RL3 & RL4

Amadeus Basin

2017 Ooraminna 2D Seismic Survey Interpretation Report

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1. Project Summary

The following report details the reprocessing of the 2007 Ooraminna 2D Seismic Survey, conducted in 2017. The survey area is located approximately 50km SE of Alice Springs, NT, over a pronounced surface anticlinal feature encompassed by RLs 3 and 4 (Figure 1).

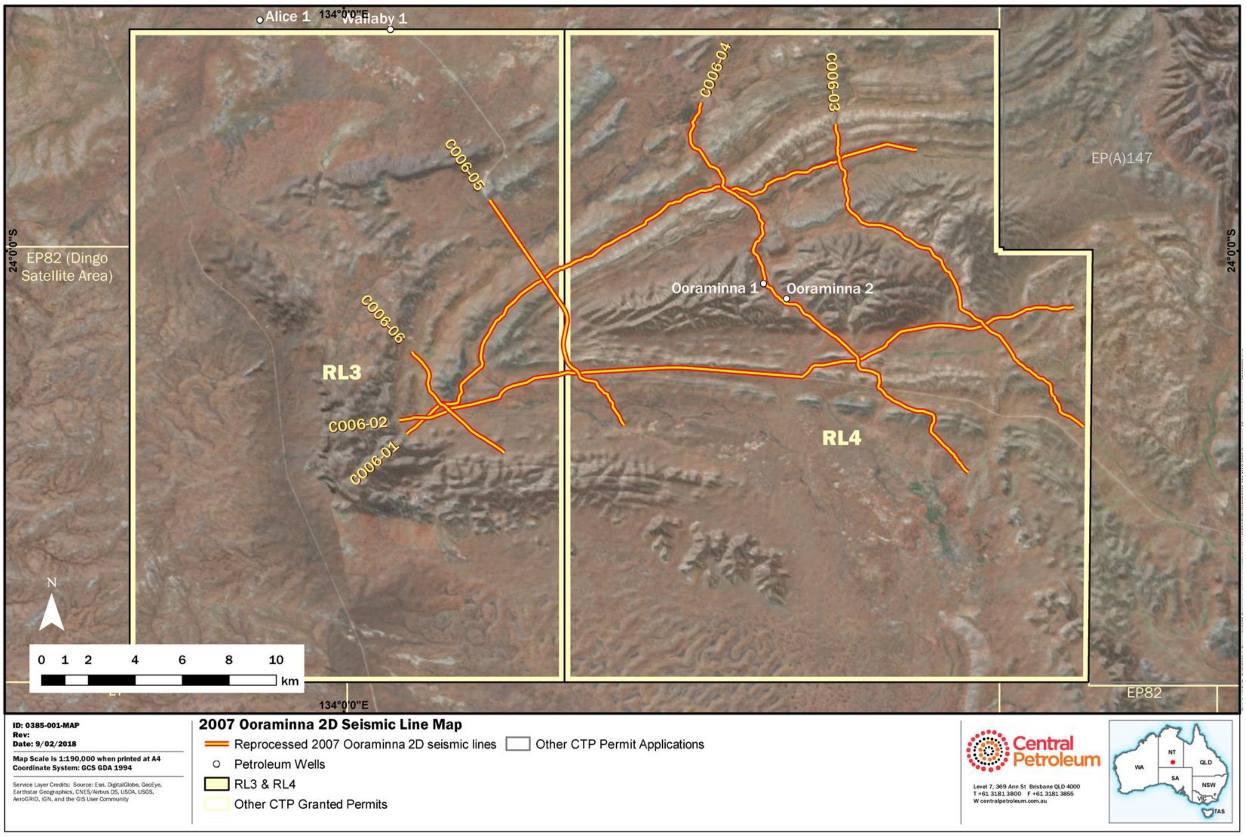

Figure 1: 2007 Ooraminna 2D Seismic Survey location map

The survey consists of 4 N-S dip lines and 2 longer E-W strike lines across the structure, comprising 110km coverage in total. A line listing is shown in Table 1.

Table 1: Ooraminna 2D seismic line listing

Line Name	SP Range	CMP Range	Total Length (km)
CO06-01	220-1250	440-2500	25.75
CO06-02	220-1330	440-2660	27.75
CO06-03	200-910	400-1820	17.75
CO06-04	200-1072	400-2144	21.8
CO06-05	190-650	380-1300	11.5
CO06-06	201-434	401-868	5.83
			110.4 km

1.1. Acquisition Parameters

Source array:	25m (Hemi 60 vibs, 12.5m pad-pad centred on station)
Sweep:	1x12s (5-60Hz monosweep, 200ms taper)
Receiver array:	25m (12 phones with 2.08m spacing)
Sample rate:	2ms
Record length:	6s
Channels:	300
Offset:	3737.5 – 12.5 – 0 – 12.5 – 3737.5m
Fold:	150

1.2. Data Processing History

The Ooraminna 2D seismic survey was originally processed by Just Geo (Houston) in 2007. Select lines were reprocessed by Fugro (Perth) in 2010 in support of drilling the Ooraminna 2 well. However, this current reprocessing effort is the first time all 6 lines from the survey have been reprocessed. The processing history of the seismic survey is summarised in Table 2 along with an indication of the seismic line on which the two existing petroleum wells, Ooraminna 1 and 2, have been drilled.

The reprocessing work was conducted by Velseis Processing (Brisbane) between 2nd May and 22nd June 2017. The contractor's Final Processing Report is included with this report.

Table 2: Ooraminna 2D reprocessing history

Line	2007 Just Geo	2010 Fugro	2017 Velseis	Wells drilled on line
CO06-01	X	X	X	
CO06-02	X		X	
CO06-03	X		X	
CO06-04	X	X	X	Ooraminna 1 and 2
CO06-05	X		X	
CO06-06	X		X	

1.3. Reprocessing Objectives

The reprocessing of the Ooraminna survey in 2010 demonstrated the profound uplift achievable with the original acquired data. However, only 2 of the 6 survey lines were reprocessed; the key dip line that was drilled that year (CO06-04), and an intersecting strike line (CO06-01). Hence the chief objective of this current reprocessing effort was to refresh the entire survey ahead of drilling activity on another area of the Ooraminna structure, and potentially also improve on the 2010 reprocessing result.

Geologic challenges in the area include:

- High geologic dips
- Varying surface elevations
- Varying continuity of reflectors observed on seismic

Reprocessing objectives included:

- Improving noise attenuation through new techniques not available when the dataset was first processed
- Improving lateral continuity through more careful statics and velocity analysis
- Image structural complexity through selection of optimal migration algorithm and dip/aperture parameters
- Careful attention to retaining low-frequency content through the workflow
- General improvement in reflector continuity

Improved reflector continuity was desired to increase confidence in:

- Correlation of horizon interpretation between lines
- Final mapped grid depth and geometry
- Curvature analysis to predict areas of greatest fracturing on the final grid
- Geomechanical and fracture modelling performed on the final Pioneer surface to inform well planning
- Well path design for the upcoming well

1.4. Reprocessing Results

The objectives set for the project have been met by the reprocessing effort. Figure 2 shows a comparison of migrated stack deliverables for line CO06-05 from both processing efforts, with the reprocessed result showing clearly more continuous reflection events on both limbs of the anticline and structural information deeper within the core. Seismic events can be more confidently correlated from line to line due to more recognisable seismic character, and the Areyonga Movement (Figure 3) can be more easily recognised in the thickness variation between the Pioneer and Loves Creek interpreted horizons. The improved reflectivity in the shallow section from Arumbera and above has also enabled more confident correlation with outcrop data and with NTGS' surface geological mapping.

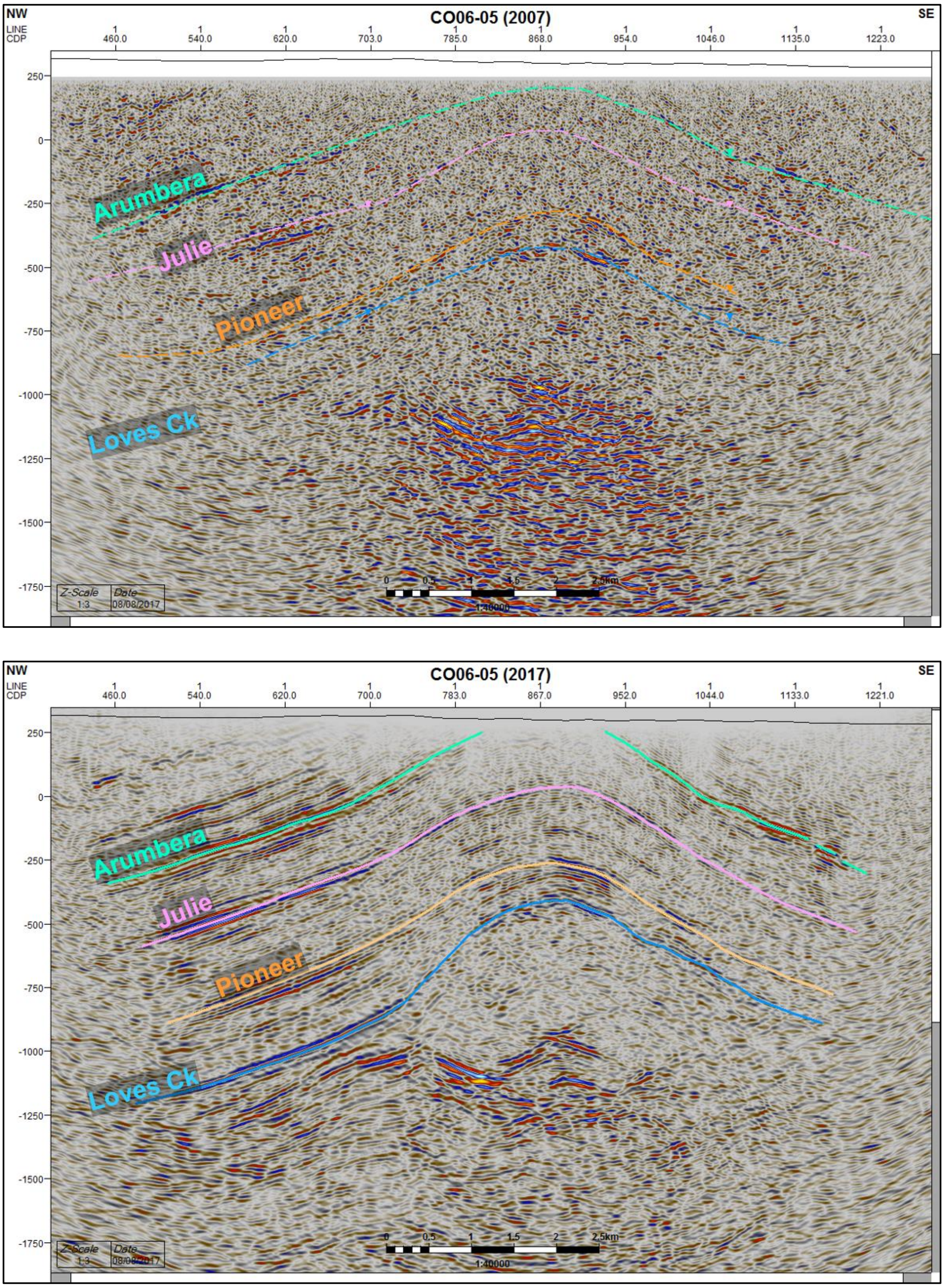

Figure 2:Comparison of migrated stack data (TWT) for line CO06-05 from 2007 processing (top) and 2017 reprocessing (bottom) with key horizons annotated

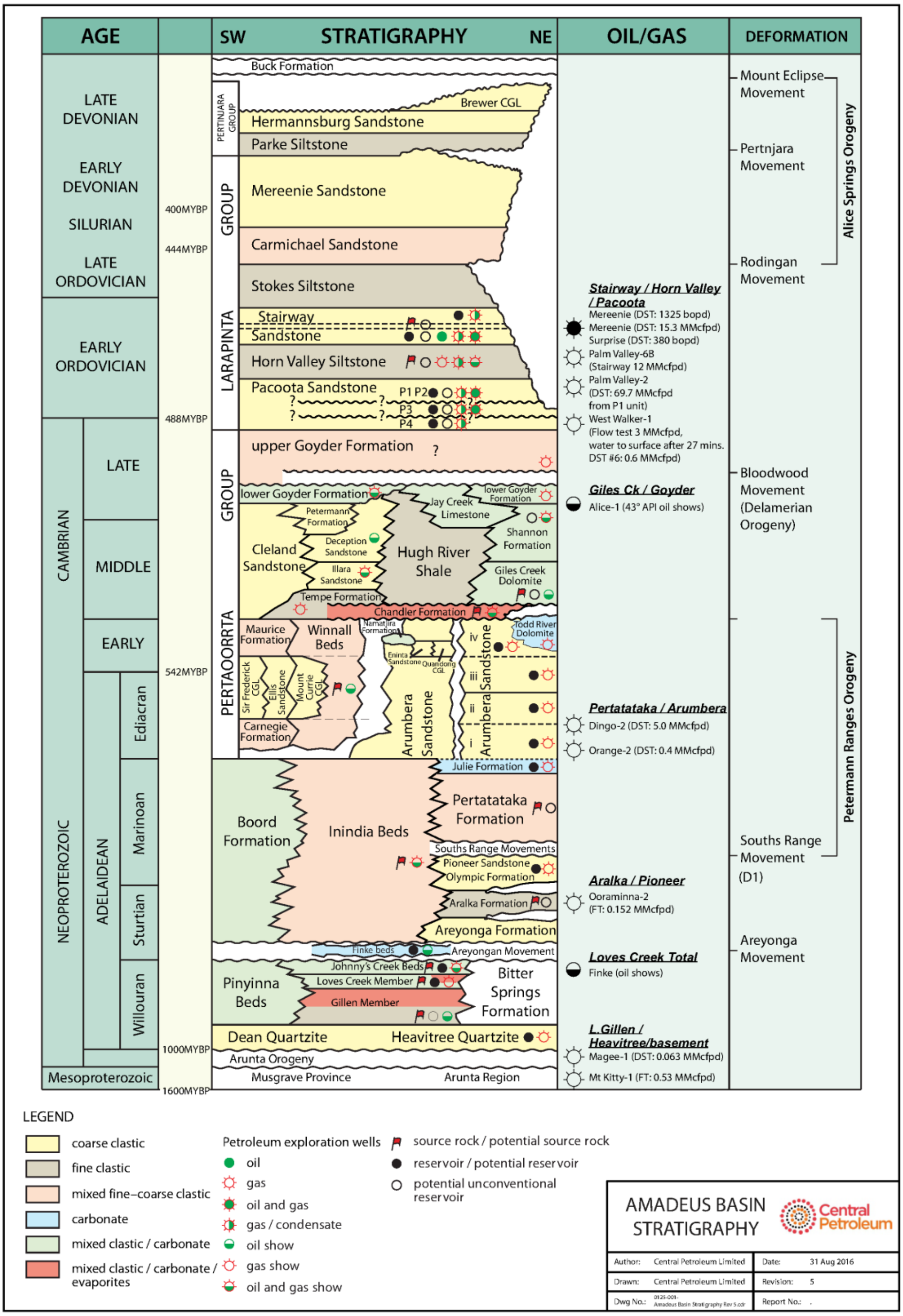

Figure 3: Amadeus Stratigraphic Column

2. Seismic Interpretation

The reprocessed seismic exhibited a clear uplift from the original 2007 processing as was hoped, showing much improved reflector continuity and signal-to-noise ratio. Velocity and static solutions were also verified by showing good alignment of seismic pre-migration stack character at line intersections after independent derivation of results on a line by line basis. The dataset was loaded to Schlumberger's Petrel seismic interpretation software for horizon interpretation, gridding and depth conversion.

The seismic data was loaded for interpretation as below:

- Time of first sample: -330ms
- Polarity retained during processing
- Data supplied as minimum phase

Interpretation of the data was enhanced not only by the reprocessing, but also by observations able to be made from outcrop data across the prospect. A problem in previous interpretations has been the sparseness of dip lines across the structure, leading to gridding algorithms tending to produce 'bulls-eyes' around the dip lines; particularly between CO06-04 and CO06-05. However, the late structuring relative to deposition at Ooraminna means reflectors are generally sub-parallel down to the Pioneer reservoir, implying the structure at the reservoir level should be relatively consistent with the structure evident in surface outcrop. To reflect this in the gridding of horizons, a rectangular grid size was chosen with a rotation to align the long dimension of the grid with the anticlinal axis (7° anti-clockwise from East). Initially, the horizon interpretation was gridded at a cell size of 4000x1000m to capture the gross anticlinal structure and avoid bulls-eyeing around the dip lines, then was re-gridded at 400x100m using the coarse grid as influence and incorporating available horizon interpretation from surrounding seismic to control grid extrapolation. The subsequent Pioneer grid aligns fairly well with structure observable from outcrop, as shown by the conformance of the Pioneer depth contour lines to outcrop patterns in Figure 4 below.

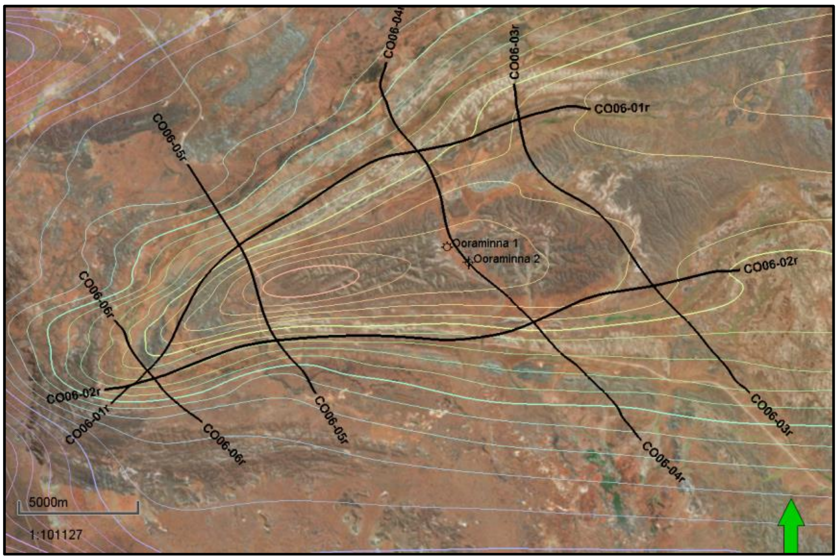

Figure 4:Pioneer depth structure map (100m contours) showing close alignment to outcrop structure from surface imagery

Additionally, as the Arumbera Sandstone outcrops in the core of the Ooraminna structure, this provided an additional constraint to the gridding process for this horizon, where a polygon picked around the outcrop boundary was set to surface elevations and used as additional input to the depth gridding process. All elevations within this polygon, i.e. the core of the structure, were set to surface elevation post-gridding (Figure 11).

2.1. Horizons Interpreted

Interpreted horizons are shown in Figure 9 and Figure 10 and their rationale are listed in Table 3.

Once all horizons were interpreted, mis-tie analysis was applied to resolve the mis-ties present at the 2D seismic line intersections post-migration. The mis-ties were calculated directly from each interpreted horizon, with the interpretation along line CO06-05 kept fixed as the reference point to which the interpretation on the remaining lines was tied to.

Table 3: Seismic horizons interpreted

Formation/Surface	Rationale for mapping
Giles Creek	Inferred on anticlinal limbs only, used to tie to outcrop observations
Arumbera Sst	Recognisable seismic marker, outcrops in core of Ooraminna structure which provides additional surface mapping control
Julie Fm	Next recognisable seismic marker below Arumbera
Pertatataka Fm	Last major seismic marker above target interval, with the significant intervening section being devoid of regionally recognisable seismic events
Pioneer Sst	Top of target interval
Areyonga Unc.	Neoproterozoic movement most evident on the northern limbs of dip lines
Loves Creek Mbr	Picked as final event in a series of reflectors at the transition to marine deposition below
Gillen Mbr	Final seismic reflector sub-parallel to main anticlinal structure. Below this is believed to be Gillen Salt, which decouples the simple anticlinal structuring above from the more brittle and complex deformation structures below

2.2. Well Ties

The key well used to tie to seismic was Ooraminna 2, which is located on seismic line CO06-04 (Figure 1). The resulting synthetic trace is shown in Figure 5. The synthetic trace is a reasonable match to the seismic over the Areyonga Fm to Loves Creek interval, but less so over the shallower Pioneer/Aralka interval. However, the strong deflection in the sonic log at the top of the Pioneer is believed to coincide with the strong amplitude event observed on the seismic. Below this, where the seismic exhibits strong amplitude events while the synthetic is relatively quiet, may be attributable to a difference in the ‘ringiness’ of the seismic wavelet vs the wavelet used to generate the synthetic trace. A plot of the synthetic trace is shown on line CO06-04 with well tops and gamma ray logs along Ooraminna 1 and 2 (converted to TWT) in Figure 6. This shows the character match of the synthetic trace to the seismic and confirms the time/depth relationship established from the Ooraminna 2 checkshot survey.

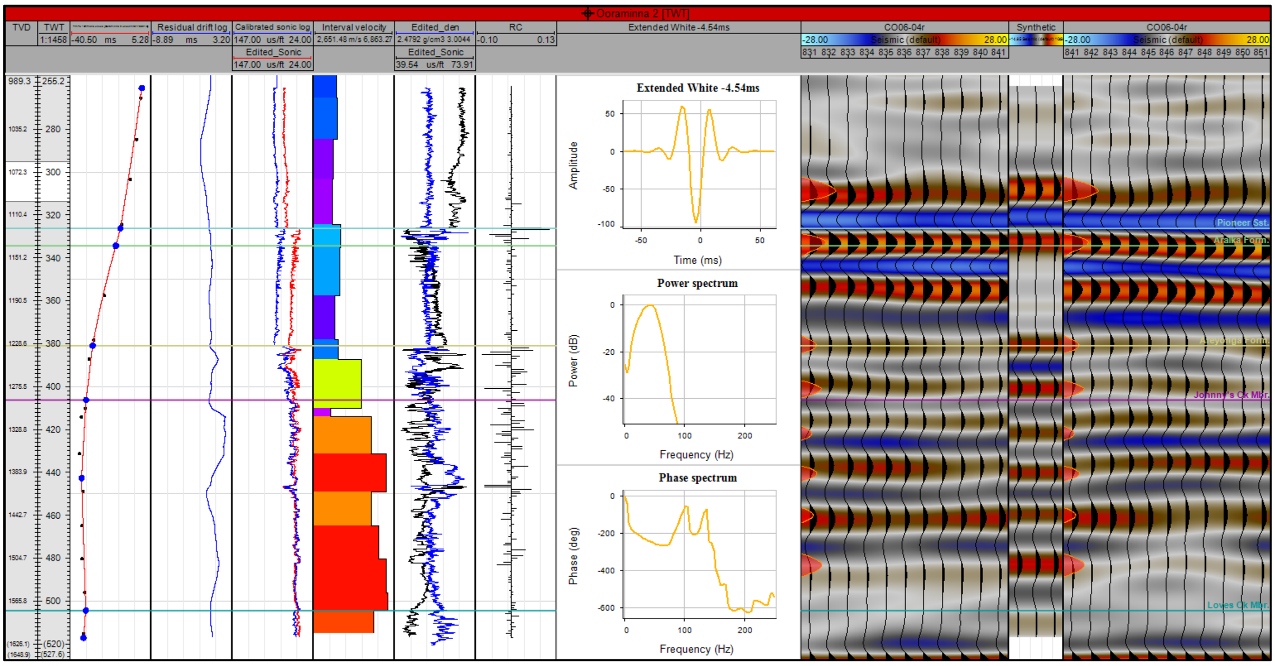

Figure 5: Synthetic trace generated at Ooraminna 2 along line CO06-04 (bulk shift of -4.5ms applied to the wavelet for a better character match)

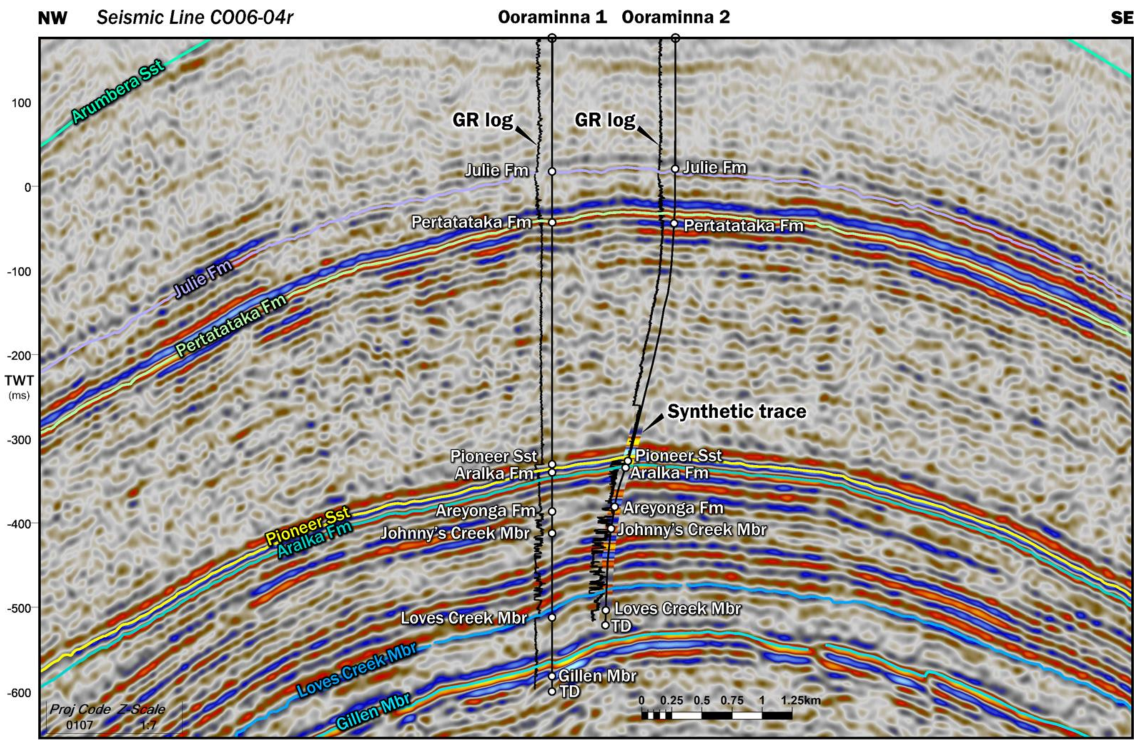

Figure 6:Ooraminna 2 synthetic trace plotted on line CO06-04 (msTWT), including well tops on Ooraminna 1 and 2 wells, gamma ray logs and horizon interpretation

2.3. Depth conversion

A velocity model was constructed using interval velocities derived from the Ooraminna 2 checkshot survey. Three distinct linear velocity trends were identified from the checkshot cross-plot (Figure 7) and assigned to corresponding time surfaces. Table 4 shows the identified interval velocities and the corresponding interpreted time surfaces they've been assigned to. A slightly faster interval velocity of 6000 m/s was selected to represent the interval beyond the checkshot depth.

An overlay of the resultant velocity model on line CO06-05 is shown in Figure 8, along with a 3D view of a timeslice through the final velocity model.

Depth structure maps were produced for the following intervals:

- Arumbera (Figure 11)
- Pertatataka (Figure 12)
- Pioneer (Figure 13)
- Loves Creek (Figure 14)
- Gillen Member (Figure 15)

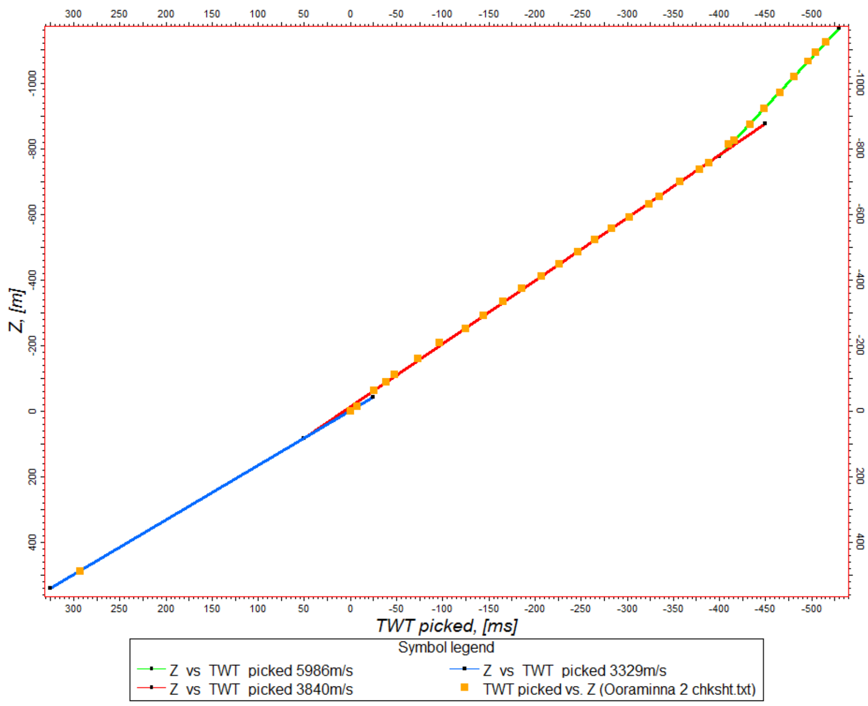

Figure 7: Cross-plot of checkshot time vs depth (orange squares) and subsequent interval velocity trends picked from the data: layer 1 (blue line) = 3329 m/s, layer 2 (red line) = 3840 m/s, layer 3 (green line) = 5986 m/s

Table 4: List of final interpreted surfaces and corresponding assigned interval velocities

Surface	Interval Velocity
Ground level	3329 m/s
Sea level	
Arumbera	3840 m/s
Julie	
Pertatataka	

Pioneer	5986 m/s
Aralka	
Loves Creek	
Gillen Member	6000 m/s

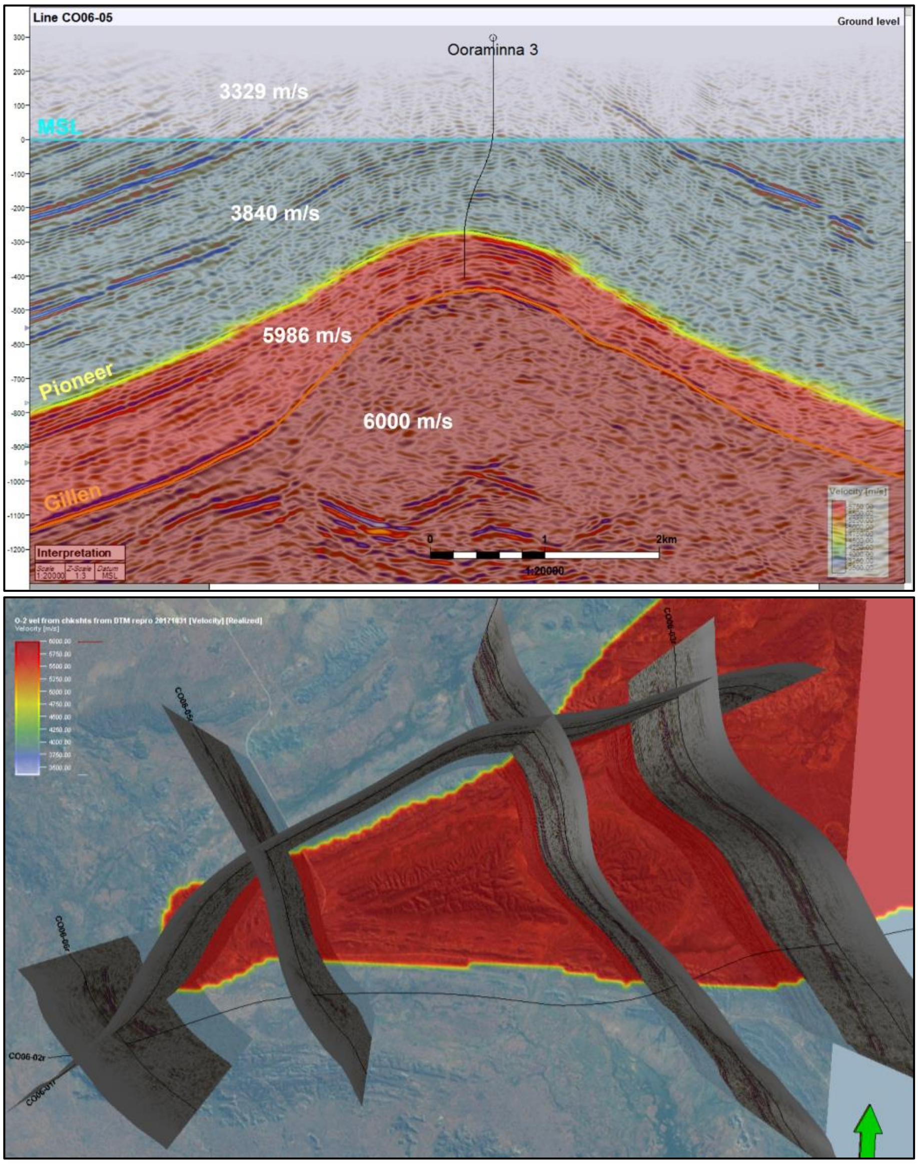

Figure 8: [Top] Seismic line CO06-05 with coloured overlay of the velocity model, showing horizons used to constrain the model and corresponding interval velocities. [Bottom] 3D view of a timeslice through the velocity model at 550msSS, showing conformity with the Ooraminna structure evident from seismic lines and surface imagery

3. Conclusions

- Reprocessing objectives of increasing signal-to-noise ratio, improved structural imaging and improved lateral continuity of reflectors were met.
- Improved reprocessing results enabled more confident tying of key reflection events from line to line and assisted in recognition of stratigraphic detail such as the Areyonga Movement.
- Choice of appropriate cell rotation and geometry, and staged gridding (coarse gridding followed by fine gridding) has resulted in good agreement between the final grid and structure evident from surface outcrop.
- A layer-based velocity model following interpreted horizons was used to convert all interpretation to depth. This should provide a more reliable depth converted result away from the Ooraminna 2 well and across the entire structure than a single function based on the checkshot data alone.
- The final Pioneer depth map (Figure 13) places the structural crest to the West of existing wells Ooraminna 1 and 2, and exhibits increased curvature in this direction. Increased curvature would suggest increased fracturing, which in turn should lead to improved fracture permeability, suggesting the Western nose of the Ooraminna structure may be a good focus for future drilling activity.
- Although outcrop data has been useful, to better constrain the geometry of the Pioneer reservoir interval, it is recommended that further seismic acquisition focus on additional coverage over:
    - the NW 'nose' of the structure, where the anticlinal axis protrudes through line CO06-01 and intersects to N end of line CO06-06
    - the mid-section of the structure, which would benefit from additional dip lines between lines CO06-04 and CO06-05, and perhaps a strike line down the axis of the structure
    - the E extent of the structure, to assist in constraining closure of the structure in this direction

Figures

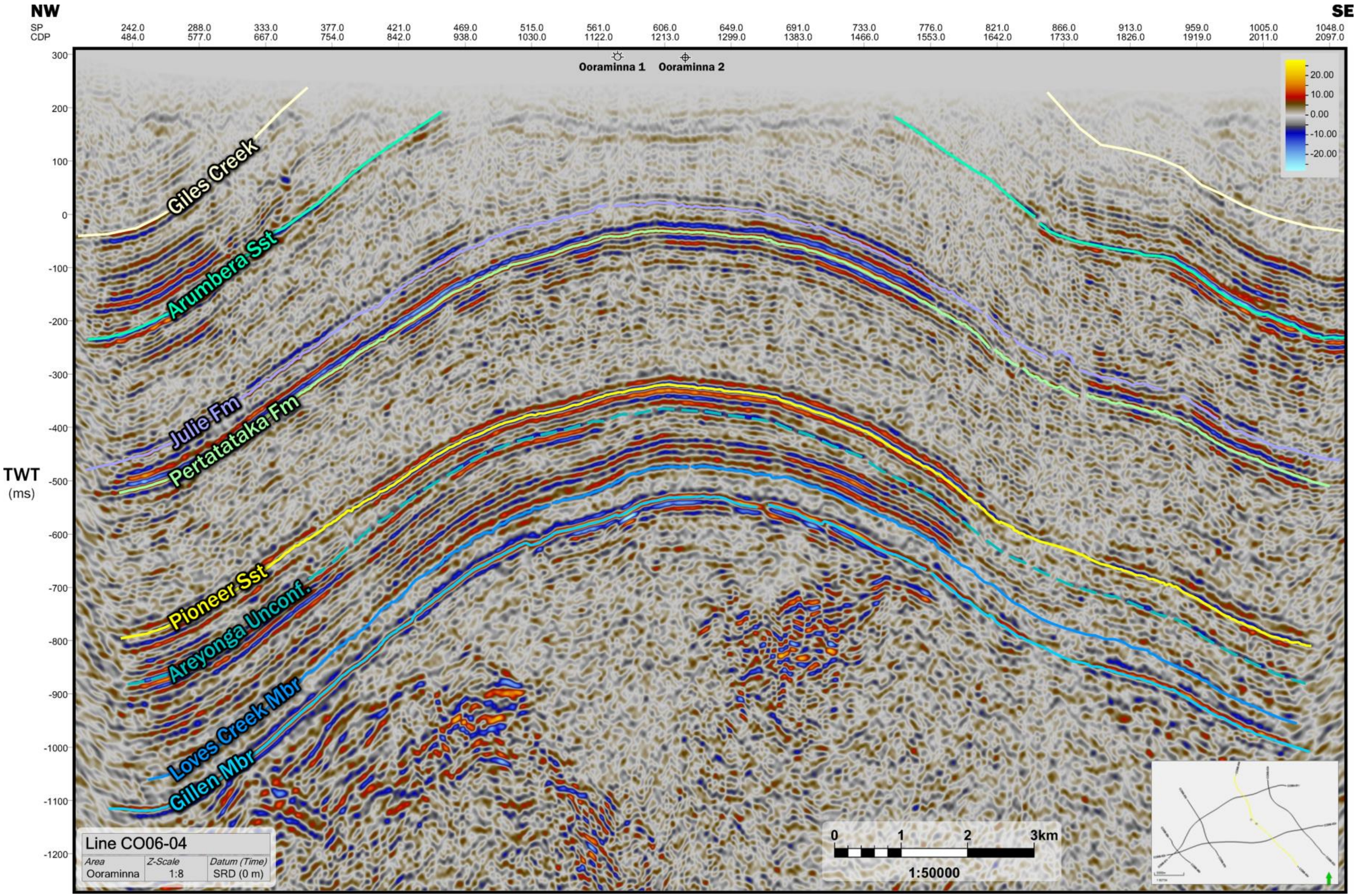

Figure 9: **Line CO06-04 with interpreted horizons (msTWT)**

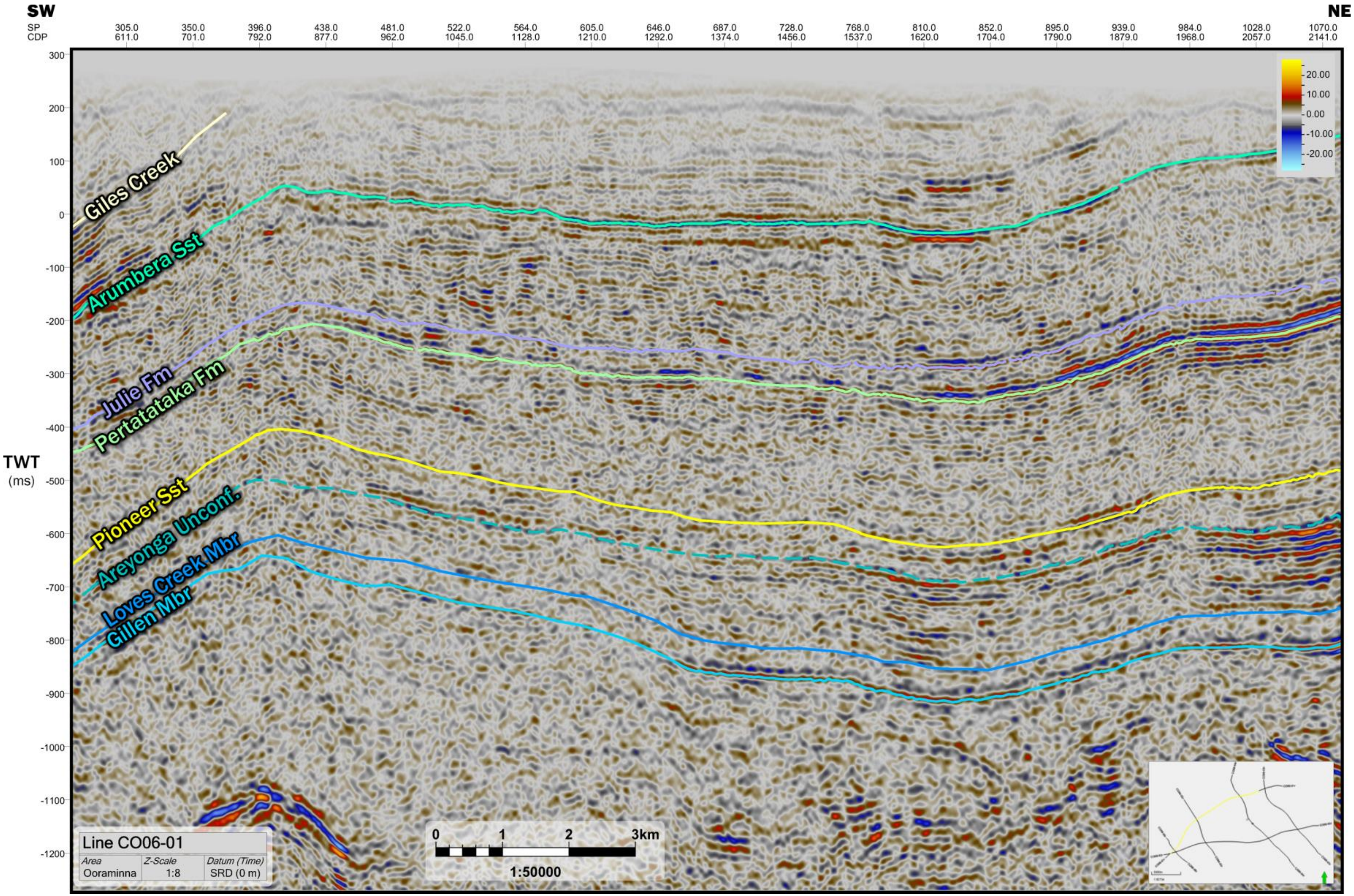

Figure 10: **Line CO06-01 with interpreted horizons (msTWT)**

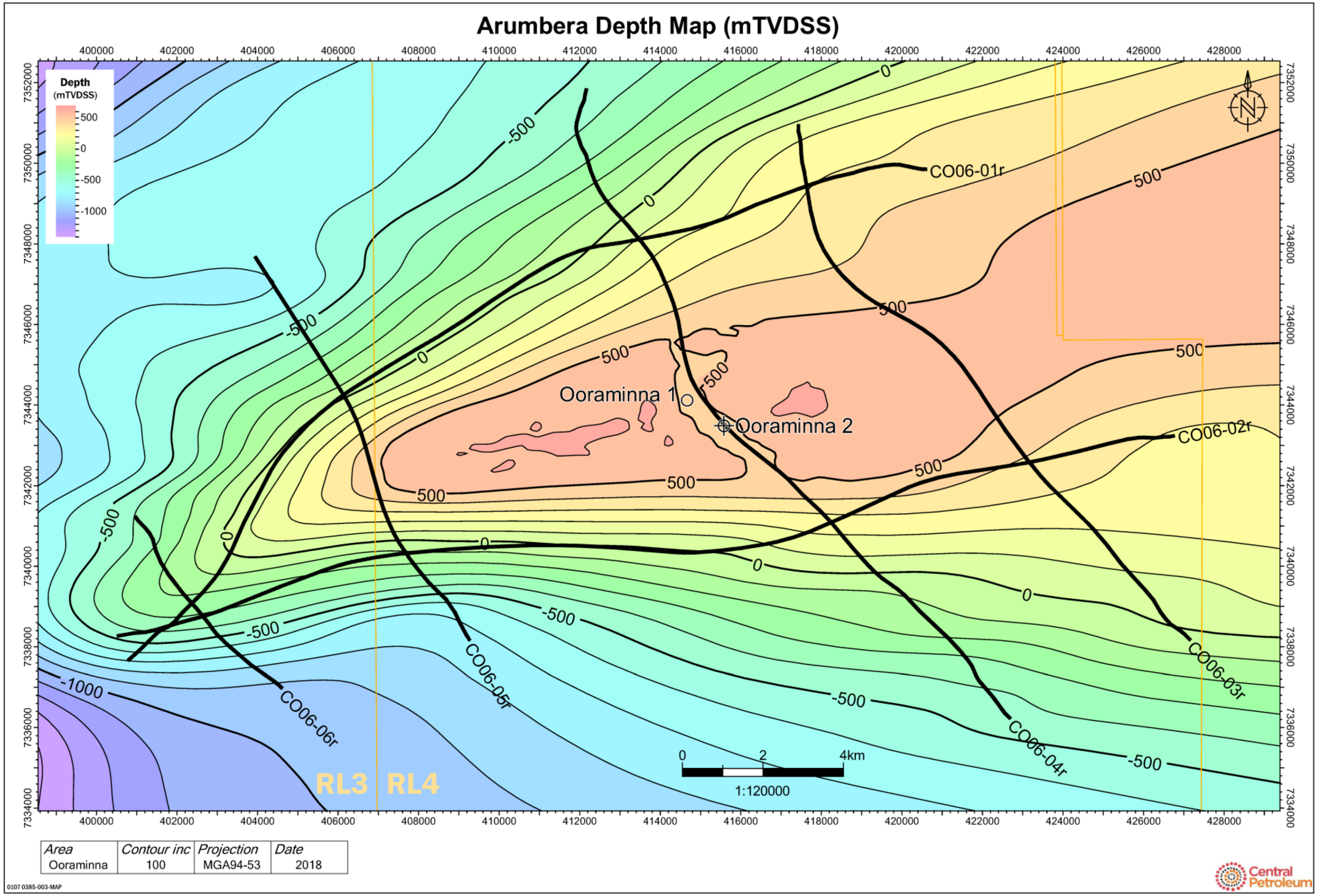

Figure 11: Arumbera depth structure map (mSS), incorporating elevation information at the core of the structure where Arumbera outcrops

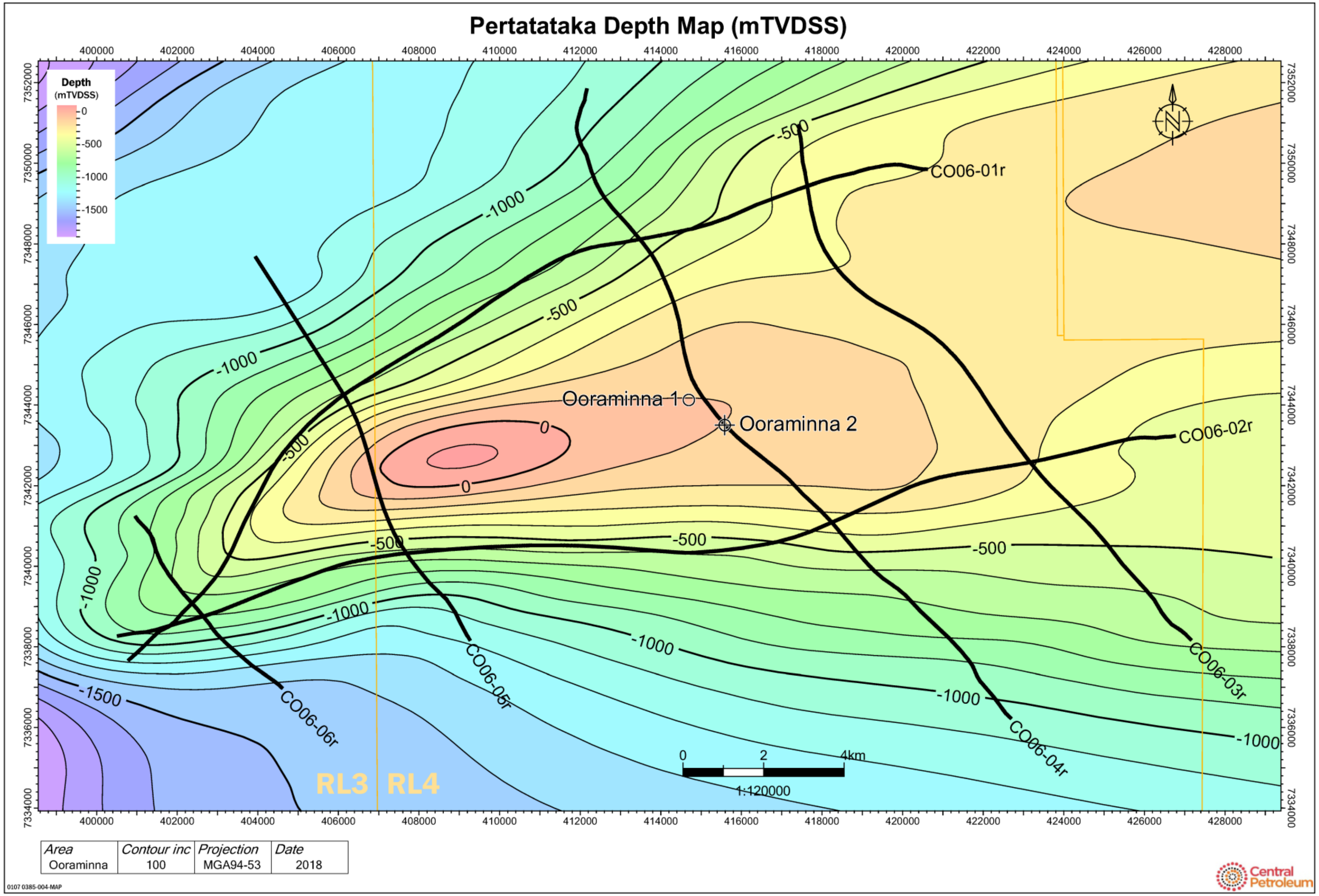

Figure 12: Pertatataka depth structure map (mSS)

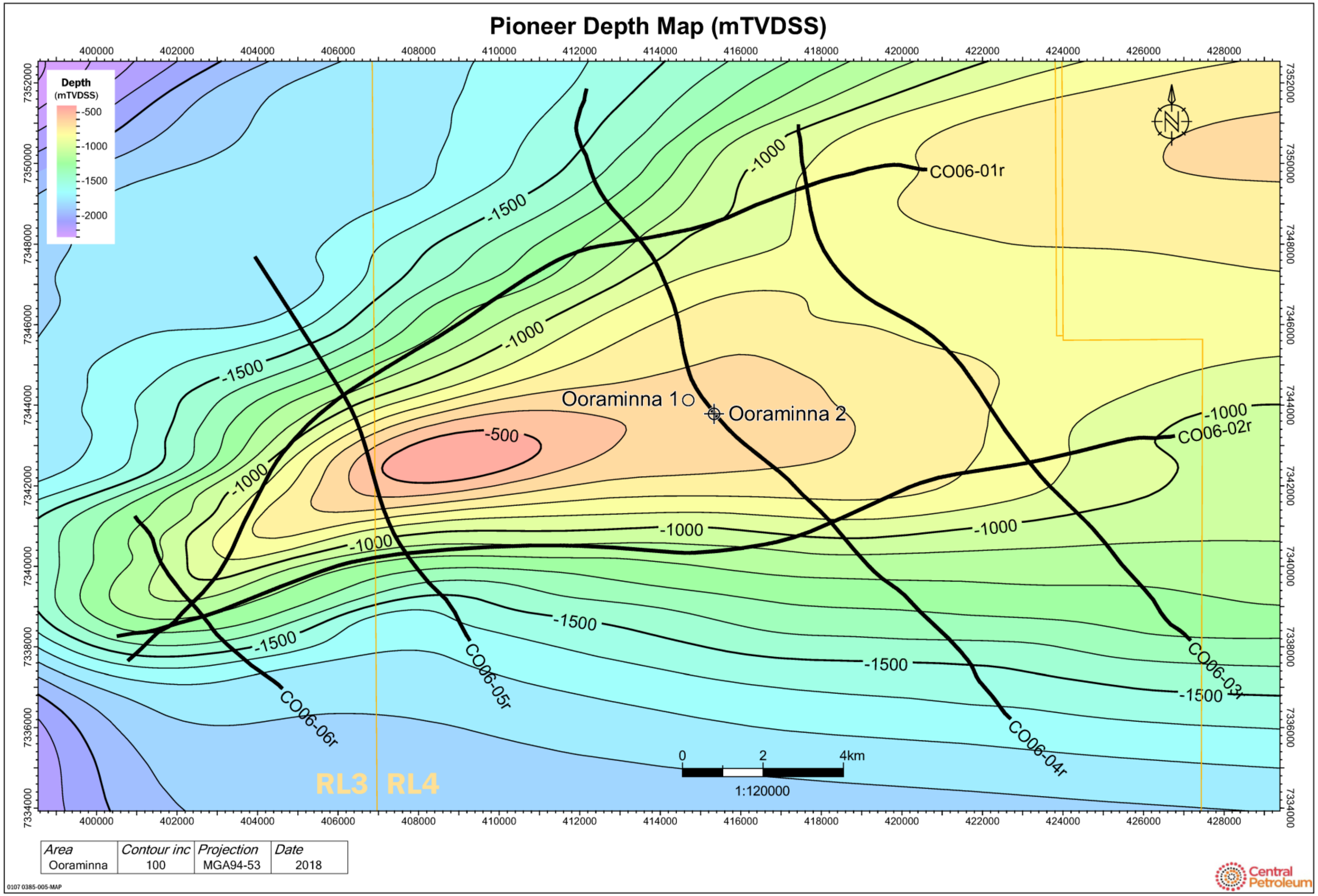

Figure 13: Pioneer depth structure map (mSS)

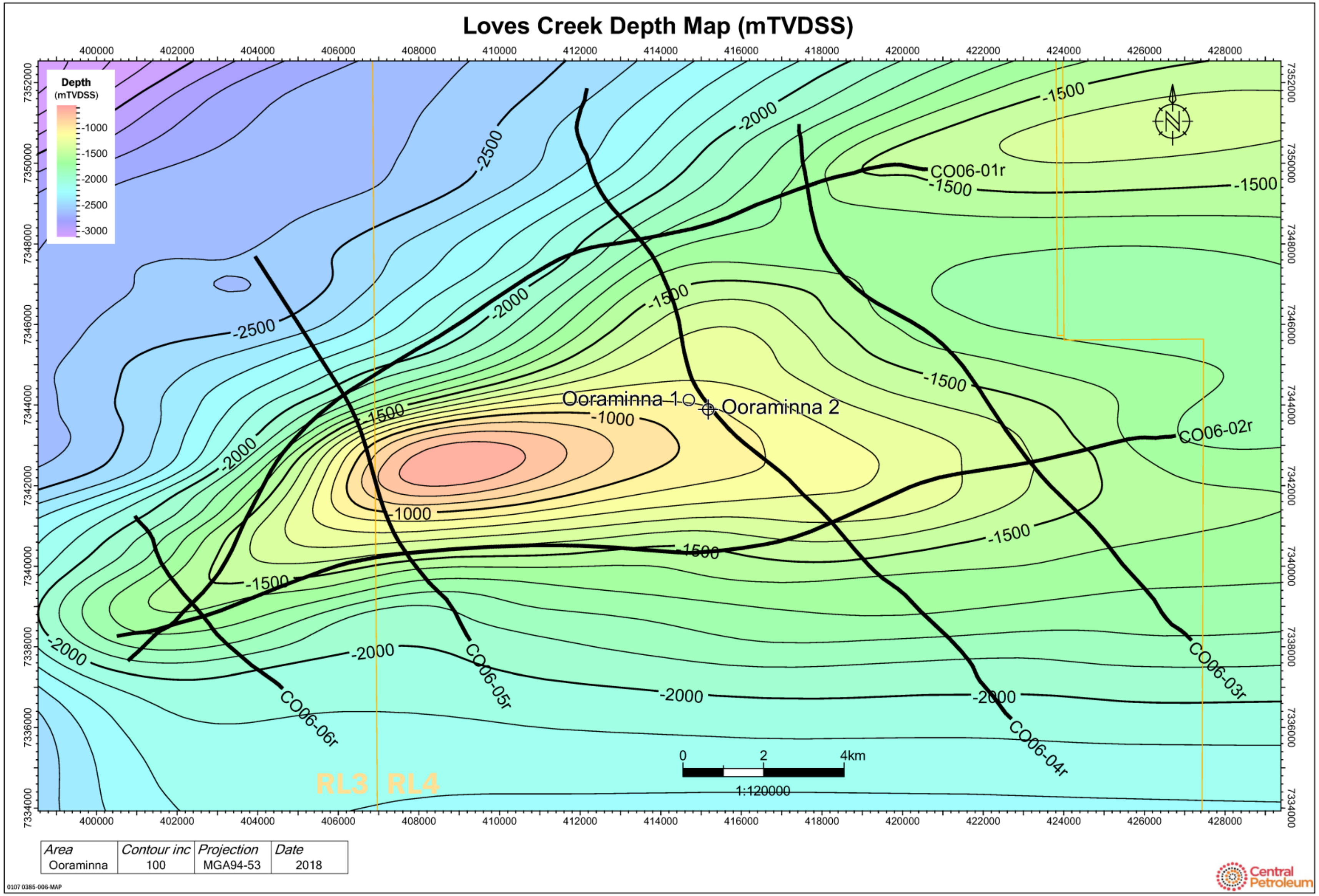

Figure 14: **Loves Creek depth structure map (mSS)**

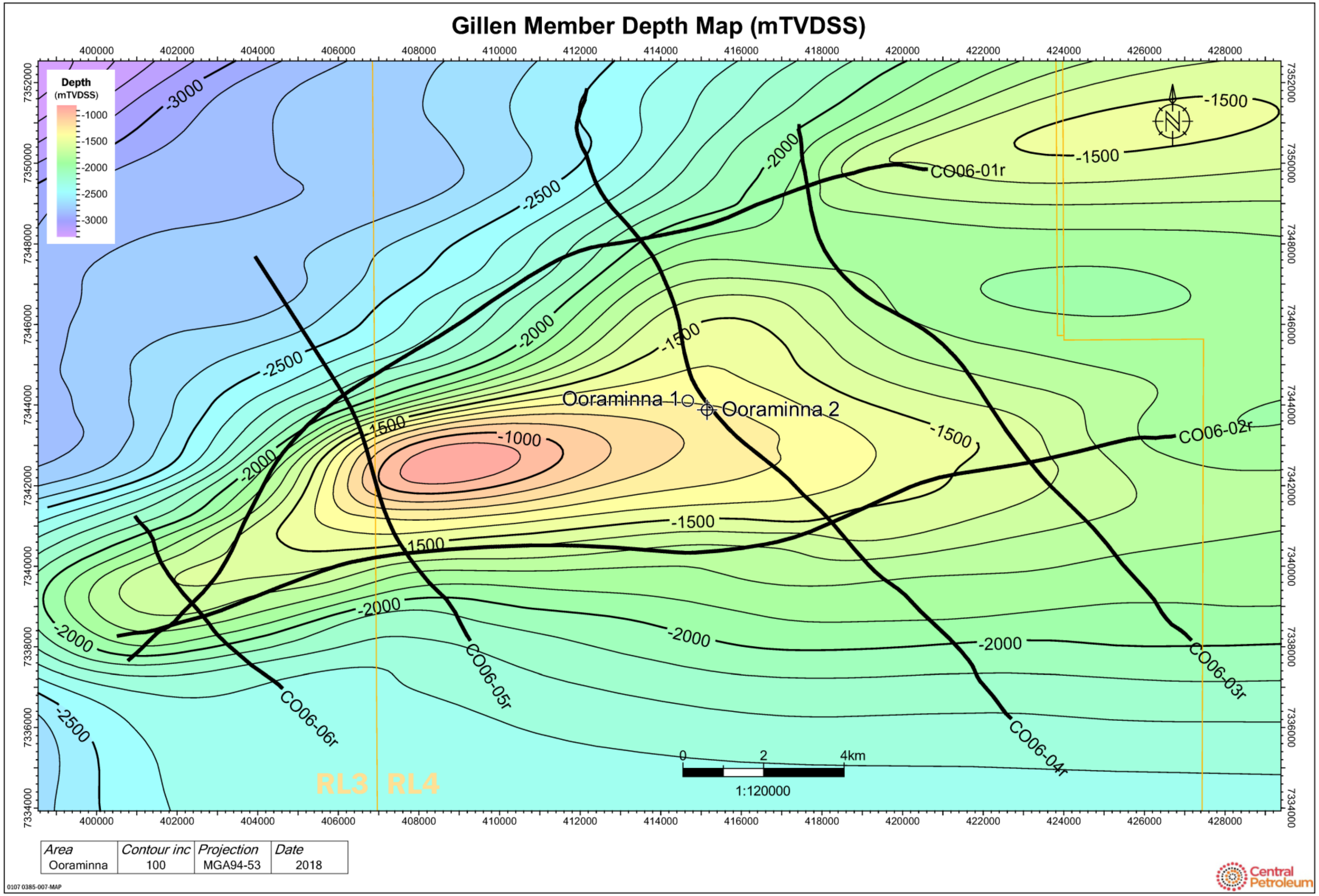

Figure 15: Gillen Member depth structure map (mSS)