# SIGNIFICANCE OF SUITABLE WAVELET ESTIMATION TO THE ANALYSIS OF SPECTRAL DECOMPOSITION METHOD TO DETECT CHANNEL FEATURE: A CASE STUDY IN THE JAISALMER SUB-BASIN, INDIA

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ABSTRACT

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Capturing the reservoir body in complex geology through regular attribute analysis is a challenging task. Subsurface imaging based on spectral decomposition analysis shows an improvement procedure for hydrocarbon exploration, especially in the complex geological setup. The spectral decomposition study was carried out in the Jaisalmer sub-basin. The sedimentary basin has the potential for hydrocarbon exploration. However, frequent alternation of lithology in the clastic and carbonate reservoir formation has made the exploration task challenging. Wavelet pattern recognition is a fundamental aspect of this process. The Continuous Wavelet Transformation (CWT) method was adopted to carry out the spectral decomposition study. A suitable wavelet was identified to characterize the reservoir lithology. The Gaussian wavelet produced a better and optimized outcome in this study than the other wavelets, such as Morlet and Mexican Hat. Few advanced attribute analyses such as geo-body capture and variance study were carried out based on volume rendering through the RGB blending process. The process was adopted using spectrally decomposed volume. The attribute analysis has produced an image that shows the extension of the reservoir lithology in the study area. One paleochannel was identified based on this study in the Pariwar formation as a potential reservoir architecture of hydrocarbon exploration.

KEY WORDS: Spectral Decomposition, Continuous Wavelet Transformation (CWT), wavelets, channel feature.

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## INTRODUCTION

The spectral decomposition method is a necessary process for seismic data analysis. This process is used based on the time-frequency analysis of the seismic data. Amplitude, phase, and frequency are three major components that develop the seismic signal. The detailed and advanced analysis of these components provides a comprehensive understanding to identify the hydrocarbon-bearing zone. The seismic data's non-stationary behaviour is challenging representation, and it shows difficulties in getting accurate knowledge of the reservoir's spectral nature. The varying frequency content of the seismic data has the potentiality to reveal the hidden subsurface features. The outcome of CWT analysis produces the result both in the time and frequency domain. In the complex geological setup, resolving the bed thickness of the reservoir is a challenging task. The study of spectral decomposition can resolve this challenge by delineating the reservoir body's structure and subtle changes (Sinha et al., 2005). We have carried out this study in the Jaisalmer sub-basin area in the Rajasthan basin. The Jaisalmer sub-basin is a Pericratonic basin situated in the northwestern part of the peninsular shield. The basin stratigraphy represents an alternate layer of clastic and carbonate sequences with clastic sandstone present as the hydrocarbon reservoir in Baisakhi-Bhadasar, Pariwar, Goru, Sanu, Khuiala formation. The structural features in this sub-basin are pretty complicated as it involves the hydrocarbon traps limited by numerous faults systems and unconformity related traps which makes the exploration of hydrocarbon difficult.

Based on the available data of the Pariwar Formation, a limited area was identified to carry out this work. Extension of the Pariwar Formation has been found from N27° 16' to E70° 45' (Report published in Director General of Hydrocarbon (DGH), 2007). The foraminiferal study of this area represents that the Pariwar Formation comes under the geological age of Neocomian to Aptian of lower Cretaceous (Singh and Nayak, 2011). The formation of the study present in between Bhadasar and Habur formation (Report published in Shodhganga, 2019). Deposition of continental sandstone and succession of regression phases of the Bhadasar Formation is found in the Pariwar Formation. The Pariwar Formation consists of arenaceous rocks in the base along with sandy siltstone and calcareous sandstone (Khan and Khan, 2015), whereas the upper layer contains only sandstone and siltstone. This formation also constitutes glauconitic sandstones and shales that infers the depositional condition into a shallow marine environment. The involvement of structural components and their effects in terms of fault entrapment has been found widely in this sub-basin (Pandey et al., 2019). The seismic reflection patterns are comparatively prominent concerning other formations in the Jaisalmer Formation of this sub-basin. The importance of time-frequency analysis has been identified in the Jaisalmer Formation. Coherency attribute analysis reveals the detailed structure of the Indian plate and the faults of the Madagascar plate and plate deformation due to tectonic activities (Pandey et al., 2019). The deformed fault system and its interaction have shown a significant development for hydrocarbon accumulation along NNW-SSE and E-W direction.

A seismic attribute such as RMS amplitude and spectral decomposition analysis was carried out to delineate challenging reservoir features in the Barmer basin's Dhravi-Dungar field. The geological setup of the reservoir formed from the turbidite environment is challenging for detecting thickness and permeability; however, the porosity range is satisfactory. Detail feature of channel morphology with bright amplitude was identified from this study in the Barmer basin (Kola et al., 2017). The study was conducted based on the combinational analysis of spectral decomposition and RGB blending, where RMS amplitude was played a crucial role. The spectral decomposition study was carried out based on CWT (Continuous Wavelet Transformation) analysis. A similar approach was also adopted in earlier instances in the Barmer basin to investigate a thin channel body in the reservoir formation (Kola et al., 2015). The study was carried out in the Barmer Hill (BH) Formation, which overlies the well-known Fatehgarh Formation. The formation shows interbedded volcanic flows within the fluvial deposition, representing the complexity of the reservoir. Study of Spectral decomposition and seismic attribute and RGB blending separated low amplitude bearing sand from the masked with high amplitude volcanic deposition within thin channel geometry. It shows the significance of spectral decomposition study in the Rajasthan basin. The spectral decomposition study was not carried out earlier in the Pariwar Formation of the Jaisalmer sub-basin region. However, the success of the study has been established in other parts of the Rajasthan basin. Despite the significant success of spectral decomposition study in the Rajasthan basin, there is an uncertainty that leads to the biased outcome of the spectral decomposition study. This uncertainty is related to the suitable choice of wavelet.

Identification of wavelets is challenging in the case of lithology alternation. In the current study, we have represented the wavelet's constraint towards identifying a suitable wavelet for conducting spectral decomposition study in the Pariwar Formation. The selection of an appropriate wavelet is one of the primary objectives of this research to get the optimal result. The current study has shown a promising outcome with comprehensive support of geo-body interpretation in the study area, carried out based on spectral decomposition and RGB blending technique, which was another objective. These approaches are unique in this study area.

Initially, the conventional method produces a frequency variation map with time from the analysis of the STFT (Short term Fourier transformation) algorithm. However, further analysis based on the STFT result shows the development scope to choose the algorithm where CWT has produced an improved result in the latter part of this study. In 2016, Salhov and Bermanis (Salhov et al., 2016) represented a kernel-based method for spectral decomposition analysis using a machine learning approach. The global acceptance of the machine learning approach significantly depends on identifying the suitable wavelet with changes in lithology. This study produced variable results for spectral decomposition analysis based on different wavelets, such as Morlet, Gaussian, and Mexican Hat. Identification of suitable wavelet function in the form of Mother wavelet is the most critical part of spectral decomposition study. This method involves the seismic signal multiplied by a wavelet function whose length is adjusted according to the required frequency resolution. This current study represents a comparative analysis of the CWT method using different wavelets to map the stratigraphic channel in the Pariwar Formation with precisely identify the lithology of the zone of interest in the study area.

## GEOLOGY OF THE STUDY AREA

### A summary of the geological history of the Jaisalmer sub-basin

The Jaisalmer sub-basin is a significant sedimentary basin for hydrocarbon exploration located in the northwestern part of the Indian peninsular shield and spreads over 30,000 $km^2$ area (Goswami, 2014). This sub-basin is a part of the Rajasthan shelf situated about 23° south of the equator (Pandey et al., 2012). According to the geological age, the Rajasthan basin has been distributed from the Mesozoic to Cenozoic (Report published in Director General of Hydrocarbon (DGH), 2010). This Pericratonic basin is dipping in the northwest direction and surrounded by mountains and ridges. The western flank covers by Aravalli and the Delhi-Sargodha ridge is present in the eastern part. Two uplifted fault blocks Birmania-Barmer and Nagar-Parkar arch, are situated in the northern part, while the Saurashtra peninsula is situated in the southern part (Goswami, 2014). Tectonically, the basin is classified into four tectonic blocks as Kishangarh sub-basin, Jaisalmer-Mari high, Shahgarh sub-basin, and Miajhar sub-basin (Sharma et al., 2016). The Jaisalmer-Mari high separates the Kishangarh sub-basin and Shahgarh sub-basin and covers the Jaisalmer sub-basin's central part.

The Jaisalmer sedimentary basin mainly consists of an alternating sequence of clastic and carbonate rocks. The Precambrian rock forms the basement of the basin, predominantly made up of igneous rock or metamorphic rocks (Khan and Khan, 2015). The igneous rock Malani and the metamorphic rock such as Phyllite and Schist constitute the basement where different sedimentary sequences overlie from early Proterozoic to Quaternary age. The Randha Formation is considered the oldest sedimentary deposit that rests conformably over the Precambrian Basement. Comprehensively the basin consists of thirteen formations ranging from the Randha formation to Shumar Formation (Report published in Shodhganga, 2019).

## Geological setup of the Pariwar Formation

The Pariwar Formation lies between Bhadasar and Habur Formation. The study of the nannofossils shows that the primary depositional environment of the Pariwar Formation is a marine setup connected with the open ocean environment of the Albian age (Rai et al., 2013) with calcareous nature. On the other hand, the plant fossils found in this formation implied the non-marine environment setting representing the formation's Neocomian age. The sandy calcareous shale beds present within the poorly sorted fine-grained sandstone show the calcareous fossil's rich diversity.

Fig. 1 shows the geographical map on an extension of the Pariwar formation in the study area. This formation was formed due to the high-energy coastal setting's deposition and the tidal current (Rai et al., 2013). It constitutes an alternate sediment sequence of both highly bioturbated and non-bioturbated indicated alternating slow and rapid sedimentation. The structural feature like bipolar cross-bedding found in the cross-bedded sandstone represents the consequences of the tidal current. This formation is considered a fluvial-deltaic deposition and is followed by the marine transgression throughout the basin (Khan and Khan, 2015) (Pandey et al., 2018). Lithologically, this formation is dominated by medium to fine-grained compacted sandstone, and the carbonaceous shale found as the interbedded coarse-grained lithology. The lignite structures are also found occasionally in this formation (Singh, 2006).

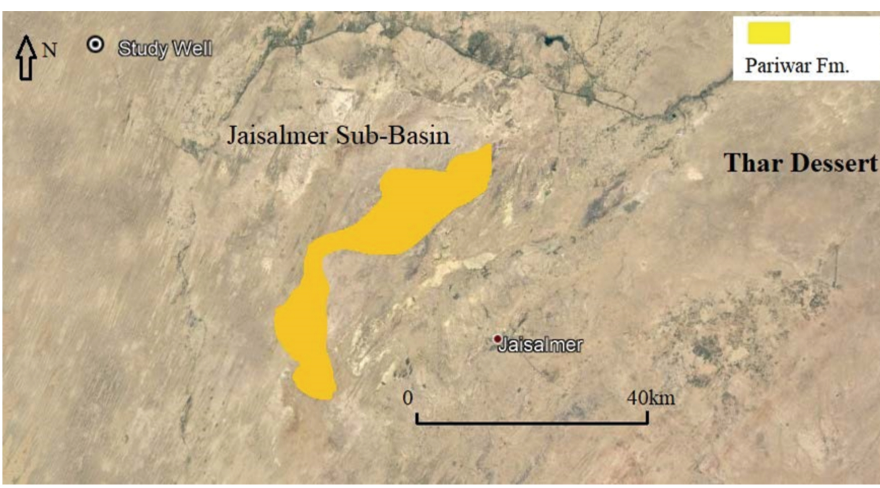



Fig. 1. Location map of the study area in the Jaisalmer sub-basin region; the map represents the sub-surface extension of the Pariwar Formation (formation for investigation) in the study area (Google Earth, 2019).

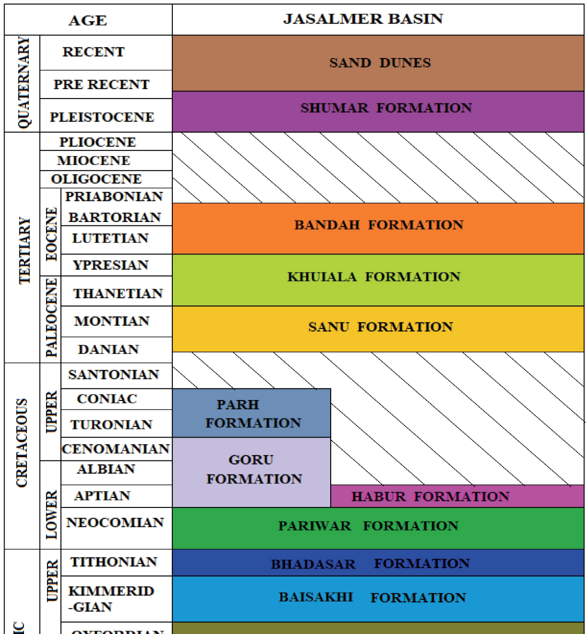
## Stratigraphy of the Jaisalmer subbasin

The sedimentation process in the Jaisalmer basin started in the Permian age with the deposition of shales and sandstones in the Karanpur Formation (Awasthi, 2002) (Fig. 2). The Triassic and early Jurassic phases constitute a significant regression followed by Sumarwali and Lathi Formations' deposition. The Sumarwali Formation consists of sandstones and claystone, while the Lathi Formation has clay, claystone, and shale. In the middle of the Jurassic, marine transgression took place along with a thick carbonate rock layer was observed in the region of the Jaisalmer Formation (Report published in Director General of Hydrocarbon (DGH), 2010). After the Jaisalmer Formation deposition in the marine environment, the other formations such as Baisakhi and Bhadasar were deposited in the upper Jurassic age. These formations primarily consist of shale and sandstones. A repeated regression phase is observed in the lower Cretaceous age of the Pariwar formation in shallow marine and brackish conditions (Report published in Director General of Hydrocarbon (DGH), 2010). The Pariwar Formation overlain by Habur Formation comprises mainly of alternate calcareous sandstone, limestone in the lower part, whereas in the upper part, there exists another layer of poorly bedded calcareous sandstone, sandy marls, and limestone (Khan and Khan, 2015). The marine deposited Goru Formation formed after the shallow marine Habur Formation. A significant uplift has taken place during the upper Cretaceous and lower Paleocene, which marks this marine deposition cycle.

The next cycle of sedimentation was started in the form of transgression during the early Paleocene to Middle Eocene and deposited the Sanu, Khuiala, and Bandah Formation. The Shumar Formation developed recently to Pleistocene age under the fluvial-lacustrine aeolian environment consists of sand dune, gravel with ferruginous nodules (Khan and Khan, 2015).

## Stratigraphic of the Pariwar Formation

A significant regression has been observed in the Pariwar Formation, including marine incursion (Khan and Khan, 2015). There are several theories about the deposition of the Pariwar Formation. According to Dasgupta (Dasgupta, 1975), the depositional environment's nature is continental to deltaic. On the other hand, as per Lukose (Lukose et al., 1977) theory, the inferred depositional environment varies from shallow marine with brackish water to the continental environment. The paleographic map supports the theories about depositional history, suggesting the basal part's dominance by fluvial environment preceded by the deltaic environment with mudflats (Pandey et al., 2018). A comprehensive study of a seismic section is required to get a detailed understanding of stratigraphic influence and its


AGE
JASALMER BASIN
QUATERNARY
RECENT
PRE RECENT
PLEISTOCENE
SAND DUNES
SHUMAR FORMATION
TERTIARY
PLIOCENE
MIOCENE
OLIGOCENE
EOCENE
PRIABONIAN
BARTORIAN
LUTETIAN
YPRESIAN
PALEOCENE
THANETIAN
MONTIAN
DANIAN
BANDAH FORMATION
KHUIALA FORMATION
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APTIAN
NEOCOMIAN
PARH FORMATION
GORU FORMATION
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PARIWAR FORMATION
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OXFORDIAN
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BAISAKHI FORMATION

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pattern in the formation. The analysis of the time-frequency component will support this study significantly. The spectral decomposition method provides a better understanding of the sub-surface geology by removing the shortcomings while dealing with the seismic section. The continuous wavelet transform (CWT) method is an appropriate method to adopt this study to capture the seismic signal frequency in a non-stationary state.

## METHODOLOGY

### Short Time Fourier Transform (STFT)

The STFT method provides the time-frequency spectrum by convolving a signal with a chosen time window function (Sinha et al., 2005). The method is primarily based on the pre-selection of an optimal window function and dependent on the user-specified window function, as a result of which the time-frequency resolution encountered a limitation in analyzing the seismic signals (Durak and Arikan, 2003). Mathematically, the short time Fourier transform (STFT) can be represented as

$$STFT(\tau, \omega) = \left[u(t) g(t-\tau) e^{iwt}\right] = \int_{-\infty}^{\infty} u(t)\, \bar{g}(t-\tau) e^{-iwt} dt \,. \quad (1)$$

Here, $\tau$ is the translational parameter and $\bar{g}\ (t-\tau)$is the complex conjugate of $(t-\tau)$ (Shokrollahi et al., 2013).

### Continuous Wavelet Transform (CWT) method

The methods of time-frequency analysis are used to get an effective result that helps interpret the seismic section. The CWT is the method involved in the evaluation of the frequency distribution of the seismic signal. This method's main advantage is that it does not require any predefined window width, which may impose constraints in the time-frequency resolution. The narrow width window results in good temporal resolution, but it deteriorates the frequency resolution. For a large window width, the result gives good frequency resolution while the temporal resolution becomes poor. To overcome such a situation, CWT is widely used with the aid of a mother wavelet, which primarily depends on the research work's objective.

The Continuous wavelet transform (CWT) of a function $(t)$ is mathematically given as (Zhou and Adeli, 2003)

$$W = \int_{-\infty}^{+\infty} f(t) \frac{1}{\sqrt{|a|}} \varphi^* \left(\frac{t-b}{a}\right) dt \quad . \quad (2)$$

The term $\frac{1}{\sqrt{|a|}}$ is used for normalization of the energy with the values of $a$ and b, where $a$ is defined as the scale parameter ($a$ > 0), b is the translational parameter and $\varphi^*$is the complex conjugate of the mother wavelet $\varphi(t)$ defined as

$$\varphi(t) = \frac{1}{\sqrt{|a|}}\varphi\left(\frac{t-b}{a}\right) \quad . \tag{3}$$

The scale parameter shows the signal's local frequency distribution and adjusted to get the optimal frequency resolution. The translational parameters help in wavelet function localization (Zhou and Adeli, 2003).

## Selection of Mother Wavelet

The selection of suitable wavelets plays a vital role in evaluating the spectral nature of the signal that must be calculated at different scales. The mother wavelet forms the base of the CWT method, which usually helps to yield improved frequency resolution and temporal resolution (Chopra and Marfurt, 2015). The selection of the best mother wavelet has always been of prime importance and purely based on the method's purpose and somehow dependent on the acquired seismic data.

### *Morlet wavelet*

Morlet wavelet is a sine wave tapered by a Gaussian window (Bruns, 2004; Cohen, 2014; Cole and Bradley, 2017; Jones, 2016). A complex Morlet wavelet is used to ensure the localization of the signal in the time-frequency analysis. This analysis is defined as the product of a complex sine wave and a Gaussian window function. Mathematically, the Morlet wavelet can be expressed as,

$$\boldsymbol{\varphi}(t) = \exp\,(i\omega_0 t) exp\left(\frac{-t^2}{2\sigma^2}\right) \quad . \tag{4}$$

Here $\omega_0$ is the frequency, t is the time and $\sigma$ is the length of the Gaussian window (Tangborn, 2010).

Morlet wavelet has the properties of velocity dispersion and energy attenuation to detect the hydrocarbon zone (Saadatinejad et al., 2012). The property of energy absorption is superior to the other wavelets, and it also proved to be an indicator for the exploration of the gas-bearing zone (Lin and Qu, 2000). One disadvantage of this wavelet is that it has a lower vertical resolution due to side lobes on the side and the centre of the wavelet (Bussow, 2007).

*Mexican Hat wavelet*

Mexican Hat wavelet is also called the Marr wavelet, one of the essential wavelets used in seismic interpretation. It is defined as the negative normalized second derivative of the Gaussian function. This wavelet can be represented mathematically (Zhou and Adeli, 2003) as,

$$\varphi(t) = \frac{2}{\sqrt{3}}\pi^{-1/4}(1 - t^2)e^{-t^2/2} \quad . \tag{5}$$

Here, $\varphi(t)$ represents the Mexican Hat wavelet where $t$ is the time in second. The Mexican Hat wavelet is superior to the Morlet wavelet in terms of resolution as it has minor side lobes (Shark and Yu, 2006). This wavelet has the advantage of analytically derivable Fourier transform, which helps in data correlation faster (Mi et al., 2005). Simultaneously, the frequency domain's limited extent helps to sample the frequency domain (Ryan, 1994; Hosken, 1988).

*Gaussian wavelet*

Gaussian wavelet or sometimes called the Gabor function is also a principal wavelet used for characterization purposes to reveal the target zone's unseen lithology (Navarro and Tabernero, 1991). A Gaussian wavelet can be represented mathematically (Haddad et al., 2004) as,

$$\varphi(t) = -2\sqrt[4]{2/\pi}\, t\, exp(-t^2) \quad . \tag{6}$$

Here, $\varphi(t)$ represents the Gaussian wavelet where $t$ is the time in seconds. The Gaussian wavelet has the property of reciprocity in both the frequency and time domain. It retains its functional form because the Fourier transform of a Gaussian function is also a Gaussian function that alternately provides better resolution to extract information of subsurface features.

## RGB colour blending technique

The main task in seismic data interpretation through RGB blending is to get an insight into the unseen features through better and contrast visualization. The RGB (Red Green Blue) colour blending highlights the features and reduces uncertainty in locating the stratigraphic features. The technique was based on the vector of 3D colour space cube and expressed as

$$I_{RGB}(L) = S[I_R(L), I_G(L), I_B(L)] \quad . \tag{7}$$

Here, $I_{RGB}(L)$ is the colour intensity in the red, green, blue 3D colour space, $L = (X, Y, Z)$ is the location within the 3D colour space cube, S is the RGB transformation function, $I_R$ is the colour intensity in the red axis, $I_G$ is the colour intensity in the green axis, $I_B$ is the colour intensity of the blue axis (Leaungvongpaisan and Wongpornchai, 2016).

The RGB blending method presents the process of frequency decomposition that helps in the evaluation of stratigraphic features. The red colour represents low frequency, green represents the middle frequency, while blue represents higher frequency components. These frequencies are blended to generate a better subsurface image. This method works through the frequency bands' interference and reveals very minute details of the target zone. The subtle information is identified by the colour and intensities of the RGB technique, which ultimately depends on the hidden features' rock properties and geometries. With some additional prior knowledge, this technique proves to be a powerful tool with richer visualization in seismic interpretation.

## Analysis of Horizon probe and Variance attribute

The RGB blending method is compared with the geo-body capturing method or the horizon probe technique used for this analysis. The technique was conducted in between two interpreted surfaces of Pariwar formation. The geo-body capturing process is controlled by another seismic attribute called Variance. The Variance cube is sensitive to seismic data's discontinuity feature towards capturing major geological features-based waveform similarity analysis of post-stack seismic data. The horizon probe technique is a valuable visualization tool for delineating the subtle features and useful to mark the fluvial channels (Saeid et al., 2018). Sometimes, this technique may not give satisfactory results, but combining with other visualization tools gives a relatively better and improved result and unravels the stratigraphic features. Similarly, Variance is a significant seismic attribute used to examine geological features like fluvial channels, reefs, and faults.

## RESULT and DISCUSSION

The computed structural contour map shows a smooth trend of the Pariwar Formation. Fig. 3 displays the structural contour map of the top part of this formation with study well location. However, a significant trace of the fault is present in the central part of the study area. Fig. 4 represents the structural contour map of the bottom part of the Pariwar Formation. The structural contour map shows the smooth extension of the surface. The time-frequency analysis is carried out to study the seismic section of the Pariwar Formation.

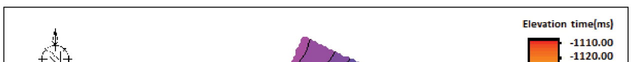


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Fig. 5 shows the Time-Frequency analysis obtained by using the Morlet, Gaussian, and Mexican Hat wavelet. Among the three wavelets, the Morlet wavelet gives a better result than Mexican Hat, and the result obtained by the Gaussian wavelet is not satisfactory.

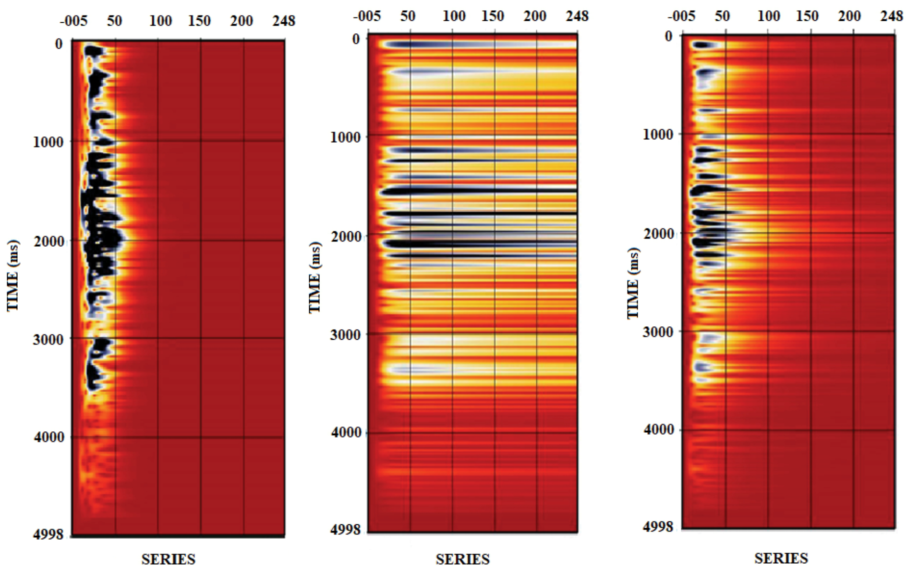
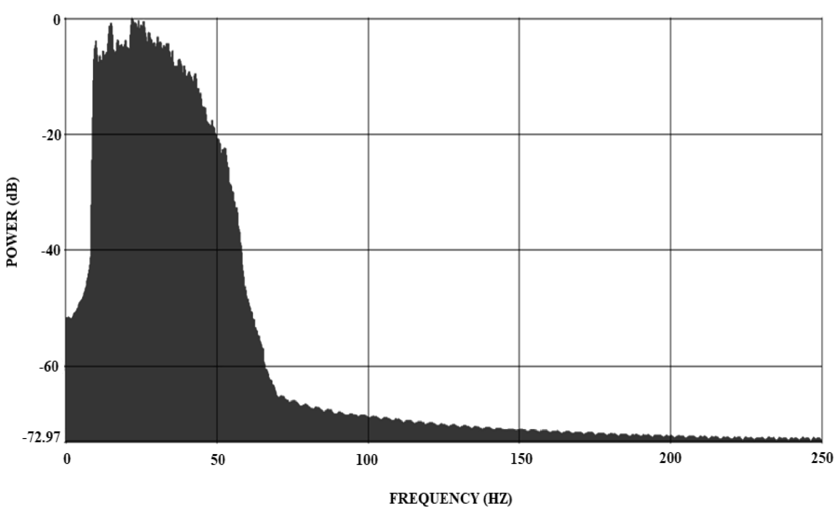



Fig. 5. A comparison study of the frequency responses for Morlet, Gaussian and Mexican Hat wavelets; analysis has been conducted based on time-frequency response.

Comprehensive knowledge of the frequency distribution of the zone of interest is required to conduct the further steps of spectral decomposition study. A power spectrum is a tool that gives the descriptive representation of the frequencies present in the seismic data. It may define as the magnitude squared of the Fourier transform of a signal function (Semmlow, 2011). Fig. 6 represents the power spectrum of the seismic data. The spectrum provides information about the dominant frequency in the data corresponding to the peak frequencies, which contained the most energy. The results of the power spectrum show the dominant frequencies of 10 Hz, 15 Hz, 22 Hz. These identified frequencies were used to investigate the seismic data to capture an accurate image of the sub-surface geology in the study area.

The CWT method was conducted on the post-stack seismic data along the dip direction at 10, 15, 22 Hz using Morlet, Mexican Hat, and Gaussian wavelet. Figs. 7 to 9 show the results of the CWT of Morlet, Mexican Hat, and Gaussian wavelet at 10, 15, 22 Hz. In Fig. 7, Mexican Hat and Gaussian wavelet give better resolution than Morlet wavelet at 10 Hz. In Fig. 8, the Gaussian wavelet provides a relatively better resolution than the Mexican Hat wavelet, which is better than the Morlet wavelet at 15 Hz. At a frequency of 22 Hz in Fig. 9, the Gaussian wavelet gives a better resolution than Mexican Hat, while the Morlet wavelet gives a low resolution. The results obtained from CWT (Continuous wavelet transform):

(i) At frequencies of 10 and 22 Hz, Mexican Hat and Gaussian wavelets performed better than Morlet wavelet.
(ii) At frequency 15 Hz, all three wavelets performed better than at 10 and 22 Hz. Gaussian, Mexican Hat, and Morlet wavelets performed better, respectively.




(iii)

Fig. 6. Power spectrum analysis of the seismic data along the dip direction (In-line) shows the estimated frequencies of the seismic data – (a) 10 Hz, (b)15 Hz and (c) 22 Hz.

RGB represents red, green, blue colour which gives better clarity as compared to other visualization tools. The dominant frequency 10 Hz defines the red colour, 15 Hz defines the green colour, while 22 Hz represents the blue colour. Fig. 10 shows the result of RGB blending of the Morlet wavelet in the dip and strike direction, whereas Fig. 11 represents the signature of the RGB blending along time slice 1600 ms. A similar analysis has been carried out for the other two wavelets, such as Mexican Hat and Gaussian. The analysis shows the variation of the result derived from RGB blending in the dip and strike direction with the time slice extension at 1600 ms. The time slice comes under the zone of investigation in the Pariwar Formation. Figs. 12 and 13 represent the result of Mexican Hat wavelet, whereas the Gaussian wavelet outcomes have been represented in Figs. 14 and 15. The channel features have been identified based on (Figs. 16, 17 and 18) analysis of RGB colour blending of Morlet, Mexican Hat, and Gaussian wavelet. The Gaussian wavelet gives the best result for the detection of the channel through RGB blending. The Mexican Hat can also detect the channel, but the resolution is comparatively low than the Gaussian wavelet. On the other hand, RGB colour blending with Morlet wavelet gives a low resolution.

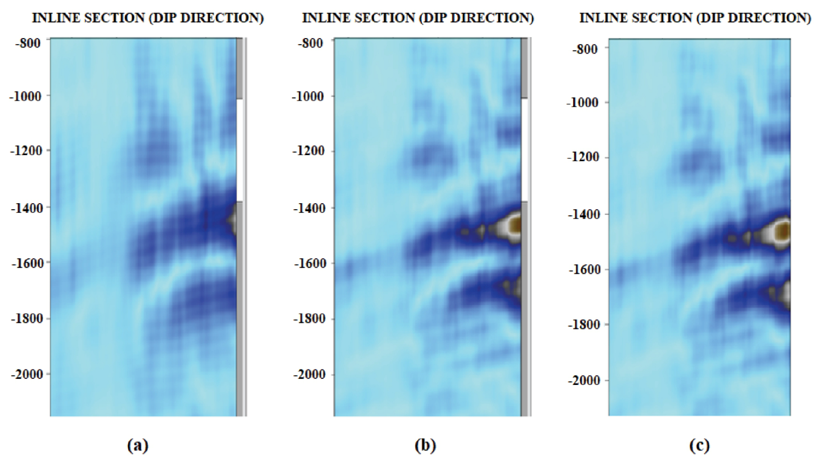



Fig. 7. Power spectrum analysis of the seismic data along the dip direction (In-line) at 10Hz frequency: (a) Morlet, (b) Mexican Hat and (c) Gaussian.

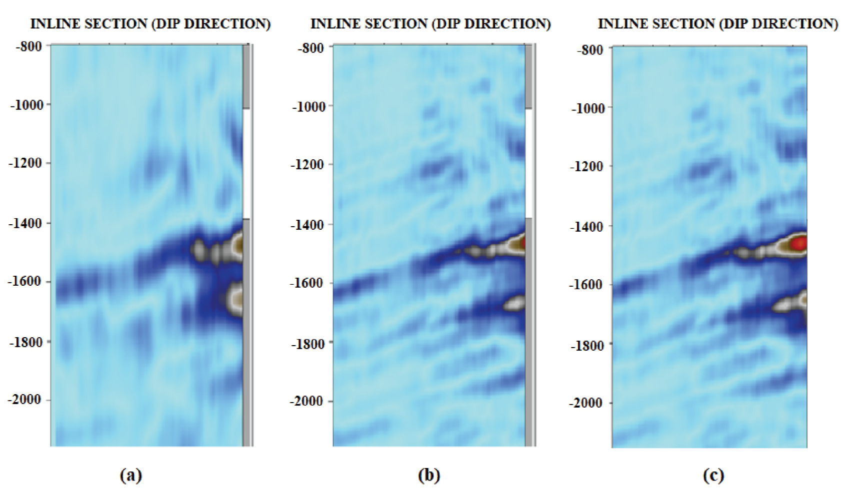



Fig. 8. Power spectrum analysis of the seismic data along the dip direction (In-line) at 15Hz frequency: (a) Morlet, (b) Mexican Hat and (c) Gaussian.

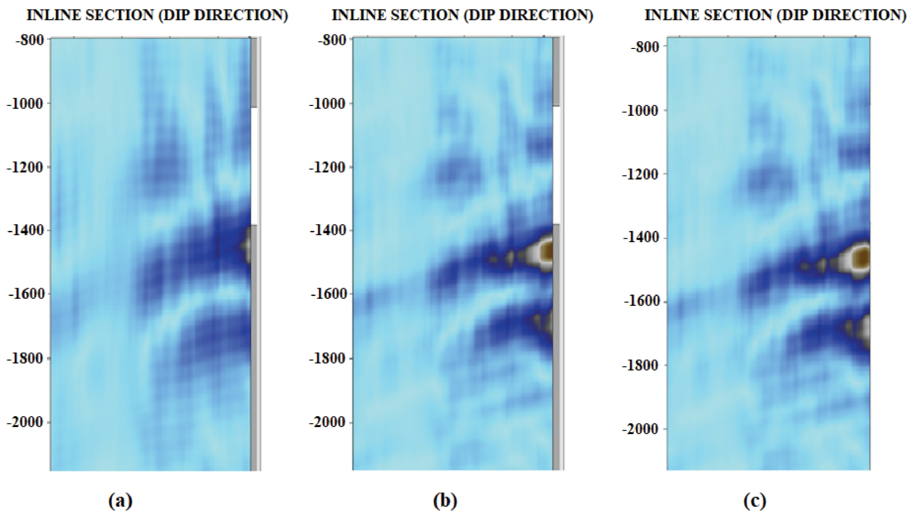



Fig. 9. Power spectrum analysis of the seismic data along the dip direction (In-line) at 22 Hz frequency: (a) Morlet, (b) Mexican Hat and (c) Gaussian.

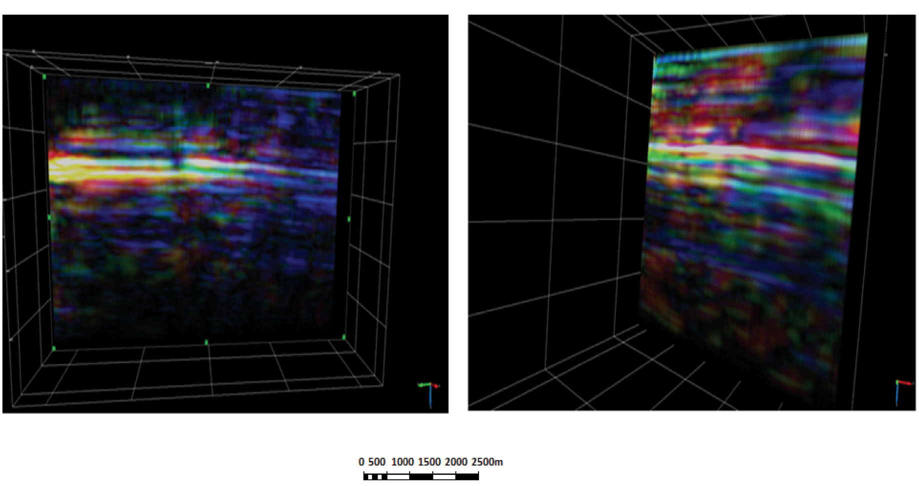



Fig. 10. Analysis of RGB blending to capture the geo-body interpretation of the reservoir in the Pariwar Formation; the study has been carried out based on the Morlet wavelet; the variation of the outcome has been captured along dip and strike direction.

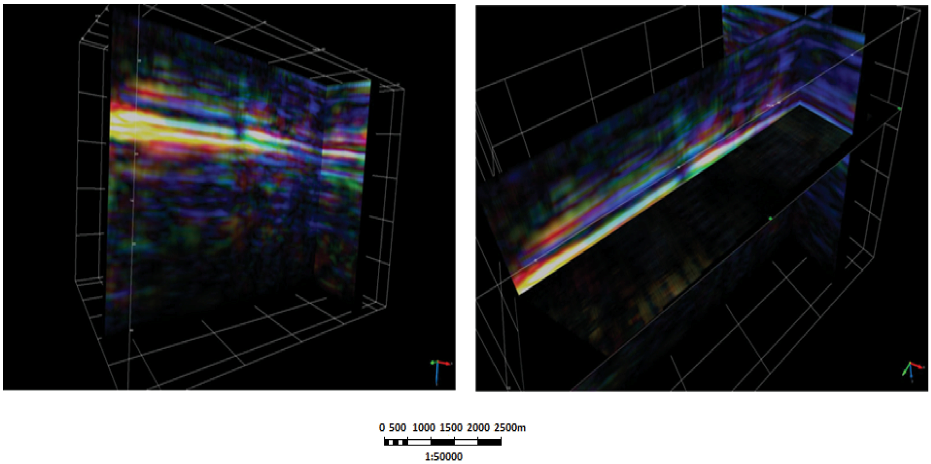



Fig. 11. Analysis of RGB blending to capture the geo-body interpretation of the reservoir in the Pariwar Formation; the study has been carried out based on the Morlet wavelet; the variation of the outcome has been captured along dip and strike direction with the extension of time slice at 1600 ms (zone of investigation).

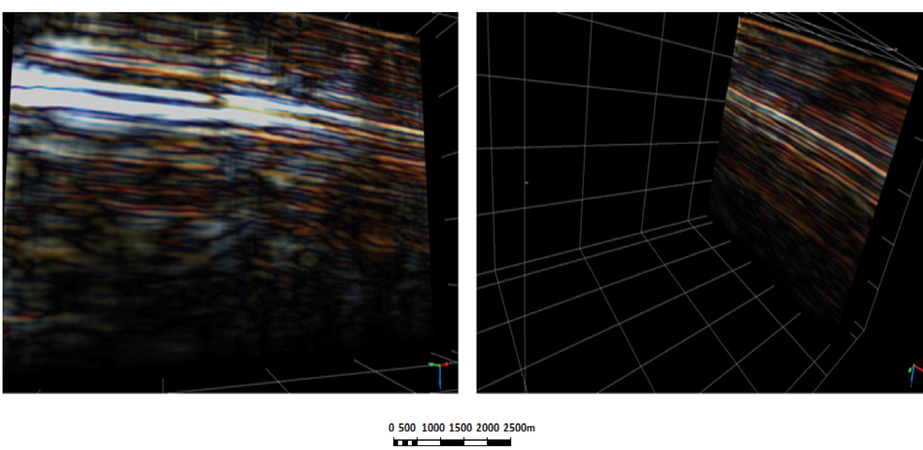



Fig. 12. Analysis of RGB blending to capture the geo-body interpretation of the reservoir in the Pariwar Formation; the study has been carried out based on the Mexican Hat wavelet; the variation of the outcome has been captured along dip and strike direction.

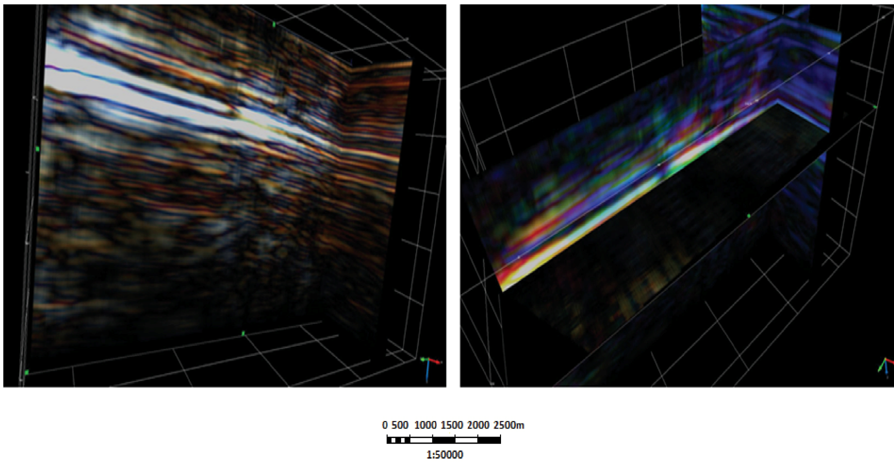



Fig. 13. Analysis of RGB blending to capture the geo-body interpretation of the reservoir in the Pariwar Formation; the study has been carried out based on the Mexican Hat wavelet; the variation of the outcome has been captured along dip and strike direction with the extension of time slice at 1600 ms (zone of investigation).

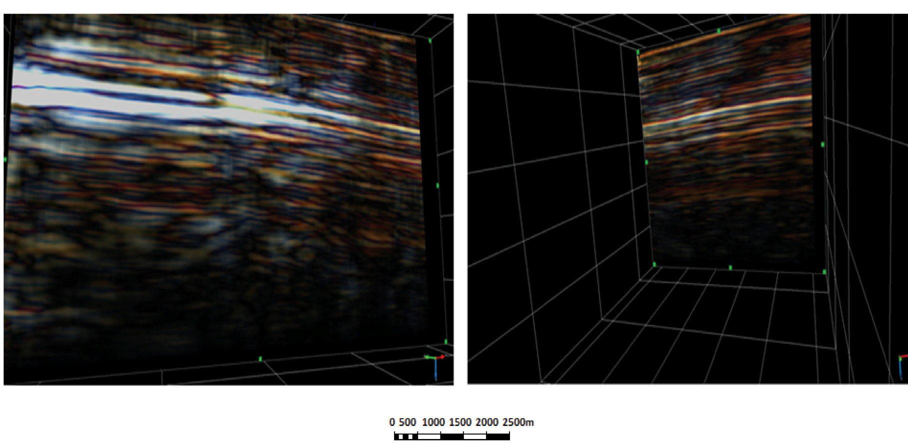



Fig. 14. Analysis of RGB blending to capture the geo-body interpretation of the reservoir in the Pariwar Formation; the study has been carried out based on the Gaussian wavelet; the variation of the outcome has been captured along dip and strike direction.

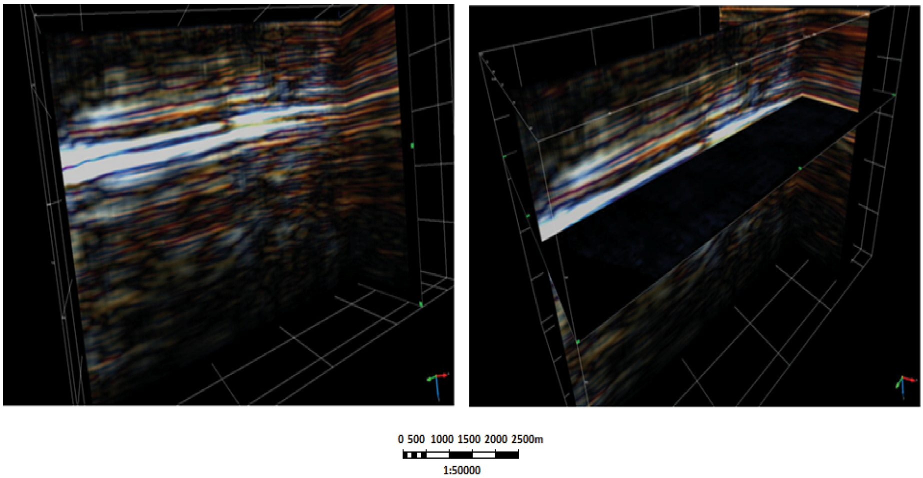



Fig. 15. Analysis of RGB blending to capture the geo-body interpretation of the reservoir in the Pariwar Formation; the study has been carried out based on the Gaussian wavelet; the variation of the outcome has been captured along dip and strike direction with the extension of time slice at 1600 ms (zone of investigation).

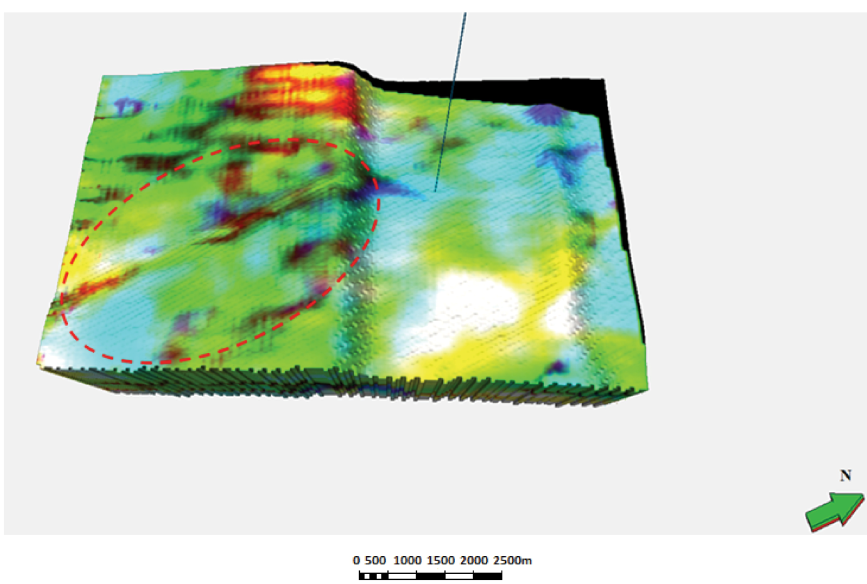



Fig. 16. Identification of channel feature in the reservoir formation (Pariwar) based on analysis of RGB colour; the analysis has been carried out based on the Morlet wavelet.

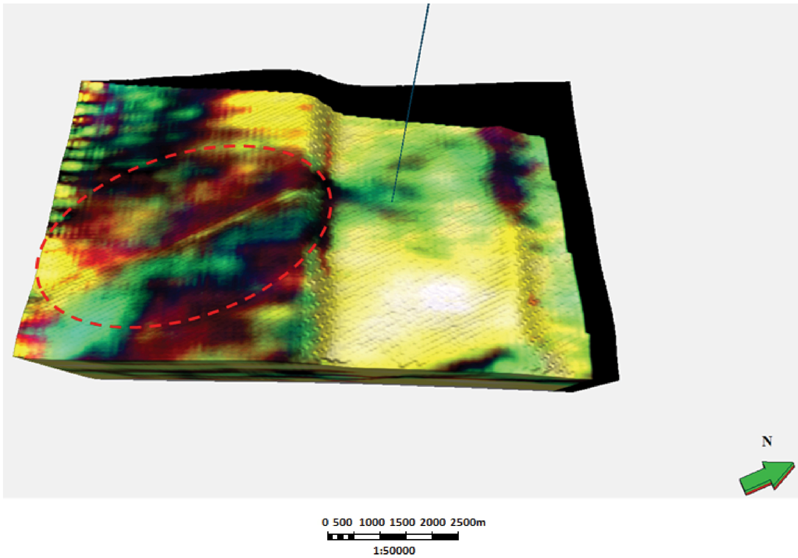



Fig. 17. Identification of channel feature in the reservoir formation (Pariwar) based on analysis of RGB colour; the analysis has been carried out based on the Mexican Hat wavelet.

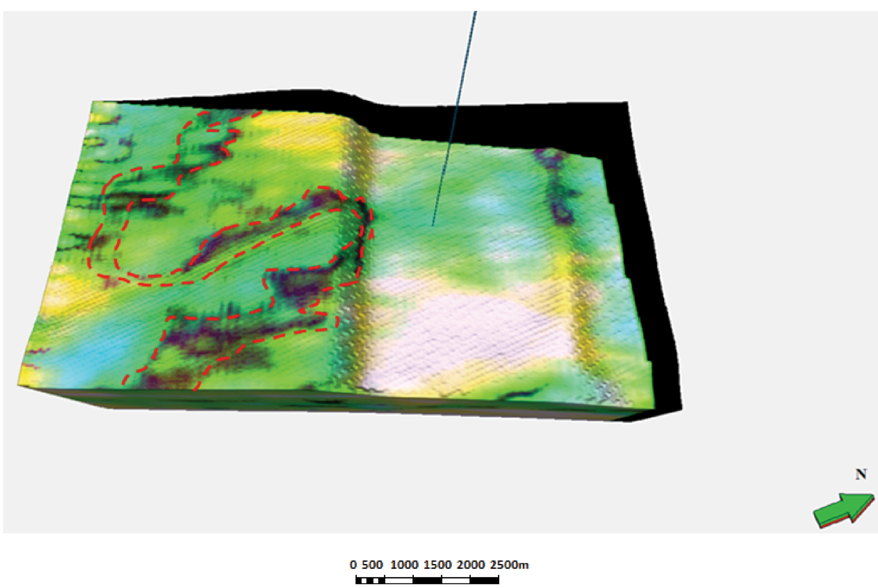



Fig. 18. Identification of channel feature in the reservoir formation (Pariwar) based on analysis of RGB colour; the analysis has been carried out based on the Gaussian wavelet.

Fig. 19 shows the image obtained by the horizon probe on post-stack seismic data and variance data. From this figure, the stratigraphic channel is identified clearly. The comparison study has been carried out between the results obtained from the RGB technique, horizon probe, and variance tool, and it confirms the presence of a stratigraphic channel in the Pariwar formation.

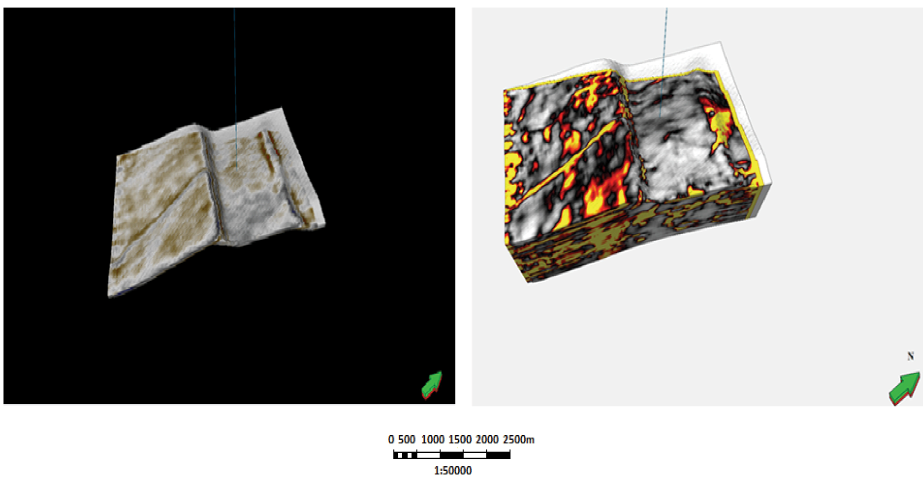



Fig. 19. Analysis of geo-body interpretation based on post-stack seismic data and seismic attribute volume; variance analysis was carried out for attribute analysis; the study has been carried out based on horizon probe analysis which shows a distinguished image of channel feature in the Pariwar Formation towards identification of reservoir body.

## CONCLUSION

The following conclusions have been drawn based on this study in the Jaisalmer sub-basin area:

i. The current study has shown the significance of the spectral decomposition method for delineating reservoir body in challenging reservoir setup.

ii. A detailed channel feature has been identified in the Jaisalmer sub-basin study area based on spectral decomposition analysis, where only post-stack seismic data was available.

iii. The lithology compositions frequently change in the Pariwar Formation of the study area, which had shown limitation for using conventional attributes as acoustic impedance of the reservoir rock varies. The limitations had been over by spectral decomposition study, and the detailed channel geometry was identified in the reservoir.

iv. This study has represented the importance of the proper wavelet selection to produce the best acceptable image of the sub-surface for spectral decomposition study when rock character changes. In the Pariwar Formation, the Gaussian wavelet produced the most robust and authenticate result at 15 Hz frequency compared to the other two wavelets, such as Morlet and Mexican Hat. The identification was carried out based on the CWT approach for the spectral decomposition method.

v. We adopted the RGB blending technique and analysis of variance attribute for geo-body capturing over spectrally decomposed volume. The analysis provided a critical control for detecting the channel body clearly in the reservoir.

vi. The selection of an optimal mother wavelet is highly significant for spectral decomposition study, and it depends on the target lithology, which may vary with the type of usage or requirement of the given seismic data.

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