AMY 2D Seismic Survey Interpretation Report
EPs 127, 128, 103, 104
Southern Georgina Basin, Northern Territory

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1 Summary

This is a report on the seismic interpretation of the 2013 AMY seismic data in time and the subsequent depth conversion, based on a time-depth function from well data across the area. This report comes in addition to the earlier report from Peter Boult1 (figure 1). This project did not repeat all the work done by Boult although the seismic has been interpreted over the entire area as the additional seismic data may have led to some modifications to the earlier interpretation. However no significant differences in interpretation have been recognized on the legacy data. Data quality issues are also discussed, in particular the relationship between the structural style of the area and its effect on data quality. This will be important for the planning of future seismic surveys in the area.

2 'The Play'

The play is an 'unconventional' play and is summarized in Figure 2 (from Dunster et al., 2007)[2]. In this southern area of the Georgina Basin it is believed the play lies within the oil maturity zone. Two main geological formations make up the play and as such this is termed a 'hybrid play'. The first (upper) unit is the Arthur Creek Hot Shale (ACHS) which constitutes the lowermost Arthur Creek Formation. It is a 'shale play' and as such is a more typical unconventional play. This shale has both sufficient organic richness and reservoir properties to be able to generate and hold hydrocarbons but can also give up some of its hydrocarbons into the underlying Thorntonia Limestone. The lithology can be quite variable with carbonate content increasing to such an amount it can be difficult to differentiate the contact with the underlying Thorntonia Limestone – such is the case in the Owen wells area for example.

The ACHS has been deposited directly on the Thorntonia Limestone ('dolostone' – or 'dolomite' according to its traditional meaning) in a large part of the licence area. In addition to having the potential as a reservoir for the hydrocarbons generated in the ACHS, the Thorntonia Limestone contains organically-rich zones which are an additional (maybe main) source for hydrocarbons reservoired in the formation.

This interpretation study focuses on the Arthur Creek and Thorntonia Limestone Formations.

3 Acquisition and Processing of AMY 2D Seismic

The acquisition and processing of the AMY 2D seismic is covered elsewhere and will not be covered in this report. A map showing the new seismic lines acquired in 2013 and the pre-existing (legacy) data is shown in figure 3 and the various datasets are listed in figure 4.

3.1 The Seismic Dataset

Seismic has been acquired in the South Georgina since 1988. The legacy dataset includes 9 different surveys. These are summarized in figure 4. The latest survey has been designed to extend the seismic coverage further to the south towards the basin margin and to the north. This is in order to achieve a better understanding of the main play (see below) and at the same time fulfil licence commitments. Figure 3 shows the distribution of the new lines along with the legacy data.

It has long been recognized that the South Georgina Basin is an area of relatively poor seismic data. Close inspection of the data shows, in fact, zones of moderately good data separated by zones of little or no data. These zones of no data vary in extent between being laterally very narrow and localized to being very broad covering significant proportions of some lines. They, in most cases, affect the dataset from 'shallow to deep' and are interpreted to represent zones of intense deformation, possibly shear zones occurring as splays from the main deformation zone along occurring along the southern margin of the basin.

An interesting exercise is to compare the seismic quality with the NTGS fault map (figure 5) exported from the interactive 'STRIKE' database on the Northern Territory Geological Survey's website[3]. A zoomed version of this map focusing on the

AMY 2D lines and reprocessed legacy data is shown in figure 6. Two seismic lines with the position of the surface lineaments indicated are shown in figure 7. Correlation with faults in the seismic is quite evident. An additional interpretation of these faults has been performed (present study) and is shown in figure 8.
The structuring is interpreted as being related to a strike-slip basin with the southernmost zone of deformation marking the southern boundary of the basin with an approximate WNW-ESE trend. A series of splay features extend northwards in to the southern part of the basin with a more NW-SE trend. This NW-SE grain is cross-cut by occasional NE-SW trending faults.
Figures 9-12 show the final PSDM data (displayed in time) for the northern acquisition area (figure 9), the southern area (figure 10) and the 2013 reprocessed legacy data (figures 11 & 12).
Seismic lines crossing the structural grain generally have better data quality with narrower zones of poor data whereas lines paralleling the structural trend and located close to the features tend to suffer from a general degradation of data quality and in some cases give rise to very broad zones of little or no coherent data. To the north, line A (Figure 9) parallels two lineaments and the loss of data quality is clearly seen where the line follows the structuring (Figure 6). The remaining two lines in the northern area (Lines B & C, figure 9) are either in areas of less structuring or are perpendicular to the structural grain (figure 6) and hence are of much better quality. Similarly in the south, data quality of line D (figure 10) is poor over the eastern two-thirds of the line and from the structural elements map (figure 6) it is clear this part of the line is along a major zone of deformation. The remaining two 'AMY' lines in this southern area (figure 10 E & F) are close to being perpendicular to the structural grain (figure 6) and are consequently of significantly better quality. All three legacy lines, reprocessed as part of the current project, are of good data quality (figures 11 & 12) and these lines lie within less-structured areas and/or crossing the structural grain (figure 6).
Future acquisition programmes need to pay close attention to the structural grain in order to get the best data quality possible.

3.2 Well database and ties to seismic

One is referred to the report by Peter Boult regarding well ties. The present study has QC'd the relevant wells and it was decided there was no need to repeat the exercise here.

4 Interpretation

A full interpretation has been performed for two key seismic horizons - Top Progrades (Near Top Arthur Creek) and (Near) Top Thorntonia. The present study has been an interpretation of the new (AMY 2D) lines and their integration with the legacy data and the existing Peter Boult's interpretation. Well ties have not been re-run and there has been no significantly different seismic interpretation throughout the area of the legacy data.
Major faults have been interpreted and taken into account when gridding and contouring Thorntonia Limestone time and depth maps although the more minor faults remain uncorrelated and have not been taken into the mapping in the form of fault polygons – these are usually small faults and with no obvious correlation when based exclusively on seismic data. The trends of these faults have been discussed in more detail above.
Two key seismic events have been interpreted throughout the licence area (see example of interpretation in figure 13):
1. `Top Progrades'
This is not an actual continuous seismic horizon as such but rather the seismic event representing the upper envelope of the prograding units seen in the upper part of the Arthur Creek and taken as an approximation to the Top Arthur Creek. The progrades are widely visible in the seismic, even in areas of relatively low data quality and represent a good reliable seismic marker (Figure 13).
2. `Near Top Thorntonia'
This seismic reflection is usually the strongest event at any particular CDP location in the seismic (Figure 13). The event is the boundary between the lowermost Arthur Creek (The Arthur Creek Hot Shale) and the Thorntonia Limestone which is dolomitized and is often described as a dolostone rather than the historical term 'dolomite'. This seismic event shows a fair degree of variation around the licence area, in part due to lithological variations and in part due to data quality – see

description of data quality above. The Owen well area is a good example of why a poor reflection can be seen from the Arthur Creek/Thorntonia boundary. In this area the event is poorly visible but the area is characterized by faulting and the lithological contrast is not well-defined. The Arthur Creek is carbonate-rich and the contact with the underlying Thorntonia is gradational but can be identified by the resistivity laterolog.

4.1 Time Maps

Following horizon 'picking' the next stage was to grid and to contour the data. The distribution of the seismic lines throws up the question of how tight a grid can the data withstand and produce a reasonable gridded and contoured product even when extending into the areas with little or no seismic. While analysing the data for misties a 50m grid interval was used. This was seen to give a surprisingly robust gridding result and it was decided to keep this for the main gridding of the data. Polygons representing the more significant faults were also taken into account in the mapping. The resulting time maps for the Near Top Thorntonia and Top Progrades are shown in Figures 14 and 15 respectively.

4.2 Depth Conversion

Rocks of the South Georgina basin are of Cambrian age in our licence area and are characterized by very high interval velocities (in excess of 5000m/s). A well data derived approach to depth conversion was decided on. Wells from the licence area with well-defined stratigraphy and acceptable seismic quality were chosen as the basis for the depth conversion. Seven wells were used which gave a good coverage of the licence area both geographically and depth-wise. (Figure 16).
The depth conversion used a time depth function derived from the 7 wells. Depths were extracted from the well completion report and adjusted to seismic datum (400 m MSL) and values cross plotted against times from the seismic interpretation. Whereas the depths could be quite precise the errors in the time picks are more significant. A shift from a max peak to a neighbouring trough represents approximately 25 metres with velocities in the order of 5000 m/s.
Despite the potential errors, a quite acceptable T-D cross plot was generated with points lying within 5% of the best-fit trend line (figure 16). The equation of this trend line was used to convert the time grid to depth.
See Table 1 below listing the wells, times and depths used in the depth conversion

TOP THORNTONIA LIMESTONE

Well	Time (ms)SD	D (m) SD
Owen-3	534	1259
Baldwin-2	393	948
MacIntyre	362	834
Ross	433	1008
Lucy Creek	500	1173
Sandover	400	1019
Cockroach	590	1415

NEAR TOP ARTHUR CREEK/TOP PROGRADES

Well	Time(ms) SD	D(m) SD
Owen-3	338	863
Baldwin-2	248	530
MacIntyre	289	599
Ross	307	744
Lucy Creek	321	816
Sandover	279	749
Cockroach	408	991

Table 1 Wells, time (ms from seismic datum) and depth (from seismic datum) used in the depth conversion

4.3 Depth Maps

Final depth maps are shown in figures17 and 18.
As an addition to the basic depth maps, the map of the Near Top Thorntonia was also inlaid into the Northern Territory depth to basement map (derived from Northern Territory Geological Survey's potential field data[3]) in order to put it into a regional context (Figure 19).

5 Conclusions

The Emma interpretation report (Peter Boult) has been supplemented by the present study which includes the 2013 AMY 2D seismic lines and their interpretation. No revision of well ties has been undertaken here although a slightly different approach to depth conversion has been used. It is believed the approach to depth conversion is a fairly robust method. The new interpretation extends the coverage of more reliable mapping to the southeast and north although data quality deteriorates in both these areas due to the effects of structuring on the data. Seismic data acquired in a direction perpendicular to significant fault zones may be expected to be better quality – something to be taken into consideration should there be further acquisition in the area.

6 References

[1] Boult, Peter, 2012; "Seismic Interpretation, Structural Mapping and Geological review of 2011 Emma (Ross Infill) seismic survey, including reprocessed 2009, 2010 surveys and some pre 2009 vintage lines"
[2] Dunster, JN; Kruse, PD; Duffet, ML and Ambrose, GJ: "Geology and resource potential of the southern Georgina Basin", DIP 007, October 2007
[3] Northern Territory GIS database on their web site NTGS STRIKE:
http://geoscience.nt.gov.au/GeosambaU/strike_gs_webclient/default.aspx

App A List of time maps

Top Thorntonia Formation Time Structure (TWT)
Near Top Arthur Creek Formation Time Structure (TWT)

App B List of depth maps

Top Thorntonia Formation Depth from Ground Level (m GL)
Near Top Arthur Creek Formation Depth from Ground Level (m GL)
Top Thorntonia Formation Depth from Ground Level pasted into NTGS Basin Structure Map (m GL)

: Seismic Interpretation Report 2012- EPs 103, 104, 127 PetroFrontier

GINKGO ENP GNG

PetroFrontier

Seismic Interpretation, Structural Mapping and Geological Review of

2011 Emma (Ross Infill) seismic survey, including reprocessed 2009, 2010 surveys and some pre 2009 vintage lines

Onshore Georgina Basin: Northern Territory

CONFIDENTIAL REPORT 2012

For
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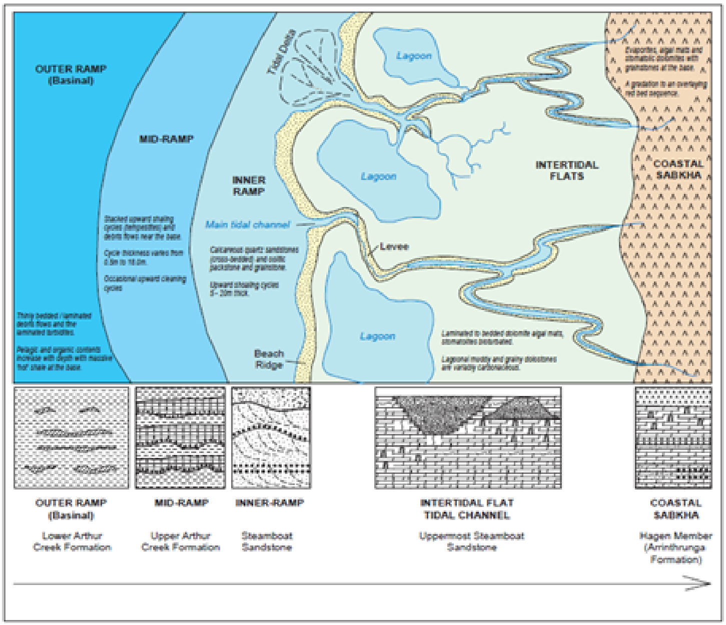
Peter Boult,
Consulting Geoscientist

Figure 1 Reference to Peter Boult 2011 'Emma' Seismic Interpretation Report

Depositional model

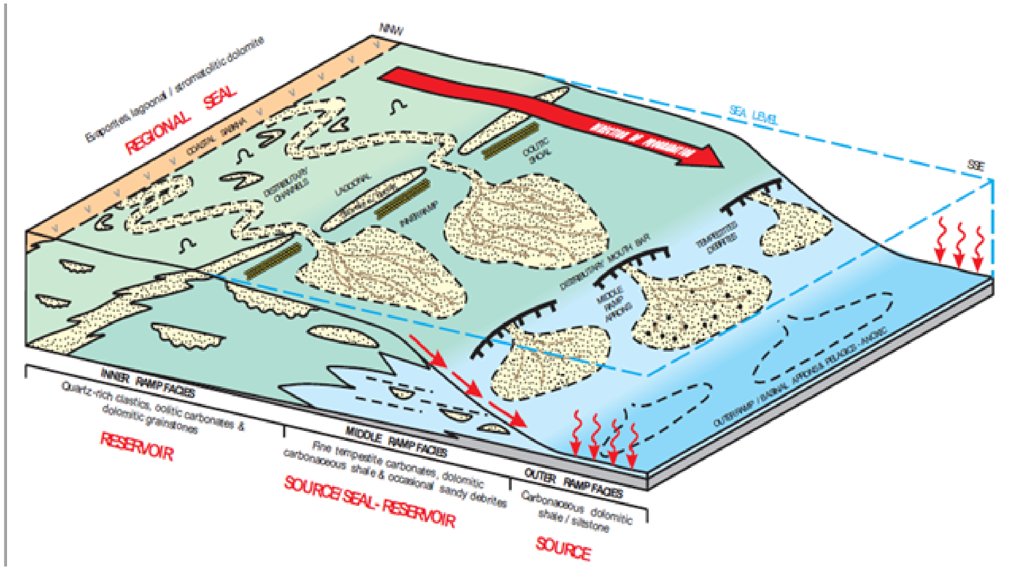


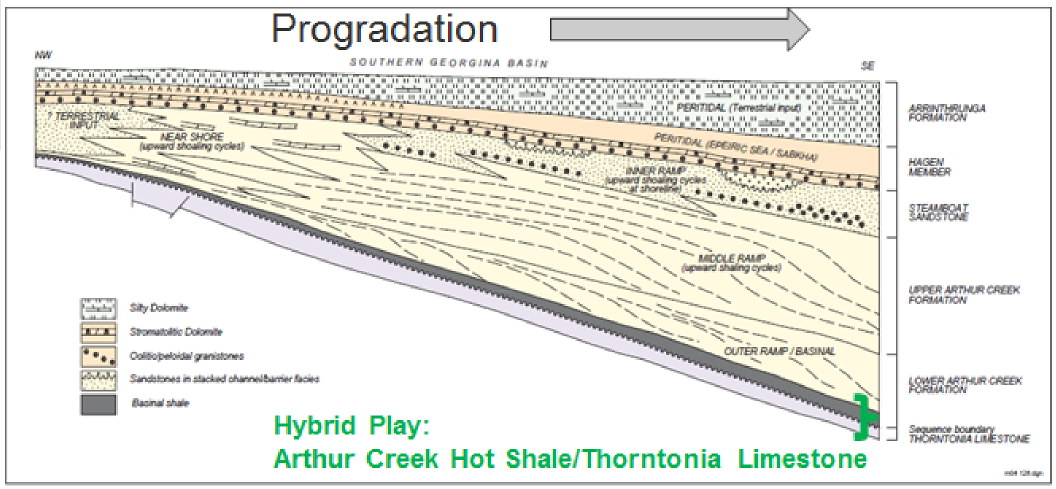
Depositional facies of the Arthur Creek Formation (plan view).

Arthur Creek Hot Shale and Thorntonia Fm were deposited in an carbonate outer ramp basinal setting in a sag basin

Regressive system with mid ramp, inner ramp and tidal channels deposited above.

Areally extensive depositional system





. Southern Georgina Basin, stratigraphy and facies relationships.

Figure 2 South Georgina Basin Depositional Model, from Dunster et al., 2007

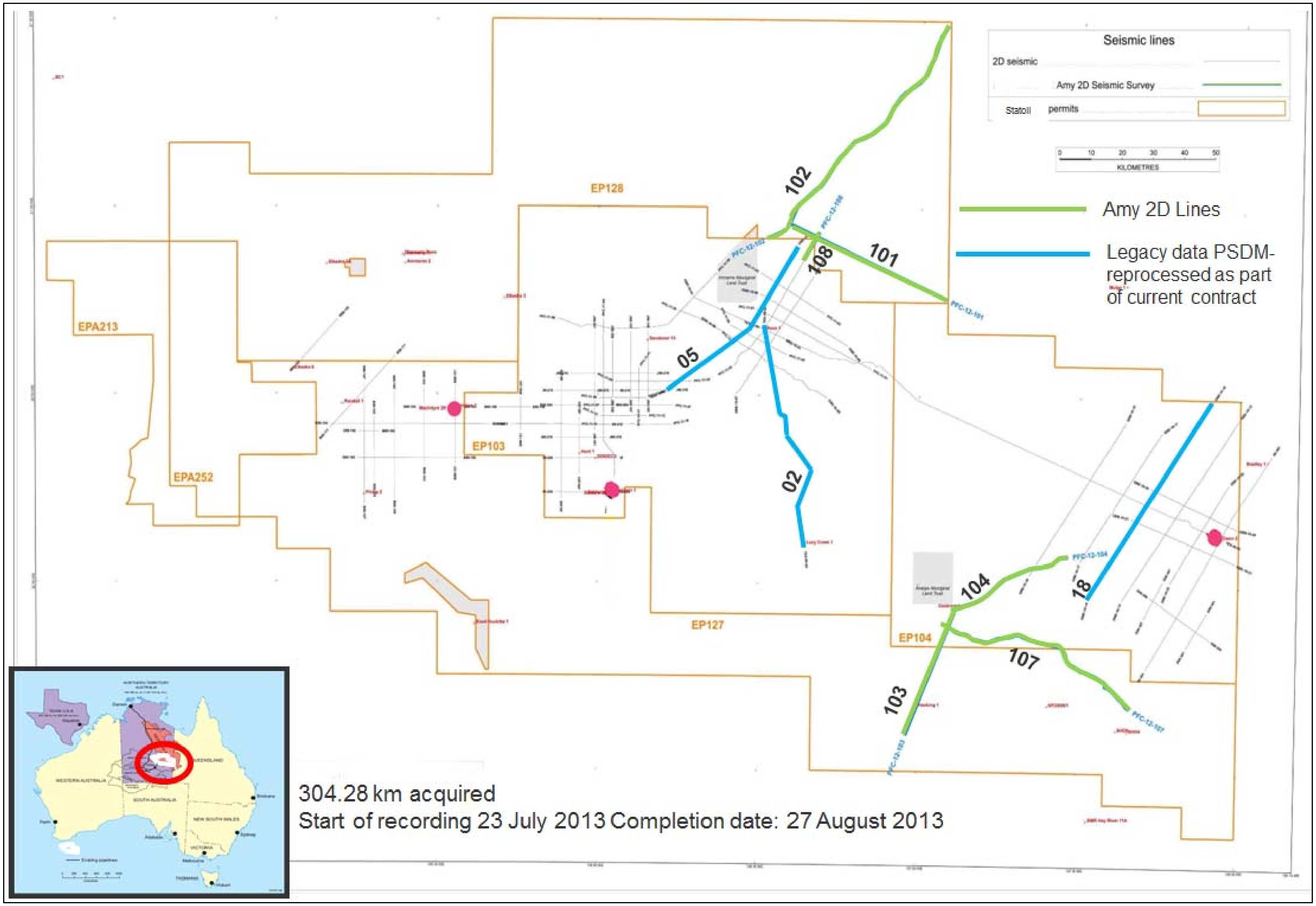


Figure 3 South Georgina 'AMY' 2D Seismic Acquisition 2013 – includes legacy lines reprocessed as part of current activity

Year	Operator	Name	Line prefix on maps
1988	Pacific Oil and gas Pty Ltd	Bundey River 2D SS1988	B88
1989	Pacific Oil and gas Pty Ltd	Georgina River Basin 2D SS 1989	89
1990	Pacific Oil and gas Pty Ltd	Georgina Basin 2D SS 1990	B90, G90 & J90
2009	Texalta Petroleum Ltd	Georgina Basin 2D SS 2009	TEX
2010	Georgina Basin Energy Pty Ltd		GBE
2011	PetroFrontier Pty Ltd	Emma (Ross Infill)	PFC
2011	PetroFrontier Pty Ltd	Emma (PPP delineation)	PFC
2013	PetroFrontier Pty Ltd *	AMY	PFC12

*Statoil assumed operatorship on 1st September 2013 and were responsible for the processing of the ‘AMY’ 2D

Figure 4 South Georgina Legacy Seismic Data Vintages

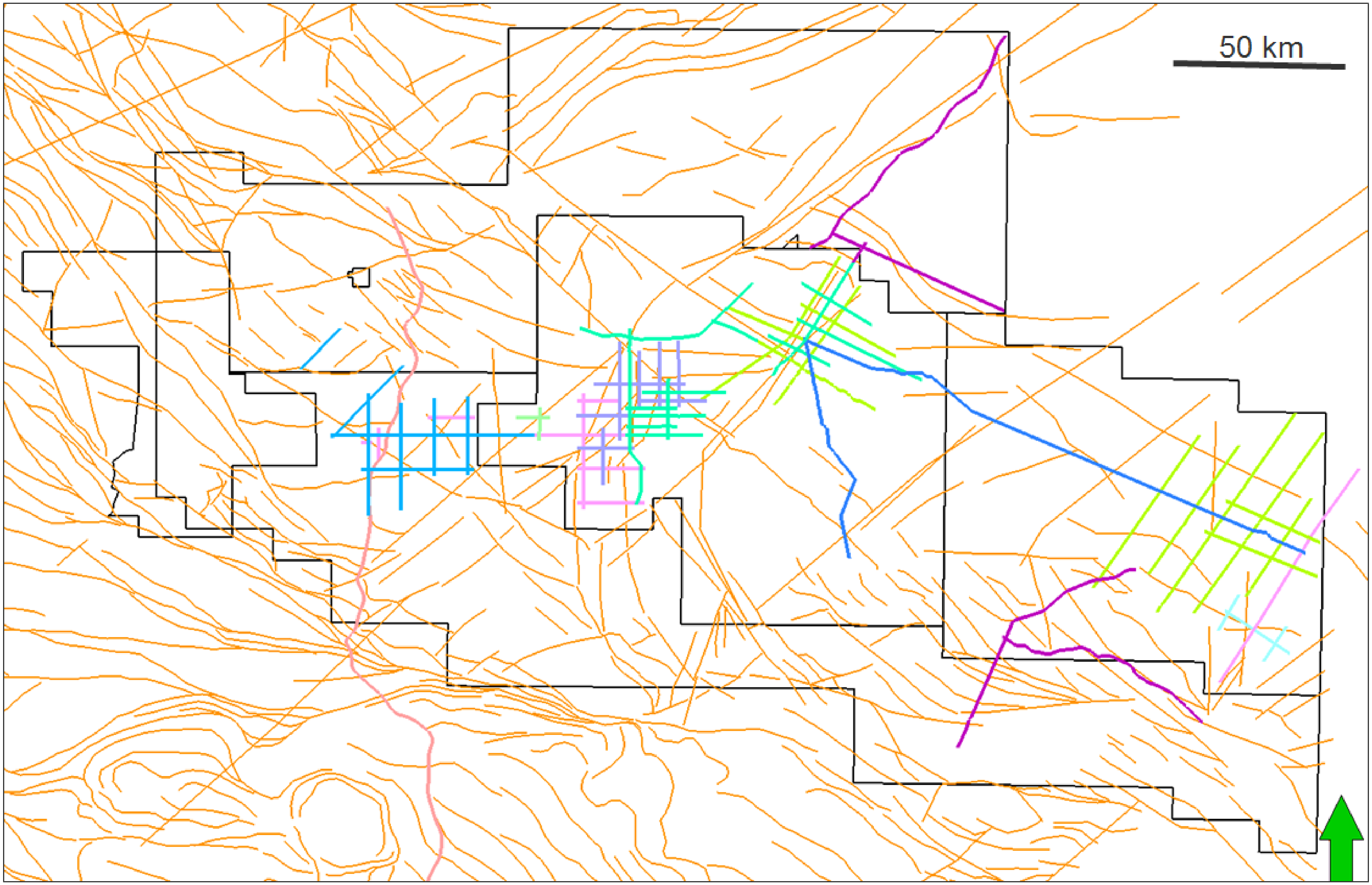


Figure 5 Northern Territory Lineament (Fault) Map – from 'STRIKE' interactive database

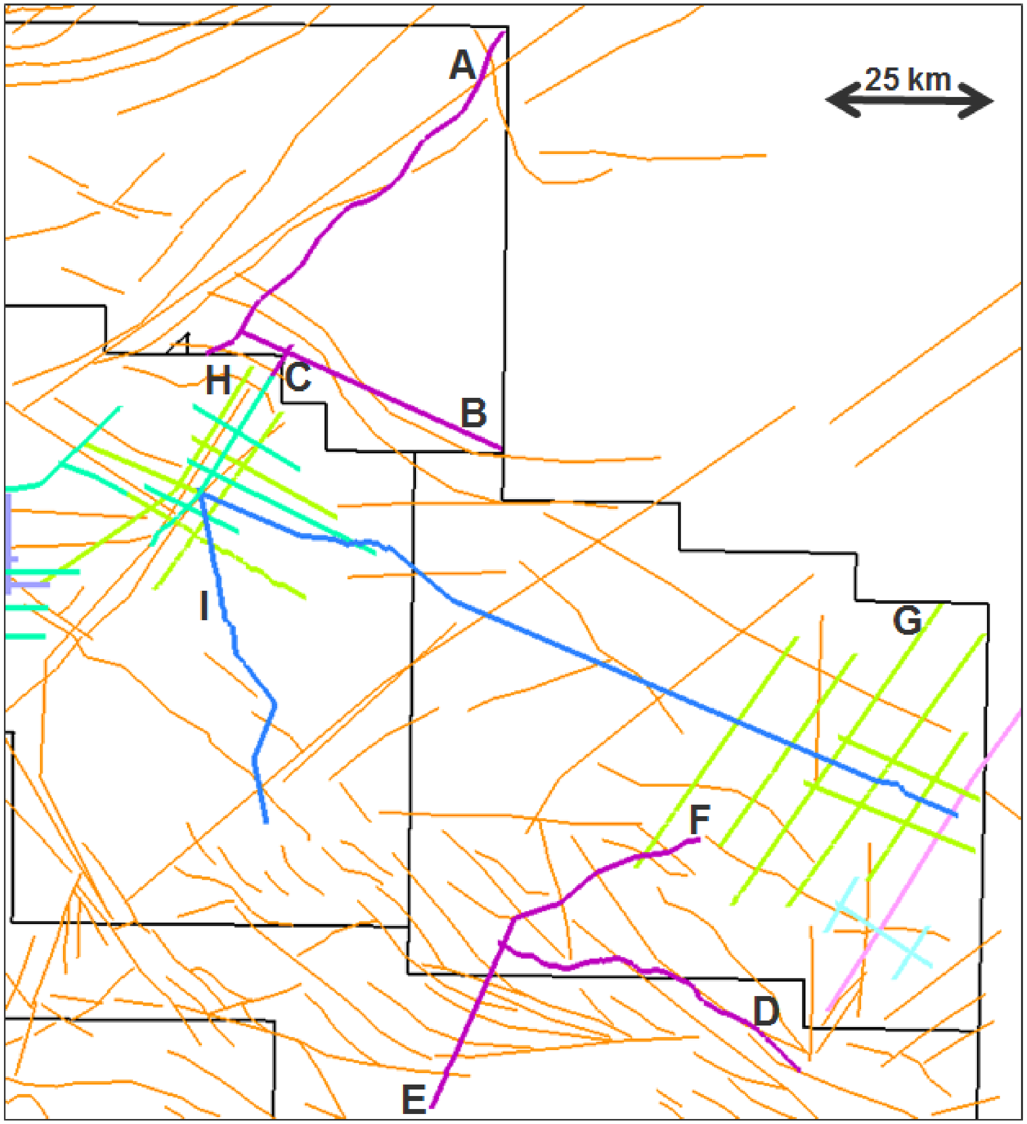
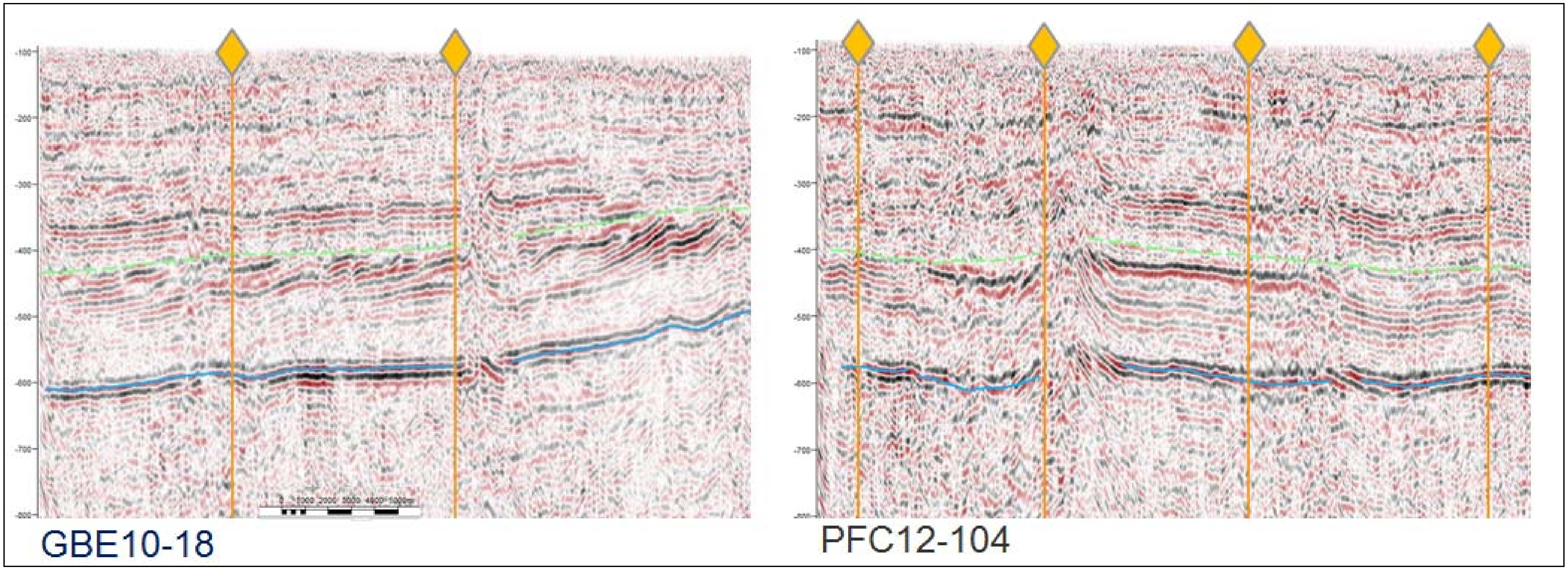


Figure 6 Northern Territory Lineament (Fault) Map – zoomed to show AMY 2D and reprocessed legacy data



Line G, Figure 6)

Line F, Figure 6

Figure 7 Example seismic lines showing locations of lineaments included in Northern Territory Lineament (Fault) Map

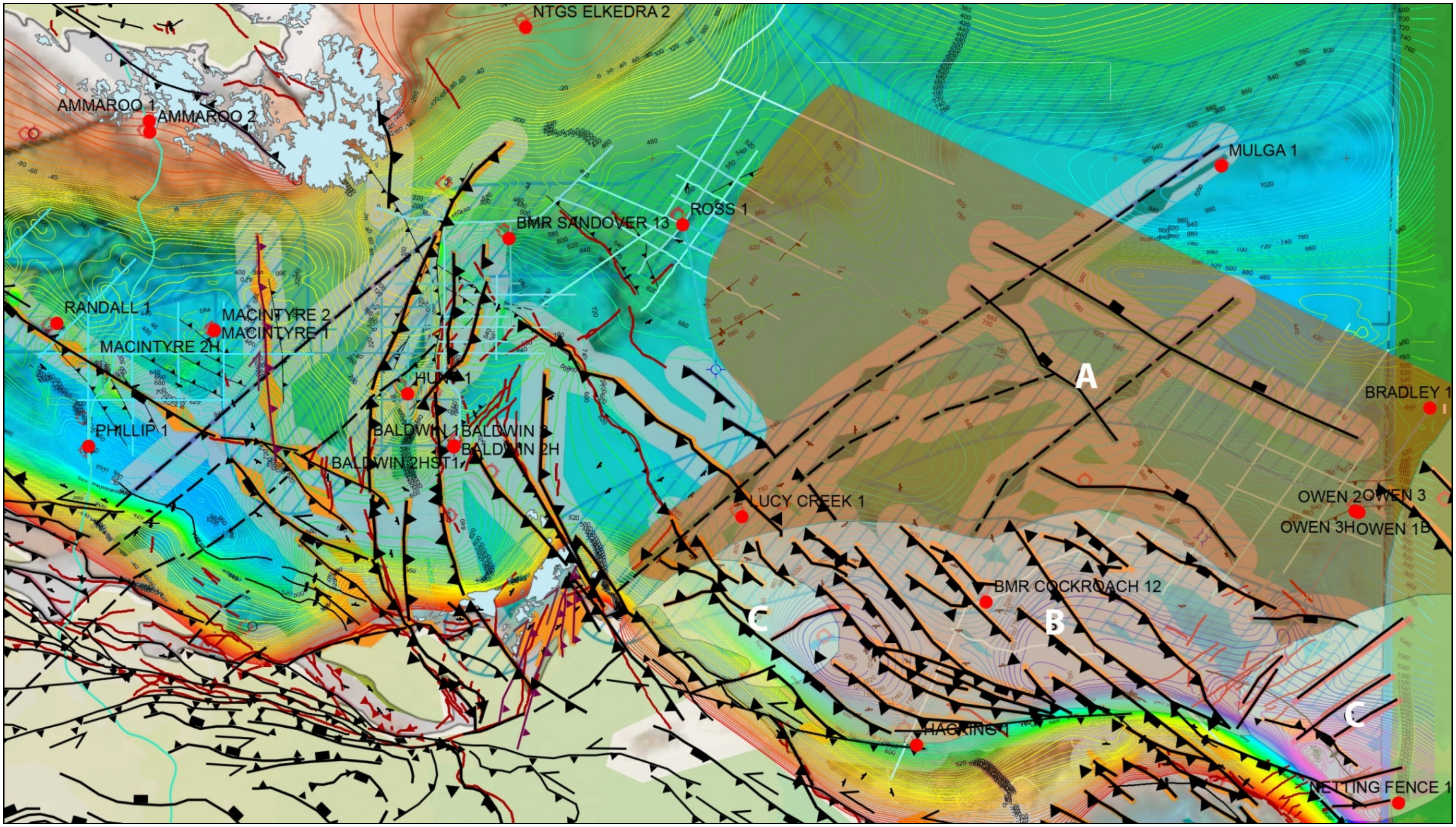


Figure 8 Detailed interpretation of the NTGS lineament (fault) map

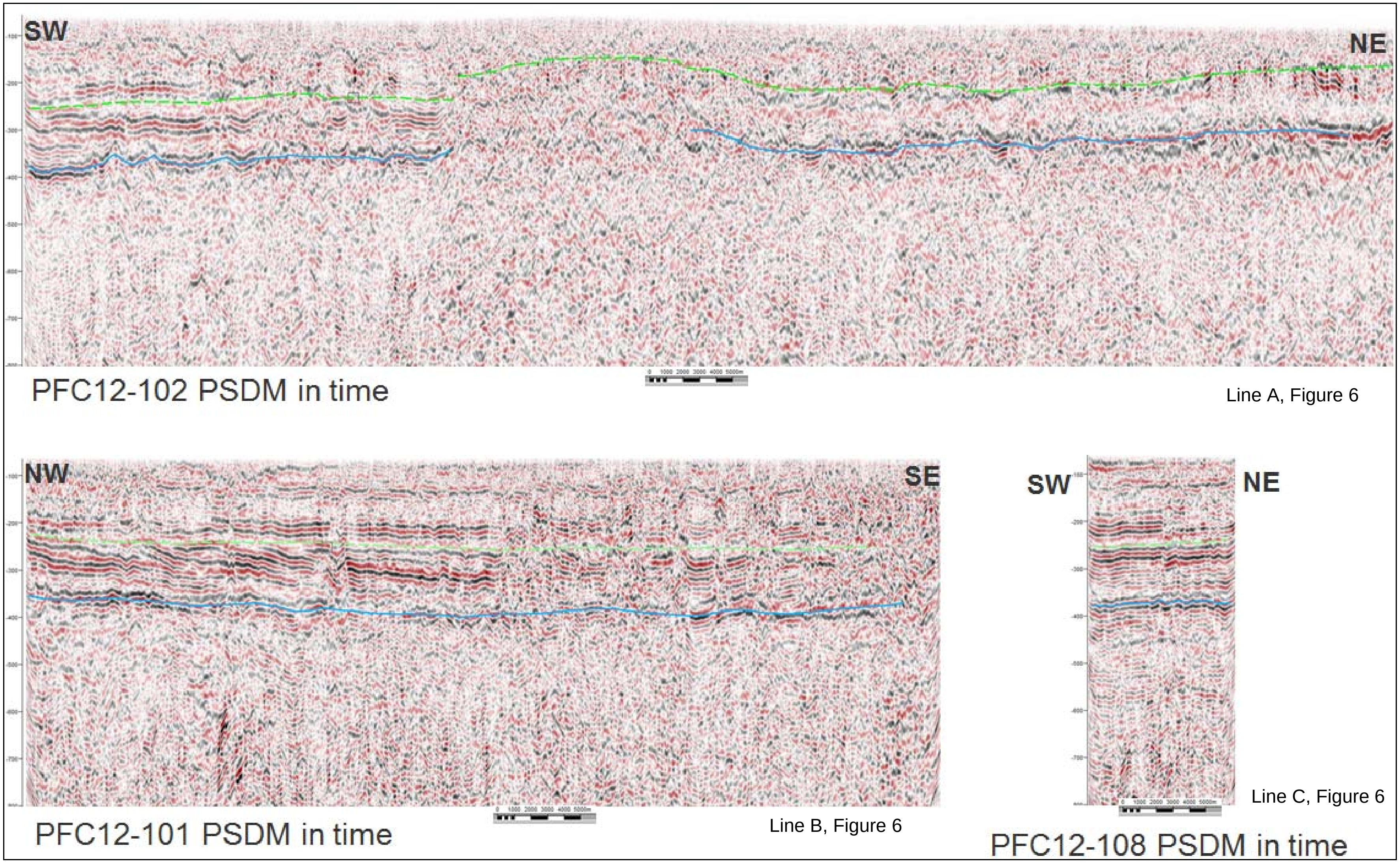


Figure 9 Northern acquisition area seismic lines, PSDM in time

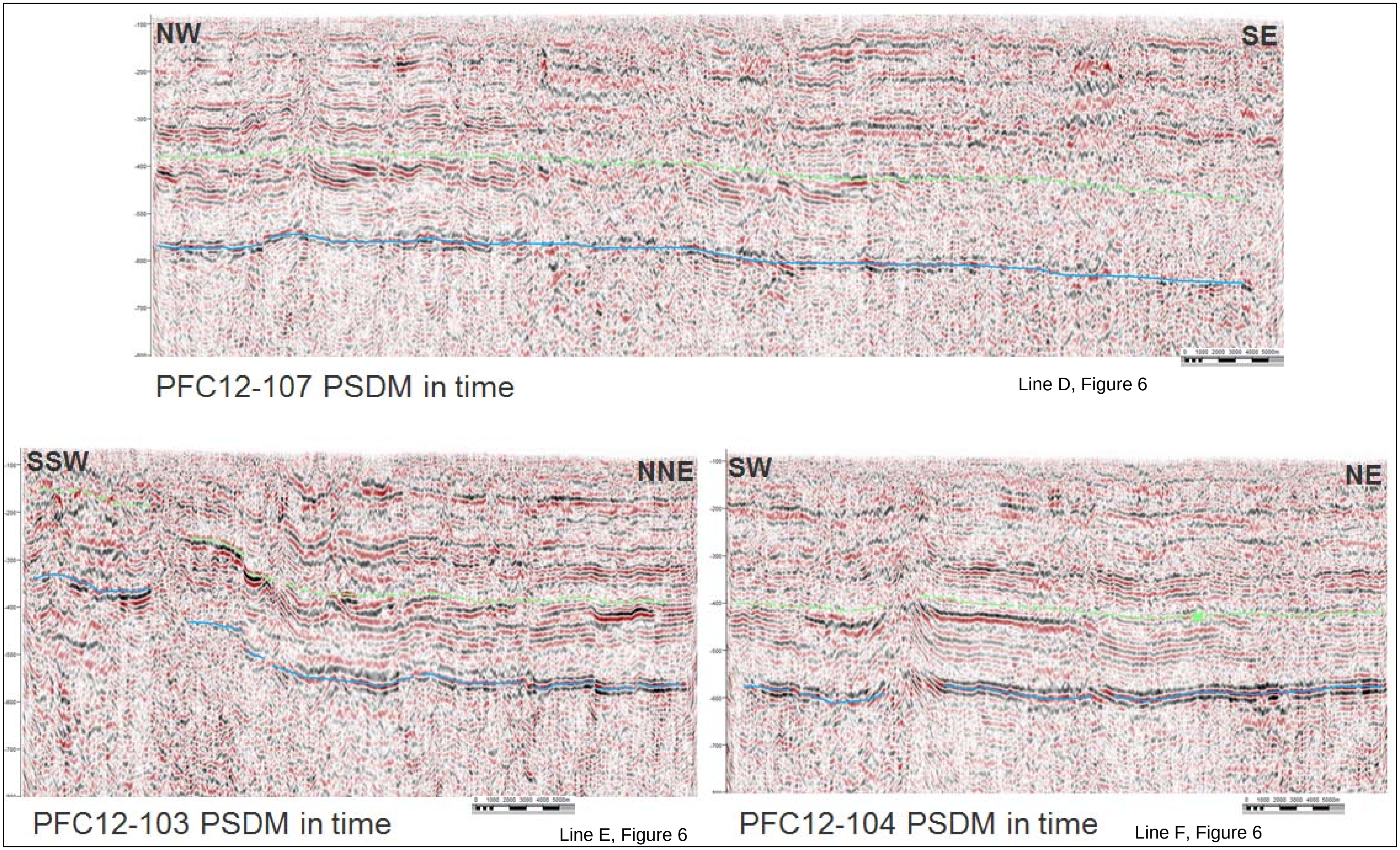


Figure 10 Southern acquisition area seismic lines, PSDM in time

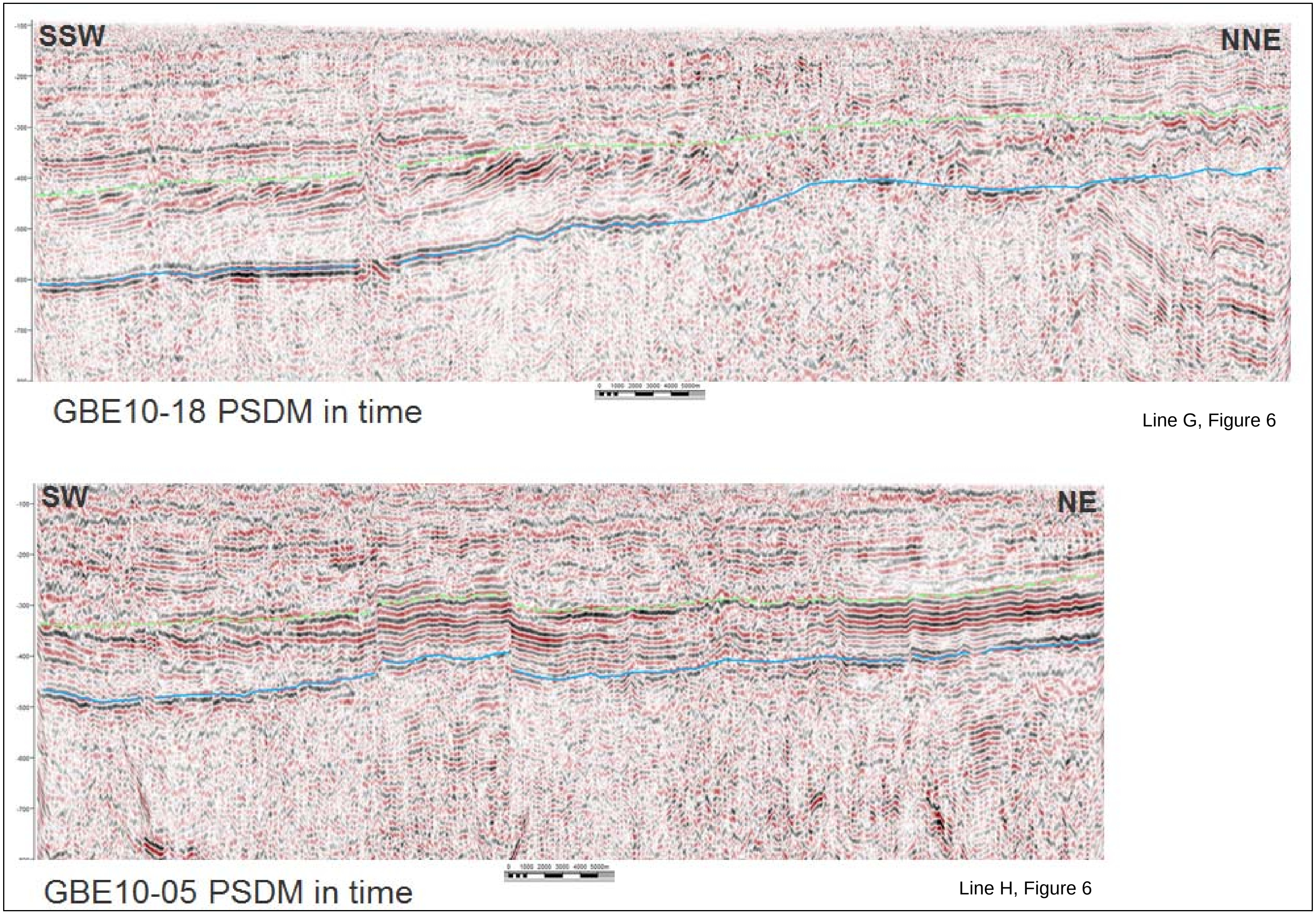


Figure 11 Legacy data PSDM-processed displayed in time (1)

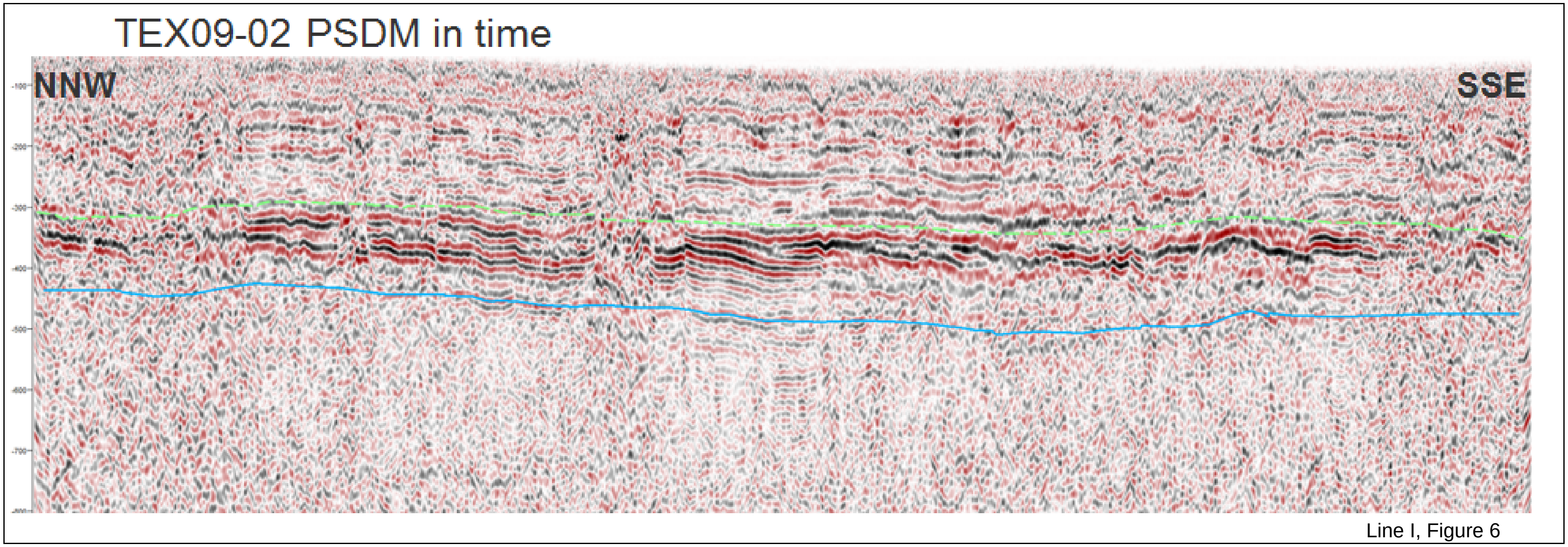


Figure 12 Legacy data PSDM-processed displayed in time (2)

- Seismic Events Picked
  - Near Top Arthur Creek/Top Progrades
    - The prograde occur in the upper part of the Arthur Creek Fm are are seen across much of the licence area. The true top Arthur Creek is above these progrades but not a consistent event and therefore not interpreted
  - Near Base Arthur Creek/Near Top Thorntonia
    - The most obvious seismic event is that corresponding to the transition between the Arthur Creek Fm and the Thorntonia Limestone Fm. The strength of this event varies regionally due to the lithological variations in the Arthur Creek – varying from a more shaley facies to a very limey facies almost indistinguishable from the underlying Thorntonia Limestone (Dolomite)

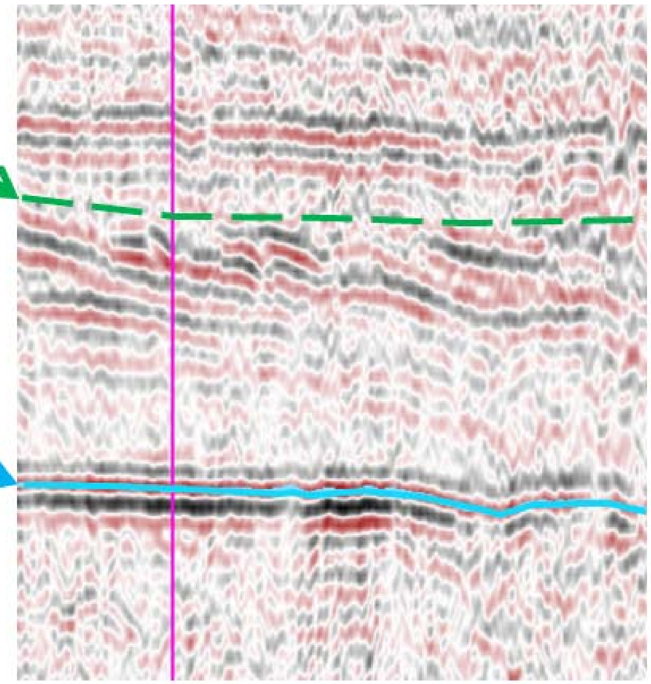


Figure 13 Horizons picked and their expression in the seismic data

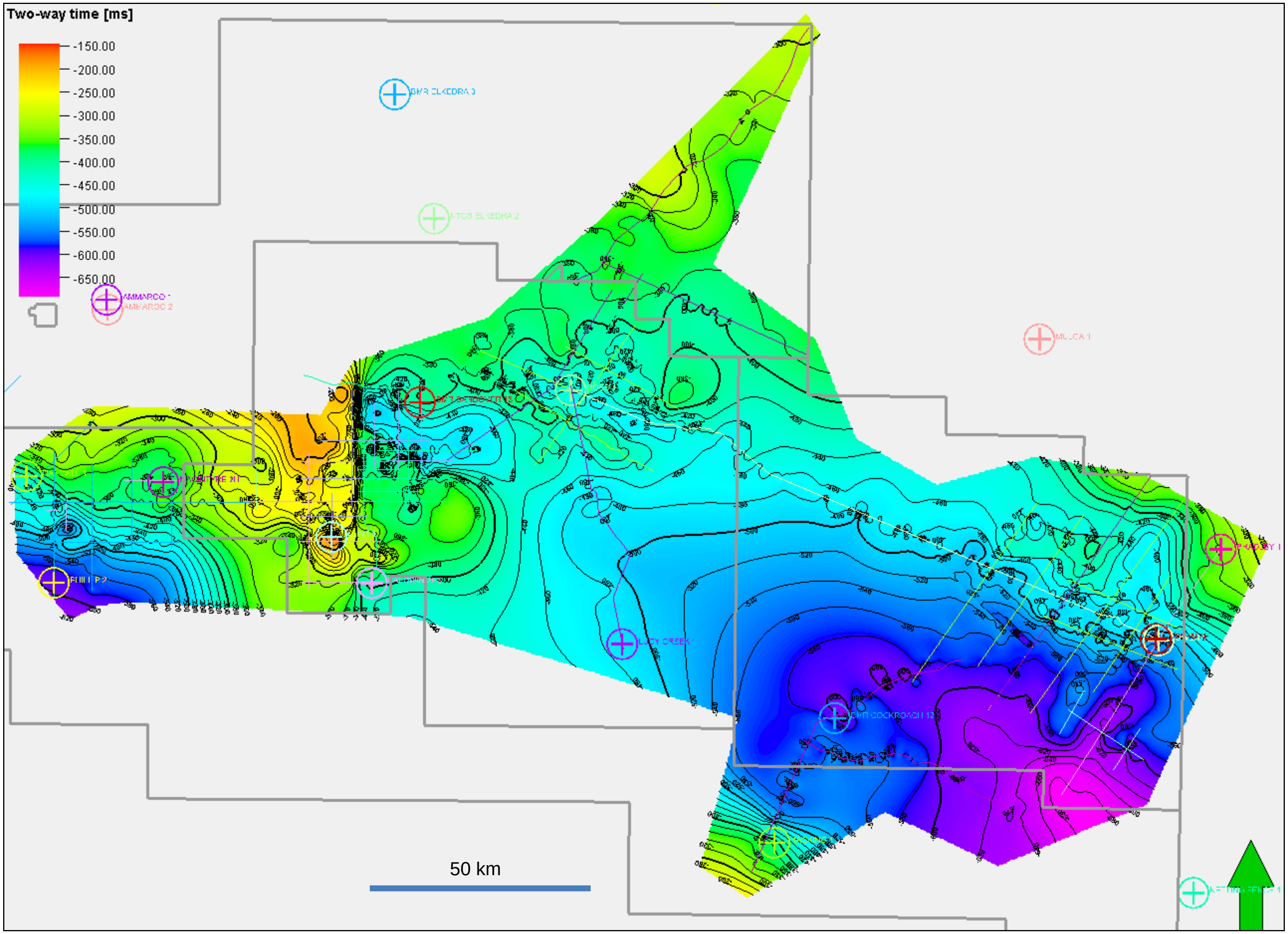


Figure 14 Top Thorntonia Formation Time Structure (TWT)

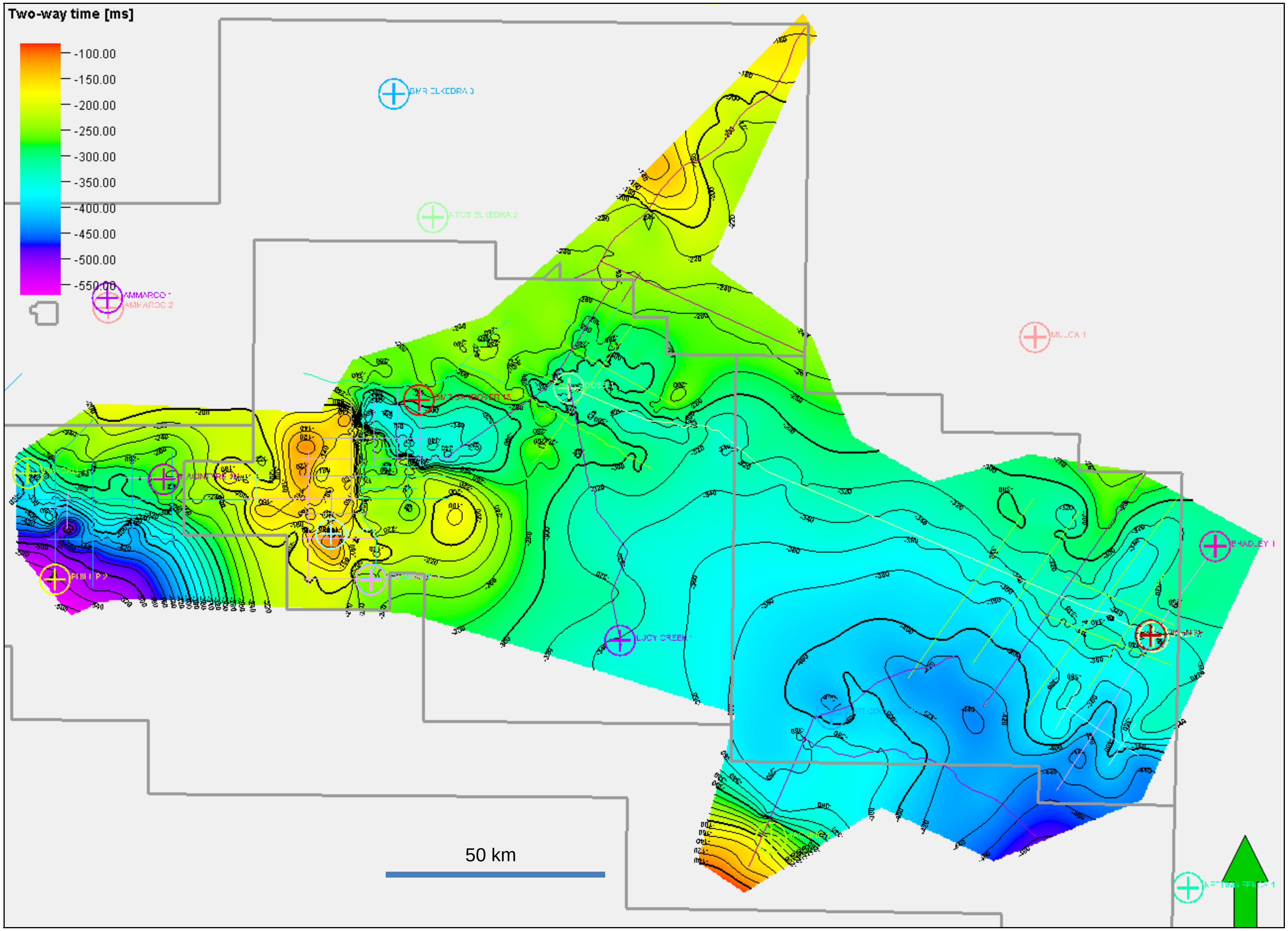


Figure 15 Near Top Arthur Creek Formation Time Structure (TWT)

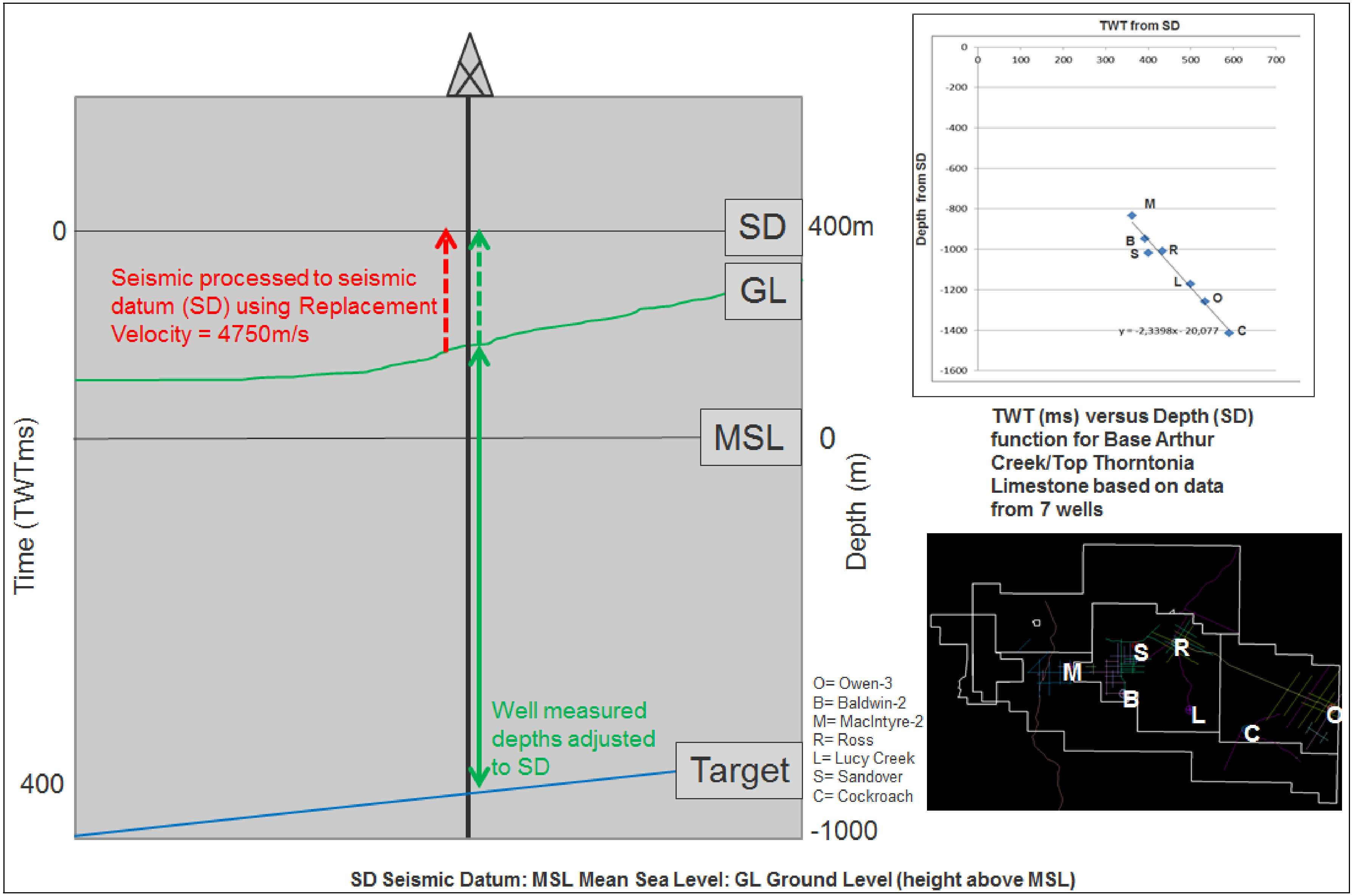


Figure 16 Outline of depth conversion approach

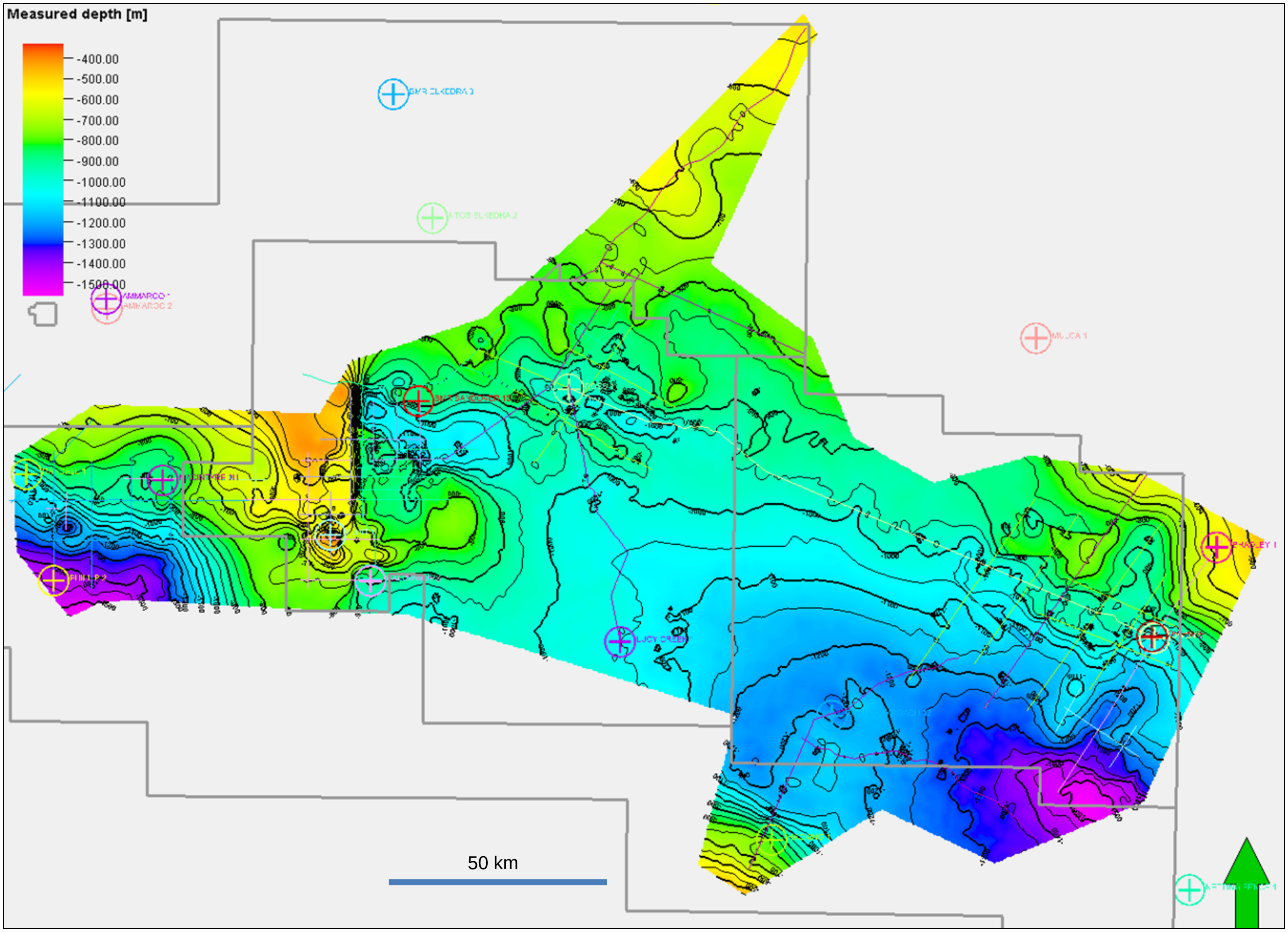


Figure 17 Top Thorntonia Formation Depth from Ground Level (m)

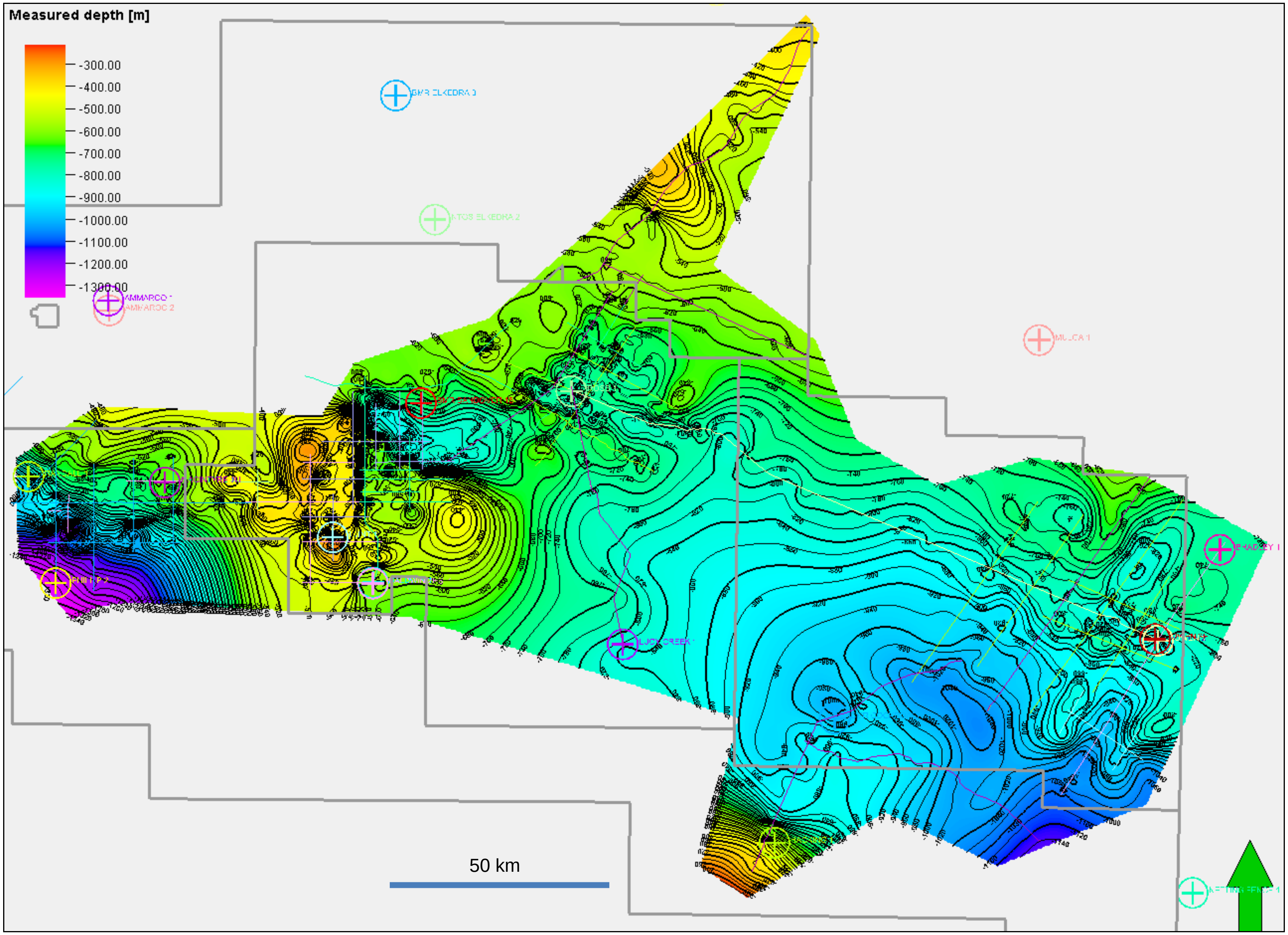


Figure 18 Top Arthur Creek Formation Depth from Ground Level (m)

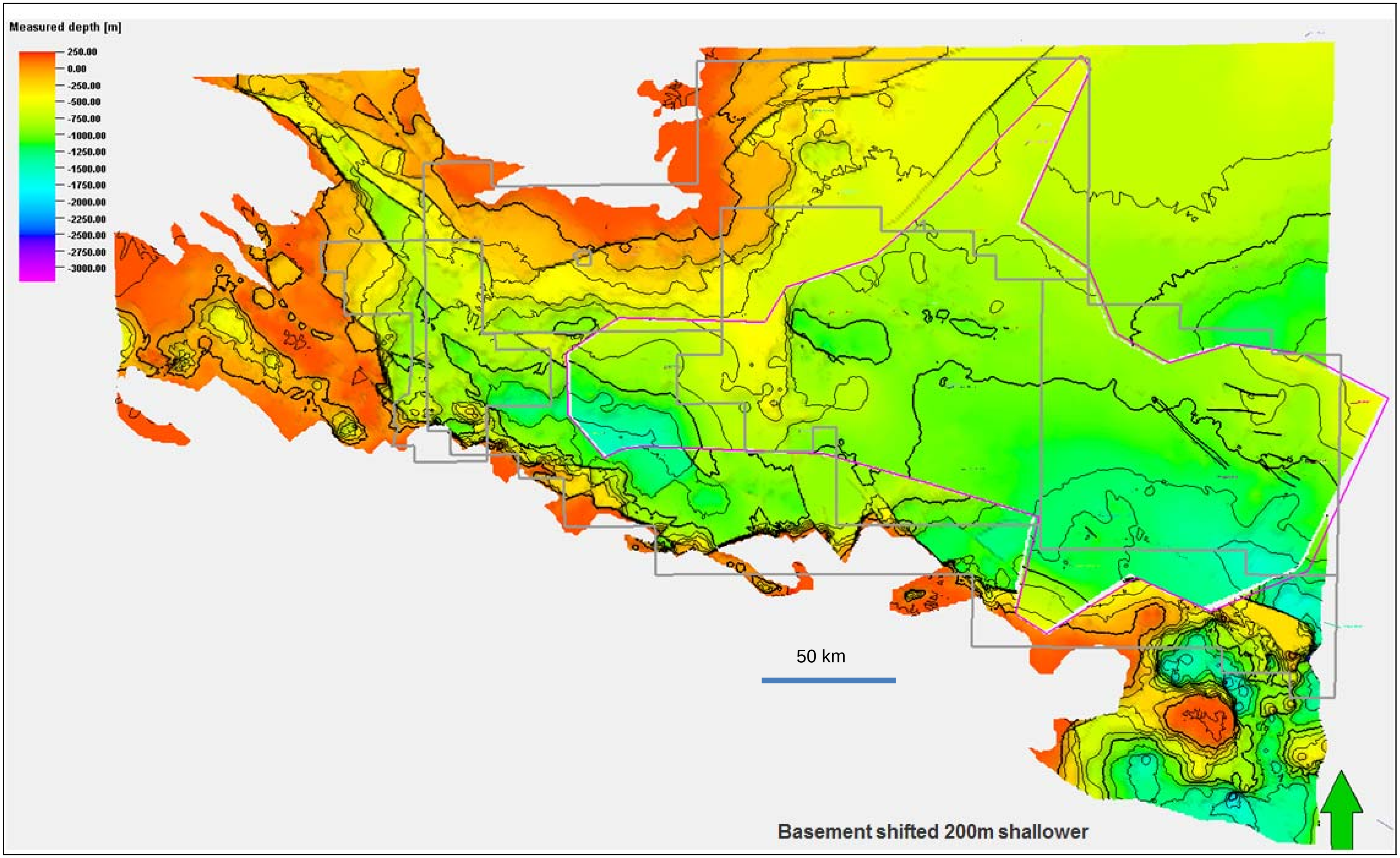


Figure 19 Top Thorntonia Formation Depth from Ground Level pasted into NTGS Basin Structure Map (m)