Low-Fold 3D Seismic: A Key to Unlocking Exploration Potential Cost-Effectively in the Eromanga Basin

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SUMMARY

ATP 636 is a lightly explored permit on the eastern margin of the Cooper-Eromanga Basin, more than 60km northeast of the Jackson Oil Field in South-West Queensland. Prior to award of the permit, heritage seismic data was very limited and no wells had been drilled within the permit area.

Low-fold 3D seismic was acquired (the “Gumbo 3D”) in place of a more conventional program of 2D seismic followed by 3D seismic. The location of the low-fold 3D seismic survey within the permit was determined using play-based exploration principles.

The seismic data quality compares favourably with full-fold 3D seismic from a structural perspective and provides good imaging of faults and key stratigraphic units. The result is a robust interpretation and a well-defined inventory of prospects and leads.

Key words: 3D Seismic, Low-Fold, Eromanga Basin, Exploration.

INTRODUCTION AND REGIONAL SETTING

ATP 636 (“The Permit”) is a lightly explored permit on the eastern margin of the Cooper-Eromanga Basin, more than 60km north-east of the Jackson Oil Field in South West Queensland. Prior to award of the permit, heritage seismic data was very limited and no wells had been drilled within the permit area. Heritage seismic within the permit was 2D data of mixed vintage, with line spacing varying from 4km up to 20km in places (Figure 1).

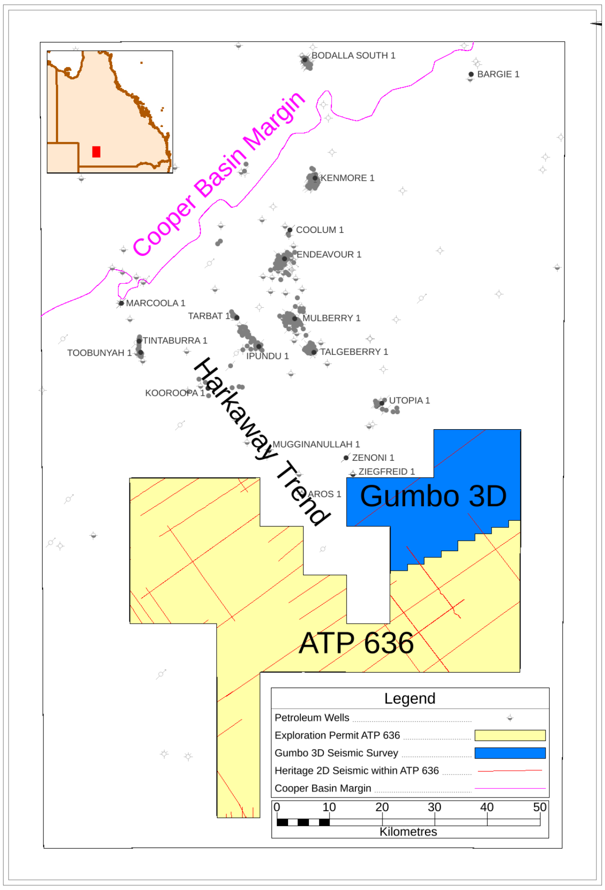

Figure 1. Reference Map for ATP 636, showing the Gumbo 3D and heritage 2D seismic within the permit (*inset: map location*).

The targeted play in this region is oil reservoired in Jurassic-Cretaceous Eromanga Basin sandstones, trapped primarily in 4-way dip anticlines. Potential reservoirs include Birkhead Fm, Hutton Sst, Murta Mbr and Wyandra Sst (Figure 2). Charge is interpreted to come primarily from the Permian coals of the Cooper Basin, with the source kitchen located to the north-west of the permit area. The Cooper Basin section is truncated by the Base Eromanga Unconformity before reaching the permit area. Hydrocarbon charge was from the Cooper Basin sub-crop edge, with migration along carrier beds within the Eromanga Basin section, similar to that described by Heath *et al* (1989). This charge mechanism has been proven by multiple nearby oil fields such as Tintaburra, Kooroopa, and Utopia, with oil discoveries extending more than 50km from the Cooper Basin sub-crop edge. Geochemical analysis (Plummer, 2013) indicates that local Jurassic source rocks are also contributing to charge in some nearby fields.

Play analysis indicates that the key geological risk for prospects in ATP 636 is charge, due to the distance from the source kitchen. The closest commercial oil discovery to ATP 636 is the Utopia Field, however the migration pathway into this field is poorly constrained by sparse seismic data in places. Spill from the Utopia Field is believed to be the source of the oil shows and discoveries in the nearby Zenoni-1 and Ziegfreid-1 wells, and could also provide charge to the north-eastern portion of ATP 636. Located on the northern flank of the Harkaway Trend, the north-eastern area of ATP 636 is interpreted to have the lowest charge risk, and was chosen as the focal area for the first phase of exploration.

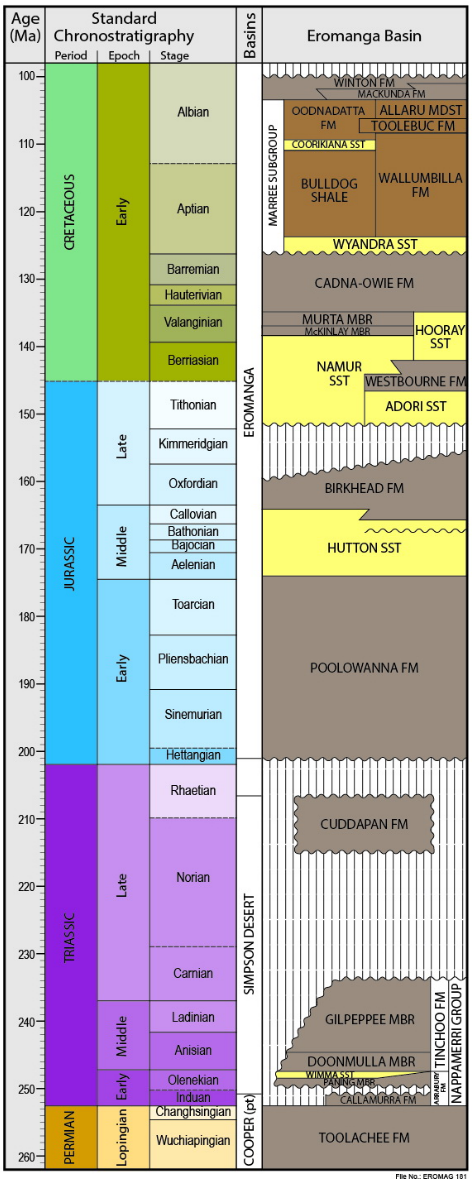

Figure 2. Stratigraphic chart of the Eromanga Basin.

Due to the sparse 2D seismic coverage, additional seismic data was required to address the closure (structural) risk in ATP 636. A standard exploration program in an area of little data might include regional 2D seismic to identify the gross structural form, followed by infill 2D seismic to identify key leads, 3D seismic to mature leads to drill ready prospects, then drilling of key prospects. While some nearby wells have been drilled on 2D seismic data, the success rate is significantly higher with 3D seismic, particularly in areas where misties may be of similar magnitude to the vertical relief of the structures. Sufficient heritage 2D seismic data already existed to identify the gross structural form, with the Harkaway Trend interpreted to be running through the middle of the permit.

Initially, a 2D seismic program was planned as the first exploration activity in ATP 636, however local rain and flooding of the Gumbo Gumbo Creek system in early 2014 resulted in the program being cancelled. Following cancellation of the 2D survey, a strategic decision was made to shorten the exploration phase by instead acquiring a low-fold 3D seismic survey, with acquisition completed in early February 2015.

As the targets in this area are primarily 4-way dip anticlines, low-fold 3D was determined to be adequate to map these features to a high level of confidence. It provides a higher density of data than 2D seismic, access to 3D seismic migration, and no misties. With lower data density than most modern 3D seismic surveys, this low-fold 3D might not be appropriate for areas where AVO analysis is required, or attributes are used to define reservoir presence, but it is an ideal fit for purpose solution to structural uncertainty.

As low-fold 3D seismic is approximately 60% of the cost of full-fold 3D seismic, a larger seismic survey was able to be acquired for a similar price to a focussed full-fold survey, and the infill 2D seismic phase was completely avoided, resulting in a net time and cost saving. Bypassing the infill 2D seismic phase also reduces cycle time from first exploration expenditure to prospects being drill-ready. Additionally, by acquiring a larger 3D seismic survey at low-fold, a larger number of leads may be matured to drill-ready than from a smaller focussed 3D survey.

SEISMIC ACQUISITION AND PROCESSING

The Gumbo 3D survey design is a low-fold survey aimed at providing structural information over a large area whilst remaining cost effective in comparison to conventional development 3D acquisition. In order to image the relatively shallow target, sources were recorded along both conventional source and receiver lines to provide additional near traces. The other benefit of acquiring source points along the receiver line is to provide high fold lines in a north south direction, every 320m, providing more stable imaging, statics and velocity control.

This low-fold 3D or "2.5D" seismic survey was designed purely for structural imaging. In preference to recording a sparse grid of 2D lines, a low-fold 3D survey was designed to allow for coverage of a large area at economical rates. The subsequent final volume is to be used for structural interpretation. If there is interest in attributes and a justification for further resolution, a smaller targeted, high resolution or conventional 3D survey could be designed and recorded covering that area.

The processing of the pre-stack data was similar to a conventional 3D survey. The exception, due to the sparse spatial sampling and low fold, was that no regularisation, interpolation or pre-stack migration was attempted.

The noise in this survey is quite strong although it can be at least partly attributed to the terrain on which the survey was recorded. The majority of the coherent noise was attenuated pre-stack but some residual noise remaining had to be removed post stack with conventional processes of trace mix and band pass filtering.

The disadvantage of the acquisition design is a very strong footprint, particularly in the receiver line direction enhanced by the additional source lines in that orientation. This is also compounded by the fact that the target is shallow where the footprint is stronger. Various processes were attempted to reduce this amplitude induced footprint, both pre-stack and post stack. Many of the options tested were not effective due to the poor spatial sampling. Fold of stack compensation had a partial improvement but a cross line scalar, direction of cyclical amplitude variation, provided additional amplitude balancing. Applying this post stack provided the best outcome as did a mild three trace mix, the latter not strong enough to be any detriment to the spatial resolution.

SEISMIC INTERPRETATION AND PROSPECTIVITY

The final processed volume of the Gumbo 3D was received in January 2016 and interpretation commenced immediately. Data quality is good and compares favourably to 3D seismic data quality from nearby higher fold surveys. Multiple volumes were produced for use in interpretation, each with slightly different noise attenuation parameters. The smoothest volume was used for horizon and key fault interpretation, while a slightly noisier volume that showed more detail was used to cross-check correlation and vertical extent of faults. Both volumes were structurally consistent (Figure 3).

Key horizons interpreted included the Cadna-owie Fm, the Murta Mbr, the Westbourne Fm and Basement. The Birkhead Fm and Hutton Sst were unable to be interpreted due to poor reflectivity at that stratigraphic level; a problem common to most seismic surveys in this region.

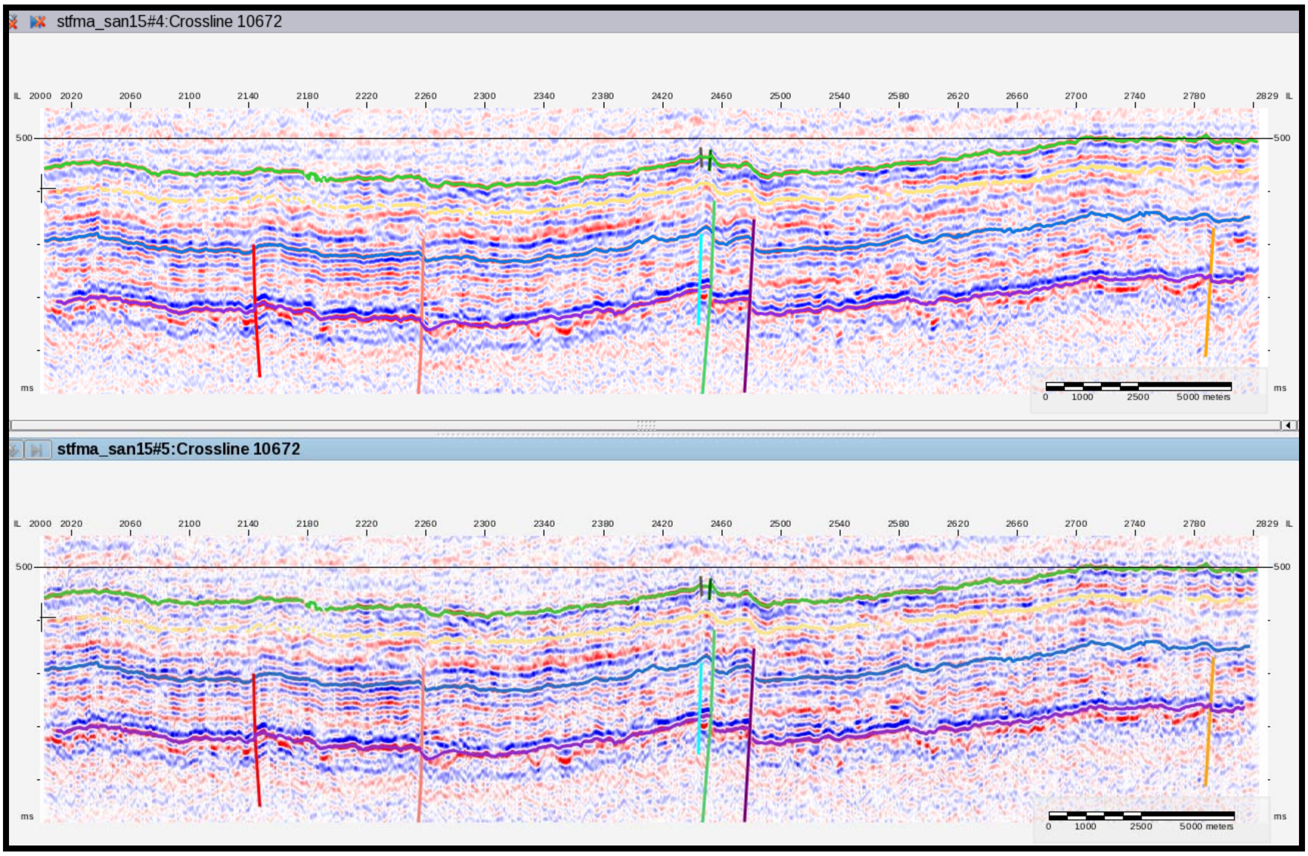

Figure 3. Crossline 10672 through the Gumbo 3D. The two panels show the same crossline and interpretation, but with different seismic volumes. The top panel is the smooth volume used for horizon and fault interpretation, while the bottom panel is the volume used to cross-check fault correlations and vertical extent. Green horizon = Cadna-Owie, Yellow = Murta, Blue = Westbourne, Purple = Basement.

Three key prospects have been identified from the new seismic, along with three leads (Figure 4). The prospects have been named Jambalaya, Roffignac and Beignet.

The Jambalaya Prospect is a 4-way dip anticline located over a basement trap-door feature in the centre of the seismic survey, on a NNW trending anticline which plunges towards the Utopia Field. It has vertical relief of up to 30ms at the Westbourne Fm.

The Roffignac Prospect appears to be draped over a steeply dipping Adavale Basin basement feature, with vertical relief of more than 35ms at the Murta Mbr. The Hutton Fm appears to onlap the flanks of the basement feature and is expected to be absent on the crest, although the other reservoir targets are all interpreted to be present.

The Beignet Prospect is located on a bend in a large regional NNW trending fault. It has vertical relief of up to 20ms at the Cadna-owie Fm.

Isochron mapping suggests that both Jambalaya and Roffignac were in a position to receive charge spilling from Utopia at time of generation and migration, although a region of particularly sparse 2D data to the north of ATP 636 makes the exact spill-point uncertain. Structural reactivation during the Tertiary (Shaw, 1991), which would have caused some restructuring and tilting of the nearby fields (including Utopia), may have resulted in a later spill of hydrocarbons with potential for migration into Jambalaya and Roffignac at that time. Beignet is interpreted to be in a position to receive charge from Roffignac, if the prospect was full to spill, both at time of generation and following Tertiary reactivation.

Estimates of oil in place will vary depending on thickness of reservoir and percentage fill, but the Jambalaya and Roffignac structures are estimated to be able to hold up to 4.1mmbbls and 4.7mmbbls, respectively, of oil in place at the Murta level alone. The Murta Mbr is the key producing reservoir in the Utopia Field, although oil is also reported to have been intersected in the Birkhead and Hutton at Utopia 17 (Bounty Oil and Gas NL, 2013).

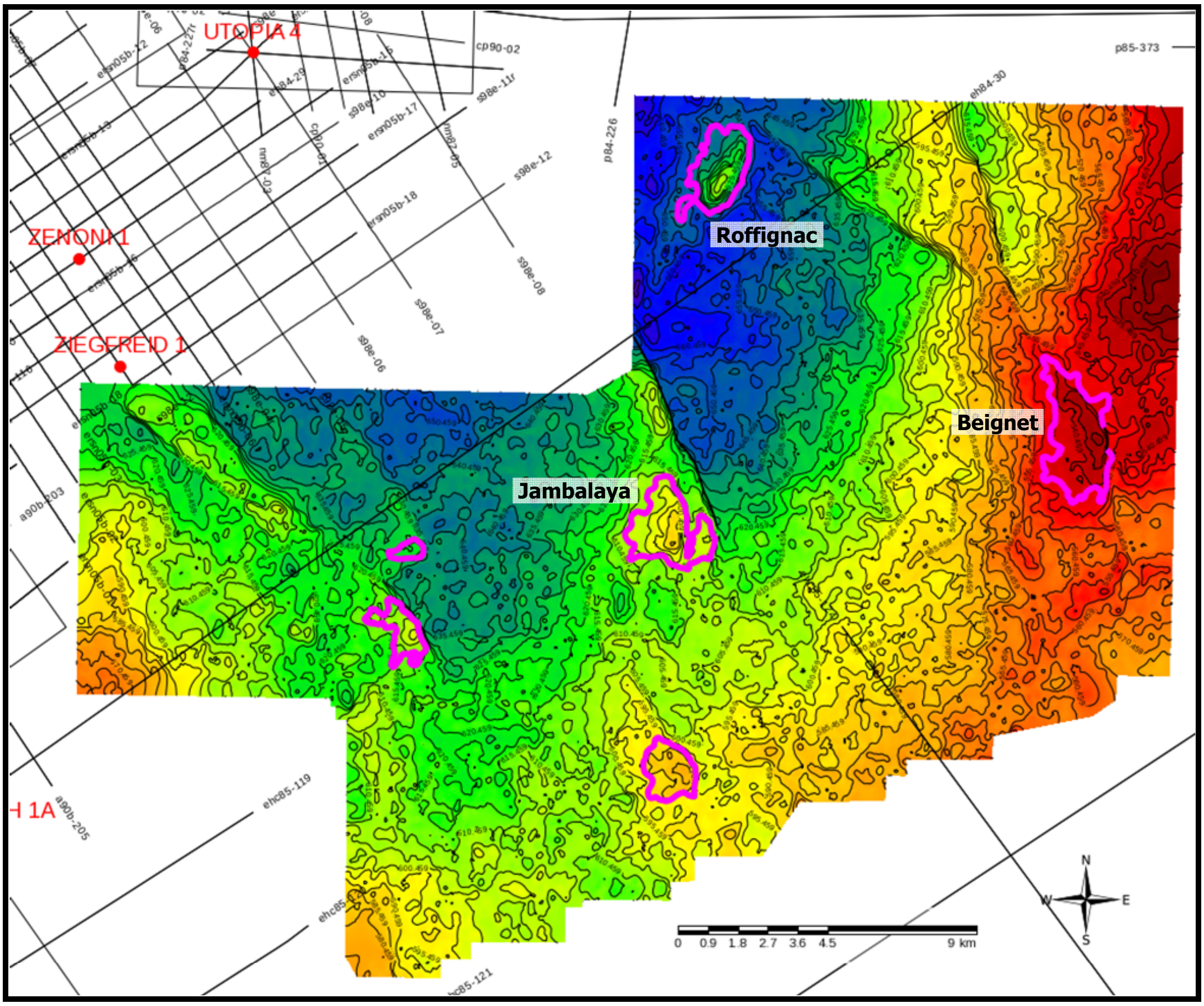

Figure 4. Murta Mbr TWT map, showing the identified prospects and leads.

CONCLUSIONS

The low-fold Gumbo 3D seismic survey is a good quality data set that compares favourably with full-fold 3D seismic, from a structural perspective, and resulted in good imaging of faults and key stratigraphic units.

It provides a higher density of data than 2D seismic, the ability to apply 3D seismic migration, and no misties. With lower data density than most modern 3D seismic surveys, this low-fold 3D might not be appropriate for areas where AVO analysis is required, or attributes are used to define reservoir presence, but it is an ideal fit for purpose solution to structural uncertainty.

Bypassing the infill 2D seismic phase by instead acquiring low-fold 3D also reduces cycle time from first exploration expenditure to prospects becoming drill-ready. The prospects and leads mapped on the Gumbo 3D would not all have been identified by the original planned 2D seismic survey. Additionally, by acquiring this larger 3D seismic survey at low-fold, more leads were matured to drill-ready than would have been matured from a smaller focussed 3D survey.

This style of seismic survey would be ideal for mapping large areas with little pre-existing seismic data at a moderate cost, particularly where structures may be subtle or small enough to be missed by a coarse 2D seismic grid.

ACKNOWLEDGMENTS

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