Ilorin Journal of Science
FAPSCON 2024 PROCEEDINGS, 2024, pp. 43 – 50 (Printed in Nigeria)
ISSN: 2408 – 4840 © 2024 Faculty of Physical Sciences, University of Ilorin
hhttps://doi.org/10.54908/iljs.fapscon.2024.11.03.1006

ILORIN JOURNAL OF SCEINCE

ILJS-24-056 (SPECIAL EDITION)

Attribute Analysis in Reservoir Characterization and Discrimination, a Case Study of Y-Field, Niger Delta Basin, Nigeria

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Abstract

Various parameters have been used in reservoir characterization, among them is the use of multiple attribute approach in which various seismic attributes of significance linked with various petrophysical properties were utilized to study the characteristics of Y-field reservoirs in Niger Delta basin. The study aims to identify the various hydrocarbon-bearing units for production optimization. Different attributes were extracted from the seimic amplitude data using relevant quantitative models. The study revealed that differences in Extract value indicated variation in background amplitude, Arc length variation responds to lithologic heterogeneity. Average amplitude and RMS revealed the presence or effect of hydrocarbon or geological structures or both, while Average energy and Maximum amplitude showed hydrocarbon presence only. Half energy revealed porous regions, Positive to negative ratio was able to define the reservoir thicknesses while net-to-sand ratio were revealed by Sum of magnitude maps. The study concluded that multiple attribute study can serve as critical tools for reservoir characterisation.

Keywords: Seismic attributes, Arc length, Root mean square (RMS), Average energy and Half energy.

1.0 Introduction

Several parameters have been of immense importance in characterizing reservoir rock units among them is the use of seismic attribute analysis for the purpose of compartmentalizing the reservoirs into components or different compartments, discriminating one portion of the reservoir from another based-on possibilities of meaningful hydrocarbon accumulations. The basic parameter in attribute study is seismic amplitude which is tuned by geology and fluid content.

Seismic attribute is any measurable physical parameters inherent in seismic reflection data. According to Chambers and Yarus, (2002) attribute is a seismic-derived characteristics computed from both pre-stack

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and post-stack while Marfurt, (2005) defined seismic attribute as a measure derived from seismic data and aids quantification and interpretation. Seismic reflection attributes is important because it had been utilised as a veritable tool to define the reservoirs. It has capability to link or relate reflection data with physical properties of the rocks. It is also a viable means to detect sub-seismic structural features and therefore show structures and patterns in the seismic which might not be noticed. Previous workers such as Barnes, (2000), Roberts, (2001), Chambers and Yarus, (2002), Chopra and Marfurt, (2008), and Schlumberger, (2009) discussed the lithological and structural importance of attributes/characters. The amplitude of the Niger Delta sediments based on reflection strength was grouped into three: low, middle and high amplitude by Okeke, (1999). Bachrach and Gofer (2020) characterised the reservoirs using inversion as a seismic attribute and various lithologies characterising the field were shown. Tysse et al. (2022) discussed seismic impedance as an attribute to estimate petrophysical properties and provided useful information and confidence about the main pay locations.

Attributes study have been used in resolving several reservoirs and their fluid identification ambiguity by the following authors. Chiadikobi et al., (2012) utilised seismic attribute in the Niger Delta oil province and noted that the high amplitude and strong reflection strength along the fault edges are due to fault smearing and sealing of the reservoirs by clays, thereby trapping the further hydrocarbon migration within the closures. Jubrin and Raji (2014) deployed dip-steered multi-trace similarity extraction to detect sub-seismic structures aiding hydrocarbon accumulation in offshore Niger Delta. David and Phillips, (2015) also used seismic attributes in providing information which complement that obtained from seismic interpretation. Naimeh and Christopher, (2016) applied curvature attribute to locate sub-seismic fractures in the study of Viewfield Bakken tight Oil Reservoir. Das and Mukerji (2020) applied convolutional neural networks for seismic inversion (attribute study) revealing hydrocarbon zone. Hosnie (2023) employed RVR-GWO algorithm to one of the attribute study for permeability estimation through reservoirs characterisation.

2. Geologic Setting and Methodology

2.1 Geological Setting

Numerous authors such as Bouvier et al., (1989), Doust and Omatsola, (1990), Evamy et al., (1978), Etu-Efeotor, (1997), Tuttle et al., (1999) and Reyment, (1965) described the Niger Delta been characterised by three lithologies namely; Akata Formation at the bottom, majorly made up of shale. Agbada Formation made of paralic sequence of sandstone and shale alternation directly overlies the Akata Formation. Benin Formation is the youngest and it is made up of continental sand. It overlies the Agbada Units. They are characterised with complex structures that host oil and gas.

2.2 Methodology

Several wells were used for this research but two were shown. The wells contain several logs which include gamma, resistivity, density, neutron, sonic, s-wave, etc. Log analysis was carried out on the different available logs. Correlation was done and it was good. Gamma ray log was used for lithological identification, the ant-tracking between resistivity and density was used for fluid identification. Seismic horizons were picked from the seismic section, analysed and interpreted. Time structure map were generated followed by generation of depth structure maps. Finally, about nine different attributes were extracted around and along each of the reservoirs within different windows of interest to check for structural conformance or conformance of structure capable of hosting hydrocarbon in order to give more credence to the interpretation. Certain attributes are sensitive to certain reservoir properties and therefore they were selected based on different reservoir parameters of interest. The attributes were derived from various mathematical and statistical transformation.

2.2.1 Attributes Extraction over the Reservoirs and Reservoir Characterisation

Some sub-seismic features and reservoir properties not seen in the reflection data due to seismic resolution can be visualized by extracting attribute such as amplitude. The amplitude spectrum of a seismic within the analysis window are tuned and controlled by the geologic units and fluid within the interval. Therefore units with different geology and fluid content will exhibit different amplitude and this served as the basis to characterise the reservoirs. The variation in 'Extract value' shows the variation in background amplitude, variation in 'Arc length' is due to lithologic heterogeneity. Both 'Average amplitude' and 'RMS amplitude' map the presence of hydrocarbon or geological structures or both while 'Average energy' and 'Maximum amplitude' map presence of hydrocarbon only. 'Half energy' maps porosity, 'Positive to negative ratio' maps reservoir thickness while 'Sum of magnitude' maps net-sand-ratio (Schlumberger, 2009).

3. Results and Discussion

Several wells were used in this work but only two are presented for analysis and discussion. They are well Nd-7p and Ok-16. Nd-7p (Figure 1) does not really contain hydrocarbon-bearing units and has a maximum depth of 9380 feet, characterised with various sandstone units having porosity up to 36% but with low resistivity indicating no hydrocarbon. The sandstone were marked and named as Hor 1 to N. But Ok-16 (Figure 2) showed some sandstone units with hydrocarbon occurrence with a stop depth of about 10967.5ft and with many sandy units of high resistivity ranging from 12 to 91 ohmmeter, effective porosity (between 27 and 40%), low water saturation (0.1-0.2) with conspicuous anti correlation between resistivity and density at Hor 3, Hor 5, above Hor 7 and Hor 10. The picked horizons on the seismic section (Figure 3) were analysed. They were characterised with numerous structures including growth fault, antithetic fault and collapsed crestal structure etc. Depth structure map of Hor 7 is presented in Figure 4. The extracted attributes applied over the horizon time-structure map are shown in Figure 5. This was done to show the variation of different attributes across the reservoir and was used to characterise the reservoirs.

In Figure 5, the reservoir has faulted anticlines, synclines, fault-assisted closures and four way closure. The reservoir was characterised using attributes in order to predict next drilling point(s) for production optimisation. Both the 'Extract value' (Figure 5a) and 'Arc length' (Figure 5b) maps had pointed out clearly region of high amplitude above the background amplitude which is dictated by geology and/ fluid and this corresponds with the structure characterising the reservoir. 'Average magnitude' (Figure 5c) and 'RMS' (Figure 5d) have again shown that this anomaly may represent hydrocarbon presence or geological features or both. This can be observed clearly around northeast, northwest and down to the central portion of the map.

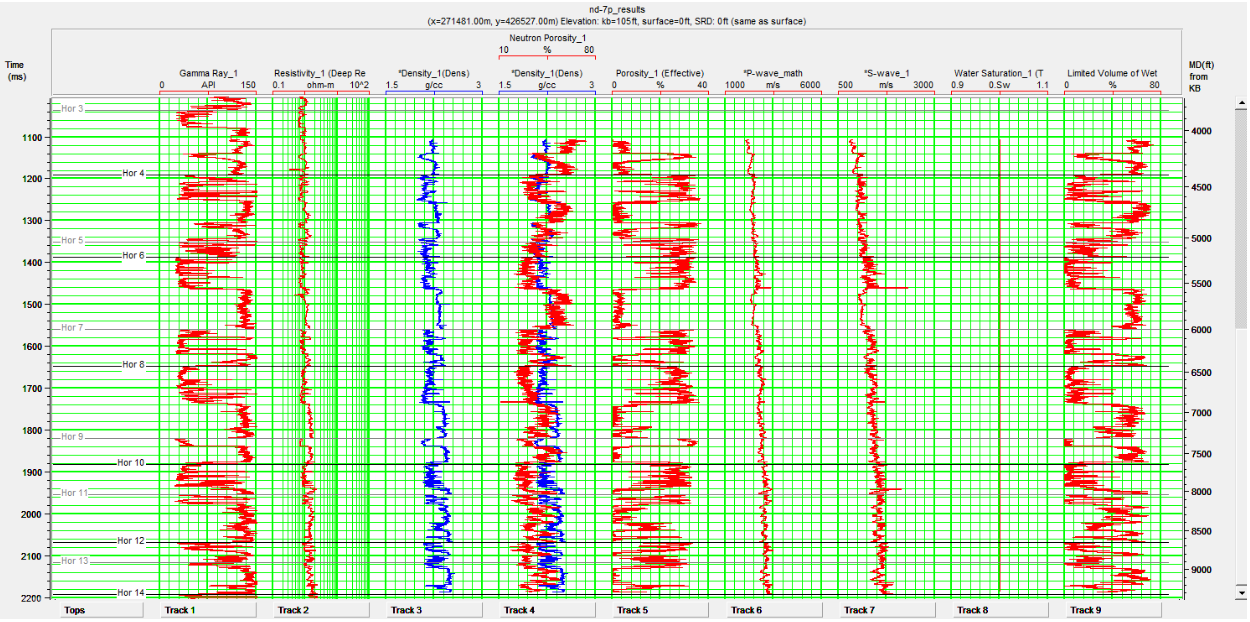

Figure 1: Well Nd-7p showing some selected logs with well tops. Track 1: Gamma log, Track 2: Deep resistivity, Track 3: Density, Track 4: Density (blue) and Neutron log (red), Track 5: Effective porosity, Track 6: P-wave, Track 7: S-wave, Track 8: Water saturation, and Track 9: Volume of shale/clay.

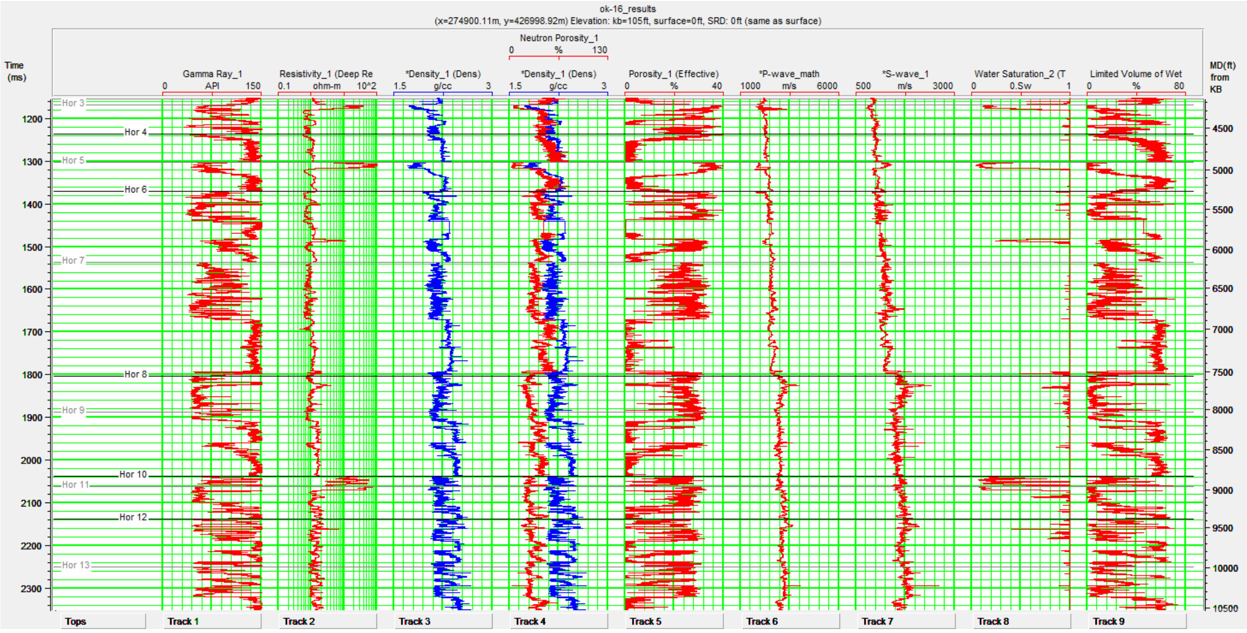

Figure 2: Well Ok-16 showing some selected logs with well tops. Track 1: Gamma log, Track 2: Deep resistivity, Track 3: Density, Track 4: Density (blue) and Neutron log (red), Track 5: Effective porosity, Track 6: P-wave, Track 7: S-wave, Track 8: Water saturation, and Track 9: Volume of shale/clay.

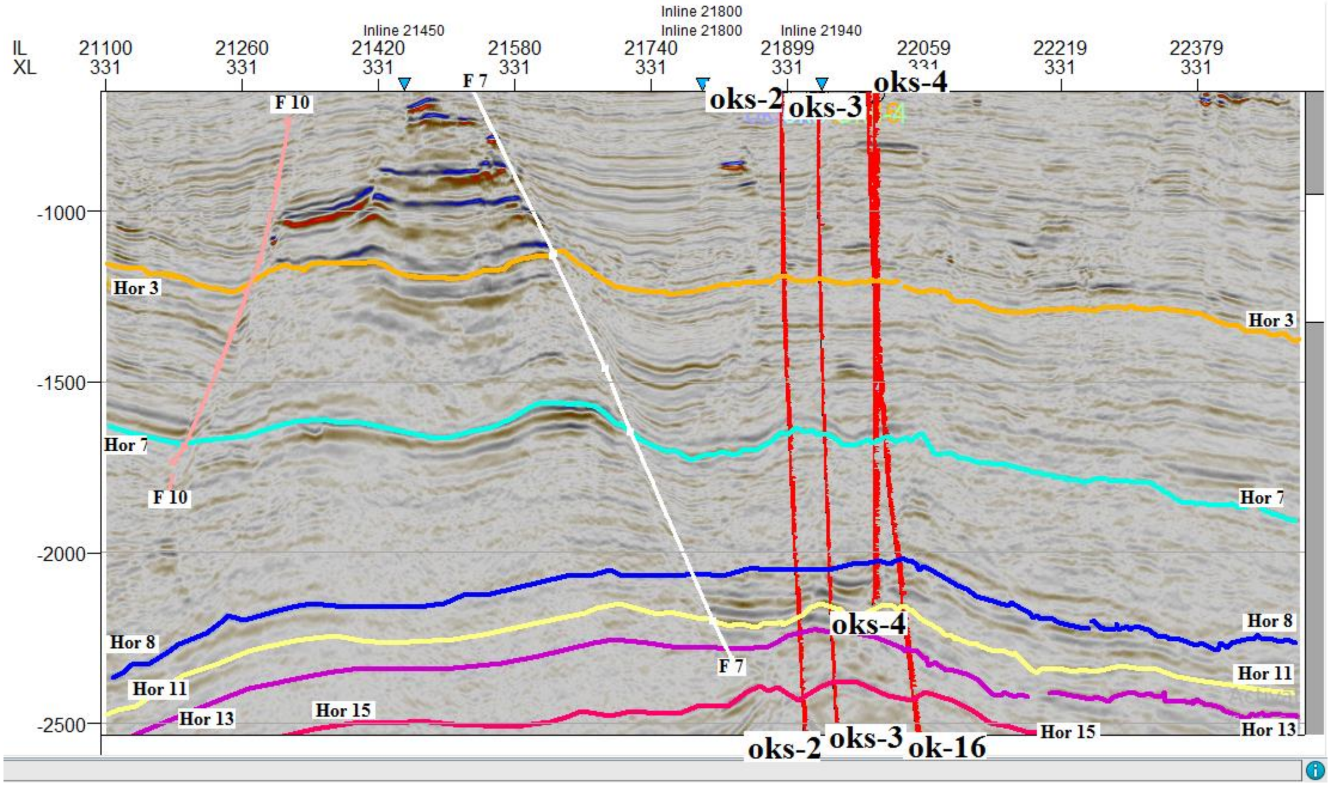

Figure 3: Seismic section showing interpreted reservoirs, well positions and Gamma Ray log (Red) along cross line 331 showing growth fault and collapsed crestal structures.

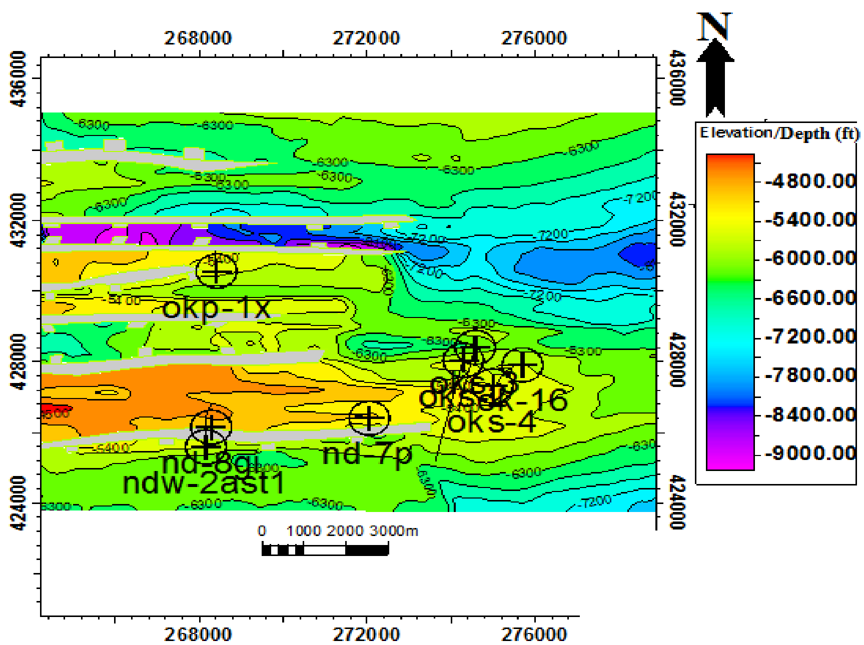

Figure 4: Depth structure map for reservoir Hor 7 showing fault polygons, fault-assisted closure and four-way closure

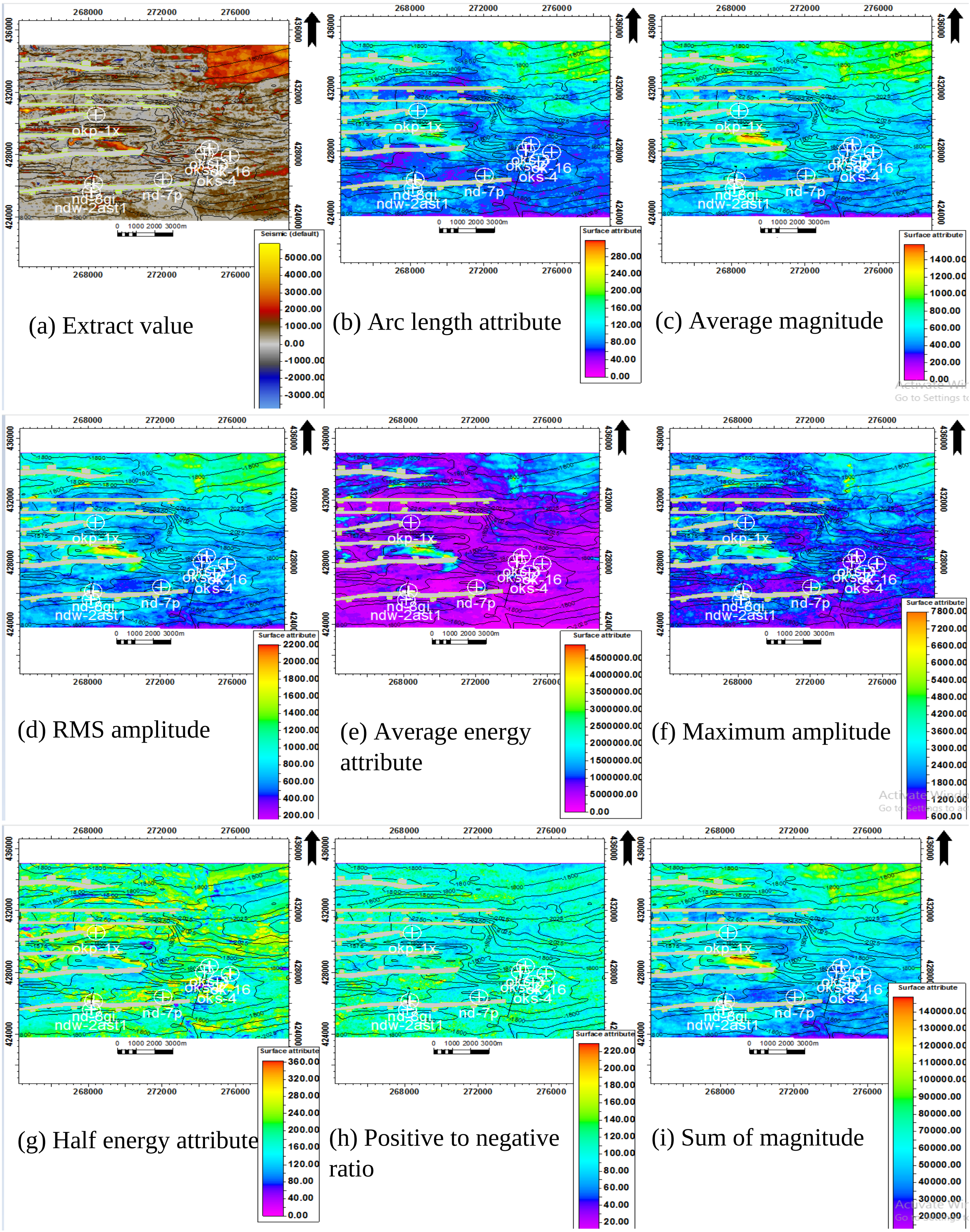

Figure 5: Surface attributes extracted around reservoir Hor 7 within time window 1500 – 1875ms, showing promising regions, red=highest amplitude and purple=lowest amplitude region.

The anomaly strength seem to be reduced in both 'Average energy' (Figure 5e) and 'Maximum amplitude' (Figure 5f) maps around these regions indicating accumulations of hydrocarbon. Those identified regions are porous as shown by 'Half energy' (Figure 5g)) map with relatively uniform thickness as shown by 'Positive to negative' map (Figure 5h) and high net-sand-ratio revealed by 'Sum of magnitudes' map (Figure 5i). Finally this interpretation suggested geological structures with likelihood of hydrocarbon occurrences at the stated locations

4. Conclusion

Log analysis, seismic evaluation and seismic attribute analysis have been jointly applied to study and characterise the reservoir rocks in Y-field. The reservoirs seem to be characterised with complex geological structures characteristic of Niger Delta. The log study revealed both water-bearing and hydrocarbon-bearing intervals. Well Nd-7p does not contain hydrocarbon but characterised with brine saturated units while Ok-16 has reservoirs saturated with hydrocarbon as shown by the log analysis results of Figures 1 and 2. Seismic evaluation showed structural features capable of hosting hydrocarbon with alot of structural closures which were identified and shown by the seismic sections and depth maps. The attribute maps extracted over the horizons showed structural conformance as the high amplitude values characterised this structures. New driilling locations were identified from the attribute maps. The identified regions with possible hydrocarbon accumulations are characterised by high porosity, high thickness with high net-sand ratio as was observed from the attribute maps. Therefore, it can be concluded that, logs, detailed seismic study and attribute analysis and evaluation can be effectively used to characterise the reservoirs and to determine reservoir continuity and extent which can help in locating new drilling point(s) for optimum production especially in a marginal field.

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