Seismic Facies Classification and RGB Blending as Tools For Prospect Generation: A Case Study

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Abstract

A case study of Bhuvanagiri area, Cauvery basin, India is presented where application of seismic facies classification using neuronal network algorithm supplemented by RGB blending of spectral decomposition components has proved to be useful tools for prospect identification. Seismic reflections has unique characteristics like amplitude, continuity, vertical separation, parallelism etc which arises due to various unique depositional environments and if meticulously classified into groups may help the interpreter in identifying the lithology and seismic sequences present in the data. Common Classification methods are unsupervised or supervised. Unsupervised facies classification methods are based on automatic classification of the unique reflection patterns into separate groups whereas supervised methods classify reflection patterns based on pilot traces extracted at well locations. Both methods use neuronal, hybrid or hierarchical algorithms to hard group the data. We find that unsupervised facies classification using multiple attributes and neuronal classification approach has provided better results than seismic trace shape classification using same methods. RGB blending of multi-attributes with some degree of commonality amongst themselves has been popular for quite some time now. We performed RGB blending of three spectral decomposition components centered around the tuning frequency of the prospect to better resolve the geobody. These results have aided in optimally placing two exploratory well locations which will be drilled shortly.

Introduction

The study area (L-1 Block) is located south of Pondicherry, Tamil-Nadu, South India in the Ariyalur-Pondicherry sub-basin and covers an area of 1100 SqKm. (Fig.1). The objective was to find suitable drilling location in a prominent channel and gravity slides (in Bhuvanagiri formation) characterizing the area.

The Cauvery basin had evolved as a result of rift-drift phenomenon of the then Indian plate from East Gondwanaland in Late Jurassic-Early Cretaceous period. Andimadam Formation (Fig. 2) deposited from Jurassic to Albian period is classified as Syn-rift sequence, followed by a marine transgression leading to widespread deposition of Sattapadi shales. The overlying Bhuvanagiri Formation belonging to Cenomanian-Turonian age was deposited as early post rift sediments. Sandstone belonging to Bhuvanagiri Formation, has been proved to be oil/gas bearing.

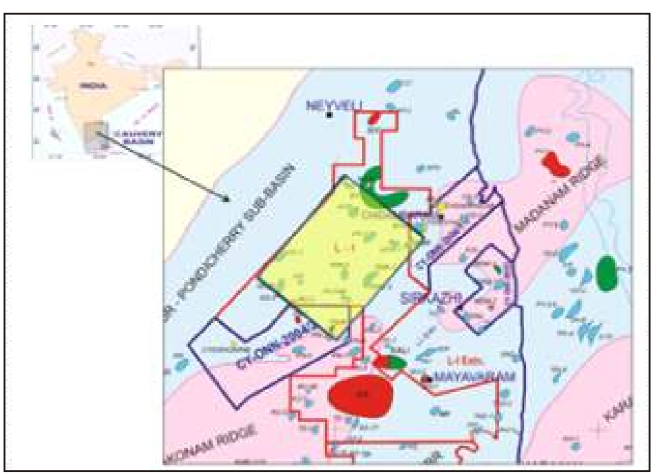


Fig. 1: Location map of the study area (yellow). Nearby oil and gas fields are shown in green and red respectively.

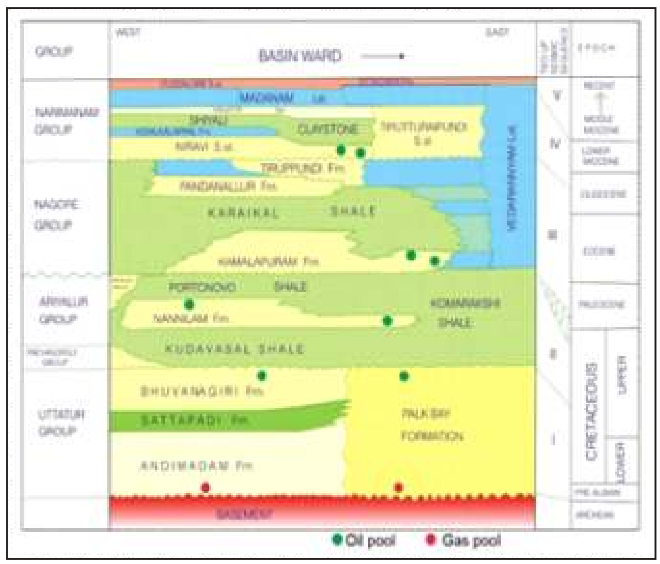


Fig. 2: Brief stratigraphy of the study area.

Bhuvanagiri Formation is characterized by multiple thick cycles of massive pebbly sandstone, and fine grained sandstone and siltstone alternations., deposited in deep marine to open marine environment with bottom current activities, predominantly deposited by debris flow movements. Canyon activity has started sometime during post-Santonian and continued during Palaeocene and Middle Eocene time resulting in deposition of coarser clastics along numerous channels in the form of debris flow deposits.

Methodology

Seismic facies classification

Seismic facies classification is based on the fact that various lithology deposited at different geological times have distinct seismic reflection patterns. Quantifiable properties of seismic reflections like amplitude, frequency, phase and continuity/coherency provides useful and distinct information that can be used to segregate various seismic reflection patterns, which in turn may be linked to lithofacies. The inputs can be the seismic itself or seismic attributes with geological significance. We then carried out facies analysis using industry standard commercially available software that classifies reflection patterns by analyzing trace shape similarity.

Implemented steps for seismic facies analysis

1. Generation & selection of seismic attributes.
2. Dimension reduction by Principal component analysis (PCA)
3. Facies class determination and classification using neuronal algorithm based on Kohonen SOM.
4. Seismic facies correlation with lithofacies.
5. Detail supervised facies classification at area of interest.

Migrated seismic volume (Fig. 3) along with the post-stack inverted impedance volume were the initial inputs chosen. Difficulty arises in choosing seismic attributes with meaningful geological information. Recent years have seen an exponential growth of attributes leading to a lot of confusion. Barnes.et.al.,2006, have shown that amplitude attributes like RMS, Reflection strength, Peak amplitude, Amplitude variance or average energy have either linear or quadratic relation amongst them. Thus, the cross-plot method reveals that most of them carry the same information and therefore using too many of them in facies analysis is duplicity of information with no significant gain. Similarly to measure reflection continuity, best one amongst coherency, discontinuity or semblance attribute should suffice. In a completely unexplored area the interpreter would simply rely on only the seismic data and would follow with a waveform analysis to generate the seismic facies map. However, we had some wells and lithologs at these wells which proved to be useful providing a measurable entity for qualitative QC of our facies map. Subsequently. multi-attributes such as Discontinuity, Curvature, Reflection strength, RMS frequency, Sweetness ,which gave the best match at known well locations were also chosen.

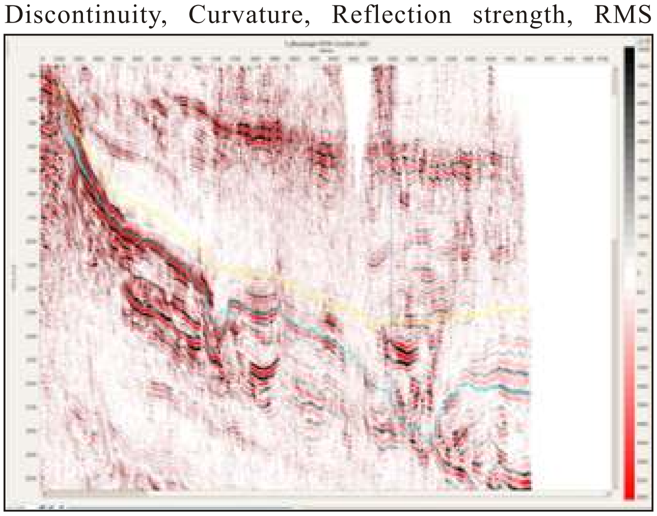


Fig. 3: Seismic section and the interpreted horizons. The zone of interest for grid based facies analysis is within the two horizons. Dot represents a probable drilling location.

The seismic data along with the multi-attributes selected for facies analysis presents a problem of over-dimensionality and redundancy. Some attributes may present the same information i.e. their variance may be negligible. It is desired that only the useful information of all the multi-attributes is retained and redundant parts are dropped, for making the facies classification process faster and meaningful. PCA (Fig. 4) plots all the attributes into n-dimensional space, where "n" represents the number of attributes, and then identifies axes of maximum variance in the original data. One can view it to be just a rotation of axes where the 1st axis (PC-1) lies in the direction of maximum data samples. PC-1 is called the direction of major variance while PC-2 orthogonal to PC-1 is called direction of lower variance. For our analysis we have taken Principle component with Eigen value >= 1, i.e. attribute variance >=100 %, thus retaining only the useful parts of multi-attributes. (Fig. 5).

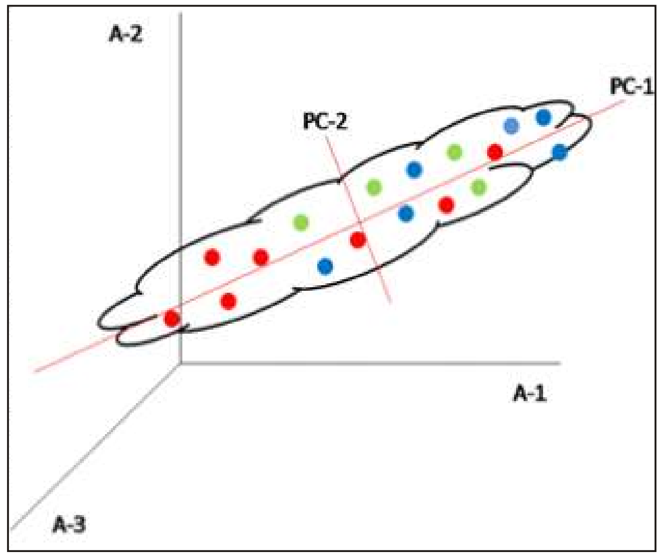


Fig. 4: PCA analysis on 3 attributes , 1st Attribute (A-1) = red, 2nd attribute (A-2) = green and 3rd attribute (A-3)=blue. PC-1 has the maximum variance of all the 3 attributes. PC-2 is orthogonal to PC-1.

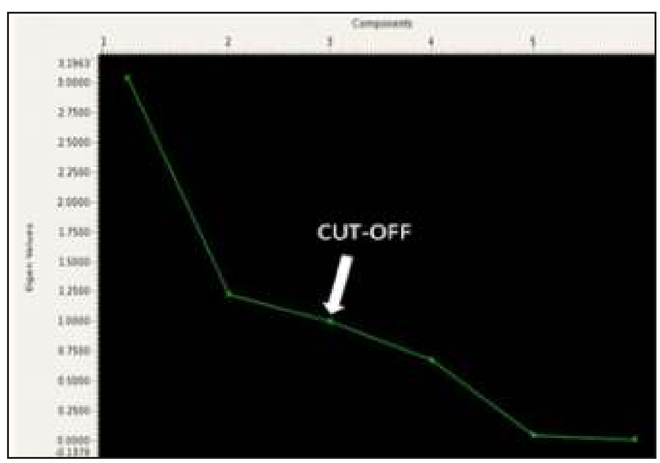
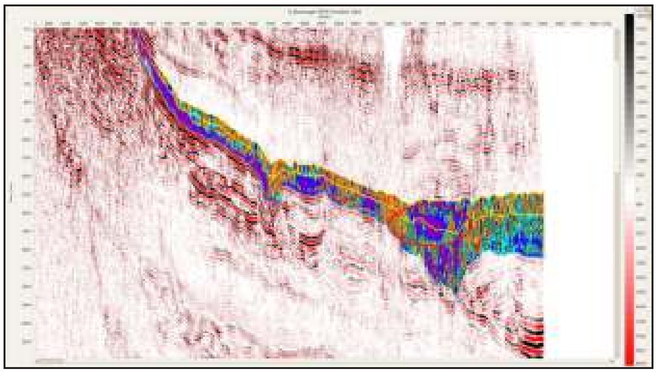


Fig. 5: Selection of PC's with Eigen value cut-off >=1. PCs with value lower than 1 doesn't contain significant information.

Subsequently, we performed unsupervised seismic facies classification using a neuronal algorithm employing the kohonen self-organizing map (SOM) technique. Initially, the interpreter has to test the number of facies classes (K). This is based on the geological understanding of the area. In our case the most appropriate value of K=7, corresponding to lithofacies in the wells was chosen. Then, the neuronal search probe scouts through the chosen attribute data samples and prepares representative traces (actually a combination of attribute values) for each "K" facies classes. After this training step, all data samples are grouped into classes based on attribute value similarity.Fig. 6-8, shows the results after seismic facies classification.



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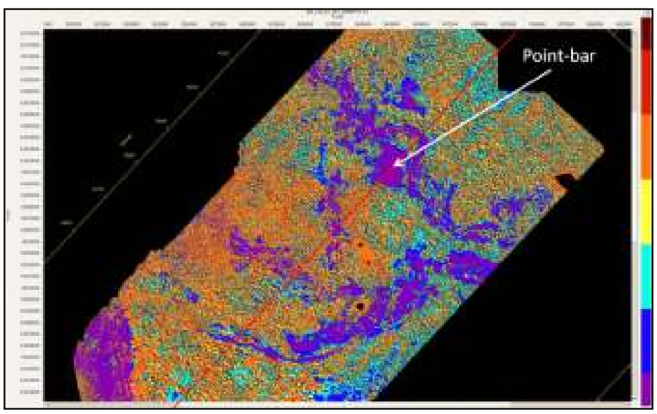
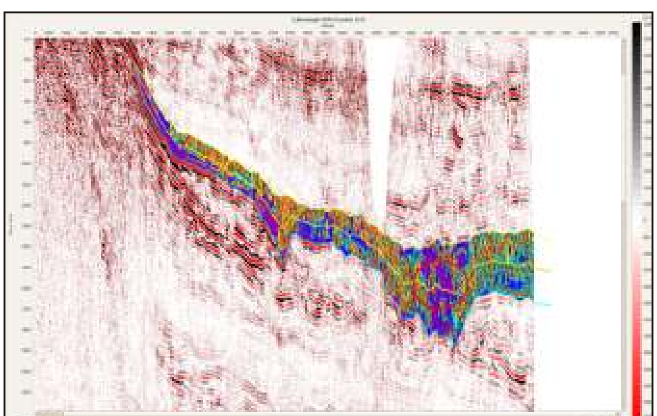


(b)

Fig. 6: Same section of fig 3 with (a) unsupervised grid based seismic facies overlaid on the seismic section (b) Proportional-slice through the facies volume close to the channel highlighting the point-bar geobody.



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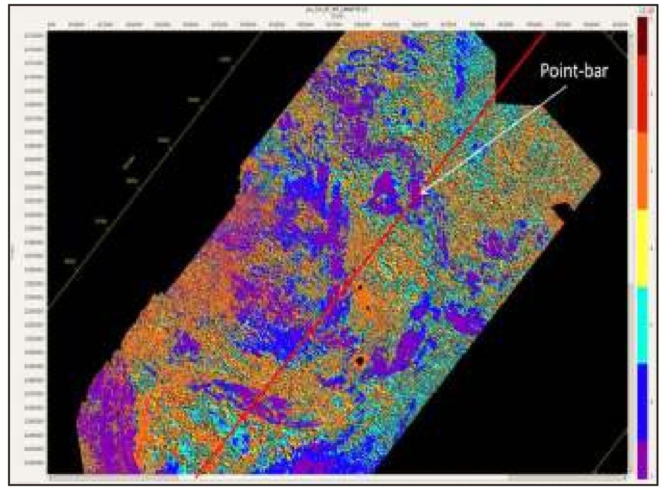

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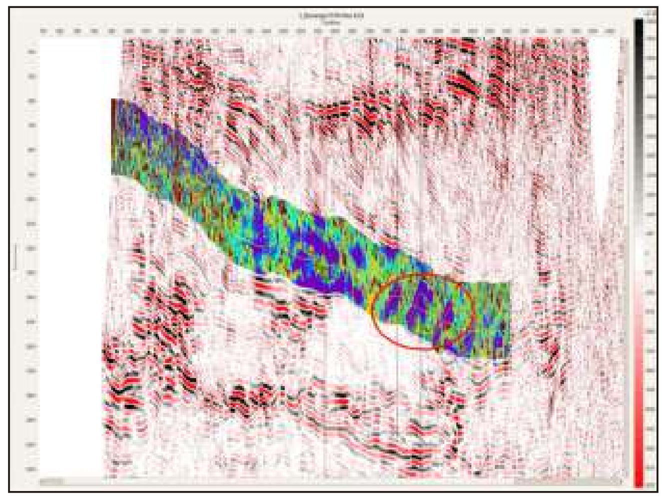
Fig. 7: Facies map at the point-bar geobody at a deeper level (a) shows the geobody in a seismic section (b) The point-bar feature in facies map.



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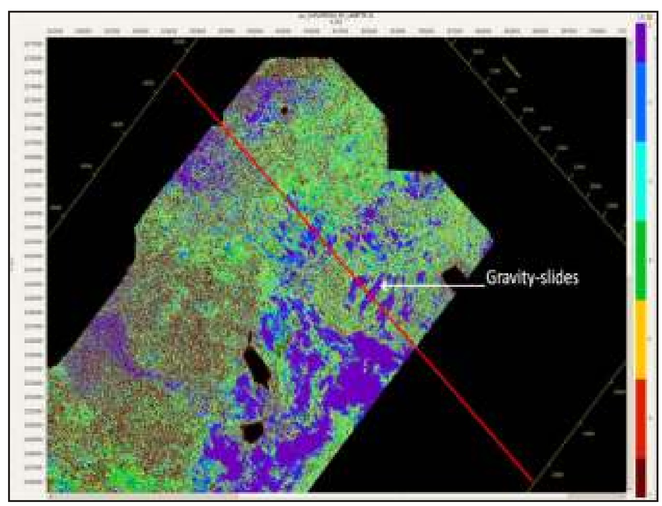
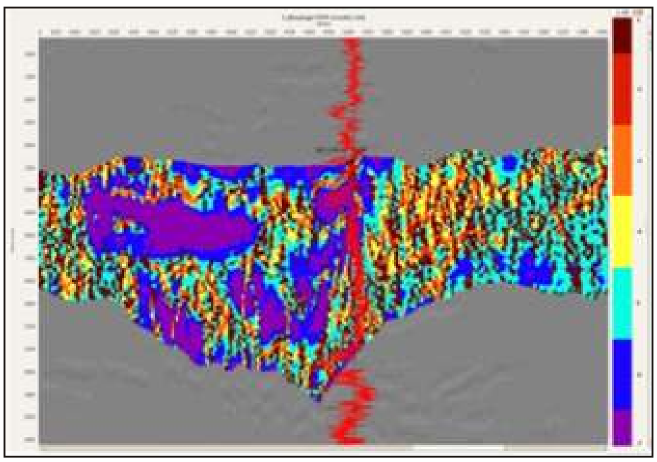


(b)

Fig. 8: (a) seismic section displaying the interpretation of gravity slides (b) Facies map over three gravity slides.

Next step is to associate the seismic facies classes with lithofacies at wells. This is done qualitatively by plotting log over the facies volume (Fig. 9) and establishing the relation.

Finally, a horizon based i.e. map based (windowed 100ms) unsupervised and supervised seismic facies classification centered at the channel feature was also carried out. The aim was to delineate facies specially found in two earlier drilled wells in the channel. Though both wells showed hydrocarbon presence , a reservoir scale accumulation was not found and well stimulation test showed little flow. So, an effort was made to discriminate at least the favorable facies found in these wells but with greater thickness to achieve commerciality. As, shown below the unsupervised windowed classification (Fig. 10) showed one facies class (blue), whereas the supervised classification (Fig. 11) showed three distinct facies Blue, pink and black. This shows the heterogeneity of the channel feature.



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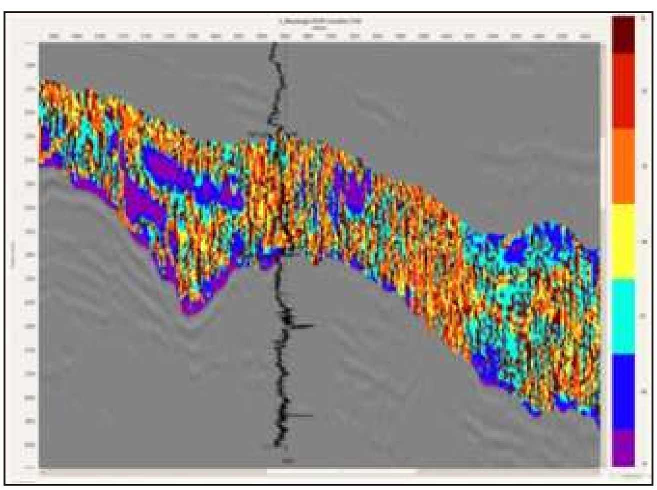
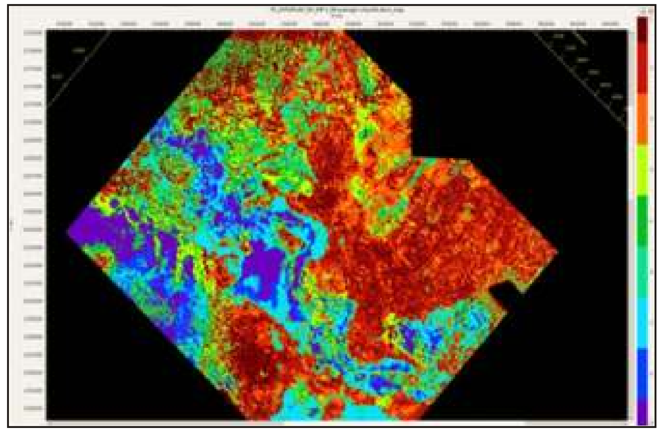


(b)

Fig. 9: Overlay of gamma log over the facies volume. Low gamma value in blue/purple colour indicates sandy facies compared to the nearby shaley facies. (a) low GR value in blue/purple zone and high values in red/yellow zone (b) high GR value at this well location where facies is mostly yellowish red.



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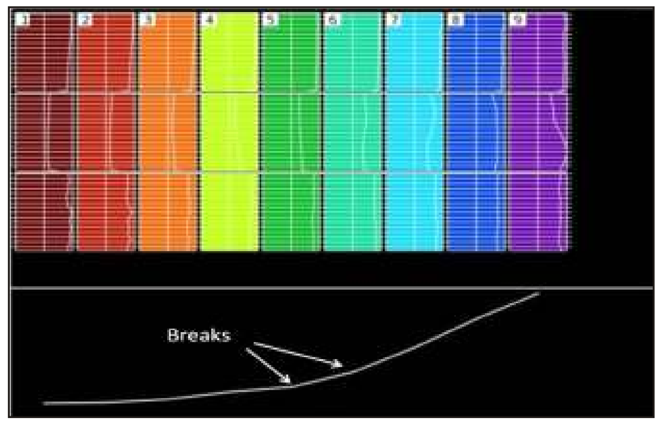
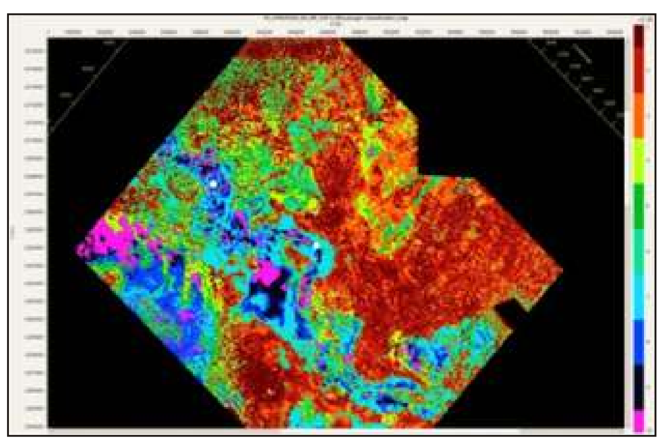


(b)

Fig. 10: Windowed unsupervised trace shape based facies classification over a 100ms window centered at the channel using P-impedance, Reflection strength and RMS frequency. (a) This facies map clearly demarcates the channel facies (blue and purple) and overbank facies (yellowish red) compared with the previous grid based facies map, highlighting the importance of proper input selection for facies analysis (b) the neuron viewer showing the correlation between the facies classes, evidently facies classes 1-4 are mostly alike, 5-6 form another group and 7-9 forms a third group as evident from the breaks in the correlation curve.



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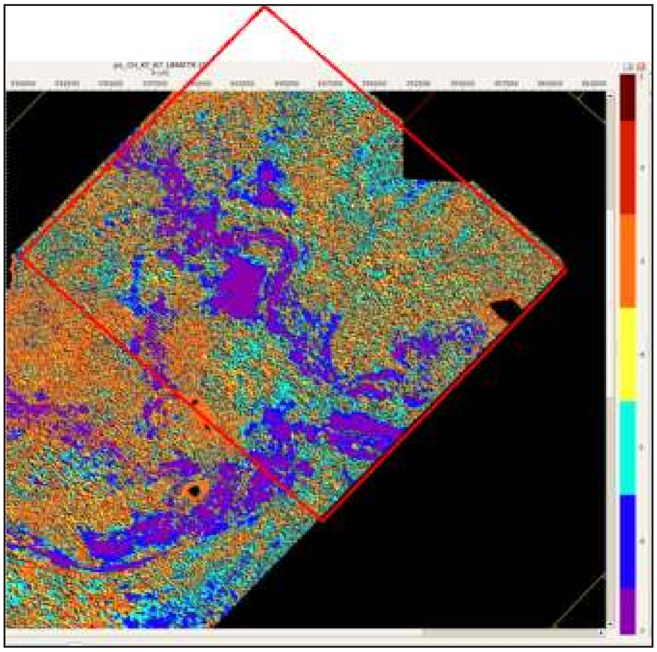


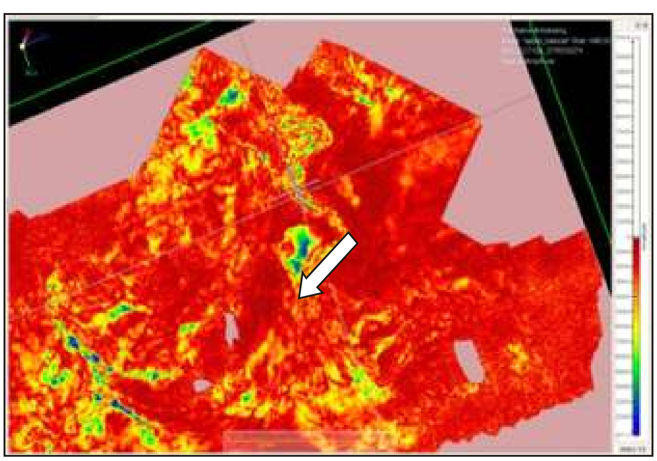
(b)

Fig. 11: (a) Supervised facies classification where pink facies is at well-X, while black facies is at well-Y. (b) comparison of previous unsupervised grid based facies analysis with the supervised facies map highlighting the detail information available from a target window analysis.

RGB blending

Blending of multi attributes for better visualization of geobody and its subsequent structural interpretation and extraction has been a popular practice. Common practice is to keep structural attributes at grayscale and stratigraphic attributes at colour scale while merging. Fig. 12 shows a firsthand quick look of a channel system in our study area.

RGB (Red, green, Blue) merging of iso-frequency volumes from spectral decomposition technique, which is breaking down the seismic signal into bandwidths where the geologic feature tunes in or out, was also used routinely in our seismic interpretation. Crucial to RGB merging is choosing proper spectrally decomposed frequency volumes which blends in such a manner that the geologic feature get enhanced.



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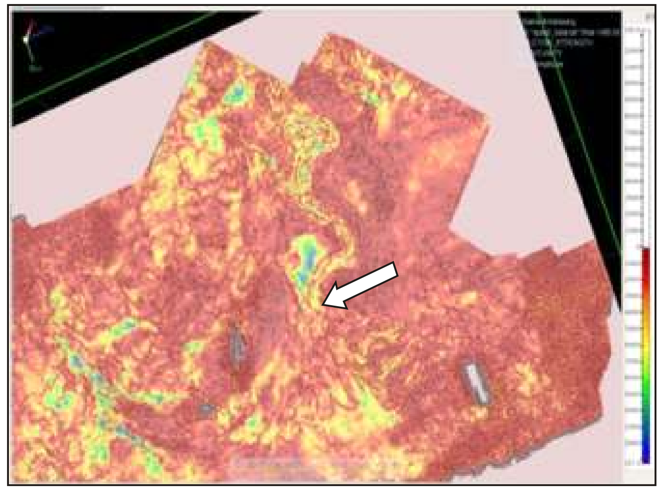


(b)

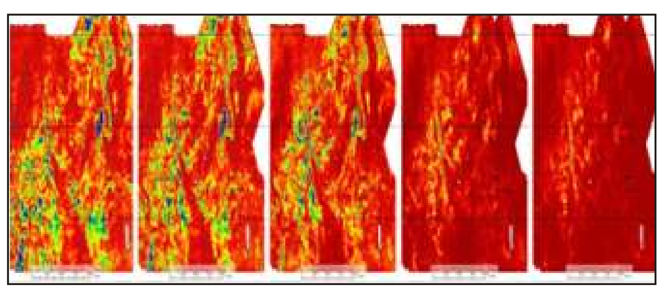
Fig. 12: Example showing multi-attribute blending for identifying structural features in the area (a) Time-slice of Reflection strength near the channel feature (b) Same time-slice with Discontinuity in grayscale and reflection strength in colour scale. Note the details of channel margins near the arrow. This analysis also provides a rough idea for animating through the spectral decomposition volumes generated for the next RGB blending exercise.

Implemented steps for RGB blending.

1. Spectral decomposition using a complex matching pursuit algorithm.
2. Animate the individual volumes to determine the approximate tuning frequency of the geobody.
3. Spectral balancing the individual volumes of interest.
4. RGB blending of frequency volumes equally spaced (+/-) centered at the tuning frequency.

The first step is to create frequency bands at an interval of 5Hz using an iterative complex trace matching pursuit algorithm which is a non-FFT algorithm. The algorithm generates Gabor-morlet wavelets with equally spaced central frequencies and convolves them with the seismic data. Iteratively, a seismic trace is decomposed to many band limited traces having spacing of 5Hz each.

Secondly, it is important to navigate through the tuning cube volume or spectral decomposed volumes (Fig. 13)to find out the tuning-in and tuning-out frequencies of the geobody.



(a) (b) (c) (d) (e)

Fig. 13: Navigating through the iso-frequencies volume (a) spectral decomposed volume at approx 10Hz (b) at 20Hz (c) at 30Hz (d) at 40Hz (e) at 50Hz. The channel body starts tuning-in at around 10Hz and tunes-out at 30Hz.

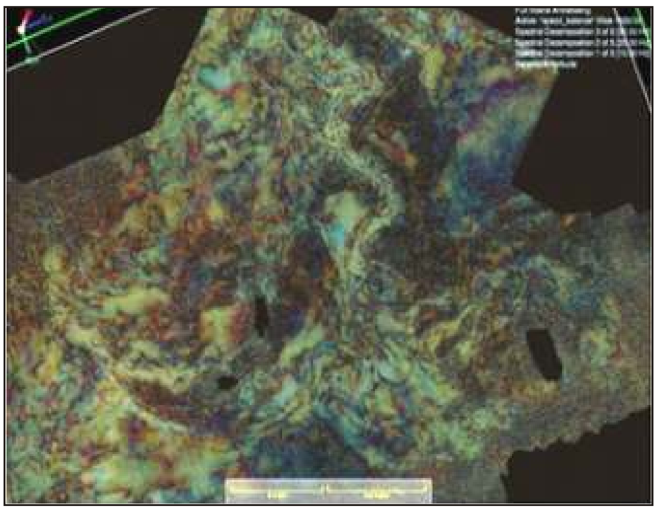
Blending of frequencies in this range gives best resolution though signal -to-noise ratio is a crucial factor at high frequencies.

In the third step spectral balancing of the iso-frequency components (Fig. 14) is done to bring the amplitude level of all the volumes to same level, so that higher amplitudes at dominant tuning frequency may not mask the amplitudes of other frequencies. This ensures that the same normalization and scale can be applied to all the three components of RGB during visualization .

The RGB volume (Fig. 15) rendering enabled us to identify the channel system and gave a qualitative indication of the thickness variation of the system. Parts of channel dominated by low frequency i.e. blue colour indicates zones of greater thickness whereas red indicates marginal zones of the channel system.

Conclusion

We have tried to highlight the combination of techniques



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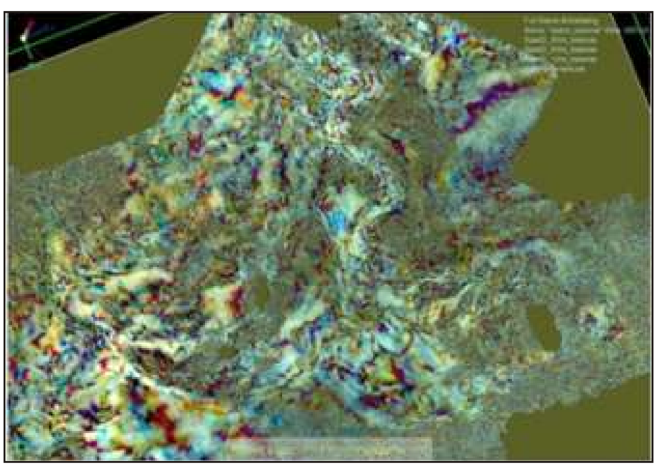
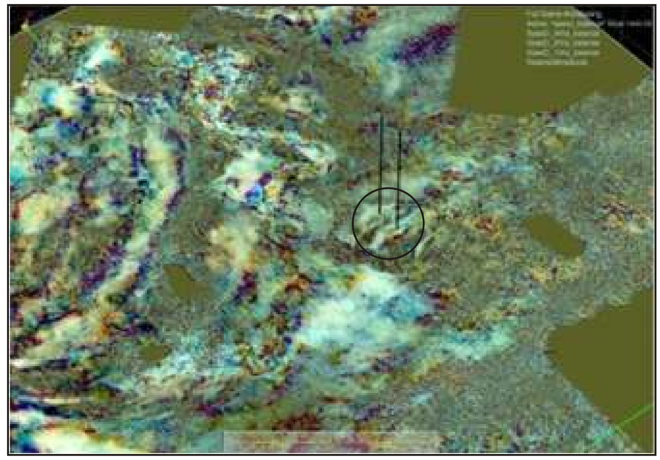


(b)

Fig. 14: Time-slice from RGB blended data, 30Hz (red), 20Hz (green), 10Hz (blue) (a) before spectral balancing and (b) After spectral balancing. Note the improvement in resolution of 10Hz(blue) and 30Hz(red) component in later case.



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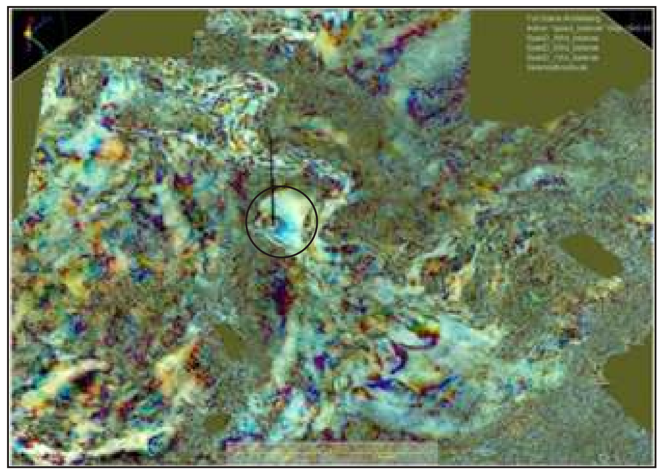

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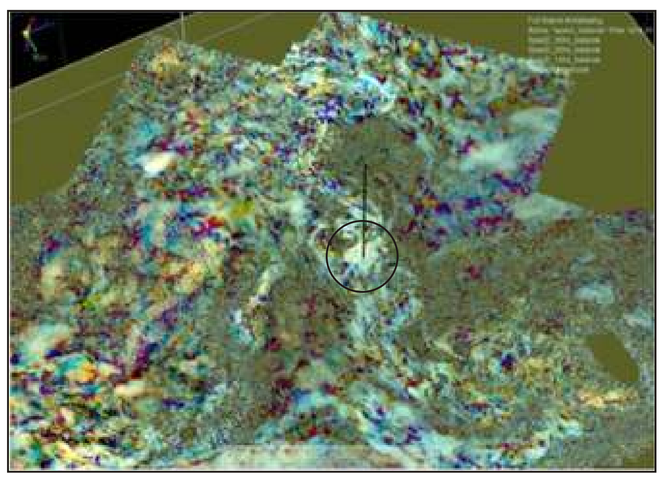

(c)

Fig. 15: RGB blended volume of spectral decomposition volumes of 30Hz (red), 20Hz (green), 30Hz (blue). Blue zones represent parts of channel with greater thickness and probable zones for exploration drilling. (a) shows the identification of gravity slides as probable exploration locations (b) location proposed on the thickest part of a probable levee (c) location proposed on a point-bar. Depth increases successively from (a) to (c).

like seismic facies analysis and RGB blending (Fig. 16) for identification of geo-bodies. Combination of these methods and other standard methods like cross-plots etc provides much valuable insight than single attribute analysis. However, these analysis are limited by the seismic scale resolution and hence may not provide reservoir scale information as evident in the grid based facies map. Though seismic facies corroborated with litho logs does provide a tentative distribution of lithofacies. We benefitted from the better visualization and perspective that these methods provide combined together. The facies maps showed the extent of favorable reservoir facies and the RGB blending combined with structural interpretation enabled us to identify zones of good thickness for reservoir scale accumulation.

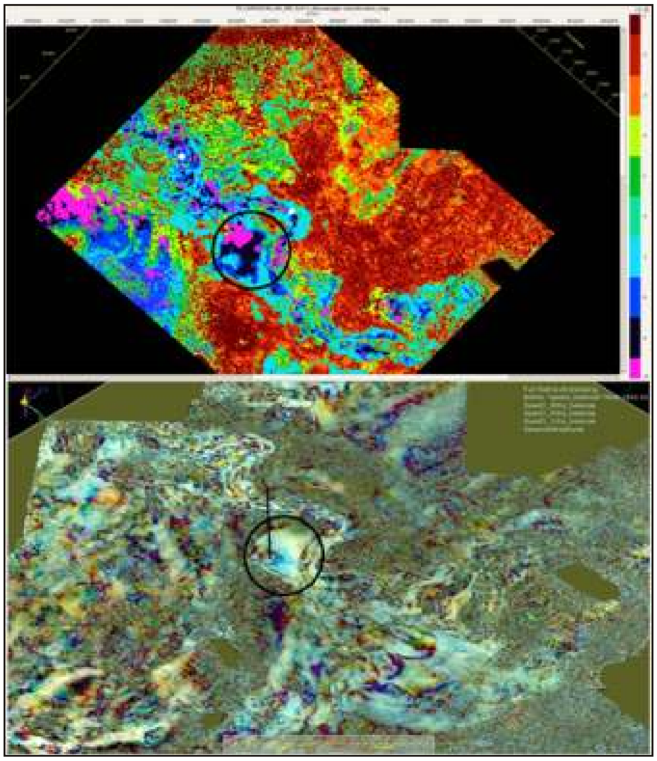

Fig. 16: Shows both slices from seismic facies analysis (SFA) and RGB blending indicating the same feature.

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References

Barnes, A., 2006, "Redundant and useless seismic attributes": SEG Annual meeting, New orleans.

Barnes, A., 2000, "Attributes for automating seismic facies analysis",SEG Expanded abstracts.

Brown, A.R., 2011, "Interpretation of three dimensional seismic data, seventh ed.:SEG.

Farzadi, P.,2006,"Seismic facies analysis based on 3D multi-attribute volume classification, Dariyan formation, SE Persian gulf", Journal of petroleum Geology, 159-174.

Jonathan, H., Purves, S.J., 2008, "Delineation of geological elements from RGB color blending of seismic attribute volumes" : The Leading Edge, 342-350, SEG.

Kohonen, T., 1995, "Self-organizing maps", 2ndedition: Springer Verlag, p362.

Poupon, M., Ingram, J.E., 1999, "Integrating seismic facies and petro-acoustic modelling", World oil magazine.

Stratimagic, M/s PARADIGM training manual.