Seismic image analysis to map fractures network associated with structural heterogeneity for hydrocarbon prospect in basement exploration

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Abstract

Exploration of fractured reservoir in basement exploration is a challenging task. However, 3D seismic data and modern seismic attribute extraction and algorithm provide a new dimension to the exploration efforts. Selection of right algorithm to extract the best geological information out of available seismic data is the key to success. No single algorithm suits to all geological setting and seismic dataset, therefore finding the correct algorithm will come only after examination of multiple seismic attributes and their comparison for intended results. It is expected that seismic response from subtle faults will be in form of seismic heterogeneity and attenuation. Therefore an integrated interpretation of seismic data involving these two element will brought out the structural style and fault architecture at trap level to the extent that possible fracture prone areas can be identified. This will facilitates to decide suitable placement of locations to explore the basement for hydrocarbon in this area.

Paper describes the seismic image analysis known as convolve attribute. This attribute found most suitable for identifying fracture network associated with basalt trap startigraphy. Result from application of this attribute on 3D seismic data in Padra Karjan area is presented in the paper.

Introduction

The Padra- Karjan area on the eastern rising flank of Broach block in Cambay Basin is distinctive as Trap basaltic rocks are commercial oil producers besides Tertiary sediments. For analysis of hydrocarbon occurrence in the area for future pathway, recently an integrated study using Landsat, outcrop, electro-log and seismic data has been carried to understand the mechanism of hydrocarbon occurrence and formulate a geological model[1]. Another approach to describe Discrete fracture network using structural restoration was evaluated by Shukla, K M et. al[2] provide a different mechanism than in the present study. Present study uses 3-D seismic response distribution of amplitude along the mapped reflector (close to top of trap) Figure-1. here 3-D seismic response means that matrix at every evaluation point of response is 3X3 matrix representing sampling in x, y and time domain.

The detailed seismic attribute study conducted in Karjan 3D seismic volume has given an important clue to map the fault structure on 2D seismic data in Padra area. Beside this it has also firmed up geological model for whole padra-Karjan area to explore the prospect within trap basalt.

The study of seismic attribute has brought out the structural grain and pattern of complex fault-fracture distribution by most of general geometric attributes like curvature and similarity. However, application of a special convolve attribute (Laplacian edge) has provided the more detail in fault dynamics and structural development associated with trap stratigraphy, that was not visible on other seismic attribute.

Seismic Attributes

Use of seismic attribute in 3D seismic data interpretation is a common task now a days. Primarily it is used as aid to guide the correlation of faults. It is also optimises the mapping of subtle faults which can not be mapped directly on vertical seismic section. There are two type of seismic attributes one is amplitude and another is geometry based attributes which are routinely used. Geometry based attributes are normally used in mapping of faults through observing seismic discontinuity. However to map subtle faults to identify the fracture corridor it is observed that attribute based on image analysis using convolve algorithm can brought out significant improvement compare to geometry based attribute like minimum curvature.

After analysing the various attribute like similarity variance and minimum curvature in the present study, it is Laplacian edge attribute that has clear edge in distinguishing the structural heterogeneities particularly in basement (trap basalt) regime of Karjan area of Cambay basin in India.

Laplacian Edge seismic attribute

Laplacian edge is one of the well known filters in image processing. Primarily it is a convolve attribute that returns a filtered response. The input data is convolved with a three- dimensional kernel. These kernels can be designed for arithmetic averaging (Low-pass), edge enhancement (Laplacian edge) or contrast enhancement. Use of any one out of these depends on the objective and data set representing characteristic geological setting. As objective of present seismic attribute study was to map finer structural grain at top of trap basalt, it is found that Laplace edge enhances subtle differences in seismic response better than other seismic attributes.

Laplacian filter is an edge enhancer and its sharpness determined by filter size. The shape parameters specifies the geometry of input samples the filters. The shape parameter specifies whether the input samples are collected in a sphere or a cube cantered around the evaluation point. In a 3x3x3 Laplace filter, the output is calculated by multiplying the central sample value with 26 and subtracting all surrounding. The convolution is characterized by the following kernel:

(-1,-1,-1) (-1,-1,-1) (-1,-1,-1)
(-1,-1,-1) (-1,-26,-1) (-1,-1,-1)
(-1,-1,-1) (-1,-1,-1) (-1,-1,-1)

In case all sample values are equal and non zero (either positive or negative), the effect of this operation is zero.

Present Study

The present example of 3D dataset belongs to the area lies in the south west of Padra in Gujarat state of India, primarily mapped for top of basalt trap. The two way time structure map of a reflector close to trap basalt is shown in figure.1 displaying relative highs and lows in general. A-1, A-2 A-3 and A-4 are location of four well drilled in the area. Only one of these well (A-2) is hydrocarbon bearing from trap basalt fractures/weathered reservoir whereas A-3 and A-4 has given indications of hydrocarbon.

Fault network also mapped in the area of study from analysis of vertical seismic section (figure-2).

Geometric attributes like similarity variance (figure-3A) and minimum curvature (figure-3(b) were used for mapping and tracking faults on vertical seismic sections.

On examination of similarity variance attribute (fig.3(a)) and mapped faults (fig.2) an area identified that seems having intense faulting at trap basalt. While mapping of faults it was observed that these faults are intercepted by minor faults at places which are difficult to map properly.

Moreover, this area expected to have number of extensional fracture corridor associated with the older and younger generation faults. these fracture corridor has potential to act as conduit/reservoir as well A-2 is hydrocarbon bearing from trap basalt, lies nearby. Therefore it was essential to map even these minor faults using seismic attributes sensitive to seismic heterogeneity.

Inbuilt seismic attributes in Kingdom, Petrel, and opendTect software were generated in the identified area and their results were compared for clarity and distinguishably fault structure.

On comparison, it was observed that convolve attribute -Laplacian edge (described above) is able to provide significant improvement even to those which difficult correlate on vertical seismic section. Result from application of this attribute is shown in figure-4(a) and its inverted image in figure-4(b).

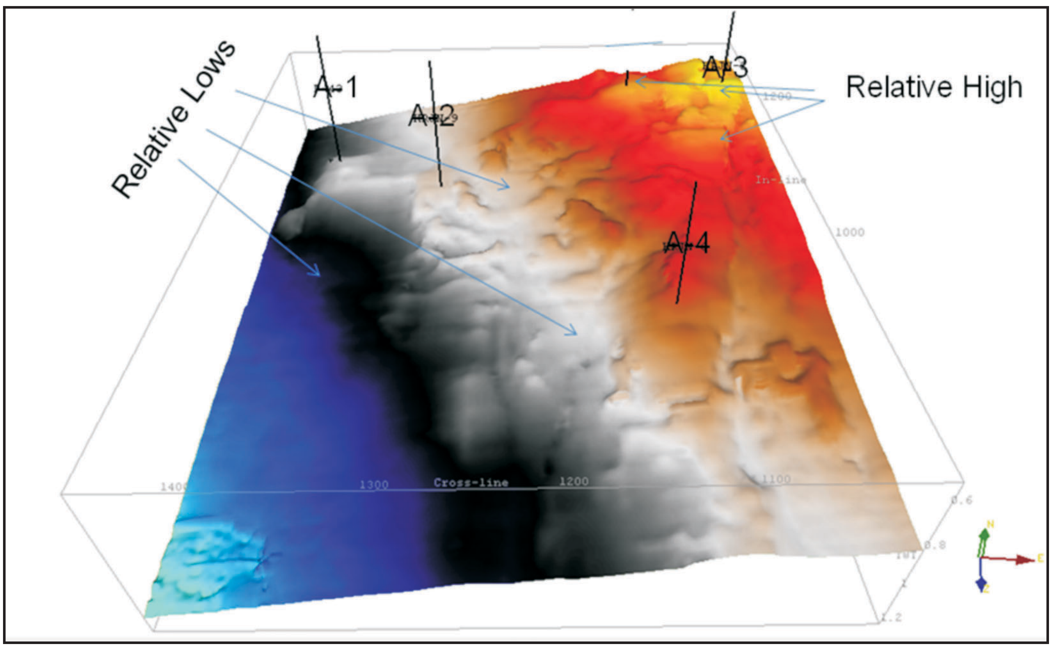

Fig.1. Two way time structure map of the studied area, showing the surface topography at top of trap basalt stratigraphic sequence. A-1, A-2 A-3 and A-4 are location of drilled well in the area.

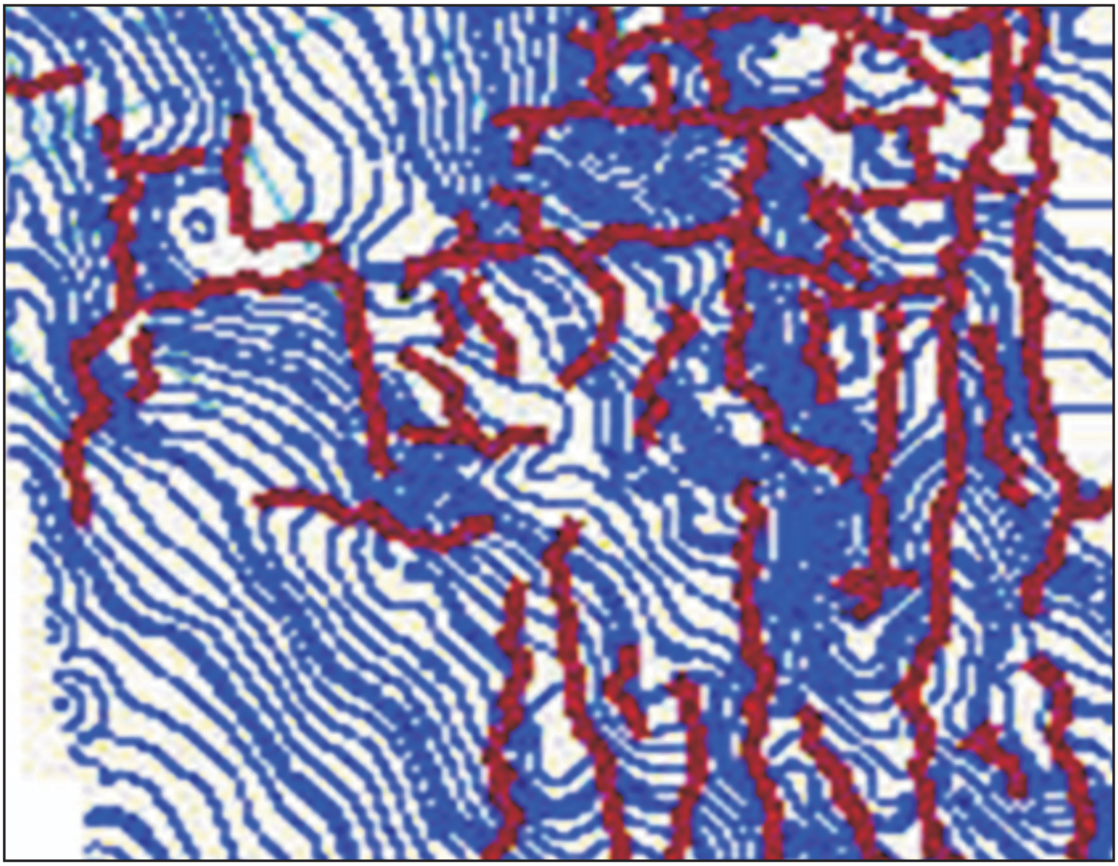

Fig.2. Faults mapped on vertical section in the area of well A-1,A-2 and A-3. (wells are not shown)

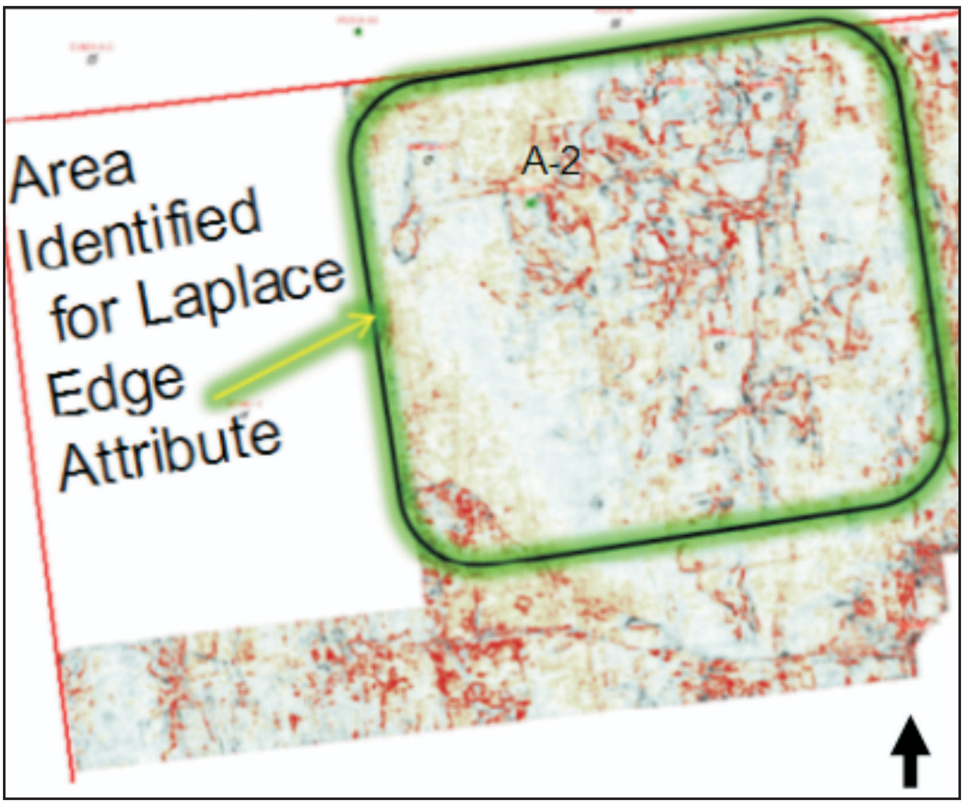

Fig.3(a) Similarity variance showing an area identified for application of convolve attribute.

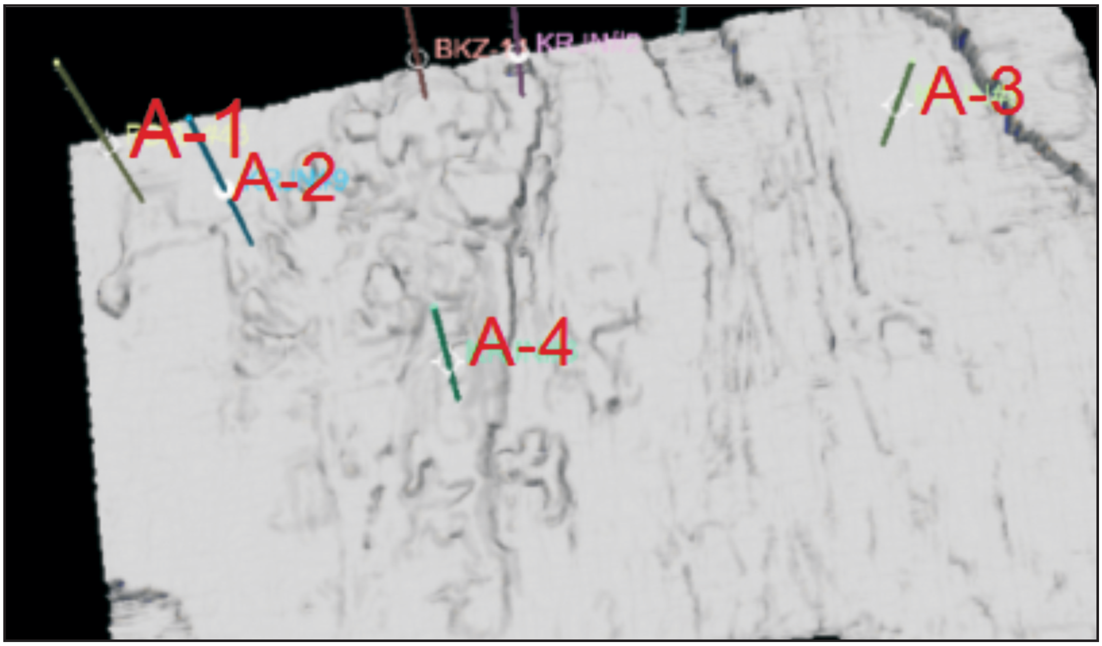

Fig.3.(b) minimum curvature attribute showing presence of intense faulting zone at trap basalt surface.

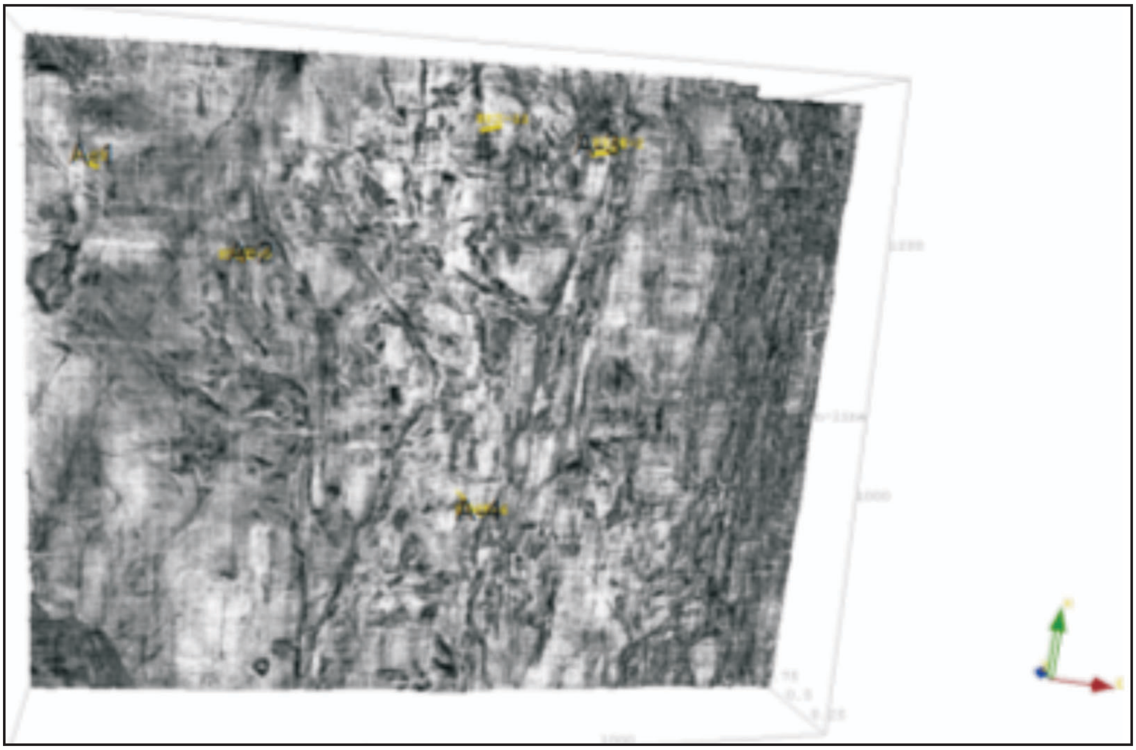

Fig.4(a). Result from application of convolve attribute showing clarity in subtle fault network delineation

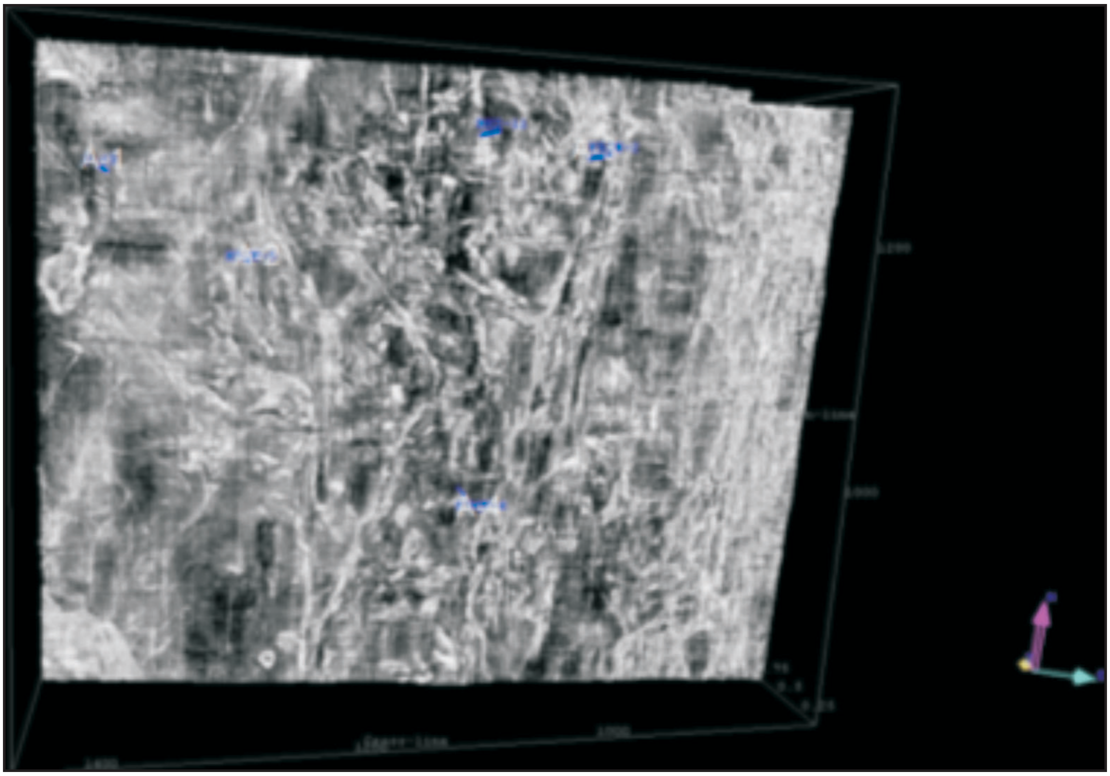

Fig.4 (b) possible fracture corridors in the area of fault culmination after inverting the image of fig.4(a).

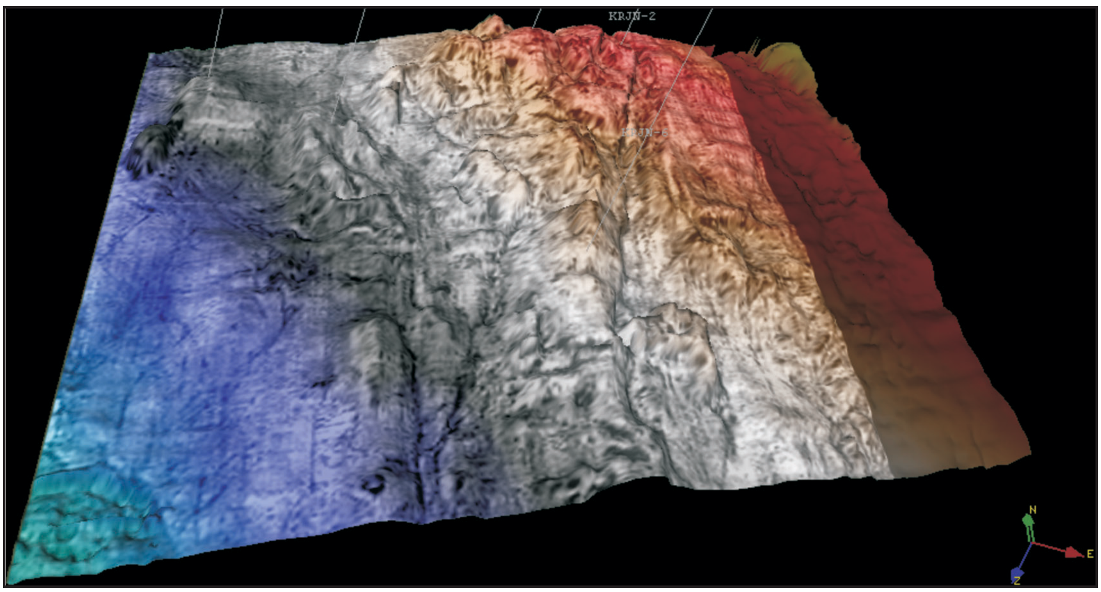

Fig.5. convolve attribute draped with surface elevation to highlight the topography at trap top and enhancing the geological features.

To improve the visibility of minor structural feature it is draped with surface elevation. The result is shown in figure-5 highlights the structural disposition of geological features not hitherto seen. Further, subtle fault trend can be visualised using blend of Laplacian edge and amplitude absorption (attribute) along discontinuities. This composite seismic attribute with relief shown in figure-6 has enhanced the assembly of minor structures and fault lineage significantly.

Wells are not shown clearly in figure for sake of visibility of fault discontinuity. In figure -4(b) the image of fig 4(a) is inverted for change in perspective and to describe the intensity of subtle faults and complexity in their networking.

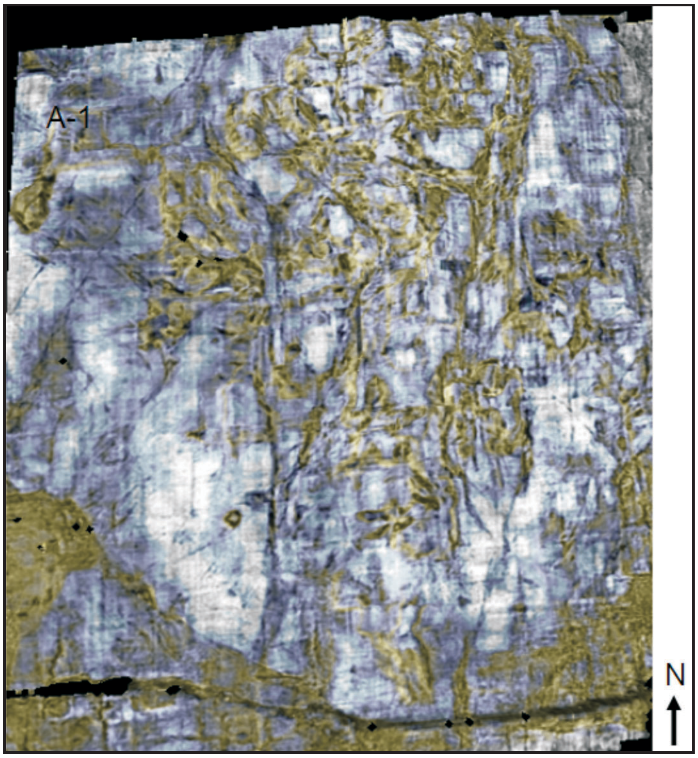

Fig.6. Laplace edge seismic attribute with relief showing subtle fault trends and assembly of minor structures.

It can be observed from figure 4(a) and 4(b) that faults are oriented primarily in two direction. One North-South and another one in almost East-west. They seems to be form due to dominant regional stress. However, the attribute is able to provide details of fault oriented locally in other direction also and terminating against the regionally oriented faults.

To develop more clarity in fault architecture, another attribute 'Q' (seismic attenuation estimation) factor was generated and superimposed on Laplace edge attribute. Further for improved clarity color scale range tuned in such a way that it shows the areas where seismic attenuation was significant. Result is presented in figure-7.

Interpretation of figure-7 provide the locales where seismic heterogeneity (white) and seismic attenuation (light red) are more favourable for presence of limited reservoir in form of fracture and associated weathering. However the occurrence of hydrocarbon will be guided by the access to charging corridor linked with these access faults.

Occurrence of Hydrocarbon in the area

Integration of production performance of wells with the remapped fault pattern in Padra field, suggests that NE-SW trending transfer faults control hydrocarbon distribution in the area [1].

Efficacy of these fracture networks with well data calibration could not be done as none of the well in the area recorded fracture data. However close observation of attribute analysis shows, that hydrocarbon occurrence in well A-2 is due to intersection of NE-SW trending fault (acting as permeability corridor for charging) extended to source area, with accessing NW-SE fracture network providing limited storage in form of fracture felicitated weathered basalt. Despite the good fracture network, well A-2 is ceased after initial production, establishes that fracture network in the area has limited storage capacity and restricted permeability corridor.

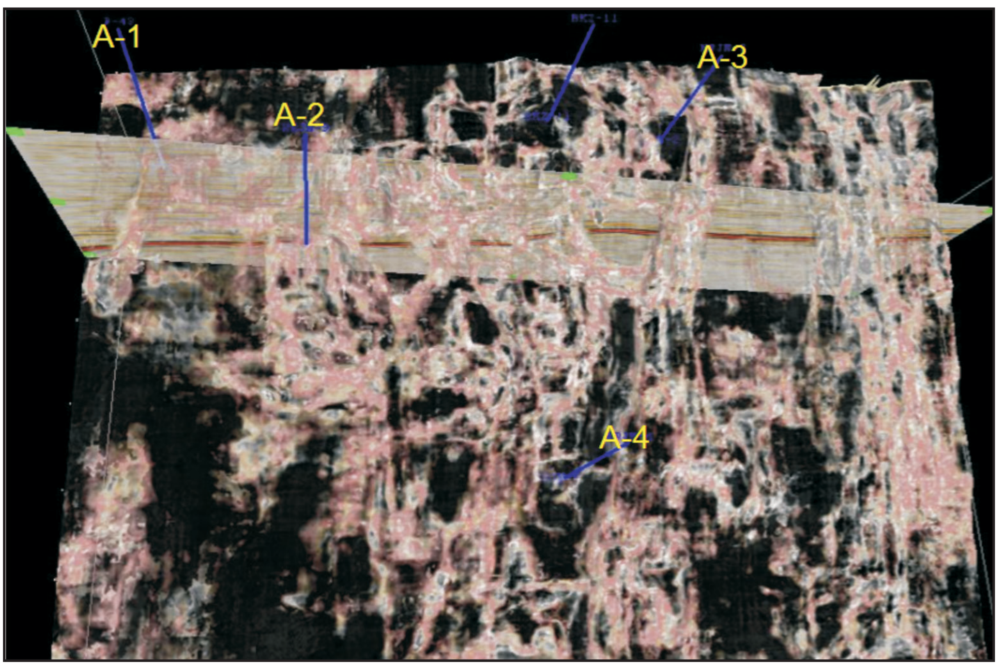

Fig.7. Fault associated fracture Network inferred from seismic attribute – ('Q' factor from cosine tapered window) analysis (Non-black areas.)

Conclusion

It has been observed while mapping the horizon related to low permeability basement rocks that structure heterogeneity do indicate the presence of fracture corridor. Paper describes the visual comparison of different seismic attribute to represent the seismic heterogeneity for mapping of associated fractures and compared for effectiveness. However, it is combination of attributes which address the recognition of fracture prone areas and network appropriately.

The study shows remarkable improvement in delineation of subtle faults in using composite attributes. Convolve attribute compare to similarity variance or minimum curvature attribute has improved visibility of minor fault structure. based on this study it is recommended to prefer convolve attribute to identify and delineate seismic heterogeneity representing geological features for basement regime. As improved spatial delineation of subtle fault of younger and older ages helps to identify fracture prone areas for basement related hydrocarbon prospects.

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