NSW GOVERNMENT

Bancannia Trough Data Package 2018 Report

April 2018

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Contents

Introduction

The Bancannia Trough Petroleum Data Package 2018 is a product of the New Frontiers Minerals and Energy Exploration Initiative of the Geological Survey of New South Wales (GSNSW), Division of Resources and Geoscience, Department of Planning and Environment. This package provides information and pre-competitive data, for potential petroleum explorers, to assess the petroleum potential of this relatively underexplored trough.

The Bancannia Trough is a sub-basin in the Darling Basin and this data package builds on the previously released Darling Basin Petroleum Data Package 2017 which is an overview of the entire Darling Basin. The Bancannia Trough Data Package 2018 provides a more focused collation and discussion of the available data on the Bancannia Trough.

The Darling Basin is the largest onshore basin in New South Wales (NSW) and one of the largest in Australia. It is located in far western NSW in a structurally complex Late Silurian to Early Carboniferous intracratonic basin. The Darling Basin covers an area of 100,000 km^2 and is comprised of multiple sub-basins, with at least 8 km of sedimentary fill believed to be preserved (Alder et al. 1998) in parts of the basin. The sediments were deposited in a range of marine to fluvial environments.

The Bancannia Trough is a sub-basin within the Darling Basin (Figure1).The Bancannia Trough is a northwest-southeast trending sedimentary sub-basin, located in far north-western NSW basin extends to northwest with some geophysical data indicating that it extends slightly into South Australia. The Bancannia Trough, as it is currently understood, is approximately 40 km wide and 230 km long and covers an area of 10,000 km^2. Estimating the full extent of the sub-basin is hampered by a lack of data in the northwestern and southwestern parts of the basin.

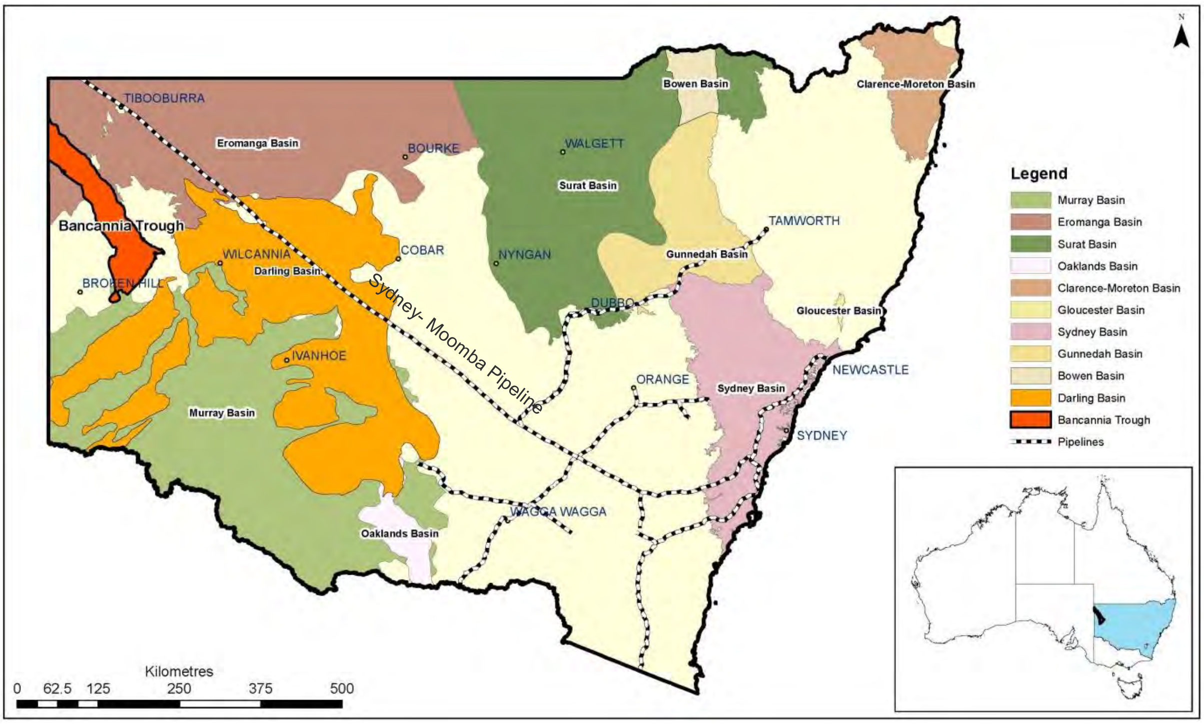


Figure 1: Location of the Bancannia Trough and the other Darling Basin troughs within NSW. The figure also shows the Bancannia Trough's proximity to the Moomba- Sydney gas pipeline.

The revised extent (Figure 2) shows that the basin extends further to the north and redraws the margins in the central and southern parts of the trough to a more limited extent. The previous trough boundary was based on modeling carried out by FrOGTech as part of the Seebase® project (FrOGTech, 2006). The revised boundary includes the most up to date interpretation and field mapping work carried out as part of the Zone 54 Seamless Geology Project (Colquhoun et al. 2016). Limited seismic and well data however, means that the revised boundary remains poorly constrained across large parts of the Bancannia Trough area.

The interpreted trough boundary includes all recognised Devonian units in the area. The sediments along the margins of the trough, where Devonian outcrop is often present, are not considered prospective for petroleum accumulations. This is due to their shallow depth and general lack of viable trapping and confinement mechanisms.

The outcrop however, does provide information on the stratigraphy and sedimentology of the trough sediments including the potential to yield information on the petroleum outlook for the trough if source type rocks or indications of the presence of hydrocarbon can be identified in these units. In addition age dating may also be performed on these units, if suitable palaeotological or palynological samples can be obtained, although to date the acquisition of definitive age dating samples has proven problematic due to the sparsity of samples and the suitability of the species extracted from samples.

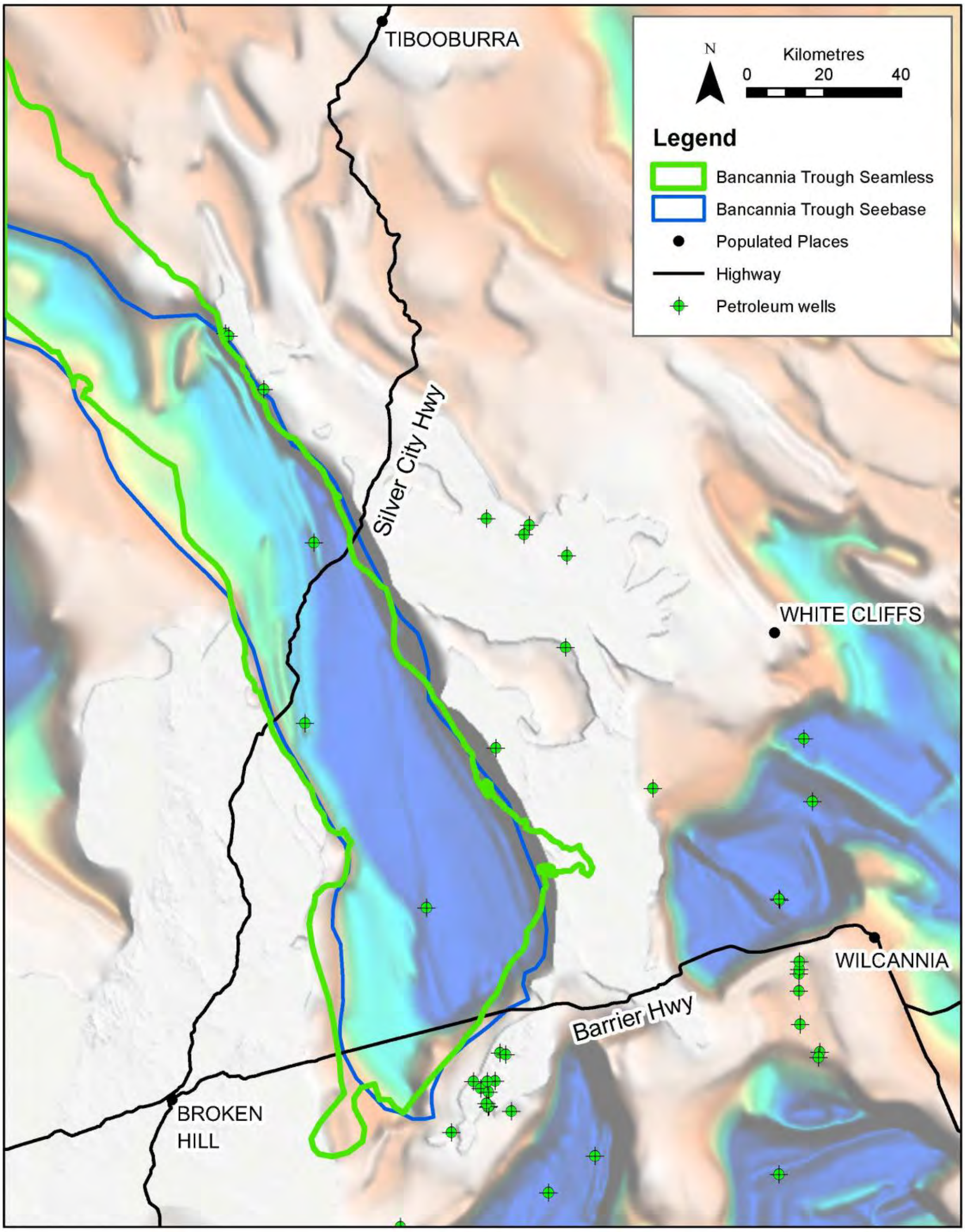


Figure 2: General location showing both the seamless geology (green line) and Seebase® (blue line) outlines of the Bancannia Trough displayed over the Seebase® image.

The estimated maximum sediment thickness of the Bancannia Trough is greater than 6 km, comprised of likely Late Silurian or Early Devonian to Early Carboniferous sediments. The sediment fill is however, predominantly Devonian (419Ma to 359Ma) aged, comprised mainly of sandstone and siltstone units. The fill overlies the Cambrian-Ordovician metasediments that are a part of an older Palaeozoic – Proterozoic basin system.

Exploration for petroleum has been limited within the Darling Basin. Petroleum exploration in the Bancannia Trough consists of three wells and approximately 1000 km of 2D seismic surveys (of varying quality) providing relatively good regional coverage within the sub-basin.

The Bancannia Trough is one of the more prospective areas for petroleum exploration in western NSW. All of the elements of a conventional petroleum system appear to be present. The trough is also relatively close to the Sydney to Moomba pipeline (Figure 1) and the all-weather Barrier Highway provides road access to the southern part of the trough.

The data presented in this package includes well, seismic, outcrop, age dating, hydrocarbon indicator data, references and a structural time and depth domain 3D model of the basic structural and stratigraphic framework of the trough. The package also includes additional relevant data outside of the Bancannia Trough which provides important information on the regional geology.

Part 1 – Geology of the Bancannia Trough

Regional Structure and Geology

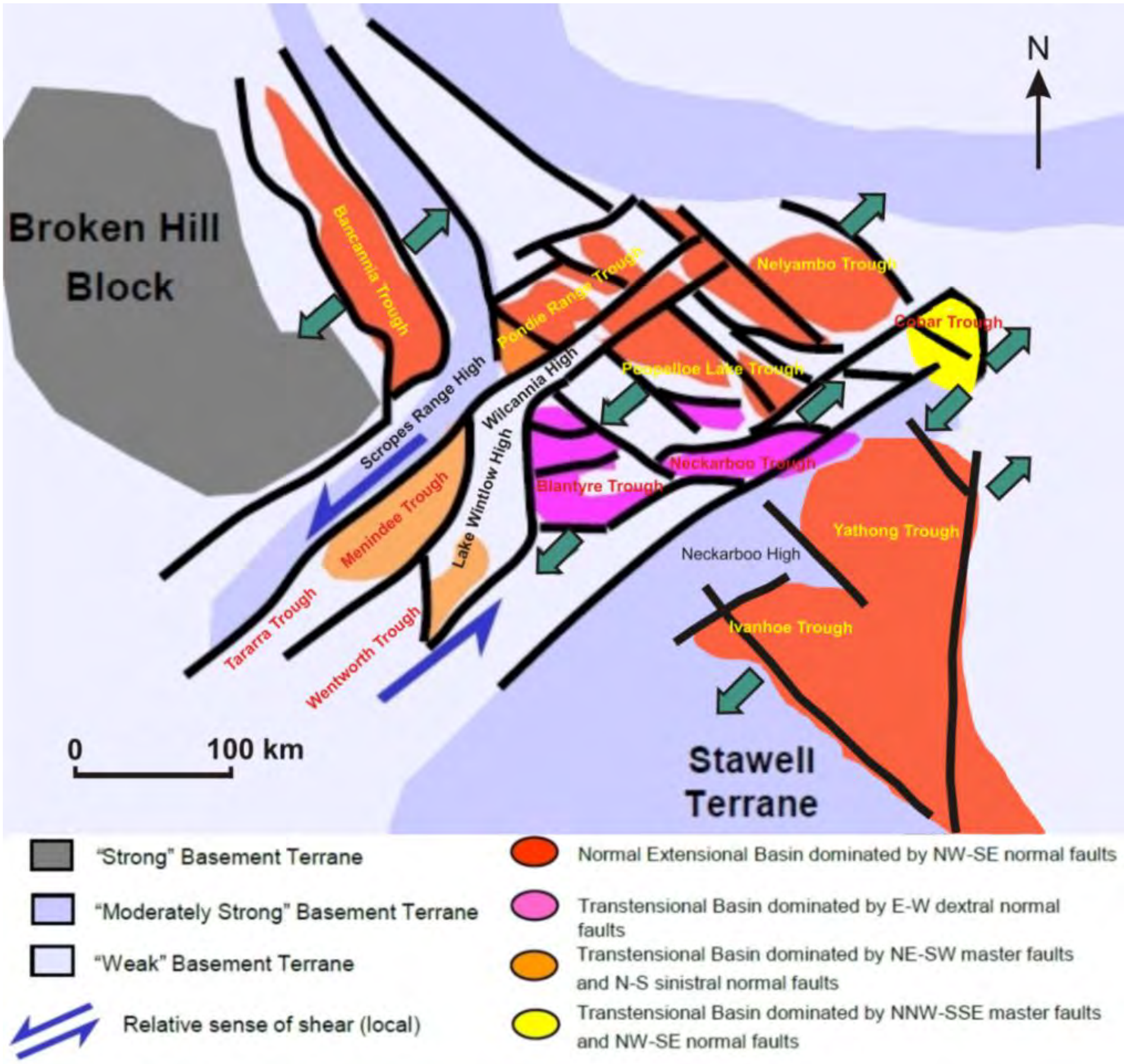


Figure 3: Deformation types recognised by Pearson (2003) in the Darling Basin. The Bancannia Trough was primarily influenced by a normal extensional regime and is delineated by major NW-SE oriented faults. It is relatively unaffected compared to the more complex structural regime present in the central part of the Darling Basin.

Numerous fault-bounded infrabasins dominate the larger Darling Basin architecture (Figure 3). These are composed of complex grabens and half-grabens formed by rifting during crustal extension. These infra-basins were modified by inversion during subsequent compressional events. The sub-basins are often bounded by extensive fault zones. These large scale fault zones are recognised in gravity and magnetic geophysical imagery. The Darling Basin is bordered by orogenic complexes on all sides. The Delamerian Orogen in the west, in the north the Thomson Orogen, and in the east and south the Lachlan Orogen.

The Bancannia Trough is an extensional basin that is dominated by mapped and inferred NW-SE normal boundary faults (Pearson, 2003). In the east the Lawrence Fault (also referred to as the Bynguano Fault in some publications) bounds the trough whilst in the west a complex series of faults (eg. the Nundooka Creek Fault) define its western edge. The southern boundary is an inferred major NW-SE striking fault separating the Delamerian Orogeny associated, metamorphosed Scropes Range Formation from the Darling Basin sequence within the Bancannia Trough. Evidence for large scale faulting within the basin itself is limited with gravity, magnetic and seismic data showing a small number of relatively large faults cross-cutting the trough fill sequence.

Evolution of the Bancannia Trough

Throughout the Darling Basin's Palaeozoic evolution the major driver of basin development has been the westward subduction of the palaeo-Pacific ocean floor under the eastern margin of Gondwanaland (Khalifa et al. 2017). This subduction led to the development of the Lachlan Fold Belt and an associated foreland basin to its west in which Cambrian to Carboniferous units were deposited.

Cambrian to Ordovician

During the Cambro-Ordovician the east-west oriented compression of the Delamerian Orogeny took place impacting eastern Australia. It was during this event that the structural confines of the later basin developed. The major faults that would later bound the basin in the east and west were most likely initiated at this time.

The Middle and Late Cambrian were periods of regional depositional hiatus, throughout eastern Australia, that was related to the uplift caused by the Delamerian Orogeny. The orogeny produced extensive west-northwest compression and deformation (Pearson 2003). This shortening event and associated volcanism provides most of the basement units that underlie the Bancannia Trough (Cambrian volcanics).

In the Late Cambrian to Late Ordovician a marine incursion (Larapintine SW-NE extension) led to renewed deposition, primarily of carbonates and conglomeratic units. Minor finer grained and potentially source prone units (Robertson Research Australia 2001), of the Gnalta Group were also deposited at this time.

The Cambrian and Ordovician units' depositional setting may correspond to some extent with that which took place in the Arrowie Basin in South Australia. The eastern extent of the Arrowie Basin is not well understood in NSW although it is likely that it terminates against the Proterozoic basement units of the Curnamona Province to the east of the Bancannia Trough. Teasdale et al (2001) indicate that the eastern extent of the Arrowie Basin in NSW is defined by major basement faults.

Whether or not deposition continued across into the area that would later become the Bancannia Trough is not clear, however based upon the gravity response in the extreme northern part of the Bancannia Trough there is some evidence that the Arrowie Basin sedimentation may have extended into this area. If this were the case then deposition of the Cambro-Ordovician Gnalta Group may have been an extension (entirely or in part) of the Arrowie Basin Cambrian sedimentation.

Early Devonian

During the Early Devonian extensive deposition commenced in the Bancannia Trough associated with north-south oriented rifting of the underlying Cambrian units (Lachlan Extension). It is inferred that the fluvial to shallow marine facies Winduck Group was deposited in this early Devonian syn-rift and late rift-fill stage (Pearson 2003).

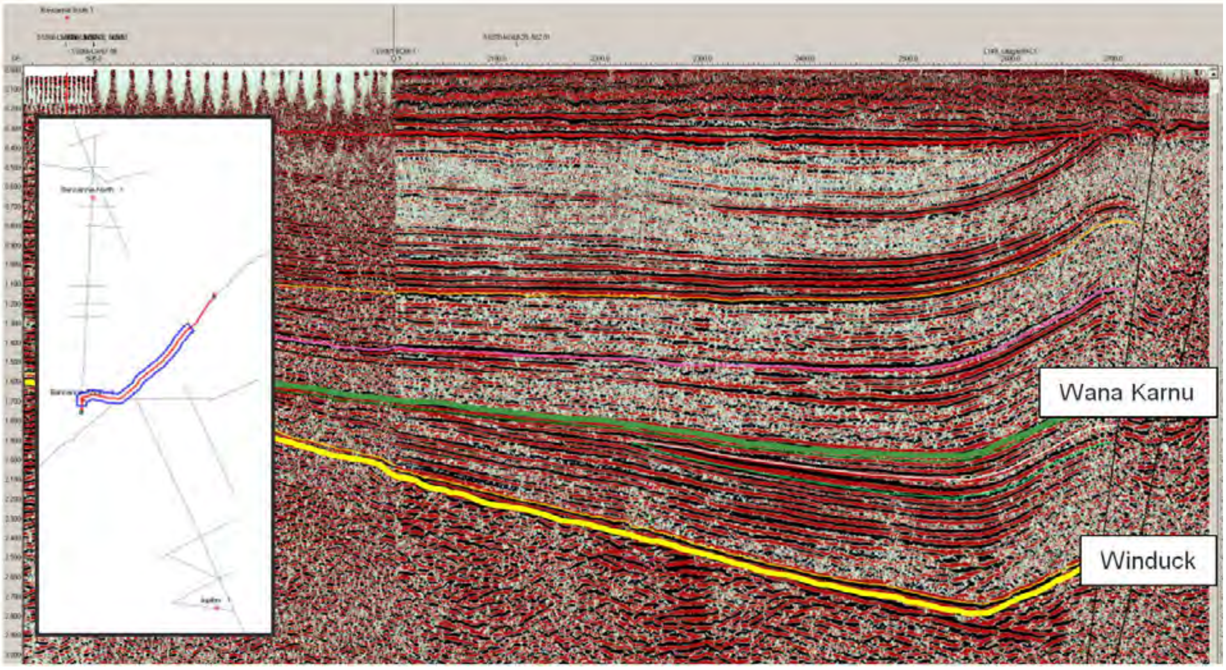


Figure 4: Composite seismic line GA99AGSC1/ SS061-BC66-01/ SS066-LW67-06, which is oriented approximately east-west across the central part of the Bancannia Trough, showing thickening of Early Devonian units towards the east and the unconformity associated with the Tabberabberan Orogeny highlighted in green. Inset: Location of seimic composite line in the central part of the Bancannia Trough.

Middle Devonian

Thermal sag of the basin during the Middle Devonian provided accommodation for the deposition of the fluvial quartzose sandstones of the Wana Karnu Group. During the late Middle Devonian the Tabberabberan Orogeny occurred. This event led to a depositional hiatus which is characterised by an angular unconformity on seismic surveys within the trough (Figure 4). The Tabberabberan SW-NE compression triggered minor reactivation of earlier fault zones which caused localized uplift and erosion of the Early Devonian.

Late Devonian

Fluvial sedimentation, similar to the Middle Devonian, continued following the Tabberabberan Orogenic uplift and erosion. The Darling Basin as a whole experienced foreland loading (Blevin et al. 2007) associated with the Late Devonian SW-NE Pillar Extension event with the sediment likely to have also included a significant easterly derived component from shedding off the uplifted Lachlan Fold Belt.

Carboniferous

In the Early Carboniferous foreland sedimentation continued with fluvial and lacustrine units being deposited. During the Middle Carboniferous the Kanimblan Orogeny caused east-west shortening in eastern Australia particularly within the Lachlan Fold Belt that underlies and also occurs to the east of the Darling Basin.

The Bancannia Trough did not undergo significant compression during this orogenic event with Blevin et al. (2007) suggesting that the lack of significant deformation within parts of the Darling Basin may be due to very hard granitic basement units. The volcanic units (Gnalta Group) underlying the Bancannia Trough could have provided resistance to compression and may have contributed to the relative lack of major deformation within the trough.

Cretaceous to present

The Devonian units are overlain by younger sediments in most parts of the trough. Units of Carboniferous and Cretaceous age have been identified through palynological work from samples collected from the upper parts of the Bancannia North 1 (Helby, 1968) and Bancannia South 1 wells (Burger 1968).

There remains potential for other Mesozoic or Palaeozoic aged units to be recognized within the Bancannia Trough area however, the limited well data means that new data is required to determine the presence and extent of post-Devonian sediments.

Most parts of the Bancannia Trough are extensively overlain by Quaternary sediments. These cover large amounts of the surface area of the trough except for limited areas of Devonian outcrop present along the central-western and central-eastern margins of the basin.

Stratigraphy and Depositional Environments

Mineral exploration to the west of the Darling Basin in the Broken Hill area and to the east around Cobar, encouraged early attempts at understanding the stratigraphy using outcrop mapping and drilling. Formal stratigraphy is defined in these two areas.

However, in between these areas, due to poor outcrop and sparse drilling across the Darling Basin, the stratigraphy is based on significant reflectors observed in regional seismic surveys. These reflectors are generally interpreted to correlate with major tectonic events. Bembrick (1997) provided an overview of sedimentation and stratigraphy.

In the last decade there has been renewed interest in understanding the depositional history and stratigraphy of the Darling Basin. Recent studies include; Kahlifa (2017), Khalifa (2010), Khalifa & Ward (2010), Carr et al. (2012), Neef (2012), Alfkey & Yusoff (2013), Khalifa & Mills (2014), Bunch (2014), Kahlifa et al. (2016) and Kahlifa et al. (2017).

Since Bembrick (1997) and Gibson (2003) the formal stratigraphy of the Koonenberry Belt, formerly known as the Wonominta Block, to the north of the Darling Basin has been updated (Greenfield et al. 2010). In the east, the space-time relationships in the Cobar area have been revised (Downes et al. 2016).

In this report the Devonian units have been divided into intervals, based on major seismic reflectors and these are discussed in place of the formal stratigraphic nomenclature based on lithology and age dating data. This approach has been applied previously, for example Bembrick (1997), Robertson Research Australia (2001) and Cooney & Mantaring (2005). This approach is necessary due to poor outcrop and limited well data. It enables the use of seismic data (the most widespread data on the Devonian units within the trough) for regional scale correlation.

High amplitude seismic reflectors are prominent in multiple seismic lines and are inferred to relate to major regional unconformities. The seismic horizons do not necessarily correspond completely with the formal stratigraphy and time correlations (Figure 5). These high amplitude seismic horizons represent the boundaries used in this report and are informally termed the “Winduck interval”, overlain by the “Wana Karnu interval” (formerly referred to as the Snake Cave interval) and then the “Ravendale interval” (Figure 6).

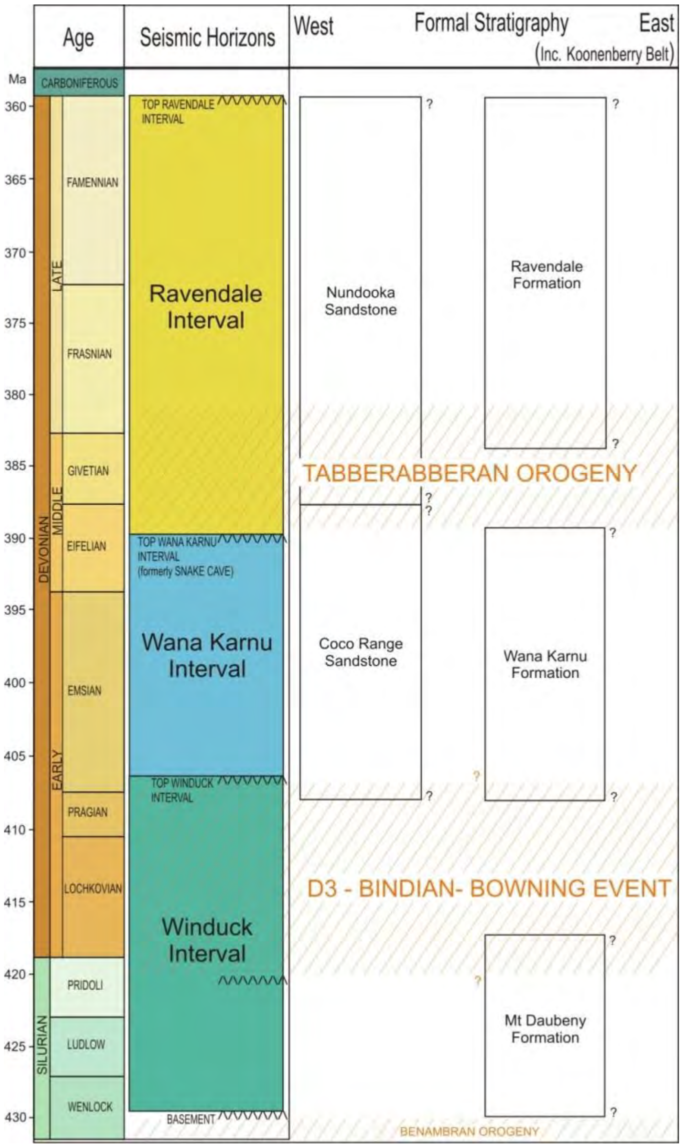


Figure 5: Stratigraphic column with ages modified after Bembrick (1997) and Kobussen & Dick (2011) using new space-time relationships from Greenfield et al. (2010) and Gilmore et al. (2012). In this report the nomenclature of the Devonian in the Koonenberry Belt is applied to the Bancannia Trough.

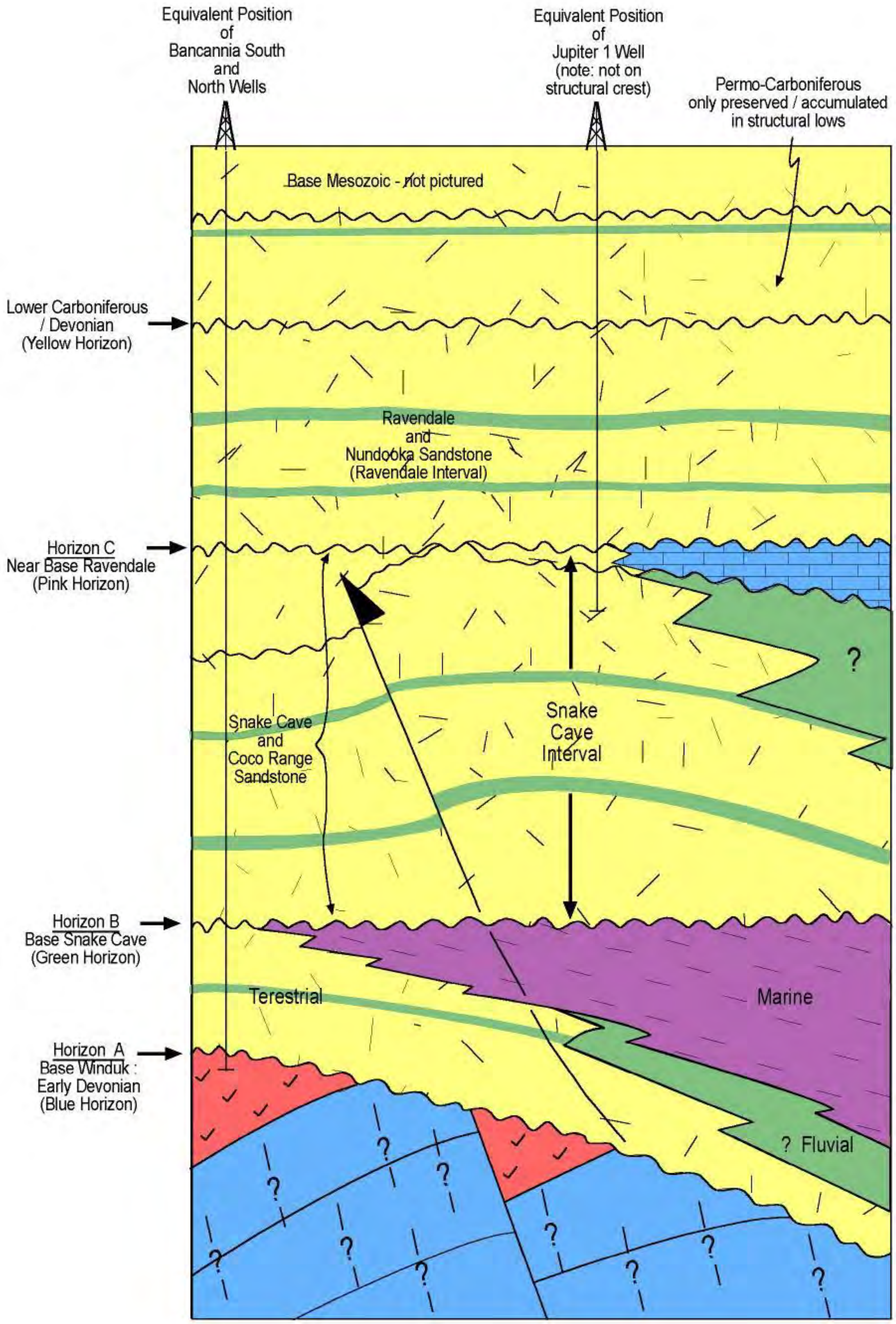


Figure 6: Basic interpretation of sedimentary facies in the Bancannia Trough (Robertson Research Australia 2001). Horizon A corresponds to the top of basement, Horizon B to the top of the Winduck interval and Horizon C to the top of the Wana Karnu (formerly Snake Cave) interval. The top of the Ravendale interval is labelled as the

Lower Carboniferous/ Devonian horizon.

Basement rocks

The basement of the Bancannia Trough is thought to be primarily made up of Cambrian units associated with the Delamerian Orogeny (Figure 7). The Bancannia South 1 well is the only well that intersected the basement. It intersected dacitic and andesitic volcanic rocks (506.1±2.7Ma) at a depth of 3257.7 m (Bodorkos et al. 2013).

The southern part of the trough is underlain by Cambrian volcanics units of the Mt Wright Volcanics (Colquhoun et al. 2016). In the southwest of the trough the Devonian sediments overlie Neoproterozoic units of the Curnamona Province.

In parts of the northwest and in the north of the trough the Gnalta Group is mapped at depth. The Gnalta Group is defined as a series of interbedded basic to acid volcanics, shale, carbonates, sandstone and siltstone deposited in a shallow water environment. The sequence has undergone regional low grade metamorphism.

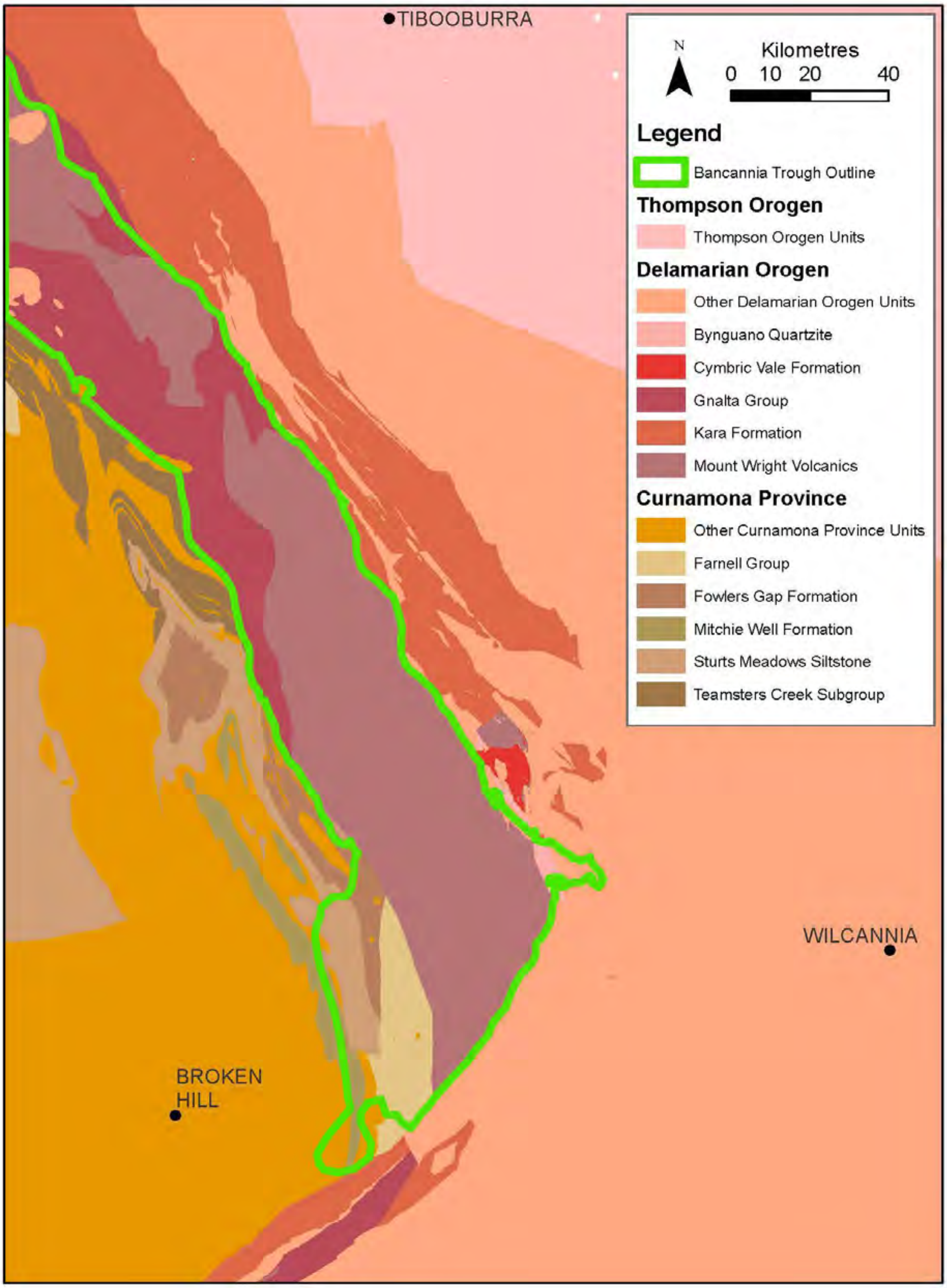


Figure 7: Basement units of the Bancannia Trough from Colquhoun et al. (2016). Locally significant units have been displayed separately.

Winduck Interval

The top of this interval is delineated by a major reflector observed on seismic data with the base constrained by another significant reflector interpreted to be the top of the Cambrian- Ordovician basement. Both reflectors are interpreted to represent major regional unconformities.

The Winduck interval is interpreted to form the basal part of the Devonian sedimentary sequence within most of the trough. Seismic interpretation indicates that the interval sits immediately on top of the Basement units except in some areas where interpreted volcanic units of unknown age are interpreted to sit between the Winduck interval and the Cambrian basement volcanics.

The Winduck Group consists of fine to medium grained quartzose sandstones with interbedded silt and mudstones. In the Bancannia Trough it thickens towards the east indicating increased accommodation associated with ongoing subsidence during deposition. Palaeocurrent observations indicate a westerly to southwesterly derived sediment source (Scheibner et al. 1987).

Wana Karnu Interval

The Wana Karnu interval is conformable with underlying sediments of the Winduck interval, as observed on seismic data, but its top is defined by a prominent reflector interpreted to represent a regional unconformity. The Wana Karnu Interval, formerly known as the Snake Cave Interval, is Middle Devonian and may be generally correlated with the formal Wanu Karnu Group of Greenfield et al. (2010).

Figure 8: Outcrop of westward dipping rocks in Mutawinji National Park of Middle to Late Devonian age (Wana Karnu- Ravendale interval). Approximate photo location -31.3064, 142.3097.

The Wanu Karnu interval consists of thickly-bedded laminated and cross-bedded medium-grained fluvial quartzose sandstones and conglomerates. Quartzites are also present and there are occasional quartzose pebbles and mud clasts. The units laid down in the Wanu Karnu interval also include redbed sandstones (Pearson 2003). Deposition was primarily influenced by a complex braided river environment with delta and alluvial fan environments (Greenfield et al. 2010). Fan type deposition was a key factor in the sediment type and distribution within the northern part of the trough however the southern areas don't appear to have the same level of development of these fan systems.

Ravendale Interval

Interpretation of available seismic data suggests that the Ravendale interval sits atop a regional unconformity associated with the Tabberabberan Orogeny that caused erosion across fault blocks uplifted during this compressive event (Greenfield et al. 2010). An unconformity truncates the top of the interval with Mesozoic to Cenozoic sediments deposited on this surface.

Figure 9: Outcrop of Middle to Late Devonian sandstone in the Mutawinji National Park. These are typical of the outcrop of the Wana Karnu and Ravendale interval sandstones. Photo location is approximately 100 m west of the location of Figure 8.

The Ravendale Formation consists of fluvial thickly bedded fine-grained quartz sandstones (Figure 9). with occasional interbedded siltstones and claystones that may occur in redbeds. The sequence fines upwards and there are localised areas where basal conglomerates occur. It is interpreted that these sediments were deposited in the Late Devonian in braided stream and alluvial fan systems (Neef & Bottrill, 1996). Deposition in a foreland basin setting occurred following the uplift and deformation caused by the Tabberabberan Orogeny (Pearson 2003).

The Ravendale interval is approximately equivalent to the Ravendale Formation and the Nundooka Sandstone which are considered to be correlatable (Neef et al. 1995). Palaeocurrent measurements in the Nundooka Sandstone indicate a westerly derived source of sediments (Neef et al. 1996).

Post-Devonian geology

Almost the entire extent of the Bancannia Trough is overlain by younger sediments. These sediments are either Cainozoic (usually Quaternary) or Cretaceous and later in age (based on palynological and palaeontological studies). There is no identified outcrop of Cretaceous units in the area. These later units are generally flat lying and almost completely undeformed. They occur above a regional unconformity and are characterized by continuous, closely spaced reflectors on seismic data.

The Mesozoic units are mapped as part of the Eromanga Basin (Jurassic to Cretaceous) sequence which extends across parts of NSW, Queensland, the Northern Territory and South Australia. In other states these units host economic petroleum resources however the generally shallow nature of this sequence in the Bancannia Trough area is likely to limit the potential for hydrocarbon accumulations.

Part 2 – Exploration history

Exploration of the Bancannia Trough for petroleum began in the early 1960s. There have been 18 Petroleum Exploration Licences (PELs) granted over parts of the trough since then. The majority of these licences were in force in the 1960s and 1970s. Significantly reduced acreage was held in the 1980s with only sparse exploration acreage held in the 1990s and 2000s and no petroleum exploration licences have been granted over the trough since 2009.

Since 1963 three wells have been drilled, ten seismic surveys, ten gravity and two magnetic surveys have been undertaken within the trough (Figure 10).

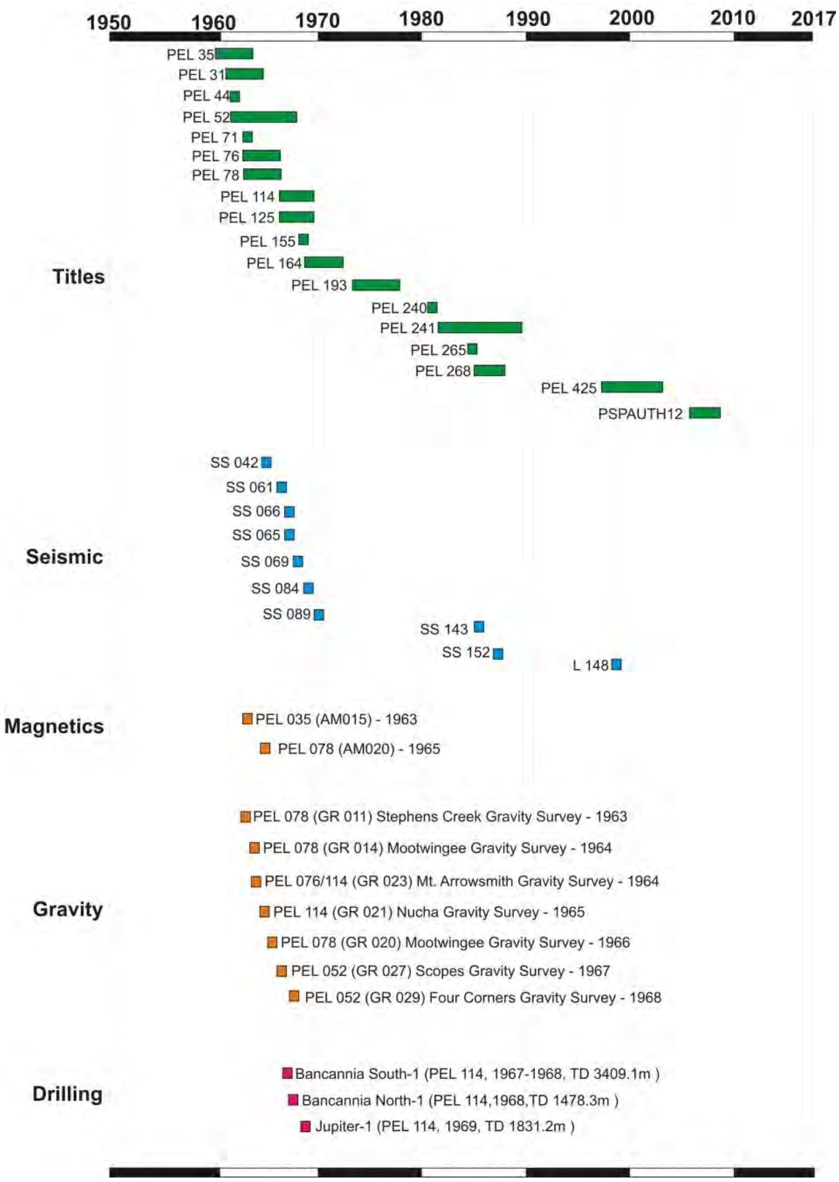


Figure 10: Summary of petroleum exploration activity in the Bancannia Trough since 1950.

Part 3 – Available data

Outcrop

Outcrop of Devonian sediments is relatively limited with most of the area covered by recent Quaternary sediments. There is sparse Devonian outcrop in the southern and central areas with none recorded in the northern parts of the trough (Figure 11). Minor Devonian outcrop of the Wana Karnu Group is present on the eastern margin of the sub-basin and Ravendale Formation litholgies are also mapped in the east. On the western margin, Nundooka Sandstone outcrop is present in limited areas. Outcrop of the Proterozoic basement units is located to the southwest and northeast of the sub-basin.

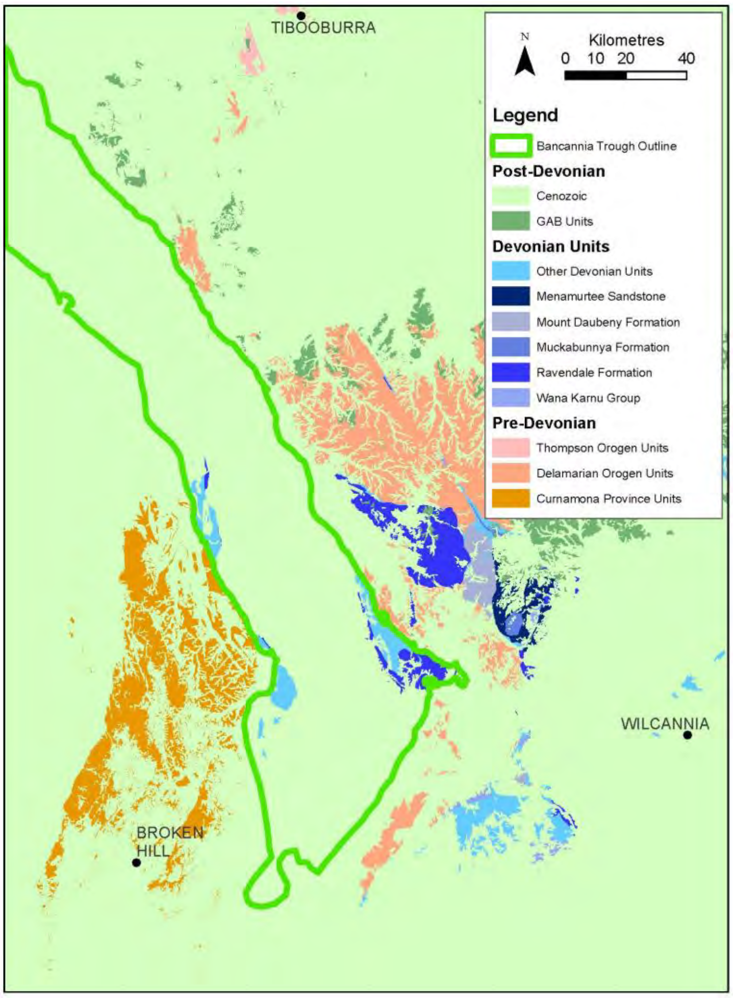


Figure 11: Devonian outcrop in the Bancannia Trough region showing the limited extent of outcrop in the area (modified from Colquhoun et al. 2016). The majority of the area is covered by recent sediments.

Drilling and downhole geophysical data

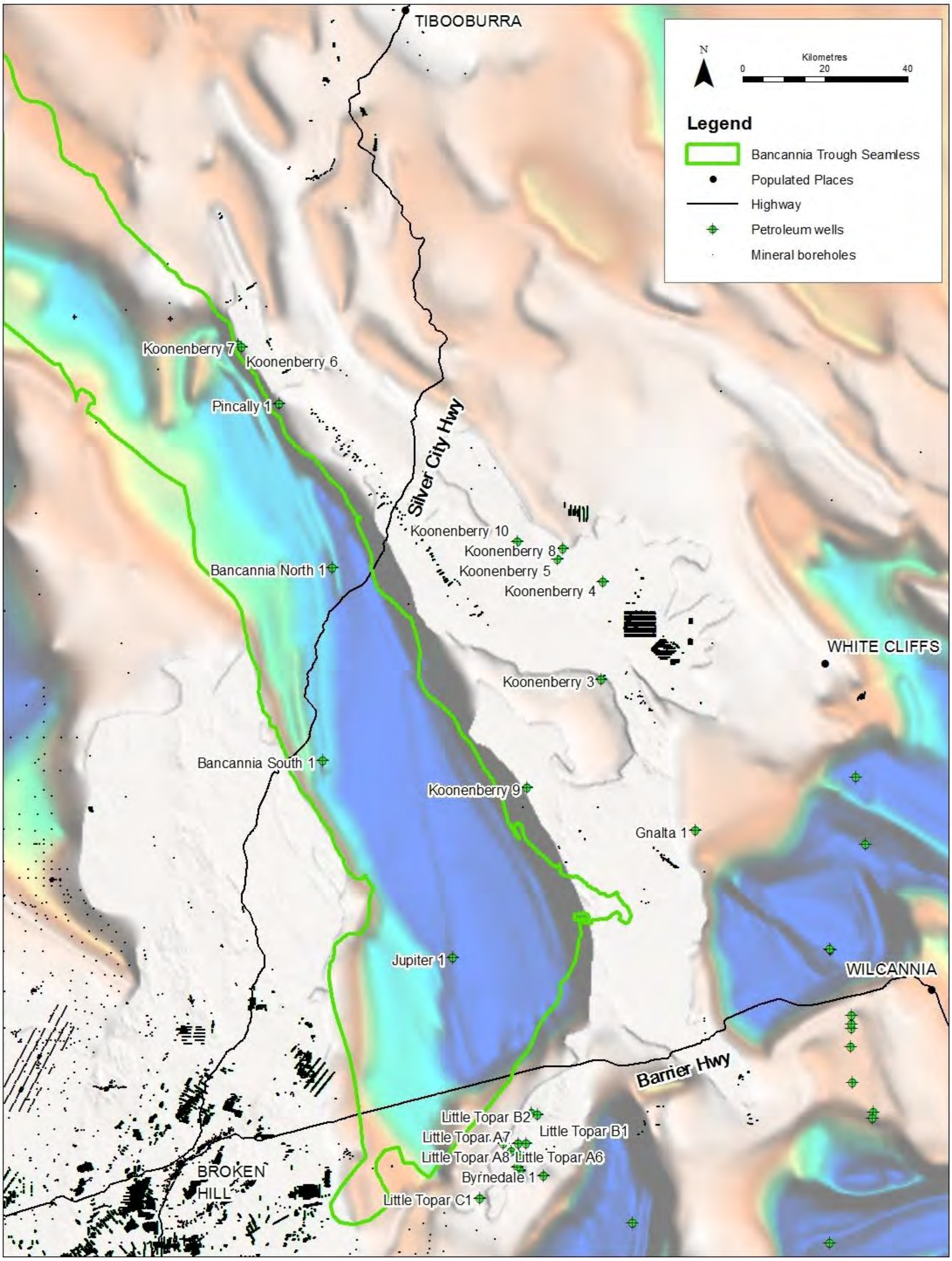


Figure 12: Location of petroleum wells and mineral exploration boreholes in the Bancannia Trough and surrounding area. These locations are superimposed on the Seebase® image.

Deep drilling within the Bancannia Trough is limited to the three petroleum exploration wells and another well drilled outside, but close to the trough boundary (Figure 12). This well, Pincally 1, only encountered Cretaceous aged units and Proterozoic basement, where it terminated. Shallower wells (the Koonenberry and Little Topar series wells) and numerous mineral exploration boreholes have been drilled around the trough margins or in Palaeozoic or Proterozoic basement. The Devonian units are not generally considered prospective by mineral explorers.

The data package contains well completion reports and other associated data from wells drilled near the Bancannia Trough. Thirteen well completion reports are included in the data package and wireline data from seven wells is provided in LAS format.

The three petroleum wells drilled in the Bancannia Trough and the acquired data are summarised in Table 1.

Bancannia South 1 (1968)

The well was drilled to test a low relief anti-formal structure. It attained a total depth of 3409 m (all measurements related to wells in this report are discussed relative to drillfloor/ kelly bushing ie. MDRT). It intersected (Bodorkos et al., 2013);

- Cenozoic units to a depth of 128 m,
- Early Cretaceous units to a depth of 215 m,
- Devonian units to a depth of 3258 m, and
- Cambrian volcanic rocks in the remainder of the well.

Porous sandstone units were common between 830 m and 1222 m with more sporadic porous sandstone units present down to approximately 2135 m.

Gas was detected in this well mainly over the interval from 423 m to 1768 m. Bitumen was present in trace amounts on cuttings from the interval between 1804 m and 1987 m. The shows in this well provide good evidence that petroleum systems were active at least at some point during the trough's history.

Bancannia North 1 (1968)

This well was drilled to test a possible anticline and terminated at a depth of 1478 m. The well intersected;

- Quaternary and probable Palaogene/ Neogene units to a depth of 123.4 m,
- Early Cretaceous units to a depth of 400 m, and
- Middle to Late Devonian red bed units to a depth of 1478 m.

Poor to fair porosity was identified in parts of the Devonian sequence in particular at depths between 936 m and 1137 m.

Subsequent geological interpretations showed that The Bancannia North-1 well was drilled off structure and in close proximity to an extensional fault or closely spaced fault zone (Robertson Research Australia 2001). It did not penetrate the deeper part of the basin, but several hydrocarbon shows were recorded throughout the Late Devonian sequence. The hydrocarbon shows in the well were limited to minor gassy water recovered during drill stem testing. No oil shows or fluorescence was detected on rock samples from the well. Significant gas was detected between ~470 m and 880 m and also between ~1235 m and total depth at 1478 m (Baarda, 1968b).

Jupiter 1 (1969)

This well was drilled on the flank of an interpreted anticline and reached a depth of 1831 m. The well intersected;

- Quaternary and Palaeogene/ Neogene units to approximately 122 m,
- undifferentiated Mesozoic units to a depth of 323 m, and
- Late Devonian units to a depth of 1831m.

The well completion report (Wiltshire, 1968) states that no suitable cap rock or source rocks were intersected. Sandstones in the well had generally poor to fair porosity with some zones of high porosity however, none of the sandstones were highly siliceous, as in many other parts of the Darling Basin. Minor gas was detected associated with some of the porous sandstones and often coincided with drill rod trips or connections. There was no fluorescence observed on cuttings and a drill stem test conducted over the zone with the highest gas readings failed to recover any gas.

Table 1: Summary of Bancannia Trough well tests and data.

Data	Bancannia South 1	Bancannia North 1	Jupiter 1
Available cores	28	13	No
Sidewall cores	30	30	No
Formation tests	4	7	1
Wireline data	Yes	Yes	Yes
Well velocity	Yes	No	No
Fluid Inclusions	Yes	Yes	No
EOM	5	2	No
Reflectance	No	2	No
TOC	9	5	No
Porosity and permeability samples	32	15	No
HC indicators	Yes	Yes	Yes
Carbonaceous material	No	Yes*	Yes*
Palaeontology	Yes	Yes	Yes
Temp./ Bottom Hole Temp.	Yes	Yes	Yes

* minor intervals in post-Devonian units.

Pincally 1 & 2 (1970)

The Pincally 1 & 2 wells are included in this data package due to their relevance to the stratigraphy of the Bancannia Trough. They were drilled to test a high intensity seismic horizon identified in the Pincally Seismic Refraction Survey conducted in 1969. Drilling was designed to determine the rock type corresponding to this seismic horizon.

The horizon was found to correlate with basement metamorphic rocks of Pre-Cambrian or Lower Palaeozoic age. Pincally 1 was terminated at a depth of 325 m after drilling problems. Pincally 2 was a step off re-drill and was terminated at approximately 441 m within basement.

Pincally 2 intersected;

- unconsolidated Palaogene/ Neogene or Cretaceous sands and silts to a depth of 274 m,
- siltstones of Cretaceous age to a depth of 414.5 m, and
- hard siltstone and quartzite units to a depth of 441 m.

The well report (Haskell, 1970) states that the units intersected are unsuitable for petroleum exploration due to the level of post-depositional alteration and metamorphism. The units intersected are unlikely to have potential as either source rocks or reservoirs.

Seismic surveys

The Bancannia Trough has moderate 2D seismic coverage compared with many of the other sub-basins within the Darling Basin (Figure 13). In the trough, 48 separate 2D seismic lines from 10 surveys were completed, totalling approximately 1000 km. The more central parts of the trough are relatively well controlled by the existing seismic data however, the margins have only sparse coverage. The quality of the seismic data varies from poor to good and only a small amount of the original seismic field data has been reprocessed using modern processing software. Field data, where available, is held by the Geological Survey of NSW. The ten 2D seismic reflection and refraction surveys, associated survey reports and available SEG-Y data are included in this data package (Table 2).

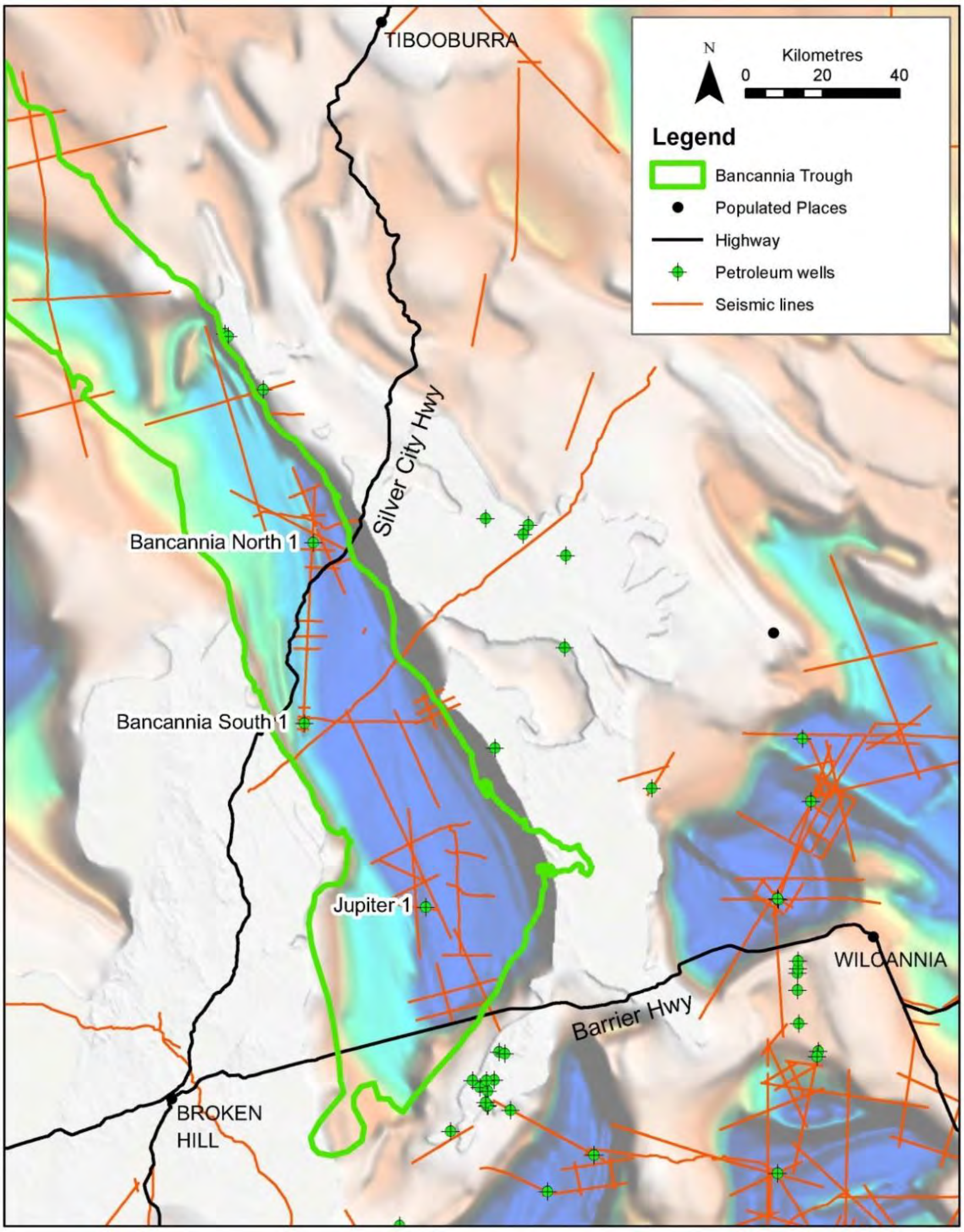


Figure 13: 2D seismic coverage of the Bancannia Trough superimposed on the Seebase® image. Note: a larger version of this map is included in Appendix 1.

Table 2: Summary of seismic surveys and associated seismic lines within the Bancannia Trough.

Line name	Line Km	Record Depth
SS042-Mootawingee (1965)		
Quality: Poor, refraction. No SEG-Y format data available.		
SS042-A	7.398727	Unknown
SS042-B	11.28404	Unknown
SS042-C	13.63307	Unknown
SS042-D	12.96538	Unknown
SS042-E	33.96798	Unknown
TOTAL	**79.25**	Unknown
SS061-Bancannia (1966)		
Quality: Poor in original format. Reprocessed SEG-Y line 1 & 2, moderate.		
SS061-BC66-1	32.25216	6 seconds
SS061-BC66-1A	0.483983	6 seconds
SS061-BC66-2	29.91603	6 seconds
SS061-BC66-3	9.507878	6 seconds
SS061-BC66-4	8.295301	6 seconds
SS061-BC66-5	1.512435	6 seconds
TOTAL	**81.97**	
SS066-Lake Windaunka (1967)		
Quality: Poor-moderate		
SS066-LW67-06	62.14799	6 seconds
SS066-LW67-07	3.195343	6 seconds
SS066-LW67-08	3.167509	6 seconds
SS066-LW67-09	3.204917	6 seconds
SS066-LW67-10	3.157149	6 seconds
TOTAL	**74.87**	
SS067- Packsaddle (1967)		
Quality: Poor in original format. Reprocessed SEG-Y line 6, moderate-good.		
SS067-PD68-11	16.28933	6 seconds
SS067-PD68-11A	18.30402	6 seconds
SS067-PD68-12	9.054673	6 seconds
SS067-PD68-13	9.539159	6 seconds
SS067-PD68-14	9.607794	6 seconds
SS067-PD68-15	6.375141	6 seconds
SS067-PD68-16	8.099531	6 seconds
SS067-PD68-17	7.547955	6 seconds
SS067-PD68-18	7.180853	6 seconds
TOTAL	**92**	
SS070- Nucha (1968)		

Line name	Line Km	Record Depth
Quality: Poor-moderate in original format. Reprocessed SEG-Y for line 20, moderate-good.		
SS070-NU68-20	65.60905	6 seconds
SS070-NU68-21	27.92943	6 seconds
SS070-NU68-22	16.24379	6 seconds
SS070-NU68-23	20.99291	6 seconds
SS070-NU68-24	39.26095	6 seconds
SS070-NU68-25	12.98254	6 seconds
SS070-NU68-26	14.72023	6 seconds
TOTAL	**197.74**	
SS080- Pincally Refraction (1969)		
Quality: Poor, refraction. No SEG-Y format data available.		
SS080-R1	40.56166	Unknown
SS080-R2	56.55019	Unknown
SS080-R3	36.43833	Unknown
TOTAL	**133.55**	Unknown
SS087- Winnathee (1969)		
Quality: Poor, refraction. No SEG-Y format data available		
SS087-1	102.5594	3 seconds
SS087-3	41.43044	3 seconds
SS087-4	26.78092	3 seconds
TOTAL	**170.77**	
SS105- Menindee Regional (1973)		
Quality: Moderate		
SS105-MR1	29.35691	5 seconds
SS105-MR6	24.00288	5 seconds
SS105-MR7	16.09194	5 seconds
SS105-MR8	20.73662	5 seconds
TOTAL	**90.18**	
SS152- Alec's Tank (1987)		
Quality: Moderate- poor. No SEG-Y format data available.		
SS152-B87-101	12.77518	12 seconds
SS152-B87-102	9.769831	12 seconds
SS152-B87-103	10.94626	12 seconds
SS152-B87-104	9.787179	12 seconds
SS152-B87-105	8.744397	12 seconds
TOTAL	**52.02**	
GA-99AGS (1999)		
Quality: High.		
GA-99AGS-C1	159.7307	16 seconds

Gravity surveys

Gravity data are available for the Bancannia Trough that shows the gravity structure in relatively high detail (Figure 14). These data are part of a statewide gravity data set compiled by The Geological Survey of NSW.

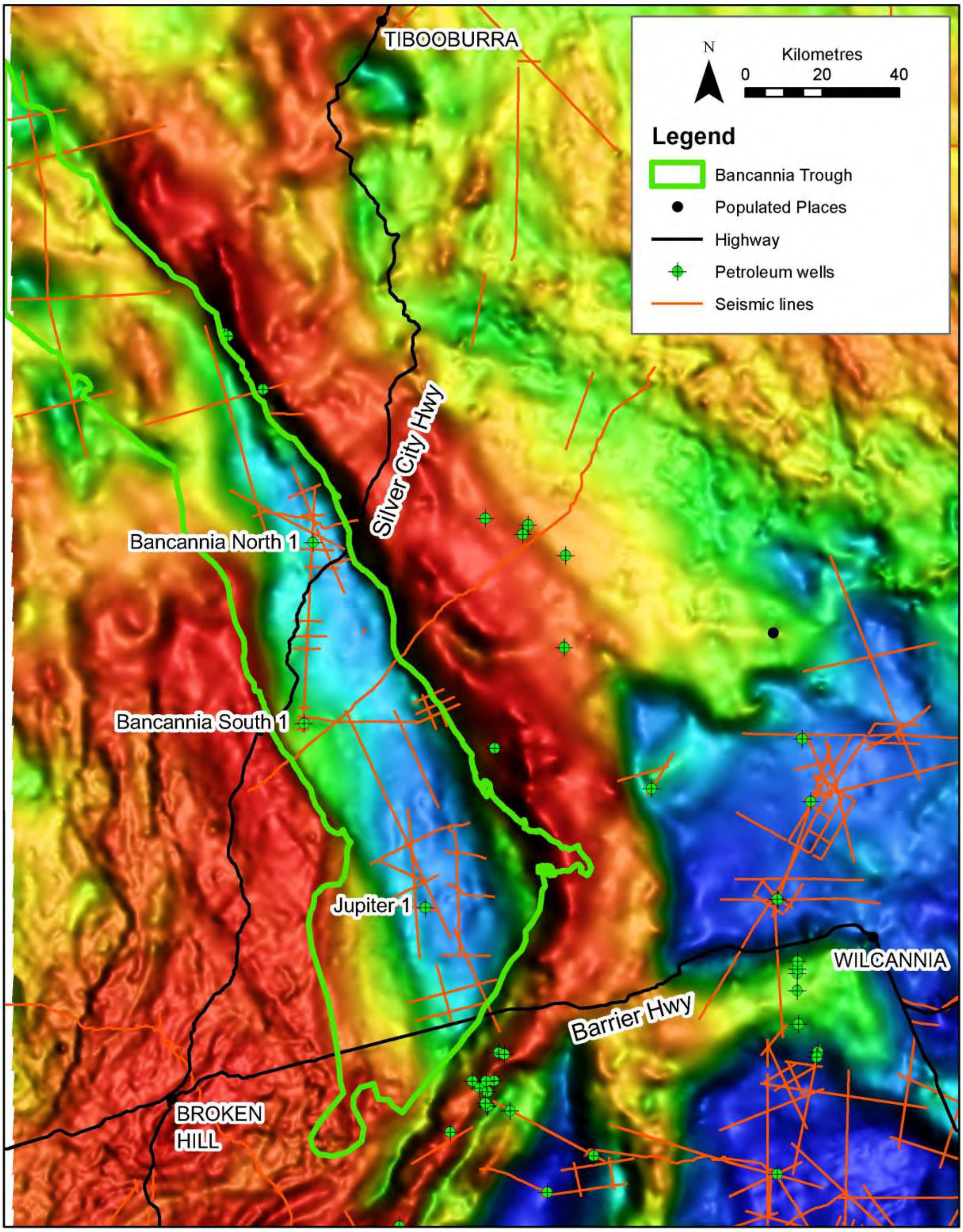


Figure 14: Isostatic Bouguer gravity image over the Bancannia Trough area. Blue represents lower gravity areas with red showing those with a higher gravimetric response.

The Bancannia Trough has a generally lower gravity response than the surrounding metamorphosed terrain. The lower values are due to the thick, lower density trough fill and potential low density emplaced intrusive bodies, possibly Silurian granites (Blevin et al. 2007) and the volcanic units of the Gnalta Group, below the trough fill.

The Bouguer anomaly gravity map and gravimetric depth-to-basement estimates in conjunction with seismic interpretation were used by Cooney (2007) to estimate the maximum thickness of Devonian sediments within the Bancannia Trough at between seven km and eight km.

Magnetic surveys

Magnetic data are available for the Bancannia Trough that shows the magnetic response in relatively high detail (Figure 15). These data are part of a statewide magnetic data set compiled by The Geological Survey of NSW.

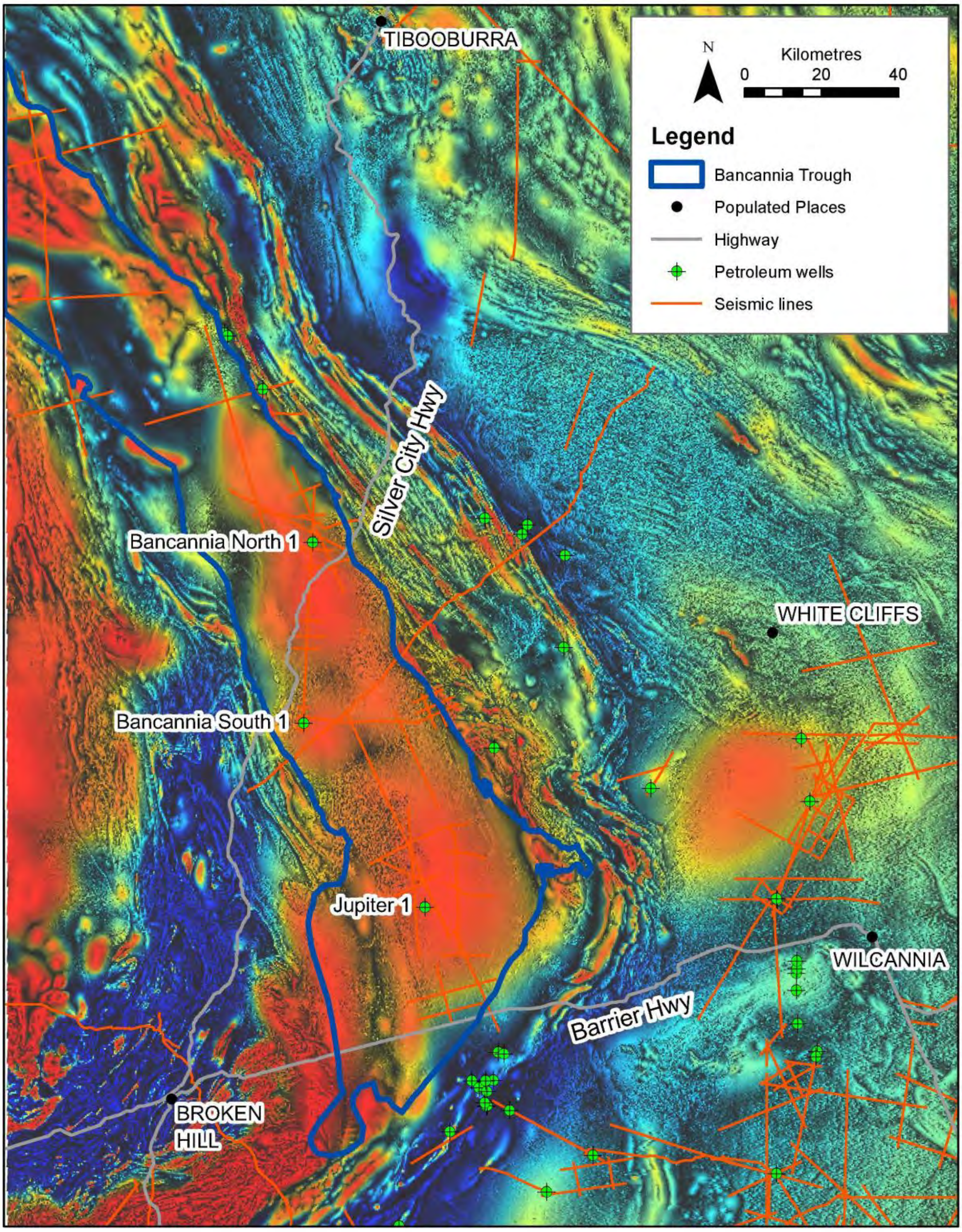


Figure 15: Total Magnetic Intensity (reduced to pole) over TMI-RTP tilt filter image of the Bancannia Trough area. Red colours indicate higher magnetic response with blue showing lower response.

The magnetic response within the trough is relatively uniform with higher than average magnetic intensity in the southern and central parts. In the north there is a marked change in intensity west of the Bancannia North 1 well with reduced values recorded on the western side of a curvilinear feature inferred to represent a major fault.

The marked difference in the nature of the magnetic response in this area may be due to several geological reasons. A difference in basement type in the southern and central areas (ie. the andesitic Mount Wright Volcanics) is the most likely cause of the magnetic intensity difference seen in the data. The presence or absence of different sediments sourced from magnetic mineral bearing rocks or the impact of restricted hydrothermal/ groundwater movement may also impact the magnetic response in the area.

Geochemical surveys

Geochemical data within the Bancannia Trough are limited. Hydrocarbon testing was only conducted in the Bancannia South 1 and Bancannia North 1 wells (Table 3, Table 4 & Table 5). Geochemical analysis was carried out on waterbore fluid samples and soil using soil gas samples.

Total Organic Carbon (TOC) values are generally poor for the Devonian sediments in the Bancannia Trough and there is only minimal extractable organic matter. Conclusions about the source rock potential cannot be fully assessed from the very limited data set and large parts of the trough remain untested.

Table 3: Bancannia Trough TOC samples.

Well	Available TOC samples	TOC Min (%)	TOC Max (%)	TOC Average (%)
Bancannia North 1	5	0.03	0.05	0.042
Bancannia South 1	9	0.03	0.09	0.0578

Table 4: Bancannia Trough Vitrinite Reflectance samples.

Well	Vitrinite Reflectance Samples	Average VR value
Bancannia North 1	2	0.925

Table 5: Bancannia Trough Extractable Organic Matter (EOM) samples.

Well	No. samples	EOM min (ppm)	EOM max (ppm)	EOM Average (ppm)
Bancannia North 1	2	39	182	110.5
Bancannia South 1	5	210	490	370

Water bore geochemical surveys

Twenty seven waterbores in the Bancannia Trough area have water geochemistry analysis results (Moffit & Weatherall 2003 and 2004). The tested waterbore depths range from 57.5 m to 637.9 m and they are relatively evenly distributed in the trough (Figure 16).

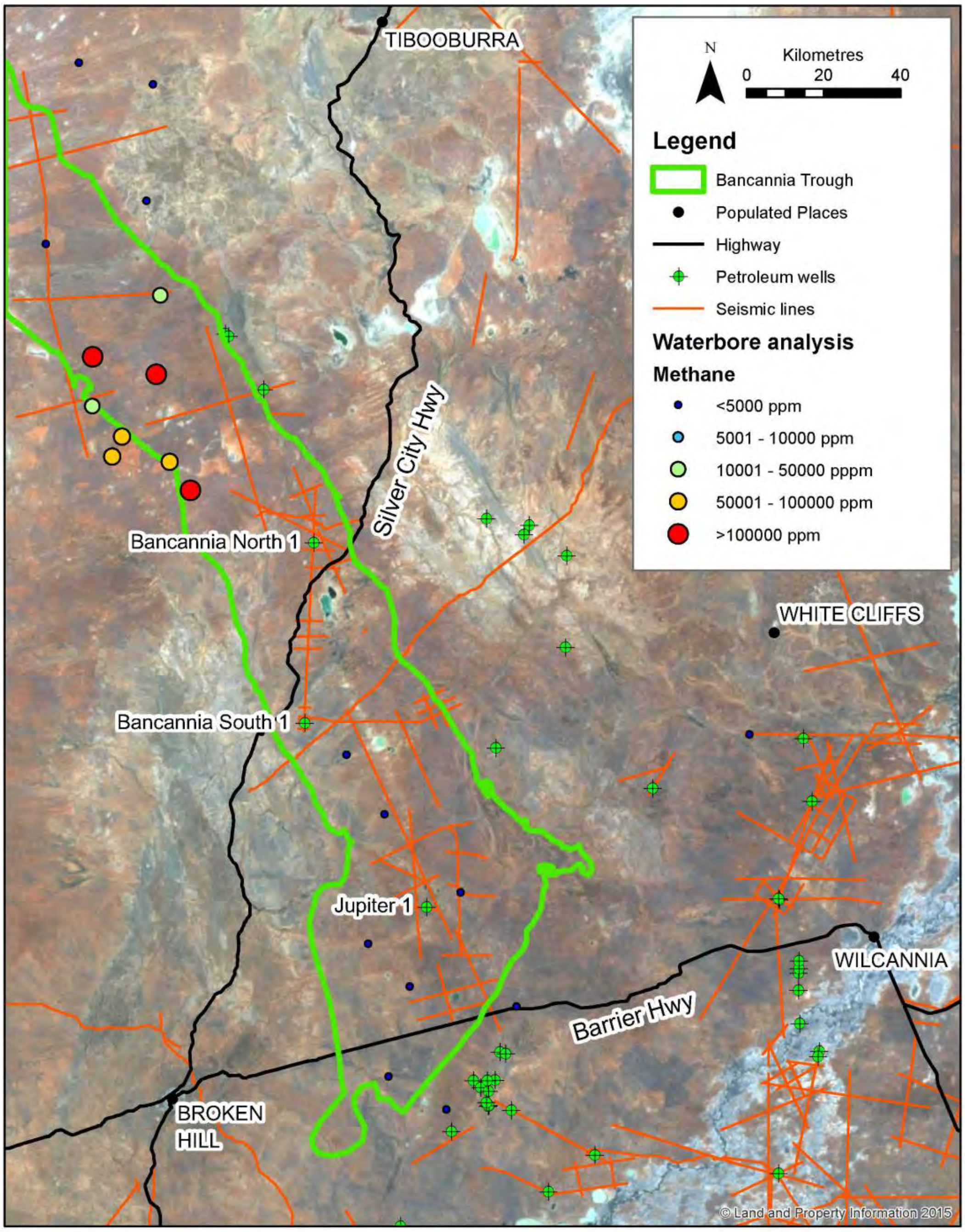


Figure 16: Location of waterbores displaying concentration of methane present in samples reported by Moffit and Weatherall (2003 & 2004).

Moffit & Weatherall (2004) found that hydrocarbon components in dissolved gas samples generally occur as trace amounts. The authors identified methane, ethane, propane and butane as the most common hydrocarbon compounds.

However, extremely high concentrations (up to 589,000ppm) were recorded in some bores. These high values may be due to sampling or testing errors or may also represent the influence of later, shallower sediments of post-Devonian age (ie. Jurassic-Cretaceous). These sediments are known to contain thin coal seams that may be generating microbial methane in relatively high concentrations. Migration of this methane in shallow groundwaters is likely to be the main reason for the high CH_4 values seen within parts of the trough within the overlying post-Devonian units.

Soil gas survey

Soil gas microseep sampling was conducted by Petrofocus Consulting Pty Ltd (2005) within the Bancannia Trough. 398 samples collected along eight seismic lines (Figure 17). The gases detected were methane with values of up to 40 ppm, ethane with values less than 1 ppm and propane with values less than 0.1 ppm.

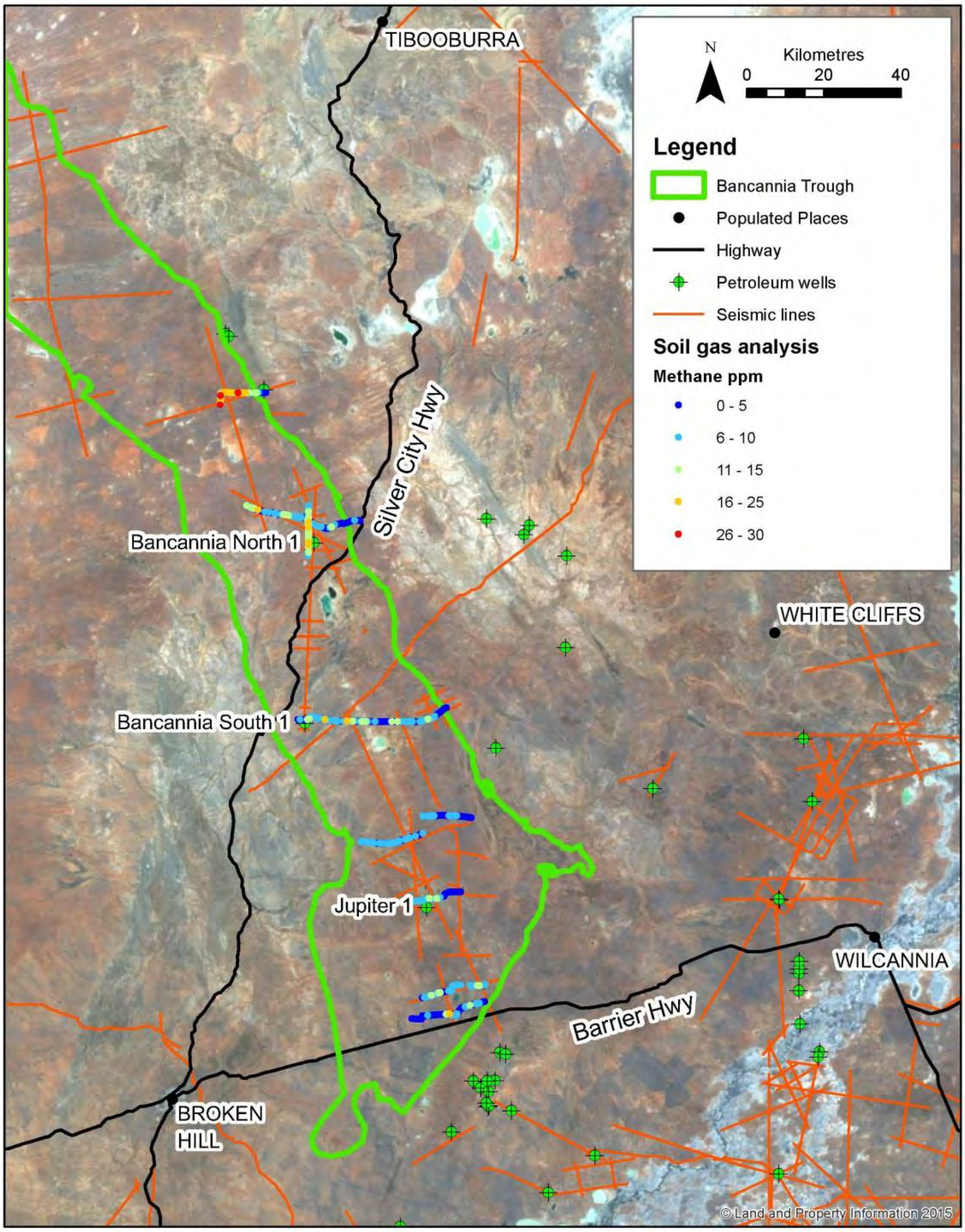


Figure 17: Map showing the locations of soil gas samples collected by Petrofocus Consulting Pty Ltd (2005) and the range of tested methane concentrations detected.

Part 4 – Data interpretation and modelling

Bancannia Trough 3D structural model

The Geological Survey of NSW developed a 3D model of the Bancannia Trough (Figure 18) to assist in understanding the structure and general seismic stratigraphy. This structural model was constructed using the SKUA-GOCAD™ modelling package with seismic horizon picks initially made in IHS Kingdom® and then imported into the SKUA-GOCAD™ 3D environment. The model is presented in this data package, including a report prepared as part of the project (Swierczek, 2018).

Horizons were interpreted and modelled from seismic data where the data quality allowed (Table 6). Picks corresponding to the major interval boundaries and several horizons within the intervals based on strong reflectors were selected for modeling. Basement was also modelled.

Table 6: List of modelled horizons (SKUA-GOCAD™ format) with corresponding horizons included in the IHS Kingdom project.

SKUA-GOCAD™ modelled horizons	IHS Kingdom project horizons
Topography	
H1 Top Permian/ Carboniferous	
H2 Top Ravendale	360_NT_Ravendale
H3 Middle Ravendale	
H4 Top Wana Karnu	390_NT_Wana Karnu
H5 Middle Wana Karnu	
H6 Top Winduck	406_NT_Winduck
H7 Base Winduck (Basement)	422_BASE_Winduck_BSMT

Several assumptions were used in the generation of this model. The northern extent of the Devonian units was confined by an inferred major fault. To the north of this fault Devonian units may be present however, there is little data to make such an inference as there is no drilling intersecting Devonian aged units and the limited seismic is poor quality. In the south, the western margin is also delineated by a major fault, in this case one inferred from on gravity and magnetic data. The Devonian units were not modelled to the west of a major inferred fault in the southwest part of the trough due to a lack of seismic control.

Most faults are interpreted to be high angle. The major basin margin faults, not covered by seismic surveys have likewise been modelled as near vertical planes.

The model shows that the post-Devonian sediments are generally relatively undeformed. The Devonian units, particularly in the north and south have more structural features in the form of fault offsets and gentle, large scale folding. The central parts are largely undeformed, although this may be a by-product of the lack of seismic data in the central part of the trough and is not necessarily an accurate depiction of the structure within this area.

The model was initially constructed in the time domain (based on seismic picks) with a velocity model used to convert the entire volume to the depth domain. This velocity model was built using data from the three available wells (Bancannia North 1, Bancannia South 1 and Jupiter 1). This conversion should be treated with caution as the very limited data used to constrain the velocity model does not provide appropriate coverage to representatively model the entire trough. Despite this, the depth conversion provides a starting point for future modelling work. The velocity model may be further constrained by the use of seismic stacking velocities, although this was outside the scope of the modelling undertaken for this data package.

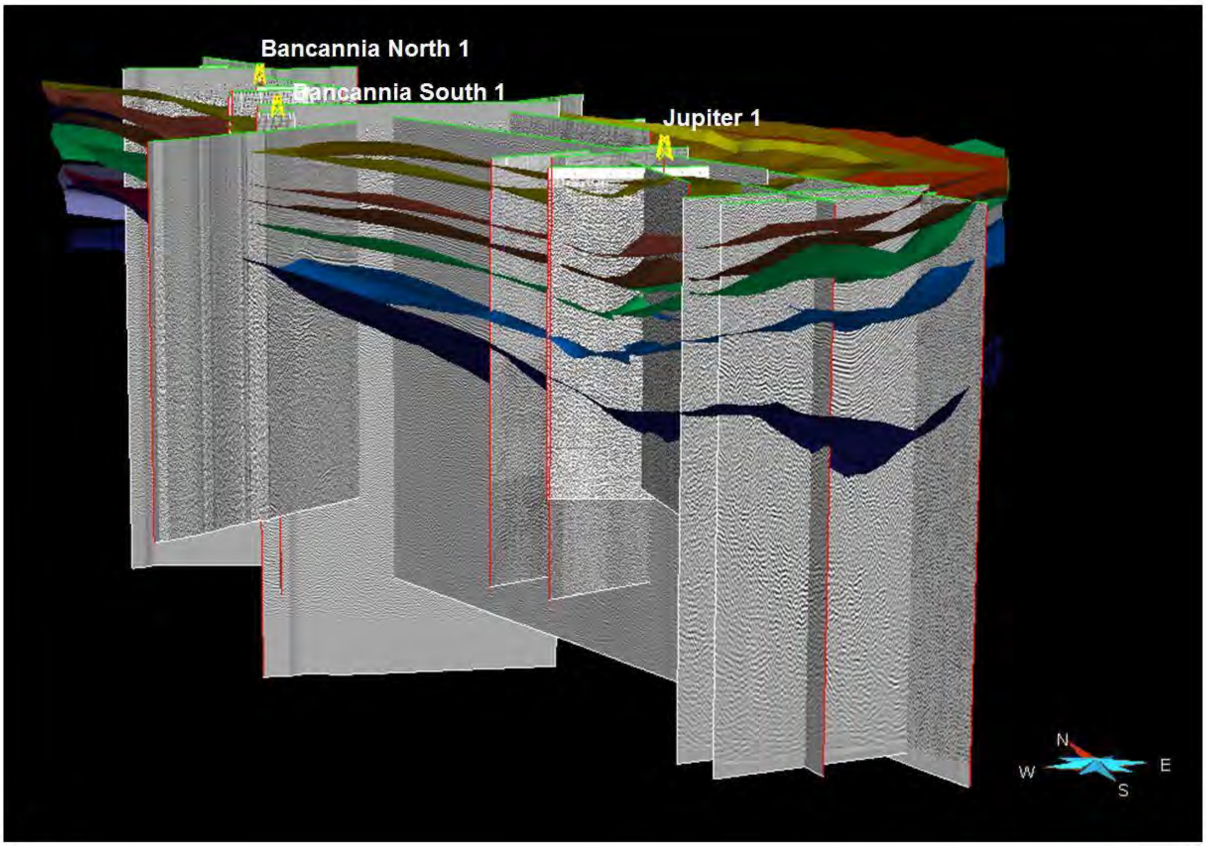


Figure 18: North-northeast facing oblique view of modelled horizons and seismic data used in the Bancannia Trough 3D model generated in SKUA-GOCAD™ (faults not displayed). Vertical exaggeration is 10x.

Of particular note is the potential play below the Jupiter 1 well path (Figure 19). The model suggests that the structure may be far larger than originally believed and that confinement of hydrocarbons may be provided by the antiformal structure and intraformational reservoir-seal pairs within the Ravendale interval. The potential play may cover an area 40 km by 5 km.

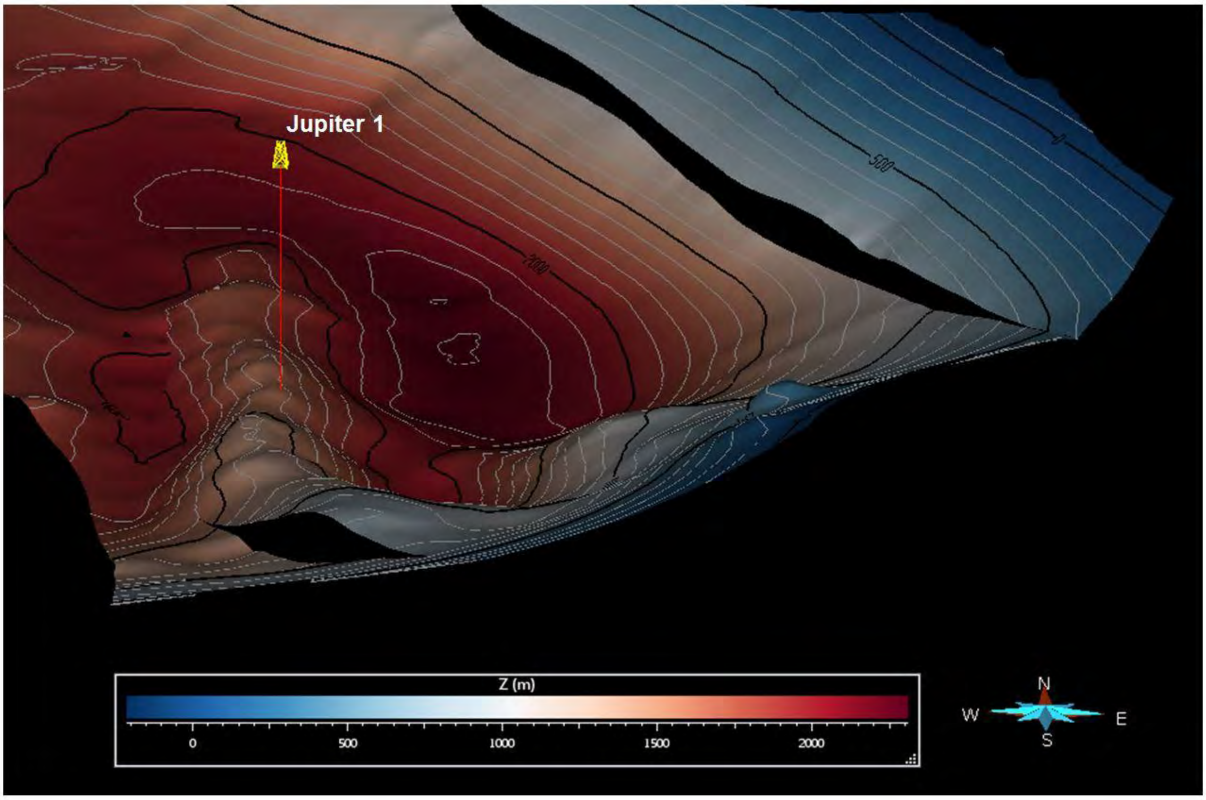


Figure 19: Oblique north-facing view of the Top Wana Karnu surface and Jupiter 1 well showing the north-south striking, gently plunging (1º - 1.5º to the north) anticline on which Jupiter 1 was drilled. Vertical exaggeration is 10x.

Hydrocarbon potential

The Bancannia Trough is considered to have relatively moderate petroleum prospectivity within the broader Darling Basin.

The three wells that intersect Devonian units within the Trough: Bancannia North 1, Bancannia South 1, and Jupiter 1 all have minor hydrocarbon shows, mainly in the form of elevated gas readings. However, Bancannia South 1 also contained traces of bitumen on cuttings. The southernmost part of the trough is believed to be the most prospective area in the Devonian units, in terms of trap development and migration of hydrocarbons from inferred Cambrian-Ordovician (Gnalta Group) or Early Devonian source rocks (Robertson Research Australia 2001).

It is possible that earlier Cambrian-Ordovician units of the Koonenberry Belt did not undergo significant metamorphism (Brown et al. 1982) during the Devonian basin fill period or later. If this is the case then petroleum generation from these older rocks may have taken place over a long period of time including during the deposition of the Devonian sequence. There is also potential for later migration of hydrocarbons into the Devonian units and post-Devonian units from the Cambrian and Ordovician rocks.

The Early Devonian units within the Bancannia Trough comprises marine facies in the east with a transition to alluvial fan and braided stream deposition in the northwest (Robertson Research Australia 2001). These marine units potentially provide a hydrocarbon source within the lower parts of the trough.

The northernmost part of the trough also has moderate hydrocarbon potential in the sand dominated Jurassic and Cretaceous units. In this area the generation or migration of gas associated with the Eromanga Basin may have led to the accumulation of shallow methane resources (Robertson Research Australia 2001).

Across the Bancannia Trough there is an apparent lack of major regional seal units. Despite the indications that regional scale sealing units are not present within the trough there still remains the potential for smaller scale, localised and intraformational seals to provide adequate confinement for the accumulation of hydrocarbons.

Hydrocarbon indications from available data

Cambrian-Ordovician units outcrop out along the Scropes Range High and Koonenberry Belt on the southern and eastern margins of the Bancannia Trough (Benedek 1968; Scott 1997; Little 2000). These units are thought to provide potential source rocks for the reservoirs of the Devonian sequence. Their presence along the trough margins suggests that they are likely to be present underlying the Devonian sediments within the Bancannia Trough. The presence of oil seeps and strata containing organic matter at the surface on the trough margins suggests that source rocks, if present, are likely to occur at significant depth within the undrilled units (Robertson Research Australia 2001).

Along the southern margin of the Bancannia Trough, on the Scropes Range High, outcrop samples reported by Benedek (1968) had a “distinct oily odour”. Shallow wells in this area (the Little Topar series wells) were drilled and core samples were recovered. These cores showed significant reservoir potential with good porosity and well sorted grains that had reasonable permeability (Benedek 1968). Topar A-4 recorded minor oil staining at a depth of ~84 metres. Topar B-2 also showed a minor oil stain (a 1 inch sandstone band) in core between 42.36 and 55.47 metres.

On the eastern margin, in the Koonenberry Belt, eight shallow cores (the Koonenberry series wells) were drilled to investigate petroleum sopurce rock potential (Little 2000). TOC tests were carried out on core samples and the results showed TOC values ranged between 0.02% and 0.53%. Core from the Koonenberry 9 well had a distinct “petroliferous odour” coming from the Gnalta Group units (Little 2000). The rocks intersected in the Koonenberry 9 well were characterised as being sourced from mixed organic matter with a possible carbonate association (Little 2000).

Work by Scott (1997) involved testing of samples from several wells and also outcrop specimens. Kewell East 1, Bancannia South 1, Little Topar A4 and B2 as well as Cymbric Vale outcrop samples were analysed and found to have a carbonate associated sources.

Both Bancannia South 1 and Bancannia North 1 exhibited hydrocarbon indications. Jupiter-1 contained sandstone with carbonaceous siltstone and shale throughout the Late Devonian (Robertson Research Australia 2001). All three wells recorded minor gas readings with occasional significant spikes in the Bancannia South 1 well.

The Bancannia South 1 well is the only well in the Bancannia Trough with significant hydrocarbon shows. The shows include bitumen staining of cuttings over a section (1984.24 m to 1987.3 m) in the Wana Karnu interval and gas readings particularly between ~1370 m and ~1645 m. These shows probably derived from source rocks in the deeper, southern part of the trough (Robertson Research Australia 2001).

Gas detector readings

The Bancannia South 1 well was drilled up-dip of the basin depocentre and reached Cambrian-Ordovician basement. It had multiple hydrocarbon indications. The gas detector (hot wire detector) recorded values of up to 90 units (Robertson Research Australia 200, Figure 20).

In the Late Devonian Ravendale interval, gas readings of up to 50 units at depths between 408 m and 515 m and between 731 and 820 m were recorded. A drill stem test completed over the interval from 1458.16 m to 1461.52 m in the Late Devonian units recovered brackish water with dissolved methane present. Gas readings of up to 90 units were also detected from 1430 m to 1490 m with trace bitumen staining of cuttings (Baarda 1968a).

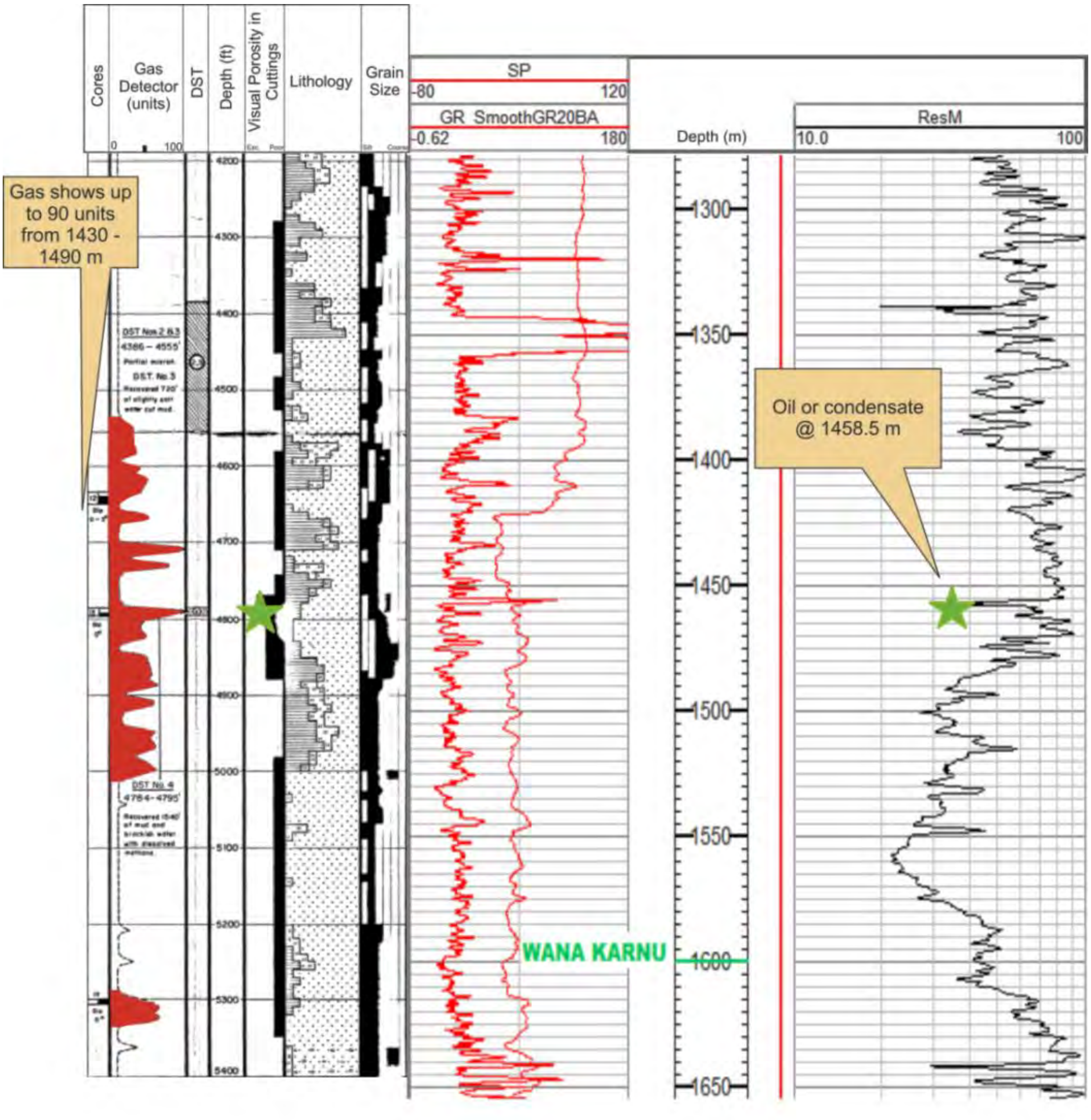


Figure 20: Bancannia South-1 well log between and ~1280 m and 1650 m with gas readings and bitumen stained cuttings shown (modified from Baarda 1968a).

Fluid inclusion

Fluid inclusion analysis were done on smaples from the Bancannia South 1 and Bancannia North 1 wells. In Bancannia South 1 the analysis showed a strong methane response from 1219.2 m to 1524 m, and also at 3231.8 m. Liquid petroleum was also observed in a thin section at 1458.5 m (Fluid Inclusion Technologies Inc. 2000a).

In the Bancannia North 1 well fluid inclusions showed some signs of minor dry gas between approximately 575 m and 1040 m (Fluid Inclusion Technologies Inc. 2000b). A thin section from a sample collected at ~1184 m showed petroleum inclusions within detrital quartz grains.

Drill stem tests

Drill stem testing of the Bancannia South 1 well recovered dissolved gas in water at 1458.5 m (corresponding with the gas show of Baarda, 1968a) and additional testing showed that these samples included oil or condensate (Fluid Inclusion Technologies Inc. 2000e).

Drill stemm test results from two tests in the Bancannia North 1 well recovered gassy water (DST No. 3 563.58 m to 575.77 m) and trace hydrocarbons (DST No. 4 831.19 m to 871.7 m). Fluid inclusion analysis also showed minor dry gas throughout the Middle to Late Devonian units (Fluid Inclusion Technologies Inc. 2000f).

Porosity and permeability

Drill stem tests on the Bancannia North 1 well were completed with the test records reporting ‘good air blow’ in DST No. 3 (563.58 m to 575.77 m), DST No. 4 (831.19 m to 871.7 m) and DST No. 7 (423.7 m to 597.74 m) (Baarda 1968b). These results indicate that the tested units probably have moderate to good permeability. In addition, the results suggest that the formations are pressurised to some degree given that formation fluids flowed into the test interval.

All three wells show poor to moderately good porosity in the Devonian sequence (Robertson Research Australia 2001). It may be inferred that the porosity and permeability has been preserved, to varying degrees, to a depths between one to two kilometres. Table 8, summarises the results of porosity and permeability testing carried out on the Bancannia South 1 & Bancannia North 1 wells. 33 samples were tested and the average porosity was 7.68%.

The permeability in these samples was generally low with horizontal permeability values usually greater than the vertical values. A single relatively high permeability result of 0.578 darcy units was recorded in Bancannia South 1 at 420.1 m depth however, this may represent a transcription error or core damage. This core (core No. 4) is logged as medium to coarse grained sandstone therefore the higher permeability result may be accurate, however given that it significantly exceeds the average permeability values this result should be treated with caution.

Soil gas testing

Soil gas microseep sampling was carried out along 8 seismic lines. The results from the 398 samples obtained showed methane values up to 40 ppm, ethane values less than 1 ppm, and propane less than 0.1 ppm (Petrofocus Consulting Pty Ltd 2005).

The majority of the trough had very low background methane and ethane values, with minimal amounts of propane and butane. The source type, whether thermogenic or biogenic, cannot be conclusively inferred based on the available data (Petrofocus Consulting Pty Ltd 2005).

There are moderate to high methane and ethane values within the central-northern portion of the trough (Figure 21), probably derived from the relatively thick Mesozoic sediments in this part of the trough (Petrofocus Consulting Pty Ltd 2005). Shallow water bores also confirm this conclusion as methane and ethane are present in these bores (Petrofocus Consulting Pty Ltd 2005).

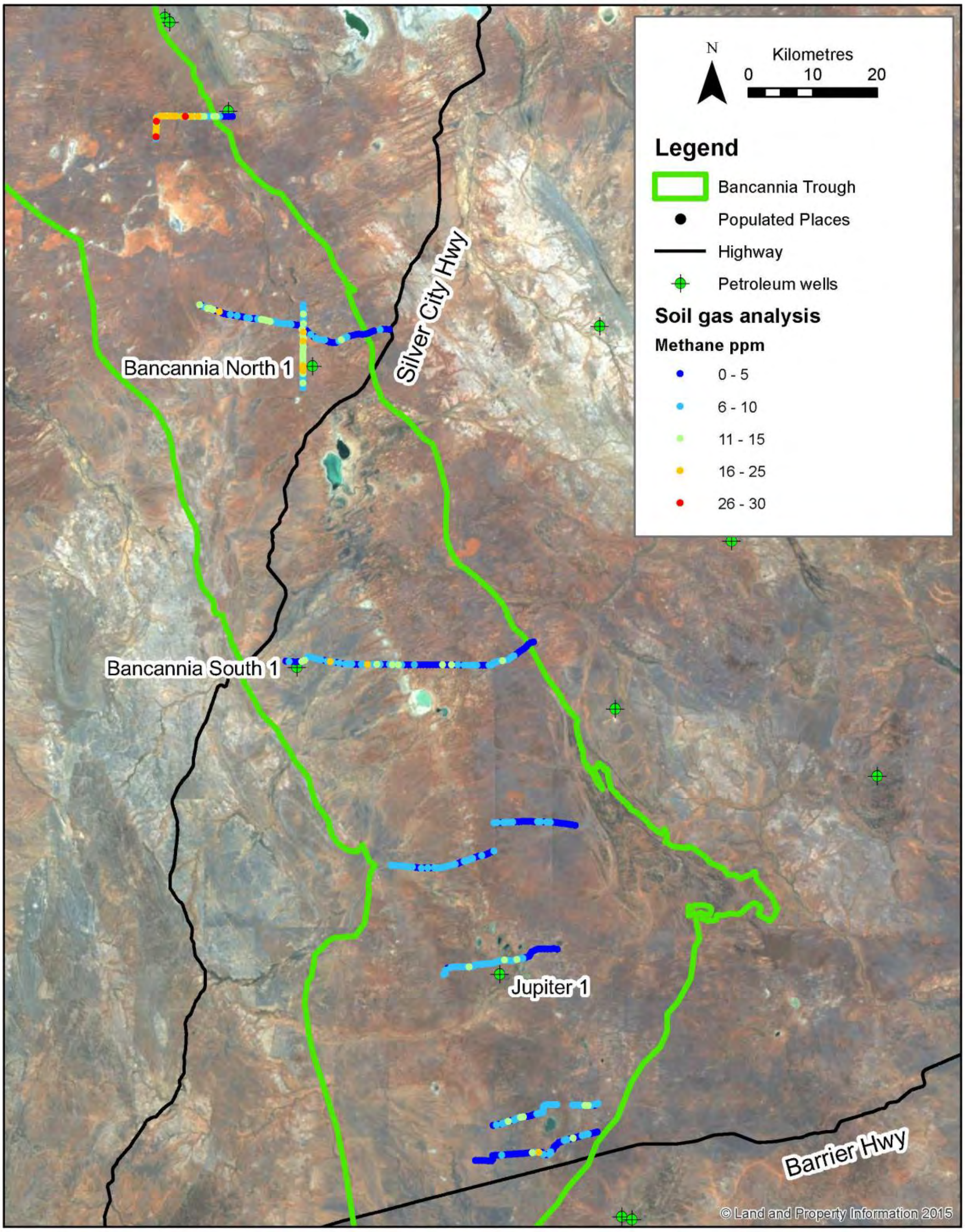


Figure 21: Methane PPM values from soil gas sample analyses undertaken by Petrofocus Consulting Pty Ltd (2005)

Waterbore geochemistry

Waterbore geochemical testing across the Darling Basin was carried out by Moffit and Weatherall (2003 & 2004). Water samples from 27 bores within the Bancannia Trough area were analysed (Figure 16). Samples were taken from bores that intersected both the Jurassic to Quaternary sediments and Devonian units, although most samples are likely to be from units of Mesozoic age given the relative shallow depth of the waterbores. The higher values obtained in the northern parts of the trough are likely associated with the shallower post-Devonian sediments.

Moffit and Weatherall (2003 & 2004) suggest that methane, propane, ethane and butane are ubiquitous and that the bore water has absorbed small amounts of thermogenic gas that is migrating within the Proterozoic basement and Darling Basin units.

Moffit and Weatherall (2004) concluded that, in areas where Darling Basin units are present near the surface, groundwater may be transporting deeper sourced hydrocarbons but, because of the lack of seal these shallow Darling Basin units are likely to have lost any significant gaseous hydrocarbon accumulations to the atmosphere.

Part 5 – Petroleum systems

The Bancannia Trough is known to contain most of the components of a conventional petroleum system. Source rock, reservoir units and structural or stratigraphic trapping configurations are known to exist in the trough. Only the presence of wide spread, laterally extensive sealing units remains unconfirmed. The lack of such units does not rule out the potential for small scale, localised or intraformational seals.

Source rocks

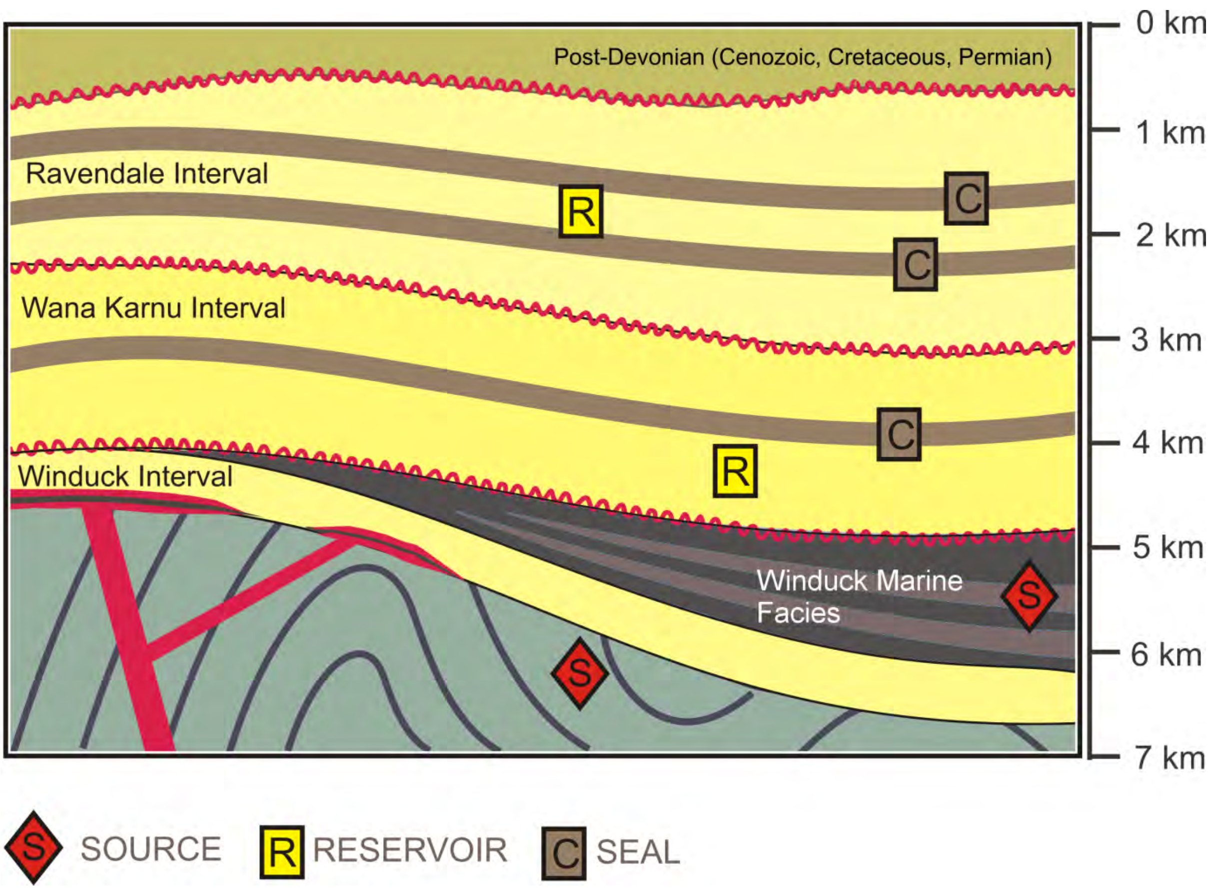


Figure **22**: Interpreted source, reservoir and possible major regional seals provided by unconformity surfaces in the Bancannia Trough.

The trough consists of marine and fluvial-deltaic sediments (Figure **22**) both of which may contain organic materials suitable for hydrocarbon generation. The source rocks with the highest potential to supply hydrocarbons are the Cambrian-Ordovician and Early Devonian sediments. There is adequate evidence of hydrocarbon (gas and oil) generation to indicate that source rocks exist somewhere within or in close proximity to the trough.

Potential source rocks are known to occur on the basin margins and in pre-Devonian units in the area. The presence of potential source rocks within the basin fill sequence itself remains unproven and no suitable units have been intersected in the three wells that have been drilled within the trough. Source rock units may be located at depths not intersected by drilling, or in areas where there is no drilling or outcrop.

Cambrian - Ordovician Source

The Cambro-Ordovician units in the Bancannia area are potential source rocks supplying hydrocarbons to the Bancannia Trough. Volcanic units interbedded with marine units are thought to underlie parts of the trough and in areas along the basin margins. Units of this age can be good hydrocarbon source rocks, for example within the Amadeus Basin in Queensland (DMR, 1993).

The Bancannia South 1 well showed traces of hydrocarbons in the Middle to Late Devonian, but the Early Devonian TOC was only 0.09% maximum, suggesting the source sequence is deeper in the undrilled part of the stratigraphy or elsewhere in or near the trough (Robertson Research Australia 2001).

Testing for hydrocarbons in the Cambro-Ordovician units intersected in the Koonenberry stratigraphic wells, Little Topar wells and Cymbric Vale outcrop locations indicate a carbonate associated source (Scott & Hartung-Kagi 1997).

Little Topar Wells

On the Scropes Range High, to the south of the Bancannia Trough twelve shallow holes were drilled to test the source rock potential of the Cambro-Ordovician sediments (insert figure reference to go back to). The holes ranged in depth from 73 m to 236 m. A “petroliferous odour” was noted from some of the cores and TOC values up to 0.4% were reported (DMR, 1993). It was concluded from the geochemical data that hydrocarbons had passed through these rocks at some point, although no conclusive evidence of source generation or migration timing was identified.

Koonenberry Stratigraphic Wells

The Koonenberry Stratigraphic wells were drilled in 1999 by GSNSW to investigate the presence of petroleum source rocks in the Koonenberry Belt east of the Bancannia Trough. Eight shallow (35 - 88 m) cored boreholes intersected units along the eastern margin of the Bancannia Trough (Little 2000). Total Organic Carbon (TOC) values were between 0.02% and 0.53%. Whilst generally low in TOC, the core from Koonenberry 9 had a distinct “petroliferous odour” (Little 2000). Samples from the Koonenberry drilling were analysed for palynological derived ages without success (Winchester-Seeto, 2000).

Cymbric Vale

Outcrop samples from the Cymbric Vale area taken from the Cambrian First Discovery Limestone were tested for oil type (location figure reminder). The sample locations were selected based on previously recorded oil seeps (Scott & Hartung-Kagi 1997). A single sample (“sample C”) was subjected to additional gas chromatograph- mass spectrometry (GCMS) testing. The GCMS analysis showed that sample C is moderately mature and of mainly marine algal/ bacterial origin.

Results from testing of samples from the Funeral Creek area by Scott & Hartung-Kagi (1997) a possible algal/ bacterial origin for hydrocarbons.

Devonian source

Within the Bancannia Trough the Early Devonian units of the Winduck interval are the most promising in terms of source rock potential. The Winduck interval units have not been encountered in drilling or recognised in outcrop within the Bancannia Trough area. The interval is inferred to occur at depth within the trough, based upon seismic interpretations and modelling.

In other parts of the Darling Basin the Winduck interval includes shallow marine to deltaic sediments and is likely to include intraformational sealing units. The marine and deltaic nature of units within the Winduck Group suggests that organic material is likely to be present and represents a possible petroleum source.

Source rock potential within the Wana Karnu and Ravendale intervals is less promising given their depositional environments and lack of thick organic rich units. Testing by Scott & Hartung-Kagi (1997) of samples from the Bancannia South 1 well between 1800 m and 2950 m in the latest Early Devonian and Middle Devonian sequence shows a mix of compounds in the C_{12} to C_{31} n-alkane range. Scott & Hartung-Kagi (1997) however, speculate that these results are more indicative of refined products than naturally occurring hydrocarbons (although they do not rule out a mixture) so this may not be a valid test of the source rock potential of these units intersected and tested in the well.

Reservoirs

Drilling data from the Bancannia Trough shows moderate to good reservoir properties (Table 7) within parts of the Devonian sequence intersected in the three wells. Porosities up to 26% and a maximum permeability of over 0.58 darcy units in a single sample from the Late to Middle Devonian are recorded.

Table 7: Reservoir properties of the Bancannia Trough wells (Blevin et al. 2007).

Well	Test	Spud Year	TD (m)	Reservoir Properties
Bancannia South 1	Low relief anticline, valid test	1967	3409	Poor to moderate porosity with variable permeability from Early to Late Devonian.
Bancannia North 1	Anticline, possible valid test	1968	1478	Poor to fair porosity and permeability between 935-1137m from the Middle to Late Devonian.
Jupiter 1	Anticline, drilled outside closure	1969	1831	Moderate porosity calculated from logs within the Upper Devonian.

Table 8: Bancannia South 1 and Bancannia North 1 porosity (%) and permeability (millidarcy (mD)) test results.

	Bancannia South-1				
	Depth (m)	Porosity (%)	H Perm (mD)	V Perm (mD)	Lithology
U. Dev	296	11	0	0	Very fine grained sandstone
	420.1	17	578	58	Medium grained sandstone
	511.2	7	0	0	Very fine grained sandstone
	647.1	7	0	0	Siltstone
	797.1	8	0.6	0	Very fine grained sandstone
M. to U. Dev	1074.5	13	55	49	Fine grained sandstone
	1216.2	17	174	1	Fine grained sandstone
	1314.9	14	81	31	Fine grained sandstone
	1414.3	9	---	8	Medium grained sandstone
	1461	5	---	0.7	Medium grained sandstone
	1617	6	0	0	Fine grained sandstone
	1723.7	4	0	0	Very fine grained sandstone
	1808.8	3	0	0	Very fine grained sandstone
	1931.2	3	0	0	Fine – Medium grained sandstone
	2019.7	8	0	0	Medium grained sandstone
	2118.1	5	0	0	Coarse grained sandstone
	2215.2	4	---	0	Medium- coarse grained sandstone
	2369.2	7	2	3	Lithic greywacke
	2528	7	0	0	Feldspathic greywacke
M. Dev	2681.4	1	0	0	Siltstone
	2846.3	3	0	0	Medium grained sandstone

	2948.1	2	0	0	Fine grained sandstone
	3093.2	1	0	0	Very fine grained sandstone
	3233.3	3	0	0	Fine – Medium grained sandstone
	3378.5	0.5	14	0	Andesite
Bancannia North-1					
	Depth (m)	Porosity (%)	H Perm (mD)	V Perm (mD)	Lithology
U. Dev	421.2	11	0	0	Fine grained sandstone
	484	11	1	1	Very fine sandstone
	573.5	12	0.9	0	Fine grained sandstone
	727.2	11	1	1	Medium grained sandstone
	869.2	10	---	5	Quartz Arenite
M. to U. Dev	1183.2	26	0	0	Medium grained sandstone & siltstone
	1305.7	5	0	0	Medium grained sandstone & siltstone
	1417.3	2	0	0	Very fine sandstone & siltstone
	1478.2	4	0.01	0.01	Very fine sandstone & siltstone

The best reservoir properties occur in the Bancannia South 1 well (Table 8). The Upper Devonian Ravendale interval, from 825 m to 1220 m, has porosities above 13% (Figure 23) and permeabilies of up to 175 mD (Figure 24). The Middle and Lower Devonian units in this well exhibit generally poor reservoir potential based upon these test results.

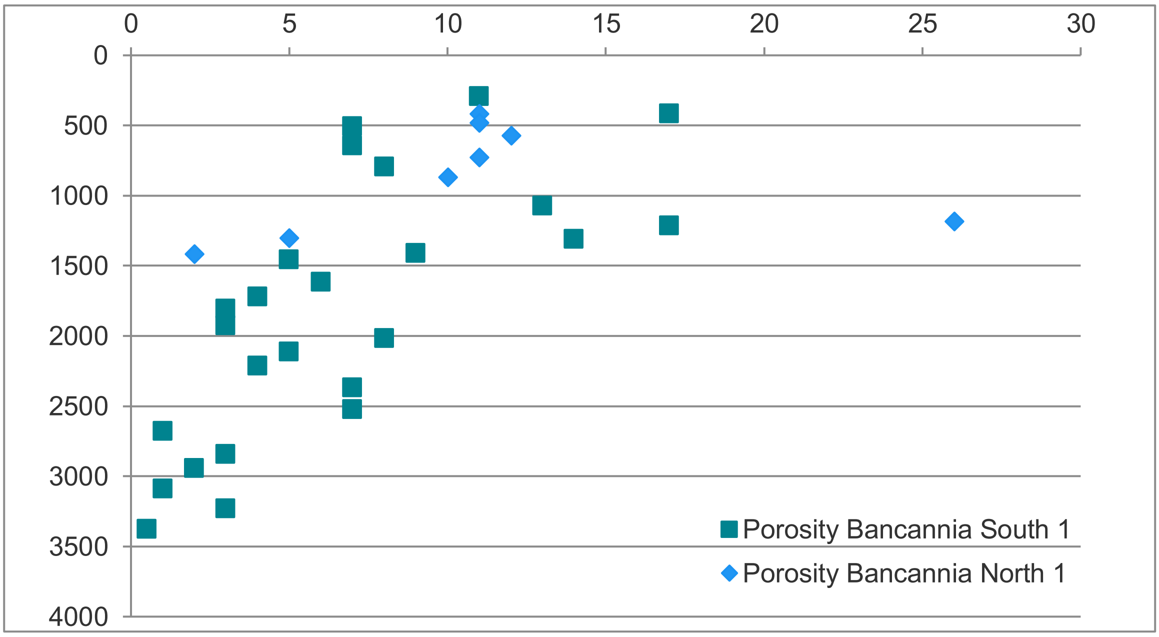


Figure 23: Porosity analysis results from Bancannia South 1 and Bancannia North 1 wells.

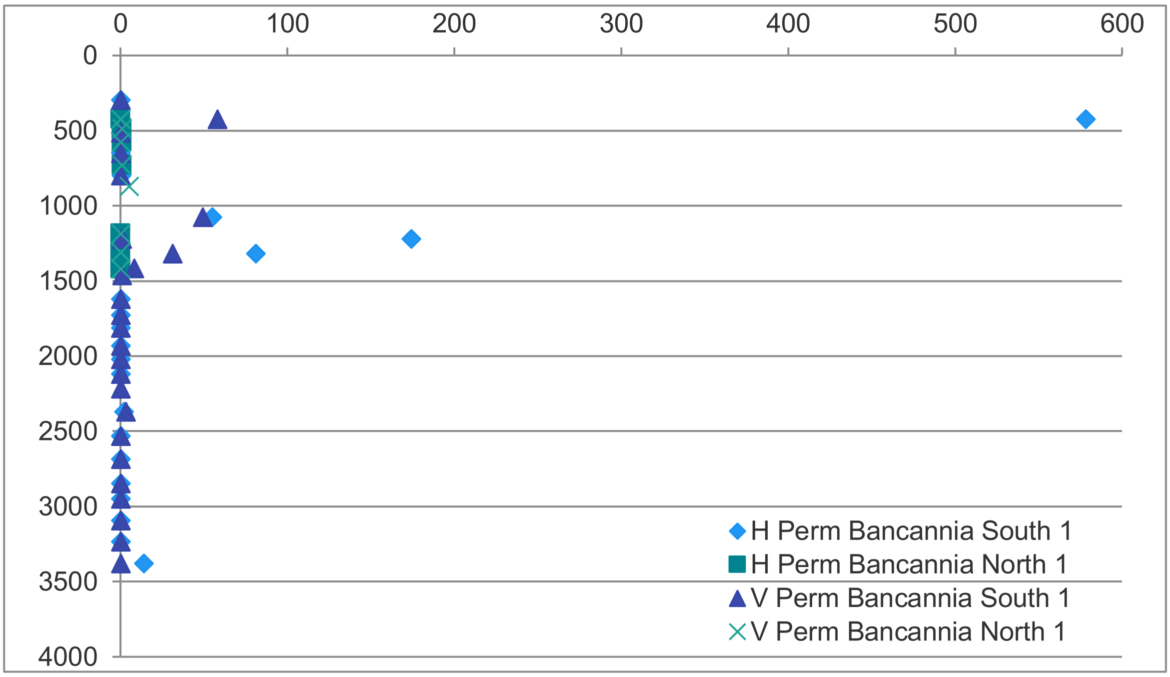


Figure 24: Horizontal and vertical permeability results (in mD) from Bancannia South 1 and Bancannia North 1 wells.

The Bancannia North 1 well shows relatively good reservoir properties in the Upper Devonian with up to 26% (Figure 23) porosity, although the permeability of these samples is low with a maximum horizontal value of 1mD and a slightly higher maximum vertical value of 5 mD permeability (Figure 24). Whilst testing of core samples was not conducted on the Jupiter 1 well indications from wireline logs are that the best reservoir potential is in the Upper Devonian units.

Wireline log data for the three wells drilled within the Bancannia Trough is shown Figure 25,Figure 26 andFigure 27. Petrophysical interpretation of the wireline data was completed in Petrolog™ software. The well zones with inferred elevated reservoir quality are highlighted in blue Figure 25,Figure 26 andFigure 27. The massive, thick sandstone dominated intervals generally exhibit greater reservoir potential then the finer grained and or interbedded units.

Bancannia South-1 (Planet Exploration)

T.D. 3409.1 m   G.L. 150 m

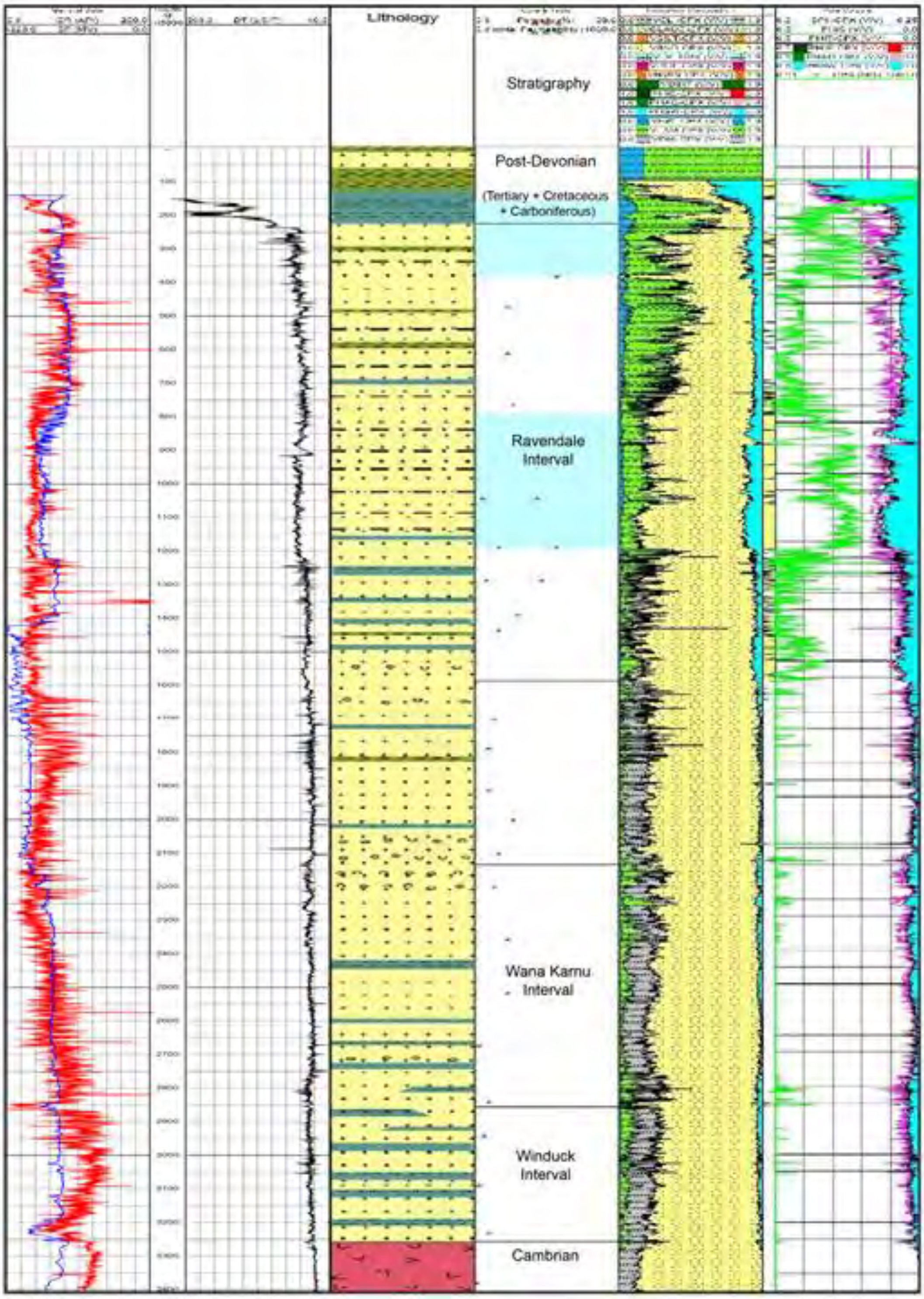


Figure 25: Bancannia South 1 well graphic log summary. The light blue shading in the Stratigraphy column indicates the section with the best reservoir characteristics, derived from geophysical log interpretation.

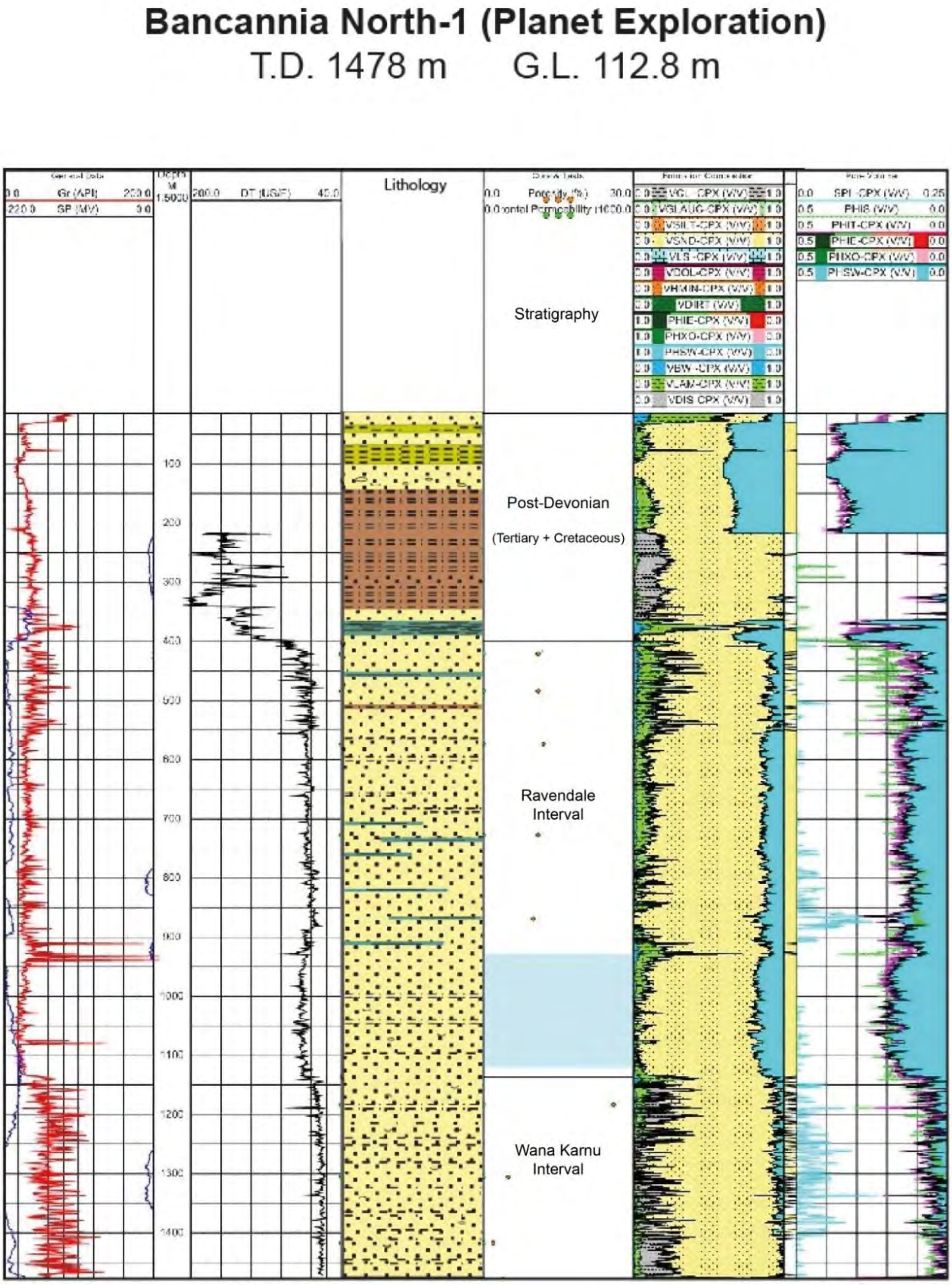


Figure 26: Bancannia North 1 well graphic log graphic log summary. The light blue shading in the Stratigraphy column indicates the section with the best reservoir characteristics, derived from geophysical log interpretation.

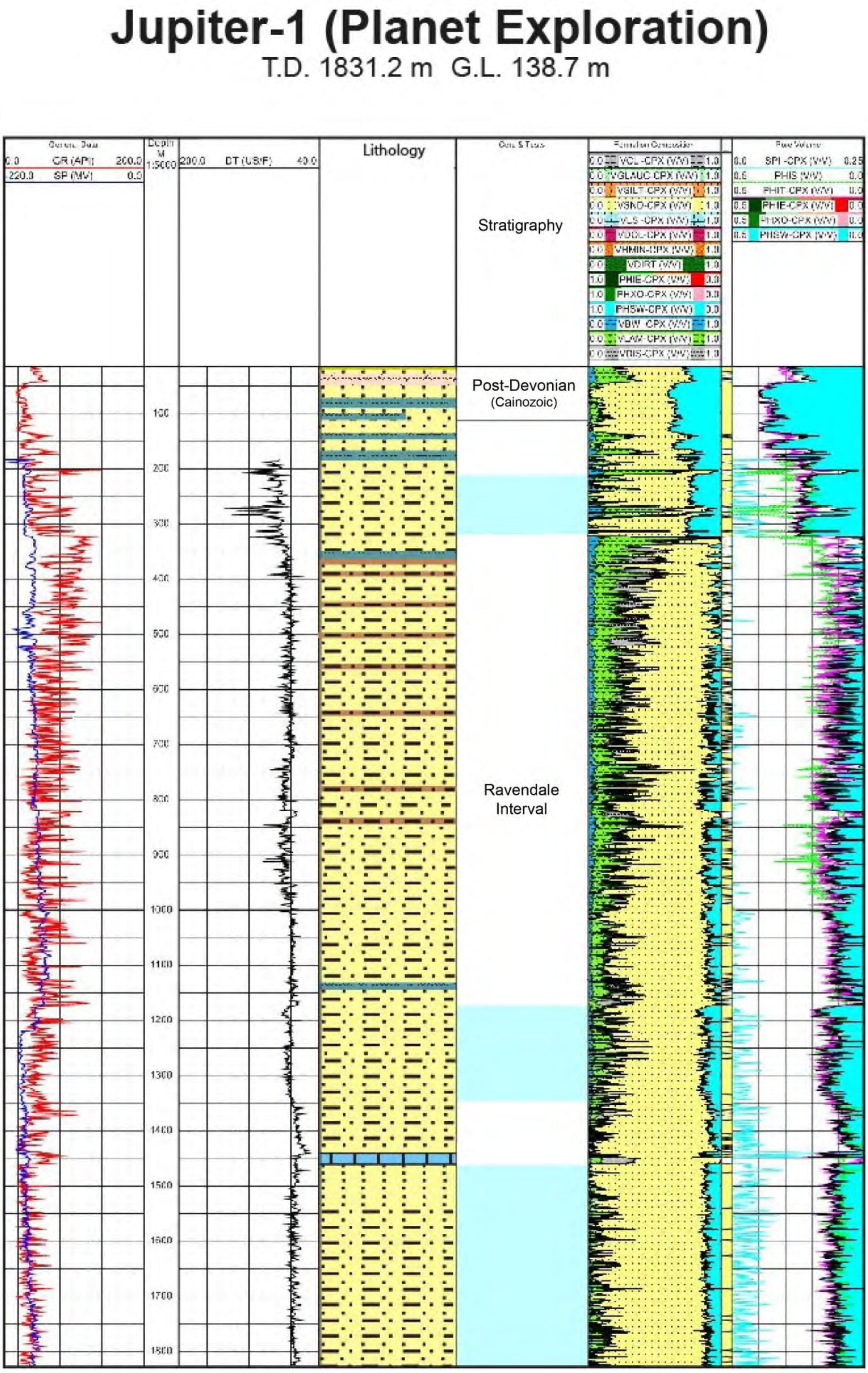


Figure 27: Jupiter 1 well graphic log summary. The light blue shading in the Stratigraphy column indicates the section with the best reservoir characteristics, derived from geophysical log interpretation.

Seals

Outcrop and well control are very limited within the Bancannia Trough. The presence of suitable regional scale seal units is unproven. Localized seals (e.g. thin fine grained packages) are likely to occur, however mapping of the distribution of these types of seals within the Devonian units is not possible due to a lack of data.

Given the changes in amplitude observed in seismic data there is some evidence that regional intraformational reservoir and seal units may be present in the Bancannia Trough however, there is little other data (ie. drilling/ outcrop) to support such an interpretation.

The three wells that intersected Devonian units all confirm the presence of sandstone units with reservoir potential. However, the absence of thick, fine grained cap rock units, in these wells, makes the likelihood of regional scale seals in the parts of the sequence intersected in these wells unlikely. This does not negate the presence of such seal units, given the limited amount of drilling and the large size of the trough.

Only relatively thin intraformational seal units are intersected in the three wells drilled and the lateral extent of these units is unknown. The sealing characteristics of these units may be sufficient for trapping of hydrocarbons but, there is no proven incidence of this within the trough.

The Early Devonian sequence appears to have the most promising seal potential based on geophysical log interpretation of the Bancannia South 1 well. In conjunction with the Early Devonian's inferred source rock potential (Scott & Hartung-Kagi 1997, GS 2002/381) this makes these older units the most prospective in terms for a combined source, reservoir and seal system.

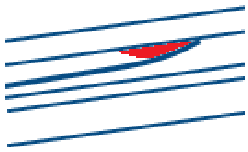
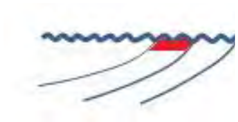
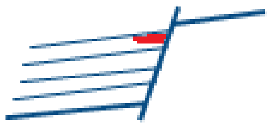
Two other potential, but speculative, seal types may be present. Regional scale unconformity surfaces have potential as seals, given their often weathered and indurated nature. Additionally, the Darling Basin, particularly in the east, is known to be heavily indurated throughout large parts of the sedimentary sequence with extensive silicification recognised. There is potential that the silica mobilisation may have extended into the Bancannia Trough and may have led to the formation of silica infilled, low-porosity zones within the sequence.

Traps

Structural hydrocarbon trapping configurations may date from the Early Devonian through to the Middle Carboniferous. These structural traps are likely to be associated with the Tabberabberan and Kanimblan Orogenies (Blevin et al, 2007). There is little evidence to suggest that the Darling Basin, as a whole, underwent any significant deformation after these events.

Three types of trapping configurations are recognised based on seismic interpretation (DPE, 2017). Types A, C and E trapping configurations are interpretted to occur (Table 9). Type 1, a fault terminated reservoir, is a newly proposed trap configuration for the trough.

Table 9: Petroleum traps interpreted to be present in the Bancannia Trough (DPE, 2016).

Name	AAPG^ trap classification	Label	Description	
Depositional regime traps (up-dip pinch outs)	Stratigraphic trap> Depositional regime> Pinch out	**A**	Trapping of hydrocarbons from a permeable up-dip formation onto an impermeable rock.	
Erosional regime traps (unconformity)	Stratigraphic trap> Erosional regime> Truncation	**C**	Trapping of hydrocarbons along an impermeable unconformity.	
Anticlinal structural trap	Structural trap> Fold regime> Local anticline	**E**	A trap formed from an arched antiformal fold with overlying impermeable sediments.	
Fault terminated reservoir	Structural trap> Fault regime> Normal/ Reverse	**1**	Trap formed by cross-cutting of a reservoir unit by a normal/ reverse fault, sealed by impermeable unit and fault plane materials.	

^ Vincelette et al. 1999

None of the three wells drilled within the trough are considered to be valid hydrocarbon traps. In each case the well is believed to have been drilled outside of any closure. There is however, some question as to whether the Bancannia South 1 well may have been drilled within closure and therefore be a valid test although further seismic data is required to confirm this. Acquisition of further seismic data however, is needed to identify and accurately map the geometry of potential trapping configurations.

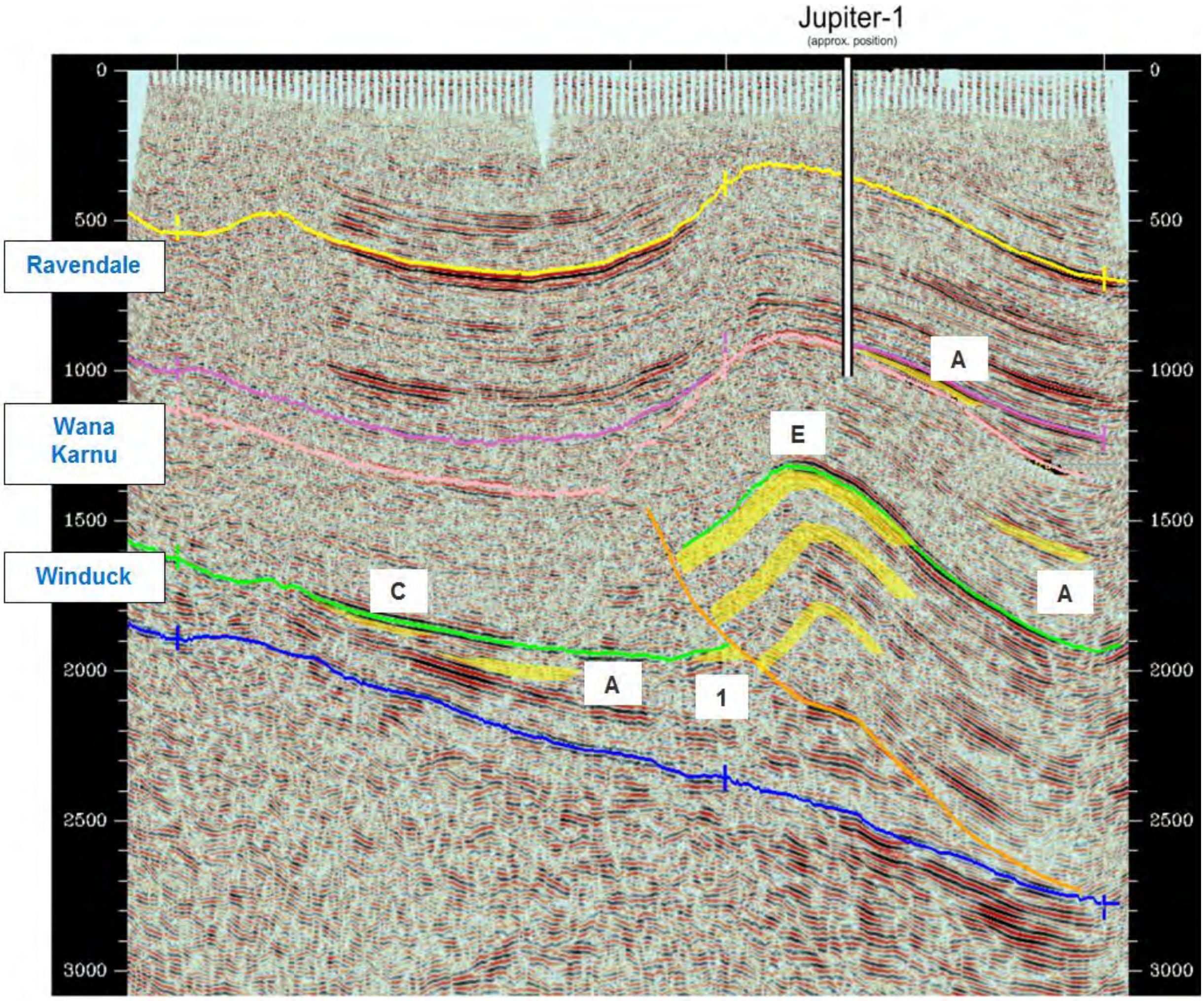


Figure 28: West-east view of SS070-68-26 showing interpreted trap types in yellow.

Trap Type A - Depositional regime traps (up-dip pinch-outs)

The pinch out of units (ie. onlap) on underlying strata is relatively common based upon seismic interpretations. Figure 28 shows the SS070-68-26 seismic line depicting interpreations of several depositional pinch-outs within the Winduck interval.

Trap Type C - Erosional regime traps

Figure 28 shows the Winduck interval eroded west of the Jupiter 1 well (extreme left side of image). A potentially truncated sandstone reservoir of the Winduck interval overlain by the basal sandstone units of the Wana Karnu interval was intersected in the Bancannia South 1 well. The Winduck/Wana Karnu unconformity surface (green line) may provide a seal of the underlying Winduck interval units, although there is no drill core data to confirm whether the erosional surface has sealing potential or not.

Trap Type E– Anticlinal structural traps

Antiformal structural traps are seen in the Winduck and Wana Karnu intervals (righthand side of Figure 28). They may be sealed by overlying, potentially impermeable unconformities or thin cap rocks. The most prominent of these trap types is located in the southern part of the trough near the Jupiter 1 well (Figure 29).

Trap Type 1- Fault terminated trap

A trap formed by the activation/ re-activation of a normal or reverse fault where reservoir rocks are terminated against the fault plane. This play relies upon the fault plane related gouge/ breccia material and the units in the opposite fault block acting as a seal.

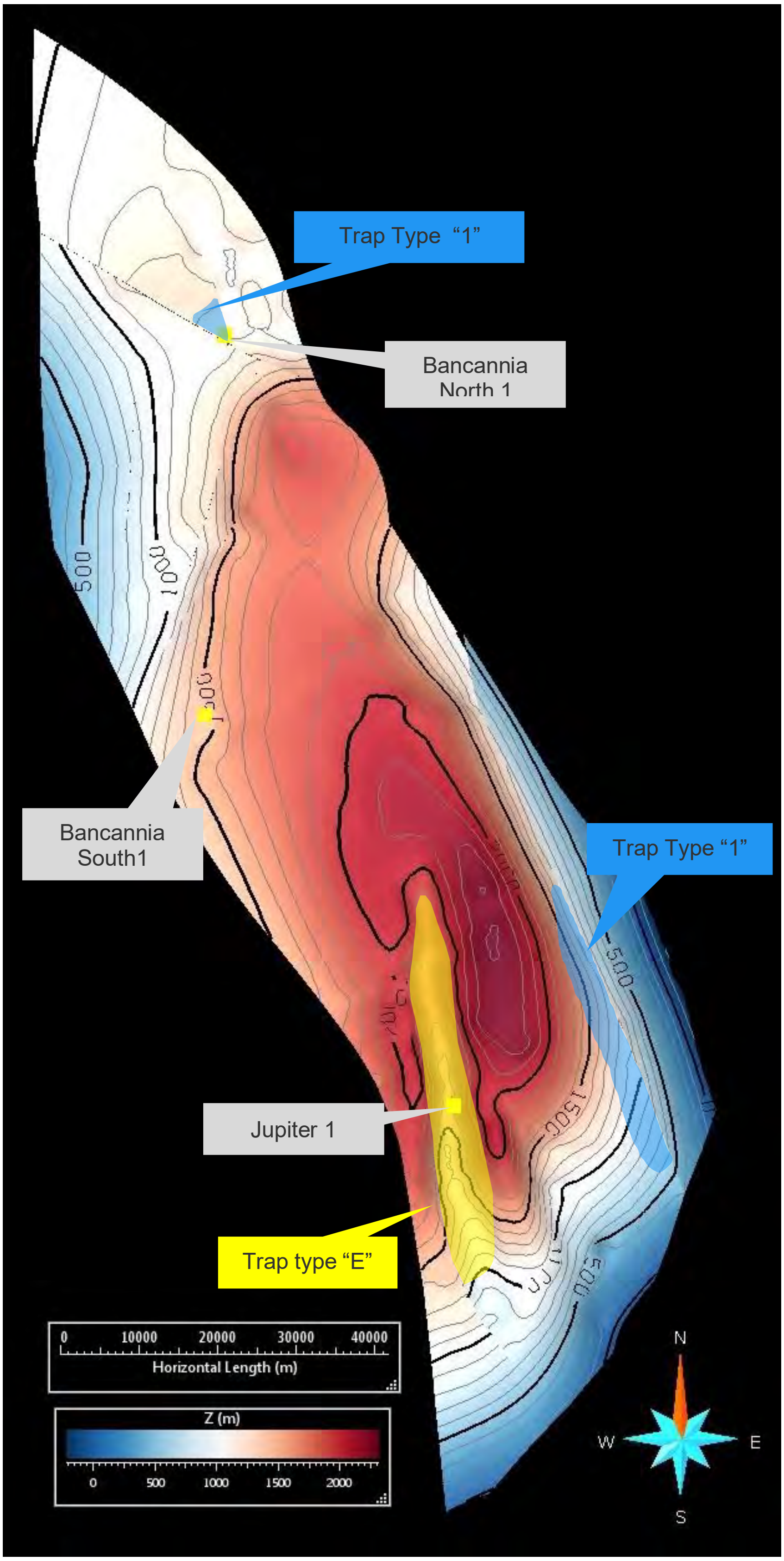


Figure 29: Top Wana Karnu interval horizon showing interpreted anticlinal trap type "E" near the Jupiter 1 well and Jupiter structure and possible trap type "1" against a major normal fault.

Maturation

The limited amount of data within the Bancannia Trough makes any assessment of hydrocarbon generation potential difficult. Basin modelling carried out by Deighton (2004), included in the Darling Basin Data Pack 2007, showed hydrocarbon generation was possible from the Middle Devonian to the Late Carboniferous (Figure 30, Figure 31Figure 32), although this is based on numerous assumptions and very limited data.

The model was built using a basic stratigraphy that divides the Devonian sequence into several discrete units from “A” to “K” (Table 10Table 10).

Table 10: List of unit abbreviations used in the WinBury™ model shown in Figure 30, Figure 31 andFigure 32 (Deighton 2004). Units of post-Devonian age are named and not sub-divided using abbreviations.

Unit	Corresponding time period	Unit	Corresponding time period
A	~354 - 358 Ma	F	~370 - 377 Ma
B	~358 - 363 Ma	G	~377 - 392 Ma
C	~363 - 365 Ma	H	~392 - 401 Ma
D	~365 - 367 Ma	I	~401 - 404 Ma
E	~367 - 370 Ma	K	~404 - 412 Ma

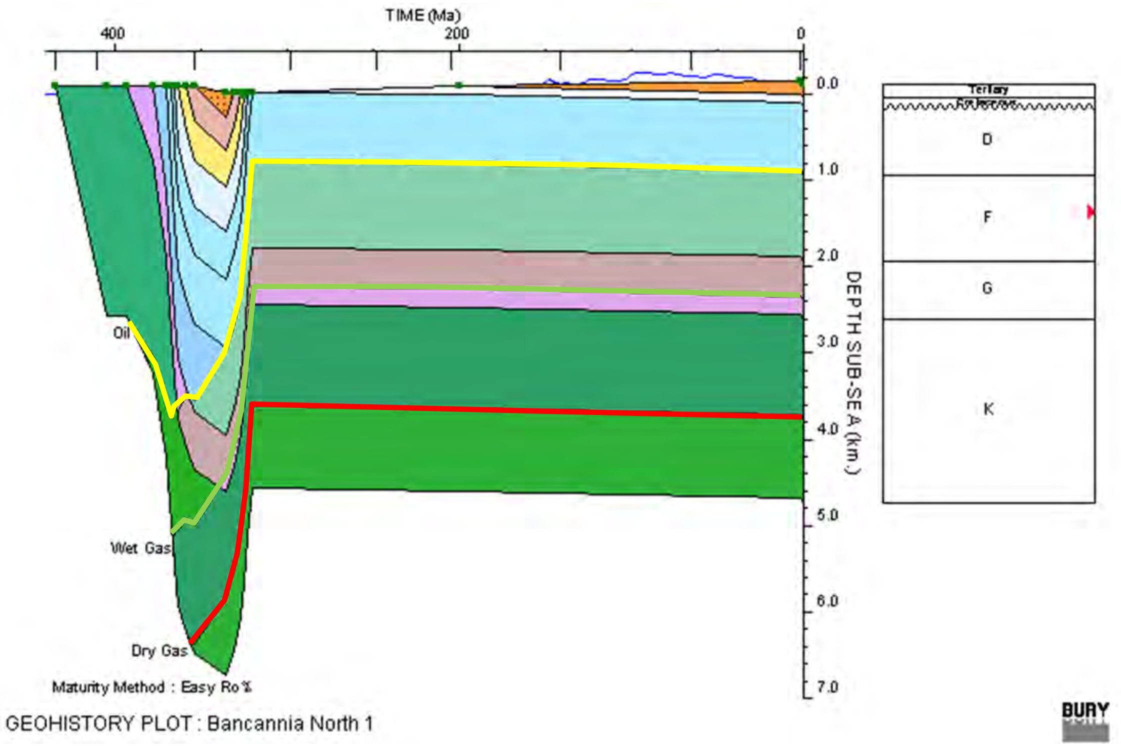


Figure 30: Burial history plot of Bancannia North 1 well showing presence of interpretted oil and gas windows at left (Deighton, 2004). The stratigraphy on the right relates to the time periods shown in Table 10.

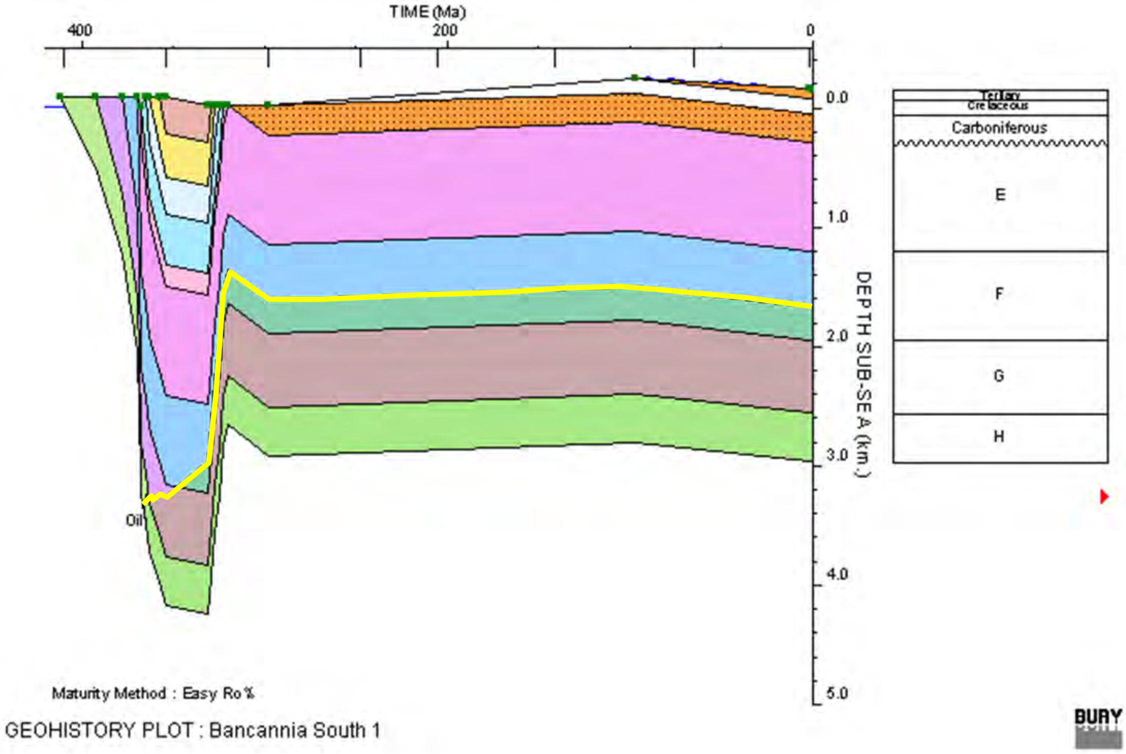


Figure 31: Burial history plot of Bancannia South 1 well showing presence of interpretted oil generation window at left (Deighton, 2004). The stratigraphy on the right relates to the time periods shown in Table 10.

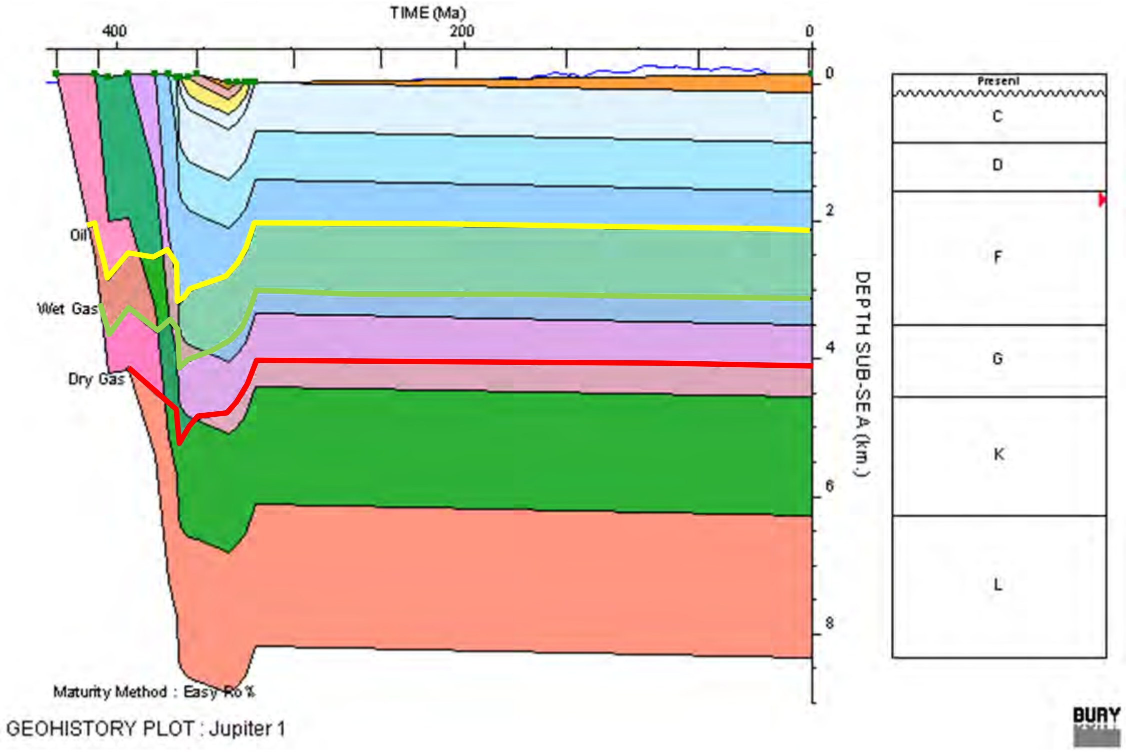


Figure 32: Burial history plot of Jupiter 1 well showing the presence of interpretted oil and gas windows at left (Deighton, 2004). The stratigraphy on the right relates to the time periods shown in Table 10.

Migration

Based upon interpretation of soilgas and airborne ethane and propane geochemistry survey results Cooney and Mantaring (2007) suggest that vertical migration of hydrocarbons from deeper parts of the Darling Basin is occurring. They propose that migration in the northern part of the Bancannia Trough may still be occurring through seepage within the sedimentary package or along fault planes. The presence of elevated methane in this area may however, be linked to biogenic processes occurring within the shallower post-Devonian sequence.

Devonian analogs- Adavale Basin

The Adavale Basin in southern-central Queensland (Figure 33) is a gas producing Middle Devonian basin and provides encouragement that Devonian Darling Basin and therefore the Bancannia Trough may host commercially viable accumulations of gas. The Darling Basin may be prospective for plays similar to the Adavale Basin's Gilmore Gas Field (DPE 2017). This field exhibits relatively low porosity and permeability reservoirs and the source remains cryptic.

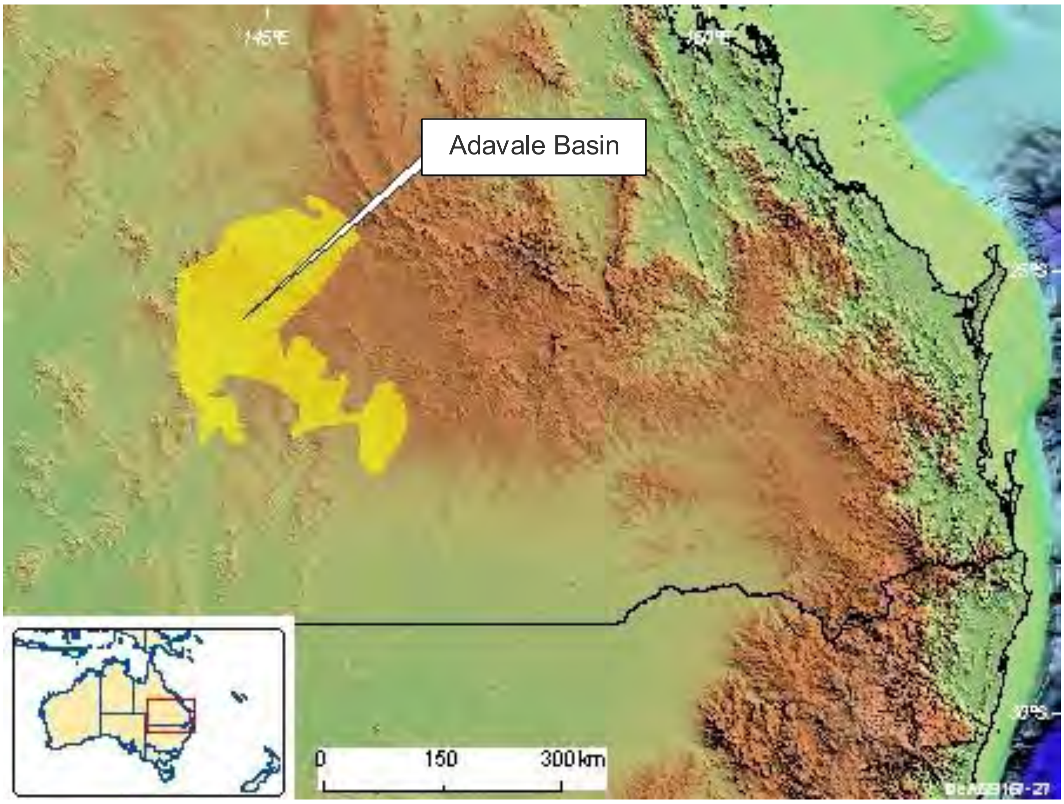


Figure 33: Location of the Adavale Basin in southern- central Queensland. © Commonwealth of Australia (Geoscience Australia) 2018.

The Adavale Basin reservoirs are Middle Devonian corresponding with the Middle and Late Devonian reservoir units within the Darling Basin. The gas source in the Adavale Basin is thought to be in close proximity to the reservoirs and the Middle to Late Devonian units are considered suitable sources.

Deep, over-mature sources may also contribute to the accumulation of wet and dry gas within the Adavale Basin. In contrast, the Bancannia Trough the source rock units are believed to be of Early Devonian or Cambro-Ordovician age and not contemporaneous with the deposition of the reservoir rock intervals.

Seals within the Adavale basin also differ from those interpreted to be present in the Bancannia Trough. Seals in the Adavale Basin are provided by evaporates and shales whilst within the Bancannia Trough may be linked with weathering profiles associated with regional scale unconformity events, localized fine grained claystone and siltstone small scale seals and fault related seals.

Whilst there are significant geological differences between the two basins the Adavale Basin example illustrates that Devonian basins can host commercially viable hydrocarbon resources. It's similar age and relatively close proximity improves the outlook for the discovery of petroleum accumulations within to the Bancannia Trough.

Part 6 – Data assessment

A qualitative assessment of the availability of petroleum data in the Bancannia Trough has been completed for five areas (Figure 34). The areas were delineated based on geology and the relative amount of data. The “North” and “South-West” sub-divisions are based on the interpreted shallowing of the basin over faults that extend into basement. The “Central-north”, “Central” and “South-east” sub-divisions are arbitrarily based on the location of the wells and seismic line density.

Nine geological factors were ranked based on the definitions set out in Table 11. For each of the areas a score for each factor was assigned after assessment (Table 12). The assessment considers the availability of data relevant to petroleum exploration in the five areas and also the occurrence of hydrocarbon indicators. A higher score indicates relatively better data quality and density.

Table 11: Explanation of rankings used in the data assessment of the trough. The scores were used to calculate a data availability value for each area.

Ranking	Score	Explanation
None	0	No data available. Unable to draw any conclusions about the geology of the area.
Very Limited	1	Only minor, sparse data availability. Regional geology of the area may be inferred.
Limited	2	Only sparse data availability. Regional geology of the area may be inferred.
Moderate	3	Resonable coverage. Regional geology may be interpreted with a degree of confidence.
Good	4	Good data availability. Regional geology can be interpreted with a higher degree of confidence and prospect scale geology may be inferred.
Excellent	5	Excellent data availability. High degree of confidence for the interpretation of regional and prospect scale geology.

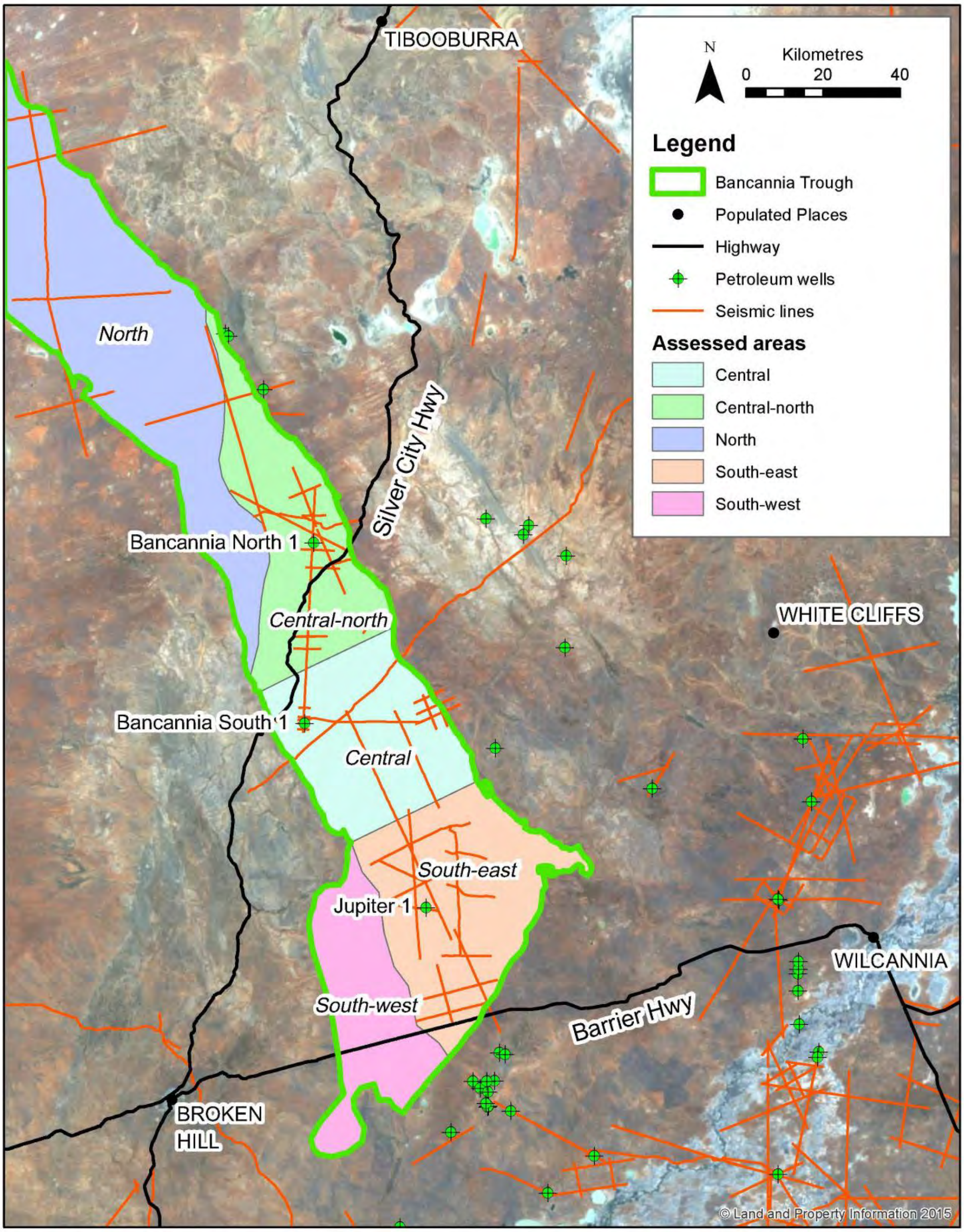


Figure 34: Location of areas considered in data assessment.

Table 12: Qualitative assessment of data availability in the Bancannia Trough based on ranking definitions set out in Table 11. The scores and percentages indicate the relative amount and quality of data available in each area.

	North		North-central		Central		South-east		South-west	
Data Availability										
Well data	0	None	1	Very Limited	1	Very Limited	1	Very Limited	0	None
Formation test data	0	None	1	Very Limited	1	Very Limited	1	Very Limited	0	None
Seismic data	1	Very Limited	4	Good	4	Good	4	Good	0	None
Borewater geochemistry data	3	Moderate	0	None	1	Very Limited	1	Very Limited	1	Very Limited
Soilgas geochemistry data	1	Very Limited	2	Limited	2	Limited	3	Moderate	1	Very Limited
Mapping data	1	Very Limited	2	Limited	4	Good	4	Good	4	Good
Geophysics data	3	Moderate	3	Moderate	3	Moderate	3	Moderate	3	Moderate
Hydrocarbon shows										
Well show	0	None	1	Very Limited	1	Very Limited	1	Very Limited	0	None
Outcrop show	0	None	0	None	0	None	0	None	1	Very Limited
Overall data assessment score (out of 45)	**9**		**14**		**17**		**18**		**10**	
Overall data %	**20**		**31**		**38**		**40**		**22**	

The assessment indicates that the North and South-west areas have low data availability. The North-central, Central and South-east areas all have relatively good data coverage particularly in terms of seismic and soil gas analysis, although drilling data remains very limited in all parts of the trough. These three areas all have hydrocarbon shows, however none of the wells drilled in these areas resulted in further follow up exploration.

Part 7 – Summary and conclusions

A review, analysis, modelling and revised interpretations of geological data, shows that there is potential for the discovery of new petroleum resources in western New South Wales.

The work completed as part of the compilation of this data package shows that many of the requirements for a conventional hydrocarbon play exist within the Bancannia Trough. The reservoir properties of core and outcrop and interpreted structural features suggest that suitable storage is present across the trough. Pre-Devonian and Early Devonian units are likely to have the necessary characteristics of source rocks. When coupled with the modelled burial history, the generation of hydrocarbons is likely to have taken place.

The only component of a viable conventional petroleum system that is not confirmed or inferred is a seal. There is little evidence of regional scale sealing units and the presence of suitable localised or intraformational seals is also inconclusive.

The southern part of the basin appears to be the most prospective for petroleum accumulations, however the lower prospectivity in the north and west of the trough is based largely on the absence of sufficient seismic or drilling data. This lack of data means that these areas cannot be discounted in any assessment of petroleum potential.

The Bancannia Trough is under-explored for hydrocarbons. Further assessment and exploration is required to properly test its petroleum resource potential and determine if commercially viable hydrocarbon accumulations likely exist.

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