The application of High-Definition Geological Expression workflows to improve the understanding of a carbonate reservoir, NW Australia

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Summary

This paper shows how using data-driven interpreter-guided Geological Expression workflows can better reveal the stratigraphic component of geology and bring more comprehensive understanding to exploration and development targets.

We present examples of how data conditioning, attribute analysis, multi-attribute visualisation, frequency decomposition and data-driven interpreter-guided geobody extractions can increase the likelihood of technical and economic success with regard to discovering hydrocarbon accumulations.

Geological Expression workflows encompassing data-driven interpreted guided methods allowed for faster expression of the geology, rapid delineation of deposition geometries and extraction of geological entities. This reduces risk in high-stake, low-return assets.

Introduction

The prospect is from the Exmouth Sub-Basin, NW Australia (Figure 1). It forms the most southern rift basin in the Carnarvon Basin. The carbonate reservoirs are typified by complex stratigraphic architecture, digenesis and lithology variations. The steady subsidence of the Exmouth Plateau from the late Cretaceous resulted in deposition of carbonate chalks, marls and oozes which were subjected to burial, compaction and digenesis. The varying mineralogical composition of the carbonates results in differential digenetic features; however, karstification remains prevalent. Identification of the reservoir characteristics and karst networks is essential in being able to define migration pathways and potential prospects.

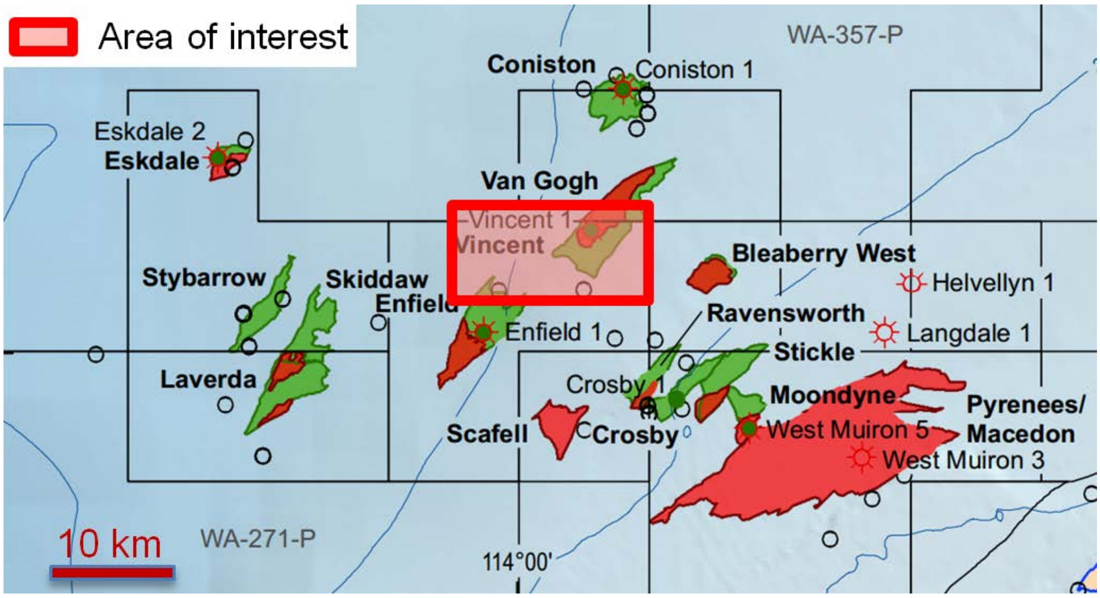

Figure 1. Location of the study area, in the Exmouth Sub-basin, NW Australia.

The study area is covered by the Vincent 3D seismic survey and a number of wells have been drilled targeting mainly the Early Cretaceous clastic reservoirs. The seismic dataset covers 808 km^2.

Two intervals showing dissolution of carbonates have been recognised in the dataset: one being the Oligocene Mandu Formation, and a deeper one at the Late Cretaceous Korojon Formation. Gas shows have been identified on the Korojon Formation in other areas of the NW shelf of Australia (Guildford-1 well, Exmouth Plateau), showing that this is a working carbonate play in the region.

High-Definition Geological Expression workflow

A High-Definition Geological Expression workflow was applied to the seismic data. This involved the application of a data conditioning workflow, including both Structurally Oriented Noise Attenuation algorithms and Spectral Enhancement. The conditioned data was then used as the input to different techniques of Frequency Decomposition and multi-attribute analysis using colour blending techniques. Finally, a data-driven interpreter-guided geobody extraction was applied to image and extract the carbonate intervals.

Data Conditioning

The first stage of the workflow involved the application of a structurally oriented and edge-preserving FMH (Finite Median Hybrid) filter targeting coherent noise, followed by a TDiffusion algorithm targeting random noise. This combination of filters resulted in an increase in the signal-to-noise ratio while preserving the fault breaks and the subtle edges of the carbonate features.

A second stage included the Spectral Enhancement workflow, which was applied to improve the vertical resolution of seismic data. This technique aims to balance the contribution of frequencies within the data, producing a “white spectrum”, in which all frequencies contribute equally to the signal power. The application of this workflow resulted on a better vertical resolution of the data and a clearer imagining on the carbonate intervals (Figure 2).

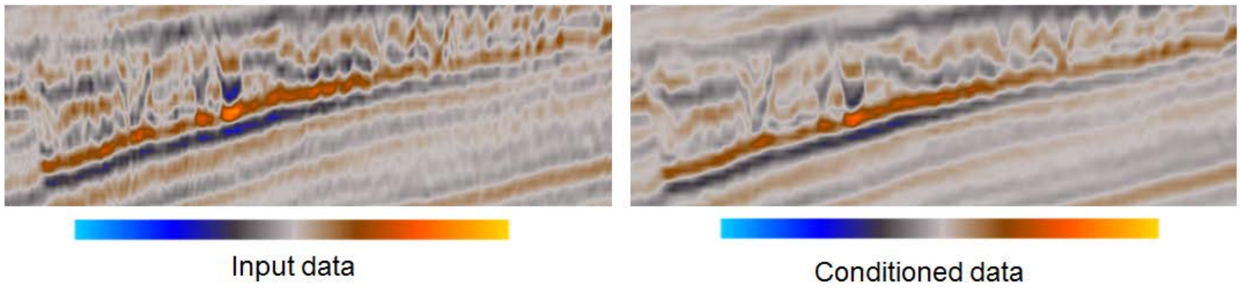

Figure 2. Noise Cancellation and Spectral Enhancement techniques were applied to the data, improving the imaging of the carbonate intervals while preserving the edges and subtle details of the geological features.

Frequency Decomposition

Frequency Decomposition and RGB (red-green-blue) blending were used as a screening tool to identify the areas where karstification is occurring on the dataset. The Frequency Decomposition workflow applied a series of band-pass filters and generated the magnitude volumes for each band-pass. These magnitude volumes were then viewed simultaneously using the RGB blending technique.

Two different Frequency Decomposition methods were tested on the data, including a method based on a Fast Fourier Transformation and a method based on a Matching Pursuit algorithm. The Matching Pursuit based method decomposed the signal with a better vertical resolution than the one based on a Fast Fourier Transformation, preserving the subtleties within the carbonates.

The Frequency Decomposition and RGB blending results showed the dissolution affecting the carbonates in a more clear way than how it was seen before in the amplitude maps. The karstification produced a number of carbonate pinnacles which were easily recognised given their different frequency response compared to the dissolved regions (Figure 3).

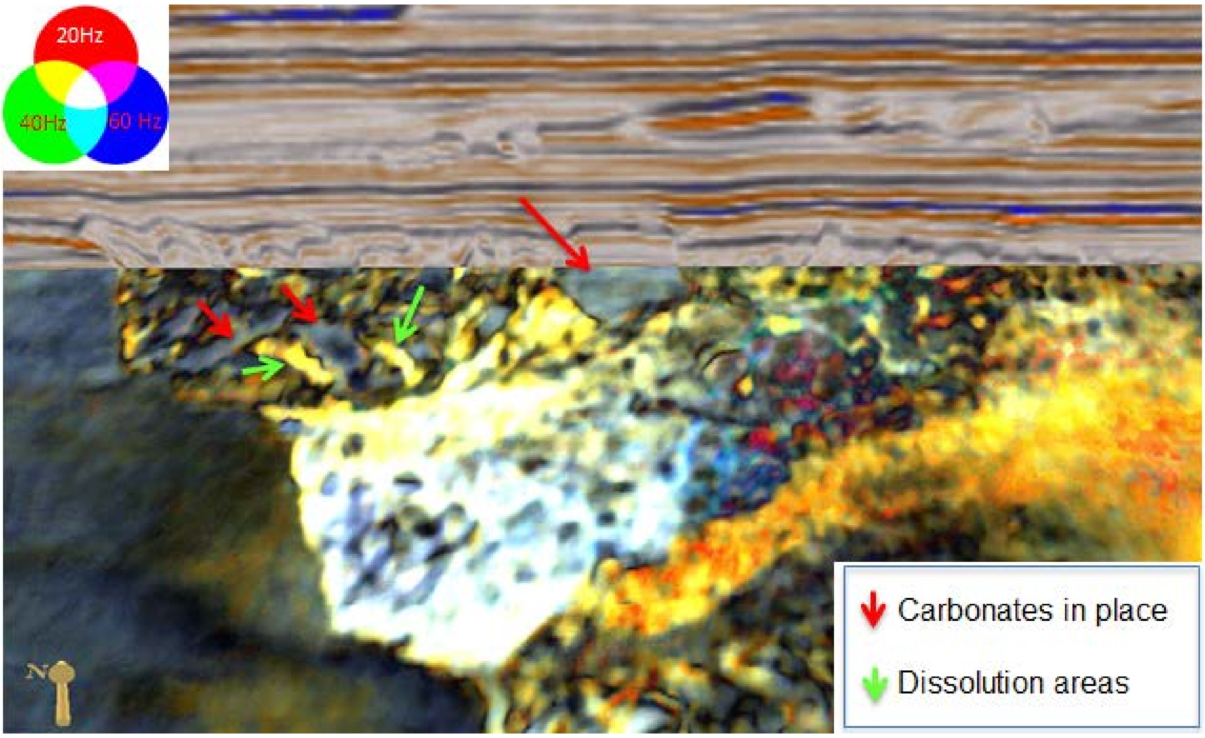

Figure 3. Frequency Decomposition technique based in a Matching Pursuit algorithm was applied to the dataset, and three output magnitude volumes blended on an RGB blend to highlight the dissolution features and the carbonates still in place.

Multi-attribute analysis

A number of attributes tailored for analysis of carbonate reservoirs were applied to the dataset, aiming to produce a more detail interpretation of the dissolution areas. Attributes such as Tensor, SO Semblance, Envelope, Chaos, and Conformance were produced and then combined in RGB and CMY blends to gain more understanding of the carbonate intervals.

Two attributes were particularly useful in highlighting the dissolved features and the carbonates in-place, these are the Tensor and the Conformance, which were combined on a TensorConformance combo volume (Figure 4).

The Tensor detected discontinuities by looking at variations in amplitude and phase, being also resistant to areas of chaos. The Conformance showed a measure of the degree of deviation from the local dominant orientation at each point, detecting lateral continuity within structures. The infill of the dissolution features showed a discontinuous pattern which was highlighted by a low conformance, while the continuous and stable carbonate pinnacles showed a high conformance.

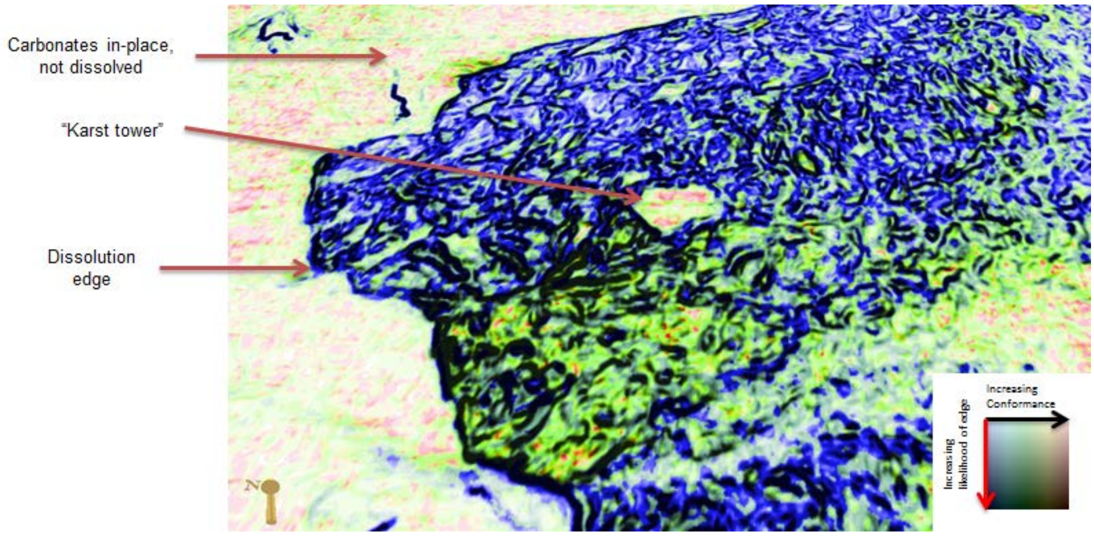

Figure 4. The TensorConformance combined volume highlights both the edges of the dissolution features and the nature of the infill. Carbonate pinnacles or karst towers show high Conformance values bounded by high Tensor values.

Geobody extraction

The final step of the Geological Expression workflow involved the extraction of fully volumetric representations of both the dissolved areas and the carbonates in-place using geobody extraction techniques.

The carbonate pinnacles that were recognised on the RGB blends were extracted using the Adaptive Geobodies tool, which extracted the pinnacles as 3D objects using a data-driven interpreter-guided algorithm. The Adaptive Geobodies also allowed for a quick volumetric estimation to be obtained.

A volumetric geobody technique involving segmentation of the conformance attribute was applied to extract the dissolved areas. The 3D geobody obtained as a result was colour-coded with thickness values allowing for the identification of areas where the dissolved package is thicker (Figure 5).

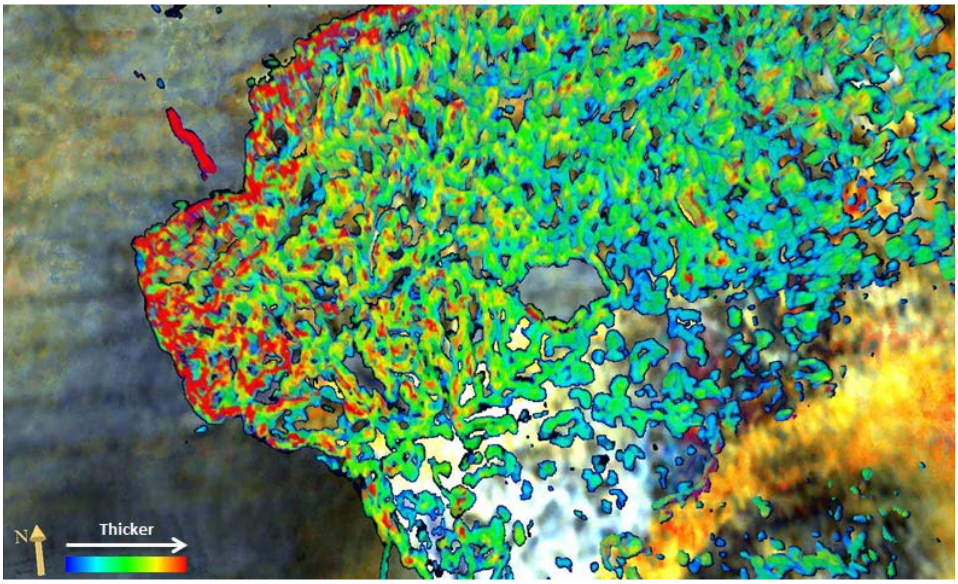

Figure 5. Dissolved carbonate areas were extracted using a volumetric 3D geobody colour-coded by thickness. The geobody shows a thicker dissolution on the western side, which correlates with the increase in thickness of the carbonate package towards the west.

Conclusions

The Geological Expression workflow encompassing data-driven interpreted guided methods allowed for faster expression of the geology, rapid delineation of deposition geometries and extraction of geological entities. In particular:

- Noise Cancellation and Spectral Enhancement techniques conditioned the data, increased the signal to noise ratio and the vertical resolution of the seismic, which ultimately improved the imaging of the carbonate intervals.
- Stratigraphic imaging, especially the Frequency Decomposition workflow, was used to produce a quick overview of the karstified intervals within the dataset.
- Multi-attribute visualization techniques identified the carbonates in-place and the dissolution features and the Adaptive Geobodies extracted both the carbonate pinnacles and the dissolved areas as 3D objects.

The results of the Geological Expression workflow were used to guide the interpretation of complex carbonate features and results can be used as a high quality input for modelling of carbonate fields.