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Application of Multi-Attributes and Spectral Decomposition with RGB blending for understanding the strati-structural features: A Case study

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Summary

Seismic attributes are one quantitative measure inherent in the amplitude, frequency and phase content of reflection data. Detection of structural and stratigraphic information based on seismic attributes and spectral decomposition is one of the fundamental workflows when it comes to interpreting subsurface features and seeking reservoir information from seismic data. Building a thorough understanding of fault network, channel geometry and sand distribution often requires working with multiple seismic attributes due to the fact that different attributes convey different information and that the seismic signature of different subsurface geological features changes through the data set. Multi-attribute analysis has the power to unlock the covariant information embedded in seismic attribute data. An effective way to visualize such information is to color blend the individual components in RGB (Red, Green, Blue) space.

This paper briefly describes a case study using combination of 3D post stack seismic attributes and spectral decomposition with RGB color blending for understanding the subsurface geological features like faults and channels.

Introduction

Among the various geophysical techniques available for characterizing the strati-structural features like faults and channels, 3D seismic attributes analysis and spectral decomposition have proven to be some of the most useful. One of the greatest strengths of 3D seismic is the dense, regular sampling of data over the region of interest, providing the images that accurately represent the areal extent of the features. When seismic amplitude changes associated with the features of interest are not noticeable on vertical sections, time or horizon slices often yield distinctive patterns that are easily recognizable. Seismic attributes are commonly used to highlight properties and structures within 3D seismic data that are often not readily visible and can be difficult to interpret directly from a seismic section. Variation of seismic response due to geologic changes is expressed only in a certain spectral ranges, buried within the broadband data. Spectral decomposition in this regards is an approach of decomposing the seismic signature into its spectral components within a time window of interpreted horizon of interest which can be utilized for understanding the minor subtle faults and channel features. Typically more

than one attribute is required to fully characterize geological features in an area of interest as different attributes convey different information of the variation of seismic signature. Attributes measurement that are made on 3D seismic data can convey a significant amount of additional information relating to geological features, such as faults and subtle structural trends within a data set. How successfully this information is conveyed that is highly dependent on the parameters of the visualization system, and by far the most significant parameter is the color mapping scheme used to display that attributes itself. One of the most successful techniques uses an RGB (Red, Green and Blue) color model to present data in a manner which is in tune with the way people perceive color. These types of blend are highly effective at visualizing data such as results of spectral decomposition attributes.

Although there are a few hundred seismic attributes that are in common use today, here we discuss the application of post stack attributes those are most effective displayed in gray scale tend like Variance cube and seismic shaded relief to be structural, and attributes that are most effective displayed in color tend like Average Absolute Amplitude (AAA), instantaneous phase, and Sweetness to be strati-

graphic attributes. We demonstrate using these attributes and spectral decomposition with RGB blending for subsurface imaging and understanding the faults and channels in the study area.

Study Area

The study area (Fig-1) situated towards eastern vicinity of Jambusar-Broach block of Cambay basin is steeply dipping towards west, and shallows towards east and north-east part. The area has witnessed many episodes of longitudinal as well as transverse faulting which have played the major role in the formulation of fault closers suitable for entrapment of hydrocarbon. The area is producing from multilayer reservoir. The zone of interest is defined within Ardol formation (Fig-2) which includes fluvial sand reservoir of middle to upper Eocene sequence.

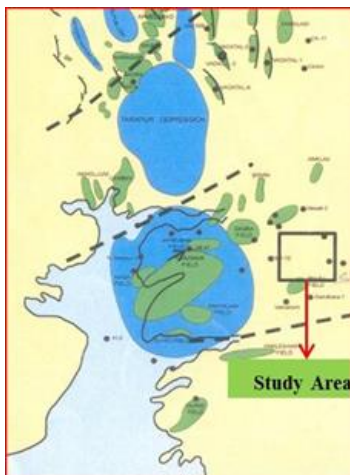


Fig-1: Location Map showing study area

Sequence	Formation	HARDH NOZA
Miocene to Recent	Post Dadhar	
Oligocene	Dadhar	
Middle	Telwa	
to	Ardol	
Upper Eocene	Kanwa	
Lower Eocene	Hazad	
	Cambay Shale	

Fig-2: Stratigraphic column of the area & Target zone of this study (Ardol Formation)

Methodology

The seismic data was calibrated with the help of log and synthetic trace (Fig-3) generated at well “A”.

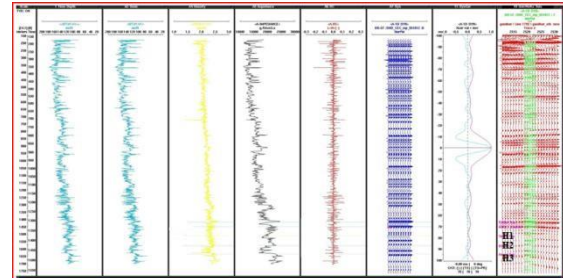


Fig-3: Well & Seismic calibration through synthetic.

As the 3D volume was in minimum phase data, zero crossing of the events was correlated with litho boundaries. Based on the calibration three seismic horizons (H1, H2 and H3) were correlated (Fig-4) throughout the area. H1 & H3 were to define the top and bottom of the target unit whereas H2 was for separating the upper & lower portion of the zone. All the three horizons were interpolated to get continuous horizon surface for extracting attributes.

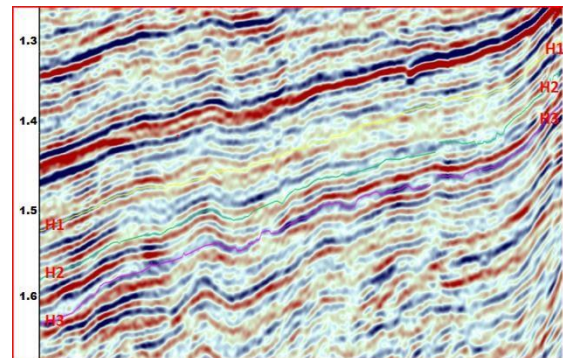


Fig-4: Interpreted Horizon in seismic section

To resolve subtle faults and channel sands extraction of multi-attributes, spectral decomposition with RGB color blending were carried out using the original 3D PSTM data after enhancing the signal / noise (S/N) through post-stack noise attenuation structure orient filtering along the structure. The workflow adopted for this study was customized in Fig-5.

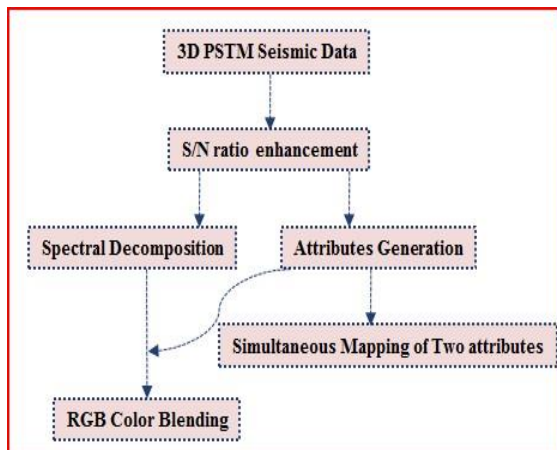


Fig-5: Workflow of Methodology

i. Noise Cancellation

The S/N ratio of the data was improved through application of structure orient filtering along the structure. Enhancing the image quality by removing of noise was important, in order to generate attributes of the highest possible resolution and which had the best chance of capturing subtle strati-structural details.

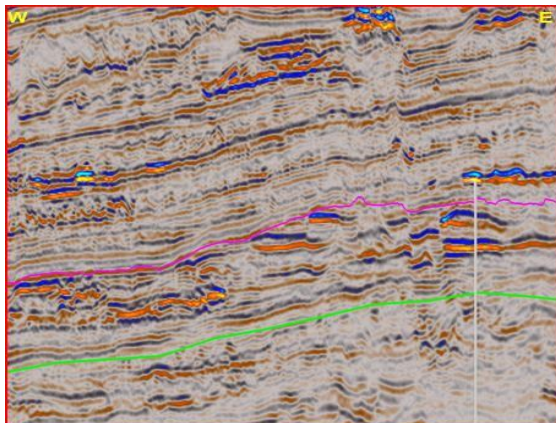


Fig -6: Original Seismic section

Removal of acquisition footprint from the seismic data after adapting filtering was shown in Fig 8.

ii. Seismic Attribute Extraction

Various seismic attributes within the zone of interest were generated from the conditioning seismic data. Note that on individual attribute the faults and channels are identifiable but the use of blending and simultaneous mapping of two individual attributes may help delineate in more detail the different episodes within the same strati-structural system with better defining the lateral discontinuities and channel geomorphology. In the present

study coherency cube, Average Absolute Amplitude and sweetness were extracted.

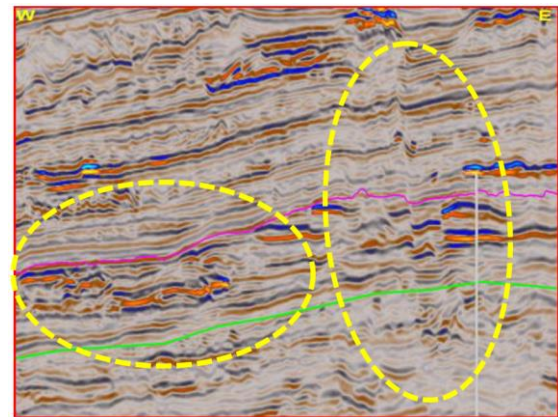


Fig-7: Noise cancelled seismic section through structure orient filtering along the structure

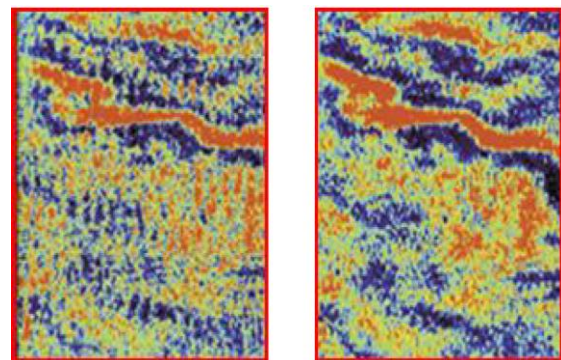


Fig-8: Before footprint removal & After footprint removal

Coherency cube: It may be measured by calculating seismic trace similarity in the inline and cross-line direction. A three trace operator is depicted. This is the minimum size required for a 3D calculation although more traces can be used. A combination of these 2-D measurements provides a measure of 3-D coherence.

Reflection Strength: It is employed to describe the waveform shape and gives the total energy at any given instant along a seismic trace of study area. High reflection strength is associated with major lithological changes between adjacent rock layers. The signatures of the geomorphologic features like channels are spotted by integrated amplitude.

Sweetness: It is defined as the reflection strength divided by the square root of instantaneous frequency, which can be very helpful for distinguish between sands and shale.

iii. Spectra Decomposition

To resolve subtle faults and to delineate channels a spectral decomposition is a tool for better imaging the geological discontinuities within 3D seismic data and it aids in seismic interpretation by analyzing the variation of amplitude spectra. At specific frequencies certain structures are more visible due to tuning effect. Spectral decomposition is process by which the seismic data is converted into discrete frequency volumes using mathematical algorithm like Discrete Fourier Transform (DFT). The output termed as tuning cube is analyzed thoroughly for finding out the frequency that represents the most significant geological features. In the present study 21,30 and 38Hz frequency were taken for generating the iso-frequency volume and horizon (H3) slices were generated for the above three frequency and slices were RGB blended.

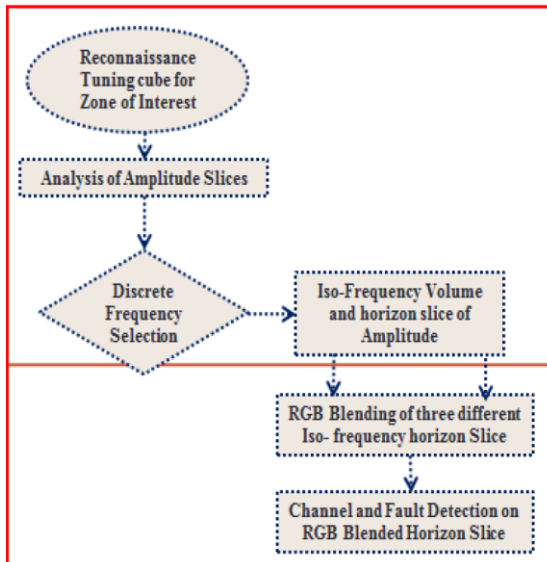


Fig-9: Spectral Decomposition Workflow

iv. RGB Color Blending

Color is a powerful visual cue that can be used effectively to encode information in most applications of scientific visualization. RGB blending is an effective use of color that has become a well-established visualization method for seismic attributes. It is well known that in a composite RGB display, each input attribute volume is mapped individually to the red, green and blue monochromatic components of the RGB space. The intensity of each primary color represents the intensity of the attribute in that channel. The information within the attributes is “mixed”

by the computer display and the interpreter’s eye to produce rich, detailed and highly intuitive visualization. The workflow of RGB blending is described in Fig-10.

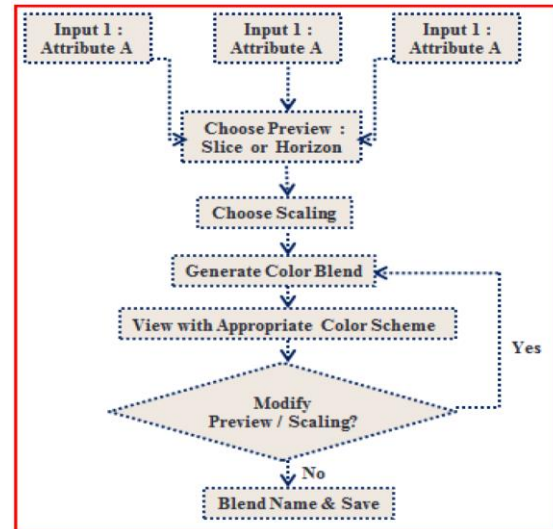


Fig-10: Flow of RGB blending

The Fig-11 shows the RGB color space used to blend the attributes. The three main axes define the monochromatic primary color scales. Each channel within an RGB blend can represent up to eight bits of information, which gives a composite RGB blend a total color depth of 24 bits or 16.7 million color. Theoretically, this provides scope for a significantly higher level of visual output than the

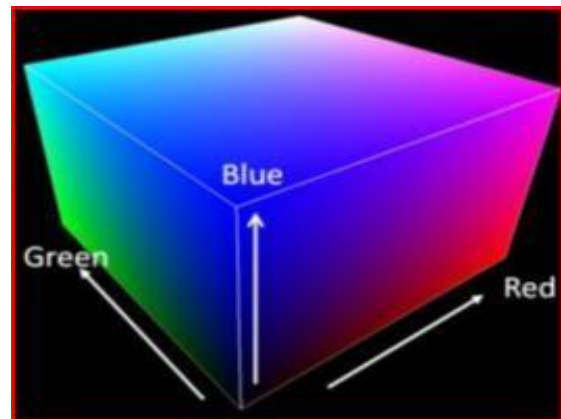


Fig-9: Primary color situated along three primary axes

monochromatic displays and hence can effectively encode more information. So when used to visualize multiple seismic attributes, significantly higher levels of detail can be seen. Zone having the maximum and minimum

intensity of the attributes reflects white or light grey and black or dark grey respectively.

Result and Discussion

Individual and Simultaneous mapping of various seismic attributes like coherency, reflection strength, Sweetness aids strati-structural interpretation by making faults and channels stand out.

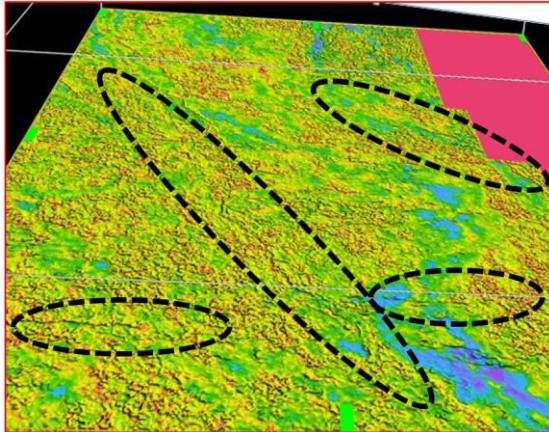


Fig-10: superimposed of reflection strength & coherency highlighting the discontinuities

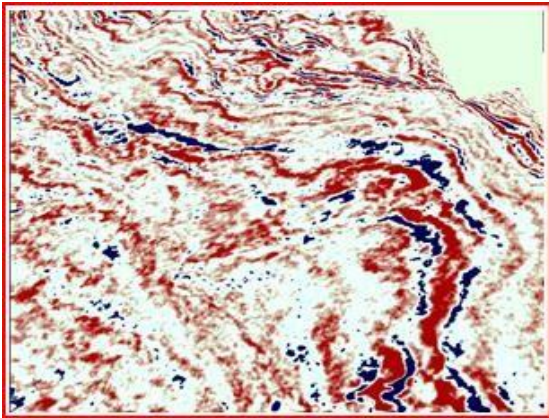


Fig-11: Time Slice

Horizon (H3) slices generated from coherency volume (Fig:-13) have brought out the major and minor extensional longitudinal and transverse fault system. On the other hand, the tuning cube from spectral decomposition calculated over the zone of interest more clearly shows northwest-southeast, north-south and northeast-southwest discontinuities on RGB blended magnitude response section of 21, 30 and 38 Hz (Fig-14).

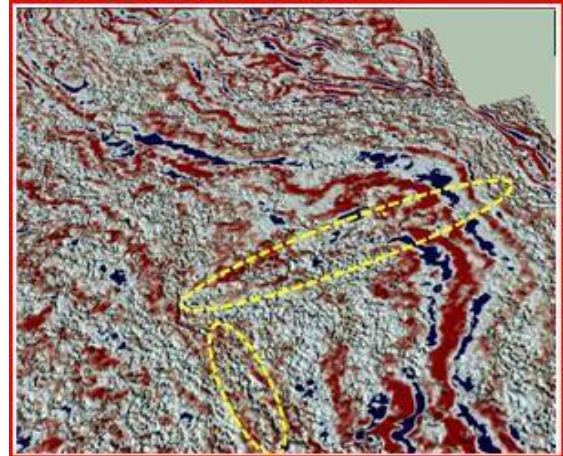


Fig-12: superimposed of Time & coherency slice highlighting the discontinuities more distinctly

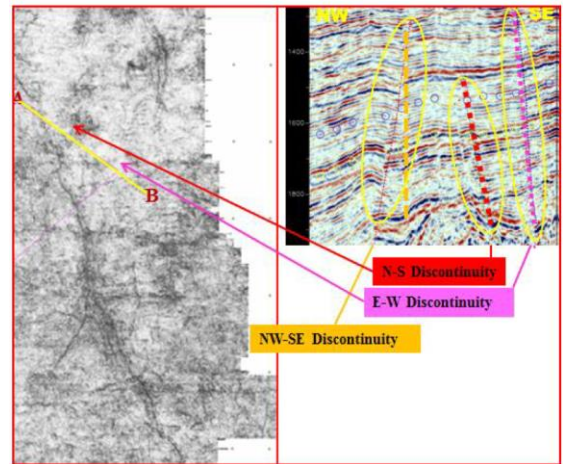


Fig-13: Coherency slice of H3 highlighting the faults layout

The northwest-southeast discontinuities and subtle faults observed on RGB blended horizon (H3) slice has even better imaged and can be more precisely mapped as compared to the discontinuities in the same direction observed on semblance. The north-south discontinuities match the regional north-south interpreted faults on conventional full-spectrum seismic data.

The northwest- southeast discontinuities most probably represent faults related with localized graben shifts/transfer zones, as they are associated with juxtaposition of opposite dipping north south faults and bends in the regional north-south faults. East-west cross fault and many subtle faults has imaged properly. Other possible geological features such as channels has imaged in the RGB blended amplitude spectrum section very accurately.

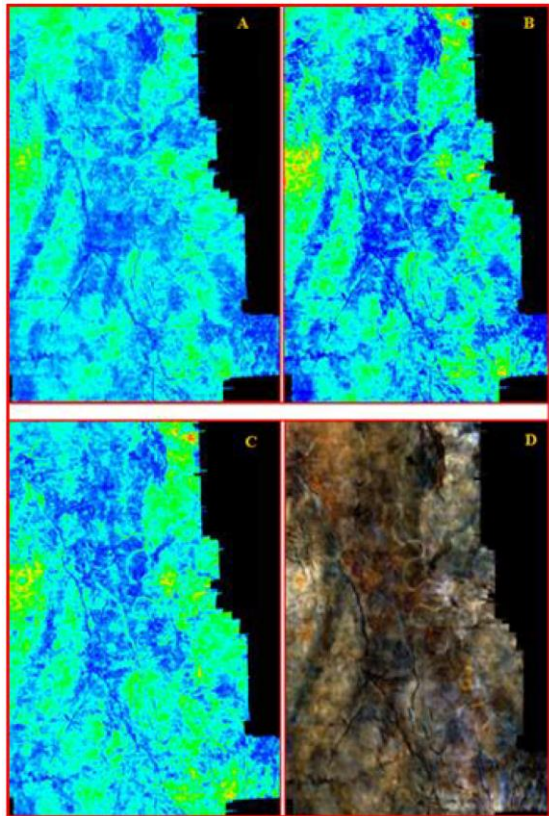


Fig-14: A) 21 Hz Frequency Slice (H3) B) 30 Hz Frequency Slice (H3) C) 38 Hz Frequency Slice (H3) D) RGB Blended of 21(Red), 30 (Green) & 38 (Blue) Hz slice

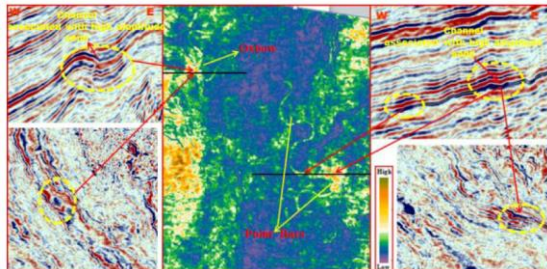


Fig-15: NW-SE meandering channel with high amplitude point bar & Oxbow geometry in Average Absolute Amplitude stratal slice 1, Seismic Section & Time Slice (Lower part of Ardol formation in Middle to upper sequence)

While studying 3D seismic data of the study area, distinct amplitude standouts were observed at various stratigraphic levels. The presence of such discrete amplitude anomalies in the seismic section of limited extent record indicated possibility of presence of channel features. In order to confirm the presence of these channel features, the sedimentary sequence between horizon H3 and H1 of Ardol formation in middle to

upper Eocene age was divided into four proportionate stratal slices. Various attributes pertaining to these stratal slices, such as average absolute amplitude (AAA), Reflection strength, and sweetness and Amplitude response from spectral decomposition were extracted to look for geometries indicating sand dispersal trends within this middle to upper Eocene sequences.

AAA and Sweetness attributes extracted over the stratal slices reflecting the amplitude anomalies throughout the area were scattered within the zone of interest along the faults and as well in the unfaulted zones. Within lower part of the Ardol formation two significant distinct channel features were observed in these two attributes extracted over the stratal slices 1. The major northwest-southeast (NW-SE) trend channel was highly meandering having high amplitude and sweetness point bar including oxbows geometry (Fig-15 & 16).

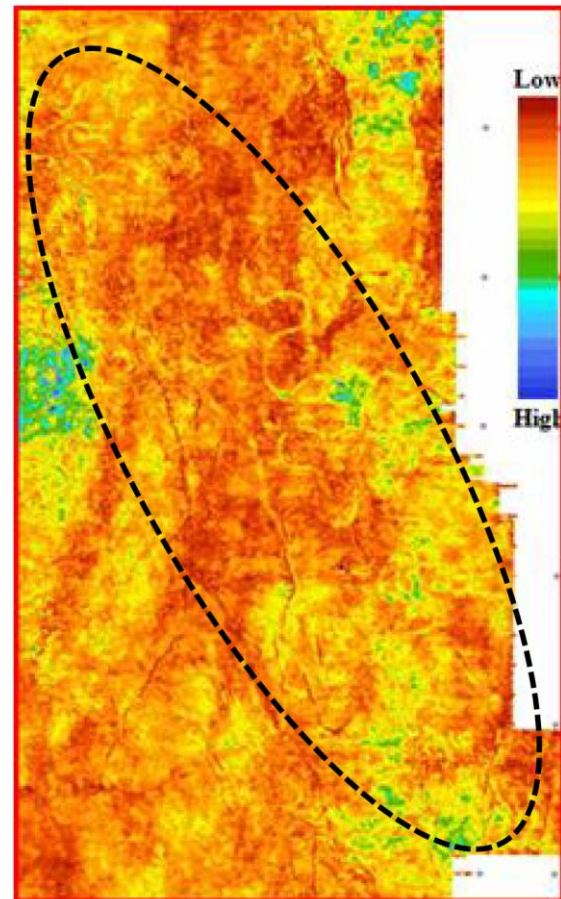


Fig-16: Sweetness attribute along strata slice 1

The spectral decomposition studies with RGB color blending also distinctly depict this channel configuration

along the proportionate stratal slice 1 (Fig-17). This meander belt defined a number of stratigraphic traps with point bar as the reservoir and clay filled channel as the up dip lateral seal.

In the south-eastern part of the study area where the sweetness and reflection strength are high in Fig-16 & 18 (indicating by yellow color in amplitude slice, green & yellow in sweetness slice) due to possible sand deposition by this channel. There is also a channel system possibly envisaged along north-south (N-S) trending in the study area. Based on these attributes it is possible reflecting that sand deposition is carried out from NW-SE and N-S.

Within the upper part of Ardol formation the AAA and Average absolute Amplitude (AAA) attributes map extracted along stratal slice 4 it was observed the presence of narrow meandering channel belt trending towards NNW-SSE and NE-SW direction (Fig-19).

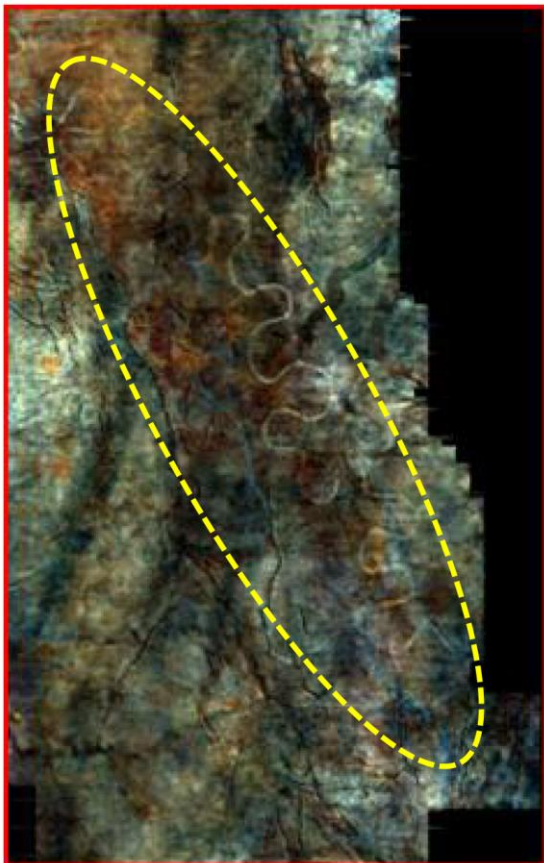


Fig-17: Horizon Slice along proportionate strata slice 1 from blended spectral decomposed volume

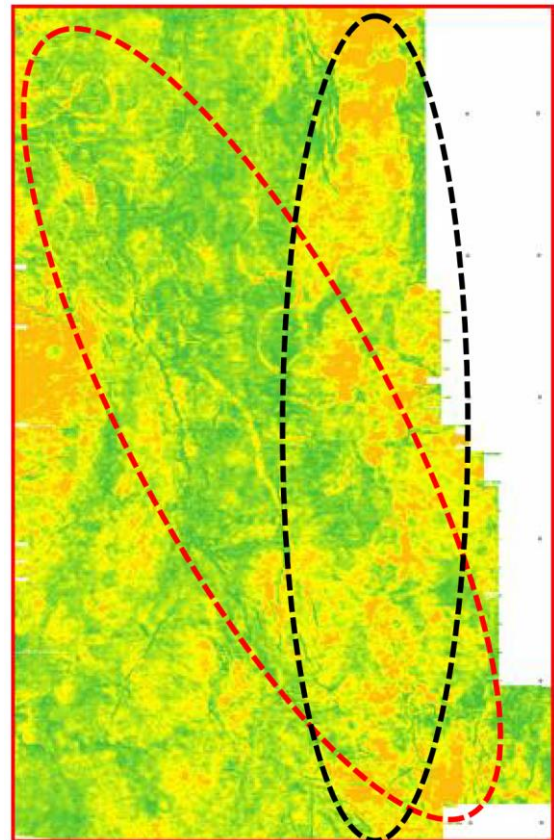


Fig-18: Average Absolute Amplitude Horizon Slice along proportionate strata slice 1

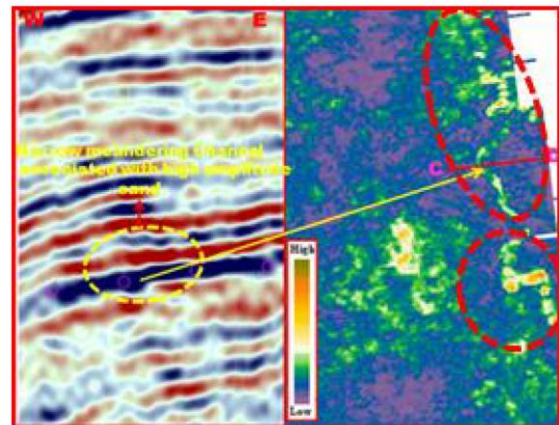


Fig-19: Avg. Abs. Amp (AAA) along proportionate slice 4 and vertical seismic section showing less meandering channel.

Conclusion

Simultaneous mapping of various seismic attributes and spectral decomposition with RGB color blending have helped in bringing out strati-structural features like faults



and channels. Above study also has demonstrated that these techniques can be used effectively to understand the sand distribution in the area.

The study has brought out the clear imaging of subtle faults especially related with graben shifts or transfer zones in the study area. Three sets of extensional fault system trending towards NW-SE, N-S and NE-SW including E-W cross fault have identified. It has also brought out the two distinct channels and sand distribution associated with fluvial systems in the zone of interest within middle to upper Eocene sequence. Among the detected channels in study area the major significant channel is highly sinuous meandering having high amplitude point bar and oxbows geometry trending towards NW-SE. Another channel within zone of interest trending towards NE-SW is less meandering. These two channel systems are contributing to two sand depositions in the southern part of the study area.

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