3D SEISMIC INTERPRETATION TO DETERMINE HYDROCARBONS IN THE 25-X-14 AND 64-JX-15 WELLS OF THE TEAPOT DOME BASIN USING ENVELOPE ATTRIBUTES AND RMS ATTRIBUTES

Putri Yunia Lestari*, M. Aryono Adhi, Wahyu Hardyanto

Department of Physics, Faculty of Mathematics and Natural Sciences, Semarang State University, Indonesia

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ABSTRACT

The Teapot Dome Basin in Wyoming is known to have significant hydrocarbon potential, but its distribution and characteristics need to be better understood. This study was conducted to analyze the presence of hydrocarbons in wells 25-1-X-14 and 64-JX-15 using 3D seismic interpretation. Envelope attributes and RMS attributes were used to identify prospective zones more accurately. The purpose of this study is to determine the results of 3D seismic data interpretation in determining the geological structure of hydrocarbons in well 25-1-X-14 and well 64-JX-15, and to determine the application of attribute envelope and rms in determining the geological structure of Teapot Dome. The method used in this research is a quantitative descriptive method, in which seismic data is numerically analyzed to describe the physical characteristics of the subsurface. The amplitude values used in this research are 10m, 20m, 30m, 40m, 50m, and 60m. Data processing is done in 3 stages, namely picking horizon, time structure map, surface attribute envelope, and RMS. The interpretation of the envelope attributes and RMS attributes shows high-amplitude bright spot zones that indicate hydrocarbons, especially in the sand section. The low amplitude areas in the shale section do not have hydrocarbon prospects. The analysis also confirmed a dominant anticline structure with an axis to the southwest of Teapot Dome.

Keywords: Envelope attribute; rms attribute; seismic attribute; teapot dome

Introduction

Energy is one of the crucial aspects in supporting human activities around the world. Among various energy sources, petroleum is one of the most important to meet global energy consumption with a significant number. This is due to old wells and new wells with very limited productivity. There are three factors that form the basis of the hydrocarbon formation process, namely the rock of origin, the transfer of hydrocarbons from the rock of origin to the reservoir rock, and the presence of geological traps. According to[1] Seismic exploration is divided into 3 stages: data acquisition, data processing, and data interpretation. Processing in the seismic method begins with data acquisition, which consists of collecting unprocessed data or raw data. The purpose of seismic data processing is to make an image that can be used to determine the structure of the subsurface layer.

Teapot Dome was known as the largest oil field in Wyoming, USA, in the early 20th century. This oil field, along with two other fields in California, was provided as an emergency reserve for the United States Navy to ensure that the Navy had a stable supply of oil in times of war or in times of crisis.[2] The accessibility and openness of Teapot Dome *open source* data information provide fortune and benefits in various fields, including research, education, policy, and the general public. *Open source* data is freely available, removing financial barriers for researchers, students, and the general public. *Open source* data is also available in digital format and can be accessed via the internet; this data is

*Corresponding author.
E-Mail: putriyuniales@gmail.com

available in various formats, including CSV, JSON, and XML.

Seismic reflection is one of the main methods that have the opportunity to obtain hydrocarbons and has undergone rapid development. In principle, seismic waves propagate through rock in the form of elastic waves that transmit energy into the dynamics of rock particles.[3] The principle of the seismic reflection method is to measure the Earth's response to seismic waves propagated by artificial waves. After the artificial waves are generated, the waves from the source will propagate through the rock medium. When these waves propagate through different mediums, such as rock layers that have should be different velocities, reflection or refraction occurs. The reflected waves will be received by a receiver such as a geophone (for land acquisition) or hydrophone (for marine acquisition). The wave signal received by the receiver will be recorded as a function of time.[4]

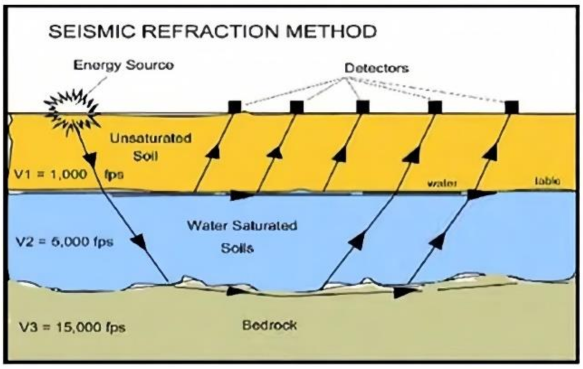

Figure 1. Seismic Refraction Method[6]

Seismic wave propagation follows Snellius' Law, which has been developed from Huygens' Principle. The main application of Snellius' Law is to determine the angles of reflection and refraction other than the 90° angle. Snellius' law explains that when light passes from one medium to another with a different density, the direction of the light will change. The incident ray, normal line, and refracted ray are always in one plane. The amount of light deflection is determined by the ratio of the refractive indices of the two mediums. In other words, this law helps us understand how light can be refracted when it enters a denser or more dense medium. Measurements of the angle of incidence and angle of reflection are calculated from the normal boundary to the boundary between two layers that have different acoustic impedances. If a P wave reaches the surface between two different mediums, some of the wave energy is reflected as a P wave and some as an S wave.[5]

3D seismic data that have been migrated sometimes show unclear cross-sectional reflections that cause ambiguity in the interpretation process.[6] To clarify data interpretation, it is necessary to determine the desired target more efficiently by adding seismic attributes. Seismic attributes consist of several types. According to,[7] attributes are clarified from the time, amplitude, frequency, and attenuation derivatives of seismic data. The quantity of data extracted from seismic data can be analyzed using seismic attributes to enhance more subtle information in conventional seismic images, leading to better geological or geophysical interpretation.[8] Therefore, seismic attributes can help clarify the interpretation of 3D seismic cross sections to avoid ambiguity.[9]

In this study, the main attribute used is the attribute envelope. Attribute envelopes are commonly used to determine acoustic impedance contrast, lithological characteristics, and bright spot zones. Based on attribute envelope characteristics, high amplitude values are generally interpreted as sand, while low amplitude values are shale. The lower the amplitude value, the more shaly the deposit. Amplitude attribute variation can be done in several ways, one of which is the analysis of reflection events, such as frequency. So that amplitude-related anomalies can be interpreted correctly and the reservoir can be described and characterized properly.[10] Attribute RMS is used for an interpretive approach to evaluating reservoirs that involves the simple assumption that the brightness (brightspot) on the seismic map associated with the amplitude size will be higher if the hydrocarbon saturation is high.[11]

This research is different from previous studies because it uses a combination of Envelope and RMS seismic attributes to improve the accuracy of detecting hydrocarbons in the Teapot Dome Basin. Previously, most studies only focused on conventional structural analysis without taking into account amplitude variations in detail. This method is superior because it is able to identify bright spot zones more clearly, making it easier to distinguish areas that contain hydrocarbons and those that do not. In addition, the use of Envelope and RMS attributes enables more accurate reservoir mapping than conventional methods. This approach also makes seismic interpretation more quantitative and objective, reducing the level of uncertainty in exploration. Another advantage is its ability to describe geological structures in greater detail, including anticlines and potential hydrocarbon traps. Thus, this method is more effective in supporting optimal hydrocarbon exploration.

The well data used is based on the depth that reaches the target zone. The target zone in well 25-1-X-14 is F1WC to THMR, while the target zone in well 64-JX-64 is F1WC to F2WC, the target zone was chosen because there has been no research in the zone. The wells used have complete data, namely Density, P-Wave, Neutron Porosity, and Gamma Ray seismic data that is already available in this field in the form of 3S PSTM.

Methods

In its application, the Envelope and RMS seismic attribute methods are used to analyze 3D seismic data to detect amplitude changes that could indicate the presence of hydrocarbons. The Envelope attribute serves to highlight areas of high reflection energy, while the RMS attribute is used to look at distribution patterns and amplitude strength. The results of the analysis of these two attributes are then mapped in order to distinguish zones that potentially contain hydrocarbons from unproductive areas. With this approach, seismic interpretation becomes more accurate and objective, supporting more effective hydrocarbon exploration.

A. Research Tools

The tools used in this research include hardware and software. Hardware includes computers and hard drives, while the software used is CGG Hampson Russel Suite 10.3.2, Schlumberger Petrel E&P Software Platform Version 2017, Microsoft Word, and Microsoft Excel.

B. Research Data

1. Seismic Data

The seismic data used is secondary data derived from Teapot Dome in the form of 3D in wells 64-JX-15 and 25-1-X-14.

Table 1. Seismic data availability

Parameters	Description
Inline Range	1 – 345
Crossline Range	1 – 188
Range Interval	110
Crossline Interval	110
Internal Sample Rate	2
Increment	10

2. Well Data

At this stage, what is done is checking the availability and completeness of seismic data, including:

Table 2. Well, data availability

Well	Checkshot	Density	Log P-Wave	Neutron	Gamma Ray	Sonic
25-1-X-14	✓	✓	✓	✓	✓	✓
64-JX-15	✗	✓	✓	✓	✓	✓

3. Well Top Data

Well, top data or marker data is the boundary of a formation. In this study, the 25-1-X-14 well uses F1WC to THMR markers, while the 65-JX-15 well uses F1WC to F2WC markers, which will later become a reference in picking horizons and well seismic ties.

C. Research Procedure

The following is a research flow chart:

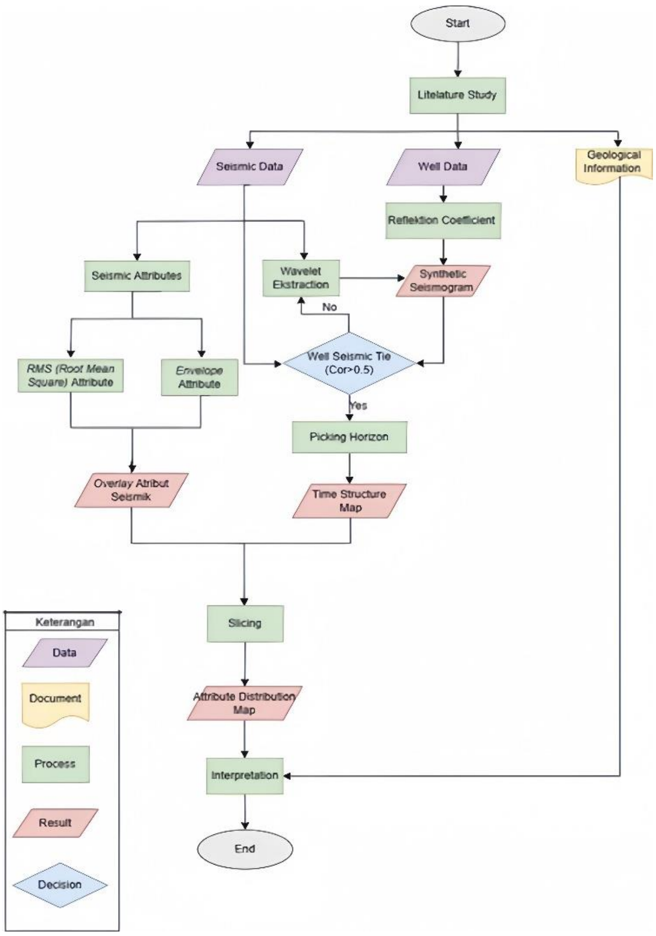

Figure 2. Research Flow Chart

D. Data Processing Stages

Seismic data processing with HRS and Petrel begins with importing the .sgy data, adjusting the headers, and determining the coordinate reference system (CRS). Afterwards, Quality Control (QC) is performed to ensure data quality before further processing through stages such as deconvolution, filtering, velocity analysis, and migration to improve signal quality.

The processed data were then used for interpretation, including horizon determination, fault interpretation, and structural and stratigraphic analysis to identify hydrocarbon prospect zones. Furthermore, seismic data is correlated with well data (.las) to improve the accuracy of reservoir mapping. HRS focuses more on raw data processing, while Petrel excels in 3D geological interpretation and modeling.

Well depth conversion in HRS and Petrel is done by importing seismic data (.sgy) as well as well data (checkshot, VSP, or velocity log). A velocity model is then created to link the time domain to depth using interval velocity or checkshot calibration methods. This model is used to convert seismic data from the time domain to depth and then validated with well data to ensure accuracy. HRS focuses more on raw velocity processing, while Petrel excels in 3D reservoir modeling and interpretation.

Result and Discussion

Well Seismic Tie (WST) is a step to link well data to seismic data. The principle is to place the seismic reflector at the actual depth with the well seismogram corresponding to a boundary plane. The results of the well seismic tie analysis will show that the synthetic seismogram can be correlated with the horizons in the seismic data that represent changes in reflection coefficients or boundary planes of rock layers.

Interpretation of seismic horizons in the form of a description of the subsurface layer can be done by picking horizons. The purpose of picking horizons is to analyze the area under study based on stratigraphy and structure. This seismic data image recording shows a good image, because each layer on the seismic trajectory is reflected in an image with a very clear color on the layer. Horizon picking is done on the peak layer and the trough layer.

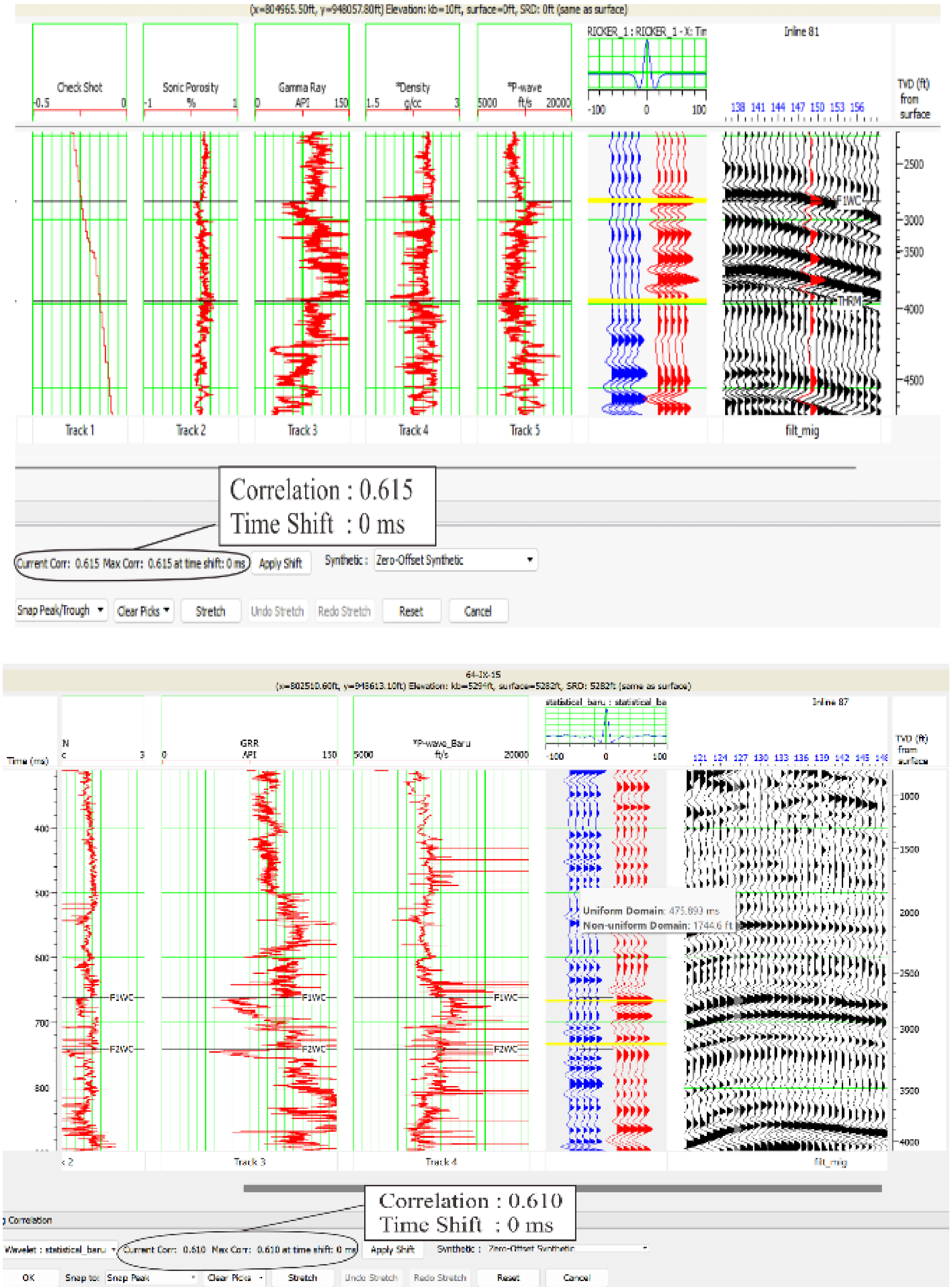

Figure 3. Well Seismic Tie 25-1-X-14 and 64-JX-15

The peak layer in well 25-1-X-14 is marked in blue, while well 64-JX-15 is marked in purple on the seismic cross section, which shows a high-amplitude layer image. The trough trajectory in well 25-1-X-14 is marked in green, while that in well 64-JX-14 is marked in orange on the seismic cross section showing the low-amplitude layer.

The increment used in this research horizon picking is 10 for all inline and crossline seismic trajectories. Increment greatly affects the results of horizon picking; the smaller the increment used, the finer the subsurface features displayed. A smaller increment distance will capture the geometry of subsurface features with more detail and clarity in a channel system with a small scale.[12]

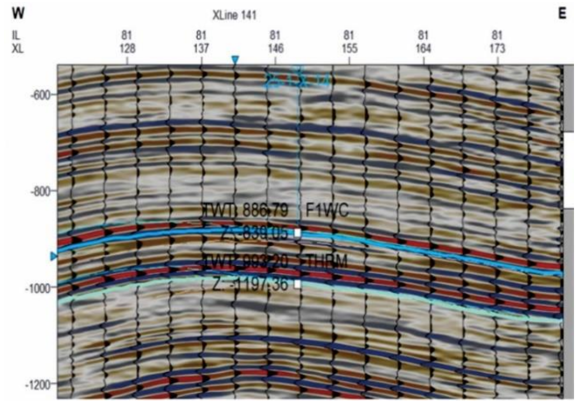

Figure 4. Horizon Picking Result Well 25-1-X-14 (m)

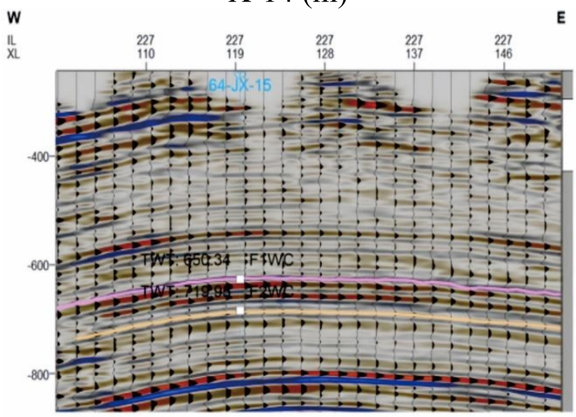

Figure 5. Horizon Picking Result Well 64-JX-15 (m)

The layers or horizons that have been picked are then gridded, and a time structure map is obtained to see the structural conditions in the research field in the time domain. The time structure map shows the depth in the time domain that can be recognized based on the color. The red color indicates a low time domain value, which indicates the area has a high topography. The purple color indicates a high time domain value, which indicates the area has low topography. The color change is usually called the height of an area.[13]

The time structure map results at well 25-1-X-14 F1WC target zone show a time domain depth of 820-1100 ms. The western edge, southern edge, and eastern edge shown in light blue to purple color have a time domain depth of about 940-1100 ms, where the topography is low. The central part marked with yellow to red color has a time domain of 820 - 880 ms, indicating a high topographic area allowing hydrocarbon prospects. While the THMR target zone shows a depth of 920-1110 ms time domain. The eastern edge and western edge shown in light blue to purple color have a time domain depth of about 1030-1110 ms with low topographic areas. The central part marked with yellow to red color has a time domain of 920-960 ms, indicating a high topographic area allowing hydrocarbon prospects.

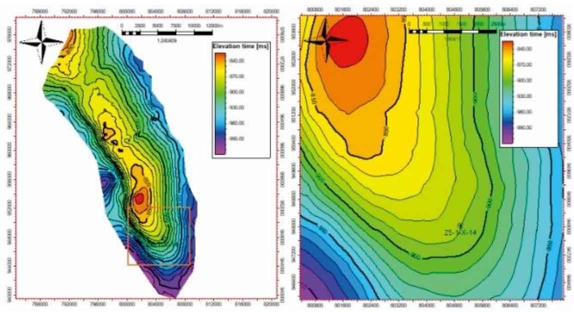

Figure 6. Time Structure Map Well 25-1-X-14 Marker F1WC

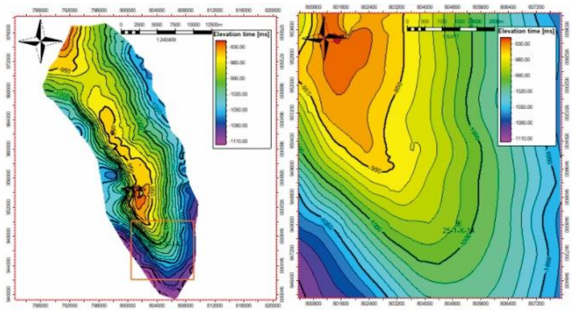

Figure 7. Time Structure Map 25-1-X-14 Marker THRM

While the results of the time structure map at well 64-JX-15 F1WC target zone show a time domain depth of 675-800 ms. The southern edge and eastern edge shown in light blue to the depth of the time domain are around 670-675 ms, where the topography area is low. The central part marked with yellow to red color has a time domain of 595-630 ms, indicating a high topographic area allowing hydrocarbon prospects. While the THMR target zone shows a depth of 675-800 ms time domain. The eastern edge shown in light blue has a time domain depth of about 740-745 ms with a low topographic area. The central part marked with yellow to red color has a time domain of 675-705 ms, indicating a high topographic area allowing hydrocarbon prospects.

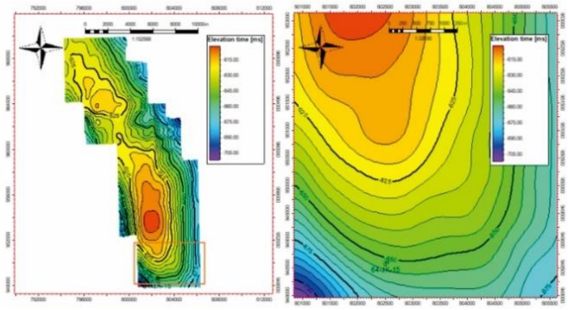

Figure 8. Time Structure Map Well 64-JX-15 Marker F1WC

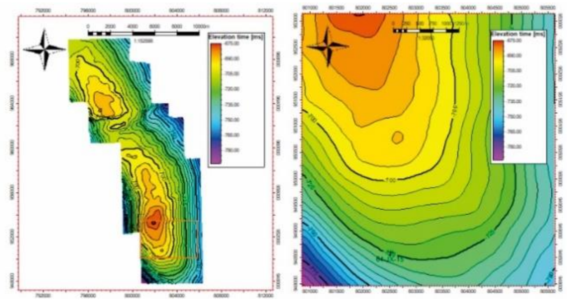

Figure 9. Time Structure Map Well 64-JX-14 Marker F2WC

The results of the analysis in wells 25-1-X-14 and 64-JX-15 on the surface attribute results map using envelope and rms can detect geological structures in the form of hydrocarbon sand and shale. The attribute envelope and attribute RMS can be used to detect a channel at high amplitude.[14] The results of this study show that the red-orange channel structure shows a bright spot that has a high amplitude value shown in red, which is generally interpreted as sand. The bright spot indicates a high probability of hydrocarbon prospects.[15] As for the low amplitude value, it is shown in blue, which generally means that the deposits are getting shale.

The determination of the geological structure at Teapot Dome, based on the interpretation of envelope attributes and RMS amplitude attributes, indicates the presence of a dominant anticline structure in the Teapot Dome field, with the anticline axis located to the southwest. Anticlines can be identified in the seismic data through the interpretation of seismic reflection, which shows an upward fold pattern. An anticline is a visual representation of a geological structure where rock layers curve upwards, forming a peak or dome. These structures are often associated with potential hydrocarbon traps as older rock layers are in the center and younger layers are on the outside.

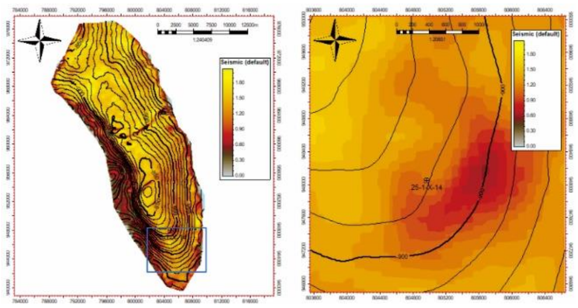

Figure 10. Surface Attribute Envelope Combination Attribute RMS Well 25-1-X-15 F1WC 40m

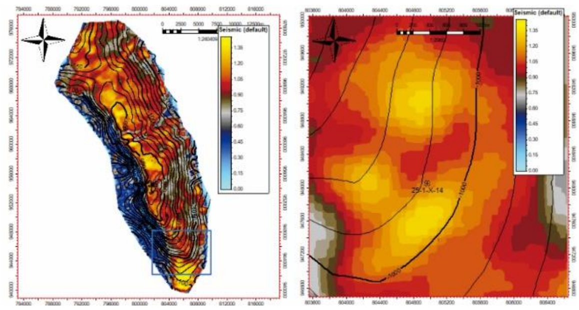

Figure 11. Surface Attribute Envelope Combination Attribute RMS Well 25-1-X-15 THRM 60m

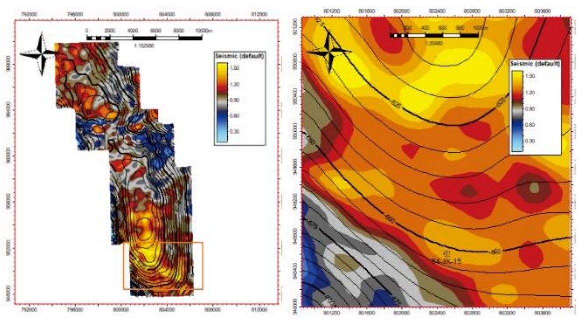

Figure 12. Surface Attribute Envelope Combination Attribute RMS Well 64-JX-15 FIWC 10m

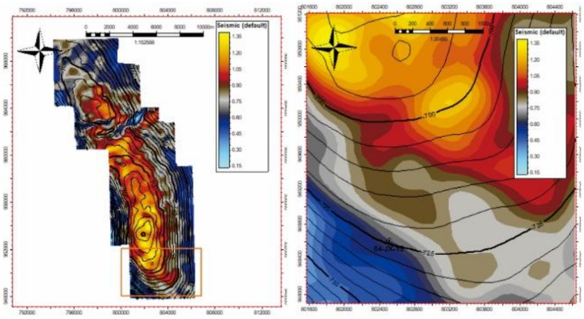

Figure 13. Surface Attribute Envelope Combination Attribute RMS Well 64-JX-15 F2WC 30m

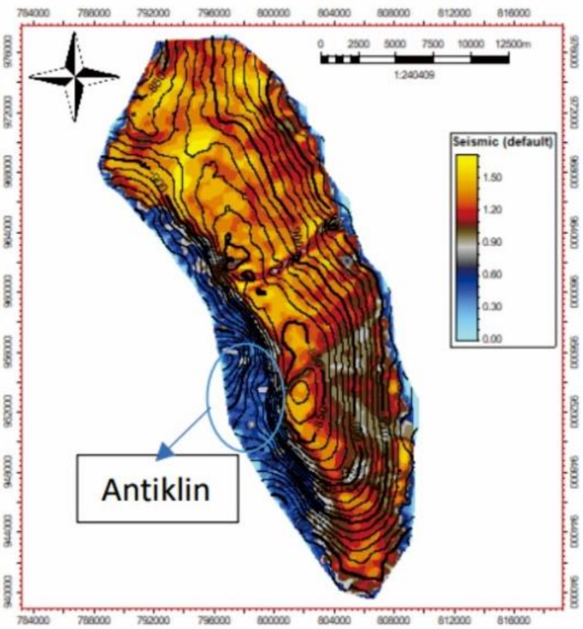

Figure 14. Teapot Dome field anticline

Conclusion

Based on the results of the research that has been done, it can be concluded that the application of attribute envelope and attribute RMS in determining the geological structure of wells 25-1-X-15 and 64-JX-15 can be done with various processes, namely horizon interpretation or horizon picking, time structure map, and volume attribute envelope. From the data processing, it can be used in determining the structure of hydrocarbon prospects in the Teapot Dome field which shows the presence of hydrocarbons shown in red orange color in the sand section, while for structural elements that have low amplitude values there are no hydrocarbon prospects shown by blue color in the shale section.

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