3D SEISMIC DATA INTERPRETATION TO IDENTIFY HYDROCARBON PRESENCE IN WELLS 25-1-X-14 AND 64-JX-15 USING SWEETNESS ATTRIBUTE IN TEAPOT DOME FIELD, WYOMING

Ummi Fauziyah, Aryono Adhi*, Wahyu Hardyanto

Department of Physics, Science and Technology of the Faculty, Semarang State University, Indonesia

Received: 19th September 2024; Revised: 3rd October 2025; Accepted: 18th October 2025

ABSTRACT

Exploration activities in Teapot Dome can be carried out by looking at the geological structure. Determination of geological structure can be done by interpreting seismic data. This study aims to identify hydrocarbon prospect zones in the Teapot Dome field through 3D seismic interpretation of wells 25-1-X-14 and 64-JX-15, and to evaluate the application of sweetness and RMS amplitude attributes in determining the geological structure of the Teapot Dome using 3D seismic reflection data. The data interpretation processing stage starts from performing wavelet extraction, well seismic tie, horizon picking, and time structure map. This research utilizes seismic sweetness and RMS amplitude attributes with amplitude values of 10 to 60ms to map hydrocarbon distribution. The results of this study show that the greatest hydrocarbon distribution occurs at both markers in well 25-1-X-14, with amplitude values of 50 ms and 20 ms, indicated by the presence of sweet spots and bright spots. In well 64-JX-15, sweet spots and bright spots are observed at the top marker with an amplitude value of 20 ms. The application of attributes in determining the geological structure in the Teapot Dome field is found to be an anticline that runs from the northwest to the southeast.

Keywords: Hydrocarbon; rms amplitude attribute; sweetnes attribute; Teapot Dome

Introduction

Demand for oil and gas is increasing, especially in the industrial and transport sectors. Worldwide oil use after the COVID-19 pandemic has surged, as can be seen in Figure 1.

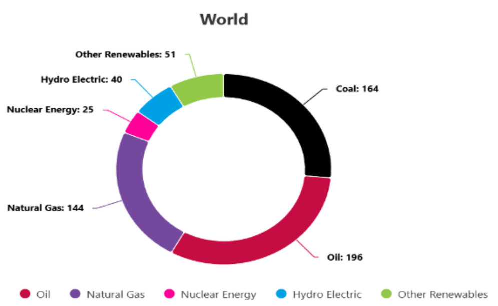


Figure 1. Data on the increase in petroleum use

According to the Energy Institute Statistical Review, oil remains the dominant energy source worldwide, accounting for the largest share of global energy consumption compared to coal, natural gas, nuclear, hydro, and other renewables. In 2022, the United States was the largest oil consumer, with actual usage reaching around 18.7 million barrels per day (bpd). Looking ahead, global oil demand is projected to increase by about 2% in 2024, with U.S. consumption expected to hover at approximately 18.1 million bpd. This growing dependence on oil and gas underscores the need for more effective exploration and exploitation strategies, while also raising concerns about balancing fossil fuel reliance with the development of cleaner, renewable energy alternatives. Oil and gas exploration can be carried out by various methods, one of which is the reflection

*Corresponding author.
E-Mail: aryono_adhi@mail.unnes.ac.id

seismic method.[1] The seismic method is a commonly used geophysical approach for investigating subsurface conditions and reservoir rock characteristics, such as porosity and permeability, through data interpretation. Within this method, seismic attributes function as tools that provide more detailed information for analysis.[2]

One of the oil and gas exploration activities occurred in the Teapot Dome field, Wyoming, USA. The field has significant hydrocarbon resource potential, including oil, natural gas, and liquefied natural gas.[3] Teapot Dome is asymmetrically folded on the southwest side of the Powder River basin.[4] The main producing zones are sandstones and limestone shales, with significant potential for recovery of undeveloped primary oil, as well as infill and horizontal drilling targets.[5]

Studies conducted at Teapot Dome, Wyoming, USA, have made important contributions to understanding geology and hydrocarbon reservoirs. Moon et al[6] have compared the collocated cokriging (CCK) and neural-network multi-attribute transform (NN-MAT) methods in predicting porosity, and found that CCK tends to overpredict. Meanwhile, Kim and Lee[7] generated 3D models for porosity and net-to-gross (N/G) of the Second Wall Creek Sand (SWCS) reservoir, which revealed porosity variations ranging from 8% to 18%. Khan[8] has focused on 3D geomodelling for the Frontier Formation, which helped understand facies distribution and higher reservoir productivity in the southern part of the Teapot Dome. Roberts et al.[9] used kinematic and mechanical models to predict natural fracture networks, which can be applied to hydrocarbon exploration and other energy projects. Meanwhile, Chika[10] used Sweetness attribute analysis in the Bornu Basin, Nigeria, to identify high-quality reservoir zones, confirming the presence of high-acidity reservoirs at -900 ms depth.

In Schneider et al.[3] research, using seismic attributes can be used to identify faults that have the potential to be hydrocarbon traps. Seismic sweetness attributes have proven effective in the identification and characterization of hydrocarbon reservoirs.[11] RMS amplitude is a seismic attribute that represents the mean square value of the seismic amplitude within a given time window.[12] This attribute is commonly used in seismic data analysis to measure the energy or strength of seismic reflections, providing insight into subsurface geological features and potential hydrocarbon reservoirs.[13] From this explanation, the use of sweetness attributes combined with rms amplitude attributes is expected to identify the distribution of hydrocarbon reservoirs in the Teapot Dome field with 3D seismic data at wells 25-1X-14 and 64-JX-15 with targeted markers.

Methods

The research location is in the Teapot Dome field, with data taken in the form of secondary data accessed through the survey-SEG Wiki in the form of 3D PSTM seismic data on wells 25-1X-14 and 64-JX-15. In data processing, several steps are taken, which can be seen in the following flowchart

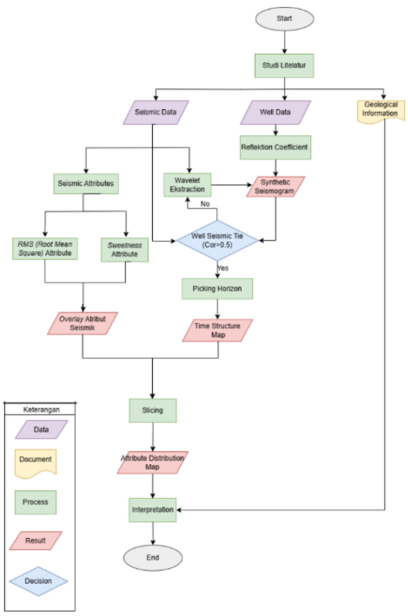


Figure 2. Flowchart in data processing

This study begins with a checklist of data completeness, including PSTM seismic data, well data from as many as two wells, consisting of logs (GR, RHOB (density), NPHI, and DT), cores, check shots, and markers.[14]

Corrections and validation of well data, namely RHOB logs, GR, and markers, are carried out, followed by target zone analysis using marker data. A well-to-seismic tie is then performed on each well so that depth-domain well data can be integrated with time-domain seismic data.

A well-to-seismic tie is conducted on each well to integrate depth-domain well data with time-domain seismic data, using synthetic seismograms and check shots. The well-to-seismic tie process is repeatedly performed by integrating the synthetic seismogram results with the original wavelet from the seismic inline or crossline of each well, in order to obtain correlation values ranging from 0 to 1 with a time shift of 0 ms. If a correlation value close to 1 with a time shift near 0 ms is achieved, the result is considered good and can be used for the next stage of processing. The output of the well-to-seismic tie (depth–time) is the corrected checkshot.

Next, the horizon is picked using the well seismic tie as a reference. The picked horizon is then used to generate a time-structure map. This map is processed to derive the Sweetness and RMS amplitude attributes. A depth-structure map is then created through time-to-depth conversion. Finally, the depth-structure map is analyzed to determine hydrocarbon distribution.

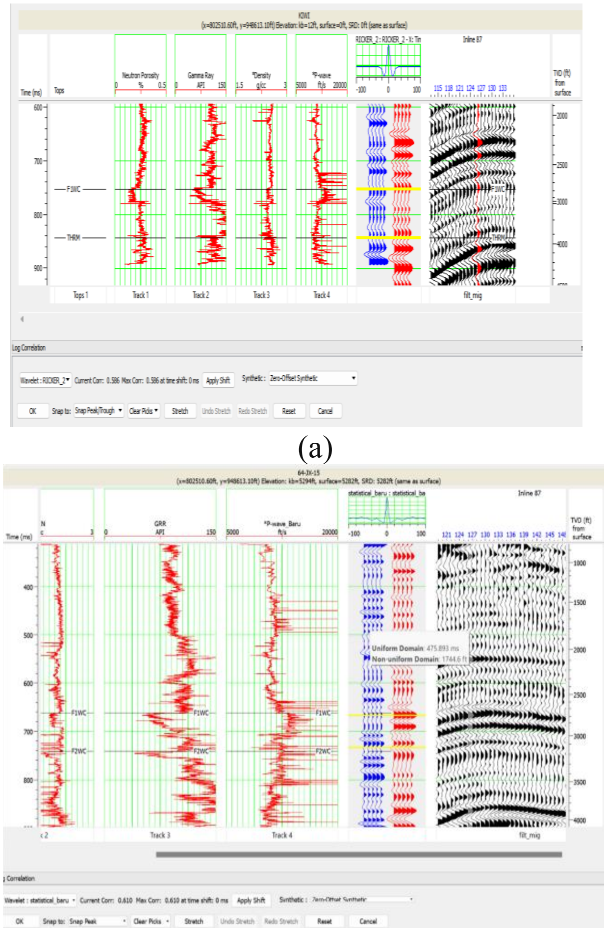
Result and Discussion

Well Sismic Tie and Picking Horizon

After tabulating the data and obtaining the target area or marker in the well, the wst results can be seen in Figure 3.

In Figure 3, the correlation in the well seismic tie in the 25-1X-14 well is 0.586 ms with the F1WC-THRM marker, while in the 64-JX-14 well it is 0.610 ms with the F1WC-F2WC marker, meaning that the value of both is almost close to the value of 1 ms, so it can be said that the correlation is good. The results of this good correlation will be used for the next process, namely picking horizons, which can be seen in Figure 4.

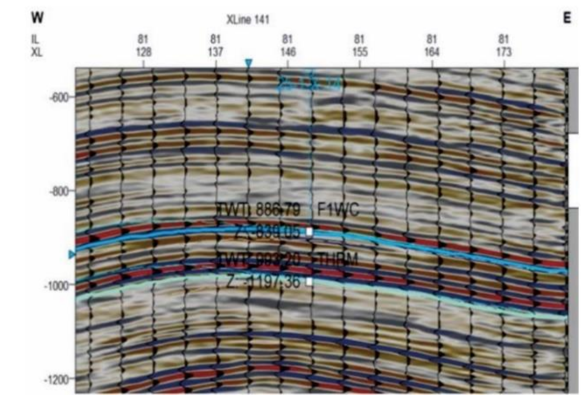
One of the steps in seismic data interpretation is using horizon picking.[14] The results of horizon picking in Figure 4 show the continuity of the seismic cross-section in accordance with the marker. During the horizon picking process, there is a reflection pattern in the observed seismic data, namely, the continuity of the cross-section at the peak and trough. The horizon picking process was carried out on the peak trajectory in well 25-1X-14, marked in blue, while in well 64-JX-15, marked in purple. The trough trajectory in well 25-1X-14 is marked in green, while that in well 64-JX-15 is marked in orange. Peak indicates that the layer has high amplitude, while trough indicates low amplitude.



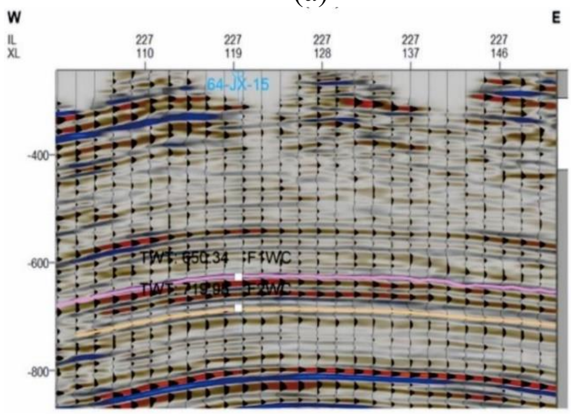
(a)

(b)

Figure 3. Well seismic tie results at wells (a). 25-1X-14 (b). 64-JX-15



(a)



(b)

Figure 4. Picking Horizon of Wells (a).25-1X-14 (b). 64-JX-15

Time Structure Map

The time structure map was created by interpreting the horizon. The selected horizon is then converted into a grid to produce a time structure map. This map was created to ascertain the state of the structure in the study area in the time domain. The following is a horizon map of wells 25-1X-14 and 64-JX-15 in the Teapot Dome field with markers F1WC-THRM and F1WC-F2WC.

The following interpretation results for the Teapot Dome field well 25-1X-14 can be seen in Figure 5.

The Time Structure Map analysis (Figure 5) identifies two potential hydrocarbon target zones: F1WC and THRM. The F1WC zone, at depths of 820–1100 ms, shows a central high area (green to red) that indicates hydrocarbon potential. Meanwhile, the western, southern, and eastern edges (light blue to purple colors) are 940-1100 ms deep with low topographic areas that may not have hydrocarbon prospects. The THRM zone is 920-1110 ms deep with a high topographic area in the center (yellow to red color), indicating potential hydrocarbon prospects. The eastern and western edges (light blue to purple colors) are 1030-1110 ms deep with low topographic areas that are unlikely to have hydrocarbon prospects. The F1WC zone shows wells in the yellow to green coloured area at a depth of 890 ms, while the THRM zone is in the green coloured area at a depth of 900 ms. Both zones are in the yellow to green color, which allows the presence of hydrocarbon reservoirs.

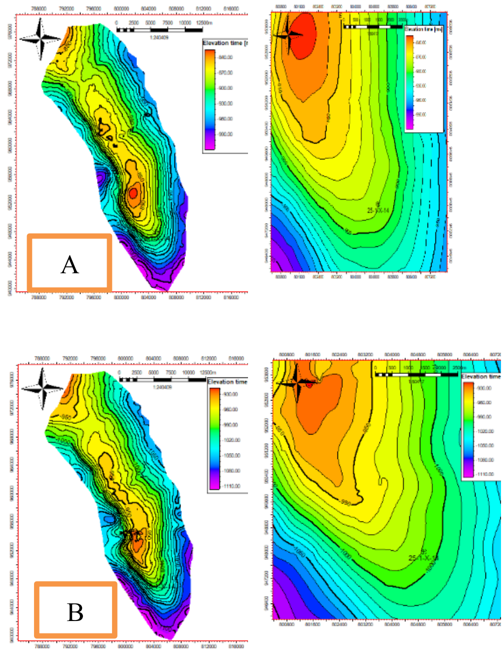


Figure 5. Time Structure Map of Well 25-1X-14 with A. F1WC, B. THRM,

The interpretation results of the Teapot Dome field well 64-JX-15 can be seen in Figure 6.

The results of the Time Structure Map analysis of well 64-JX-15 in Figure 4.5 show two potential target zones for hydrocarbon prospecting, namely the F1WC and F2WC zones. The F1WC zone has a depth of 675-800 ms with a high topography area in the middle, shown in green to red, which indicates potential hydrocarbon prospects, while the low topography is shown in light blue to purple. The F1WC and F2WC zones show wells in green coloured areas with depths of 855 ms and 725 ms, respectively. Both zones are in the yellow to green colors, which suggest possible hydrocarbon reservoirs

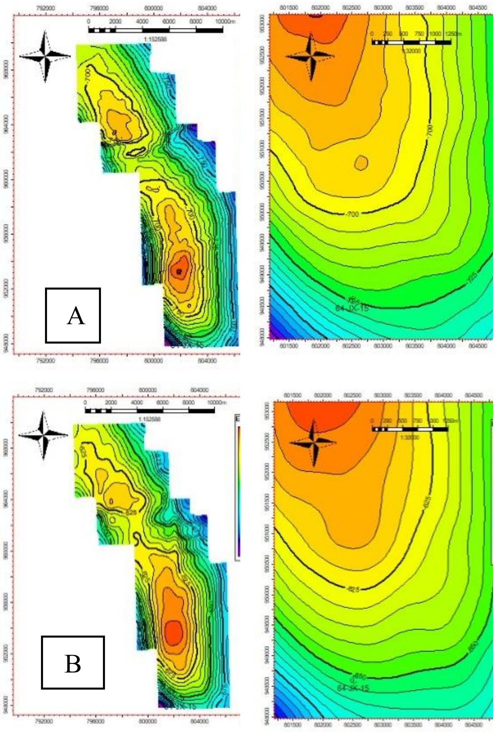


Figure 6. Time Structure Map of Well 25-1X-14 with A. F1WC, B. F2WC,

Seismic Attributes

The results of the sweetness attribute are shown in Figure 7.

The sweetness attribute is used as a supporting attribute to confirm the RMS amplitude results. It has the advantage of being sensitive to lithological changes because it contains an amplitude element. This makes the sweetness attribute useful for mapping the distribution of sandstone lithology in the field. Using this attribute can also identify sweet spots where gas and oil are easily found. In young clastic sedimentary basins, sweet spots tend to have high amplitude and low frequency. The sweet spots are shown in red to yellow colors spreading from northwest to southeast.

Application of Seismic Attributes in Geological Structure Determination

The geological structure of Teapot Dome, interpreted from the sweetness and RMS amplitude attributes, shows a dominant anticline (Figure 8). The anticline axis extends from northwest to southeast.

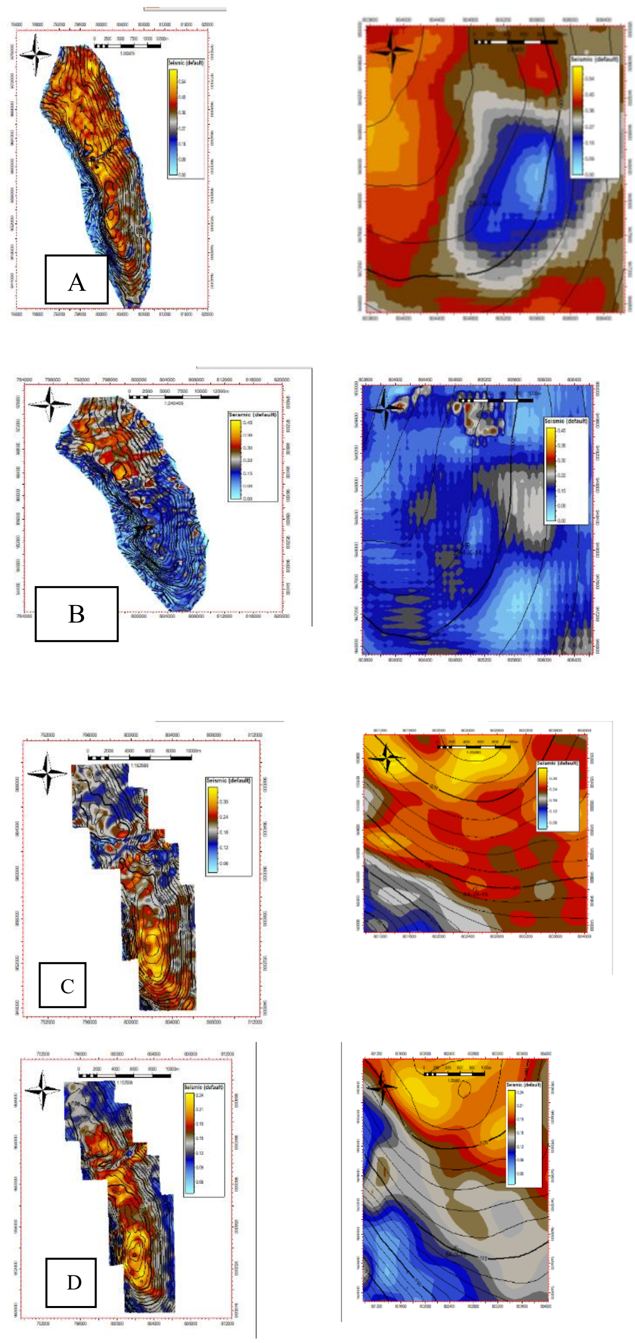


Figure 7 Scatter Map Using Sweetness Attributes With A F1WC B. THRM C. F1WC D. F2WC

Anticlines can be identified in seismic data through the interpretation of seismic reflections that show upward fold patterns.[15] 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 because older rock layers are in the center and younger layers are outside. Figure 8 shows the contours of a tight anticline showing older rock formations indicated by dark colors, while younger rock formations tend to be loose with light colors at the bottom of the anticline core.

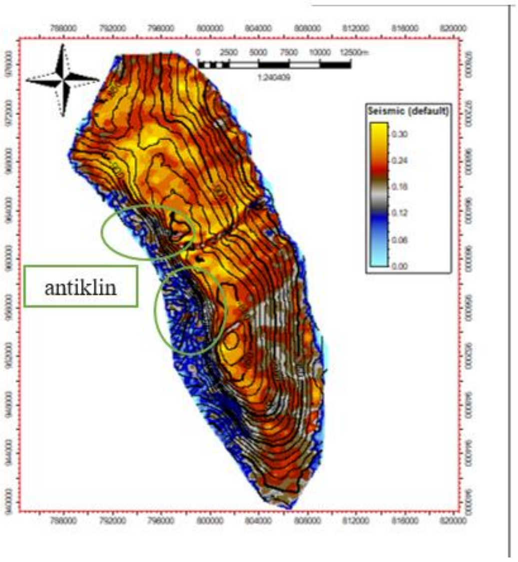


Figure 8. Anticline in the Teapot Dome Field

Conclusion

Based on the discussion, it can be concluded that seismic interpretation in the time domain and attributes has been carried out at wells 25-1-X-14 and 64-JX-15 of the Teapot Dome field. The characteristics of hydrocarbons are characterized by the presence of sandstone distribution, which has a dominant distribution pattern in the southeast-northwest. The use of sweetness and RMS amplitude attributes can determine potential hydrocarbon areas indicated by the presence of sweet spots and bright spots, colored yellow to red. The application of sweetness and RMS amplitude attributes in determining geological structures is found to be an anticline that runs from the northwest to the southeast in the Teapot Dome field.

Acknowledgment

Thanks to the Survey-SEG Wiki for providing 3D seismic data to conduct research.

References

1. Nur Azzahra M, Aryono Adhi M, Eka Nurcahya B, Fisika J, Matematika dan Ilmu Pengetahuan Alam F, Gadjah Mada U. Analisis persebaran reservoir batu pasir menggunakan metode inversi impedansi akustik pada Lapangan "Lily" Cekungan Sumatera Tengah. Upej. 2023;12(2). Available from: http://journal.unnes.ac.id/sju/index.php/upej
2. Rubiyana TF, Nurcahya BE. Study of constrained velocity inversion of seismic data in North Sumatra Basin. J Eng Technol Sci. 2021;53(1):1–16. https://doi.org/10.5614/j.eng.technol.sci.2021.53.1.5
3. Schneider S, Eichkitz CG, Schreilechner MG, Davis JC. Interpretation of fractured zones using seismic attributes—Case study from Teapot Dome, Wyoming, USA. Interpretation (UK). 2016;4(2):T249–T260. https://doi.org/10.1190/INT-2015-0210.1
4. Dolton G, Fox J. Powder River Basin Province (033). In: Gautier DL, Dolton GL, Takahashi KI, editors. 1996. p. 1–32. Available from: http://certmapper.cr.usgs.gov/data/noga95/prov33/text/prov33.pdf
5. Silverman MR. Teapot Dome: The greatest political scandal in the history of the US oil industry. Springer International Publishing; 2019. https://doi.org/10.1007/978-3-030-13880-6_5
6. Moon S, Lee GH, Kim H, Choi Y, Kim HJ. Collocated cokriging and neural-network multi-attribute transform in the prediction of effective porosity: A comparative case study for the Second Wall Creek Sand of the Teapot Dome field, Wyoming, USA. J Appl Geophys. 2016;131:69–83. https://doi.org/10.1016/j.jappgeo.2016.05.008
7. Kim H, Lee GH. A deterministic geomodeling case study for a thin clastic reservoir: The Second Wall Creek Sand,

Teapot Dome field, Wyoming, USA. J Pet Sci Eng. 2019;181:106244. https://doi.org/10.1016/j.petrol.2019.106244

8. Khan HA, Sultan M, Khan MJ, Alvarez MD, Mehdi D, Aqib M. A case study of 3D geomodelling of Frontier Formation Second Wall Creek Sand, Teapot Dome, Wyoming, USA. J Appl Geophys. 2020;180:104114. https://doi.org/10.1016/j.jappgeo.2020.104114
9. Roberts D, Luneburg C, Jin D, Kato J. Utilizing a kinematic and mechanical modelling workflow to constrain fracture network characteristics: Application to the Teapot Dome, Wyoming, USA. J Struct Geol. 2022;159:104596. https://doi.org/10.1016/j.jsg.2022.104596
10. Chika E, Chibuogwu I, Egwuonwu G, Chika Franklin E, Gabriel Ndubuisi E, Ikechukwu Udoka C. Reservoir identification in Bornu Basin, Northeastern Nigeria based on well log analysis. Int J Sci Res Phys Appl Sci. 2023;11(1):7–16. Available from: www.isroset.org
11. Chopra S, Marfurt KJ. Seismic attributes: A historical perspective. Geophysics. 2005;70(5). https://doi.org/10.1190/1.2098670
12. Hossain S. Application of seismic attribute analysis in fluvial seismic geomorphology. J Pet Explor Prod Technol. 2020;10(3):1009–19. https://doi.org/10.1007/s13202-019-00809-z
13. Aviani N. Analisis seismik atribut untuk identifikasi persebaran reservoir batupasir pada Formasi Balikpapan, Lapangan V. J Geosaintek. 2022;8(2):200. https://doi.org/10.12962/j25023659.v8i2.13619
14. Erlangga MP, Sihombing DM. Modul praktikum picking dan gridding. 2019.
15. Fossen H. Structural geology. Vol. 1. Cambridge: Cambridge University Press; 2010.