Structural and stratigraphic architecture of Australia's frontier onshore sedimentary basins: the Arckaringa, Officer, Amadeus and Georgina basins

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Lidena Carr presented this Extended Abstract to the 2011 APPEA Conference
on Tuesday, 12 April in Perth

Extended Abstract

Introduction

The Onshore Energy Security Program has been funded by the Australian Government for five years (2006–11) to provide geological information on some of Australia's frontier onshore sedimentary basins; many are under-explored with respect to hydrocarbons.

As part of this program, deep seismic reflection data have been acquired in several basins to stimulate petroleum exploration.

In 2008–9, Geoscience Australia, in conjunction with Primary Industries and Resources South Australia (PIRSA), AuScope, and the NTGS acquired two deep seismic lines. Seismic line 08GA-OM1, 634 km long, crosses the west Arckaringa Basin and east Officer Basin in SA, and the southernmost Amadeus Basin in the NT. Seismic line 09GA-GA1, 373 km long, crosses the northeast Amadeus Basin and the Georgina Basin in the NT.

Officer Basin, SA

The Officer Basin, with a surface area of 525,000 km^2, is part of the Centralian Superbasin and onlaps the easternmost Archean Yilgarn Craton, the south Mesoproterozoic Musgrave Province and the northwest Archean–Mesoproterozoic Gawler Craton. The basin formed during multiple phases of subsidence from the Neoproterozoic to the Devonian, and was affected by the latest Neoproterozoic to earliest Cambrian Petermann Orogeny and the Silurian-Carboniferous Alice Springs Orogeny. Tingate and McKirdy (2003) suggest that the basin could contain two Neoproterozoic and two Cambrian petroleum systems.

Where seismic line 08GA-OM1 crosses the Officer Basin (Fig. 1), there is a general northward thickening of the sedimentary successions. Many seismic units can be linked to outcrop. The lower units of the Neoproterozoic succession are unnamed, but are tentatively correlated with the ?Callanna Group, ?Emeroo Subgroup and ?Mundallio Subgroup of the Neoproterozoic of the Adelaide Rift Complex to the southeast. The ?Callanna Group and particularly the ?Emeroo Subgroup are represented by high amplitude, relatively continuous reflective packages. The less reflective overlying packages include diamictite and sandstone of Sturtian age (Chambers Bluff Tillite), and thick siltstone-carbonate units of Ediacaran age (?Lake Maurice and ?Ungoolya Groups).

In the vicinity of the seismic line, the basin is structurally complex, being dominated by south-directed thrust faults and fault-related folds, with evidence for at least three episodes of faulting. Early extensional faults bound small half grabens, in which the clastic-carbonate-evaporite ?Callanna Group was deposited. Rifting continued during deposition of the dominantly quartzitic ?Emeroo Subgroup. During the latest Neoproterozoic to earliest Cambrian Petermann Orogeny, the Officer Basin became a foreland basin in front of the southward-overthrusting Musgrave Province, depositing the ?Ungoolya Group, which thickens toward the Everard Thrust. This north-dipping thrust (Fig. 1d) defines the southernmost outcrop limit of the Musgrave Province.

In the early Cambrian, coarse clastics were shed from the uplifted Musgrave Province into the Officer Basin to the south, where they interfinger with finer-grained clastic rocks, carbonates and evaporites, and into a pull-apart basin, the Moorilyanna Graben, in the Musgrave Province (Fig. 1e). 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 pull-apart, with later inversion by thrusting during the Alice Springs Orogeny.

The Officer Basin is overlain, in part, by sedimentary units of the Permian Arckaringa Basin and Mesozoic Eromanga Basin. More detailed descriptions of the Officer and Arckaringa basins and interpretations of the seismic data are presented in Korsch and Kositcin (2010).

Arckaringa Basin, SA

The Permian Arckaringa Basin unconformably overlies Neoproterozoic to Devonian sedimentary rocks of the Warburton and Officer basins and the Archean to Mesoproterozoic Gawler Craton. Overlain by Jurassic to Cretaceous units of the Eromanga Basin, the mostly subsurface basin consists of a wide platform area in the north and a series of troughs in the south and east. Initially, Early Permian deposition was in a glacial marine environment. This was succeeded by deposition of non-marine swamp and lacustrine environments. About 500–1,000 m of section was eroded prior to deposition of the Eromanga Basin.

On seismic line 08GA-OM1 (Fig. 2), the Arckaringa Basin is imaged as a series of depocentres, including the West, Phillipson 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 graben structures by others. Debate over their origin continues today, with Menpes attributing a considerable erosional component to the troughs; however, Carr and Korsch do not (Korsch and Kositcin, 2010). Carr and Korsch interpret three distinct seismic packages in the troughs. The lowermost package consists of strong, irregular reflections interpreted as the glacio-marine deposits of the Boorthanna Formation.

The overlying package is characterised by sub-horizontal, weak seismic reflections, consistent with shale-dominated lithologies of the Stuart Range Formation. 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, occurred at the time of deposition.

The uppermost Mount Toondina Formation overlies the Stuart Range Formation. Seismically, this unit consists of sub-parallel reflections that become increasingly less distinct up-section. Strong reflections at the top of the succession in the West and Phillipson troughs represent coal measures (Figs 2a and c).

Amadeus Basin, NT

The Neoproterozoic to Devonian Amadeus Basin, also part of the Centralian Superbasin, covers an area of ~170,000 km^2 in the NT and WA. 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, with up to five known hydrocarbon systems (Marshall et al, 2005). Recent analysis by Vu et al (in press) supports the presence of source rocks away from the main exploration and production areas of the basin.

Seismic line 08GA-OM1 (Fig. 3) images a section across the southernmost part of the Amadeus Basin. The lowest stratigraphic unit, which lies unconformably on basement, is interpreted as the Bitter Springs Formation (consists 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. Deformation of the Neoproterozoic succession during the Petermann Orogeny was followed by deposition of the ?Devonian Finke Group above an angular unconformity.

On seismic line 09GA-GA1 (Fig. 3), components of the northeast Amadeus Basin are separated by the basement Casey Inlier. To the south of the inlier, a relatively coherent succession is interpreted to consist of Neoproterozoic units overlain by ?Cambrian Pertaoorta Group, Devonian the Mereenie Sandstone and Brewer Conglomerate.

To the north of the inlier, the Neoproterozoic succession thickens towards the north, with the Bitter Springs Formation reaching a thickness of 800 ms (TWT). In this area the basin has been highly shortened, forming an imbricate thrust zone and associated fault-bend folds. The units have detached along a décollement surface, developed in an evaporitic unit of the Bitter Springs Formation.

Georgina Basin, NT

The Neoproterozoic to Devonian Georgina Basin trends northwest–southeast, covering up to 325,000 km^2 in Queensland and NT. In the NT, the basin contains potential Cambrian hydrocarbon systems (Ambrose et al, 2001). Further analysis, also by Vu et al (in press), confirms the presence of high TOC samples from this region. Several wells have been drilled on or near the seismic line 09GA-GA1, including the Ammaroo and Phillip wells.

The south flank of the Georgina Basin consists of a series of remnant small half graben, with south-dipping bounding faults and Neoproterozoic fill. Erosion has exposed, in places, granitic basement in the rift shoulders (footwall blocks).

To the north of the half graben, seismic line 09GA-GA1 crosses a relative flat-lying succession of the Georgina Basin for nearly 120 km (Fig. 3). This succession is asymmetric and thins to the north, with some units exposed at the surface, including the Cambro-Ordovician Tomahawk Formation and Devonian Dulcie Sandstone. Stratigraphic control for the seismic interpretation is also provided by the petroleum exploration well Phillip–2, located adjacent to the seismic line, which intersected 1,489 m of Devonian to Cambrian sedimentary rocks, before terminating in basement.

Several distinct seismic units, defined by strong reflections, can be mapped, and are separated by sequence boundaries identified by stratal terminations. The major sequence boundaries occur between the Devonian Dulcie Syncline and Cambro-Ordovician Tomahawk Formation, and between the Tomahawk Formation and the Cambrian Arrinthrunga Formation. The succession in the basin has been mildly deformed with gentle folding in the south producing the Dulcie Syncline.

Conclusion

Deep seismic reflection profiles across several sedimentary basins, collected as part of the Onshore Energy Security Program, are providing new information on the basin architecture and internal geometries of these frontier basins. This will provide the basis for ongoing work that will aim to assess the petroleum potential of these basins.

Acknowledgements

The authors would like to thank Jennie Totterdell and Richard Blewett for their reviews of the manuscript and Dan McIlroy for help with production of the figures. Published with permission of the Chief Executive Officer, Geoscience Australia.

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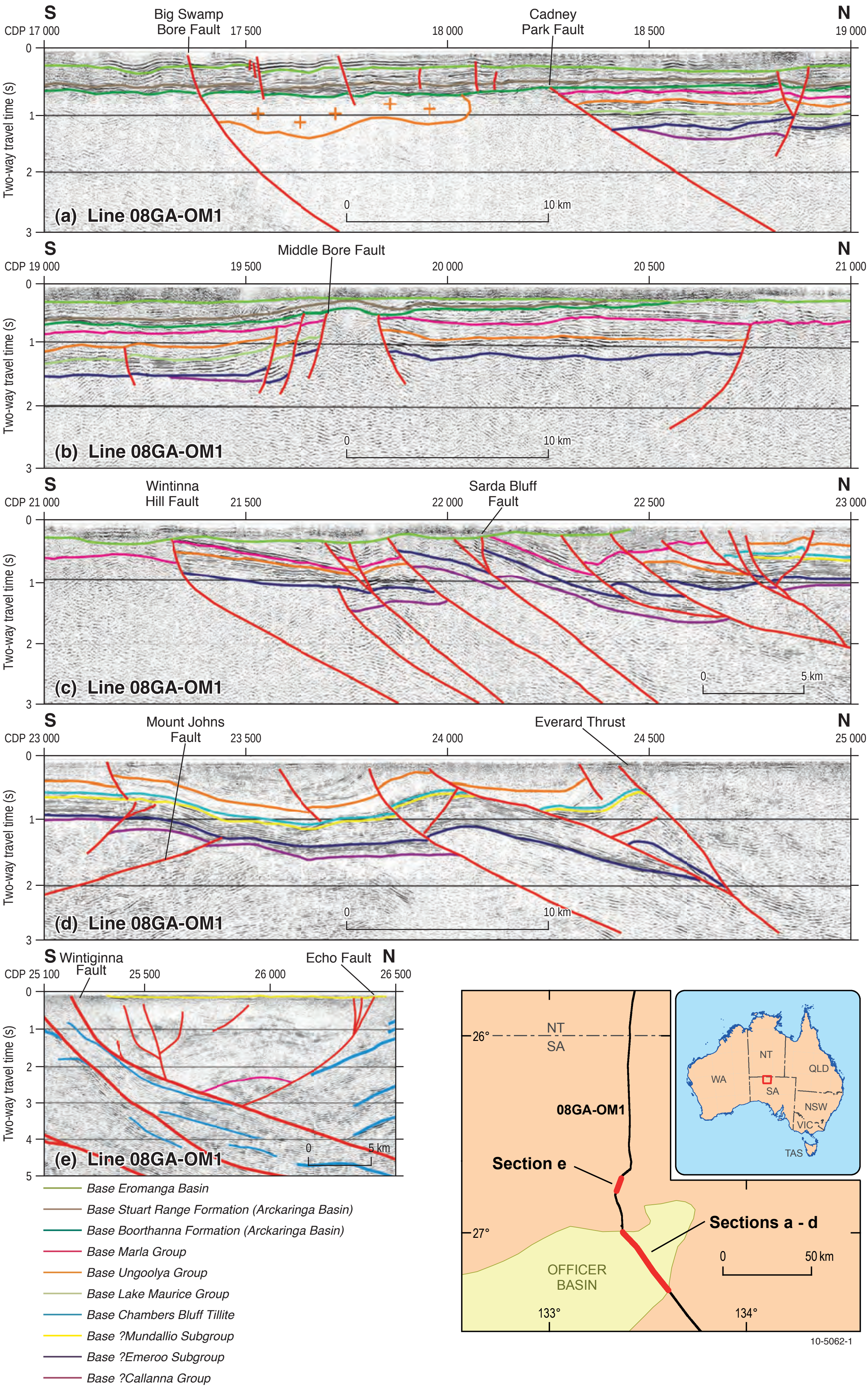
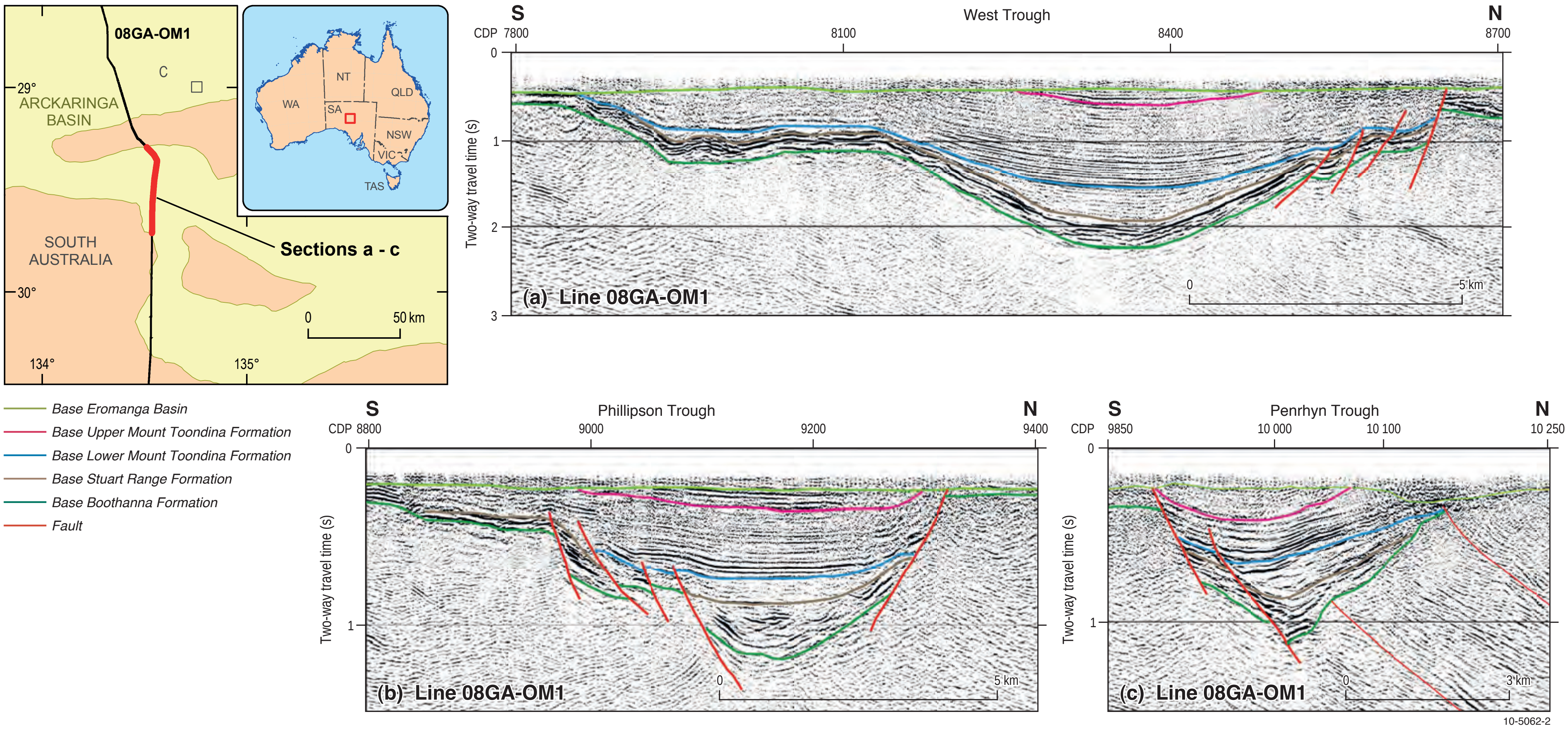
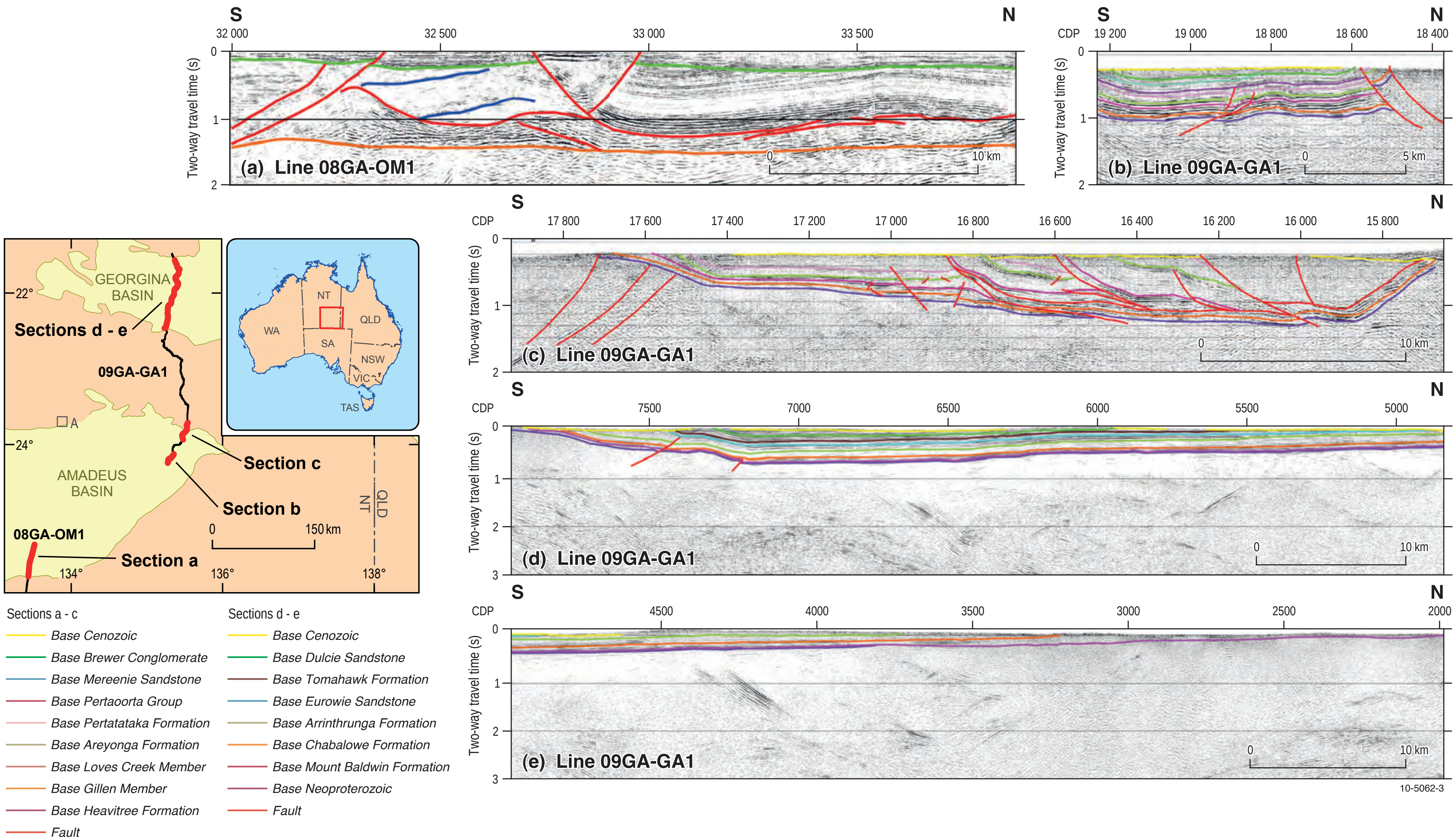


S
N
Big Swamp Bore Fault
Cadney Park Fault
CDP 17 000
17 500
18 000
18 500
19 000
Two-way travel time (s)
0
1
2
3
10 km
(a) Line 08GA-OM1
Middle Bore Fault
CDP 19 000
19 500
20 000
20 500
21 000
(b) Line 08GA-OM1
Wintinna Hill Fault
Sarda Bluff Fault
CDP 21 000
21 500
22 000
22 500
23 000
5 km
(c) Line 08GA-OM1
Mount Johns Fault
Everard Thrust
CDP 23 000
23 500
24 000
24 500
25 000
(d) Line 08GA-OM1
Wintiginna Fault
Echo Fault
CDP 25 100
25 500
26 000
26 500
4
5
(e) Line 08GA-OM1
Base Eromanga Basin
Base Stuart Range Formation (Arckaringa Basin)
Base Boorthanna Formation (Arckaringa Basin)
Base Marla Group
Base Ungoolya Group
Base Lake Maurice Group
Base Chambers Bluff Tillite
Base ?Mundallio Subgroup
Base ?Emeroo Subgroup
Base ?Callanna Group
26°
27°
NT
SA
08GA-OM1
Section e
Sections a - d
OFFICER BASIN
50 km
133°
134°
WA
QLD
NSW
VIC
TAS
10-5062-1


08GA-OM1
C
29°
ARCKARINGA
BASIN
SOUTH
AUSTRALIA
30°
134°
135°
Sections a - c
0
50 km
WA
NT
QLD
SA
NSW
VIC
TAS
S
West Trough
N
CDP 7800
8100
8400
8700
Two-way travel time (s)
0
1
2
3
5 km
(a) Line 08GA-OM1
Base Eromanga Basin
Base Upper Mount Toondina Formation
Base Lower Mount Toondina Formation
Base Stuart Range Formation
Base Boothanna Formation
Fault
S
Phillipson Trough
N
CDP 8800
9000
9200
9400
(b) Line 08GA-OM1
Penrhyn Trough
CDP 9850
10 000
10 100
10 250
3 km
(c) Line 08GA-OM1
10-5062-2


(a) Line 08GA-OM1
(b) Line 09GA-GA1
(c) Line 09GA-GA1
(d) Line 09GA-GA1
(e) Line 09GA-GA1
S
N
CDP
Two-way travel time (s)
GEORGINA BASIN
AMADEUS BASIN
Sections d - e
09GA-GA1
08GA-OM1
Section a
Section b
Section c
WA
NT
QLD
SA
NSW
VIC
TAS
22°
24°
134°
136°
138°
0
150 km
Sections a - c
Base Cenozoic
Base Brewer Conglomerate
Base Mereenie Sandstone
Base Pertaoorta Group
Base Pertatataka Formation
Base Areyonga Formation
Base Loves Creek Member
Base Gillen Member
Base Heavitree Formation
Fault
Sections d - e
Base Cenozoic
Base Dulcie Sandstone
Base Tomahawk Formation
Base Eurowie Sandstone
Base Arrinthrunga Formation
Base Chabalowe Formation
Base Mount Baldwin Formation
Base Neoproterozoic
Fault
10-5062-3