INTERNATIONAL JOURNAL OF LATEST TECHNOLOGY IN ENGINEERING, MANAGEMENT & APPLIED SCIENCE (IJLTEMAS)

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XII, Issue IX, September 2023

Identification of Hydrocarbon Zones and Chimneys Using Seismic Attributes Analysis at Woda Oil Field, Western Offshore Niger Delta

Eje, E. O, Ideozu, R. U* and Ugwueze, C. U

Department of Geology, Faculty of Science, University of Port Harcourt, Rivers State, Nigeria.

**Corresponding author*

DOI: https://doi.org/10.51583/IJLTEMAS.2023.12907

Received: 27 July 2023; Revised: 04 September 2023; Accepted: 11 September 2023; Published: 03 October 2023

Abstract: This research investigated hydrocarbon zones and chimneys using seismic attributes analysis in Woda Oil Field, Western offshore Niger Delta. Seismic attributes are powerful tools in monitoring and predicting hydrocarbon zones. Detailed application of seismic attributes on the Woda seismic data aided in the extraction of important information about the geologic features on seismic profiles. Materials used in this research include well logs, seismic data and 3D Post Stack Depth Migration (PSDM) seismic volume. Methods used were seismic attribute analysis and well log interpretation. The reservoirs of interest were identified and analyzed using well log data based on gamma ray, resistivity, and Vp sonic log response. Seismic attributes such as chaos, root mean square velocity, similarity and reflection intensity were quality controlled, enhanced, and generated which assisted in identifying chimneys and hydrocarbon zones. The majority of the chimneys in this research may have nucleated in the lower part of the faulting system below the partially permeable portion of the fault planes and across a regional partially permeable barrier as revealed by thin fault likelihood attribute. Gas expulsion along the lower portion of the complex faulting system perhaps, may have preconfigured the spatial organization of the chimneys. Pockmarks formation above the chimneys as revealed by the sweetness attribute may have inherited the same linear planiform geometry, and both structures recorded the timing of hydrocarbon zones and gas expulsion within the Woda Oil Field.

Key Words: Hydrocarbon Zones, Chimney nucleation, Seismic attributes, Pockmarks

I. Introduction

Gas chimney and hydrocarbon zone identification was carried out on a 3D seismic data acquired over WODA Oil Field, Western offshore Niger Delta using seismic attributes with a view to identifying different chimneys and hydrocarbon zones within the study area and as well, understand the petroleum system better. The study area is still undergoing post exploration activities and in recent times sidetracks drilling has identified mature, oil-prone source rocks overlying Upper Oligocene clastic reservoirs in Woda Oil Field.

According to Heggland (2000), oil and gas production has been documented as taking place adjacent to active fluid conductive faults in 330-Field, Eugene Island using chimney's identification scheme. Documentation of active gas conduits, using seismic attributes and chimney identification may provide analog for exploration and drilling which may assist in defining gas prospects and minimize risk associated with drilling through geo-hazard formations.

Chimney identification scheme using seismic attributes (fig.1) was developed in Europe, given the abundance of gas chimneys in the North Sea (Ismail *et al*., 2019). Examples of such applications was documented in Heggland et al, (2000), Meldahl *et al.*, (2001), Aminzadeh *et al.*, (2001). Eastwood 2002 define seismic attributes as components of the seismic data which can be obtained by mathematical computation. The advantages of extracting seismic attribute are to extract information from seismic data to identify prospects, chimneys distributions, gas zones, gas channels, unconformities, minor and major faults to enhance better geological and geophysical interpretation. The information content in seismic data is rich in terms of amplitude, frequency, geometry and texture (Eastwood, 2002). Thus, seismic attributes may facilitate identification of depositional environments and enhance the recognition of seismic facies. Once calibrated at well locations, attributes may identify seismic facies and provide information on lithology and fluids. Post stack seismic attributes are classified into physical, geometrical and complex attributes, (Ismail A et al., 2019). Physical attributes such as root mean square (RMS), chaos and relative acoustic impedance etc.are used in reservoir characterization and lithological classification (Ismail A et al., 2019). In complex trace attributes analysis, interpreted features are consistent with components of the analytical seismic trace such as amplitude, energy (envelope), instantaneous frequency, and instantaneous phase attributes which are computed trace-by-trace. Complex attributes more than any other seismic attributes should be displayed with a

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proper color scale range (Taner et al. 1979). Geometrical attributes such as similarity and variance attributes describe the temporal and spatial relationships related to all other attributes.

The presence of gas will show effects on the seismic data since it lowers the P-Wave velocities, increases attenuation and increase wave scattering (Bradly *et al.*,2012). Previous research has shown that, gas chimney nucleation may indicate different anomalies on the seismic data based on low amplitude (bright spot), low frequency, low coherency and high chaotic noise. This research made use of seismic attributes in horizon identification, fault picking. gas chimney and hydrocarbon zone identification.

Seismic attributes analysis was first used in the 1970s and 1980s in oil and gas exploration after the development of complex trace theory in the early 1970s. These attributes are essentially derivatives of the basic seismic measurements such as time, amplitude, frequency and attenuation which may also form the basis of their classification as documented by. Seismic attribute was defined by (Mahammad A., et al., 2017). Sheriff, 1992 as a measurement based on seismic data such as envelope, instantaneous phase, instantaneous frequency, polarity, dip, dip azimuth, etc. Mohammad A., et al., 2017 noted that, detailed attribute interpretation may supplement conventional structural interpretation and the discriminating properties of the attributes set may be critically checked for its relevance for a particular problem of a prospect. They also noted that, in attribute analysis, seismic data is treated as an analytic trace which contains real components (original input trace) and the complex (imaginary) component, usually generated from the Hilbert transforms from which various amplitudes, phase and frequency attributes can be deduced (Mohammad A., et al., 2017).

Seismic interpretation has witnessed significant development with the introduction seismic attributes and their application for imaging and interpreting geological features. The use of advanced interpretation techniques based on different seismic attributes such as similarity, energy, dip variance, frequency etc., are very sensitive in demonstrating chaotic events in seismic data. The identification of gas chimneys may provide a clue for the identifying hydrocarbons zones, assist in understanding the petroleum system of a region and identify potential over-pressured zones to mitigate drilling risks (Heggland, 2005). Attributes such as the root mean square (RMS), variance and red-green-blue color blending are used to study and interpret these chaotic events. Ilg *et al.*, (2012) identified 394 gas chimneys within the Taranaki Basin based on seismic attribute studies while Alotaibi (2015) and Wooltorton (2015) have shown that gas chimneys in the Maari prospect are related to faults.

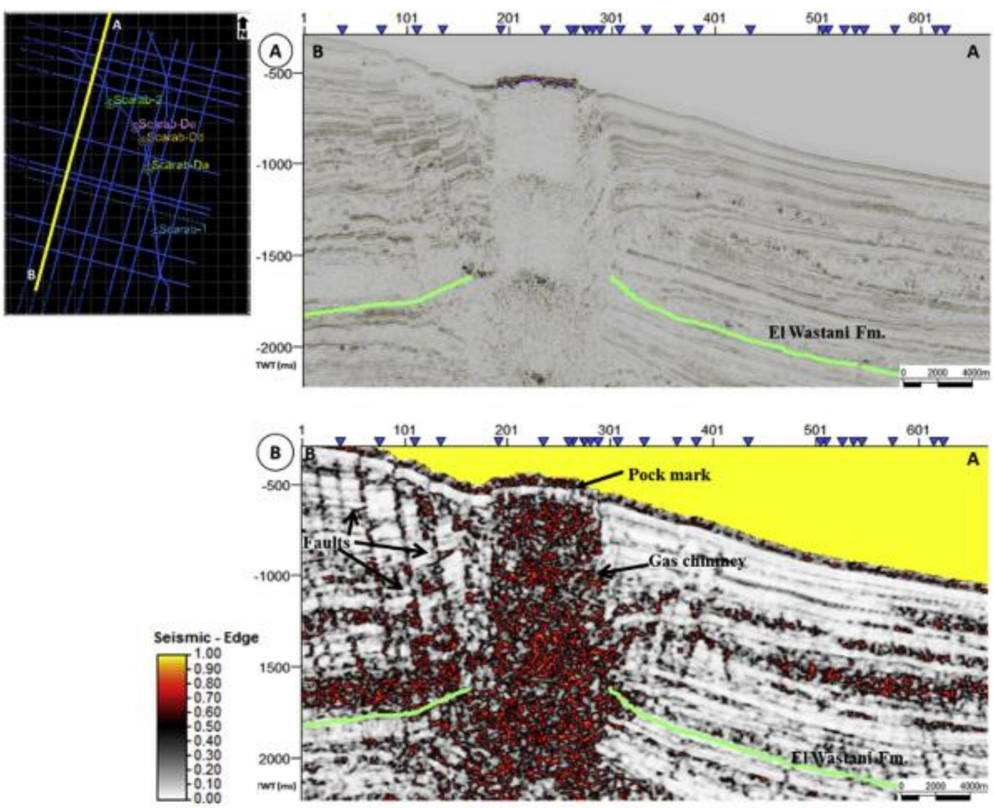

Fig. 1: (A) The seismic section with the original amplitude. (B) Chaos attribute displays the Gas chimney with its pockmark and fault zone and the black arrows point to three of these faults which well-revealed. (Source; Ismail A*et al.*, 2019).

II. Geology of the Study Area

Niger Delta is a Tertiary prograding sedimentary basin deposited under different sub environments from Eocene in the North to Pliocene in the South. The geology of this basin has been discussed by other researchers. It is situated within the Cenozoic formation of Southern Nigeria in West Africa. Its area is about 75,000 Km^2 from the Calabar Flank extending to the Abakaliki Trough in the Eastern Nigeria down to the Benin Flank in the West. It also extends to the Atlantic Ocean in the South and into the Gulf of Guinea as an extension from the Benue Trough and Anambra Basin. (Burke et al, 1972; Tuttle *et.al* 1999).

Stratigraphically, the Tertiary Niger Delta is divided into three formations, namely Akata Formation, Agbada Formation, and Benin Formation (Evamy*et al.,*1978). Akata Formation at the base of the delta is predominantly under compacted, over pressured sequence of thick marine shales, clays and siltstones (potential source rock) with turbidite sandstones (potential reservoirs in deep water). It is estimated that the formation is up to 7,000 meters thick (Doust & Omatsola, 1990). The Agbada Formation, the major petroleum-bearing unit about 3700m thick, is alternation sequence of paralic sandstones, clays and siltstone and it is reported to show a two-fold division. (Evamy*et al.,*1978). The Benin Formation overlies Agbada Formation consists of massive, unconsolidated Continental sandstones. Ugwueze*et al.,* (2015) discussed the structures and evaluated prospect zones for oil and gas in "Bonga" field, Niger Delta.

Structural traps in the Niger Delta Complex formed during synsedimentary deformation in the Agbada Formation (Evamy*et al.,*1978; Stacher, 1995) while stratigraphic traps formed preferentially along the delta flanks (Beka and Oti, 1995) define most reservoirs. The primary seal rocks are interbedded shales in the Agbada Formationhaving three types of seal recognized as clay smears along faults, interbedded sealing units juxtaposed against reservoir sands due to faulting, and vertical seals produced by laterally continuous shale-rich strata (Doust and Omatsola, 1990). Major erosion events of the early to middle Miocene age formed canyons filled with shale and these fills provide top seals on the flanks of the delta for some important offshore fields (Doust and Omatsola, 1990) seeFig. 2a.

The Woda Oil Field is located approximately 110 km SW of Forcados terminal on 4^0 33' N,4° 36' E and was discovered in 1996 by the Woda-00l Well -Western Offshore Nigeria – Fig. (2b &c) with a stratigraphically trapped sequence made up of least six channelized turbidite reservoirs (Ugwueze, 2015).

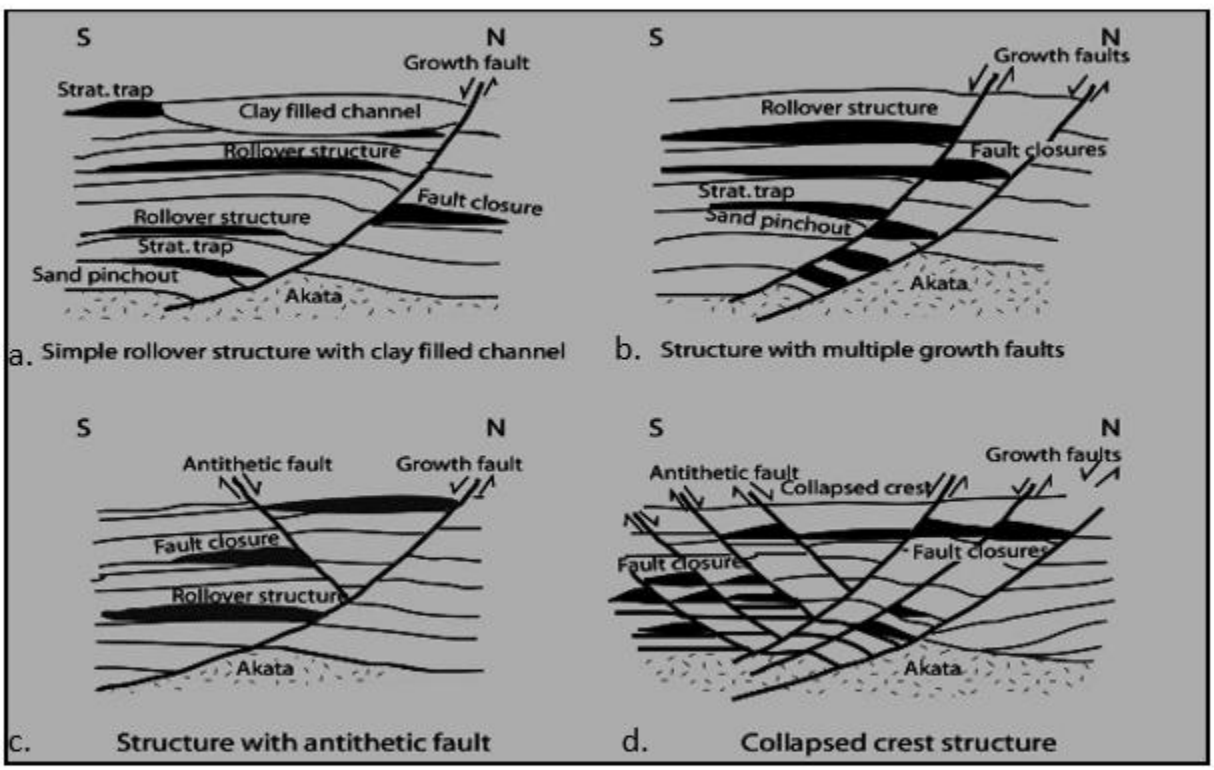

Fig 2 (a): Niger Delta oil field structures and associated traps (a.) Simple rollover structure with clay filled channel, (b.) Structure with multiple growth fault (c.) Structure with antithetic fault (d.) Collapsed crest structure. Modified from Doust and Omatsola (1990) and Stacher (1995).

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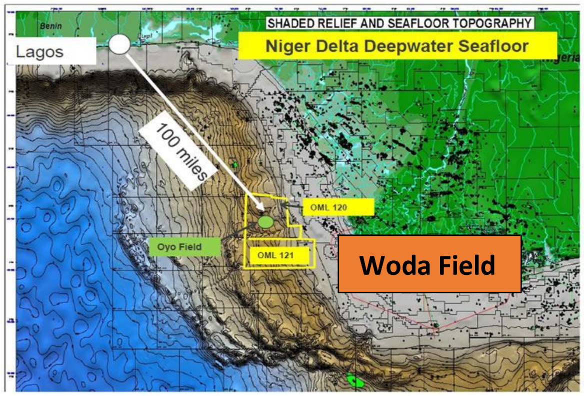

Fig. 2b: Satellite image of Woda oil field.

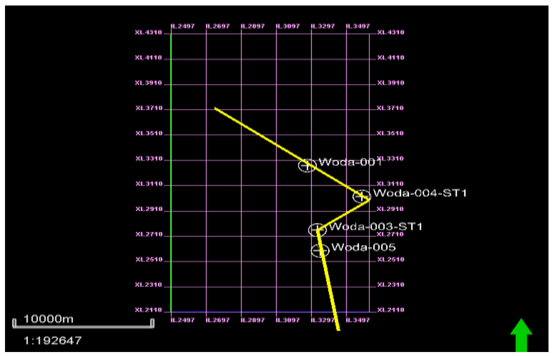

Fig. 2c: Base map of Woda field, well distributions

III. Materials and Methods

The data sets for this research were provided by the Shell Nigeria Exploration and Production Company (SNEPCO) operating within the study location with approval of the Nigeria Upstream Regulatory Commission (NUPRC). Data provided include 3D seismic data covering and 3D profile lines, Four (4) Wells (Gamma Ray, resistivity, density, neutron and sonic logs), well deviation data, well head and checkshots. The method adopted for this research is shown in Fig. 3. The identification of gas chimneys and hydrocarbon intervals was carried out using 3D seismic data and the integration of seismic attributes. Hydrocarbon leakages were observed within reservoirs D and E using log signatures and validated using seismic attributes. Well logs of four wells; Woda 001, 003, 004 and 005 were used as key component to evaluate hydrocarbon zones. Seismic data enhancement was performed to generate the 3D seismic images with best signal to noise ratio. Wavelet extraction and synthetic seismograms were extracted to correlate the formation tops from the logs with the seismic events to have an accurate tie to pick the important horizons and geological structures (fig.5). Seismic attributes analysis was carried out in the study area to give the best output as direct hydrocarbon indicator and hydrocarbon zones. Neutron density cross plots were evaluated to separate between hydrocarbon zones from non-hydrocarbon zones.

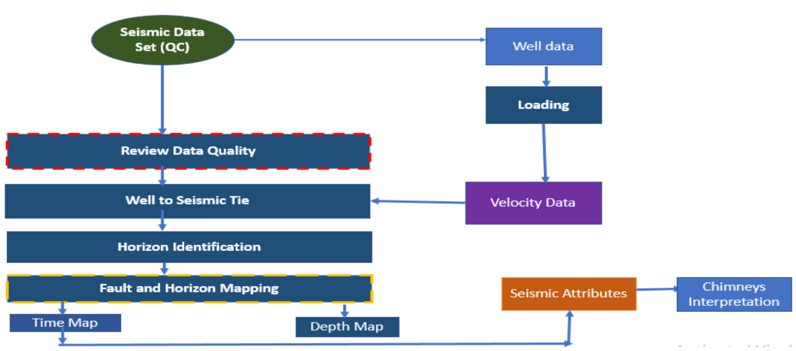

Fig.3: Study Flow Chart

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- **3D Seismic Data Analysis**

3D seismic data with zero-phased reflectivity (RZP) and PSDM was used for better resolution of the seismic data and realized into 16 bits for structural interpretation and 8 bits for attribute analysis. The algorithm used improved the spatial positioning of horizons because of appropriate velocity model that was built and used for migration of the stacks in depth domain. Seismic interpretation showed that, the seismic volume became poorer below 3.7 sec two-way travel time (TWT) around the footwall while reflectivity was visible in the hanging wall around 4.2 seconds. Synthetics were generated from Woda -001 with sonic and density logs tied to Woda Seismic for lithological identification.

- **Time to Depth Data**

The data for time (T) to Depth (Z) conversion helped in generating a polynomial curve using equation (1), derived from checkshot of Woda-001 well - the Woda-T-Z Curve (Fig.4). The time maps generated from the interpreted horizons were depth converted using Linvel velocity modelling function as it had the lowest residual among Adlinvel velocity modelling suites.

Where:

V = Vo + kZ (Equation 1)

Vo = Velocity at datum

Z = Distance of the point from datum

K= Factor showing Velocity change in the vertical direction.

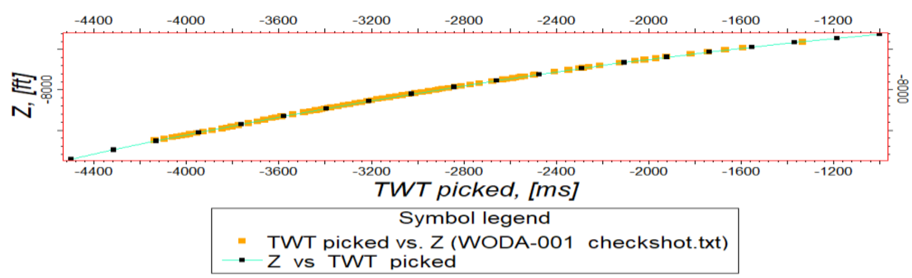

Fig 4: Time depth curve from checksot data of Woda -001 well**.**

- **Chimney Identification Using Seismic AttributesAnalysis**

The following attributes was used to identify chimneys and hydrocarbon zones in the study area.

Chaotic Attribute: The Chaotic attribute measures the lack of organization in seismic section and was used to identify discontinuities on horizontal continuity such as faults, salt/shale diapirsand channels (Chopra (2007). The chaotic attribute wasused for fault picking and gas chimneys identification in this study area. Zones of high chaoticnessare identified by complex geometrical reflector discontinuities such as fault zones, angular unconformities, channel sand bodies and zones of fractures (Ismail et al., 2019).

RMS Amplitude: The Root Mean Square (RMS) velocity amplitude calculates the amplitude average over a given time window. High RMS amplitude was used by Bradly *et al.,* (2012) to identify gas chimneys.this research used this approach to mapped chimneys within the study area. The RMS amplitude -ARMS attribute was extracted from the seismic trace within a defined window with a width of equal N of samples which gives information on the internal energy of the seismic dataEquation (2).

$$\boldsymbol{ARMS}\ (\boldsymbol{t}) = \sqrt{\frac{1}{N}} \sum_{i=1}^{N} \mathrm{A}(i)^2 \qquad (2)$$

where, ARMS is RMS amplitude, N is number of samples and A is amplitude of the sample.

Reflection Intensity/Envelop: The reflection intensity amplitude gives the average amplitude over a defined window and multipliedit by sample interval. In this research, reflection intensity was used in the horizon interpretation. Envelope attribute defined the instantaneous energy through the analytical trace, both real, imaginary parts and independent of phase, make it suitable to identify amplitude anomalies and acoustic impedance contrast (Ismailet al., 2019). Mohammad A., et al., 2017, documented that,

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the envelope attribute is useful in highlighting discontinuities, changes in lithology, faults, and changes in deposition, tuning effect, and sequence boundaries. It also is proportional to reflectivity and therefore useful for analyzing AVO anomalies. If there are two volumes that differ by constant phase shift only, their envelopes will be the same. The reflection strength of each time sample is given in equation 3.

$$F(t) = f(t) + g(t) \tag{3}$$

where, f (t) is the real part corresponding to the recorded seismic data and g (t), the imaginary part of the complex trace - the Hilbert transform of (t). The envelope is the modulus of the complex function in equation (4).

$$E(t) = \sqrt{[f^2(t) + g^2(t)]} \tag{4}$$

where, E (t) ¼ represents the total instantaneous energy.

Variance Attribute: In the probabilistic analysis, the variance is the measure of how waveform data spread around their mean value. Based on this statistical definition, by using the patented algorithm introduced by Van Bemmel and Pepper (2000). Variance attribute uses an algorithm to compute the local variance of the seismic signal with a defined multi-trace window. Variance attribute is one of the best structural attributes for structural geology interpretation process. This research used variance attribute to improve the display discontinuities and geological structures such as the faults. The similarity attribute is similar to variance attribute as it measures the similarity between the adjacent traces to detect the discontinuities.

Sweetness Attribute: Sweetness attribute may work best in geologic settings where there is a good contrast in the acoustic impedances between sands (hydrocarbon filled or brine) and shales. It derived by dividing the reflection strength (instantaneous amplitude) by the square root of instantaneous frequency (Hart, 2008). Mathematically it is shown in equation (5):

$$Sweetness = \frac{Ins(A)}{\sqrt{Ins}(f)} \tag{5}$$

where Ins. (A) represents instantaneous amplitude (reflection strength) and Ins. (f) represents the instantaneous frequency. Instantaneous frequency is the rate of change of the instantaneous phase and it is obtained by taking the derivative of the instantaneous phase with respect to time (Taner et al., 1994).

Spectral Decomposition Attributes: Time-frequency analysis or spectral decomposition is a technique that allows visualization of frequency content of seismic data along a time axis. Spectral decompositionis used to identify and map of thin beds, especially in clastic successions with sharp impedance contrasts (Partyka, G. et al., 1999; Awolola and Ideozu, 2019; Ideozu et al., 2020). These maps are interpreted qualitatively, using geomorphologic pattern-recognition and semi-quantitatively, to infer relative thickness variation. Spectral decomposition is used to study seismic data at a sub-seismic resolution or to study attenuation effects caused by hydrocarbons. The spectral decomposition may be carried out by using Fast Fourier Transformation (FFT) or Continuous Wavelet Transformation (CWT) (d GB Earth Sciences., 2021). The technique separates the time series into its amplitude and frequency components. The short-time Fourier transform (STFT) is the first method used to investigate the local frequency of a seismic trace. It breaks the trace into many subsections whose amplitude-spectrum can be calculated by using the Fourier transform. It begins by multiplying the seismic trace by a window, $w(t-T)$equation 6.

$$s(t)w(t-T) = \begin{cases} s(t) & T \approx t \\ 0, & otherwise \end{cases} \tag{6}$$

and then taking the Fourier transform of each windowed section $s(t)w(t-T)$ as follows.

$$s(t,w) = \int_{-\infty}^{\infty} s(t)w(t-T)^{-iwt}dt, \tag{7}$$

where ***t***is the vertical (usually 2-way) travel time as read from the seismic trace and ***T*** is the location of the center of the window in the ***t*** axis (Partyka et al., 1999).

IV.Results and Discussions

The results of this research are presented in Figures 5 – 13. To establish the lateral continuity of the reservoirs across the field, different reservoirs were identified across the wells using a combination of Gamma ray (GR) log. Resistivity (ILD) log, Neutron (NPHI) and Density log (RHOB) (Figure 5). The correlated sand tops were inputted into the synthetic seismogram process (Well-to-Seismic tie) Figure 9.

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- **Lithologic Analysis and Reservoir Description**

Well log analyses revealed sand and shale as the main lithologies common in the study area. The identified lithologies vary laterally and vertically across the area of study. The interval-colored yellow depicts sand whereas the interval with black indicates shale. Eight (8) reservoirs were identified and correlated based on their log signatures – reservoirs **A**, **B**, **C**, **D**, **E, F. G, H, I,** and **J**. However, reservoirs D, G and I were mapped and surface maps generated representing for the reservoirs. (Figs6-8).

- **Reservoir D**

Reservoir D top and base was located at 2462.04(m)-2487.23(m) with thickness25.19(m) in well 001, 2911.02(m)-2915.96(m) with thickness 4.94(m) in well 003, 2648.93(m)-2665.81(m) with thickness 16.88(m) in well 004, and 3117.09(m)-3143.11(m) with thickness 26.02(m) in well 005. Reservoir D was thickest in Woda 001 and thinned out at Woda 003, 004 and Woda 005 which may indicate diapiric activities. Based on the well log signatures, Reservoir D may favor the accumulation of hydrocarbon (Fig. 6).

- **Reservoir G**

Reservoir G top and base were located at 2818.45 (m) – 2829.74 (m) thickness 11.29 (m) top in well 001 and 2943.71 (m) – 2953.13 (m)thickness of 9.42 (m) base. Reservoir G thinned out in Woda 003ST1 and Woda 005. Based on the well log signatures, reservoir G favors accumulation of hydrocarbon (Fig. 7).

Reservoir I

Reservoir I top and base was located at 3040.61(m) – 3052.39(m) thickness is 11.78(m) in well 001 top and 3273.96 (m) – 3281.24 (m) with a thickness of 7.28 (m) base. Reservoir I thinned out in wells 003 and 005. Based on the well log signatures Reservoir I favors the accumulation of hydrocarbon (Fig. 8).

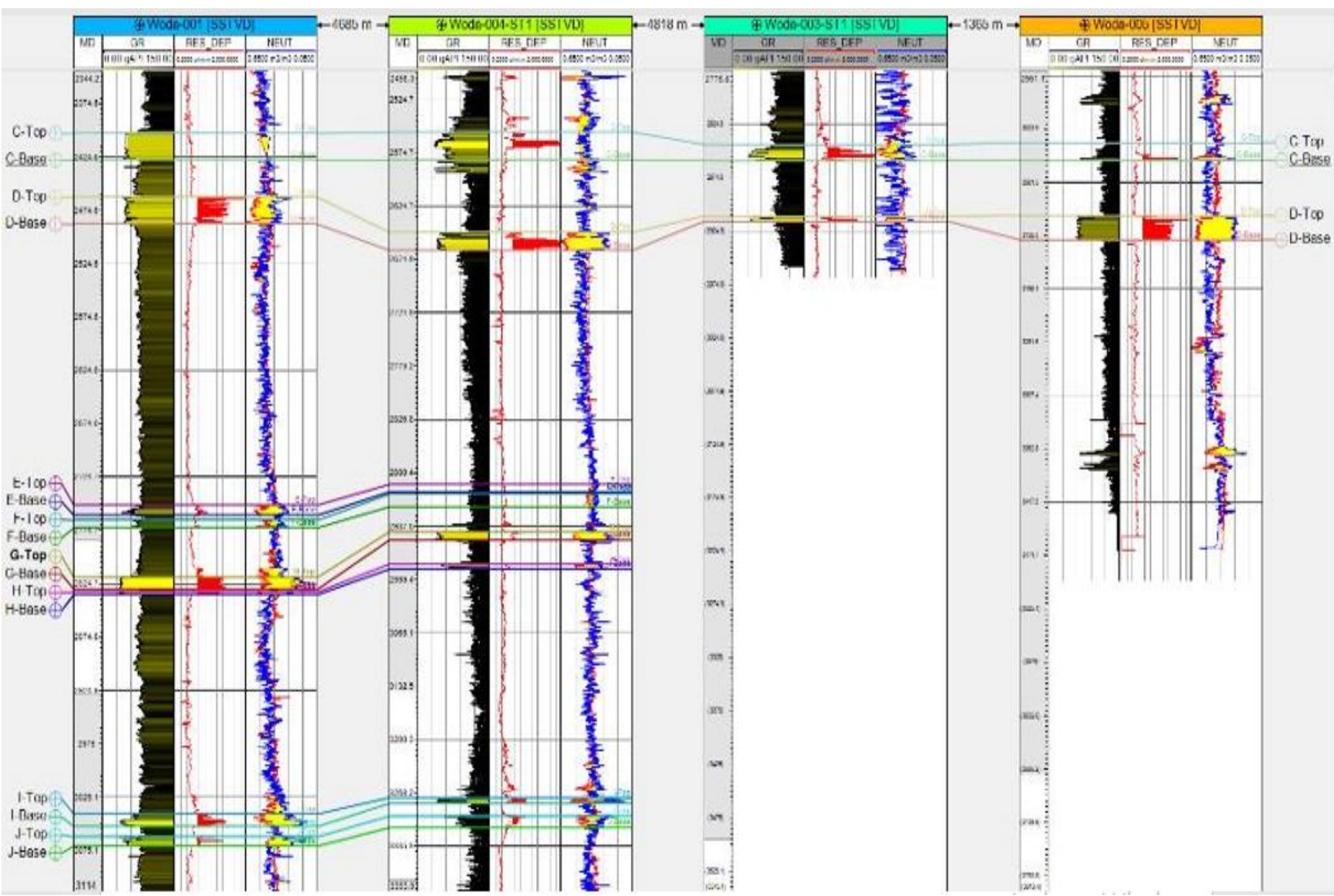

Fig. 5 Log suite used for reservoir top identification and well correlation showing Gamma Ray, Resistivity, Density and Neutron, Porosity,

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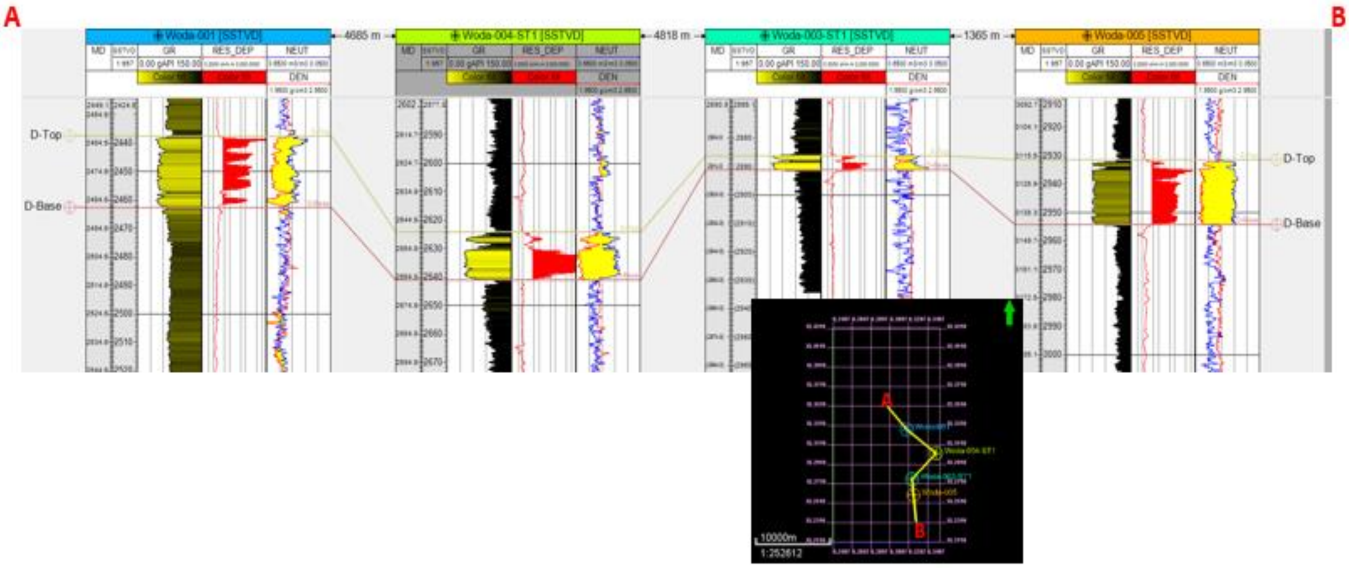

Figure 6**:** D-Top well correlation flattened on well tops.

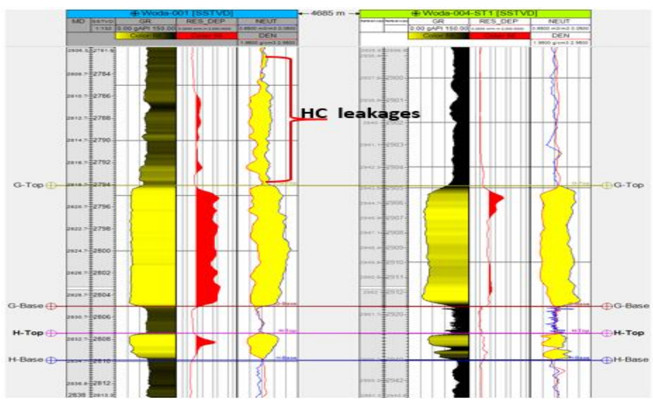

Figure 7

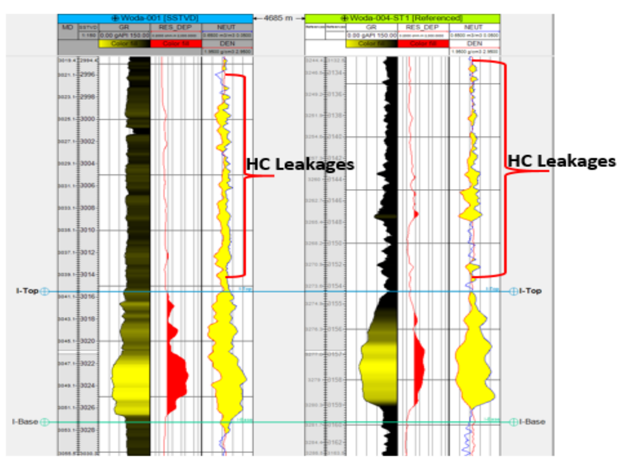

Figure 8

Fig.7: G-Top well correlation flattened on well tops showing hydrocarbon leakages in well-001. Fig. 8 I-Top well correlation flattened on well tops showing hydrocarbon leakages in well 001 and 004 ST1

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- **Well to Seismic Tie**

Well to seismic tie was carried out for Woda-001 using seismic Ricker wavelet (analytical method) and convolved with the acoustic impedance/reflectivity log generated from the density and sonic logs. A bulk shift of -5.45msec was applied which falls within the acceptable threshold see Fig. 9.

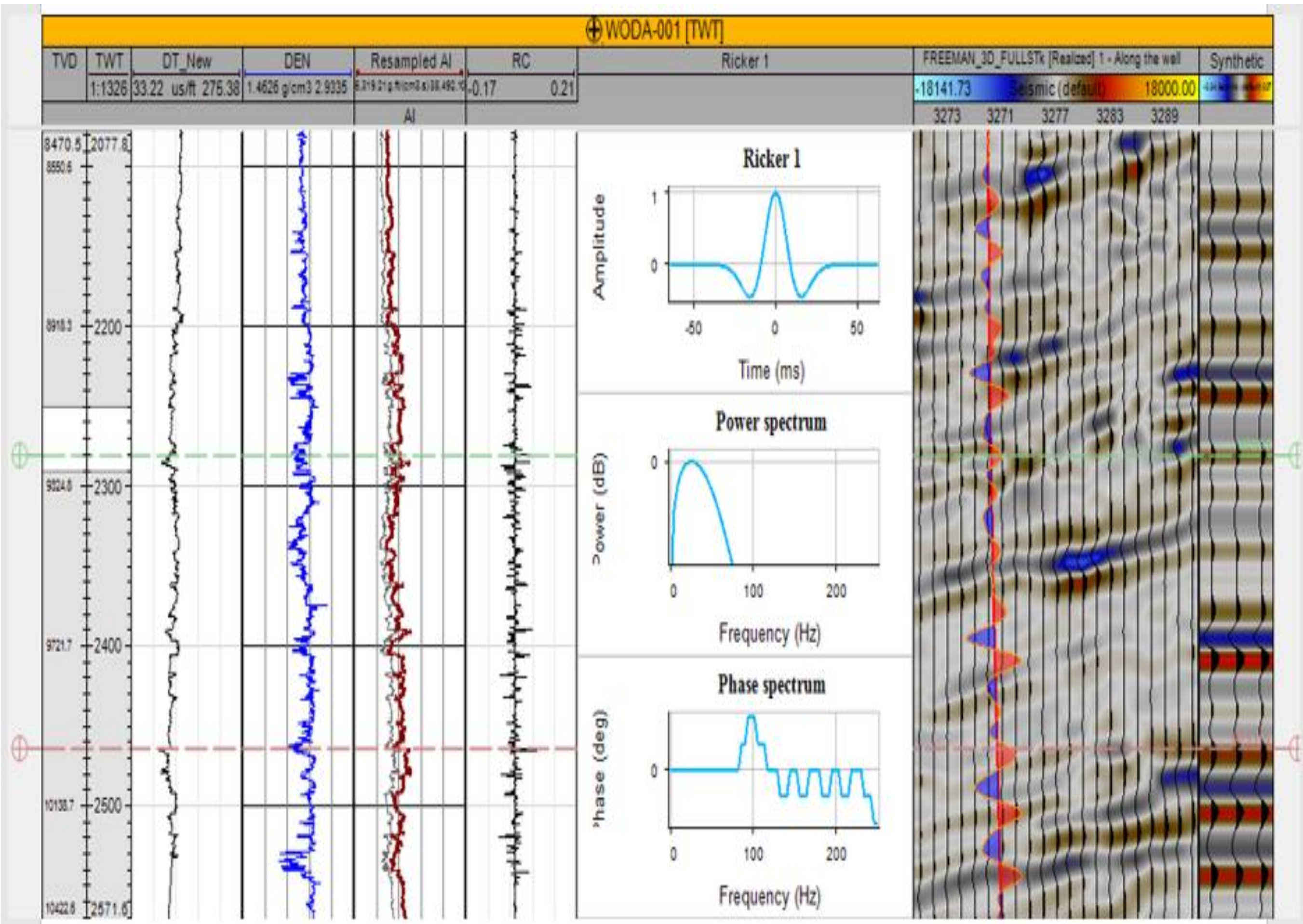

Fig. 9- Well to seismic tie for Woda 001 using seismic Ricker wavelet (analytical method).

- **Fault Interpretation**

Fault is defined as a crack in a rock volume with significant displacement as a result of mass movement. Its occurrence in Niger Delta is as a result of extensional deformation, (Doust and Omatsola, 1989). In Niger Delta, normal faults made up of syn-depositional growth faults and crestal faults has been identified by previous researchers. Another type of normal fault, known as polygonal faults and listric faults that resulted from movement during sedimentation processes were mapped in the study location. It has its dip steeper close to the surface than it's shallow as depth increases. Sixty (60) faults F1 – F60 were interpreted across thestudy area using the 3D seismic vintage generated. Variance edge seismic attribute was used to unraveled the structural trend of the reservoirs and for the fault picking. From the seismic analyses, faulting may have resulted in reservoir compartmentalization which did not appear to significantly control reservoir distribution and the hydrocarbon accumulations. The greater Woda anticline is heavily faulted but the study area appears to have significant faulting towards the NE and western part of the field as revealed by seed grid Interpretation with fault polygons (Fig. 10). The interpreted faults are polygonal, normal and listric in nature, with a major boundary fault trending NE-SW of the field.A combination of different attributes such as variance edge and thin fault likelihood attribute (TFL) were used to identify faults and fractures within the study area.Results showed that, the field is structurally controlled by the roll-over anticline formed by the NE-SW trending major growth fault. In addition, the deeper reservoirs were observed to be less faulted compared tothe shallower section. Anticlines in association with fault closures were the traps encountered as shown in fig. 11.

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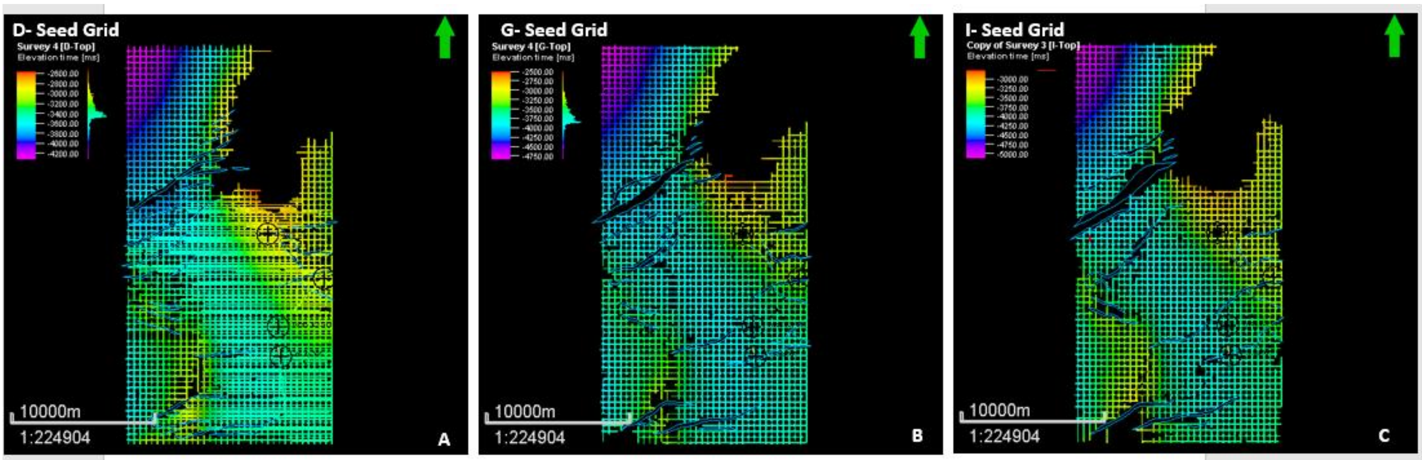

Fig 10: Reservoirs D, G and I-Top Seed Grid Interpretation with Fault Polygons

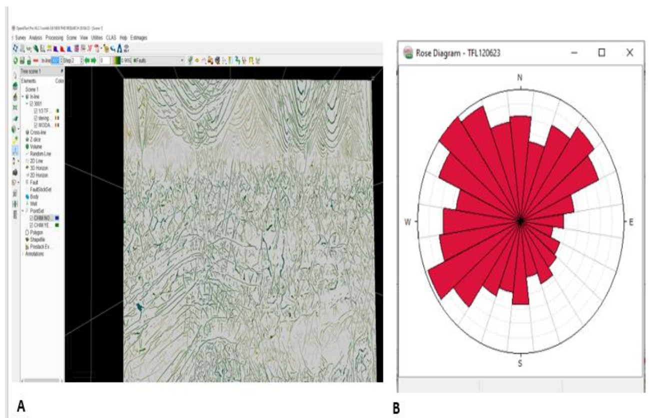

Fig. 11a

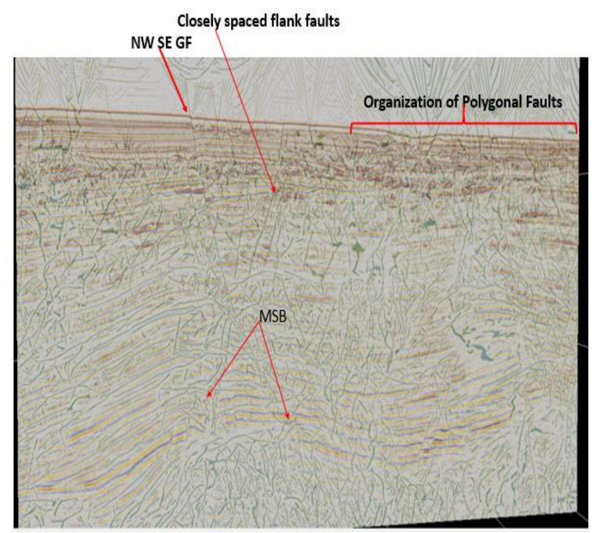

Fig. 11b

Fig. 11a (A) Thin Fault Likelihood (TFL) interpretation on IL 3001 in Woda oil field. (B) Rose diagram showing the azimuthal distribution of the faults and fractures. Fig. 11b Thin Fault Likelihood interpretation on IL 3001 sowing Major structural building fault (MSB) and organization of polygonal faults

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➢ **Horizon Mapping**

The horizon interpretation of the study area was carried out to define the geometric framework of the field. This was achieved using the well information in addition to 3D seismic data. Horizons associated with strong seismic amplitude anomalies have been interpreted. Ten (10) reservoirs (Reservoir **A-J)** were identified, (see Fig. 12). After the horizon interpretation, time and depth maps were generated for the reservoirs using the interpreted horizons.

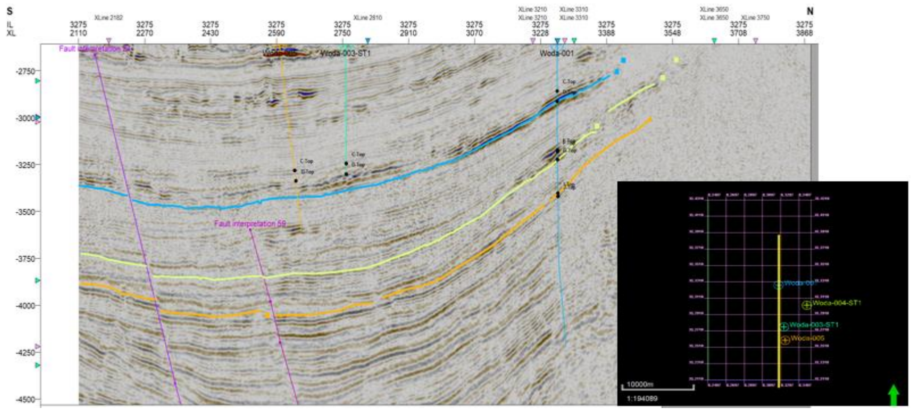

Fig.12a: Inline 3275 showing Interpreted fault and Horizon around wells Woda-001

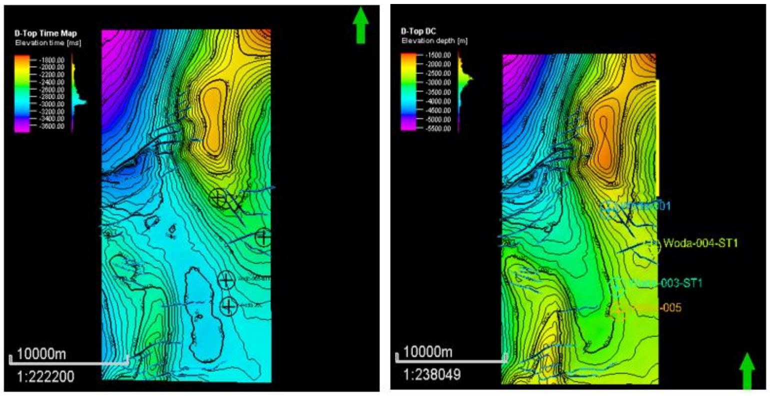

Fig. 12b

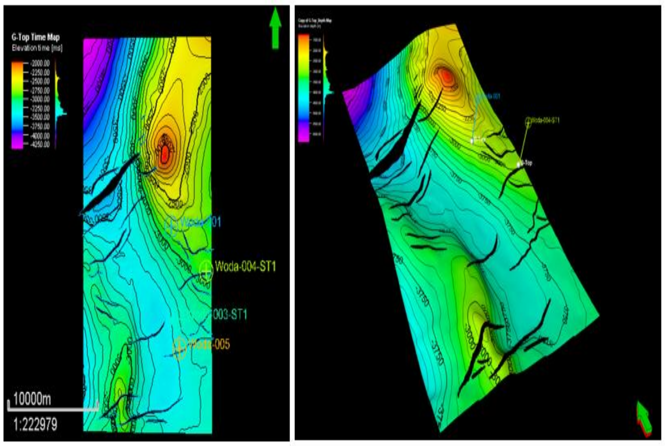

Fig. 12c

Fig. 12b Reservoir D Top time and depth maps Fig. 12cReservoirGTop time and depth maps

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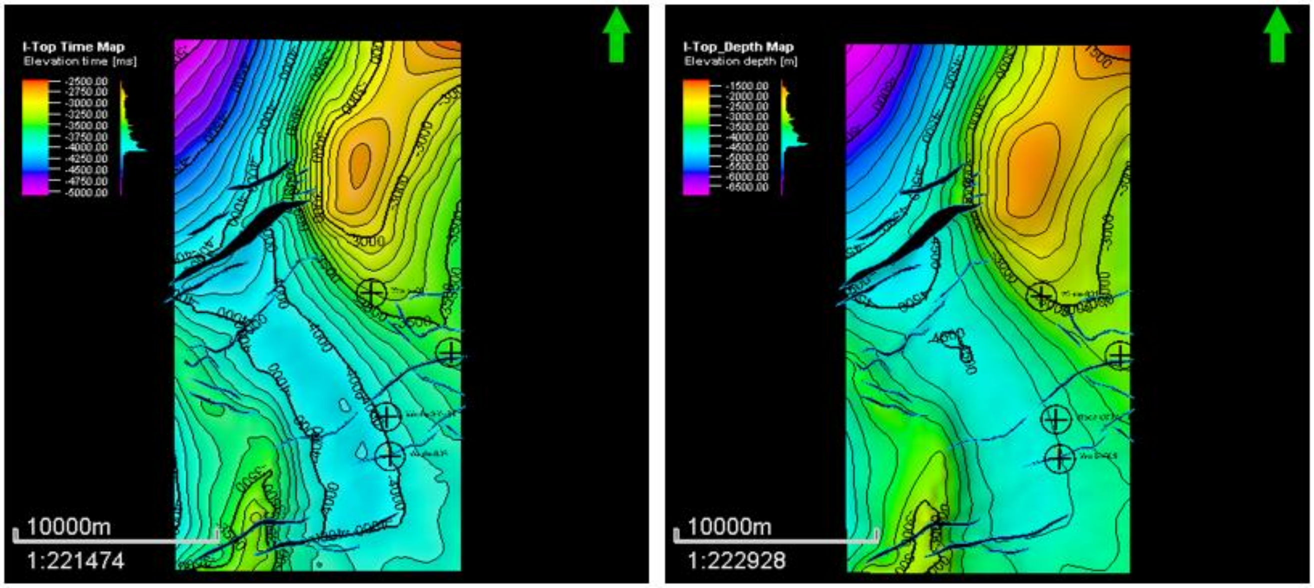

Fig. 12d: Reservoir **I** Top time and depth maps

- **Results of Chimney interpretation based seismic Attributes**

Chaos, Reflection Coefficient/Envelop, Variance Edge, Sweetness, Spectral Decomposition and RMS velocity attributes were used to enhanced interpretation of identified chimneys (See Fig. 13). In addition, volume attributes were also computed for the seismic section (Fig. 14).

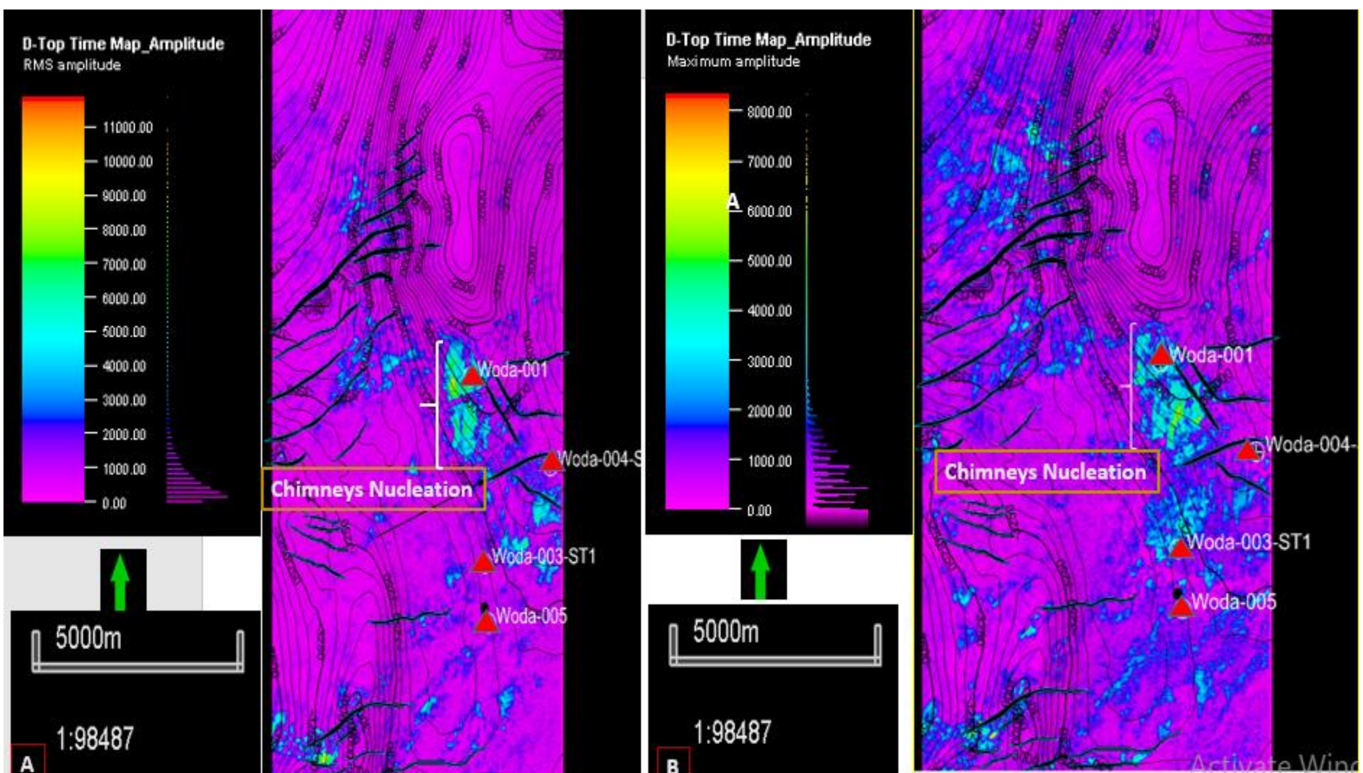

Fig.13a: Surface attributes on reservoir D surface; (A) Root Mean Square showing possible nucleation of chimneys around Woda 001 well (B). Maximum Amplitude showing chimneys distribution and hydrocarbon zones.

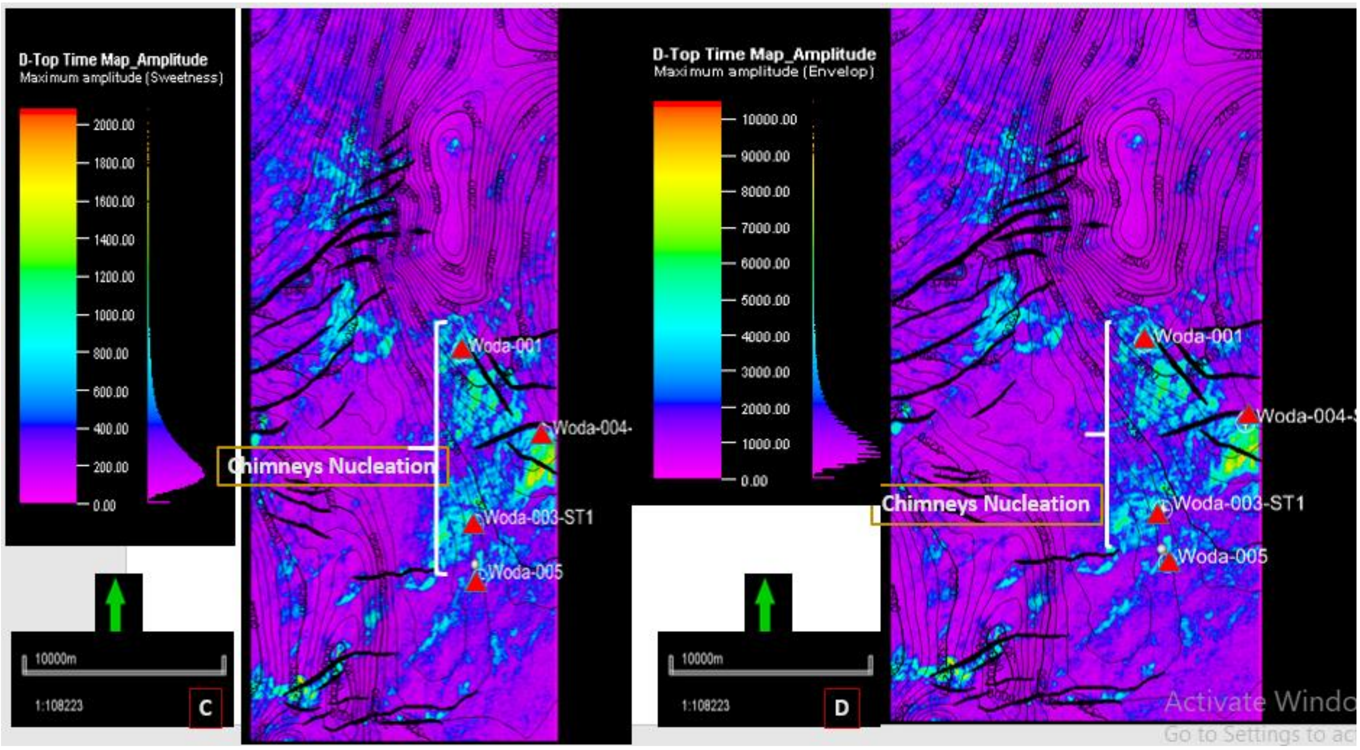

Fig.13b: Surface attributes on reservoir D surface; (C) Sweetness Attribute showing possible nucleation of chimneys around Woda 001 well (B). Envelop Attribute showing chimneys distribution and hydrocarbon zones.

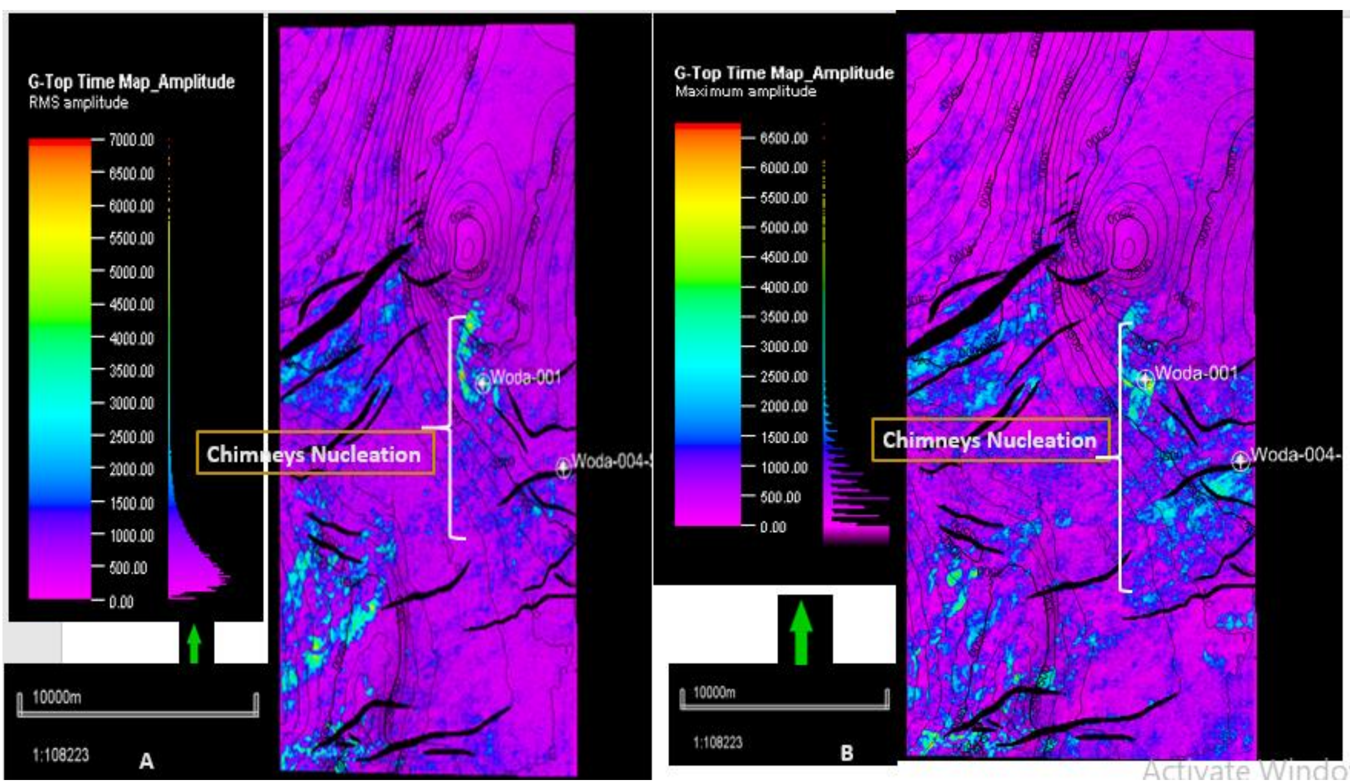

Fig.13c: Surface attributes on reservoir G surface; (A) Root Mean Square showing possible nucleation of chimneys around Woda 001 well (B) Maximum Amplitude showing chimneys distribution and hydrocarbon zones.

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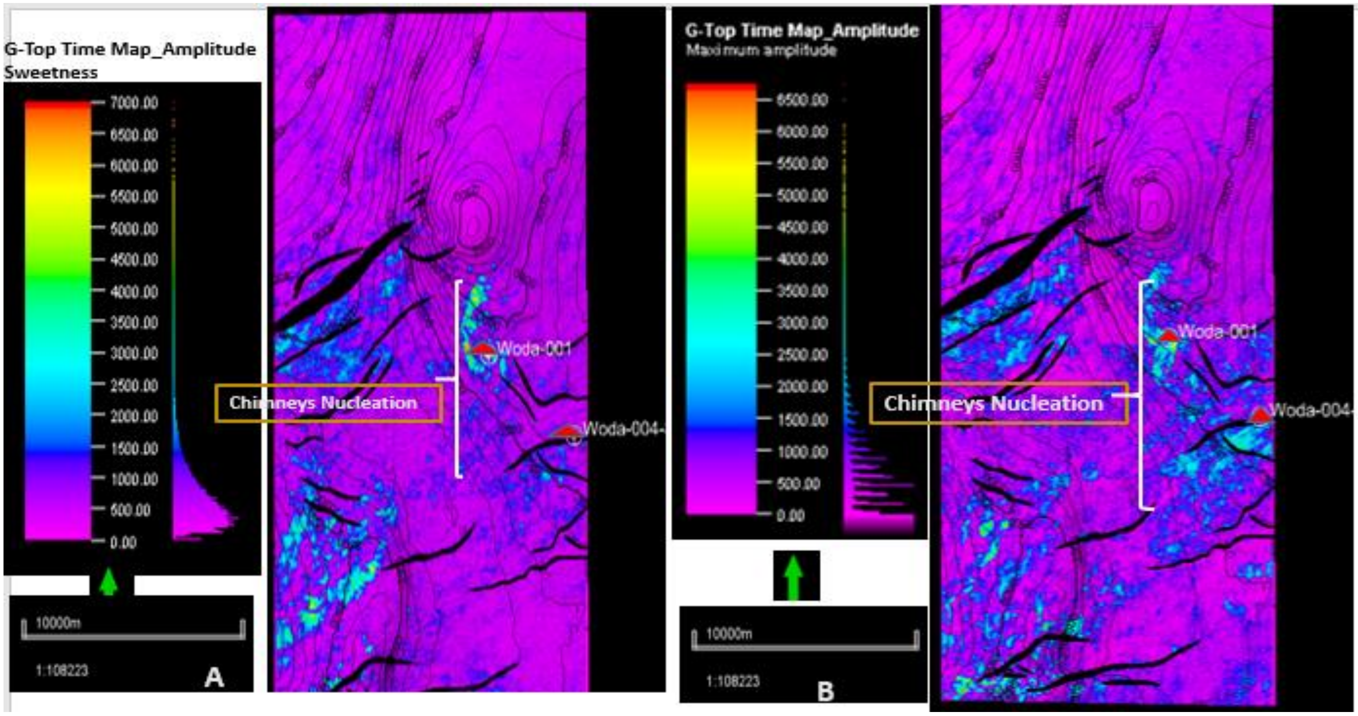

Fig.13d: Surface attributes on reservoir G surface;(A) Sweetness Attribute showing chimneys distribution and hydrocarbon zones. (B) Amplitude map showing possible nucleation of chimneys around Woda 001 well.

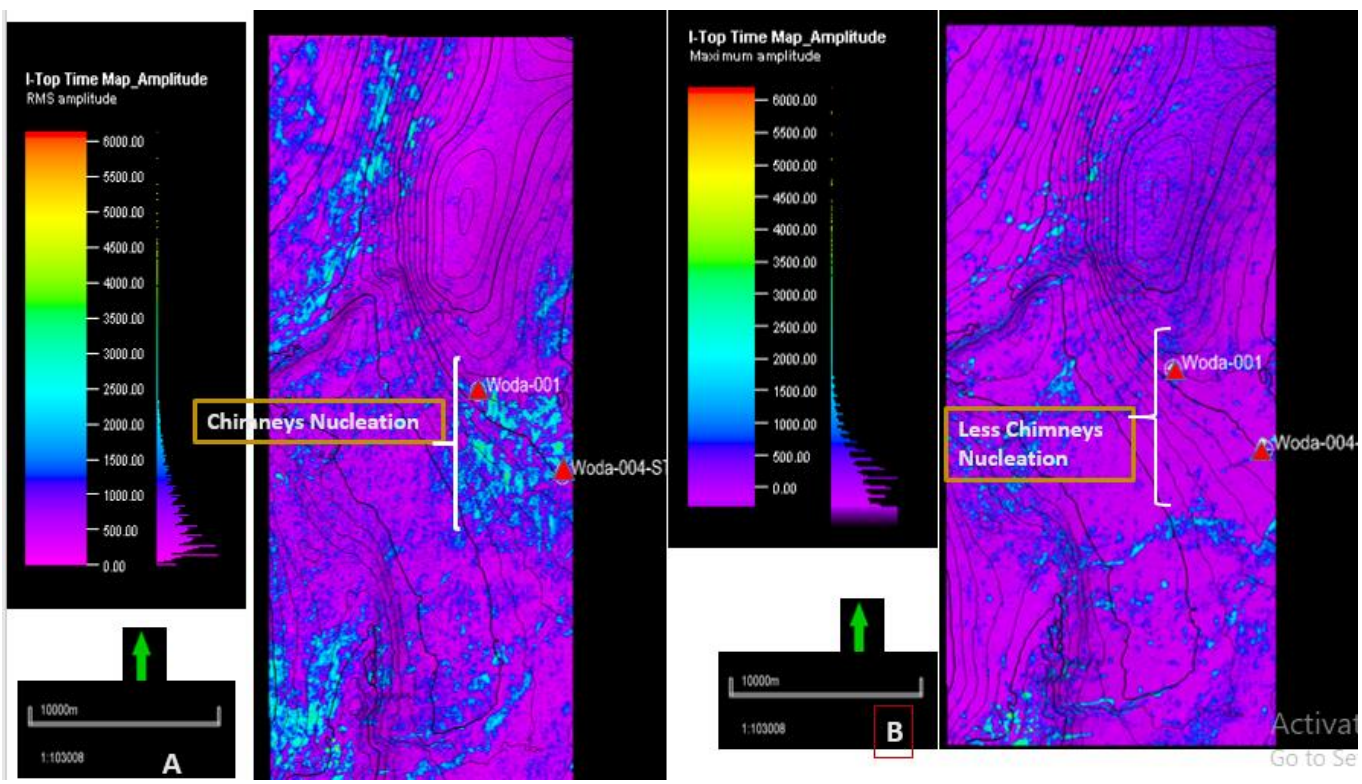

Fig.13e: Surface attributes on reservoir I surface; (A) Root Mean Square showing possible nucleation of chimneys around Woda 001 well (B) Maximum Amplitude showing low chimneys distribution as a result of hydrocarbon leakages as observed in fig 7 & 8.

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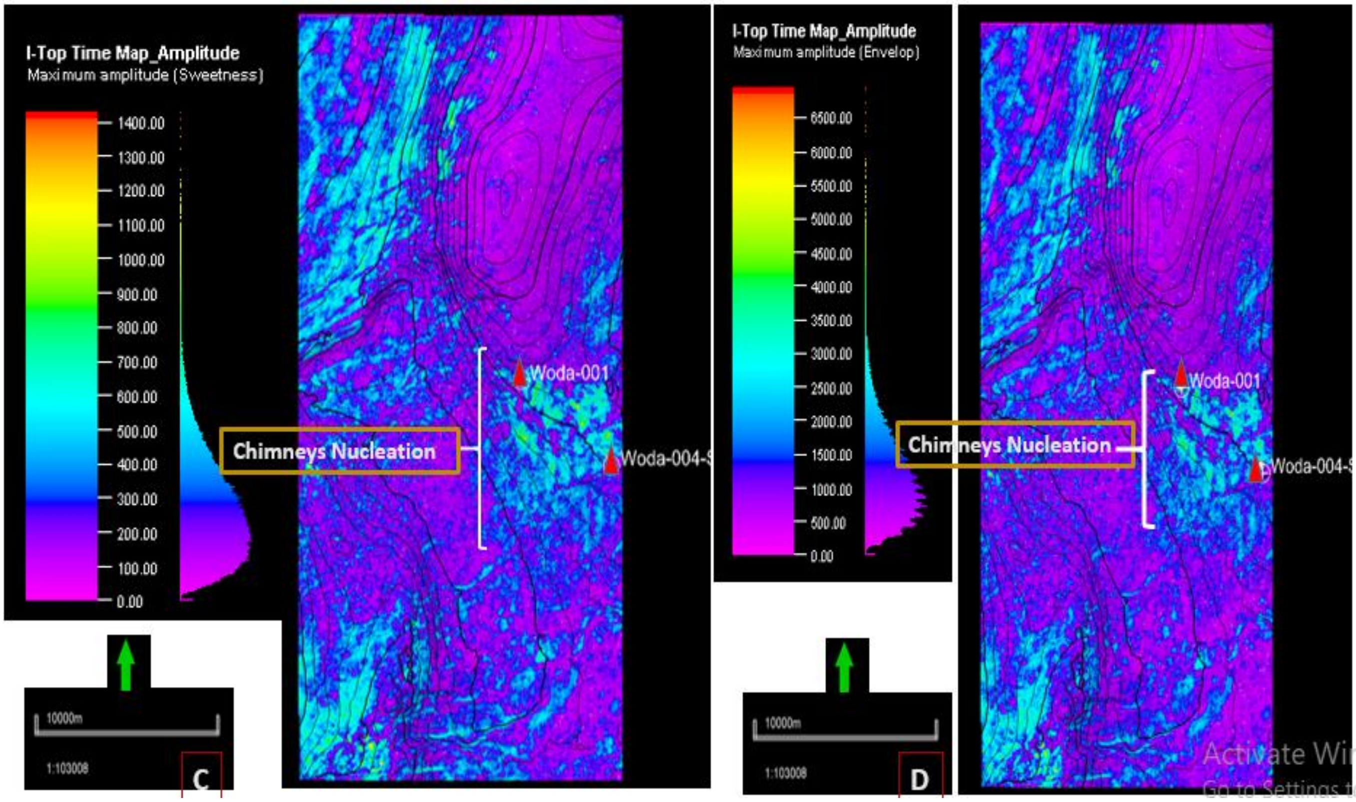

Fig.13f: Surface attributes on reservoir I surface;(C) Sweetness Attribute showing chimneys distribution and hydrocarbon zones, (D)Envelop Attribute showing possible nucleation of chimneys around Woda 001 well.

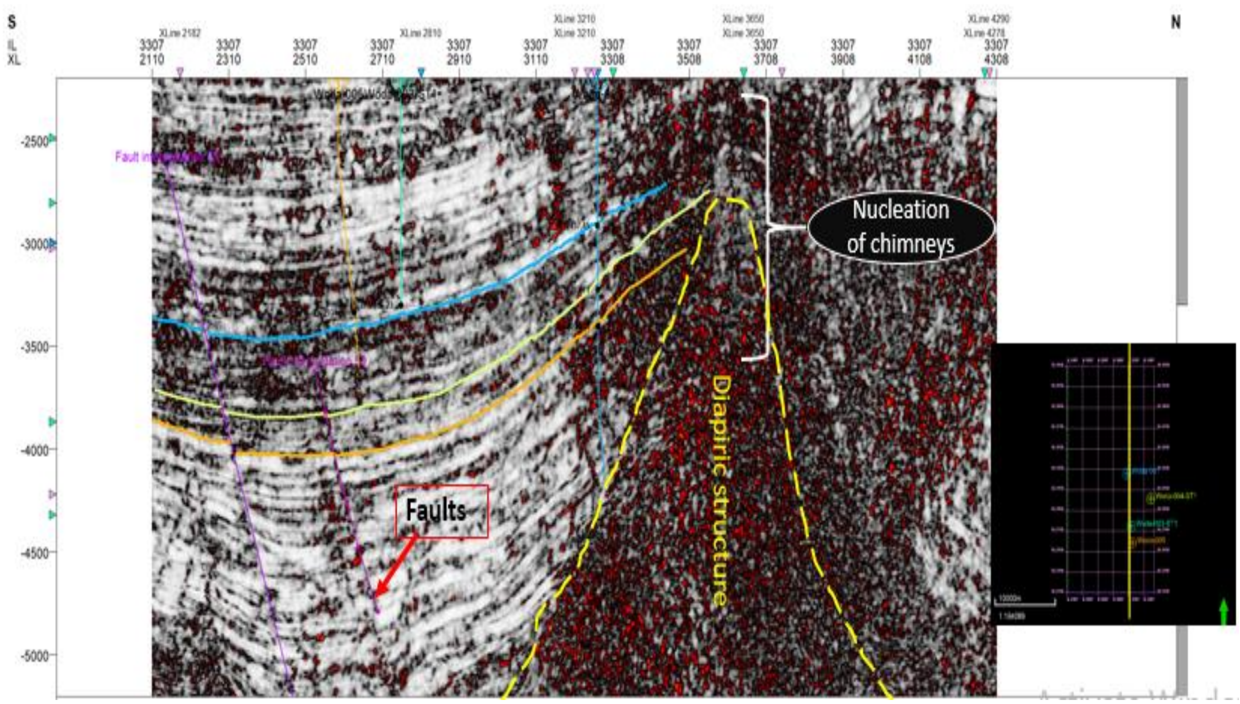

Fig.14a: Inline 3307 showing Chaos Volume Attribute which enhanced the identification of four (4) features; Gas chimneys, faults/discontinuities, diapiric intrusion and chaotic texture around reflectors.

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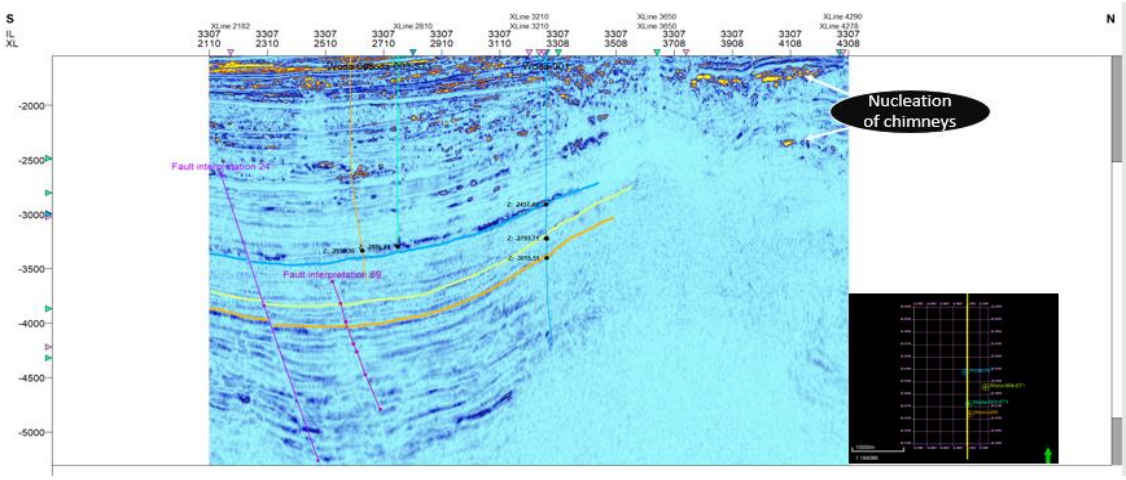

Fig.14b: Inline 3307 showing Reflection intensity/Envelop Volume Attribute.

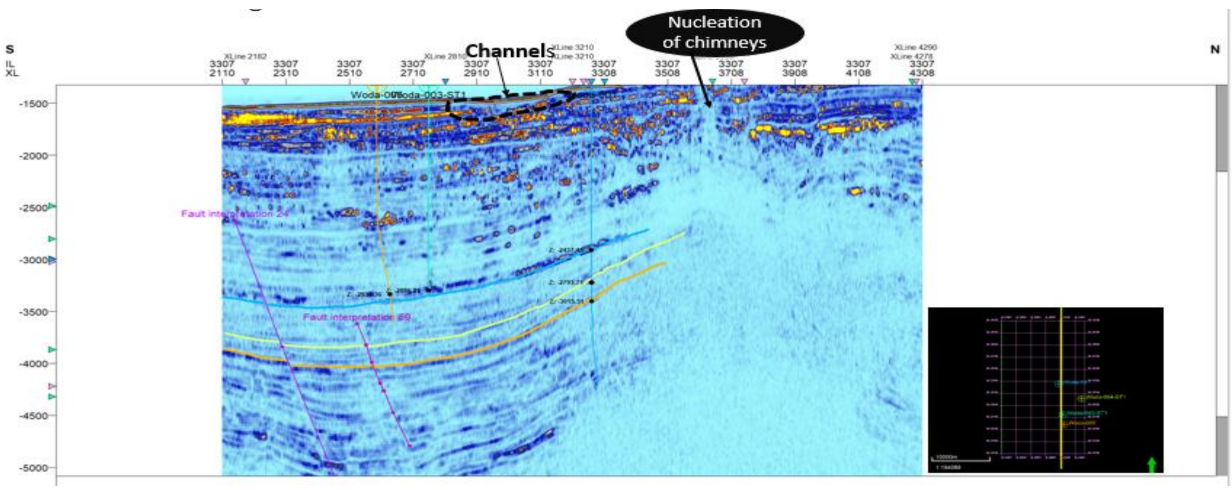

Figure 14c: Inline 3307 showing RMS volume attribute.

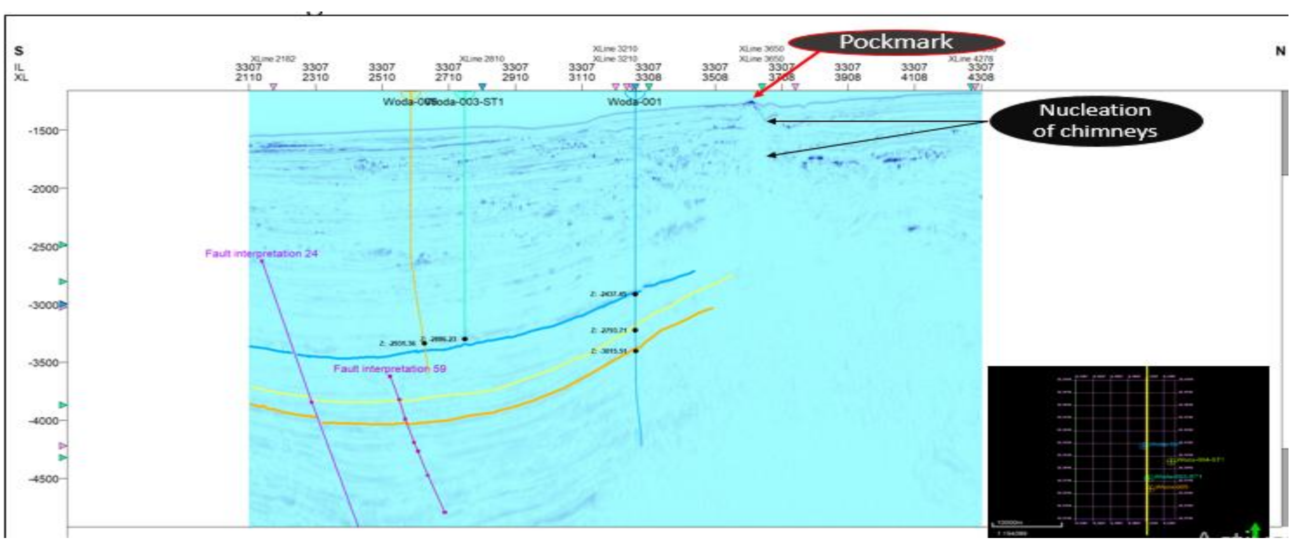

Fig.14d: Inline 3307 showing sweetness volume attribute which enhanced the identification of chimneys nucleation and pockmark.

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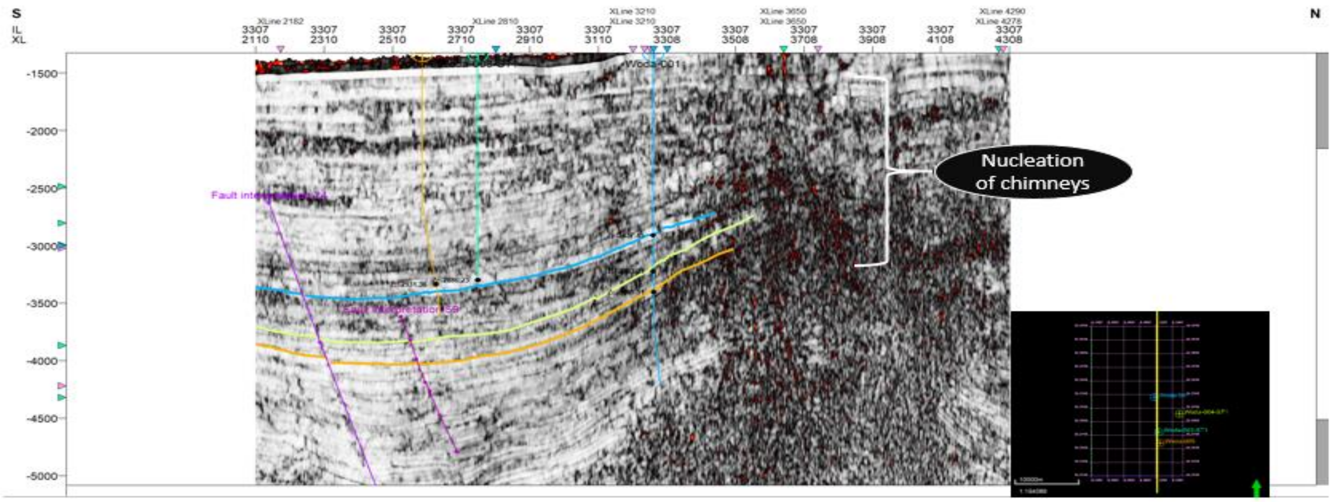

Fig.14e: Inline 3307 showing variance edge volume attribute.

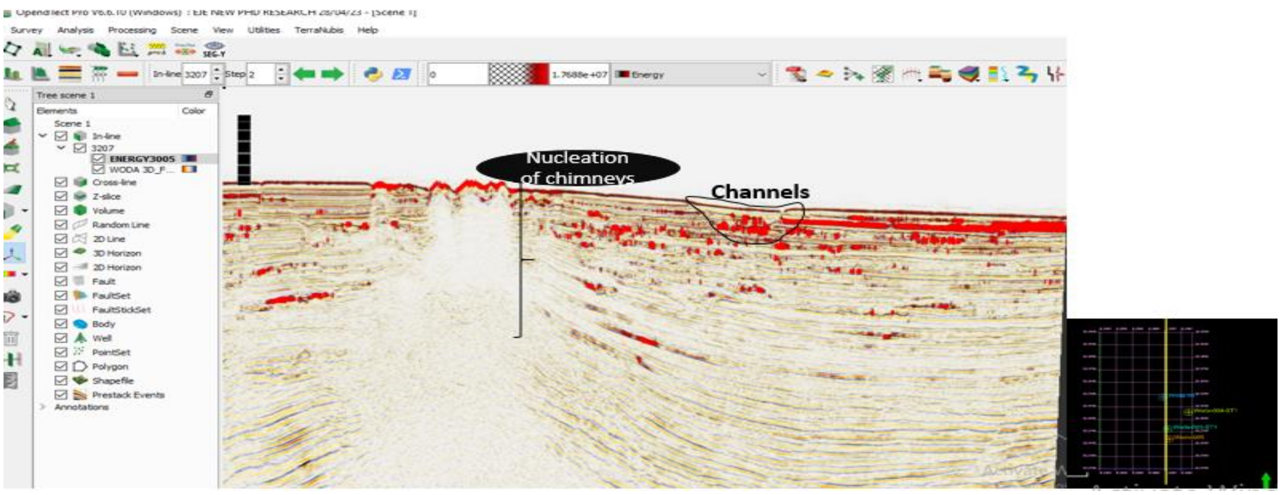

Fig.14f: Inline 3207 showing energy volume attribute showing chimneys nucleation and channels.

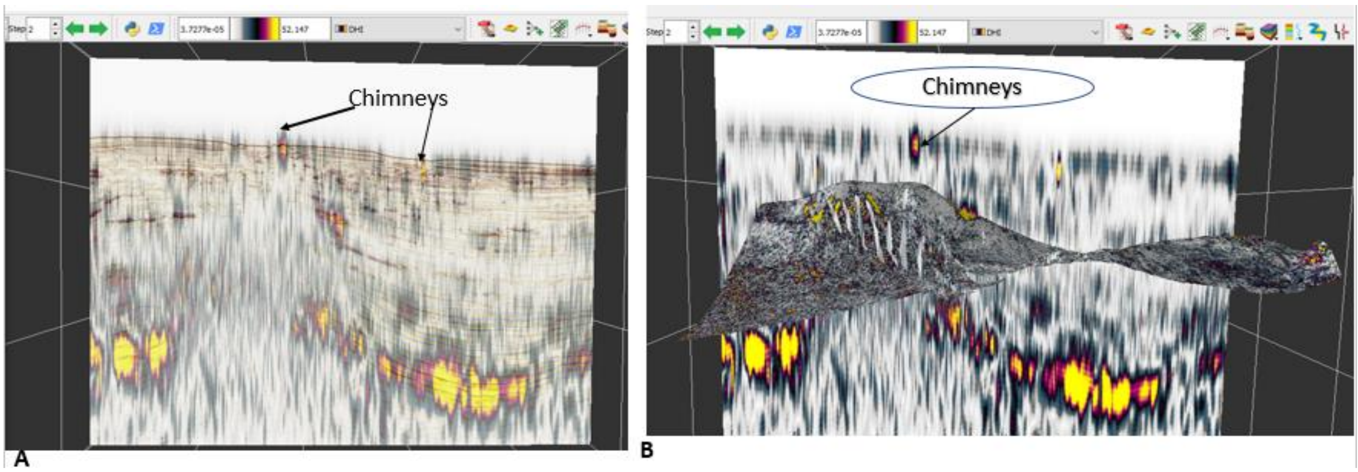

Fig. 14g: (A) Correspondent to Spectral Decomposition attribute on 3D Seismic Volume. Major and subtle lithologic changes are enhanced by the DHI contrast when compared to the original seismic section and showing part of the gas chimneys on D top Horizon in B.

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V. Discussion

Chaos attribute may show chaotic textures in seismic data and may be a direct indicator of locations of the reflector's disruption. Zones of high chaoticnessare associated with complex geometrical reflector discontinuities such as fault zones, angular unconformities, channel sand bodies and possible zones of fractures in the study area (Fig. 13). The uncolored sections in Fig.13 may represent the minimum chaoticness corresponding to continuity of lithologies, (Pigott et al., 2013). High values of chaoticness may also be related to gas chimneys in volumes where rocks were cracked or chemically altered while connate gas may produce gas chimneys, when fluids migrate upwards through the sedimentary sequence. When the fluid gets to the surface, it may create pockmarks based on sweetness attribute (Fig.14d). The presence of chimney may cause fluctuation in the compressional velocity resulting in scattering and deterioration of the signal of a propagating seismic wave. Gas chimneys are distinguished within poor data zones because of scattering effect of seismic energy in different directions by diffused gas through the cap rocks above the leaking reservoir. (Fig. 14f). The Two-Way-Time (TWT) of seismic volume ofthestudy area illustrates the effect of the high uprising gas pressure to the upper layers resulting in bending and fracturing of the layers identified by chaos attribute.Moderate to high amplitude signalsas observed on the seismic section shows asection of the channel where the main stacked channels which trend in different directions but intersect and share similar depositional environments as demonstrated by the energy attributes (Fig. 14 b-d). High amplitude values at TWT between 1317 and 2818ms may be related to lithological changes, channel sand intervals (porous sands), and gas saturated reservoir intervals. Low amplitudes values show that, the reservoir intervals contain sandy shale which may not be favorable for hydrocarbon accumulation (Yushuang and Zhu, 2013), (See Fig. 14f). Figure 13 (a, c & e)shows the RMS surface attributes and its corresponding volume attributes in Fig. 14c with high values (yellow) indicating hydrocarbon zones and chimneys. The reflection strength/envelop attribute was used to identify related seismic units based on their acoustic impedance contrast which may be proxies for gas channels, bright spot and possible gas accumulations at TWT from 1317 - 4116ms (Fig. 14b) and 13 (c & f).The Sweetness attribute identified channels and other stratigraphic features where, high amplitude seismic data with low frequencies give high sweetness at TWT 1300 - 3500ms as evidence of hydrocarbon zone (Fig 13 c, d & f). High sweetness zones with high acoustic impedance contrast identify bright spots with good quality sand zones have potential to produce gas. Poor quality seismic data may have resulted from structural movements, because ofthe heavily faulted area and diapiric activities - possibly signal absorption related to fluid migration. The mapped horizons top of reservoirs D, Gand I (Fig. 13) represent the calculated sweetness seismic attribute in the time window around reservoirs D, G and I horizons. The horizons were interpreted, interpolated and plotted as surface maps. The Maximum amplitudeattribute extracted for horizons D, G and I was interpreted in time domain window (Fig. 13). In the central part of the study area, the seismic data had poor quality in the surrounding areabut have higher values of the attribute visible in the shape of a channel-like reflection, is associated with sandstone development of Reservoir D.

➢ Summary

Seismic attribute analysis with well log interpretation wascarried out on 3D PSDM seismic data from Woda Oil Field. Results were used todefined the different chimney nucleation and hydrocarbon zones within the reservoir intervals. Attributes with moderate to high amplitude (Fig. 13 - 14) show gas channels and their direction. The main stacked channels trend in different directions but intersect and share similar depositional environments. The application of seismic attributes in the study area showed that, it is important to apply different seismic attributes with guided interpretationto identify hydrocarbon zones and chimneys. The Chaos attribute as interpreted,identified low to high value amplitudes zones and the high value of these attribute may be related to gas saturated reservoirs (Ismail et al 2019). Figure 13e showed low values of maximum Amplitude and chimneys nucleation which could beattributed to hydrocarbon leakages around G & I reservoirs as observed in fig. 7 & 8. Seismic attributes such as RMS, envelope, average energy, sweetness, and chaos have been useful in delineating the hydrocarbon and non-hydrocarbon zones in Woda Oil Field.

VI. Conclusion

Seismic attributes analysis with support of well logs interpretation were carried out on 3D PSDM seismic data and well logs from Woda Oil Field to define the different hydrocarbon zones within the targeted intervals with lithology and fluids distribution. Attributes with moderate to high amplitude show gas chimney nucleation and their direction. The different stacked channels are trended in different directions but intersect and share similar depositional environments. The location of producing wells (Woda 001,003ST1, 004 ST1 and 005) in the high amplitude zone indicate that these reservoirs interval are composed of sandstones due to the response of Gamma-ray, Vp sonic and Resistivity logs. Data conditioning for logs and seismic data was carried out as they have a significant effect directly to the final output of the interpretation. Different seismic attributes showed different clues to study the distribution and directions of the gas chimneys and other geologic structures such as channels and diapiric activities. The application presented in this research showed that, it is important to apply different seismic attributes with to identify chimneys, hydrocarbon zones and other geologic structures. The generated TWT maps showed the uprising gas pressure effect on the upper

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layers of the mapped surfaces before getting to the surface to form a pockmark. Hence, seismic attributes analyses have been proven helpful in delineating hydrocarbon zones and non-hydrocarbon zones in Woda Oil Field, Offshore Niger Delta.

- **Recommendation**

It is advised that, the geochemistry of the reservoir fluids and hydrocarbon zones be evaluated to ascertain if truly they migrated into various reservoir compartments as observed in the chimney nucleation.

References

1. Aminzadeh, F., Connolly, D., Heggland, R. and de Groot, P.F.M. (2001). Geo-hazard detection and other application of chimney cubes. Lead Edge, 21, 681-685.
2. Awolola, O. K and Ideozu, R. U. (2019). The Application of Short – Time Fourier Transform and Discrete Fourier Transform in Mapping Stratigraphic Features in TMB Field, Niger Delta. Scientia Africana, An International Journal of Pure and Applied Sciences. (Nigeria) Published by Faculty of Science, University of Port Harcourt. Volume 18, Number 1
3. Beka, F. T., & M. N. Oti, (1995). The Distal Offshore Niger Delta: Frontier Prospects of a Mature Petroleum Province, Geology of deltas: Rotterdam, A. 237-241
4. Bradly, T.U. (2012). Normal Fault and Gas Migration in an active plate boundary, Southern Taranaki Basin, Offshore New Zealand, American Association of Petroleum Geologists Bulletin, 96, 803-820.
5. Burke, K., (1972). Longshore Drift, Submarine Canyons and Submarine Fans in Development of Niger Delta: AAPG Bulletin, v. 56:1975-1983
6. Chopra S. (2007). Seismic attributes for prospect identification and reservoir characterization, SEG Geophysical Development Series Number (11).
7. D GB Earth Sciences Training Manual (2021). Introduction to Open dTect & Opend Tect Pro, Nijverheidstraat 11-27511 JM Enschede, Netherlands.
8. Doust, H., Omatsola, E. (1990). Niger Delta "Divergent/Passive Margin Basins". American Association of Petroleum Geologists Memoir, 48, 239-248.
9. Eastwood, J., (2002). Introduction-the attribute explosion. Lead Edge 21, 994.
10. Evamy, B. D., Harem boure, J., Kamerling, P., Knaap, W. A., Molloy, F. A., & Rowlands, P. H., (1978). "Hydrocarbon habitat of Tertiary Niger Delta". AAPG Bulletin. 62, 277-298.
11. Hart, B.S., (2008). Channel detection in 3-D seismic data using sweetness. AAPG Bull. 92, 733-742.
12. Heggland, R. (2005). Using gas Chimneys in seal integrity analysis; A discussion based on a case history, in evaluating fault and cap rock seals.: American Association of petroleum Geologist, Tulsa, USA.
13. Heggland, R., Meldahl, P., de Groot, P., & Aminzadeh, F. (2000). Seismic chimney interpretation examples from the Norh Sea and the Gulf of Mexico. American Association of petroleum Geologist, Tulsa, USA
14. Ideozu, R. U, Awolola, O. K and Emujak porue, G. O. (2020). Comparative Analysis of Short – Time Fourier Transform and Discrete Fourier Transform in Mapping Stratigraphic Features in TMB Field, Niger Delta. Journal of Mining and Geology, (Nigeria) Volume 56(1).17 – 22. Published by Nigerian mining and Geoscience Society
15. Ilg, B.R., Hemmings-Sykes, S., Nicol, A., Baur, J., Fohrmann, M., Funnell, R., & Milner, M. (2012). Normal faults and gas migration in an active plate boundary, southern Taranaki Basin, offshore New Zealand. American Association of Petroleum Geologists Bulletin, 96, 1733-1756.
16. Ismail M. (2019). Identification of gas zones and chimneys using seismic attributes analysis at the Scarab field, offshore, Nile Delta, Egypt, Petroleum Research.
17. Meldahl, P, Heggland, R., de Groot, P. & Bril, A., (1999). The Chimney Cube, an example of semi-automated detection of seismic bodies by directive attributes and neural network methodology. 69th SEG conference in Houston, 31-10- '99 until 5-11- '99
18. Mohammad A., &Mona G., (2017). Application of Seismic Attributes for Detecting Different Geologic Features within Kafr El Sheikh Formation, Temsah Concession, Nile Delta Basin. ResearchGate, DOI: 10.21608/sjdfs.2019.194770
19. Pigott, J.D., Kang, M.I.H., Han, H.C., (2013). First order seismic attributes for clastic seismic facies interpretation: examples from the East China Sea. J. Asian Earth Sci. 66, 34-54.
20. Partyka, G., Gridley, J., & Lopez, J., (1999). Interpretational applications of spectral decomposition in reservoir characterization: The Leading Edge, 18, 353-360.
21. Sheriff R. E. (1992): Reservoir Geophysics, Society of Exploration Geophysicist
22. Stacher, P., (1995): Niger Delta Petroleum Habitat. NAPE Bulletin. 9, 67-76.
23. Taner, M.T., Schuelke, J.S., O'Doherty, R., Baysal, E., (1994). In: Seismic Attributes Revisited: 64th Annual International Meeting, Society of Exploration Geophysicists Expanded Abstracts, 1104-1106

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XII, Issue IX, September 2023

24. Taner, M.T., Koehler, F., Sheriff, R.E., (1979). Complex seismic trace analysis. Geophysics 44 (6), 1041-1063.
25. Thrasher, J., Fleet, A.J., Hovland, M., & Dup pen becker, S. (1996). Understanding Geology as key to using seepage in exploration: The spectrum of seepage styles in hydrocarbon migration and its near-surface expression, American Association of Petroleum Geologists Memoir (66), Tulsa, USA.
26. Tuttle, M. L. W., R. R. Charpentier and M. E. Brownfield, (1999), The Niger delta Petroleum System: Niger delta province, Nigeria, Cameroon, and Equatorial Guinea, Africa: USGS Open-file report 99-50-H
27. Ugwueze, C.U. (2015). Integrated Study on Reservoir Quality and Heterogeneity of Bonga Field (OML118) Deep Offshore Western Niger Delta. Unpublished Ph.D. Thesis, University of Port Harcourt
28. Van Bemmel, P., Pepper, R., (2000). Seismic Signal Processing Method and Apparatus for Generating a Cube of Variance Values. United States Patent 615155.
29. Whiteman, A., (1982). Nigeria: It's Petroleum Geology, Resources and Potential. Journal of African Earth Sciences, 1, 177-180.
30. Wooltorton, T. (2015). Shallow hazard and gas escape systems modelling from 3D seismic. In: 2015 SEG Annual Meeting. Society of Exploration Geophysicists, 1673-1676.
31. Van Bemmel, P., Pepper, R., (2000). Seismic Signal Processing Method and Apparatus for Generating a Cube of Variance Values. United States Patent 615155.
32. Yushuang, H., Zhu, S., (2013). Predict channel sand body distribution characteristics of south eighth district based on RMS amplitude attributes & frequency division. Advanced Materials Research 734, 404-407. https://doi.org/10.4028/www.scientific.net/AMR.734-737.404