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Reservoir Heterogeneity visualized using Geological Expression workflows in the Stybarrow Reservoir, NW Australia

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Summary

In the Stybarrow reservoir, offshore NW Australia, Geological Expression workflows have been used to gain an improved understanding of the complex heterogeneity within the Macedon sands which are at the core of the play.

Keywords*: Seismic Attributes, Reservoir, Heterogeneity, Geological Expression*

Introduction

The Stybarrow-1 well was drilled in 2003 by BHP Billiton Petroleum. The well is located in the Exmouth Sub-basin of the greater Carnarvon Basin within WA-255-P which is 135 km west of northwestern Australia (Figure 1). This well was drilled to explore the possible productivity of the latest Tithonian Macedon Member sandstones (Hill 2008) based on the seismic response located within the HCA2000A 3D seismic dataset. Trace attribute calculations on the Top Macedon Horizon show some reservoir heterogeneity, but they do not provide a full picture of the geological variation within. The purpose of this study was to use Geological Expression techniques to further examine the reservoir heterogeneity and provide more insight into the causes of the changes in amplitude. Geological Expression workflows are a data driven but interpreter guided method for extracting the 3D morphology of geological elements from the data, and enable a more robust and detailed understanding of the reservoir to be achieved in a short space of time.

Background Geology

The Stybarrow-1 well was drilled into the Macedon Member Sands and encountered a 23m oil column. The Macedon itself is mainly moderately sorted, medium grained sandstone with a low concentration of argillaceous siltstone and claystone. It is bounded below by the Upper Dupuy Formation siltstones and sealed on the top by the Murion Member siltstones. It is thought that the reservoir was sourced by the Dingo Claystone (Ementon 2004).

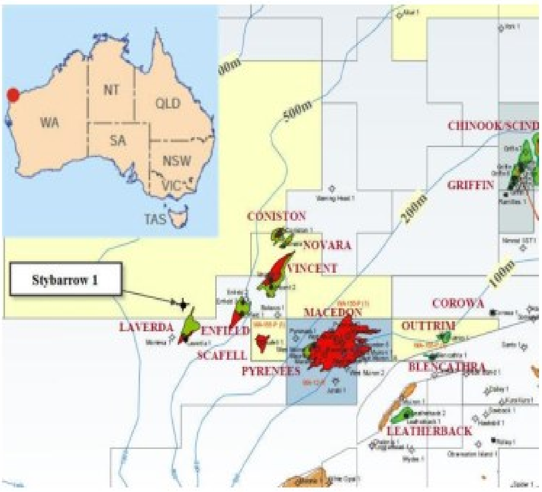

Figure 1: Location map showing Stybarrow-1 off northwest Australia coast and surrounding reservoirs (modified from DRET 2012 and Locke 2004).

The reservoir is fault bounded on a block that tilts down to the northeast (Figure 2) and is on the northern flank of the Ningaloo Arch (DRET 2010). The reservoir was probably part of a turbidite distal shelf system that was partially eroded in later times.

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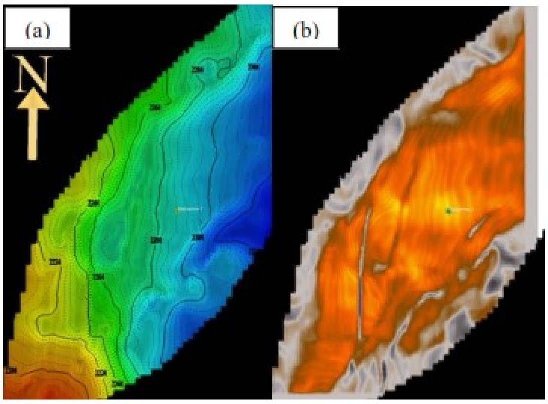

Figure 2: Macedon Member Top Horizon showing (a) time structure with red high and 20ms contour interval and (b) reflectivity with the Stybarrow-1 location just off center of the horizon.

Workflow

The Stybarrow reservoir was discovered based on 2D data and comparisons with previously explored fields. The field was later defined with 3D data by viewing differences in amplitude anomalies (Ementon 2004). These simple amplitude attributes provided enough confidence to commence a drilling program.

Before analyzing the data, it was worthwhile to first condition the volume by reducing noise with structurally oriented noise cancellation filters to increase reflector continuity and definition.

After data conditioning, simple trace attributes were run to view heterogeneities that may exist within the data. As shown in Figure 3, these attributes (RMS Energy, Envelope, Maximum Positive Amplitude, and Maximum Negative Amplitude) all produced extremely similar results but they do highlight additional amplitude anomalies within the high amplitude zone of the reservoir. Of note is the highest amplitude response trending E-W in the middle of the horizon which is perpendicular to the contour trend of the horizon. The structurally perpendicular nature of the highest amplitude suggests it is not a fluid effect and may be related to the thickness of the reservoir. Extracting a 3D geobody from the Envelope volume and measuring the thickness of the geobody reveals a thickness trend which is coincident with the amplitude trend (Fig 5b).

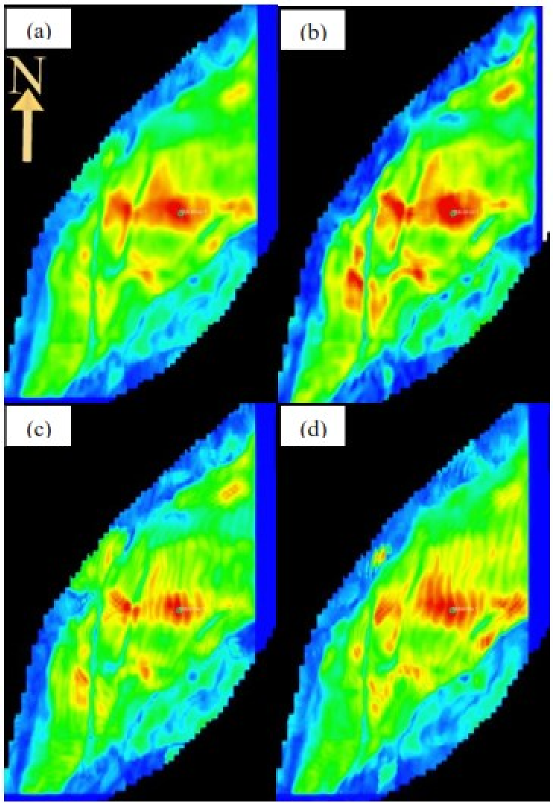

Figure 3: Typical single seismic attributes appear to show similar information with red representing a high response and blue a low response. (a) RMS Energy (b) Envelope (c) Maximum Positive Amplitude (d) Maximum Negative Amplitude.

The next step was to look at seismic attributes that show information from multiple sources, such as Frequency Decomposition and RGB blends. Frequency Decomposition is a technique that decomposes the seismic data into band limited frequency magnitude responses which were then blended together into one volume. This volume is a Red-Green-Blue (RGB) blend of three separate frequency magnitudes with the low frequency in the red channel, mid frequency in the green channel, and high frequency in the blue channel. Where there is a specific color, that indicates a high response from that particular channel, so red means a large low frequency response while yellow would mean a high response from the low and mid frequencies. White indicates a high response from all three frequencies and black indicates zero response from all three frequencies. Frequency decomposition and RGB blending is a more sensitive measure of the amplitude than the simple trace attributes shown in Figure 3, and can highlight more subtle changes within a reservoir.

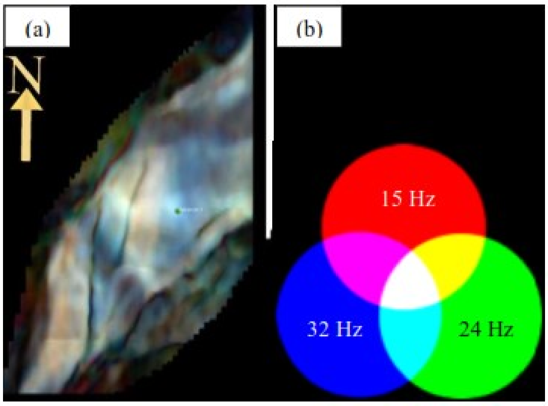

Figure 4: (a) SDFD RGB Blend with 15 Hz, 24 Hz, and 32 Hz bins and (b) RGB Blend color diagram.

In the Standard Definition Frequency Decomposition(SDFD), a blend of the 15 Hz, 24 Hz, and 32 Hzfrequencies was used to produce the RGB Blend (Fig 4a).The SDFD is created using a convolution of fixed bandwidth Gabor wavelets centered at differentfrequencies. It is quick to see that the high amplitude areasare more complex than the previous attributes have shown.Within the high amplitude E-W trend surrounding theStybarrow-1, we can see a N-S trending pink responsewhich represents the low frequency and a bright blueresponse to the east of the pink which indicates a shift to ahigh frequency response. The two dark blue zones highlight a later channel which meanders across the Macedon sand and has eroded part of the reservoir. This shift in color indicates heterogeneity within the high amplitude area that was not apparent with the previous simple amplitude attributes.

Finally, the Frequency Decomposition RGB Blends can be used to further define these color differences as individual facies classes. These classes were created with an Instantaneous Facies Classification technique which allows an interpreter to guide the selection of facies classes based on multiple volumes, in this case, the RGB Blend constrained by the full amplitude Geobody of the reservoir (Fig 5). By allowing the interpreter to guide the definition of these facies from the data to complete the Geological Expression workflow, the 3D morphology of the reservoir heterogeneity can be completely visualized and compared with the original single attribute amplitude anomalies.

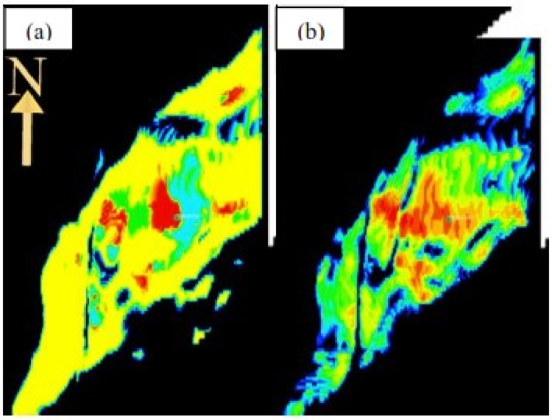

Figure 5: (a) Facies Classification with color representing different facies and (b) Thickness attribute of Macedon Geobody with red representing thickest areas of the body.

Conclusions

By utilizing Geological Expression techniques the complexity of the reservoir has been revealed. In the beginning, it was plain to see that the reservoir was not homogeneous by viewing a single attribute such as RMS Energy, but without the Geological Expression workflow that utilized multiple attributes, it was difficult to visualize the changes within those amplitude anomalies. These techniques have shown that not only is there an E-W trend within the reservoir that represents the thickest areas of sand but also that there are up to 4 separate facies within this zone which may be indicative of compartmentalization or other changes that can help explain well production differences or be used as a guide for well placement. Using single attributes is better than no attributes but just one alone is not enough to completely understand a reservoir.

Acknowledgements

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