New insights into the Exmouth Sub-basin: Seismic acquisition, processing and imaging

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INTRODUCTION

The Exmouth Sub-basin represents part of the intracratonic rift system of the Northern Carnarvon Basin, North West Shelf, Australia. It has undergone a complex tectonic history with multiple phases of rifting, magmatic underplating, uplift, erosion, inversion and regional tilting (Rohrman, 2015; Reeve et al., 2016).

Hydrocarbon exploration has resulted in the discovery of a variety of oil and gas accumulations, mainly in Upper Jurassic and Lower Cretaceous intervals. However, the distribution of the different petroleum system elements, including Jurassic and Triassic intervals, is poorly determined, but required for improved understanding of the complex charge history, as indicated by the variety of hydrocarbon types ranging from heavy, biodegraded oil, through light oil with gas caps, to dry gas columns.

The 12,000 km² WesternGeco Multiclient 3D seismic survey (Figure 1), acquired in 2017 with a multimeasurement streamer, extends to the edges of the basin to give a complete and comprehensive picture of the subsurface.

SUMMARY

Hydrocarbon exploration in the Exmouth Sub-basin, North West Shelf, Australia, has resulted in the discovery of a variety of oil and gas accumulations mainly in Upper Jurassic and Lower Cretaceous intervals. However, the distribution of the different petroleum system elements, including Jurassic and Triassic intervals, is poorly determined, but required for improved understanding of the complex charge history, as indicated by the variety of hydrocarbon types encountered in the basin.

As illustrated herein, various stages of processing and imaging have provided a more accurately imaged 3D seismic volume covering the entirety of the Exmouth Sub-basin. An increased signal-to-noise ratio for all depths now allows, 1) detailed picking of events within the entire Mesozoic (Cretaceous through to Triassic) section, enabling interpreting and correlating key events across the area, and 2) accurate investigation of the complexity of different aged fault networks and their relationships across the full Exmouth Sub-basin for the first time.

This large-scale multimeasurement survey provides a detailed insight into the deeper basin architecture of the Exmouth Sub-basin. The seamless volume imaged to depth allows accurate mapping which is critical to unravel the complex evolutionary history in a basin with proven and remaining hydrocarbon potential.

Key words: Seismic acquisition, data processing, FWI, depth imaging, Exmouth Sub-basin

The continuous line acquisition (CLA) technique was deployed for the first time on a large-scale production project using the multimeasurement streamer. This was done with the purpose of maintaining efficiency during the survey acquisition period by enabling acquisition to continue in both the straight and turning parts of the vessel track. Use of CLA reduced the non-productive time by ~30% and provided additional full-fold coverage at the survey edge without the half-cable-length taper zone in the run-in/run-out areas as required with conventional acquisition methods.

Advanced streamer steering control also increased the flexibility of the data capture in the obstructed floating production storage and offloading areas and other oilfield infrastructure zones, and, in addition, enabled data to be
collected closer to the border of the ultra-shallow-water zone near the Ningaloo World Heritage Area.

IMAGING WORKFLOW

The processing techniques were specifically designed for multimeasurement data acquired in a non-linear manner with non-linear processing flow assumptions and noise attenuation techniques targeting the additional cross-flow noise generated when the cable is towed in a circular fashion. These techniques enabled data acquired during the turns to be accepted and incorporated into the full processing volume (Watterson et al., 2015).

The premigration azimuth preservation workflow fully utilized the 3D source detector azimuth information during the signal processing and depth model building stages which allowed more-accurate depth model building in the turn areas.

Raw hydrophone data were delivered from the vessel as acquisition progressed to begin the near-surface model building. This was implemented in parallel with preprocessing stages with no preconditioning such as demultiple or deghosting required (Vigh et al., 2016) to increase the imaging workflow efficiency.

The model building consisted of two major stages: firstly, using full waveform inversion (FWI) to derive the near-surface velocity field, and secondly, common image point (CIP) tomography to update the deeper section that is beyond the FWI illumination zone.

The two bands of FWI utilized the earlier arrivals captured by the 8 km cable length, successfully correcting the background velocity trend and resolving the spatial and vertical velocity variations in the complex geological overburden. The resulting accuracy and high resolution in the near-surface model allowed the subsequent CIP tomography to update the deeper section more effectively.

The reflection CIP tomography was designed to be updated at all depths. With this, as illustrated by Figure 2 (compare b to c), only minor updates were seen in the overburden due to the high velocity accuracies input from the FWI model, thus allowing the CIP tomography workflow to focus on updating deeper portions below the FWI illumination zone. As a result, this allowed increased efficiency in the model building workflow and improved resolution in the deeper part of the model, producing an early depth imaging product for geological interpretation.

Subsequently, the early interpretation and geological information obtained from the intermediate depth imaging products was used to revise the anisotropic model, and also used as a guide during the following CIP tomography updates thus achieving a more geologically plausible earth model that correlated the well information and seismic data.

RESULTS

A good correlation of final velocities with geological units and unconformities, even in areas with complex faulting and significant lithological variations (including channels and carbonates) as supported by information from multiple wells across the volume, gives confidence in the model building approach and results. As illustrated in Figures 2 and 3, by better resolving the shallow intervals imaging in the deeper portions has benefited. Within the Early Cretaceous Barrow Group, stratigraphic events are now better defined and trackable with improved resolution across the basin, giving more confidence in the identification of subtle lithological contrasts and dipping events.

Within the model building workflow, applying seismic azimuthal anisotropy addressed the complex azimuthal-dependent velocity variation within the Barrow Group interval and enhanced the continuity of the primary structures, thus providing increased confidence in events picked and geometries observed.

Multiple passes of noise attenuation at various stages of processing increased the overall signal-to-noise ratio for all depths allowing, 1) detailed picking of the events within the entire Mesozoic (Triassic to Cretaceous) section, allowing interpreting and correlating key events across the area, and 2) accurate investigation of the complexity of differently-aged fault networks and their relationships across the full Exmouth Sub-basin for the first time.

CONCLUSIONS

In summary, this large-scale multimeasurement 3D seismic survey provides a detailed insight into the deeper basin architecture of the Exmouth Sub-basin. The seamless volume imaged to depth now allows accurate mapping across the full record length, which is critical to unravel the complex evolutionary history in a basin with proven and remaining hydrocarbon potential.

REFERENCES

Rohrman, M., 2015, Delineating the Exmouth mantle plume (NW Australia) from denudation and magmatic addition estimates. Lithosphere, 7, 589-600.


Watterson, P. A., Mahat, S., Cunnell, C., and Ramsumair, R., 2015, Increasing acquisition efficiency by acquisition of data during turns, using a multi-measurement streamer. 77th EAGE Conference & Exhibition, Extended Abstract

Figure 3. Uplift comparison showing A: the initial smooth starting model vs. B: FWI output updated model illustrating the improved velocity resolution around the shallow intervals, and C: Kirchhoff prestack depth migration depth stack cross section overlaid with the near-final velocity model highlighting how image quality, event continuity, and overall image sharpness from shallow through to deep intervals benefited from the accurate shallow velocity model and subsequent CIP tomography updates.