill of about 9000–12,000 m (30,000–40,000ft) and terminates at different intervals by trangressive sequence (Short and Stauble, 1967).

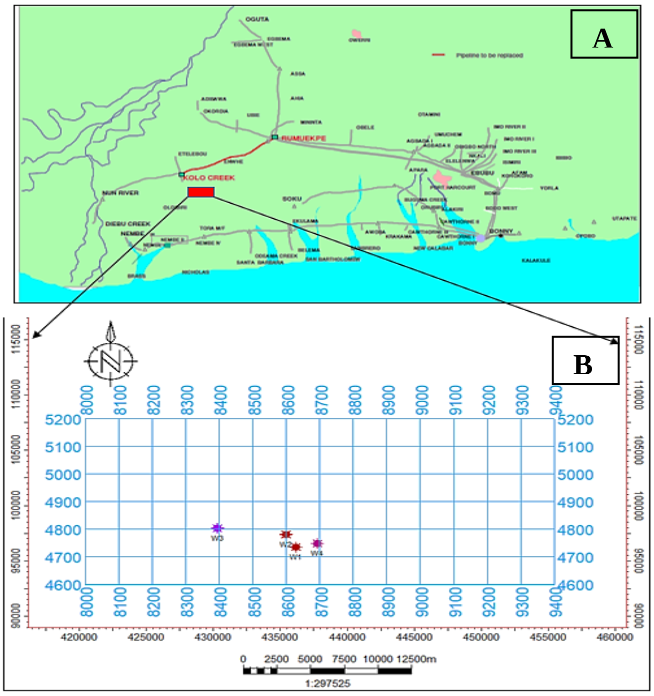


**Figure 1:** (A) Location of the study area (SPDC, 2004) and (B) the base map of W-field

## 3. Materials and Methods

| Table 1: Data inventory showing the wells information utilized for this study | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Wells | Well Header | Well Deviation | GR log | Resistivity Log | Density Log | Neutron Log | Sonic Log | Checkshot |
| W1 | YES | YES | YES | YES | YES | YES | YES | YES |
| W2 | YES | YES | YES | YES | YES | YES | NO | NO |
| W3 | YES | YES | YES | YES | YES | YES | NO | NO |
| W4 | YES | YES | YES | YES | YES | YES | NO | NO |

| Table 2: Seismic attributes and their mathematical expressions | |
|---|---|
| Sweetness (instantaneous amplitude divided by the square-root of instantaneous frequency) is defined as the trace envelope $a(t)$ divided by the square root of the average frequency $f_a(t)$ (Koson et al., 2014). | $s(t) = \frac{a(t)}{\sqrt{f_a(t)}}$ <br> $s(t) = sweetness$ <br> $a(t) = traceenvelop$ <br> $f_a(t) = averagefrequency$ |
| Root Mean Square (RMS) Amplitude provides a scaled estimate of the trace envelope. It is computed in a sliding tapered window of N samples as the square root of the sum of all the trace values *x* squared where *w* and *n* are the window values (Koson et al., 2014). | $x_{rms} = \sqrt{\frac{1}{N}\sum_{n=1}^{N} w_n x_n^2}$ <br> $x_{rms} = rootmeansquareamplitude$ <br> $w_n = windowvalues$ <br> $N = nmuber\ of\ samples\ in\ the\ window$ <br> $x = trace\ value$ |
| The average energy attribute of the seismic wave is calculated by adding the square of each sample, then dividing by the number of samples in the window to yield the mean (Landau and Lifshitz, 1986). | $AverageEnergy = \frac{\sum_{i=1}^{n} A_i^2}{n}$ <br> $A_i = amplitudeofthesamplingpoininagiventimewindow$ <br> $n = numberofsamplingpoints$ |

Data utilized for this study comprised 3-D seismic data in segy format, well data (well header, well logs, well deviations) in LAS format where the well logs include Gamma ray log, density log, Caliper log, Resistivity log and a checkshot in ASCII format containing the measured depth (MD) and two-way travel time (TWT) shot in the well. The seismic data covers an area of 840 sqkm and aids in mapping the field's structural style with the bulk volume estimation for hydrocarbon volume determination. Four (4) wells were used for this study (Table 1). The well header data file provided for all wells shows the exact geographic locations of the wells in space and time including the well names, the well reference datum and the total well drilled depth. The original well trajectory is contained in the well deviation data file, which includes the azimuth, the dip and measured depth for each well. This information aids the conversion of true vertical depth (TVD) from measured depth (MD). The well logs available included gamma ray (GR), density (RHOB), sonic (DT), deep resistivity (LLD) and neutron (NPHI). The logs were used for lithologic and reservoir identification, seismic well tie, hydrocarbon discrimination, and hydrocarbon volumetric estimation. The log depths were provided in feet, GR in GAPI, RHOB in g/cm$^3$, sonic in µs/ft, LLD in Ohm.m and NPHI in m$^3$/m$^3$. Schlumberger Petrel software was utilizedfor this study and it was used for well correlation, petrophysical evaluation, seismic interpretation, velocity modeling and attributes analysis. Table 2 showed some of the seismic attributes and their mathematical expression.

## 4. Results

Well correlation was done to properly delineate the reservoir and Petrophysical parameters were evaluated. Figure 2 shows the correlation panel for three reservoirs (A, B, C) identified across the field. The sands are colour-coded yellow while the shales are colour-coded black. These reservoirs were identified using gamma ray and resistivity logs. Several serrations are found within the sands on the GR log indicating the presence of shales. Reservoir C was utilized in this study for seismic interpretation based on high thickness, hydrocarbon presence in all wells and availability of logs for computation.

## 4.1 Seismic Well Tie

The results for seismic well tie performed on X-Field using W1 well are presented in Figure 3. The Isis time statistical wavelet used for the convolution process, power and phase spectrum generated are all presented in Figure 3. A good tie was achieved only after a minor bulk time shift of -5 milliseconds. The well tie revealed that the reservoirs are high impedance sands since they conform to peak events (troughs).

## 4.2 Fault Interpretation

Figure 4 shows a seismic time slice extracted from the original seismic data poorly revealing faults while Figure 5 shows a time slice generated using the variance discontinuity attribute better enhancing faults. Figure 6 shows all faults interpreted across the entire seismic data validated on a variance time slice. Fault and Horizon interpretations were done in delivery of a 3D structural map of the reservoir (Figure 7) showing faults and horizons interpreted on an inline section. Most discontinuities identified are synthetic faults with minor antithetic faults.

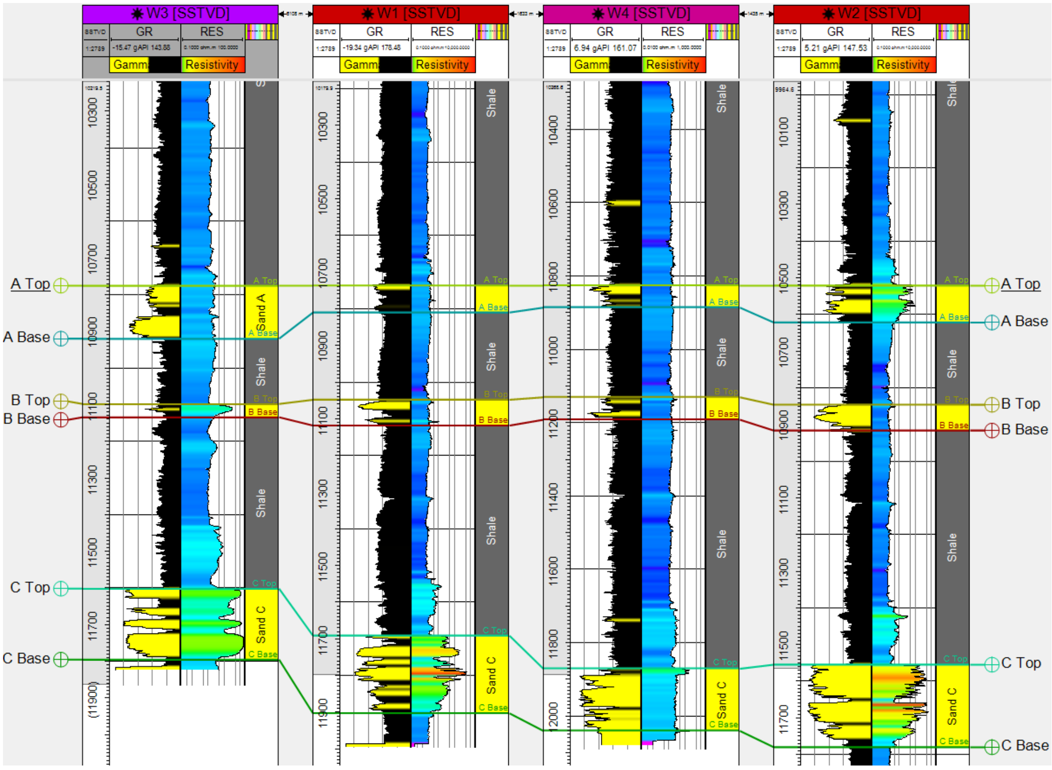


**Figure 2:** Well section window showing correlation of A, B and C reservoir sand bodies

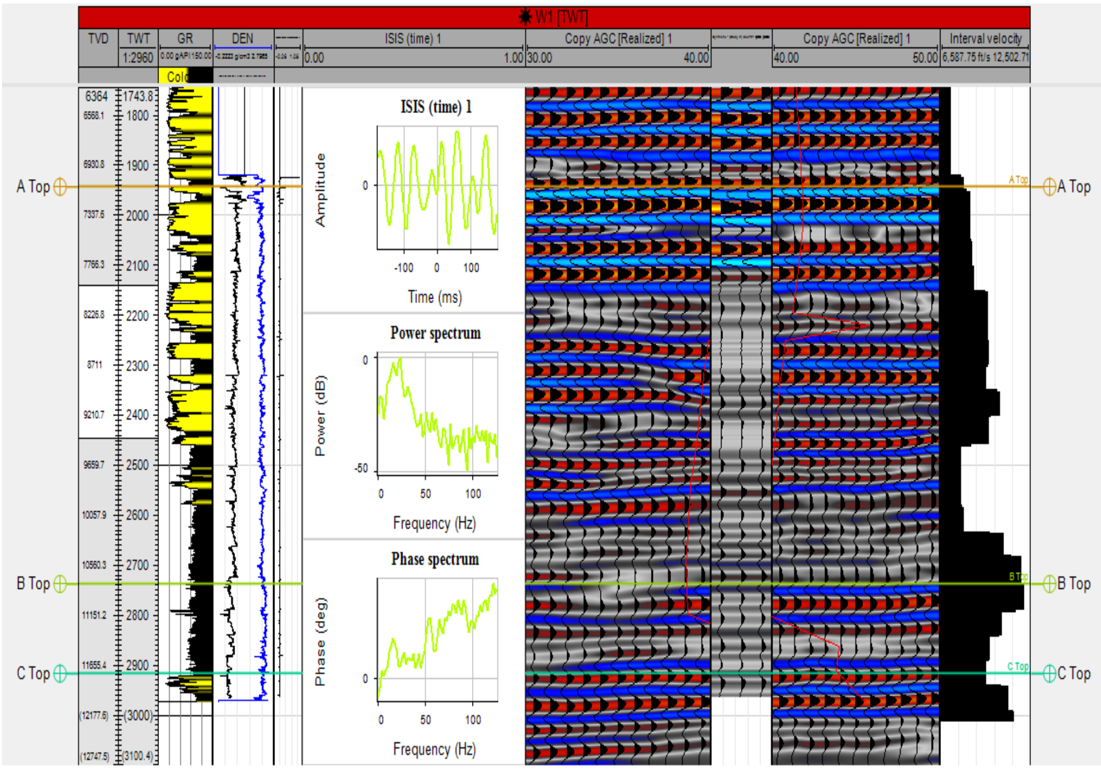


**Figure 3:** Synthetic seismogram generated and utilized for seismic well tie in well W1

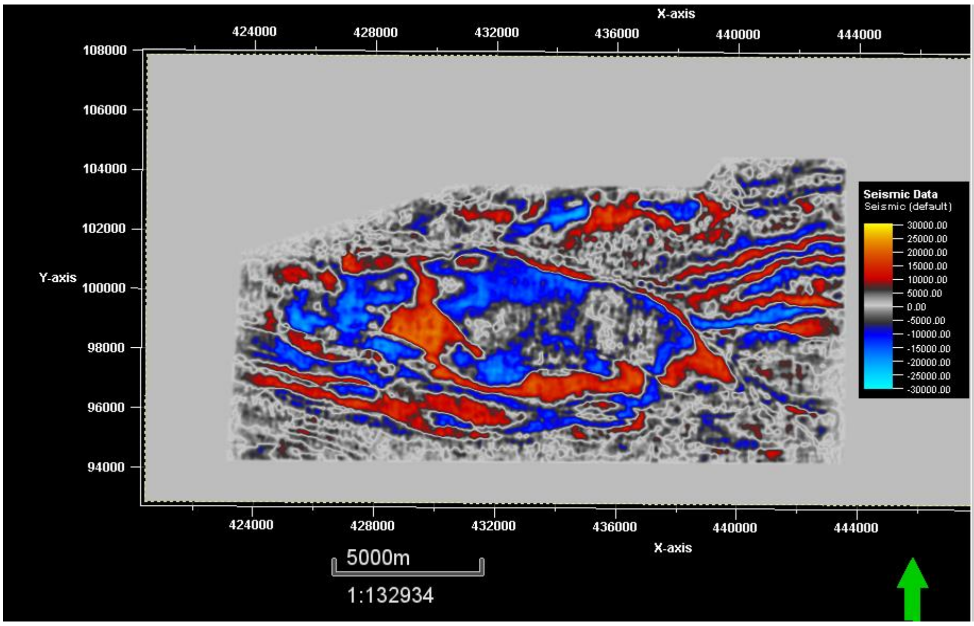


**Figure 4:** Original seismic data poorly revealing faults

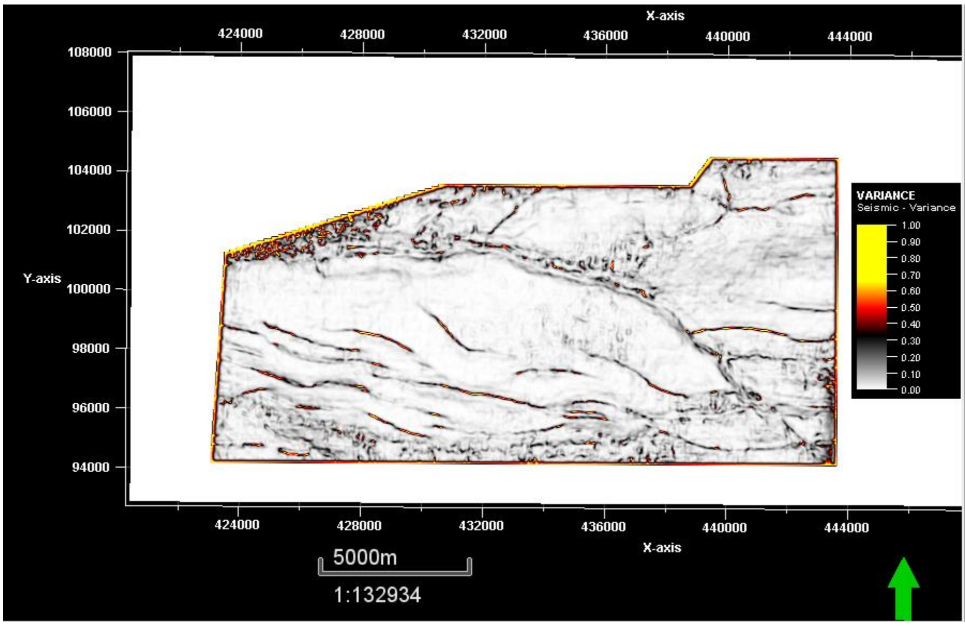


**Figure 5:** Variance seismic attribute greatly enhances faults better than original seismic data

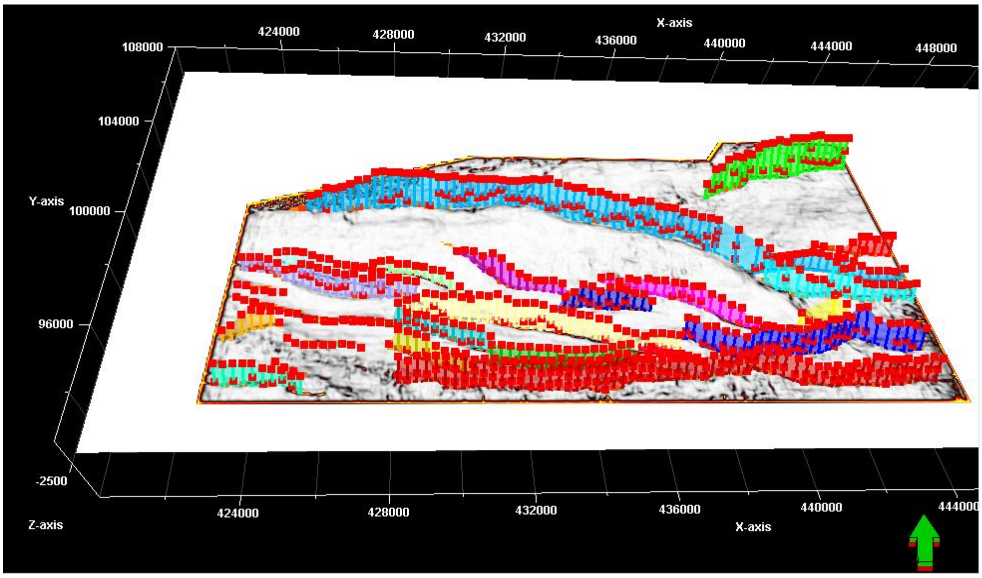


**Figure 6:** Faults interpreted displayed on a variance discontinuity time slice for validation

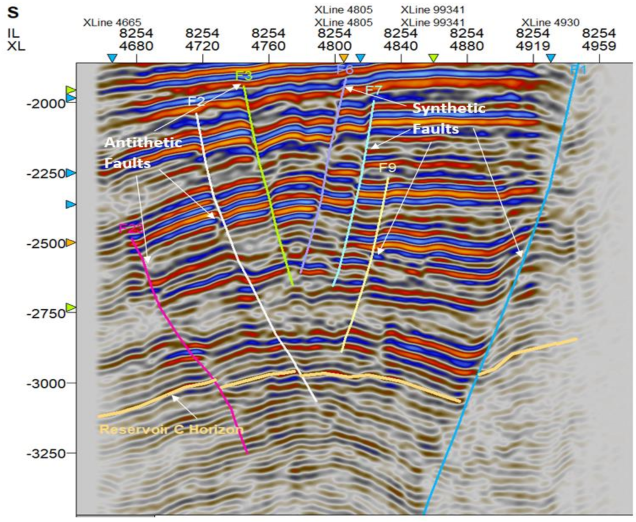


**Figure 7:** Seismic inline section showing faults and horizon top interpreted on seismic data

## 4.3 Horizon and Surface Interpretation

Figure 7 shows the seismic horizon C mapped across the entire seismic data. The seismic horizon seed grid generated after the mapping process is presented in Figures 8. On the seismic horizon, fault polygons (the intersection of the fault lines on the reservoir surface) were drawn and eliminated to reveal the presence of the fault traces on the horizon. The seed grid was used as the input for the time surface map generation. Figure 9 shows the time surface map generated for the seismic horizon C. The time surface map reveals that the reservoir is anticlinal and the identified closure is fault supported. All drilled wells were found within the closure area.

## 4.4 Velocity Model

The velocity model utilized for converting reservoir surfaces from time to depth is presented in Figure 10. Although many velocity models were tested for depth conversion (linear velocity, average velocity and polynomial velocity function), the third order polynomial function gave the best fit to the updated checkshot generated from the seismic well tie process. Also, comparing the original checkshot with the updated checkshot revealed no significant difference (Figure 10).

## 4.5 Depth Surfaces

The reservoir depth top structure map generated after applying the velocity model to the time structure map is presented in Figure 11. The depth surface maps show no significant difference in structure when compared with the time surface map, indicating that the velocity model utilized for depth conversion is very good. On the depth surface map, the shallowest depth is found at 9250 ft and its deepest depth is at 13500ft. As stated earlier, the reservoir structure is anticlinal with a fault-assisted closure.

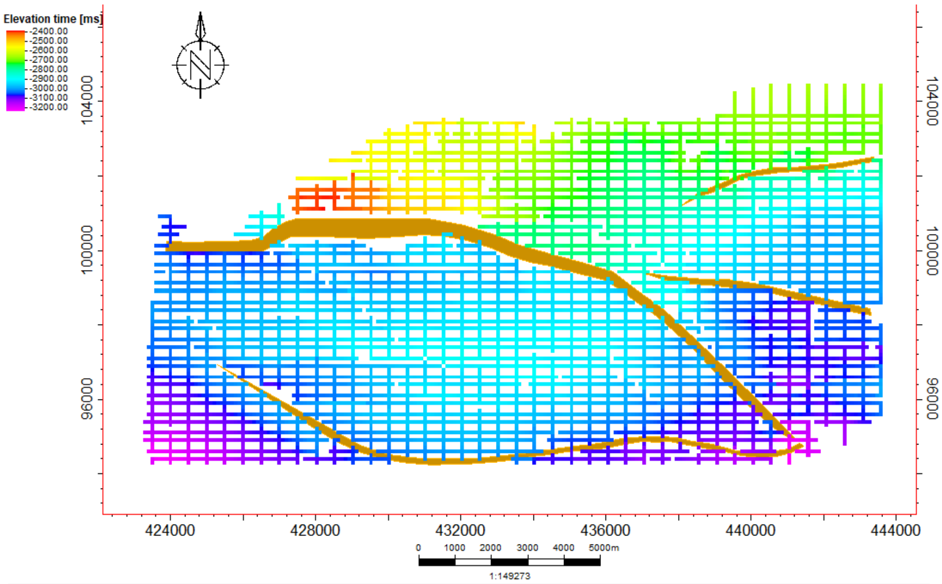


**Figure 8:** Seed grid used for reservoir C horizon generation

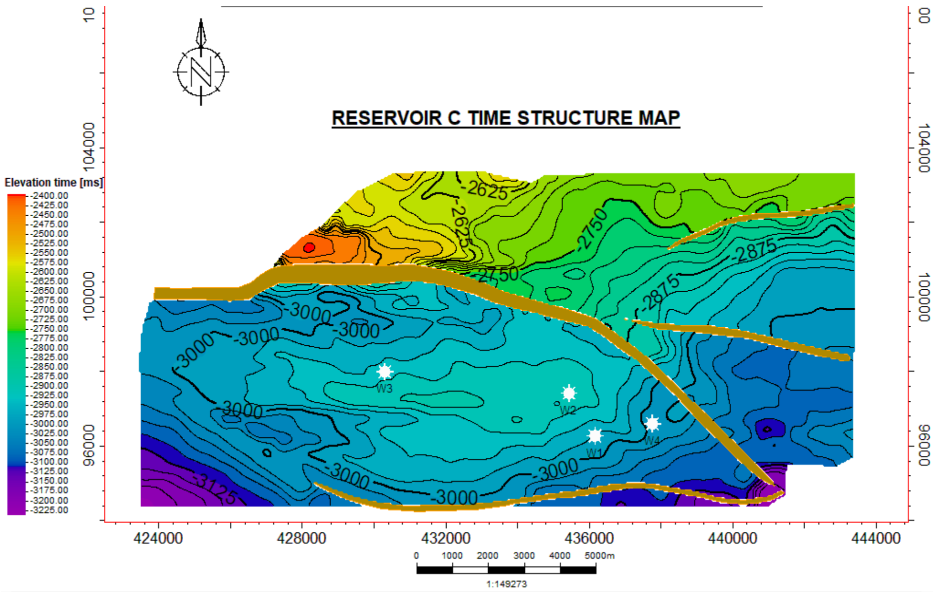


**Figure 9:** Time structure map generated for horizon C

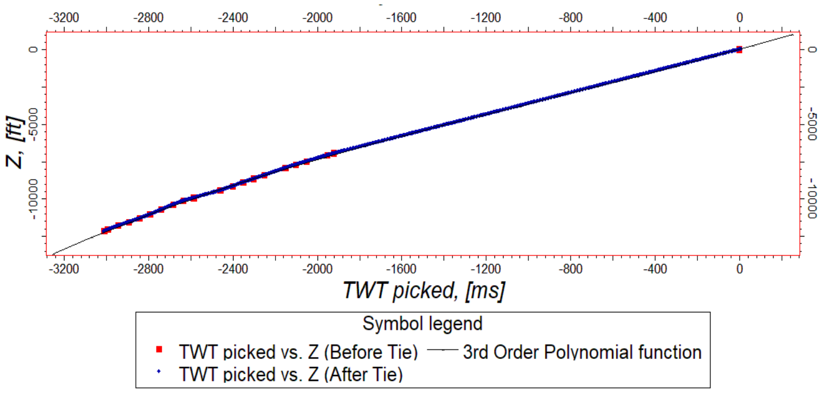


**Figure 10:** Velocity model utilized for converting reservoir surface C from time to depth

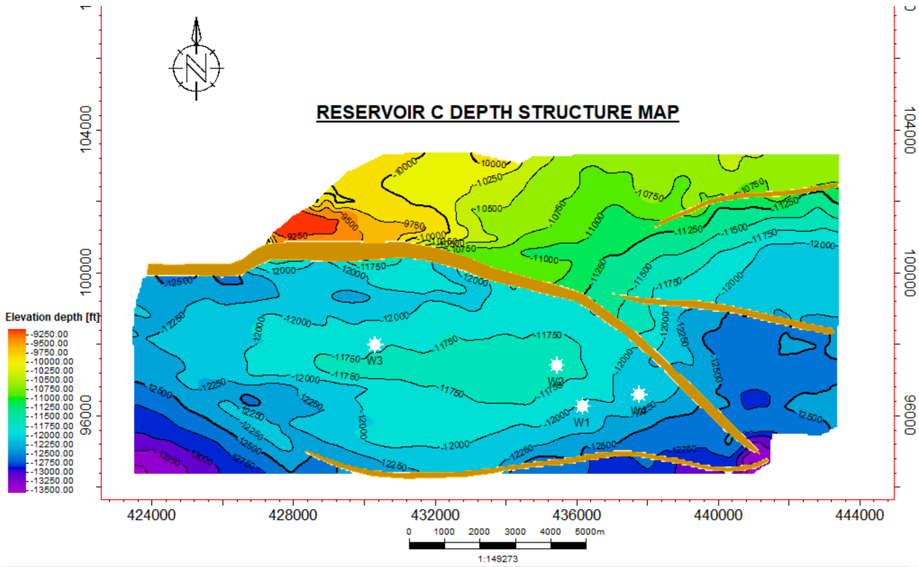


**Figure 11:** Depth structure map for reservoir C

## 4.6 Seismic Attributes

### *4.6.1 Maximum Amplitude Attribute*

The maximum amplitude attributes extracted on the time structure map and overlain on the depth structure map for reservoir C shows areas with bright amplitude anomalies around closures are indicative of hydrocarbon charged sands (Figure 12).

### *4.6.2 Root Mean Square Attribute*

The root mean square (RMS) attributes generated for reservoir C surface (Figure 13) emphasizes the variations in acoustic impedance over a selected sample interval. The higher the variations in acoustic impedance in overlying sequences, the higher the RMS value will be. In a case where a layer has hydrocarbons, the difference in acoustic impedance between the overlying formation and the formation filled with hydrocarbons will produce a very high RMS value. Hence, areas on the reservoir depth surface (Figure 13) having high RMS anomalies are indicative of hydrocarbons presence.

### *4.6.3 Average Energy Attribute*

The results for average energy attribute generated for A, B and C reservoirs (Figures 14) were used to validate the interpretations made using both maximum amplitude attribute and RMS attribute. Average Energy attribute is a good direct hydrocarbon indicator (DHI). Areas with bright spots on the maps are indicative of hydrocarbon presence, provided those areas conforms to structure.

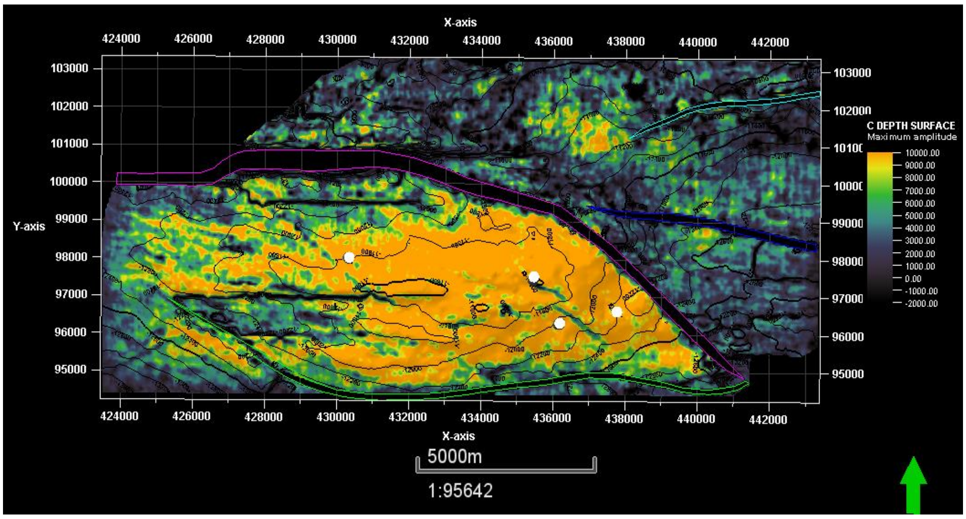


**Figure 12:** Maximum amplitude attribute generated for surface C reservoir

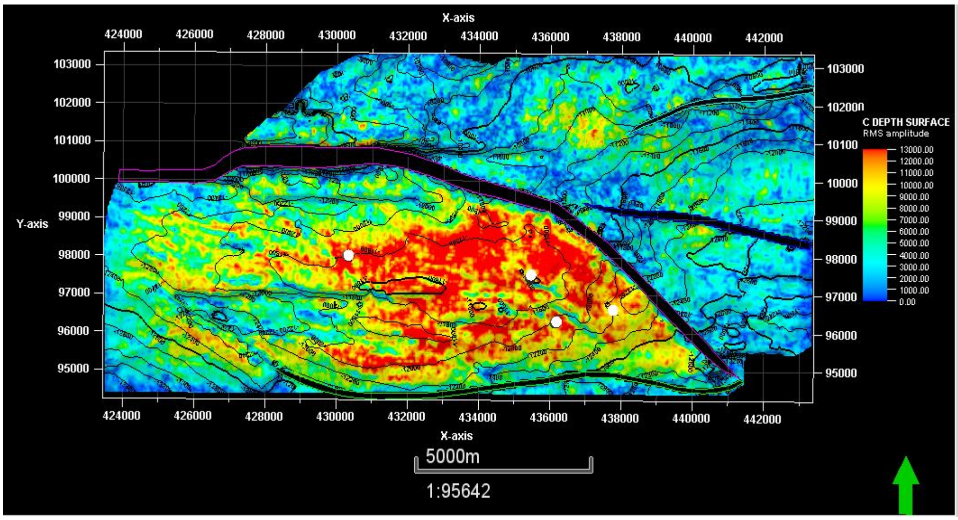


**Figure 13:** RMS attribute generated for surface C reservoir

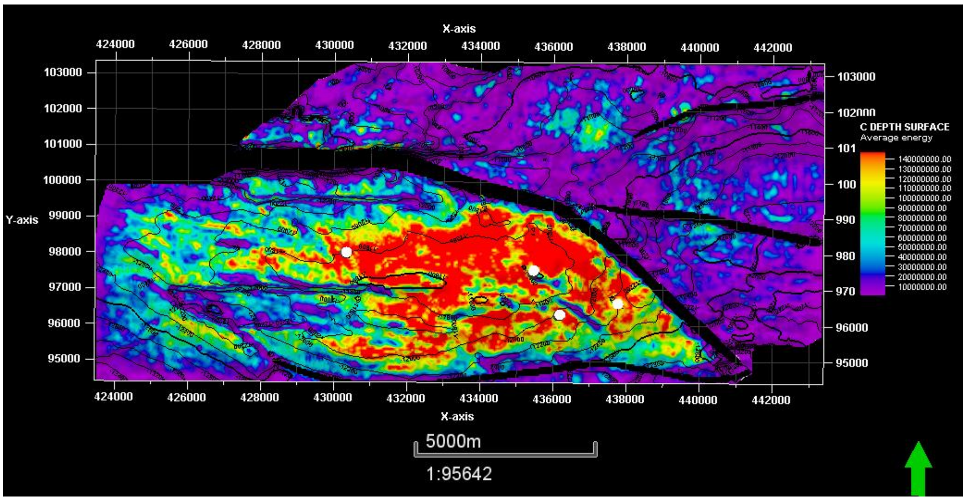


**Figure 14:** Average energy attribute generated for surface C reservoir

#### *4.6.4 Sweetness Attribute*

The results for the sweetness attribute generated for reservoir C depth structure map (Figure 15) is another good DHI and can be used to screen hydrocarbon bearing sands. Areas with high sweetness values are indicative of sands that are hydrocarbon bearing, provided they conform to structure in the reservoir.

#### *4.6.5 Multitrace Attributes*

The sweetness attribute was coblended with the variance structural attribute in order to identify bright spots that conform to structures on the time slice (Figure 16). The time slice was generated around the areas where the reservoir C interval was mapped. The resulting multi-trace time slice generated was compared with the attribute generated for the reservoir surface in order to determine if volume attributes could be utilized as a quick look for reservoir characterization. The results showed no significant difference in the volume attribute displayed on time slices and the reservoir surface attributes displayed on the depth structure maps (Figure 15 and 16).

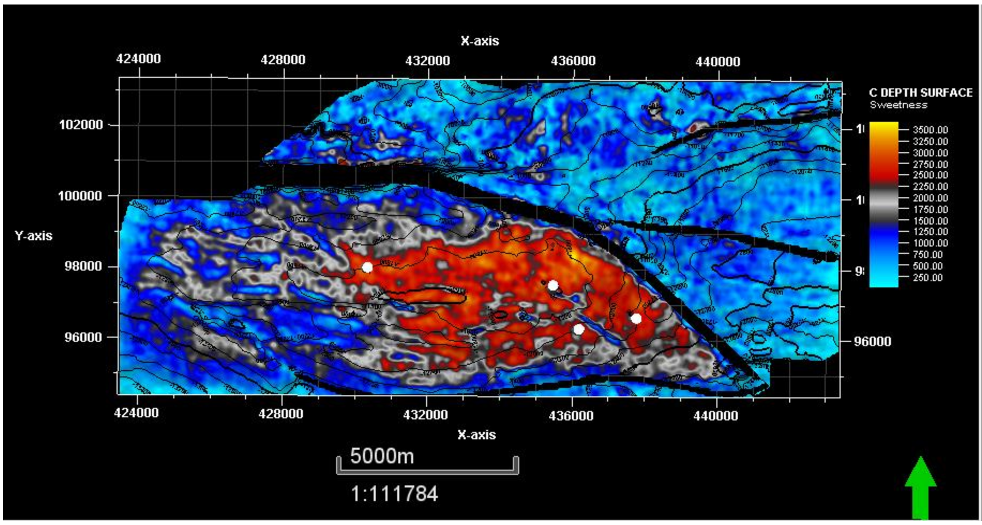


**Figure 15:** Sweetness attribute generated for surface C reservoir

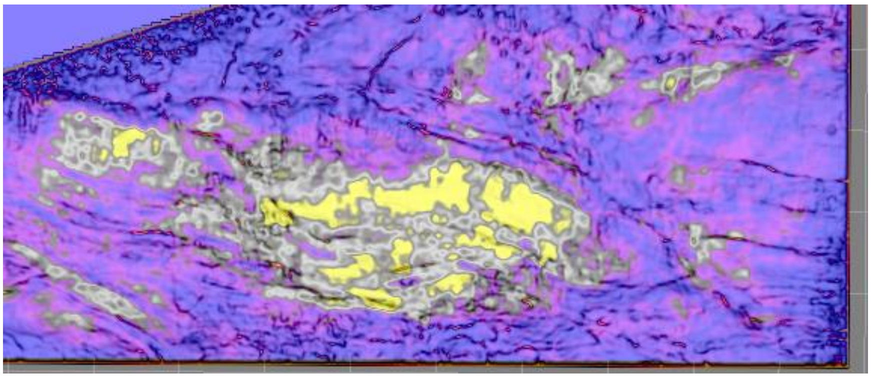

**Figure 16:** Multiattribute (sweetness+variance) generated for -3020 ms timeslice around C reservoir

### 4.7 Prospect Evaluation

The average energy attribute was utilized for prospect evaluation and the result is presented in Figures 17. One large prospect was identified on reservoir C surface. The prospect areas were identified as bright spots with amplitude anomalies that conform to structure.

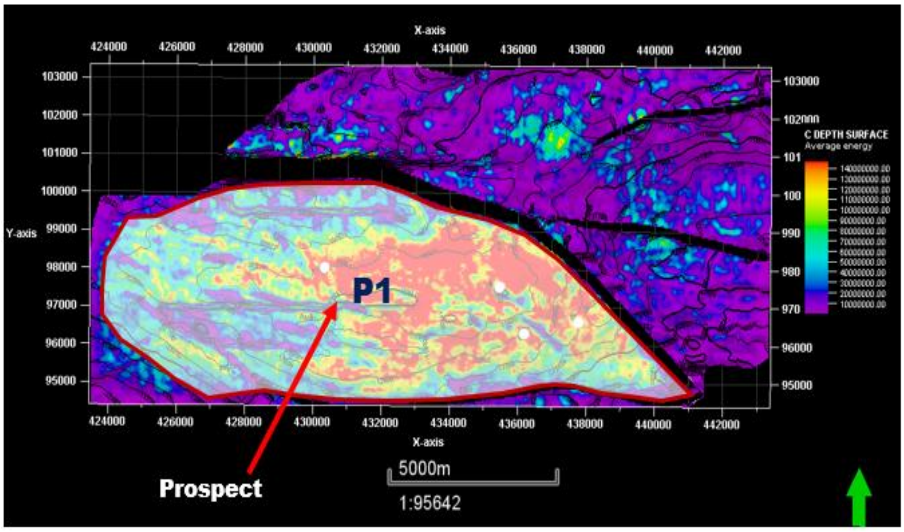


**Figure 17:** Average energy attribute generated for surface C reservoir

## 5. Discussion

Three representative reservoir intervals (A, B, C) were identified and correlated across four wells (W1, W2, W3, W4) in W-field. The reservoir C interval was selected and utilized for seismic interpretation. Seismic well tie revealed that the reservoir is high impedance sand, and this information served as the basis for extracting seismic attributes. The application of variance discontinuity attribute aided in enhancing the visibility of faults across the seismic data. From structural analysis, the field is composed of normal faults that are predominantly synthetic and a few antithetic faults. The time and depth structure map for reservoir C revealed that the field is anticlinal and fault controlled. Hydrocarbon prospect evaluation was achieved using four seismic attributes that are direct hydrocarbon indicators (DHI) and they include; Maximum amplitude attribute, root mean square attribute, average energy attribute and sweetness attribute.

The presence of hydrocarbons in a reservoir gives rise to bright amplitude anomalies because of the huge difference in acoustic impedance associated with the overlying layer and the hydrocarbon bearing layer. Hence, bright amplitudes are indicative of hydrocarbon presence, if and only if the bright amplitude anomaly is associated with a defined structure. Bright spots were identified on reservoir C that was associated with structural anticlinal closures that terminates on faults. The RMS seismic attribute produced similar results like the maximum amplitude attribute. This confirms the presence of hydrocarbons in the three reservoir intervals. The higher the RMS value, the brighter the amplitudes. Average energy attribute also supported interpretations made using both RMS and maximum amplitude attributes. The difference only being that the anomalies is brighter and sharper using the average energy seismic attribute. The sweetness attribute was also used to determine hydrocarbon bearing intervals.

The sweetness attribute reveals bright amplitudes in areas having high amplitudes and low frequency. These characteristics are indicative of hydrocarbon bearing rocks. The sweetness attribute extracted confirmed that the reservoir is hydrocarbon bearing. Time slices generated using volume based multitrace attributes (sweetness and variance) around the reservoir of interest revealed that there is no significant difference in structure and bright amplitude anomalies with those recognized using the surface attributes. This suggests that the volume based multitrace attributes can be used as a quick look for the identification of reliable prospects in W-field. Based on the information obtained from the depth structural map and seismic attribute maps, a large hydrocarbon prospect was identified on reservoir C using bright spot anomalies.

## 6. Conclusion

This study was conducted with the aim of using seismic attributes for reservoir characterization in W-Field, onshore Niger Delta. Structural analysis of the field revealed that the reservoir rock is a collapsed crestal structure flanked by major faults that are relevant for generating viable traps. The faults identified are both synthetic and antithetic faults that are typical of Niger Delta fault regimes. Seismic attributes analysis performed using maximum amplitude, root mean square attribute, average energy attribute and sweetness attribute all revealed bright amplitude anomalies on closures associated with the collapsed crestal structure. These bright amplitude anomalies are similar on all the extracted attributes, confirming that the bright spots associated with the closures are indeed indicators of hydrocarbons.

On the reservoir surface, one large prospect was identified. The identified prospect was associated with bright amplitude anomalies. The attributes did not only show the presence of hydrocarbons, but also were able to define the area covered by hydrocarbons. Multi-trace attribute analysis performed on a time slice at the vicinity of the reservoir surface revealed similarities in structure and amplitude anomalies with the surface attributes maps generated after interpreting horizons. This suggests that interpretation cycles can be reduced by the application of volume attributes for reconnaissance assessment of reservoir prospects. Seismic attributes have successfully revealed the presence of hydrocarbons in reservoir C. Not only was seismic attribute able to reveal the presence of hydrocarbons, they also revealed the area occupied by hydrocarbons within the identified closure.

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