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Increasing the reliability of geological models based on multi-attribute seismic analysis.

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Summary

Over the past decade, digital geological modelling based on the analysis of three-dimensional seismic and well information has become a standard practice in exploration and development of oil and gas reservoirs at various scales. The range of tasks undertaken by operators and partners each year for an assets maturation include but are not limited too; appraisal, risk & uncertainty assessment, accurate in place reserves estimation and optimization of development scenarios [Zakrevsky, 2011]. These tasks are commonly performed using a 3D reservoir model. The accuracy of the reservoir model is largely dependent on the complexity of the geological structure, the quality and quantity of the data, and interpreter experience as well as other subjective and objective factors. The technical challenge of model building is particularly acute for geological objects such as complex fluvial channels where the interpretation of the channels is heavily dependent on seeing and extracting the information from the seismic data.

Introduction

The objective of this study was to build a true aesthetic representation of a complex geological channel to deliver a more accurate geocellular model, by transferring the level of detail that can be captured from the seismic into the geocellular model. A key feature of the work scope was to utilize a Geological Expression interpretive approach for the three-dimensional geomorphology identification of the Eskdale channel itself [Henderson, 2012]. This approach involves a series of successive transformations of the seismic signal to maximize the limits of perception of geological information that is potentially present in the data. Depending on the task it may include noise reduction procedures, standard and high-definition frequency decomposition, color blending, edge detection procedures, geobodies extraction and interactive seismic facies classification respectively.

Geological Setting

A 3D post-stack time domain seismic cube was used for interpretation. The area of research was in the northwest shelf of Australia, 65 km from the coastline within the Exmouth sub-basin. The Exmouth Sub-basin evolved from a pre rift sag basin in the Late Palaeozoic through tectonically active polycyclic extension in the Jurassic to Early Cretaceous producing syn-rift sub basins to a passive margin carbonate shelf in the Cenozoic. The main hydrocarbon potential associated with the Late Jurassic is the Eskdale formation reservoir. Rocks are oil-gas rich, fine-grained sandstone and mudstone with a gross hydrocarbon column of 36.9 m based on well results and proven contacts. Limited well data indicates the average porosity to be 28.8%.

Workflow

The development of a geocellular model of the Eskdale Channel was carried out in three key stages:

- Structural analysis and fault interpretation
- Seismic Facies analysis, geobody delineation and facies characterization

- Creating the geocellular model and property distribution using seismic facies

Structural analysis and fault interpretation

Cyan-Magenta-Yellow (CMY) color blends of 3 edge attributes are an effective way of revealing the complete fault network (Purves and Basford, 2011). Reservoir scale faults can become visible that are not seen when a single attribute is used, and the regional faults are often imaged in a more complete and less ambiguous manner. Interpreting faults directly on the CMY blend gave increased confidence in the interpretation. The interpreted faults formed the basis of the structural model.

Seismic Facies analysis, geobody delineation and facies characterization

Frequency decomposition and RGB color blending is a powerful tool for the study of heterogeneity of the geological environment. The explicit encoding of the absolute amplitude values extracted at different frequencies from the total spectrum into an RGB blend reveals subtle elements of the geology of interest that cannot be discerned from looking at one volume alone. This enables interpretation not just of a channel as a whole, but the individual facies within the channel (Figure 1a).

An Adaptive Geobody was created directly on the RGB blend to capture the full “container” of the channel system (Figure 1b). This accurately described the shape and extent of the channel system and provided a boundary within which the more detailed facies classification was run. It also provided surfaces for inclusion in the geocellular model.

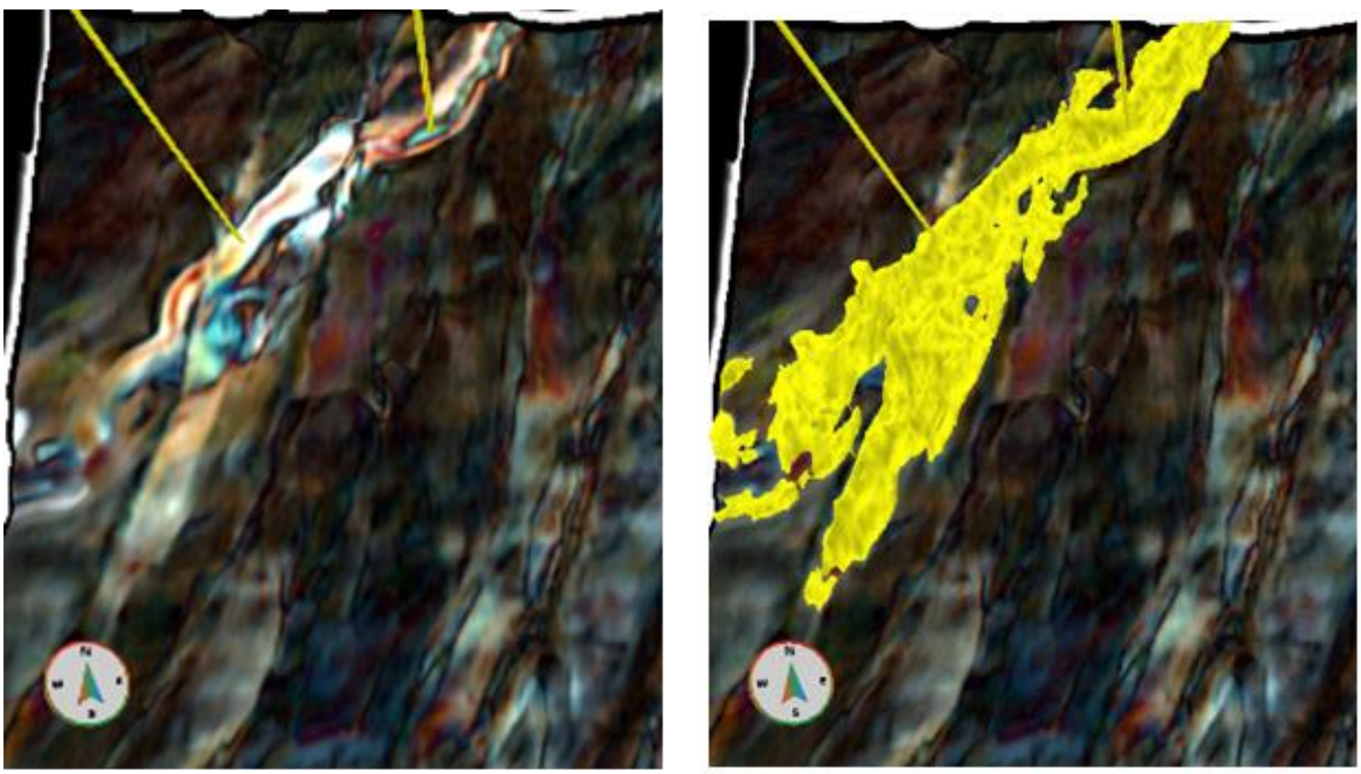

Figure 1. *RGB blend of three frequency magnitude response volumes displayed along the Macedon horizon (left). The Adaptive Geobody tracked on the RGB blend volume (right).*

Interactive Facies Classification (IFC) enabled a multi-attribute classification of the RGB blend constrained by the Adaptive Geobody in order to delineate the different facies in the reservoir. This is a partially supervised form of classification where an interpretation of the depositional episodes visible in the RGB blends is used to define the class centers, the distribution and inclusion of data into those classes is based on a Bayesian classification. The results show a data driven but interpreter guided classification of the internal seismic facies of the channel and clearly differentiates the different depositional episodes (Figure 2).

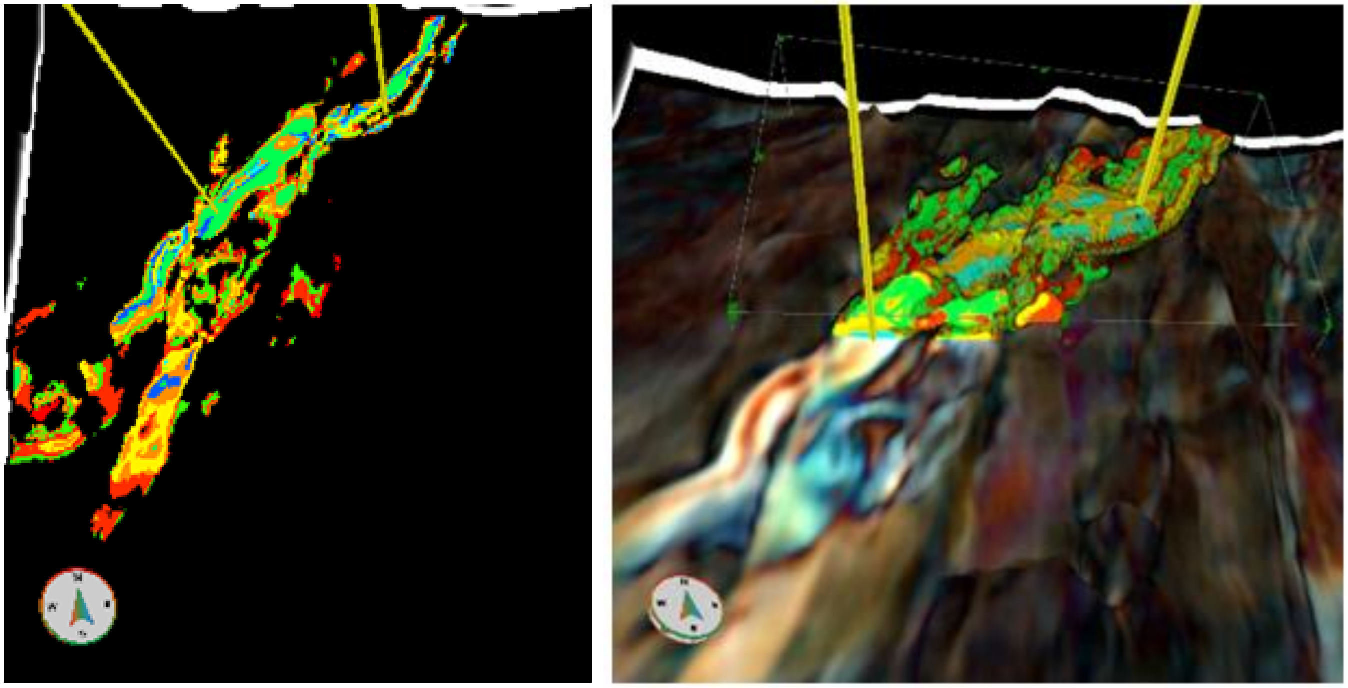

Figure 2. *The result of the Interactive Facies Classification process constrained by the Adaptive Geobody and displayed on the Macedon horizon (left). Volume rendered facies classification volume displayed above the source RGB blend (right).*

Creating the geocellular model and property distribution using seismic facies

A geocellular model was created with 15m x 15m X and Y spacing to maintain reasonable lateral resolution to preserve geological representation. The output volume from the Interactive Facies Classification process was directly embedded into the model maintaining the discrete facies descriptions that were classified. This gave the ability to rapidly build a geologically correct facies model with limited well data that preserved intra channel complexities.

The petrophysical data from the available wells was biased to an intersecting facies type that was geologically distributed and represented the channel complexity we know exits in the subsurface. This gave us a property model that was statistically accurate at the well location and had a high confidence of accuracy away from the wells even though a seismic driven deterministic method of propagation was used laterally (Figure 3).

This resulted in an accurate description of the reservoir potential for further development plans and greatly reduced the risk associated with simplification of facies & petrophysical models.

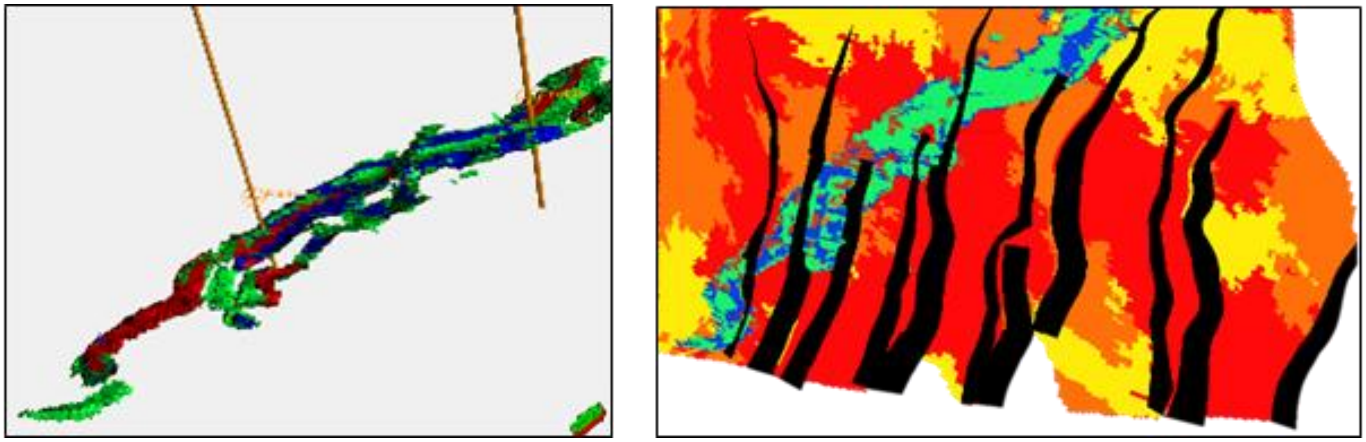

Figure 3. *An IFC Property Model (left) and an embedded IFC in an existing well driven facies model.*

Conclusions

This new approach to the integration of information from seismic data into the reservoir model results in a more accurate model with greater confidence in the property distribution away from the well locations. Spectral decomposition techniques and RGB blending applied to fluvial deposits in the Eskdale formation allowed us to distinguish fine details of the inner structure and morphology of the object not seen in the reflectivity data. The level of true geological representation in the final geological model was promoted by the inclusion of the top and base of the channel, as well as the use of seismic facies trends based on the frequency decomposition. The additional features incorporated from the seismic data were effective at tracking the spatial distribution of key reservoir petrophysical properties in further analysis of the Eskdale Channel.

References

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