Insights into the Anketell and West Barnicarndy Faults, Paterson Province, using reprocessed legacy seismic data

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SUMMARY

Over 800,000 line kms of legacy seismic data exists onshore Australia, acquired since the 1960's for petroleum exploration, and more recently for deeper crustal studies. Much of the existing processing did not focus on imaging features of interest for mineral explorers. Reprocessing of relevant lines with a mineral exploration mindset is adding considerable new insights into the understanding of minerals systems.

Reprocessing of key 2D seismic lines in the Paterson Province has provided much improved imaging of the NeoProterozoic Yeneena Basin, the Barnicarndy Graben basin margins and key structures. Key to obtaining the highest quality results, and thus maximising geological insight, is a strong geological input to focus and select appropriate processing algorithms – five different leading seismic processing companies were used and the project included strong collaboration throughout the processing workflow.

The complex and long-lived structural history of the Anketell Fault is clear; including extension associated with the formation of the Barnicarndy Graben, and subsequent inversion. The newly processed seismic data also reveals a previously unknown west-dipping, high-angle reverse fault to the east of the Anketell Fault with an associated hanging-wall anticline. On the west side of the graben, the West Barnicarndy Fault does not show the same complexity as the Anketell Fault system, but does appear to have been reactivated with shallow faults potentially extending to the surface.

Another important consideration for ongoing exploration programs is determining depth of cover. The reprocessed data clearly provides detail on this bedrock topography on both sides of the Barnicarndy Graben, and highlights localized areas of basement bedrock highs.

The improved imaging of the basement also suggests the continuation of the regional structures below the Barnicarndy Graben.

Key words: seismic, Paterson, reprocessing, Barnicarndy

INTRODUCTION

Australia's next generation of mineral deposits are masked by variable thickness of cover, and the discovery process requires a different exploration approach. Ongoing exploration will rely strongly on geophysical techniques including seismic. Mineral explorers and State and Federal Geological Surveys are already acquiring new seismic to better understand critical structural and stratigraphic information, both deep crustal and near-surface.

However, an extensive database of legacy seismic data already exists onshore Australia. Over 800,000 line kms of 2D seismic has been acquired since the 1960's for petroleum exploration, and more recently for deeper crustal studies. Some of these data have never been reprocessed; and in particular very little has been reprocessed with a focus to image features of interest for mineral explorers. Such features include Archaean and Proterozoic "basement" rocks; steep dipping faults and a focus on the near-surface.

Three lines of 2D seismic data (H96-01, H96-05 and H96-09) were acquired by Hunt Oil in 1996 to explore the petroleum potential of the Waukarlycarly Graben (now renamed the Barnicarndy Graben) in the Paterson Province (Figure 1). The Barnicarndy Graben is a rift embayment developed during multi-phase subsidence and filled with Palaeozoic and Mesozoic sediments of the Canning Basin. The graben is flanked and underlain by the Neoproterozoic Yeneena Basin sediments, which host significant mineralisation such as the Telfer Au-Cu, Winu-Ngapakarra Cu-Au, Obelix Cu-Au and Nifty Cu deposits. The nature and history of the bounding faults is not clear, largely due to lack of good exposure.

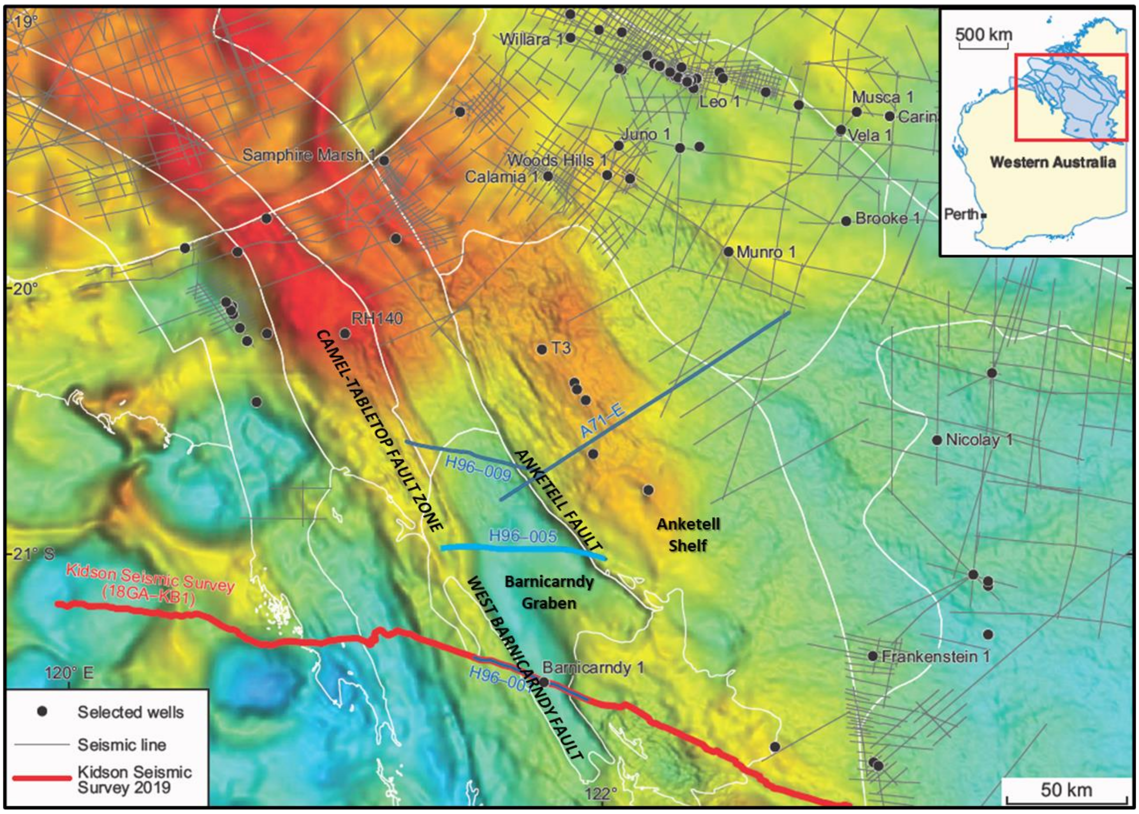

Figure 1. Location of study area showing the distribution of legacy seismic in the Paterson Province superimposed on imaged gravity data (figure modified from Zhan, 2021). The 2D seismic line H96-05 extending across the Barnicarndy Graben is highlighted in light blue.

Published geological mapping in the project area is also limited due to the poor outcrop. Structural and geological interpretation maps (e.g. Bath *et al*, 2017) have relied on extrapolating from known outcrops and drillholes using airborne geophysical data.

Alavi (2013) provides a comprehensive interpretation of the Barnicarndy Embayment using the original processed data of the 3 seismic lines acquired by Hunt Oil, integrated with available gravity and magnetic data. Whilst exploration implications for petroleum potential of the Embayment were discussed, there was no focus on assessing the nature of the bounding faults, the structural history of the Proterozoic sequences on the flank and any implications for ongoing mineral exploration in the region.

Searcher commissioned five leading seismic contractors with both mineral and O&G experience to reprocess key seismic lines in the Paterson Province, including line H96-05. The objective of selecting contractors with differing processing experience and expertise was to be able to compare and contrast the results, and also ascertain the most applicable processing workflows.

Seismic line H96-05 covers 64.33km across the widest part of the Barnicarndy Graben. It extends onto the shallow Proterozoic sequences of the Camel-Tabletop Fault Zone, as defined by Alavi (2013), and the Anketell Shelf to the west and east respectively, as shown in Figure 1.

KEY SEISMIC PROCESSING PARAMETERS

Original processing of the Waukarlycarly 2D seismic lines in 1996 was focused on the sedimentary successions within the graben. Hence there is limited imaging of the Proterozoic Yeneena Group below and on either side of the graben, as that was not of interest for petroleum exploration. The 2D seismic lines were acquired with a 120-fold coverage and a record length of 6s. Despite the high resolution acquisition specifications and resulting high quality data, these lines have never been reprocessed. The improvement in the data through the new reprocessing is significant, both due to considerable improvements in seismic processing algorithms in the last 25 years, but also due to the different focus for the results.

Key to obtaining detailed imaging results, and thus maximising geological insight, was a strong client input to focus and select appropriate processing algorithms – five different leading seismic processing companies were used and the project included strong collaboration throughout the processing workflow. Two key processing methods had the most impact for this line.

- velocity modelling utilizing variable velocity migration scans rather than the traditional normal moveout (NMO) analysis for picking. This is important where reflector dips are steep, as velocity changes move events laterally as well as vertically. Such variable velocity migration scans assisted to better image steeply dipping beds, as well as fault planes.
- Non linear processing flow testing. Instead of proceeding step wise through a standard processing flow, big advantages were seen by iterating whole flow changes, and assessing early stage alterations on late stage images. This style of processing has only become possible with modern increase in computing power, as it enables the entire processing flow to be run 20- 40 times, instead of once in a more traditional flow.

While the key geological features could be identified in all the final processing results, there were considerable variations obtained from the differing processing workflows. Inherently the different (often proprietary) processing techniques emphasise diverse geological features; such as direct imaging of steep faults rather than imaging of stratigraphic breaks; higher definition of near-surface; better depth imaging. Comparing and contrasting the final reprocessing versions provided confidence in the new geological features that can be interpreted.

IMAGING OF ANKETELL AND WEST BARNICARNDY FAULTS

The complex and long-lived structural history of the Anketell Fault is clear; including extension associated with the formation of the Barnicarndy Graben, and subsequent inversion. Figure 2 shows the legacy seismic data and two versions of the reprocessed data. The broad zone of seismic disturbance corresponding to the Anketell Fault is clear on the reprocessed seismic data, which illustrates the complexity of the fault zone, rather than a single fault plane. Alavi (2013) observed that the wedge of sediments against the fault scarp may either be an alluvial fan or talus being deposited against the fault scarp. Inversion of the fault post-deposition of the Permian Grant Group can also now be interpreted from the reprocessed data.

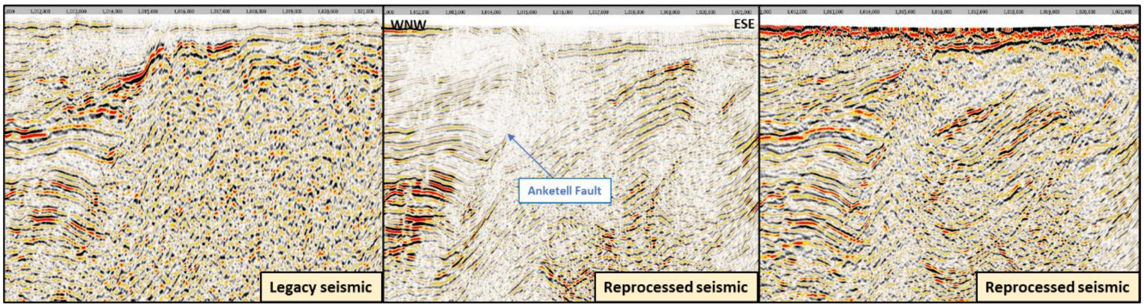

Figure 2. Comparison of legacy seismic and reprocessed seismic data from eastern end of H96-05. Two different versions of the processing are shown to highlight the differences in contractor's processing algorithms. Multiclient seismic reprocessed data shown courtesy of Searcher.

The West Barnicarndy Fault, which signifies the eastern extent of the Camel-Tabletop Fault Zone, does not show the same complexity as the Anketell Fault, being imaged as single fault plane. However the reprocessed data from the one of the seismic contractors with specific expertise in near-surface imaging, clearly shows some recent reactivation with shallow faults potentially extending to the surface (Figure 3). This reactivation is post-deposition of Grant Formation, and could potentially provide pathways for geochemical indicator minerals derived from the Proterozoic.

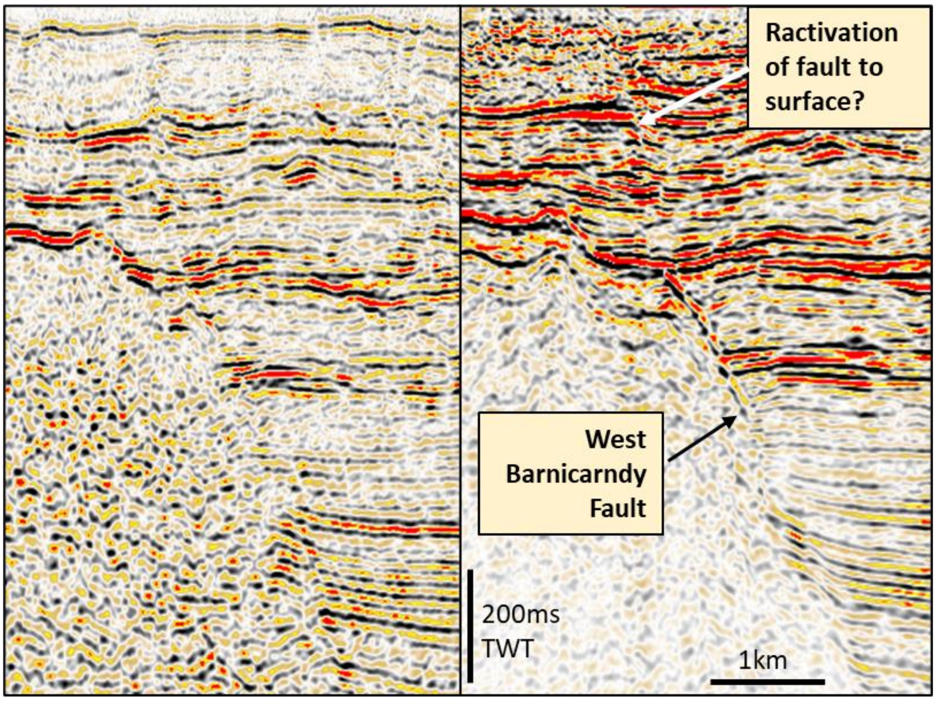

Figure 3. Comparison of legacy seismic (left) and one version of the reprocessed seismic data from western end of H96-05 (right). The reprocessed seismic shows excellent imaging of the West Barnicarndy fault zone, as well as additional near-surface detail. Multiclient seismic reprocessed data shown courtesy of Searcher.

IMAGING OF ANKETELL SHELF

The legacy seismic data included in Figure 2 shows little to no imaging of the complex geology of the Proterozoic Yeneena Group. In contrast, all versions of the reprocessed seismic lines show significant improvement. As evident in Figure 4, a significant apparent W to NW-dipping, high-angle reverse fault is now evident on line H96-05 to the east of the Anketell Fault; with anticlinal folding of the Yeneena sediments on the hanging-wall of this fault. This fault does not appear to offset the overlying unconformable Permian sediments.

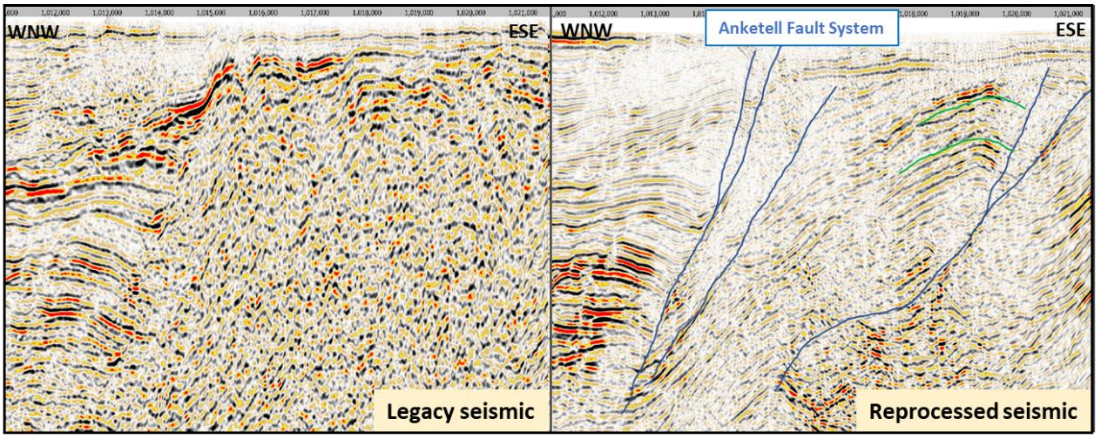

Figure 4. Comparison of legacy seismic and reprocessed seismic data from eastern end of H96-05. The Anketell Fault marking the eastern edge of the Barnicarndy Graven is shown, as well as an interpreted W-verging high-angle reverse fault further to the east. Multiclient seismic reprocessed data shown courtesy of Searcher.

The eastern end of this seismic line terminates in the Folly Project area. The interpreted solid geology (Clarke, 2019) of this area shows Lower Yeneena Group sediments folded into an anticline and intruded by NeoProterozoic granites. Only small outcrops of NW-trending quartz reefs are exposed through the thin Palaeozoic and Mesozoic cover sequences. The seismic line swings to a WNW-ESE trend in this section, running subparallel to the magnetic stratigraphy in this area; hence true dips are difficult to ascertain from the seismic. Reviewing the seismic in conjunction with the magnetic data implies that the main reverse fault may be slightly to the east, with only a splay imaged on the seismic line.

No evidence can be found in the limited literature for this newly imaged and significant reverse fault; potentially it may be analogous to the west-dipping Thorny Devil Fault known at the Winu Cu-Au deposit in a similar structural setting approximately 42km to the NW along the Anketell Fault

Reprocessing of seismic line A71-E and the other seismic lines from the Waukarlycarly 2D seismic survey highlight localized areas of basement bedrock highs, such as that as seen at the Winu Cu-Au deposit.

INSIGHTS INTO PROTEROZOIC BASIN BELOW THE GRABEN

The improved imaging in the newly reprocessed data also suggests the continuation of the regional structures impacting the Proterozoic sediments below the Barnicarndy Graben. Alavi (2013) provides a basement model for the graben, derived from the integrated interpretation of the seismic, gravity and magnetic data, to comprise two sub-parallel grabens with a central basement high representing an axial flexure zone. The H96-05 seismic line shows the unconformity marking the base of the graben to be of uniform depth, suggesting the gravity and magnetic response relates to changes in basement lithologies. The reprocessed seismic data reveals intriguing basement structures; potentially reflecting a major structure parallel to the northerly extension of the Parallel Range Fault. Johnson *et al.* (2021) noted that the Parallel Range Fault may separate isotopically distinct crust. Hence, these reprocessed seismic images may be providing key information on the architecture of the Proterozoic beneath the Barnicarndy Graben.

DISCUSSION

There exists a significant amount of seismic data throughout Australia acquired for petroleum exploration. These data contain valuable stratigraphic and structural information for mineral explorers now looking for mineral systems under sedimentary cover. Much of these data have not been reprocessed with modern processing techniques, nor with suitable processing workflows focussed on features of relevance for mineral explorers.

Line H96-05 in the Paterson Province was reprocessed trialling different processing workflows offered by five leading seismic contractors. Part of the focus was to review the applicability of the workflows to this geological environment. Key to obtaining detailed imaging results, and thus maximising geological insight, was a strong client input to focus and select appropriate processing algorithms, as well as strong ongoing collaboration throughout the processing workflow.

The improvement in seismic imaging along line H96-05 is significant, both due to considerable developments in seismic processing algorithms in the last 25 years, but also because of the mineral exploration mindset applied. New geological insights includes enhanced definition of the West Barnicarndy and Anketell Faults; definition of a previously unknown regional reverse fault within the Yeneena Group, as well as raising questions regarding the basement structure below the Graben.

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