# Geological Expression from Seismic Data in Unconventional Shale reservoirs

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## Introduction

The use of 3D seismic data and its contribution to the success of an unconventional play is dependent mainly on the ability to predict reservoir properties such as total organic content (TOC), fracture density (brittleness), thickness, porosity, and mineralogy. Recent advances in seismic acquisition and processing technologies and their application to the characterisation of unconventional reservoirs has led to the generation of multiple data volume types, including: partial stacks, azimuthal volumes, HTI, AVO and AVA(Z) volumes, elastic inversion volumes, to name but a few (Figure 1).

| Analysis | Objective |
|---|---|
| **Geometrical** | |
| Data Conditioning | Noise removal; increased vertical resolution |
| Edge Detection | Identify major faults |
| Curvature (maximum, minimum, most positive, most negative, mean & Gaussian) | Fault and fracture identification |
| Cross plotting of Curvature and Edge detection attributes | Isolation of high stress zones |
| Frequency decomposition | Illumination of depositional and structural heterogeneity |
| **Geomechanical** | |
| Elastic inversion to generate P & S Impedance volumes; density, Lambda-Rho, Mu-rho and Vp/Vs; Poisson's ratio & Young's Modulus etc | Identification of brittle and ductile zones |
| HTI; AVA(Z) and RMO(Z) processing for azimuthal and angle dependent behaviour of velocity | Stress intensity and orientation |
| **Combining Attributes** | |
| Cross plotting geometrical vs geomechanical attributes | Seismic characterisation of the shale |
| Co-visualisation of geometrical and geomechanical attributes | Indicators for sweet-spot identification |

**Fig. 1** *A typical suite of seismic volumes and their use in shale interpretation*

What the industry requires is a robust, comprehensive and user-friendly tool that can be used to analyse the results of this enormous financial investment in new data in order to quickly and accurately characterise unconventional shale reservoirs to assist in maximizing the impact of overall development strategies as well as the completion strategy of an individual well.

GeoTeric employs a Geological Expression approach which is an innovative data-driven, interpreter-guided approach and has been shown to significantly improve interpretation productivity in shale environments.

Geological Expression workflows have added value in shale interpretation through:

- Improving the signal to noise ratio and vertical resolution of seismic reflectivity data;
- Delineating regional and small scale faulting;
- Detecting drilling hazards;
- Differentiating prospective areas on the basis of subtle variations in seismic character and frequency content that can indicate variations in reservoir thickness, lithology, and kerogen content;
- Predicting zones of increased tectonic deformation;
- Determining dominant stress directions and the orientation of natural fracturing through azimuthally sectored datasets and anisotropy analysis.

## Data conditioning

The application of structurally oriented and edge preserving filters has been extremely effective in improving signal-to-noise ratios in seismic datasets from all play styles, and this is particularly true in shale data. Often onshore datasets used in the interpretation of shales are of older vintage, lower fold, constrained by acquisition practicalities, and subject to greater challenges such as processing statics.

An equally important workflow is Spectral Enhancement, which allows the interpreter to whiten the frequency spectrum in a targeted fashion and reveal high frequency information in the seismic, which is usually masked by lower frequency ranges. This can be critical in enhancing interpretability of thin events, and increase the likelihood of successful well landings in thin formations (Figure 2).

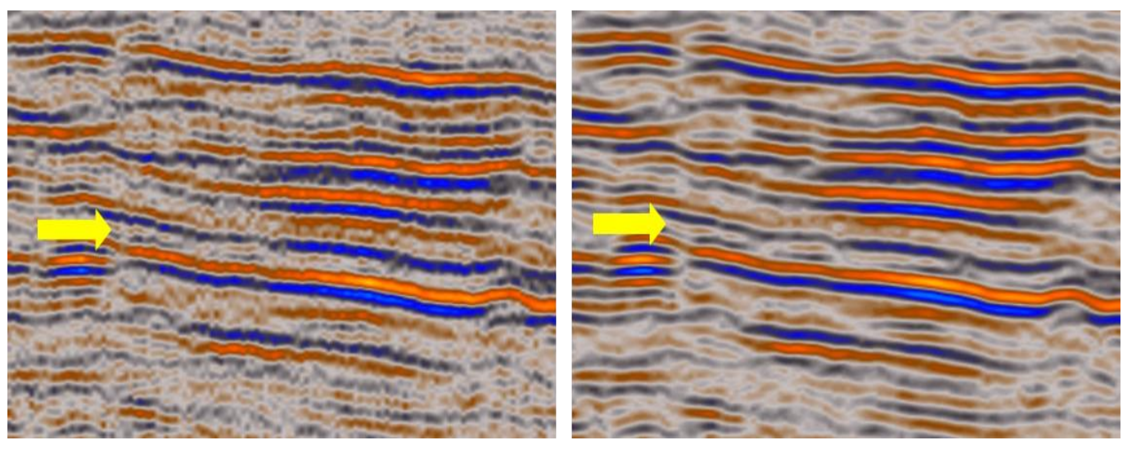

**Fig. 2** *A legacy seismic volume (left) is significantly enhanced in quality after noise cancellation and spectral enhancement (right). Yellow arrows indicate the Barnett Shale. (Data courtesy of BEG).*

## Structural and Stratigraphic Expression

The stratigraphic variations in shale or gross shale packages can be related to thickness, lithology and kerogen content, and are often expressed in the form of frequency variations in seismic data. Being able to rapidly measure, extract and interpret frequency content from seismic data is vital for accurate analysis of shale reservoirs and has been achieved using Frequency Decomposition and RGB blending.

Prospective shale plays are often a product of the tectonic setting and history in which they developed. As the seismic expression of structure can be highly variable, multi attribute visualisation techniques such as CMY blending (cyan, magenta and yellow) are important for interpreting the information contained in multiple volumes simultaneously (Figure 3).

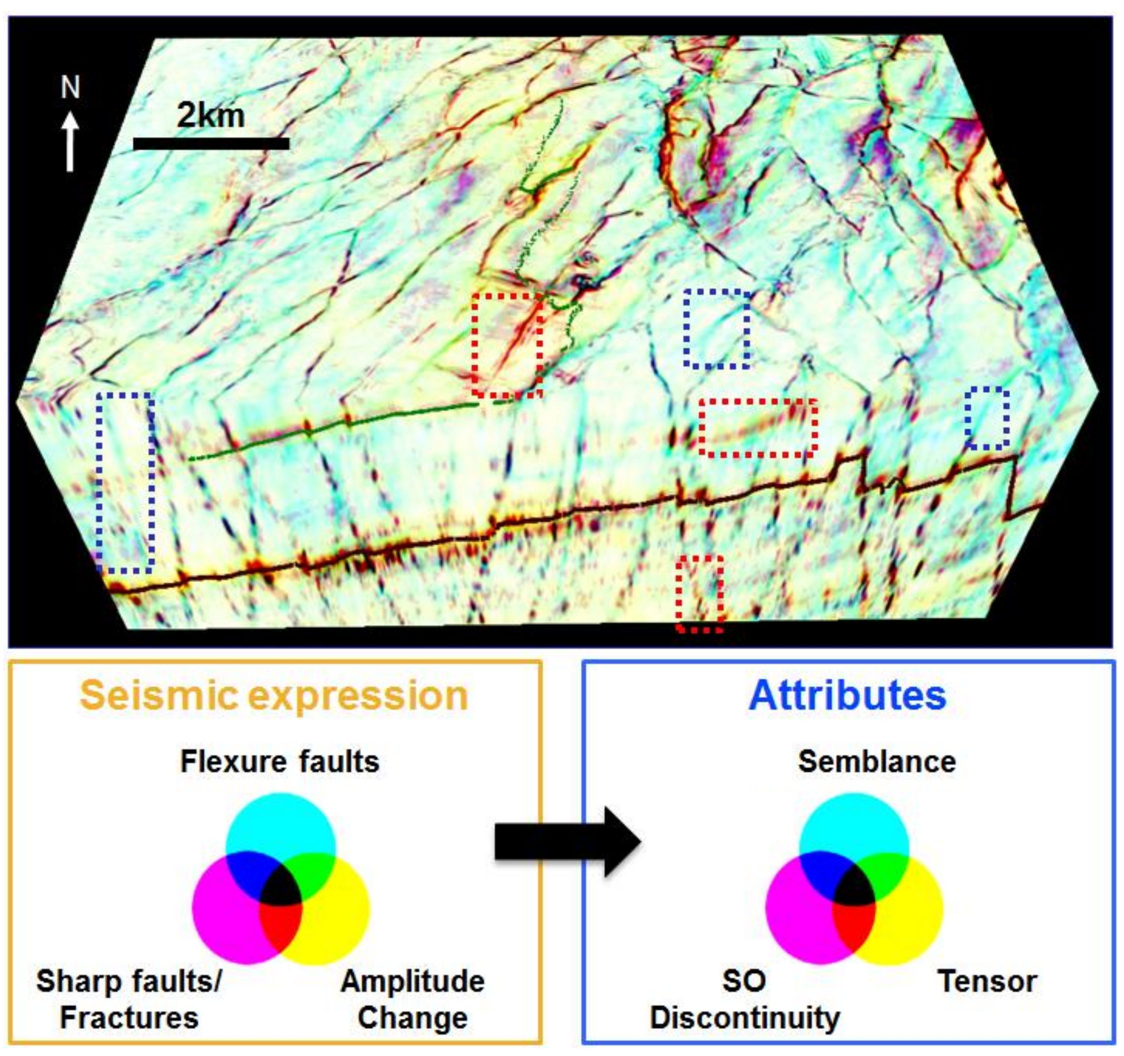


**Fig. 3** *A more complete picture of the structural framework is shown by CMY blending. Different expressions of faulting are shown by individual attributes, as shown in the dashed boxes, but in combination they can be interpreted together. (Data courtesy of Geoscience Australia).*

## Fracture analysis

Predicting the presence of natural fractures is a challenge critical to good well performance, but due to scale cannot be achieved directly from seismic data. One method is to use macro-scale structural trends such as faults, flexures or dip planes, which are commonly extracted from seismic data, and measure their relative abundance throughout the data (Figure 4).

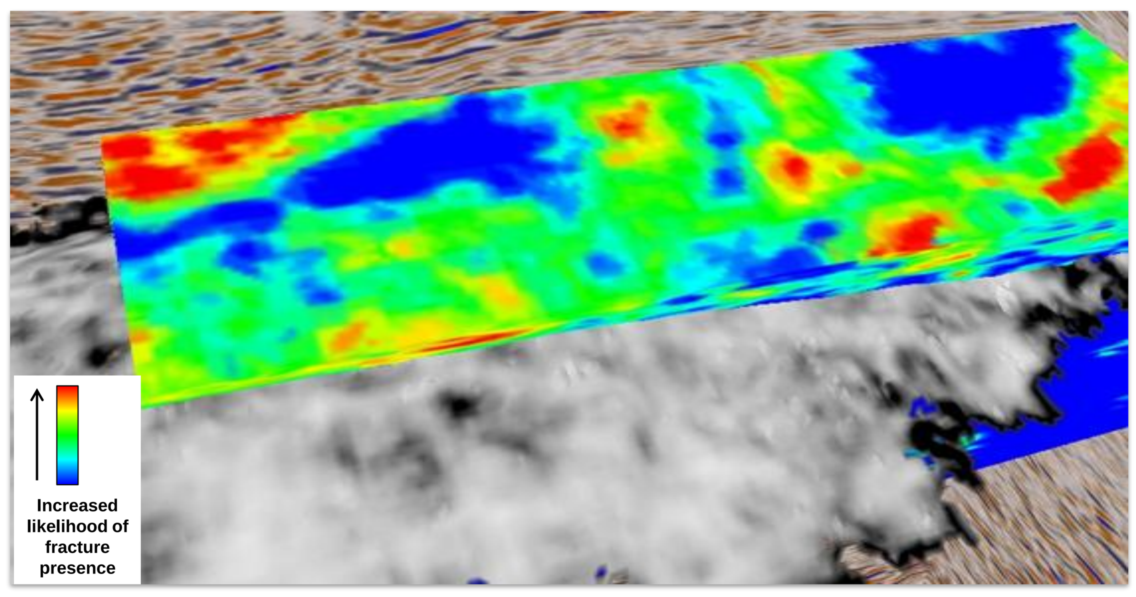


**Fig. 4** *A Fracture density volume shows the likelihood of fracture presence on the reservoir interval (Niobara shale, Wyoming). This Fracture density volume can be used to derive a facies classification, or to generate a map of prospective drilling locations or fracking challenges. (Data courtesy of US Department of Energy).*

## Multi-attribute visualisation

One volume, or even one technique rarely gives the whole story, and we have found that analysing multiple seismic attributes and combining them together with sophisticated colour blending techniques is an effective way of improving the understanding of shale play (Figure 5).

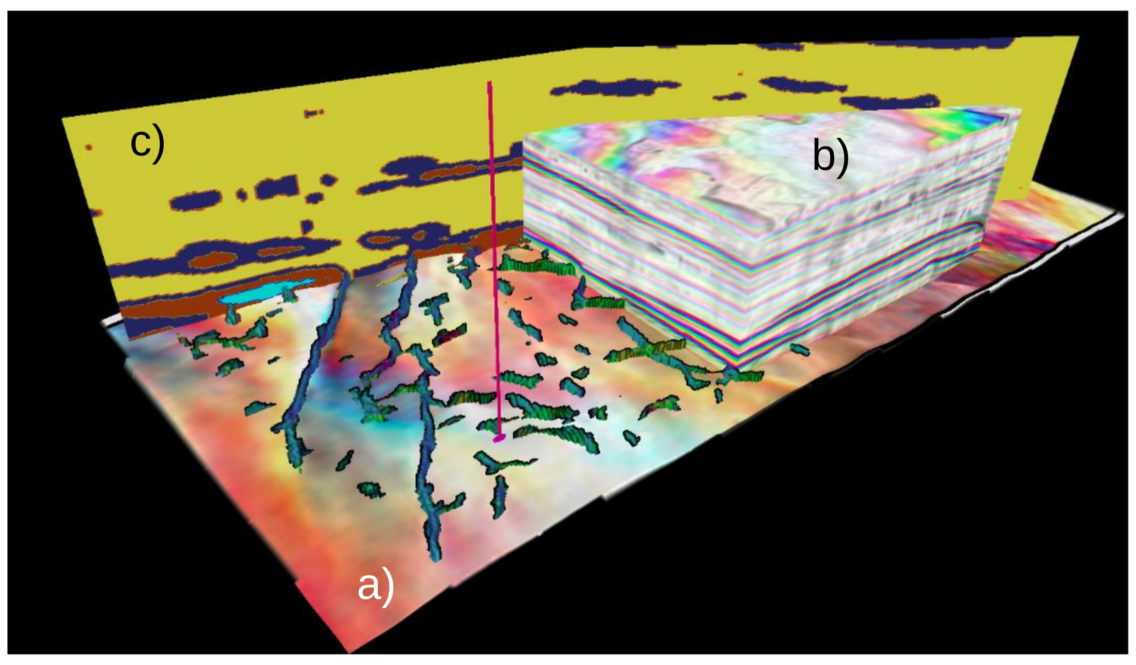


**Fig. 5** *a) An RGB blend of three frequency magnitude volumes displayed on the Top Muderong shale horizon, along with extracted faults and fractures, b) an HSV blend showing the phase response along with amplitude and dip, c) Facies classification based on the RGB response. (Data courtesy of Geoscience Australia).*

## Conclusions

- Data conditioning increased the signal-to-noise ratio, enhanced interpretability of thin events, and increased the likelihood of successful well landings in thin formations.
- Structural and Stratigraphic expression techniques analysed the seismic expression of structural and stratigraphic features, enabling a better understanding of the shale play.
- Fracture analysis highlighted areas of higher likelihood of fracture presence, enabling the generation of a probability map of prospective sweet spots.

## References

Henning, A., Martin, R. and Paton, G. (2010). Data conditioning and seismic attribute analysis in the Eagle Ford Shale Play. SEG Denver oral presentation.