Key features of new deep seismic reflection lines across frontier sedimentary basins in central Australia: the Arckaringa, Officer, Amadeus and Georgina Basins

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SUMMARY

The Onshore Energy Security Program, funded by the Australian Government and conducted by Geoscience Australia, in conjunction with State and Territory geological surveys, has acquired deep seismic reflection data across several frontier sedimentary basins to stimulate petroleum exploration in onshore Australia.

Here, we present the key aspects of the stratigraphy and structural architecture identified using seismic data from the Arckaringa, Officer, Amadeus and Georgina basins on seismic lines 09GA-GA1 and 08GAOM1.

Key words: Arckaringa Basin, Officer Basin, Amadeus Basin, Georgina Basin.

INTRODUCTION

The Onshore Energy Security Program was a five year program (2006-2011) funded by the Australian Government to provide geological information on frontier onshore sedimentary basins in Australia. As part of this program, deep seismic reflection data have been acquired in several frontier basins to stimulate hydrocarbon exploration.

Table 1: Seismic acquisition parameters

Line and source type	08GA-OM1, 3 IVI Hemi 60 vibrators
Sweep frequency	6-64 Hz, 12-96 Hz, 8-72 Hz
Line and source type	09GA-GA1, 3 AHV-IV vibrators
Sweep frequency	7-56 Hz, 12-96 Hz, 8-80 Hz
Source array	15 m pad-to-pad, 15 m moveup
Sweep length	3 x 12 s
Vibration point (VP) interval	80 m
Receiver group	12 geophones at 3.3 m spacing
Group interval	40 m
Number of recorded channels	300
Fold (nominal)	75
Record length	20 s at 2 ms

In 2008 and 2009, Geoscience Australia, in conjunction with Primary Industries and Resources South Australia (PIRSA), AuScope, and the Northern Territory Geological Survey, acquired several deep seismic lines. Here we focus on two north-south oriented lines in northern South Australia and the Northern Territory, the Seismic acquisition parameters are shown in Table 1. Seismic line 08GA-OM1 (GOMA), 634 km long, crosses the western Arckaringa Basin and eastern Officer Basin in South Australia, and the southernmost Amadeus Basin in the Northern Territory. Seismic line 09GA-GA1, 373 km long, crosses the northeastern Amadeus Basin and the Georgina Basin in the Northern Territory (Figure 1). The key findings from the seismic lines for each basin will be presented here.

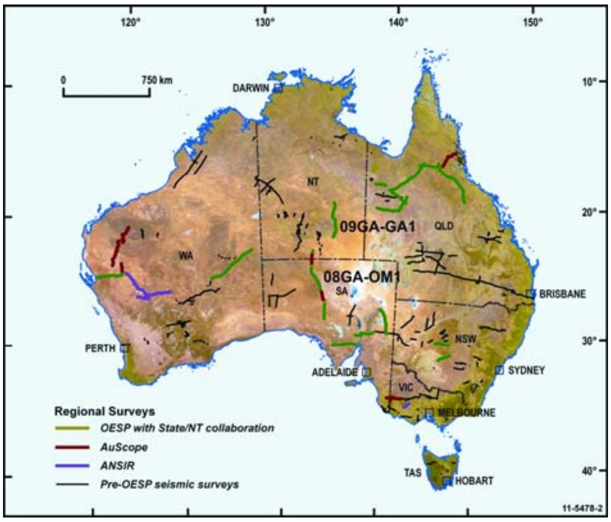

Figure 1. Location of seismic lines collected as part of the Onshore Energy Security Program, including seismic lines 08GA-OM1 and 09GA-GA1, described here.

ARCKARINGA BASIN, SOUTH AUSTRALIA

The Permian Arckaringa Basin unconformably overlies Neoproterozoic to Devonian sedimentary rocks of the Officer

Basin and the Archean to Mesoproterozoic Gawler Craton. The basin is largely overlain by Jurassic to Cretaceous units of the Eromanga Basin and consists of a wide platform area in the north and a series of troughs in the south and east.
On seismic line 08GA-OM1, the Arckaringa Basin is imaged as a series of depocentres, including the West, Phillipson (Figure 2a, 2b) and Penrhyn troughs, with a much thinner succession connecting the depocentres, and extending well to the north. These troughs have been interpreted previously as erosional features formed by glacial scour by some authors and as extensional graben by others. Debate over their origin continues, most recently in Menpes et al. (2010).

Menpes (in Menpes et. al., 2010) suggests that glacial scour formed the troughs, followed by deglaciation and a marine transgression. The deglaciation phase resulted in the deposition of the Boorthanna Formation, followed by a generally quiet, deeper water environment during deposition of the Stuart Range and lower Mount Toondina formations. The upper Mount Toondina Formation records a regressive environment interpreted as a shallowing upward delta sequence with coals deposited at the top. Minor contraction and possibly differential compaction is interpreted during deposition of the Mount Toondina Formation. This model uses palynology and organic geochemistry data from the Arkeeta 1 petroleum exploration well as evidence of lacustrine to restricted marine conditions, including periods of anoxia during the deposition of the upper Stuart Range and lower Mount Toondina formations.

Carr and Korsch (in Menpes et. al., 2010), conversely, interpret the troughs to be extensional containing three distinct seismic packages. The lowermost package, consisting of strong, irregular reflections, is interpreted as the Early Permian glaciomarine deposits of the Boorthanna Formation. This was succeeded by deposition of nonmarine swamp and lacustrine environments. Approximately 500 m to 1000 m of section was eroded prior to deposition of the Eromanga Basin (Department of Mines and Energy, 1989).

A key aspect to this interpretation is the strong and irregular reflections in the West Trough (Figure 2a). These maintain a relatively constant thickness across the trough, suggesting that they were deposited on a relatively flat surface, and were later rotated to their current position. Another important aspect of this interpretation is the package interpreted to be the Stuart Range Formation, which is characterised by subhorizontal, weak seismic reflections, consistent with shale-dominated lithologies. Importantly for the interpretation, the package onlaps both the underlying Boorthanna Formation and the sides of the trough, suggesting that subsidence, possibly due to thermal relaxation and/or compaction, was occurring at the time of deposition. Hence, the troughs are interpreted to have been formed by extension and relaxation of the crust. The uppermost unit, the Mount Toondina Formation, seismically consists of subparallel reflections which become increasingly less distinct up-section. Strong reflections at the top of the succession in the West and Phillipson troughs represent coal measures (Figure 2a, 2b).

OFFICER BASIN, SOUTH AUSTRALIA

The Officer Basin, with a surface area of 525,000 km^2, is part of the Centralian Superbasin (Walter et al, 1995) and onlaps the easternmost Archean Yilgarn Craton, the southern Mesoproterozoic Musgrave Province and the northwestern Archean-Mesoproterozoic Gawler Craton. The GOMA seismic line provides the longest single cross section of the Officer Basin available, extending from the northern margin, where the basin is overthrust by the Musgrave Province (Figure 2c), to the southern limit of Neoproterozoic and Cambrian sedimentary rock. The Officer Basin is overlain, in part, by sedimentary units of the Permian Arckaringa Basin and Mesozoic Eromanga Basin. The basin formed during multiple phases of subsidence from the Neoproterozoic to the Devonian. A gradual northward increase in thickness of the sediments in the basin is evident in the seismic data, as are the influences of at least three major episodes of faulting which have controlled and modified the basin architecture:

1. Willourian and Torrensian (early Neoproterozoic) extensional faulting,
2. Latest Neoproterozoic thrusting associated with the Petermann Orogeny, and
3. Mid-late Paleozoic thrusting associated with the Alice Springs Orogeny.

In the vicinity of the seismic line, the basin is structurally complex, being dominated by south-directed thrust faults and fault-related folds. The thrusts are not thin-skinned, but are rooted in the basement, and there is no decollement within the cover succession. Many thrusts are likely to result from reactivation of Proterozoic structures in the basement.

The GOMA seismic survey records a substantial part of the sedimentary and tectonic history of the Officer Basin, including stratigraphy interpreted as equivalent to the Neoproterozoic Callanna Group and the Emeroo and Mundallio Subgroups in the Adelaide Rift System (Preiss et al., 2010). Rifting in the early Neoproterozoic led to formation of small half graben with evaporitic sedimentation, followed by more extensive clastic packages. Sturtian glacial sedimentation occurred only in the north, and thickens towards the Musgrave Province. Sag-phase sedimentation preserved in the Adelaide Rift System is much reduced or absent in the platformal Officer Basin, but onset of the Petermann Orogeny towards the end of the Neoproterozoic converted the platform into a deeply-subsiding foreland basin. Cambrian transgression followed large-scale uplift and erosion of the Musgrave Province. In the early Cambrian, coarse clastics were shed from the uplifted Musgrave Province into the Officer Basin to the south, and also into a pullapart basin, the Moorilyanna Graben, within the Musgrave Province. This graben is bounded in the south by the Wintiginna Fault and in the north by the Echo Fault. Both faults appear to have had dextral movement during formation of the pullapart, with later inversion by thrusting during the Alice Springs Orogeny. Sedimentation continued intermittently until the Devonian, and was terminated by the Alice Springs Orogeny.

AMADEUS BASIN, NORTHERN TERRITORY

The Neoproterozoic to Devonian Amadeus Basin covers an area of ~170,000 km^2 in the Northern Territory and Western Australia (Beck, 2002). Present basin trends are east-west, due to Paleozoic tectonics of the Petermann and Alice Springs Orogenies, forming overthrust margins with the Arunta Region to the north and the Musgrave Province to the south. The basin produces both oil and gas (Jackson et al., 1984), with up to five known hydrocarbon systems (Marshall et. al., 2005).

Seismic line 08GA-OM1 images a section across the southernmost part of the Amadeus Basin. The key aspect to interpreting this seismic line, without well control, has been the use of outcrops from geological mapping and the comparison with other seismic studies to understand the nature of the reflections from various formations. Based on this, the lowermost stratigraphic unit, which lies unconformably on basement, is interpreted as the Bitter Springs Formation (consisting of the Gillen and Loves Creek Members), and consists of high amplitude, irregular reflections. This is overlain by a variably reflective package, interpreted as the Neoproterozoic Inindia beds and Winnall beds, which crop out at the surface.

On seismic line 09GA-GA1, components of the northeastern Amadeus Basin are separated by the basement Casey Inlier. To the south of the Inlier, a relatively coherent succession occurs compared to the north of the Casey Inlier, where, the Neoproterozoic succession thickens towards the north. In this area, the basin has been highly shortened, forming an imbricate thrust zone and associated fault-bend folds (Figure 2d). The units have detached along a décollement surface, developed in an evaporitic unit of the Bitter Springs Formation.

GEORGINA BASIN, NORTHERN TERRITORY

The Neoproterozoic to Devonian Georgina Basin trends northwest-southeast, covering up to 325,000 km^2 of Queensland and the Northern Territory. In the Northern Territory, the basin contains potential Cambrian hydrocarbon systems (Ambrose et. al, 2001) and, high Total Organic Carbon's (TOC's) have recently been confirmed by Vu et al. (2011). Several wells have been drilled on or near the seismic line 09GA-GA1, and this seismic section has been interpreted using control from the Phillip 2 well and surface geology.

The southern flank of the Georgina Basin consists of a series of remnant small extensional half graben, with south-dipping bounding faults and Neoproterozoic fill. Erosion has locally exposed granitic basement in the rift shoulders. Where the seismic line crosses a relative flat-lying succession of the basin (for ~120 km; Figure 2e) the succession thins to the north, with some units exposed at the surface, providing stratigraphic control, including the Cambro-Ordovician Tomahawk Formation and Devonian Dulcie Sandstone. A gentle syncline is mapped at the surface. Stratigraphic control for the interpretation is also provided by the petroleum exploration well Phillip 2, located adjacent to the seismic line, which intersected 1489 m of Cambrian to Devonian sedimentary rocks, before terminating in basement.

Several distinct seismic units are defined by strong reflections and major sequence boundaries, which occur between the Devonian Dulcie Sandstone and Cambro-Ordovician Tomahawk Formation, and between the Tomahawk Formation and the Cambrian Arrinthrunga Formation.

CONCLUSION

Deep seismic reflection profiles across several sedimentary basins, collected as part of the Onshore Energy Security Program in conjunction with State and Territory geological surveys, have provided new information on the basin architecture and internal geometries of these frontier basins. This new information increases our knowledge of these basins, hopefully leading to decreased hydrocarbon exploration risk.

ACKNOWLEDGMENTS

The Authors wish to thank Bianca Reese for the production of figures and Anthony Schofield and David Huston for reviewing the mauscript. Published with permission of the Chief Executive Officer, Geoscience Australia.

REFERENCES

Ambrose, G.J, Kruse, P.D. and Putnam P.E., 2001. Geology and hydrocarbon potential of the southern Georgina Basin, Australia. APPEA Journal, 41, 139–163.

Beck, L., 2002. The Amadeus Basin, Northern Territory, Australia. Northern Territory Geological Survey Report Book 2002-002.

Department of Mines and Energy, 1989. Petroleum exploration opportunity north eastern Arckaringa Basin; data package brochure – area D. Department of Mines and Energy, South Australia, Envelope 8081.

Jackson, K.S., McKirdy, D.M. and Deckelman, J.A., 1984. Hydrocarbon generation in the Amadeus Basin, central Australia, APEA Journal, 24 (1), 42-65.

Marshall, T.R., Dyson, I.A. and Keyu, L., 2005. Petroleum systems in the Amadeus Basin, central Australia: Were they all oil prone? In: Munson, T.J. and Ambrose G.J. (editors), Central Australian Basins Symposium. Northern Territory Geological Survey, Special Publication, 2, 136-146.

Menpes S.A., Korsch R.J. and Carr L.K., 2010. 2008 Gawler Craton-Officer Basin-Musgrave Province-Amadeus Basin (GOMA) seismic survey, 08GA-OM1: Geological interpretation of the Arckaringa Basin, in Korsch, R.J. and Kositcin, N., editors. GOMA (Gawler Craton-Officer Basin-Musgrave Province-Amadeus Basin) Seismic and MT Workshop 2010. Geoscience Australia, Record, 2010/39, 16-31.

Preiss W.V., Korsch R.J. and Carr L.K., 2010. 2008 Gawler Craton-Officer Basin-Musgrave Province-Amadeus Basin (GOMA) seismic survey, 08GA-OM1: Geological interpretation of the Officer Basin. In Korsch, R.J. and Kositcin, N., editors, 2010. GOMA (Gawler Craton-Officer Basin-Musgrave Province-Amadeus Basin) Seismic and MT Workshop 2010. Geoscience Australia, Record, 2010/39, 32-46.

Walter, M.R., Veevers, J.J., Calver, C.R. and Grey, K. 1995. Neoproterozoic stratigraphy of the Centralian Superbasin, Australia, Precambrian Research, 73, 173-195.

Vu, T.A.T., Horsfield, B. and Di Primio, R., 2011. Shale gas potential of the Amadeus and Georgina Basins, Australia: preliminary insights. Geoscience Australia, Record, 2011/10.

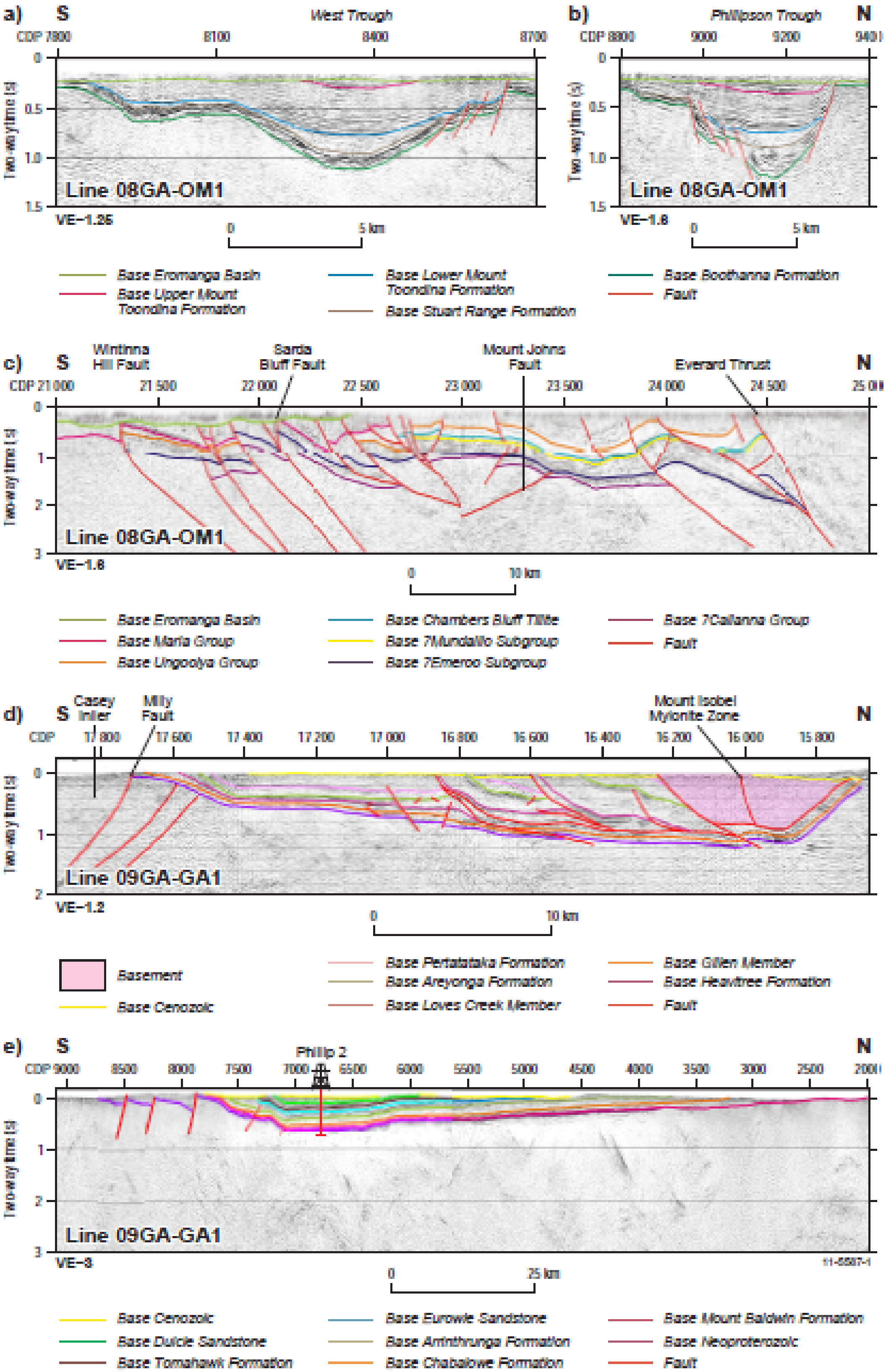

Figure 2. Sections from seismic line 08GA-OM1 showing the Arckaringa Basin (a and b) and the Officer Basin (c), and sections from seismic line 09GA-GA1 showing the Amadeus Basin (d) and Georgina Basin (e).