

Understanding the architecture and petroleum potential of Australia's onshore sedimentary basins with deep seismic reflection data

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SUMMARY

The Onshore Energy Security Program, funded by the Australian Government and conducted by Geoscience Australia, has acquired deep seismic reflection data across several frontier sedimentary basins to stimulate petroleum exploration in onshore Australia. Interpretation of the new seismic data from these onshore basins, focusing on overall basin geometry, internal sequence stratigraphy and petroleum potential, will be presented here. This will provide the basis for ongoing work which will aim to assess the petroleum potential of these basins.

Key words: Seismic data, Arrowie Basin, Millungera Basin, Georgina Basin, Yathong Trough, Darling Basin.

INTRODUCTION

Many of Australia's onshore basins are under explored with respect to hydrocarbons. To date, only the Cooper-Eromanga basin system maintains its status as a major commercial oil and natural gas producer, but recently, this has been complemented by commercialisation of coal seam gas resources in the Bowen and Surat basins in Queensland. With domestic oil production in steady decline, and increasing offshore exploration costs, the Onshore Energy Security Program (OESP) was funded by the Australian Government with ~\$59 million over five years (2006–2011). The program aims to provide precompetitive geoscience data and assessments of the potential for onshore energy resources to stimulate exploration in onshore Australia.

Interpretation of deep seismic reflection profiles, collected as part of the OESP, from four frontier sedimentary basins will be discussed here. The focus of this work is on the overall architecture and internal geometry of these basins, with the eventual aim of assessing their petroleum potential. The basins studied here are the Georgina Basin (northwest QLD),

Millungera Basin, (northwest QLD), eastern Darling Basin (western NSW) and Arrowie Basin (SA) (Fig. 1).

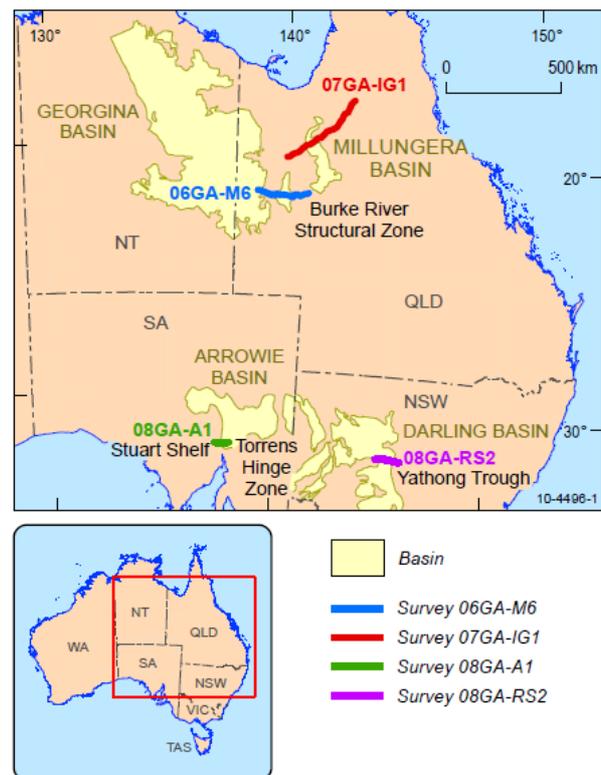


Figure 1 Map showing locations of the seismic lines described in this paper.

GEORGINA BASIN, NORTHWEST QUEENSLAND

At the southern end of the exposed part of the Mt Isa Province, northwest Queensland, a deep seismic line (06GA-M6) was acquired across the Burke River Structural Zone of the Neoproterozoic to Early Paleozoic Georgina Basin (Fig. 1). In the NT, there are numerous oil and gas shows in the basin, and solid bitumen has been recovered from drillcore (Volk *et al.*, 2007). The basin is considered to be prospective for hydrocarbons, with parts of the basin in southeastern NT considered to be in the oil window. Exploration drilling has been very limited, but there are several known Middle to Late Cambrian potential petroleum systems in the NT part of the Georgina Basin (Boreham and Ambrose, 2007). Although the Burke River Structural Zone is known for its phosphate resources (e.g. Duchess phosphate mine), virtually no exploration has been undertaken for hydrocarbons in this area.

Seismic line 06GA-M6 (Fig. 2a) provides the first seismic image across the Burke River Structural Zone. Here, the basin is ~65 km wide, with a half graben geometry, being bounded in the west by a rift border fault. It has a maximum thickness of ~2800 m (calculated from stacking velocities). Interpretation of the stratigraphy is constrained by scattered outcrops in the vicinity of the seismic line. The lowermost sequence is interpreted to be the Early Cambrian Mount Birnie beds. Based on well control from the nearby BMR Duchess 18 drillhole, the overlying Thornton Limestone is identified as a pair of strong seismic reflections. Stratigraphic units adjacent to the basin-bounding fault do not occur farther to the east, suggesting that they were either not deposited or have been eroded, with a major unconformity occurring above the Thornton Limestone. There has been intense inversion on the basin-bounding fault, and the hanging wall strata have been rotated to steep dips (up to 75°). The zone of inversion is bounded to the west by the Pilgrim Fault, which is a reactivated basement fault. To the east of the Pilgrim Fault, the basin is essentially undeformed and preserves its original geometry.

MILLUNGERA BASIN, NORTHWEST QUEENSLAND

Completely covered by the thin Jurassic–Cretaceous Eromanga–Carpentaria Basin, the Millungera Basin in northwest Queensland was not discovered until 2006, when relatively short segments across the western part of the basin were first observed on two seismic lines (06GA-M4 and 06GA-M5). Following this, seismic line 07GA-IG1 (Fig. 1) imaged a 65 km wide section of the basin (Korsch *et al.*, 2009) (Fig. 2b). Interpretation of aeromagnetic data suggests that the basin could have real dimensions of up to 280 km by 95 km (Hutton *et al.*, 2009). Apart from geophysical data, virtually no geological information exists on the basin.

Scarce water bores in the overlying Eromanga–Carpentaria Basin intersect the organic-rich Toolebuc Formation at a depth of about 185 m, with the basin being about 200–300 m thick in this region. There is a noticeable angular unconformity between the two basins, indicating that part of the Millungera Basin was eroded prior to deposition of the Eromanga–Carpentaria Basin. Below this, the Millungera Basin consists of three distinct sedimentary packages, mapped in the seismic section, which thicken slightly to the east (Fig. 2b). In the

seismic section, the base of the basin is at a maximum depth of ~3200 m (calculated from stacking velocities). Interpretation of gravity profiles suggests that the basin deepens to the south, possibly reaching a maximum thickness of 4000 m. Both the western and eastern margins of the Millungera Basin are truncated by thrust faults, with well-developed hanging wall anticlines occurring above the thrusts at the eastern margin (Fig. 2b). Several granites are interpreted to occur below the Millungera Basin, raising the possibility of geothermal plays. Given the unknown age of the basin, several possibilities exist. It might be related to the Galilee Basin to the southeast, the Georgina Basin to the southwest, the Adavale Basin to the south, or even to Mesoproterozoic rocks of the Isa Superbasin to the northwest. The geometry of internal stratigraphic sequences and post-depositional thrust margins indicate that the original succession was much thicker than preserved today, and the basin may have potential for a petroleum system. Further work is warranted.

ARROWIE BASIN, SOUTH AUSTRALIA

The western part of the Arrowie Basin, west of the central Flinders Ranges, forms part of the Stuart Shelf and the Torrens Hinge Zone. This part of the basin has received almost no attention for hydrocarbon exploration since the shallow Wilkatana wells were drilled in the 1950s to a maximum depth of ~670 m. Some of these wells encountered non-commercial bituminous hydrocarbons in the Cambrian succession. The Cambrian source rocks are considered to have previously generated oil and, in some places, are still within the oil generation and preservation window (McKirdy, 1994).

Seismic line 08GA-A1 (Fig. 1) crossed the Cambrian Arrowie Basin, which is underlain by a Neoproterozoic succession of the Adelaide Rift System. Stratigraphic sequences have been mapped and are tied to recent drilling for mineral and geothermal exploration. The seismic line shows that the Arrowie Basin (Fig. 2c) is asymmetrical, varying in thickness from about 700 m in the west, to about 3800 m in the east. There is very limited stratigraphic control in this region, and the Wilkatana wells, about 15 km to the south of the seismic section, most end in the Cambrian succession. Recent mineral industry drilling (TDKH1A, 1002 m total depth) to the south of the seismic line, intersected part of the Neoproterozoic succession. Several sequence boundaries, mapped using sequence stratigraphic principles, are correlated tentatively with the sequence boundaries between the major Neoproterozoic stratigraphic groups in the Adelaide Rift System, which have been mapped in outcrop in the Flinders Ranges to the east.

The east-dipping Yadlamalka Fault (~CDP 4000, Fig. 2c) is a post-depositional thrust fault defining the eastern limit of the Stuart Shelf, to the east of which is the Torrens Hinge Zone. To the south of the seismic line, recent mineral exploration drilling intersected the Beda Volcanics (part of the basal Neoproterozoic Callanna Group) in the hanging wall of the thrust, indicating that there has been at least 1200 m of pre-Cenozoic throw on the fault. A narrow, linear magnetic high on the aeromagnetic images is interpreted to represent the upthrust Beda Volcanics on the eastern side of the Yadlamalka Fault. In this seismic section, there is only a thin remnant of the Cambrian succession preserved, to the east of the Yadlamalka Fault. A series of east-dipping thrust faults disrupt the stratigraphic section in the easternmost part of the

seismic section. These faults might be related, in part, to the currently active, east-dipping, Wilkatana Fault, which occurs immediately east of the seismic line and is associated with the recent uplift of the Flinders Ranges.

YATHONG TROUGH, DARLING BASIN, WESTERN NSW

The Yathong Trough occurs in the southeast part of the Darling Basin in western NSW (Fig 1). The Darling Basin, although under explored, is known to contain more than 8000 m of Late Silurian to Early Carboniferous sedimentary rocks. This section is dominated by Middle to Late Devonian red beds, and contains potential source rocks and at least one active Paleozoic petroleum system (Alder et al, 1998). The basin was last deformed during the Carboniferous Kanimblan Orogeny, with thrust faults and related hanging wall anticlines having the potential to act as traps for hydrocarbons (Stewart and Alder, 1995). Prior to the Onshore Energy Security Program the trough has not been explored through seismic acquisition or drilling.

The trough was imaged in seismic line 08GA-RS2 (Fig. 2d), which shows a thick basin fill characterised by alternating high and low amplitude seismic reflections that are interpreted to represent the expected Devonian succession of nonmarine mudstones and sandstones. Using sequence stratigraphic principles, four major packages have been identified, and interpreted to be (from the base up): Ordovician turbidites of the Lachlan Orogen forming the basement; the Late Silurian-Early Devonian rift-fill package; the Early Devonian Winduck Group deposited on a shallow marine shelf; and a very thick succession of Middle-Late Devonian red beds forming the Mulga Downs Group. The Winduck and Mulga Downs Groups form a very thick succession up to ~2.95 s TWT (~7200 m) thick. The sequence boundary at the base of the Mulga Downs Group is a marked erosion surface, denoting the change from shelf to continental sedimentation. The trough is fault bounded in the west by a positive flower structure associated with a north-south trending strike-slip fault. Near the eastern margin of the trough, an east-directed thrust fault has a hanging wall anticline on its western side. The eastern margin of the trough is terminated by a major, west-directed thrust fault. Possible traps include anticlinal and fault closures near the eastern margin of the trough.

CONCLUSIONS

Deep seismic reflection profiles across onshore Australian 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 which will aim to assess the petroleum potential of these basins.

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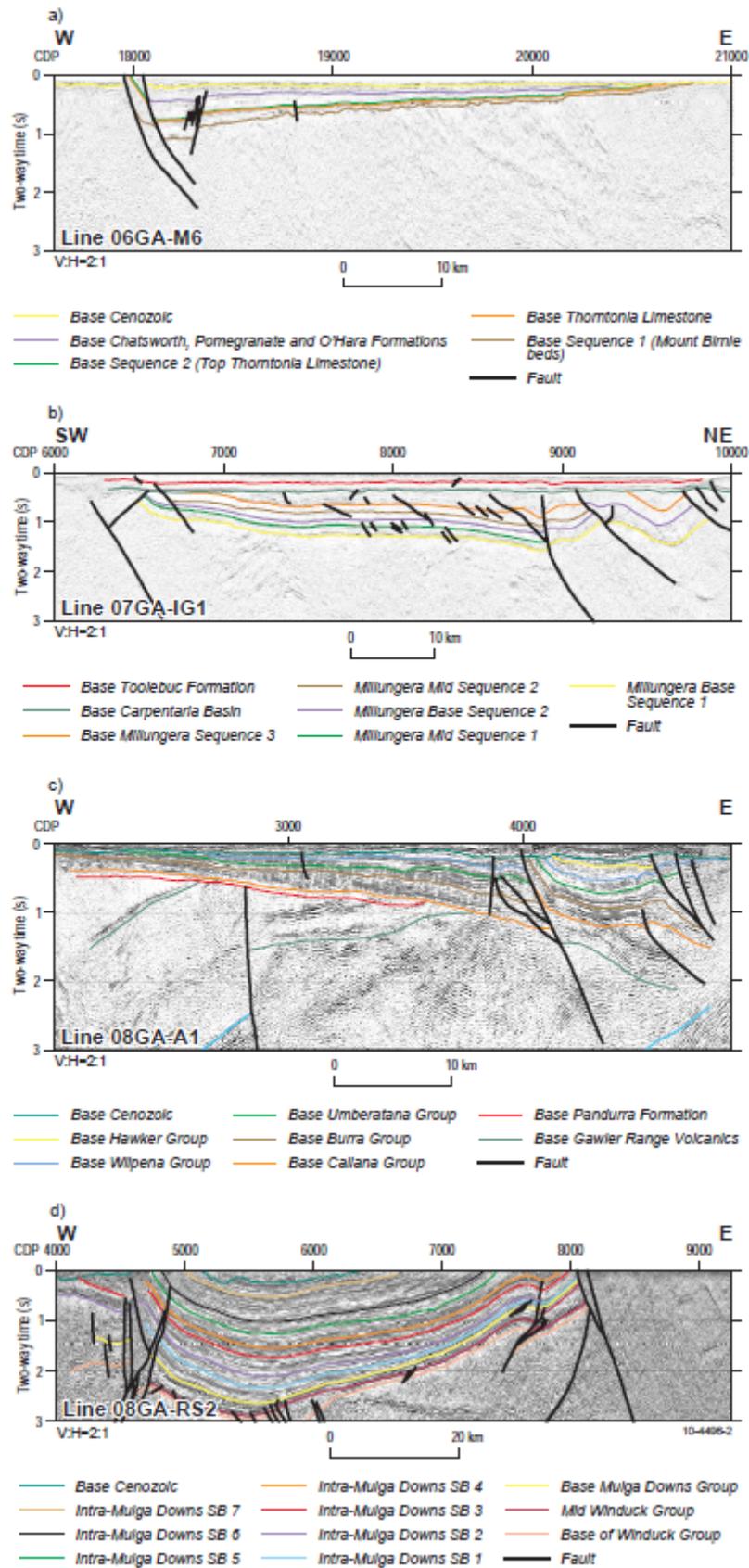


Figure 2 Geological interpretations of seismic lines across the (a) Georgina and (b) Millungera basins in northwest QLD, (c) Arrowie Basin (SA), and (d) Yathong Trough (Darling Basin, NSW).