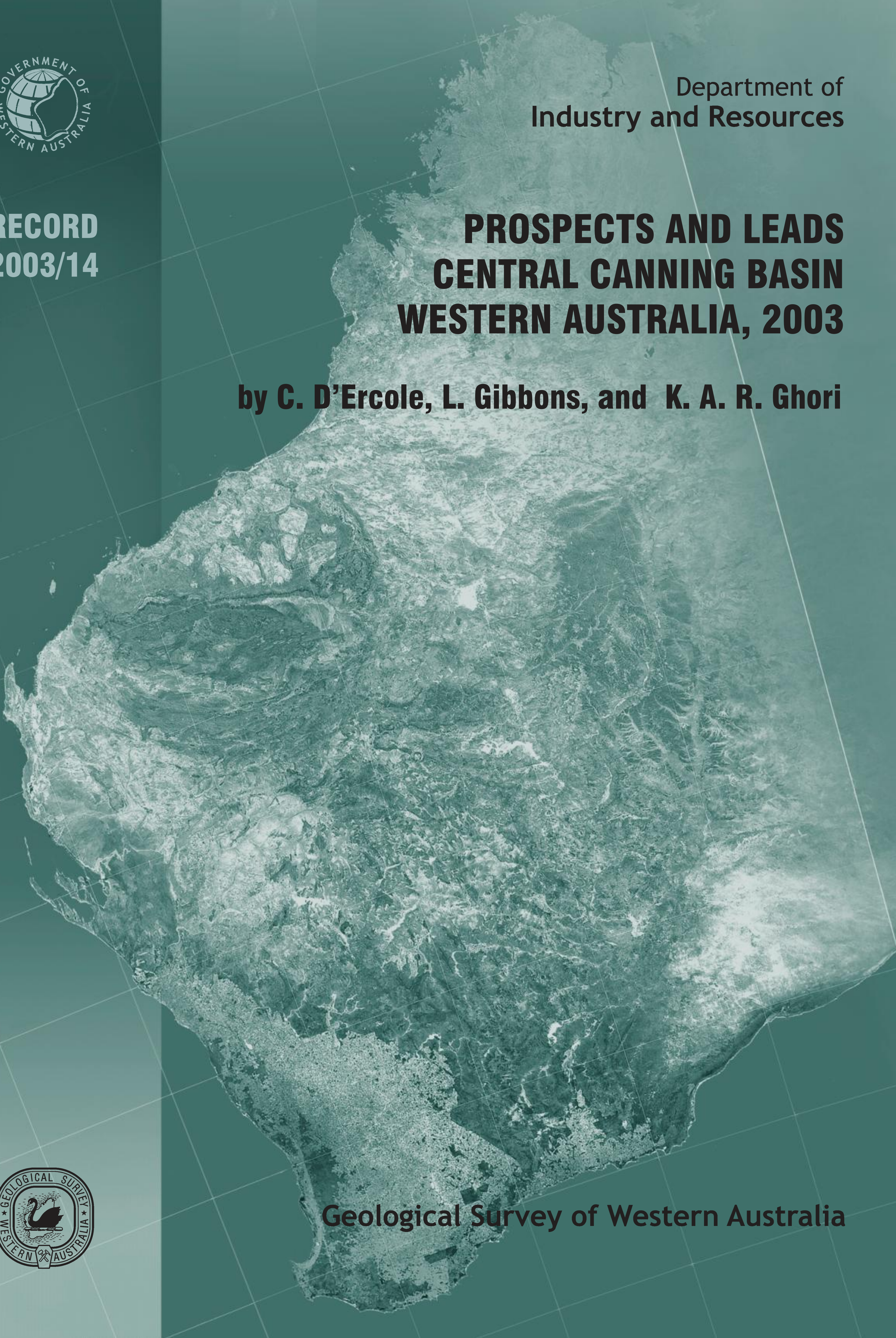

Department of
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RECORD
2003/14

PROSPECTS AND LEADS CENTRAL CANNING BASIN WESTERN AUSTRALIA, 2003

by C. D'Ercole, L. Gibbons, and K. A. R. Ghori

Geological Survey of Western Australia

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

Record 2003/14

PROSPECTS AND LEADS, CENTRAL CANNING BASIN, WESTERN AUSTRALIA, 2003

compiled by
C. D'Ercole, L. Gibbons[1], and K. A. R. Ghori

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Prospects and leads, central Canning Basin, Western Australia, 2003

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Abstract

This study provides information on the geology and hydrocarbon potential of undrilled leads and prospects proposed by exploration companies since 1980 over four acreage release areas within the central part of the Canning Basin, between latitudes 18°S and 20°15'S. The areas cover parts of the Barbwire, Jurgurra, and Mowla Terraces, Broome and Crossland Platforms, and Fitzroy Trough, and contain a sedimentary section extending from the Ordovician to Late Permian, with an extensive but thin Mesozoic cover. Petroleum exploration since 1980 has been primarily in the northern and central parts of the basin, with wells drilled on the Lennard Shelf, Broome Platform, Barbwire and Jurgurra Terraces, and Fitzroy Trough. Six commercial oilfields have been discovered on the Lennard Shelf. Within the acreage release areas and their surrounds, there are over 28 000 line-km of seismic data and 67 stratigraphic and petroleum exploration wells. Exploration to date demonstrates that the Canning Basin remains an underexplored basin that has all the necessary elements for a hydrocarbon province.

Limited geochemical data available for the acreage release areas indicate high-quality oil-prone source rocks within the upper part of the Ordovician Goldwyer Formation. These are presently within the oil-generative window or immature, rather than overmature. Oil and gas shows, indicating good migration pathways and mature source rock, are widespread throughout the Lower Ordovician to Permian part of the stratigraphic column, across the Barbwire, Jurgurra, and Mowla Terraces, Broome Platform, and Fitzroy Trough.

The most significant hydrocarbon shows on the Barbwire and Mowla Terraces are within the Nita, Goldwyer, and Willara Formations, and Upper Devonian units, those in the Fitzroy Trough are within the Carboniferous–Permian section, whereas oilfields in the Lennard Shelf span the Upper Devonian to Lower Permian sections. The most prospective play types in the central Canning Basin have either Ordovician objectives below the Mallowa Salt, or younger post-salt plays with Devonian to Lower Permian objectives. Key risks in all these plays are charge, timing, migration, and trap integrity. The prospects and leads have not been reassessed economically and are taken from reports completed by exploration companies that held licences in the acreage release areas.

KEYWORDS: petroleum potential, reservoir rock, source rock, Canning Basin, Western Australia.

Introduction

This Record presents the geology and hydrocarbon potential of undrilled leads and prospects proposed by exploration companies since 1980 that worked within the central part of the Canning Basin, between latitudes 18°S and 20°15'S (Fig. 1; Plate 1). The area covers parts of the Barbwire, Jurgurra, and Mowla Terraces, Broome and Crossland Platforms, and Fitzroy Trough. The prospects and leads have been assessed according to play elements of trap, source, migration and timing, and reservoir. No attempt has been made to assign an economic value to any of the leads and prospects.

The Canning Basin is the largest sedimentary basin in Western Australia, with an onshore areal extent of about 430 000 km^2 (Fig. 1). Several episodes of Phanerozoic subsidence and extension resulted in the deposition of an Ordovician – Lower Cretaceous sedimentary section up to 15 km thick, overlain by thin Quaternary cover (Towner and Gibson, 1983; Yeates et al., 1984; Kennard et al., 1994; Shaw et al., 1994). The Canning Basin onlaps Precambrian rocks of the King Leopold and Halls Creek Orogens to the northeast, and the Pilbara Craton and Paterson Orogen to the southwest, and is faulted against, and unconformable on, Proterozoic basins and metamorphic complexes to the east. To the south, the basin thins onto the Officer Basin and appears to be gradational into the Gunbarrel Basin. Offshore, the mostly Palaeozoic section of the Canning Basin is overlain by Mesozoic

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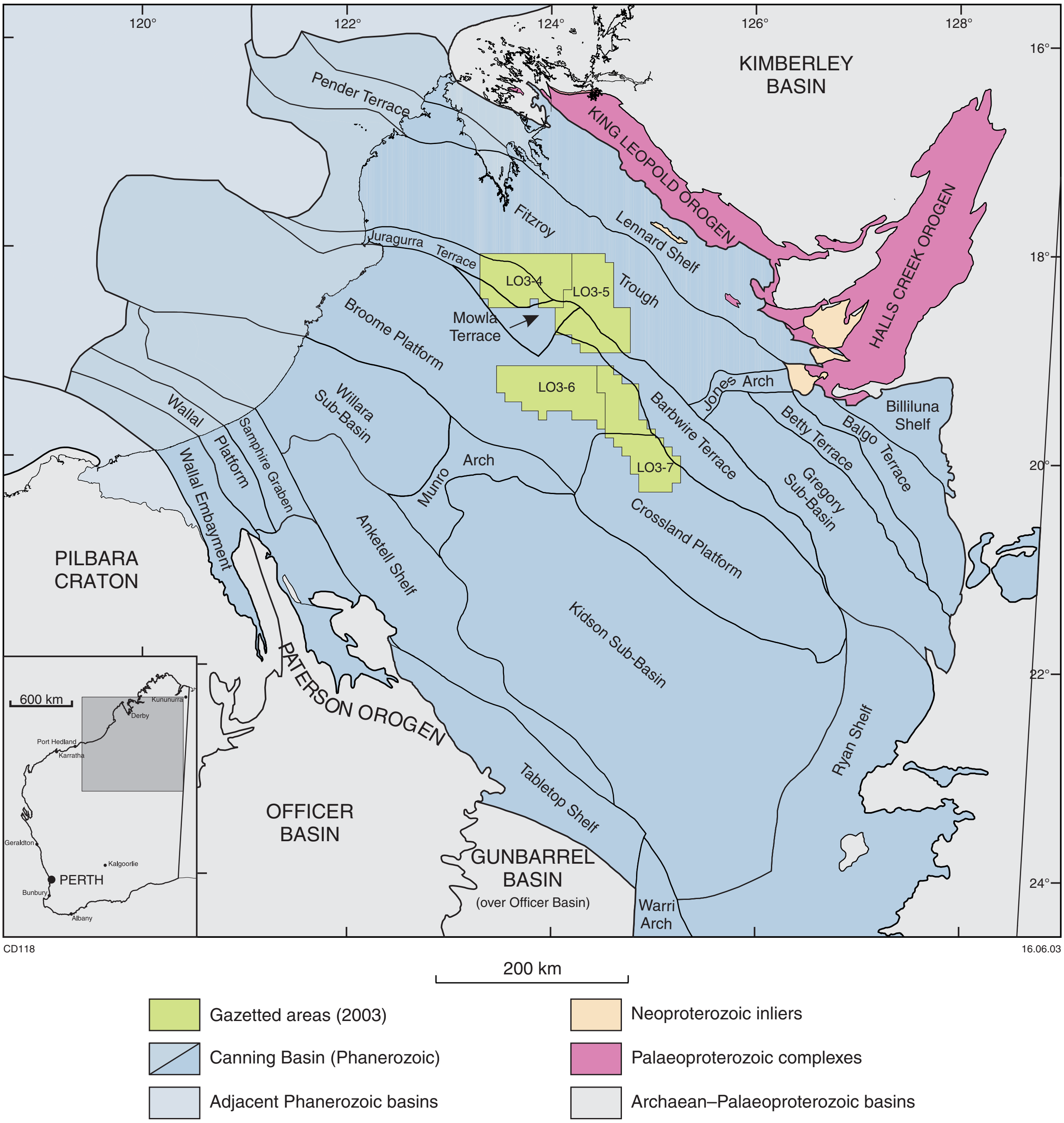


Figure 1. Location of the Canning Basin, showing tectonic units, basin framework, and acreage release areas (modified from Tyler and Hocking, 2002)

strata of the Westralian Superbasin. The Canning Basin contains two major, northwesterly trending depocentres with flanking shelves and a mid-basin arch. The northern depocentre is centred on the Fitzroy Trough and Gregory Sub-basin, and the southern depocentre on the Willara and Kidson Sub-basins (Fig. 1).

The oldest known rocks regarded as part of the Canning Basin are of Ordovician age. Successive episodes of subsidence, in part related to extension, resulted in the deposition of four major tectono-stratigraphic megasequences (Ordovician–Silurian, Devonian – Lower Carboniferous, Upper Carboniferous – Permian, and Jurassic – Lower Cretaceous) controlled by major, northwesterly trending fault systems (Kennard et al., 1994). In addition, there was extensive but thin Early Triassic deposition along the Fitzroy Trough, peripheral to major Triassic depocentres along the North West Shelf. The Canning Basin developed into a passive marginal basin during the middle Mesozoic following continental breakup (Brown et al., 1984; Middleton, 1990; Kennard et al., 1994; Shaw et al., 1994), and the focus of subsidence changed from onshore to offshore (Shaw et al., 1994), where it has remained since.

The Canning Basin has long been regarded as having all the elements of a major petroleum province, such as source, seal, and traps, apart from significant production. The search for hydrocarbons in the Canning Basin has yielded six small, commercial oilfields: Blina, Boundary, Lloyd, Sundown, West Kora, and West Terrace. Exploration activities have been largely focused on the northern and central parts of the basin, with relatively little work elsewhere. In recent years, most exploration has concentrated on the Lennard Shelf, Fitzroy Trough, and Broome Platform. Due to unsuccessful exploration efforts, interest in the basin has declined. However, there is scope for further exploration, especially if the current play models are reassessed and revised.

The two main industrial centres in the Canning Basin, Broome and Derby, have oil storage and transport facilities (Fig. 2). Broome serves as the shipping terminal for the crude oil produced from the Lennard Shelf. Minor pipeline grids exist near Derby. Major roads service the northern and western edges of the basin, with other access roads prepared specifically to facilitate operations at remote drilling locations.

Structural and tectonic framework

Structural elements

Western Australian basins have traditionally been subdivided primarily on their present structural configurations rather than focusing on depocentres or major sequences (Hocking et al., 1994; Tyler and Hocking, 2002). Most of the structural elements of the Canning Basin are defined by major, northwesterly trending Palaeozoic faults, and have axes parallel to the elongation of the basin. The most distinctive features are two major, northwesterly trending depocentres, each containing thick sedimentary sections, separated by a mid-basinal arch (Fig. 1).

The northern depocentre is divided into the Fitzroy Trough and Gregory Sub-basin, and contains up to 15 km of predominantly Devonian and younger strata. The Fitzroy Trough and Gregory Sub-basin are separated by a basement high called the Jones Arch (Fig. 1). They are separated from outcropping Proterozoic rocks to the north and northeast by the Lennard and Billiluna Shelves, and Balgo and Betty Terraces. These contain mostly Ordovician–Devonian carbonate rocks covered by a thin Carboniferous and Permian section.

The southern depocentre is divided into the Willara and Kidson Sub-basins, and contains a predominantly Ordovician–Silurian succession up to 5 km thick with a thin (<1 km) cover of Devonian and younger rocks. They are separated from Precambrian rocks to the southwest by a series of shelves (Anketell, Ryan, and Tabletop Shelves) and embayments (Samphire Graben, Wallal Platform, and Wallal Embayment), which contain a thin (<1 km) Carboniferous–Permian section directly overlying basement. Very little is known about these southwest marginal areas.

The mid-basinal arch, which in places has less than 2 km of Ordovician, Devonian, and Permian strata, consists of the Broome and Crossland Platforms (Fig. 1). These platforms are elevated basement ridges that step down to the Jurgurra, Mowla, and Barbwire Terraces, which are a series of rotated fault blocks, and finally to the Fitzroy Trough via the Fenton Fault System (a throw of up to 1000–1500 m). The Jurgurra, Mowla, and Barbwire Terraces contain a 2–4 km-thick Ordovician and Devonian section.

Tectonic evolution

The onshore Canning Basin is a long-lived, westward-opening intracratonic basin that had a complex structural history since its inception in the Ordovician. Several tectonic events have affected the basin, and led to four major phases of deposition (Fig. 3). The major controls on basin development have been thermal subsidence and periodic extensional events. The following summary of the tectonic history is based on Brown et al. (1984), Middleton (1990), Kennard et al. (1994), and Shaw et al. (1994).

The earliest tectonic phase was extension and rapid subsidence in the Early Ordovician (Samphire Marsh Movement; Kennard et al., 1994). An initial Early Ordovician transgression led to the deposition of shallow-marine sand, mud, silt, and carbonate facies (Nambeet and Willara Formations, and Prices Creek Group in the north) in several depocentres, especially in the southern sub-basins. Deposition slowed down by the Middle Ordovician, giving way to a regressive phase, with both clastic and carbonate facies (Goldwyer and Nita Formations). During this time, several episodes of erosion and non-deposition are evident, and extensional faulting commenced along the northern margins of the Fitzroy Trough and Willara Sub-basin, developing the Admiral Bay Fault Zone in the latter case. This rifting was followed by a prolonged Late Ordovician to Silurian sag stage (Carribuddy Sag Phase; Shaw et al., 1994), with associated widespread evaporitic deposits (Carribuddy Group) in the Kidson and Willara Sub-basins and Fitzroy Trough. Uplift and regional tilting followed in the latest Ordovician or Early Silurian. After the Silurian, basin evolution was dominated by a main period of extension and rifting.

The second tectonic phase (Prices Creek Compressional Movement; Kennard et al., 1994) began with minor folding, regional uplift, and erosion during the Early Devonian. Laterally extensive, eolian and terrestrial sediments (Tandalgoo Sandstone and Worral Formation) were deposited in the south, and marginal-marine carbonate and clastic sediments (Poulton Formation) in the north. There was extensive erosion on the Broome and Crossland Platforms and associated terraces to the north

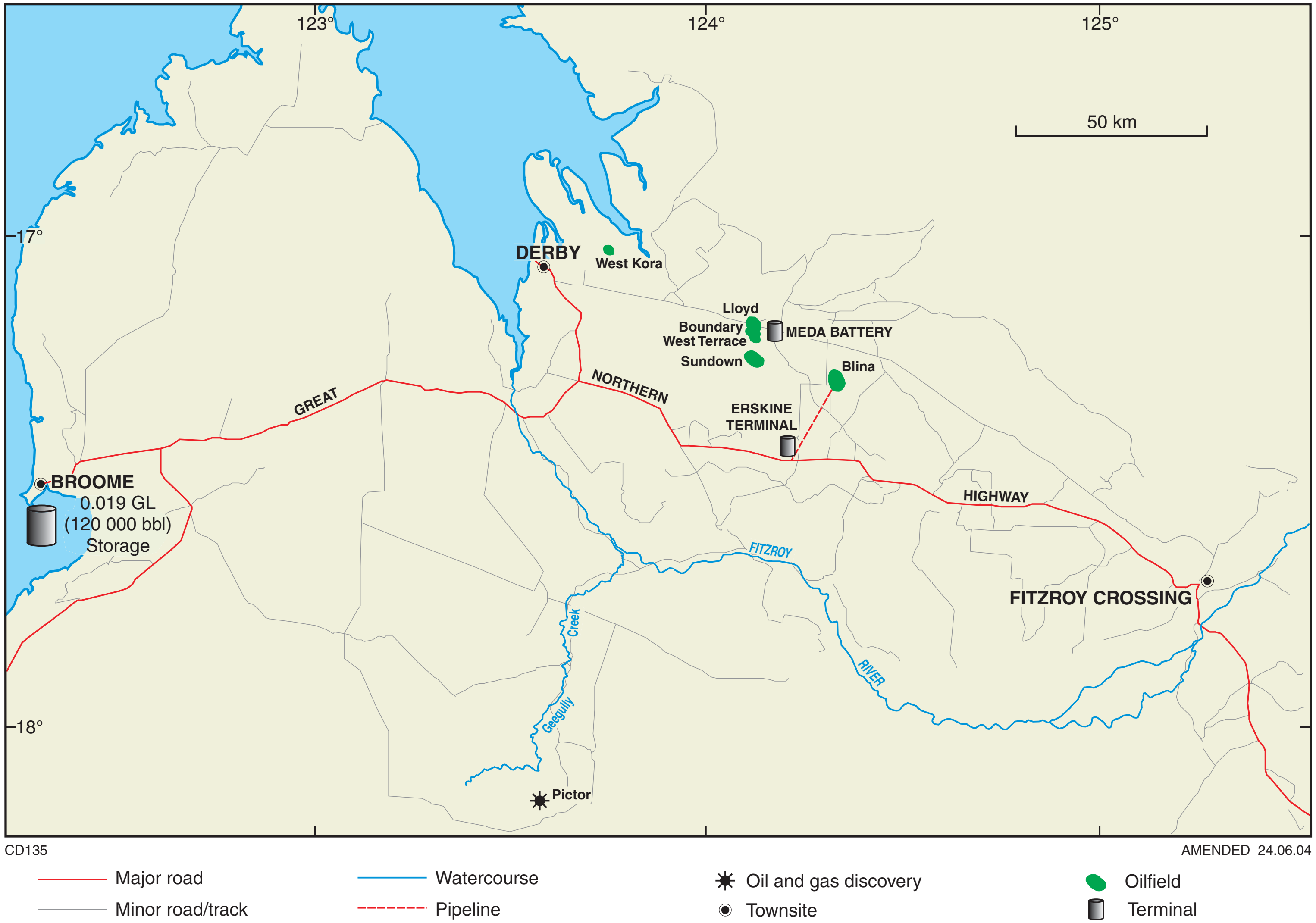
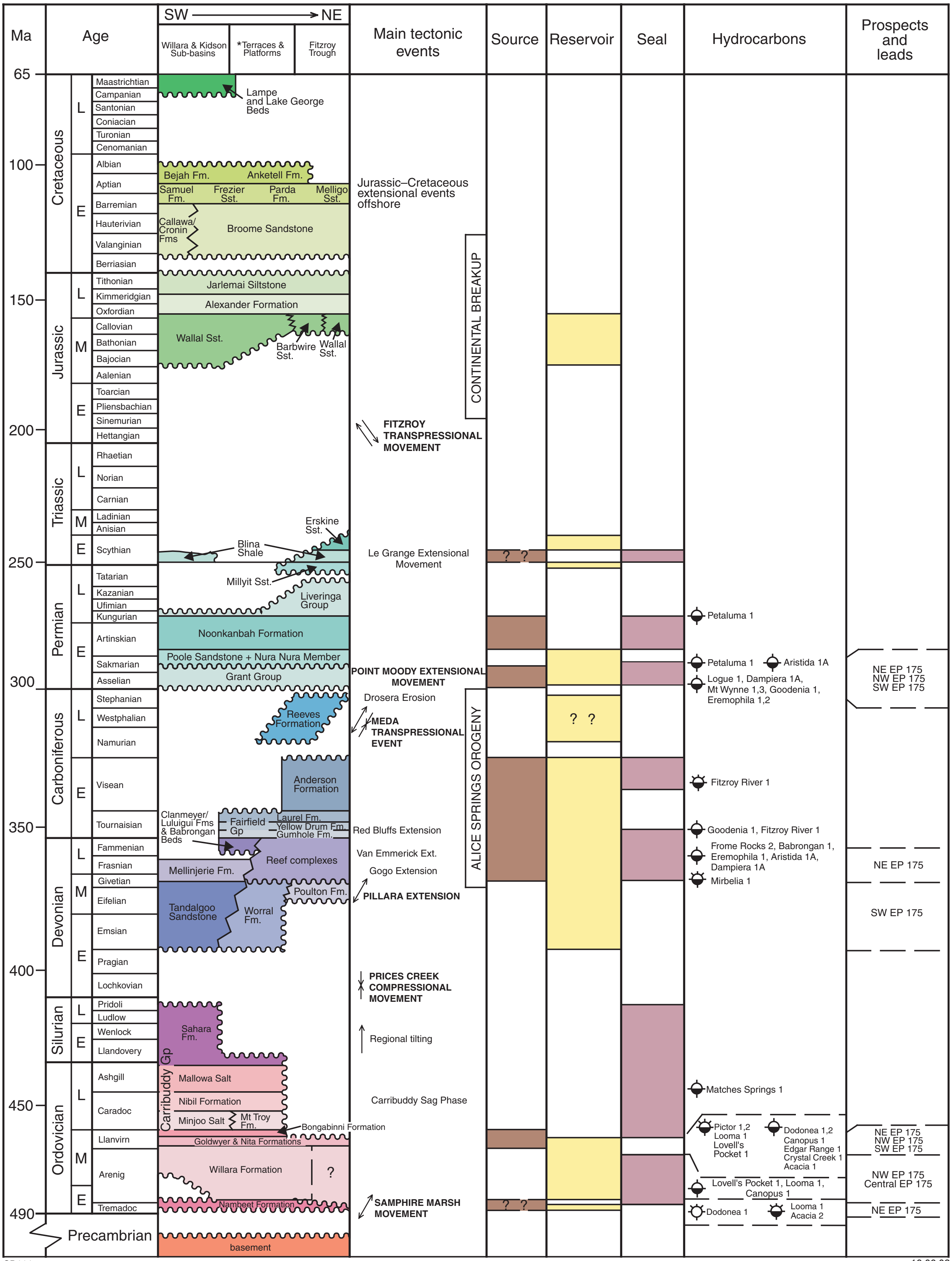


Figure 2. Fields and existing facilities and infrastructure of the Canning Basin



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☼	Gas show, abandoned	Ext.	Extension	Sst.	Sandstone
●	Oil show, abandoned	Fm.	Formation	∿∿∿	Unconformity
☀	Oil and gas show, abandoned	Gp	Group		

*Jurgurra, Mowla, and Barbwire Terraces, Broome and Crossland Platforms

Figure 3. Stratigraphy, tectonic events, and petroleum elements of the central Canning Basin (modified from Kennard et al., 1994)

during this time. The Kidson and Willara Sub-basins underwent gentle subsidence with little faulting during the Silurian to Early Devonian. The Broome Platform developed as a separate entity during the Early Devonian, and has remained a positive feature since that time.

The third tectonic phase combined major extension, rifting, and rapid subsidence of the Fitzroy Trough and Gregory Sub-basin in the Givetian (Pillara Extension; Kennard et al., 1994). Extensive reefal deposits (Devonian reef complexes) accumulated to the north on the Lennard Shelf, and shallow-marine platform carbonate and clastic facies accumulated over the southern terraces and parts of the Broome Platform. The deeper portions of the Fitzroy Trough and Gregory, Kidson, and Willara Sub-basins received a large influx of mainly fine-grained, siliciclastic sediments (Fairfield Group and Anderson Formation; Middleton, 1990). The Pillara Extension was interrupted by at least three tectonic pulses (Gogo, Van Emmerick, and Red Bluffs Extensions; Kennard et al., 1994; Shaw et al., 1994), at which times syn-extensional tilting and fault-block movements resulted in semi-regional subsidence followed by uplift (Kennard et al., 1994). These pulses are marked by the influx of conglomerates on the margins of the Lennard and Billiluna Shelves.

Deposition within the Canning Basin contracted to the Fitzroy Trough and southern Lennard Shelf during the Early Carboniferous. The post-Early Carboniferous period saw the initiation of compression and inversion of Devonian normal faults during a fourth major tectonic phase (Meda Transpressional Movement; Kennard et al., 1994; Shaw et al., 1994). This phase has been correlated with the peak of the Alice Springs Orogeny in central Australia, and is marked by thick syntectonic fluvial deposits (Reeves Formation). The fifth tectonic phase (Point Moody Extensional Movement; Kennard et al., 1994) involved a major recurrence of extension and rapid subsidence of the Fitzroy Trough during the Early Permian. This coincided with the onset of major Gondwana-wide glaciation (Grant Group). The end of the glacial period was marked by the deposition of transgressive, shallow-marine to deltaic sands (Poole Sandstone), followed by deeper water, lower energy, predominantly siltstone succession (Noonkanbah Formation), capped by regressive sand-dominated facies (Liveringa Group). There was a pulse of minor uplift and erosion at the end of this phase (Legrange Extensional Movement).

The sixth and final tectonic phase (Fitzroy Transpressional Movement; Kennard et al., 1994) was accompanied by regional dextral wrench movements, which reactivated the faulted margins of the Fitzroy Trough during the Late Triassic to earliest Jurassic. During this phase, strata within the Broome and Crossland Platforms, and their northern bordering terraces, formed a broad arch (Shaw et al., 1994). The Willara and Kidson Sub-basins were subjected to minor regional uplift with negligible faulting. After continental breakup, significiant sedimentation and major periods of extension were largely restricted to the offshore Canning Basin (Westralian Superbasin). During the Mesozoic and Cainozoic, subaerial erosion continued and large-scale drainage was developed, but became inactive in the mid-Cainozoic.

Stratigraphy and depositional history

This summary of the stratigraphy of the central-southern Canning Basin, around the acreage release areas, is based on the interpretation of well data, seismic data, and surface geology (Brown et al., 1984; Yeates et al., 1984; Middleton, 1990; Kennard et al., 1994; Romine et al., 1994; Fig. 3). Four main phases of sedimentation have been identified within the basin: Ordovician–Silurian, Devonian – Lower Carboniferous, Lower Carboniferous – Permian, and Jurassic – Lower Cretaceous, all of which lie below a thin but extensive Cainozoic cover in the study area. Two stratigraphic correlations across the acreage release areas for the Permian and Ordovician sections are shown in Figures 4 and 5 and Plates 2 and 3. Due to insufficient biostratigraphic data, poorly sampled intervals, and inconsistencies between company formation tops, the individual formations within the Grant Group were not differentiated, and individual horizons within the Ordovician formations have not been distinguished. Further detailed work is needed to resolve these horizons.

Ordovician–Silurian

The oldest units within the prospective part of the basin are widespread Lower–Middle Ordovician, shallow-marine carbonate and clastic facies of the Nambeet, Willara, Goldwyer, and Nita Formations. These are overlain in the central and southern Canning Basin by the Ordovician – Lower Silurian Carribuddy Group — an evaporitic and redbed succession, which is poorly constrained with respect to age and stratigraphic relationships. These successions unconformably overlie a variety of Precambrian crystalline and sedimentary rocks.

The Nambeet Formation is an interbedded quartz sandstone, dolomite, and shale unit of shallow-marine origin that progressively youngs from west to east, and was deposited in basement depressions (Kennard et al., 1994; Romine et al., 1994). The maximum intersected thickness of the Nambeet Formation is 327.5 m in Setaria 1. The unit has some reservoir and source potential. Total organic carbon (TOC) values of up to 1.7% have been recorded in the unit.

As transgression proceeded, a carbonate shelf developed in a shallow epeiric setting, as shown by near-shore carbonate ramp and shallow tidal-flat facies of the overlying Willara Formation (Kennard et al., 1994; Romine et al., 1994; King, 1998). This carbonate-dominated succession, with some shale and sandstone, conformably overlies the Nambeet Formation, and is commonly around 200–300 m thick across the area, with the thickest known section in Pictor 1 (427 m; Fig. 6). The informal 'Acacia sandstone member' within the Willara Formation has excellent reservoir properties (porosities of up to 19.3% and permeabilities of up to 385 mD), but this member has been intersected only in the southern part of the area (Fig. 7). The thickest known development of the member is in the southern part of the Barbwire Terrace around Dodonea 1 (121 m), Acacia 2 (101 m), and Setaria 1 (113 m).

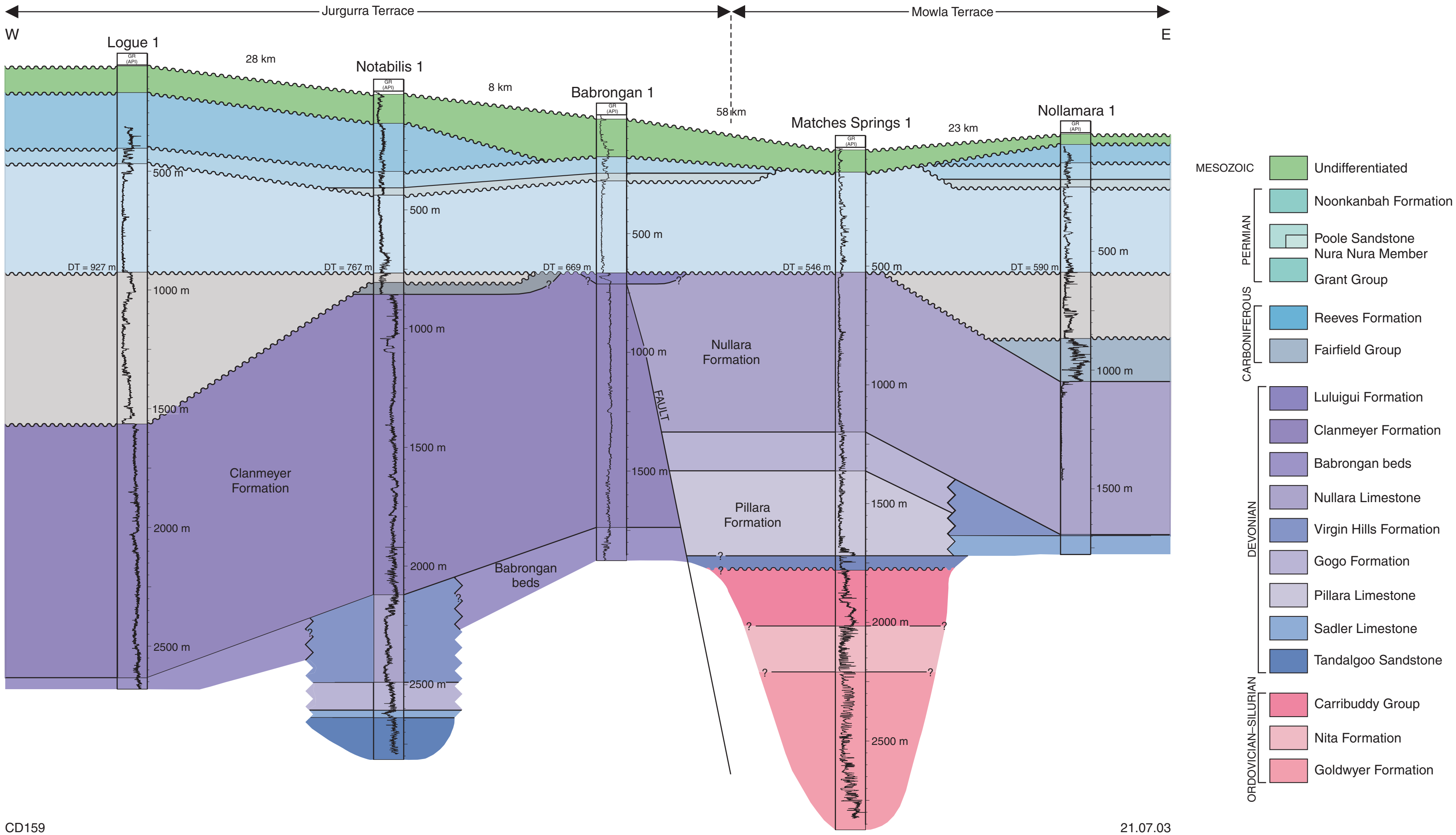


Figure 4. Simplified stratigraphic correlation across the Jurgurra and Mowla Terraces. The Grant Group units were not differentiated due to poorly sampled palynology. Datum level is the base of the Grant Group. Refer also to Plate 2

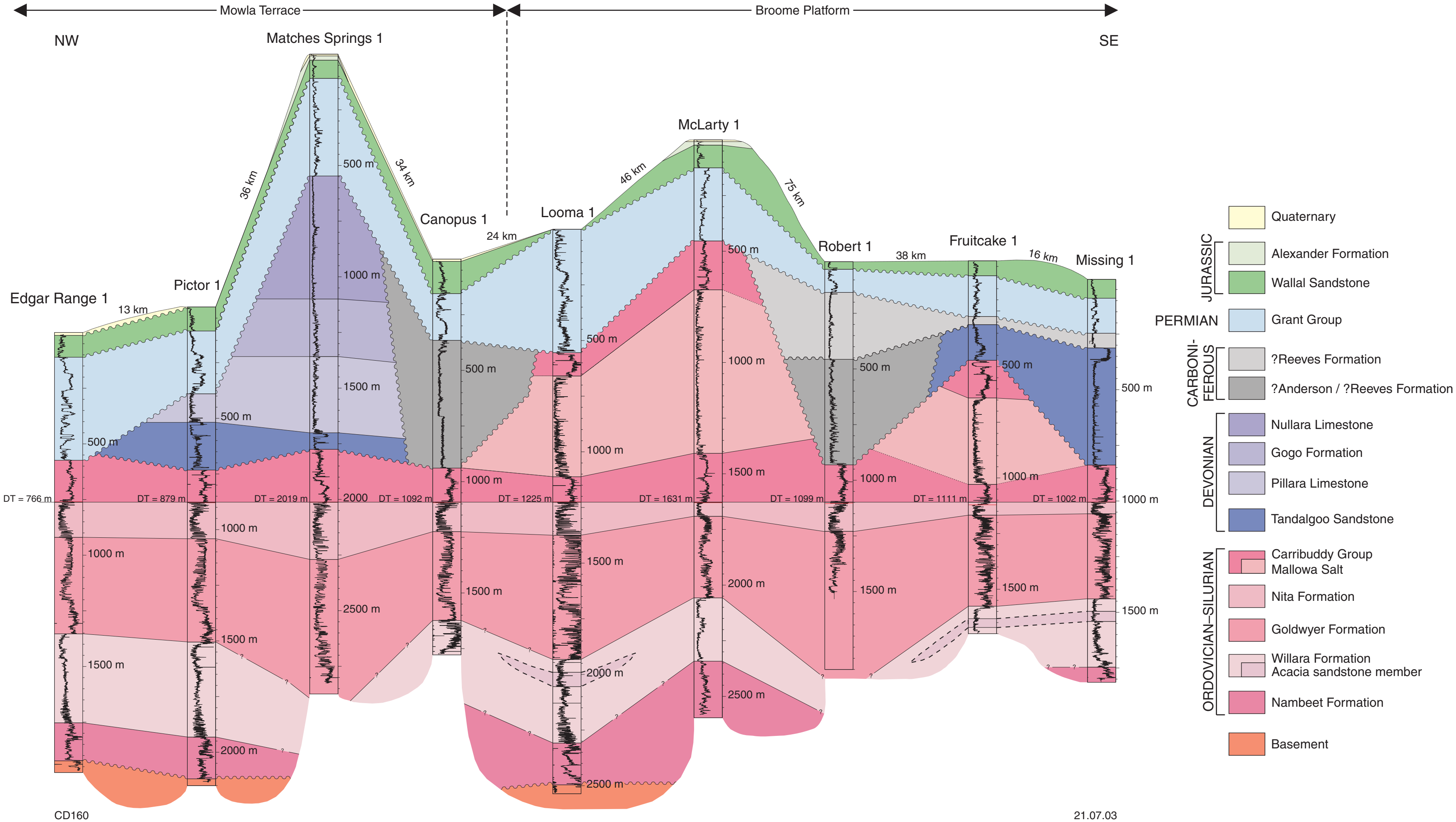


Figure 5. **Simplified stratigraphic correlation across the Mowla Terrace and Broome Platform. The individual packages within each of the Ordovician formations were not differentiated at this scale. Datum level is the top of the Nita Formation. Refer also to Plate 3**

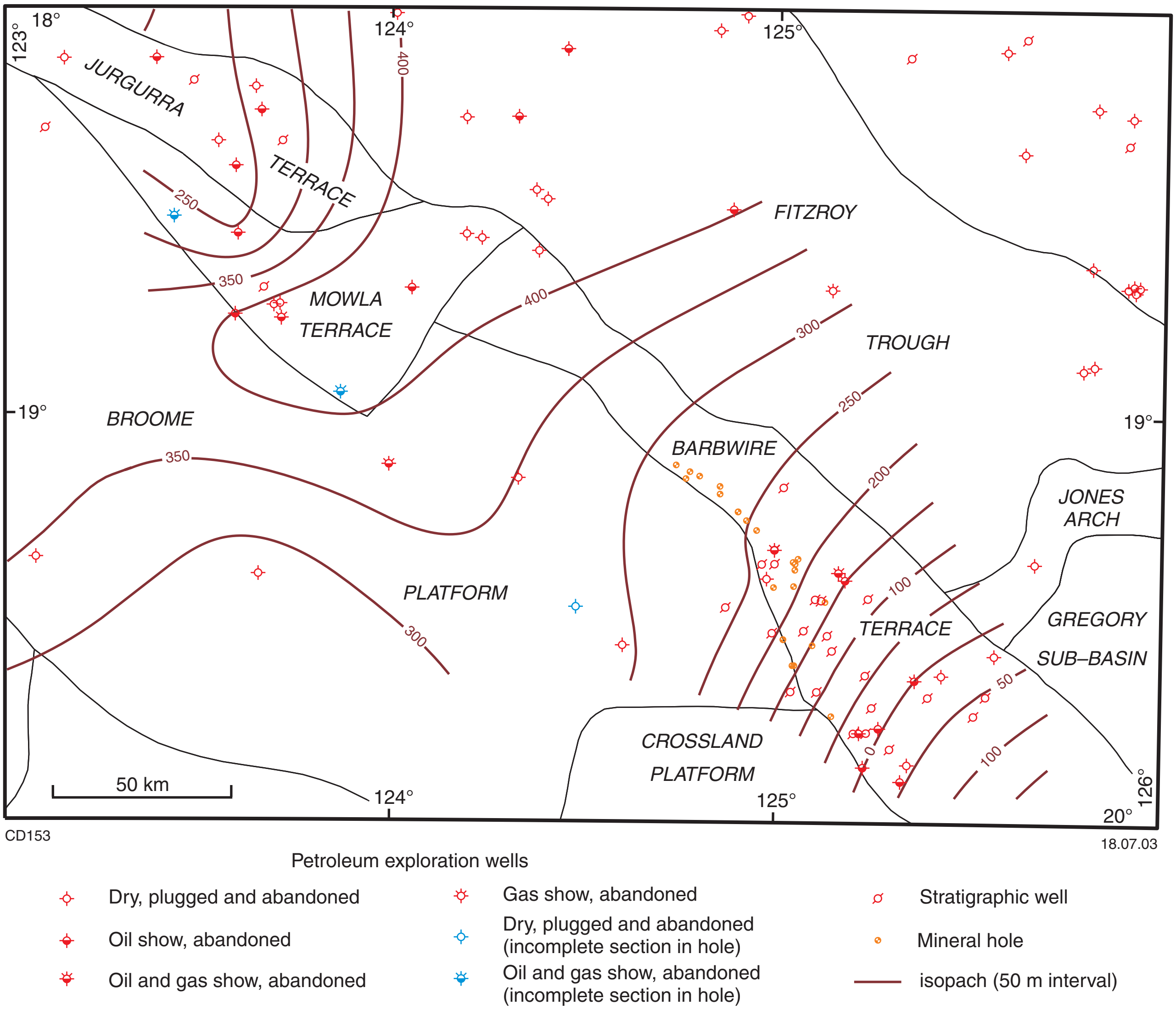


Figure 6. Isopachs of the Willara Formation

Local emergence at the end of the deposition of the Willara Formation resulted in karstic weathering, localized dolomitization, and porosity development on the Broome Platform, particularly along the Jurgurra, Mowla, and Barbwire Terraces. Elsewhere, the Willara Formation is conformably overlain by the Goldwyer Formation, which is predominantly shale and siltstone with some carbonaceous and pyritic intervals, and a middle limestone member in basinal areas, but is dominated by carbonate facies on the platforms and terraces. The Goldwyer Formation has a uniform thickness in the central part of the acreage release area (Fig. 5), but thins dramatically in a small area on the Barbwire Terrace around Mirbelia 2, where it is absent, and thickens northward towards the Fitzroy Trough (Fig. 8). Thinning of the Goldwyer Formation is probably erosional rather than depositional. Shales within this unit have excellent source-rock potential, with TOC values locally as high as 6.4%. Sandstone and carbonate facies within the Goldwyer Formation typically show low porosites and little, if any, permeability.

The Nita Formation is conformable on the Goldwyer Formation and consists of platform carbonate facies and interbedded shale. The unit is extensively dolomitized and represents a primary reservoir target. The Nita Formation has a uniform thickness on the Jurgurra and Mowla Terraces (Fig. 5), with a maximum drilled thickness of 215.6 m in Crystal Creek 1 (Fig. 9). On parts of the Barbwire Terrace, gentle Late Ordovician to Early Silurian uplift and erosion removed part the Nita Formation and most of the upper part of the Goldwyer Formation, particularly around Dodonea 1 (Romine et al., 1994). The Nambeet, Nita, and Willara Formations display fairly uniform thicknesses across the acreage release area (Fig. 5).

The Carribuddy Group conformably overlies the Nita Formation in most wells, and is an evaporitic, fine-grained redbed, clastic, and carbonate unit with rare organic-rich, calcareous mudstones (previously referred to as coal intervals by Kennard et al., 1994 and Romine et al., 1994). The late Llanvirnian to Silurian age of the Carribuddy

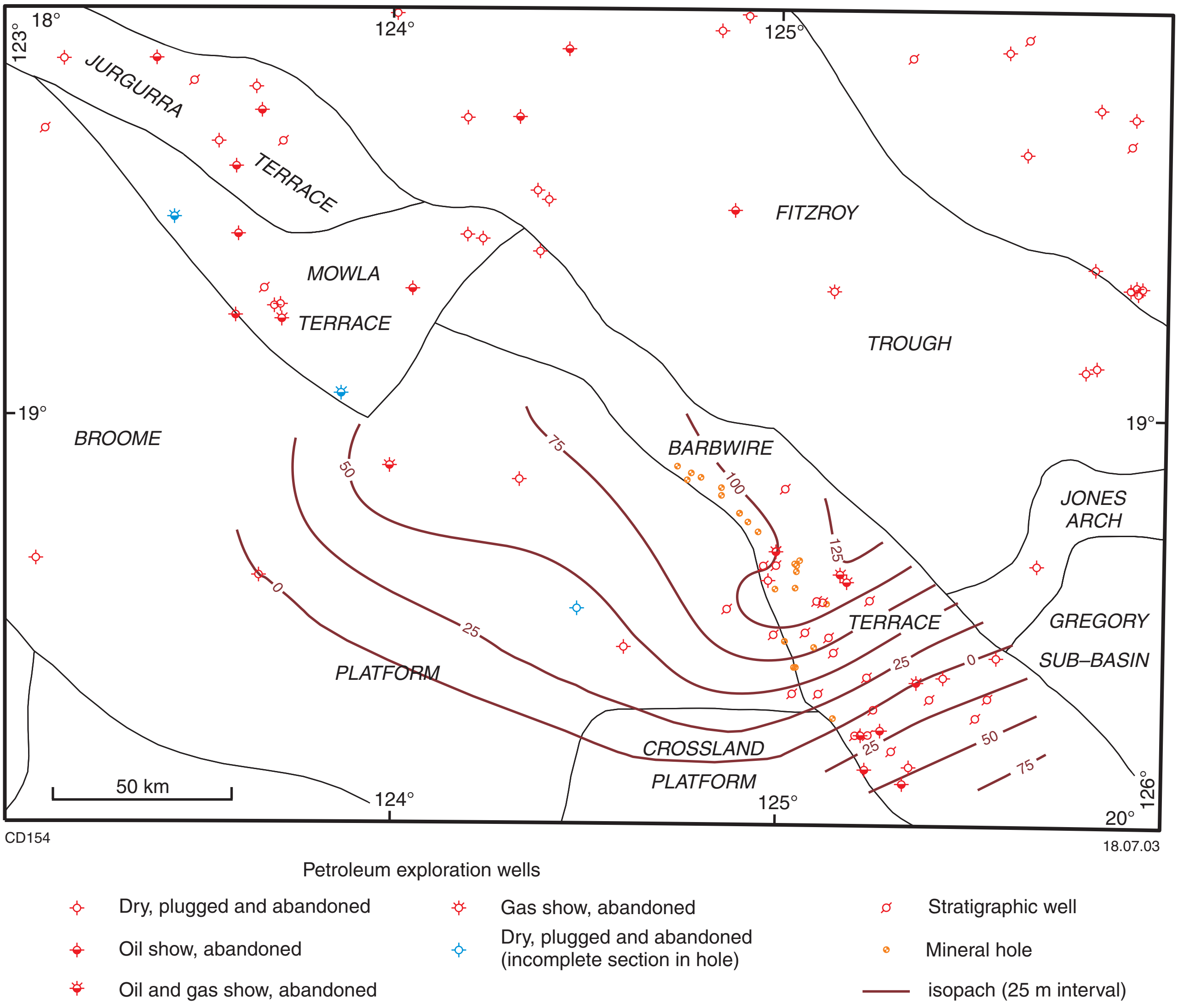


Figure 7. Isopachs of the 'Acacia sandstone member', Willara Formation

Group is based on sparse palynological and conodont evidence (Kennard et al., 1994; Nicoll et al., 1994; Jones et al., 1998). The group contains five formations: in ascending order, the Bongabinni Formation (predominantly claystone), Minjoo Salt (halite and claystone) and the laterally equivalent Mount Troy Formation (dolomite, shale, and siltstone), Nibil Formation (claystone, dolomite, and siltstone, with rare sandstone beds), Mallowa Salt (massive halite), and Sahara Formation (dolomite, siltstone, and rare sandstone beds). To date, only six petroleum exploration wells have penetrated a complete section of the group in the basin: Barbwire 1, Contention Heights 1, Frankenstein 1, Kidson 1, Matches Springs 1, and Wilson Cliffs 1. In all other wells that have intersected the group, the upper part has been eroded. The thickest known section in the study area is 1179 m, with 740 m of Mallowa Salt, in McLarty 1 (Fig. 5). The thickness of the group varies with the thickness of salt, but regionally it thins towards the north and east (Fig. 10) and is thickest in the southwestern area (Plate 3, Fig. 5). There is a reasonably thick section of salt to the north in Frome Rocks 1 (533 m) but this is due to salt movement. Within the acreage release area, the Mallowa Salt has been recorded from wells on the Broome Platform and Mowla Terrace. Thick accumulations of salt are present in the Kidson and Willara Sub-basins (Romine et al., 1994), Broome Platform, and Jurgurra Terrace.

Devonian – Lower Carboniferous

Regional regression and climate change during the Early Devonian resulted in a change from evaporitic environments to the deposition of continental and shallow-marine sand and minor fine-grained clastic sediments (Tandalgoo Sandstone) in the southern part of the Canning Basin. This lithologically homogeneous unit unconformably overlies the Carribuddy Group, and is a

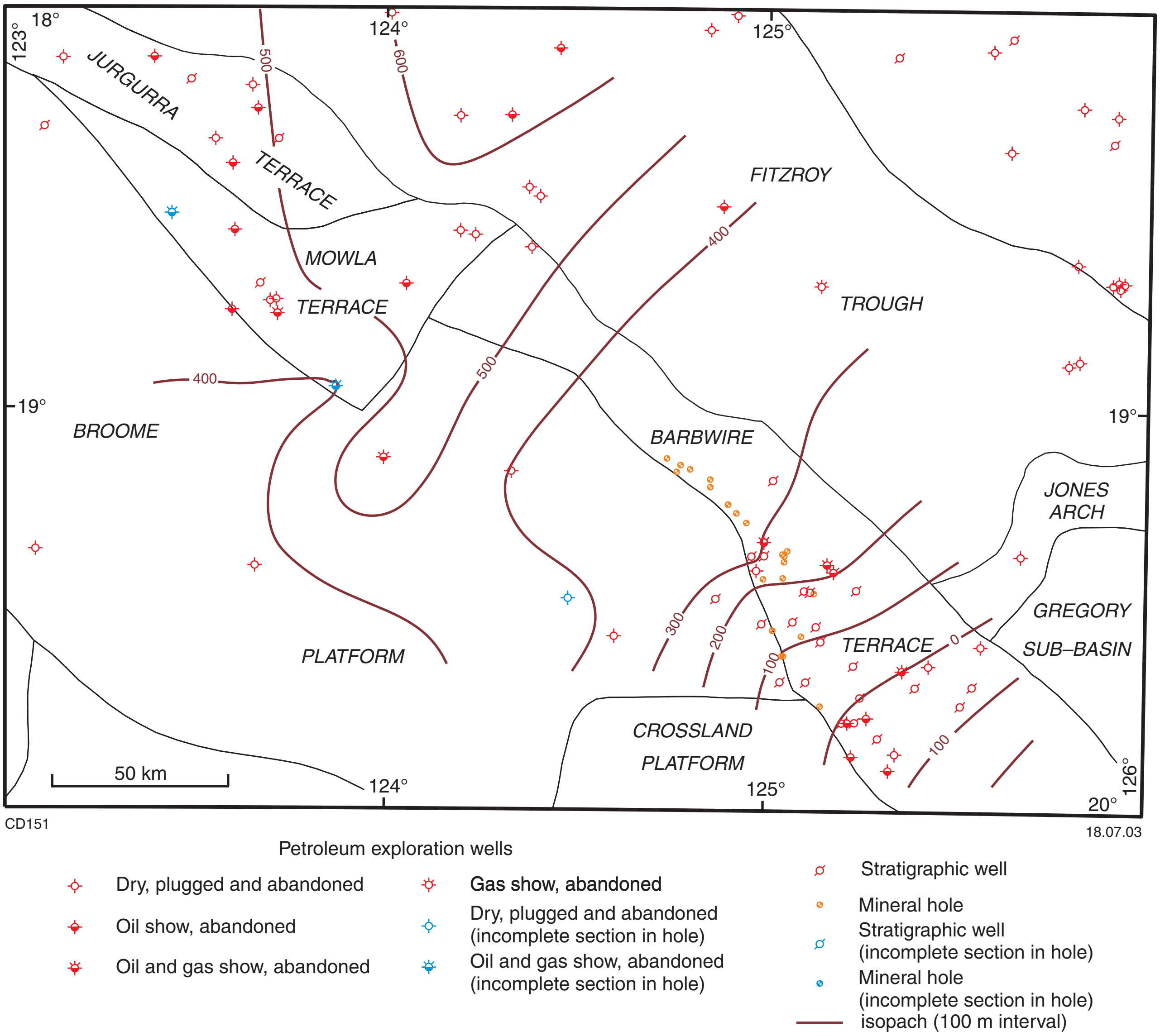


Figure 8. Isopachs of the Goldwyer Formation

good potential reservoir. The unit has been eroded over much of the Broome Platform and is locally absent in some areas. The Tandalgoo Sandstone thins from 229.3 m in Capparis 1 in the east (Fig. 11), to 31.6 m in Vela 1 to the west. In the central Canning Basin, the Worral Formation is a marginal-marine, lateral equivalent to the Tandalgoo Sandstone, and has been intersected only in the eastern part of the Broome Platform (Fig. 5) and Barbwire Terrace. The Poulton Formation, deposited in marine to marginal-marine conditions, is another lateral equivalent of the Tandalgoo Sandstone, but is restricted to the northern part of the Canning Basin.

The Clanmeyer, Luluigui, and Mellinjerie Formations overlie the Tandalgoo Sandstone on the terraces and platforms. The Mellinjerie Formation consists of shallow-marine limestone, dolomite, and shale (Middleton, 1990). In the central Canning Basin, this unit has only been intersected on the Barbwire Terrace, with the thickest known section in Pratia 1 (164 m), and contains good potential source rock with TOC values of up to 4%. The Clanmeyer Formation is a predominantly siltstone and shale unit with the thickest known section in Notabilis 1 (1265 m; Fig. 4). In the study area, the formation is organically lean in the four wells that have intersected it on the Jurgurra Terrace (Babrongan 1, Frome Rocks 2, Logue 1, and Notabilis 1), and the one on the eastern edge of the Barbwire Terrace (Mangaloo 1). This unit has not been intersected in any wells south of Babrongan 1, where it is cut off by a fault that intersects Babrongan 1 (Fig. 4), possibly due to later uplift and erosion in the Mowla Terrace. The transgressive Clanmeyer Formation is overlain by the regressive Luluigui Formation, which consists of siltstone, shale, limestone, and some sandstone (Middleton, 1990). Within the acreage release area, the Luluigui Formation has only been intersected in three wells on the Jurgurra Terrace (Babrongan 1, 44 m; Doran 1, 22 m; and Frome Rocks 2, 879 m).

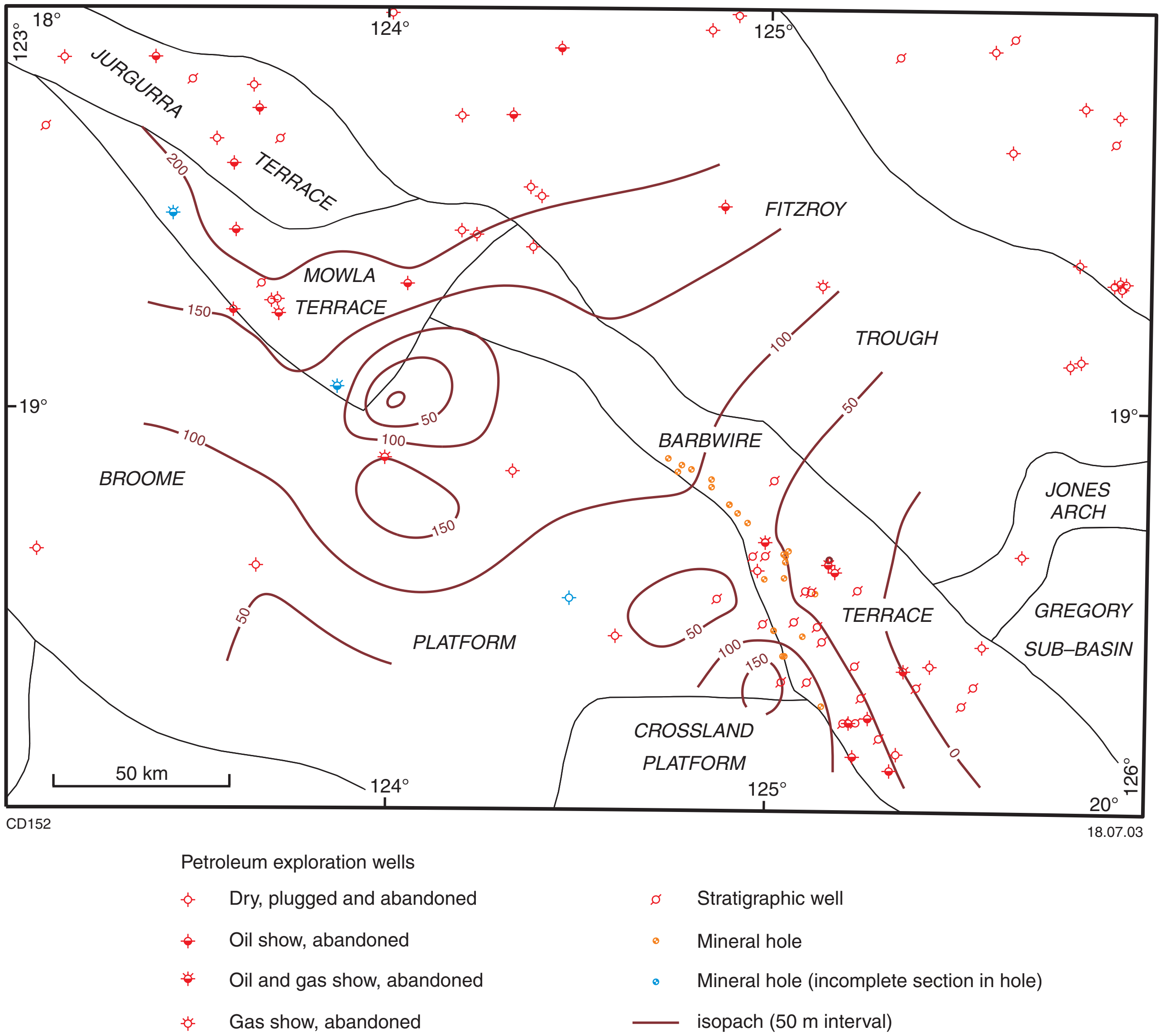


Figure 9. Isopachs of the Nita Formation

Givetian–Famennian reef complexes and associated siliciclastic conglomerates unconformably overlie the Tandalgoo Sandstone and its lateral equivalents in the central and northern part of the Canning Basin. In the central Canning Basin, the reef complexes are thickest on the Barbwire Terrace (up to 1898 m), with a thinner section on the Mowla and Jurgurra Terraces (typically between 130 and 600 m). An example of a reef mound, comprising the Nullara and Pillara Limestones, is located in the Matches Springs 1 area (Figs 4 and 5). This part of the section contains good potential seals and reservoirs, but source potential is commonly low (average TOC values of 0.17%), with some exceptions (see **Source rock and maturity**).

The Fairfield Group is a shallow-marine carbonate- and shale-dominated succession, containing good potential source rocks, seals, and reservoirs, which conformably overlies the Devonian reefal carbonate section and spans the Devonian–Carboniferous boundary. The group is absent over the southwestern part of the study area, but thickens towards the Fitzroy Trough in the northeast (1761 m in Fitzroy River 1). This unit is overlain by fluvial–deltaic sandstone and siltstone of the Anderson Formation.

Upper Carboniferous – Permian

Uplift in the mid-Carboniferous resulted in a basin-wide unconformity. The overlying Upper Carboniferous – Permian succession consists of, in ascending order, the Reeves Formation, glacigene Grant Group, Poole Sandstone, Noonkanbah Formation, and Liveringa Group. All but the Reeves Formation are exposed along the northern margin of the Fitzroy Trough and on the Lennard Shelf.

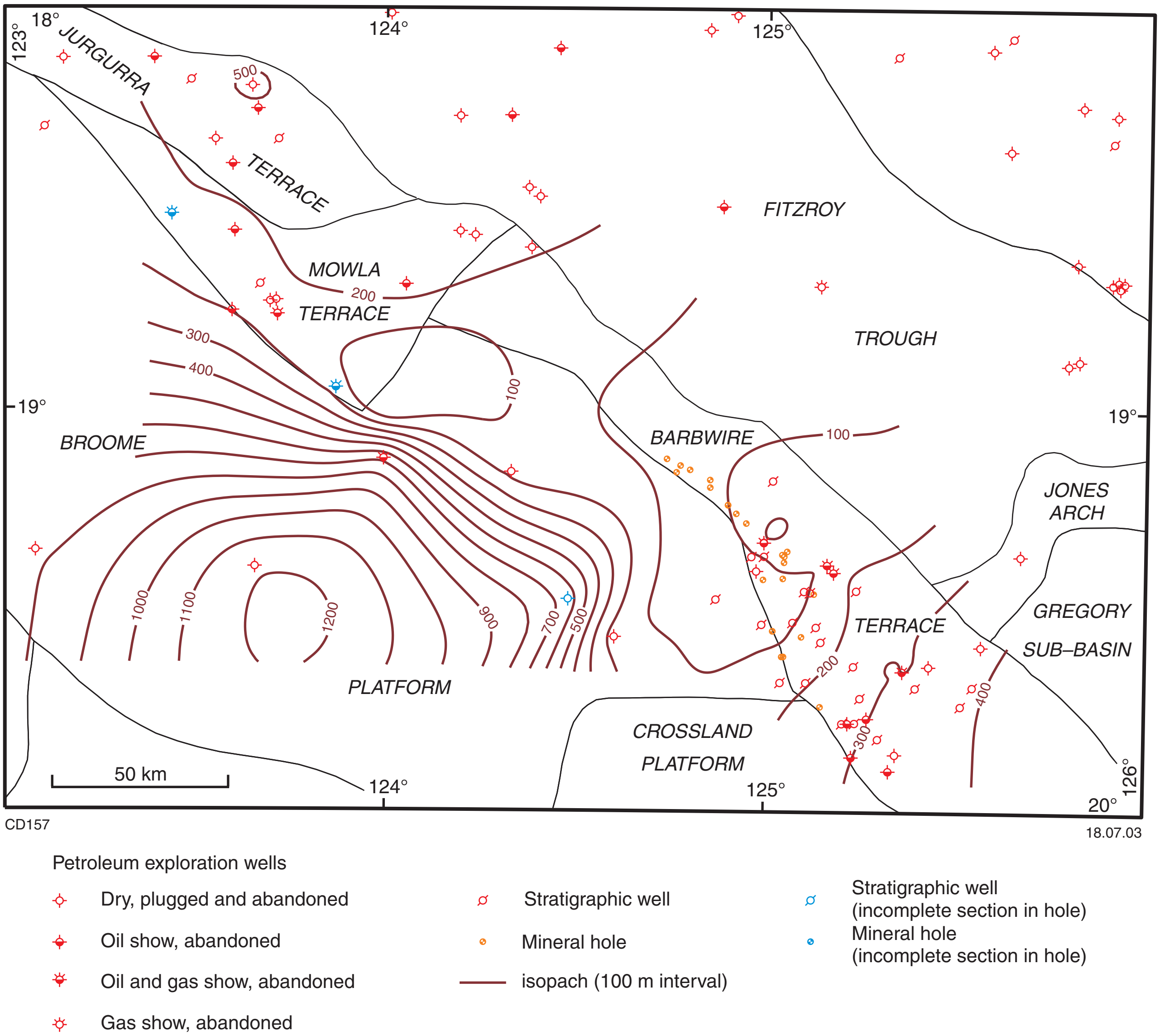


Figure 10. Isopachs of the Carribuddy Group

The Reeves Formation (Apak and Backhouse, 1998; 1999; Eyles et al., 2001), previously referred to as the 'lower Grant Group', consists of sandstone interbedded with shale and siltstone deposited in a fluvial–marine setting on a mid-Carboniferous unconformity. The unit is largely restricted to the central part of the Fitzroy Trough and Gregory Sub-basin, with thin intersections on the Crossland and Broome Platforms, and Barbwire, Mowla, and Jurgurra Terraces (Fig. 12; Apak and Backhouse, 1999). In the acreage release area, the Reeves Formation has been intersected in Canopus 1, Doran 1, Grant Range 1, Logue 1, Nollamara 1, and Notabilis 1 based on palynology from the well completion reports (Purcell 1984b, 1985, 1987; Figs 4 and 5; Plates 2 and 3). In Canopus 1, for example, the interval (previously ascribed to the Tandalgoo Sandstone) contains palynomorphs of the *Pseudoreticulatispora confluens* Zone to *Spelaeotriletes ybertii* Assemblage (Plate 2) indicating a Namurian to early Asselian age. The formation is also interpreted in Fruitcake 1, Missing 1, Nerrima 1 (AFO), and Robert 1 based on the gamma ray response (Fig. 5). The thickest section of the Reeves Formation within the study area is in the Fitzroy Trough (1805 m in Grant Range 1), but it thins rapidly to the southwest on the Broome Platform and to the southeast on the Barbwire Terrace (51 m in Ficus 1; Fig. 12).

Continental-scale glaciation in the Late Carboniferous influenced deposition of the Grant Group, which is a thick succession of fluvial, marine, deltaic, and clastic deposits dominated by quartzose sandstone. Apak and Backhouse (1999) noted an unconformable contact between the Reeves Formation and overlying Grant Group in some areas. The Grant Group is a known reservoir on the Lennard Shelf (Boundary, Sundown, and West Terrace oilfields), but its potential elsewhere is poorly known. Nine wells (Fig. 3; Table 1) have oil shows within the Grant Group in the acreage release area. Sandstones within the

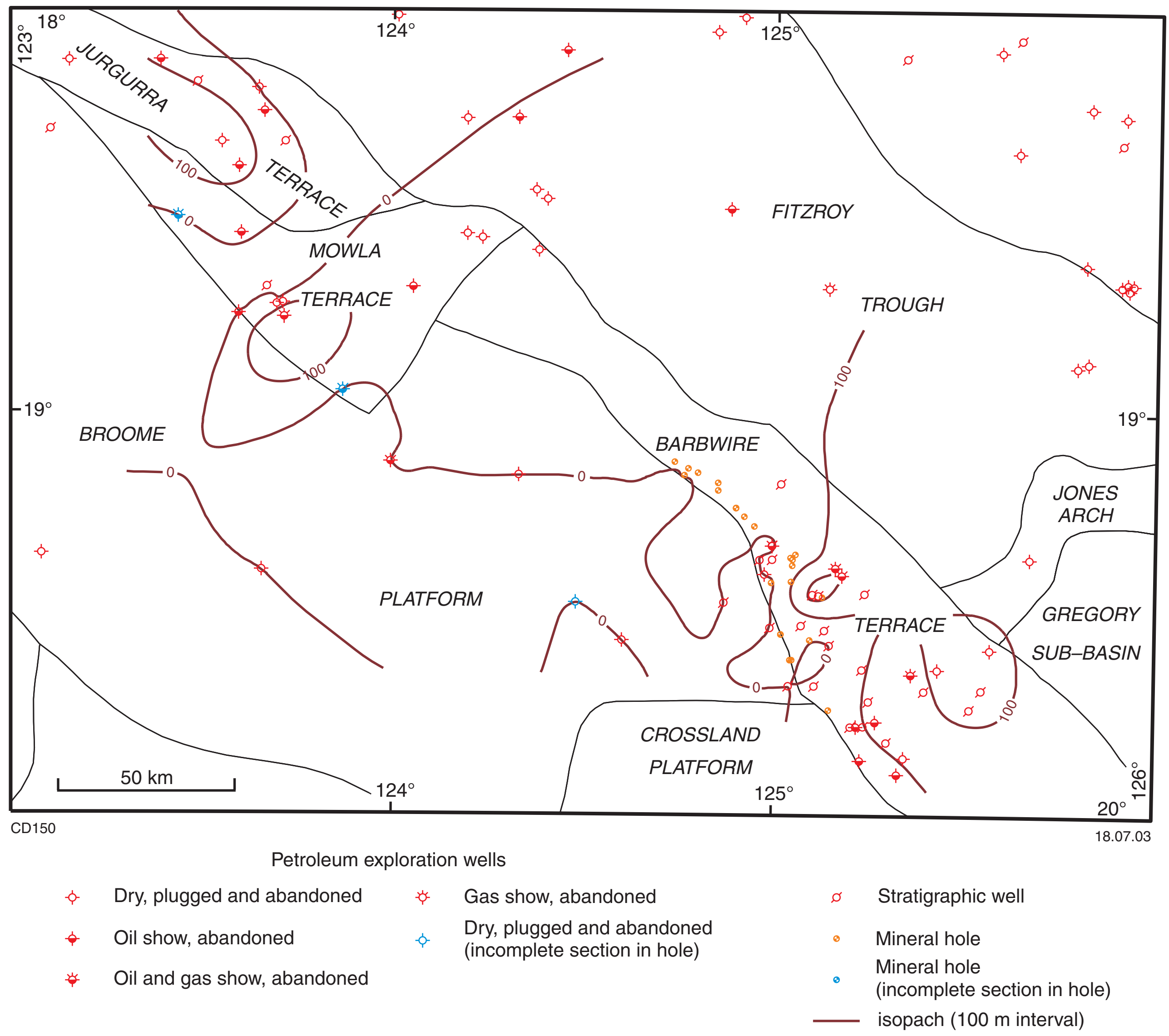


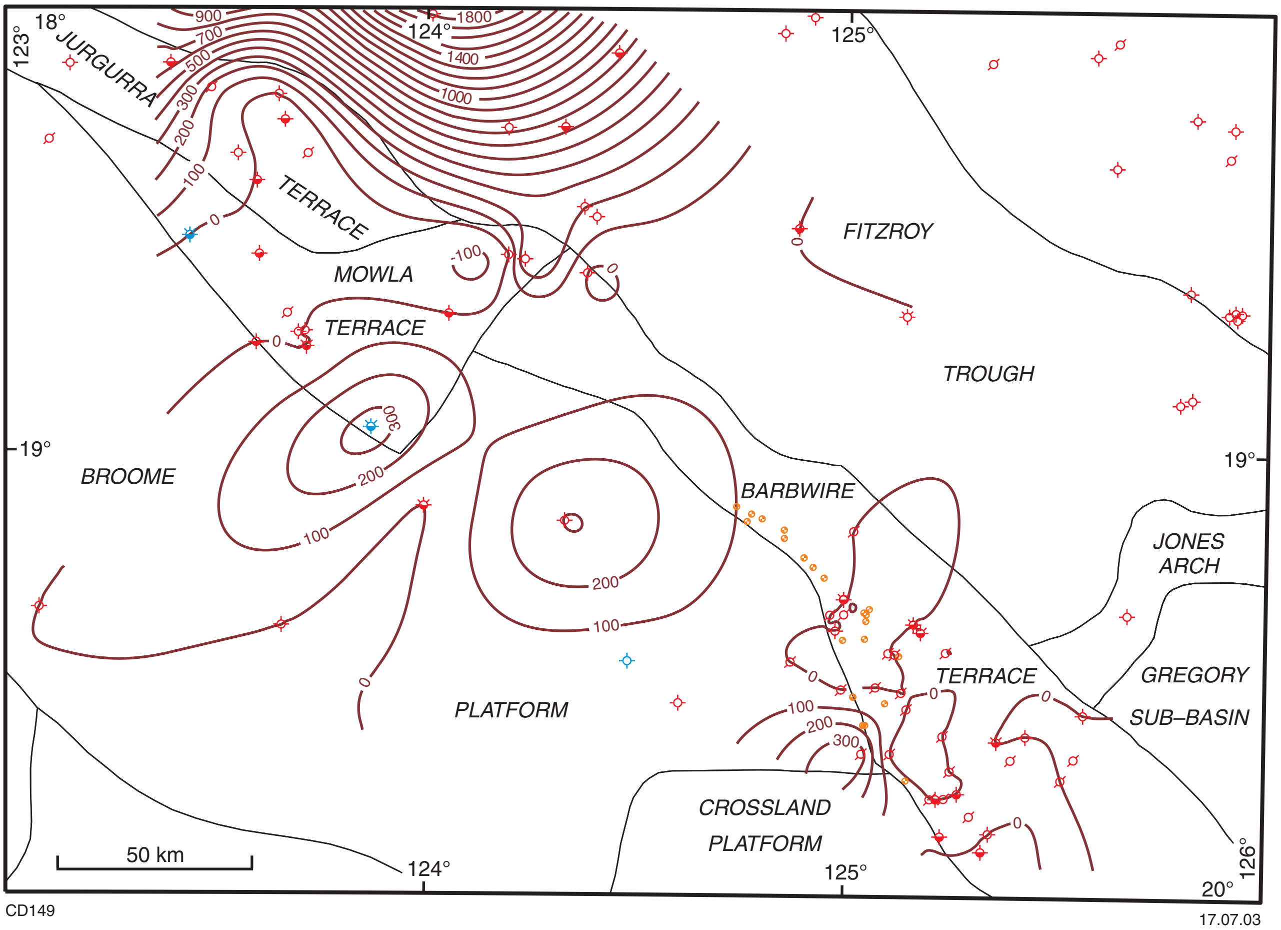
Figure 11. Isopachs of the Tandalgoo Sandstone

group are the most consistently porous and permeable potential reservoirs in the area. The group is moderately uniform in thickness (average of 200–300 m) across the central part of the area (Broome and Crossland Platforms, and Barbwire, Jurgurra, and Mowla Terraces; Figs 4 and 5), but thickens dramatically to the north in the Fitzroy Trough (Fig. 13) reaching 1578.9 m in Nerrima 1 (AFO), and to the south into the Kidson Sub-basin. A tillite unit at the base of the Grant Group has been recorded in some wells (Plate 3), but cannot be correlated across the entire area. Shale beds within the group are commonly organically lean and source potential is poor, but some units have recorded TOC values of up to 1.45%

The shallow-marine to coastal Poole Sandstone marks the termination of glacial conditions across the basin (Kennard et al., 1994). Thicknesses across the Mowla and Jurgurra Terraces are in the order of 90–120 m (Fig. 4), and the thickest known section is in Nerrima 1 (FKO) within the Fitzroy Trough (398 m). The siltstone-dominated Nura Nura Member of the Poole Sandstone is a potential seal, with the thickest known section in Petaluma 1 (121.7 m). The member thins rapidly to the west and south (Fig. 14). Siltstone of the overlying Noonkanbah Formation was deposited under shallow-marine, restricted-circulation conditions, and is thicker on the Jurgurra Terrace than on the Mowla Terrace (Fig. 4). The youngest Permian rocks, the Liveringa Group, are dominated by sandstone of shallow-marine to fluvial origin. The units within this group are typically at too shallow a depth, if not outcropping, to be relevant to petroleum prospectivity.

Jurassic – Lower Cretaceous

A period of major uplift and faulting in the Late Triassic and Early Jurassic separates the Jurassic succession from older rocks. The Blina Shale and Erskine Sandstone constitute the only Triassic units in the central and southern Canning Basin; however, they are not present in



Petroleum exploration wells

- Dry, plugged and abandoned
- Oil show, abandoned
- Oil and gas show, abandoned
- Gas show, abandoned
- Stratigraphic well
- Mineral hole
- isopach (100 m interval)

Figure 12. Isopachs of the Reeves Formation

the study area. The oldest Jurassic rocks, the Wallal Sandstone and the laterally equivalent Barbwire Sandstone, are dominated by sandstone and minor siltstone of shallow-marine to fluvial origin, and rest unconformably on the Grant Group or Noonkanbah Formation, depending on the degree of erosion in the Late Triassic and Early Jurassic. The Alexander Formation is a mixed sandstone and siltstone unit of shallow-marine origin and is conformable on the Wallal Sandstone. The Jarlemai Siltstone is gradational from the Alexander Formation and is a predominantly siltstone unit, with minor sandstone intervals. Apart from the Jarlemai Siltstone, most of the Jurassic units have excellent reservoir potential, but lack overlying or intraformational sealing units in the area other than the laterally discontinuous Jarlemai Siltstone. As with the later Permian units, these units are generally at too shallow a depth, if not outcropping, to be relevant to petroleum prospectivity. Thin but extensive lateritic, alluvial, and eolian sediments of Cainozoic age cover these Jurassic units.

Petroleum exploration history

Almost 250 wells have been drilled in the onshore Canning Basin, most of them between 1980 and 1985. Although several wells had significant shows (Table 1), there are only six commercial oilfields, all on the Lennard Shelf (Table 2). A detailed account of the petroleum exploration history in the Canning Basin is given in Purcell (1984a).

The first exploration in the basin by Freney Kimberley Oil Company, which drilled several wells from 1922 to 1955, appears to have been motivated by oil shows reported in a waterbore near Prices Creek in 1919. The next significant activity was by the Bureau of Mineral Resources (BMR, now Geoscience Australia), who conducted gravity and seismic surveys in 1953 to delineate large faults and structures. West Australian Petroleum Pty Ltd (WAPET), in conjunction with BMR, explored a

Table 1. Significant hydrocarbon shows within the acreage release areas and surrounds, onshore Canning Basin

Well name	*Year*	*Reservoir*	*Age of reservoir*	*Tectonic unit*	*Trap*	*Hydrocarbon type*	*Comments*
Acacia 1	1981	Nita Goldwyer	Ordovician	Barbwire Terrace	Carbonate mound	Oil	Live oil (bleeding from core), fluorescence, residual oil, cut, bitumen, and minor gas
Aristida 1/1A	1983	Grant Nullara	Permian Upper Devonian	Barbwire Terrace	Anticline	Oil	Asphalt, live oil, fluorescence, cut, and residual oil
Babrongan 1	1962	Babrongan Grant	Upper Devonian Permian	Jurgurra Terrace	Anticline	Oil Minor gas	Bitumen
Canopus 1	1982	Nita Goldwyer Willara Carribuddy	Ordovician Silurian/Ordovician	Mowla Terrace	Pinnacle reef	Oil Minor gas	Live oil and fluorescence
Crystal Creek 1	1988	Nita	Ordovician	Mowla Terrace	Faulted anticline	Oil	Bitumen and oil stains
Dampiera 1/1A	1982	Grant Nullara	Permian Upper Devonian	Barbwire Terrace	Carbonate mound	Oil	Fluorescence and residual oil
Dodonea 1	1985	Goldwyer Nambeet	Ordovician	Barbwire Terrace	Faulted anticline	Oil Gas	Produced 10 L of 18.5° API oil and 85 m^3/day gas
Dodonea 2	1985	Nita Goldwyer	Ordovician	Barbwire Terrace	Faulted anticline	Oil	Heavy live oil (bleeding from core), fluorescence, and cut
Edgar Range 1	1968	Nita	Ordovician	Mowla Terrace	Faulted anticline	Oil	Trace oil, and fluorescence
Eremophila 1	1982	basal Grant Nullara/Pillara	Permian Upper Devonian	Barbwire Terrace	Carbonate mound	Oil	Fluorescence, oil stains, heavy oil, and residual oil
Eremophila 2	1983	basal Permian (Grant)	Permian	Barbwire Terrace	Carbonate mound	Oil	Fluorescence and live oil
Fitzroy River 1	1980	Fairfield (Laurel) Anderson	Devonian–Carboniferous Lower Carboniferous	Fitzroy Trough	Anticline (reefal build-up)	Oil + minor gas	
Frome Rocks 2	1959	Luluigui	Upper Devonian	Jurgurra Terrace	Anticline	Oil	Fluorescence and oil stains
Goodenia 1	1983	basal Grant Fairfield	Permian Devonian–Carboniferous	Barbwire Terrace	Stratigraphic	Oil	Oil stains, asphalt, globules of heavy oil, and fluorescence
Kunzea 1	1984	Nita Goldwyer	Ordovician	Barbwire Terrace	Stratigraphic	Oil	Fluorescence, cut, residual oil, and oil stains, some odour

Table 1 (continued)

Well name	*Year*	*Reservoir*	*Age of reservoir*	*Tectonic unit*	*Trap*	*Hydrocarbon type*	*Comments*
Looma 1	1996	Nita Willara (Acacia) Nambeet	Ordovician	Broome Platform	Anticline	Oil + gas Oil Gas + oil	Live oil (bleeding from core)
Lovell's Pocket 1	1990	Nita Willara	Ordovician	Mowla Terrace	Faulted anticline	Oil + gas Oil	Oil stains and fluorescence
Matches Springs 1	1969	basal Carribuddy	Ordovician	Mowla Terrace	Anticline	Oil	Fluorescence
Mirbelia 1	1985	Mellinjerie	Upper Devonian	Barbwire Terrace	Faulted anticline	Oil	Live oil and gas (bleeding from core), fluorescence, oil stains, asphalt, bitumen and strong odour
Mount Wynne 1	1923	Grant	Permian	Fitzroy Trough	Anticline	Oil	Asphalt and bitumen
Mount Wynne 3	1925	Grant	Permian	Fitzroy Trough	Anticline	Oil	Globular oil and bitumen
Nerrima 1 (AFO)	1955	Grant	Permian	Fitzroy Trough	Anticline	Minor oil	
Petaluma 1	1987	Liveringa Noonkanbah Poole	Permian	Fitzroy Trough	Faulted anticline	Minor oil	Oil stains and background gas
Pictor 1	1984	Nita	Ordovician	Mowla Terrace	Faulted anticline	Oil + gas	Produced 3.8 kL/day oil and 62 300 m^3/day gas
Pictor 2	1990	Nita	Ordovician	Mowla Terrace	Faulted anticline	Oil + gas	Produced 1.67 kL/day oil and 73 901 m^3/day gas
Santalum 1A	1983	Goldwyer	Ordovician	Barbwire Terrace	Anticline	Oil	Fluorescence, cut, residual oil, and oil stains, some odour
Solanum 1	1984	Nita Goldwyer	Ordovician	Barbwire Terrace	Faulted anticline	Oil	Fluorescence, cut, residual oil, and oil stains, some odour

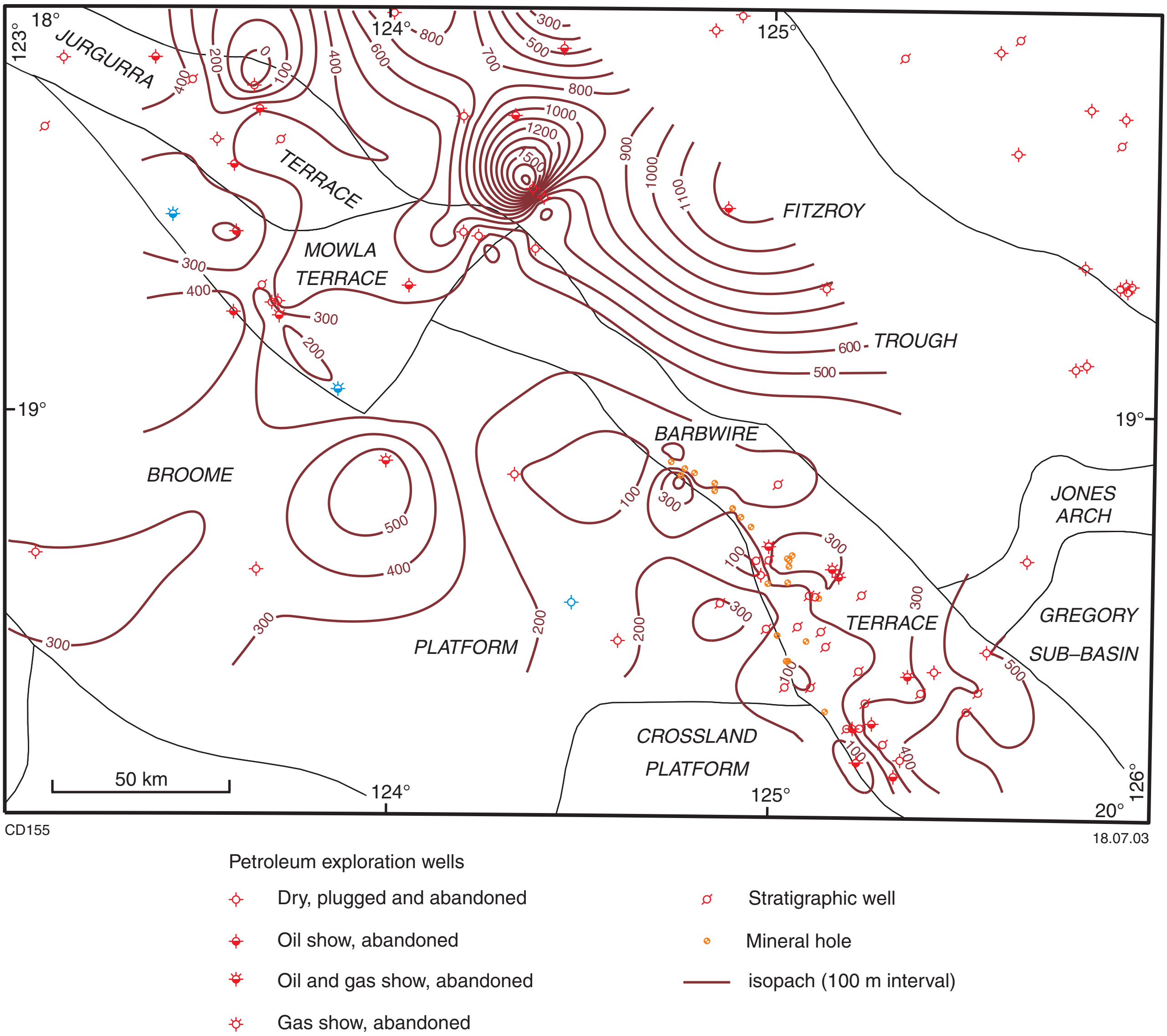


Figure 13. Isopachs of the Grant Group

major portion of the basin through various reconnaissance geophysical surveys, field mapping, and drilling from 1955 to 1975. Prior to 1955, all wells were drilled on major surface anticlines in the Fitzroy Trough, but these activities failed to discover commercial hydrocarbons. In the 1960s, the Geological Survey of Western Australia (GSWA), with BMR, commenced detailed studies of the Devonian reef complexes on the Lennard Shelf (Playford and Lowry, 1966; Playford et al., 1975; Playford, 1980).

Exploration in the Canning Basin from 1965 onward by various companies included seismic, gravity, magnetic, and geochemical surveys, aerial interpretation, detailed and reconnaissance field mapping, and drilling. A significant amount of exploration was carried out in the northern and central parts of the basin up to the mid-1980s, with wells drilled on the Lennard Shelf, Broome Platform, Barbwire and Jurgurra Terraces, and Fitzroy Trough. To date, the Lennard Shelf has been the most prospective area in terms of economic accumulations.

The first oil recovered in the basin was from Meda 1 on the Lennard Shelf in 1958 from the Carboniferous Laurel Formation (Fairfield Group). The first commercial oil discovery (Blina 1) was made in 1981, by Home Energy Company Ltd, in the Yellow Drum Formation and Nullara Limestone, also on the Lennard Shelf. In following years, the company made further commercial oil discoveries on the Lennard Shelf: Sundown in 1982 (from clastic rocks of the Grant Group and Anderson Formation); West Kora in 1984; West Terrace in 1985; and Lloyd in 1987. The Lloyd and West Kora oilfields produced from the Anderson Formation, and the West Terrace oilfield produces from the Betty Formation (Grant Group). The latest commercial oil discovery in the basin, Boundary, made by Petroleum Securities Energy Ltd in 1990, produces from the Betty Formation (Grant Group).

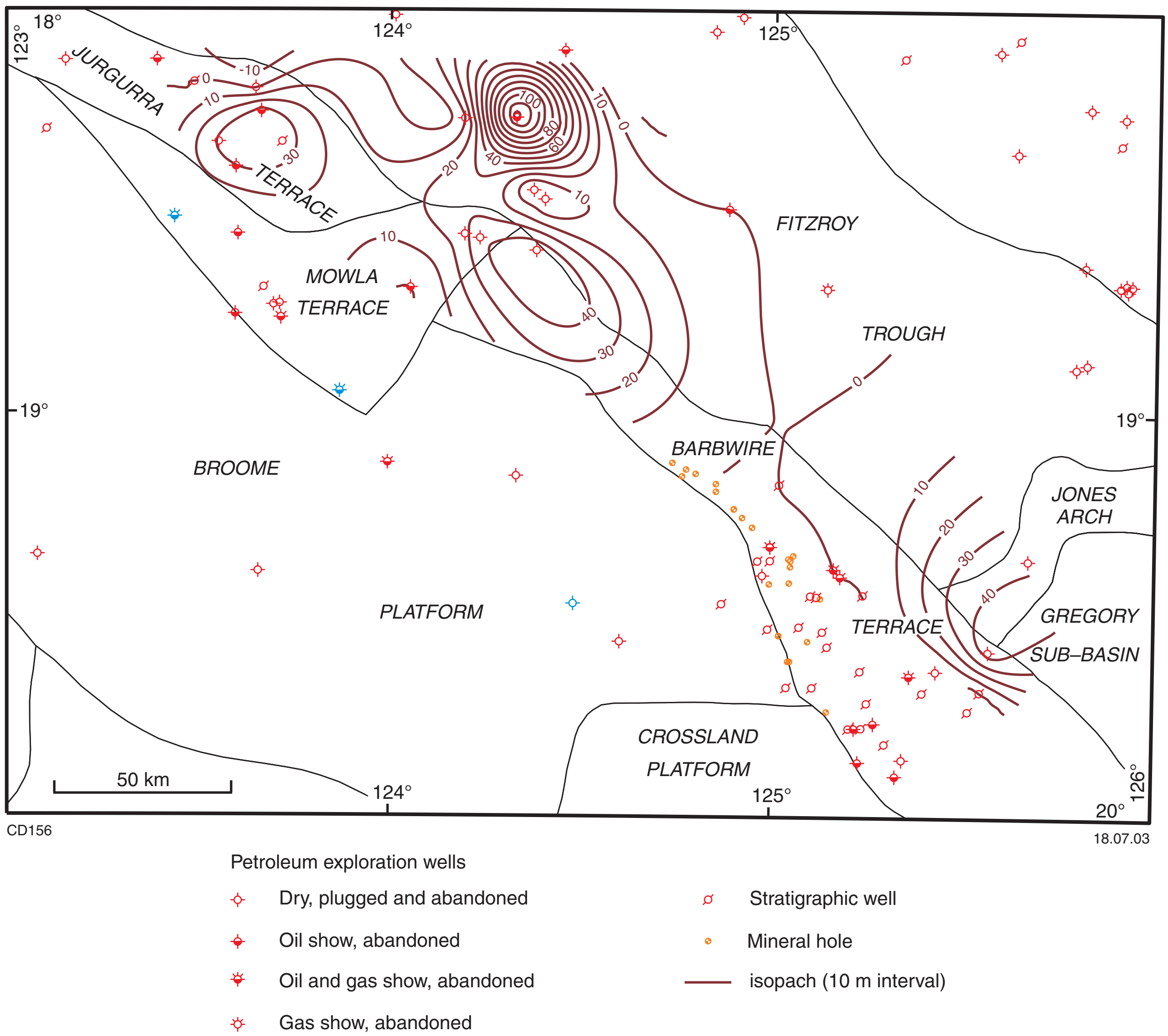


Figure 14. Isopachs of the Nura Nura Member

Exploration activity in the central and southern Canning Basin increased in the 1980s, with numerous wells drilled by Western Mining Corporation Ltd (WMC), BHP Petroleum, and Bridge Oil Ltd. Many of these were shallow stratigraphic wells, with total depths less than 1000 m, which targeted features such as topographic, gravity, or magnetic anomalies, rather than seismically defined structures (Appendix 1). The vast majority of these wells did not penetrate deep enough to test Ordovician reservoirs, which have the best potential in the area.

Within the acreage release areas and its surrounds, there are 67 petroleum-related wells (36 exploration, 29 stratigraphic, 2 extension; Plate 1, Appendix 2), over 28 000 line-kms of seismic data (Fig. 15), and several mineral holes. Summaries of selected wells are given in Appendix 1. Significant hydrocarbon shows were noted from several wells (Table 1).

Petroleum prospectivity

Four petroleum systems have been defined in the onshore Canning Basin: Larapintine 2, Larapintine 3, Larapintine 4, and Gondwanan 1 (Bradshaw et al., 1994; Kennard et al., 1994; Longley et al., 2001). The Larapintine systems are characterized by lower Palaeozoic marine facies deposited in tropical epicontinental areas, and the Gondwanan system is dominated by Permian terrestrial facies (Longley et al., 2001). The stratigraphic distribution of source rocks, reservoirs, and seals is summarized in Table 3 and Figure 3.

Six commercial fields have been discovered within the western part of the Lennard Shelf (Fig. 2; Table 2), of which the Blina oilfield is the largest, with a cumulative production of 0.280 GL (1.76 MMbbl).

Table 2. Oilfields in the onshore Canning Basin

Field name	*Year*	*Reservoir*	*Source*	*Seal*	*API gravity (°API)*	*Cumulative production (GL)*
Blina	1981	Nullara Limestone Yellow Drum Formation	Gogo Formation	Gumhole Formation Intraformational shales in Laurel Formation	37.7 36.7	0.280
Boundary	1990	Grant Group	Laurel Formation	Intraformational shales	32.77	0.018
Lloyd	1987	Anderson Formation	Laurel Formation	Intraformational shales	40.4	0.029
Sundown	1982	Grant Group	Laurel Formation	Intraformational shales Nura Nura Member	38–40	0.062
West Kora	1984	Anderson Formation	Laurel Formation	Intraformational shales	46–49	0.0037
West Terrace	1985	Grant Group	Laurel Formation	Intraformational shales	32.8	0.029

Source rock and maturity

Geochemical data for 28 wells in the acreage release areas and surrounds are available. These wells are spread over the Fitzroy Trough, Jurgurra and Barbwire Terraces, Broome Platform, and Kidson Sub-basin. Of these wells, six contain source rocks in the Ordovician section and three in the Upper Devonian section, identified on the basis of Rock-Eval pyrolysis analyses in which S_2 is equal to or greater than 2.5 mg/g rock (Table 4). Anomalous potential-yield values (S_1+S_2), production index (PI), and T_{max} indicate that organic-rich samples from McLarty 1 are contaminated by oil products used during drilling (Fig. 16), so these data are excluded from Table 4.

The best oil-prone source rocks of the study area are within the Middle Ordovician Goldwyer Formation, with TOC up to 6.4%, S_2 up to 36.5 mg/g rock, and hydrogen indices (HI) up to 1178 (Table 4). The microbial-rich, argillaceous facies within the formation have been identified as the major source interval in the central and southern Canning Basin (Foster et al., 1986; Brown et al., 1994; Scott, 1994; Edwards et al., 1997; King, 1998).

The oil-prone source rock intervals in Acacia 1 (Fig. 17), Dodonea 1 (Fig. 18), Matches Springs 1 (Fig. 19), Santalum 1A (Fig. 20), and Solanum 1 (Fig. 21) are within the upper part of the Goldwyer Formation. The source rocks identified within the lower part of the Goldwyer Formation in Crystal Creek 1, Matches Springs 1, and Solanum 1 are gas-prone (Figs 22, 19, and 21 respectively). Other possible Ordovician source rocks are shale intervals within the Nambeet Formation, which have TOC values of up to 1.7% (BHP Petroleum Pty Ltd, 1986), and shale and siltstone intervals in the Willara Formation (Kennard et al., 1994).

Source-rock potential has also been noted in a microbial-rich bed within the Carribuddy Group on the Broome Platform from a mineral exploration hole (Taylor, 1992), and ascribed to the Bongabinni Formation by Kennard et al. (1994). This bed contained TOC values of up to 54.3%, S_2 values of up to 174.8 mg/g rock, and HI of up to 417. McCracken (1997) reported a number of similar horizons (up to 46% TOC values) in the lower part of the Bongabinni Formation along the Admiral Bay Fault Zone. These horizons are very thin and could be missed in uncored petroleum holes. Consequently, these source-rock intervals could be more widespread than initially thought and may extent in to the acreage release areas. McCracken (1994, 1997) believed that source rocks of the Bongabinni Formation, as well as the Goldwyer Formation, are presently in the oil window along the Admiral Bay Fault Zone. Based on geochemical fingerprinting, all the oils within this zone are sourced from these rocks (McCracken 1997; Edwards et al., 1995).

Upper Devonian source rocks within the Mellinjerie Formation in Dodonea 1 (Fig. 18), an unnamed carbonate unit in Eremophila 1 (Fig. 23), and the Boab Sandstone in Mirbelia 1 (Fig. 24) have TOC values of up to 4.18%, S_2 values of up to 5.8 mg/g rock, and HI of up to 303. The source-rock interval is oil-prone in Dodonea 1 (one sample), and gas-prone in Eremophila 1 and Mirbelia 1 (Table 4), but are leaner than the Ordovician section in the area. Other well-documented late Middle and Upper Devonian source rocks include the fore-reef and platform facies of the Pillara Limestone, and calcareous claystone with abundant carbonaceous material within the basinal Gogo Formation (Scott, 1994).

The Fairfield Group (Laurel Formation, TOC values of up to 4.64%, S_2 values of up to 20.3 mg/g rock, HI of up to 418; Kennard et al., 1994) contains effective source rocks on the Lennard Shelf, and probably has similar potential within the study area. Source rocks may also be present in the Grant Group, Poole Sandstone, and Anderson and Noonkanbah Formations (Kennard et al., 1994). The Grant Group overall is organically lean, but has recorded TOC values of up to 1.45%. Ellyard (1983) noted several intervals in the Grant Group with marginal to high organic richness, including several interglacial-maxima shales (TOC of 0.3 – 0.9%) and coaly intervals within fluvial sandstones (TOC of 16.9%). The Anderson Formation has some rare horizons moderately rich in organic matter, with TOC values of up to 2%. The Noonkanbah and Anderson Formations have some organically rich horizons, from which TOC values of up to 4.8% are recorded.

In summary, the limited geochemical data available indicate that high-quality oil-prone source rocks are present within the upper part of the Ordovician Goldwyer Formation in the southeastern part of the acreage release area, but they are presently immature to within the oil-generative window, rather than overmature.

Reservoir

Good potential reservoir rocks in the Canning Basin are present from the Middle Ordovician through to the Jurassic. Oil and minor gas have been produced from both carbonate and clastic rocks in the Nullara Limestone, Fairfield Group (Yellow Drum Formation), Grant Group, and Anderson Formation on the Lennard Shelf (Table 2).

Reservoir rocks within the Ordovician section include the Nambeet Formation, and porous dolomites within the Willara, Goldwyer, and Nita Formations. The overall porosity and permeability of the Nambeet Formation are typically low (average porosity of 5.55%, average permeability of 0.03 mD), although the highest porosity

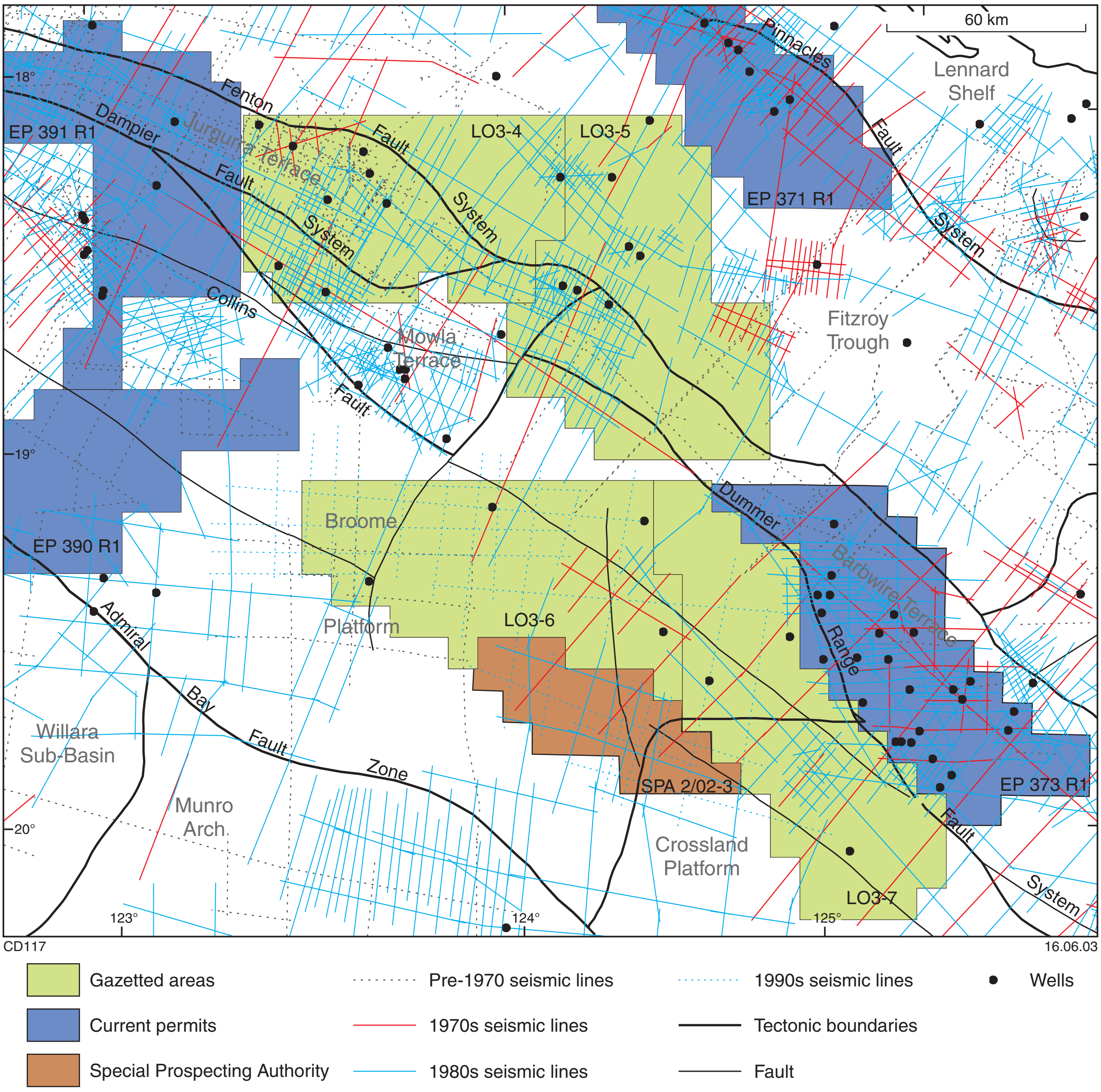


Figure 15. Wells and seismic coverage over the acreage release areas of the central Canning Basin

Table 3. Summary of the petroleum potential of the Canning Basin

Unit	*Source*	*Reservoir*	*Seal*	*Comments*
Permian				
Liveringa Group	no	high ϕ and k	?intraformational	HC shows: Petaluma 1
Noonkanbah Formation	possible (some organic-rich units)	low ϕ and k	possible	HC shows: Petaluma 1
Poole Sandstone	possible (some organic-rich units)	moderate ϕ and k	yes (Nura Nura Member)	HC shows: Petaluma 1
Grant Group	yes (marine shales)	moderate to very high ϕ and k, some low ϕ and k	individual formations and intraformational (Betty and Winifred Formations)	Boundary, Sundown, West Terrace oilfields. HC shows: Aristida 1A, Eremophila 1 + 2, Goodenia 1, Mount Wynne 3, Nerrima 1 (AFO)
Upper Carboniferous				
Reeves Formation	no	moderate to very high ϕ and k	uncertain	
Anderson Formation	no	moderate ϕ and k	intraformational and regional	Lloyd, West Kora oilfields. HC shows: Fitzroy River 1
Upper Devonian – Lower Carboniferous				
Fairfield Group	yes (Laurel Formation)	moderate to very high ϕ and k (Laurel and Yellow Drum Formations)	individual formations and intraformational (Gumhole and Laurel Formations)	Blina oilfield. HC shows: Goodenia 1, Fitzroy River 1, Nuytsia 1, Placer Camelgooda 1
Devonian				
Luluigui Formation	no	limited, sandstone beds	yes	HC shows: Frome Rocks 2
Clanmeyer Formation	?	no	yes	
Reef complexes	yes (Pillara Limestone, Boab Sandstone, Gogo Formation)	low to excellent ϕ and k (fractured dolomite and thin sandstone)	intraformational	Blina oilfield. HC shows: Aristida 1A, Eremophila 1
Mellinjerie Formation	yes	low to moderate ϕ and k		HC shows: Mirbelia 1
Tandalgoo Sandstone	no	high ϕ and k	no	
Worral Formation	no	high ϕ and k	no	
Ordovician–Silurian				
Carribuddy Group	yes	low to moderate ϕ and very low k (Sahara and Nibil Formations)	individual formations and intraformational (shales, impermeable carbonates, and evaporites)	HC shows: Carina 1, Musca 1, Matches Springs 1
Ordovician				
Nita Formation	no	low to moderate ϕ and low k	possible intraformational	HC shows: Pictor 1 and 2, Acacia 1 and 2, Canopus 1, Dodonea 2, Looma 1
Goldwyer Formation	yes	low to moderate ϕ and k	intraformational (marine shales)	HC shows: Acacia 1, Canopus 1, Dodonea 2
Willara Formation	possible	low to moderate ϕ and very low k 'Acacia sandstone member': moderate to high ϕ and k	intraformational (marine shales and tight, impermeable limestones)	HC shows: Looma 1
Nambeet Formation	possible	low ϕ and very low k	possible intraformational (marine shales and tight, impermeable limestones)	HC shows: Dodonea 1

NOTES: ϕ: porosity
HC: hydrocarbons
k: permeability

Table 4. Organic-rich samples with values of S_2 equal to or greater than 2.5 mg/g rock

Well	*Depth (m)*	*TOC (%)*	*T_{max} (°C)*	*S_1*	*S_2*	*PI*	*HI*	*Formation*
				_ (mg/g rock) __				
Acacia 1	779	0.96	432	0.01	3.09	–	322	Goldwyer Formation
Acacia 1	780	1.69	427	0.08	8.52	0.01	504	Goldwyer Formation
Acacia 1	783	4.03	439	0.62	36.50	0.02	907	Goldwyer Formation
Acacia 1	786	1.19	437	0.12	3.43	0.03	288	Goldwyer Formation
Crystal Creek 1	2181	3.37	453	1.51	2.61	0.37	77	Goldwyer Formation
Dodonea 1	1033	4.00	426	0.92	12.10	0.07	303	Mellinjerie Formation
Dodonea 1	1538	3.60	441	1.11	23.50	0.04	654	Goldwyer Formation
Dodonea 1	1538	3.60	441	1.11	23.50	0.04	654	Goldwyer Formation
Dodonea 1	1538	1.70	442	0.75	8.34	0.08	491	Goldwyer Formation
Dodonea 1	1538	1.70	442	0.75	8.34	0.08	491	Goldwyer Formation
Dodonea 1	1538	2.20	438	0.80	13.30	0.06	609	Goldwyer Formation
Dodonea 1	1540	1.80	442	0.94	10.30	0.08	572	Goldwyer Formation
Dodonea 1	1540	1.80	442	0.94	10.30	0.08	572	Goldwyer Formation
Dodonea 1	1540	2.10	441	0.81	12.80	0.06	611	Goldwyer Formation
Dodonea 1	1540	2.10	441	0.81	12.80	0.06	611	Goldwyer Formation
Dodonea 1	1540	1.05	440	1.25	28.30	0.04	2697	Goldwyer Formation
Dodonea 1	1540	4.05	440	1.25	28.30	0.04	699	Goldwyer Formation
Dodonea 1	1542	0.87	444	0.26	2.64	0.09	303	Goldwyer Formation
Dodonea 1	1542	0.87	444	0.26	2.64	0.09	303	Goldwyer Formation
Dodonea 1	1542	1.05	442	0.35	2.98	0.11	284	Goldwyer Formation
Dodonea 1	1542	1.05	442	0.35	2.98	0.11	284	Goldwyer Formation
Dodonea 1	1548	1.40	444	0.59	6.83	0.08	488	Goldwyer Formation
Dodonea 1	1548	1.40	444	0.59	6.83	0.08	488	Goldwyer Formation
Dodonea 1	1549	1.50	443	0.62	7.07	0.08	471	Goldwyer Formation
Dodonea 1	1549	1.50	443	0.62	7.07	0.08	471	Goldwyer Formation
Eremophila 1	1058	3.10	428	0.16	5.06	0.03	163	Upper Devonian
Eremophila 1	1187	1.08	427	0.36	3.03	0.11	281	Upper Devonian
Matches Springs 1	2405	1.52	443	2.30	9.56	0.19	629	Goldwyer Formation
Matches Springs 1	2408	1.77	443	1.78	9.93	0.15	561	Goldwyer Formation
Matches Springs 1	2430	1.88	443	1.18	5.10	0.19	271	Goldwyer Formation
Matches Springs 1	2769	2.11	441	1.30	3.21	0.29	152	Goldwyer Formation
Mirbelia 1	1680	4.18	442	0.57	5.80	0.09	139	Upper Devonian
Santalum 1A	453.81	1.03	434	0.11	6.36	0.02	616	Goldwyer Formation
Santalum 1A	470.00	6.4	433	0.5	52.96	0.01	828	Goldwyer Formation
Santalum 1A	470.71	1.15	435	0.06	7.94	0.01	690	Goldwyer Formation
Santalum 1A	478.50	0.65	435	0.06	3.53	0.01	543	Goldwyer Formation
Santalum 1A	490.80	1.28	437	0.14	8.34	0.02	652	Goldwyer Formation
Santalum 1A	495.40	1.35	437	0.18	5.81	0.03	430	Goldwyer Formation
Santalum 1A	495.80	1.86	438	0.24	10.74	0.02	577	Goldwyer Formation
Santalum 1A	503.00	0.78	438	0.1	3.73	0.03	478	Goldwyer Formation
Solanum 1	302	0.91	439	0.18	4.36	0.04	479	Goldwyer Formation
Solanum 1	303	0.95	440	0.21	5.14	0.04	541	Goldwyer Formation
Solanum 1	307	1.08	439	0.16	6.21	0.03	575	Goldwyer Formation
Solanum 1	308	1.31	438	0.34	7.99	0.04	610	Goldwyer Formation
Solanum 1	309	1.74	440	0.32	12.04	0.03	692	Goldwyer Formation
Solanum 1	309	2.44	438	0.48	19.31	0.02	791	Goldwyer Formation
Solanum 1	312	1.51	438	0.61	17.58	0.03	1164	Goldwyer Formation
Solanum 1	312	0.37	440	0.13	4.36	0.03	1178	Goldwyer Formation
Solanum 1	313	1.28	439	0.50	14.97	0.03	1170	Goldwyer Formation
Solanum 1	315	0.78	439	0.30	9.12	0.03	1169	Goldwyer Formation
Solanum 1	315	1.13	438	0.36	13.20	0.03	1168	Goldwyer Formation
Solanum 1	315	1.22	439	0.40	14.32	0.03	1174	Goldwyer Formation
Solanum 1	315	2.32	442	0.63	16.50	0.04	715	Goldwyer Formation
Solanum 1	316	0.77	437	0.33	8.96	0.04	1164	Goldwyer Formation
Solanum 1	317	0.81	439	0.38	9.36	0.04	1156	Goldwyer Formation
Solanum 1	318	1.00	438	0.16	4.64	0.03	464	Goldwyer Formation
Solanum 1	318	1.55	439	0.26	7.66	0.03	494	Goldwyer Formation
Solanum 1	318	1.06	437	0.20	4.82	0.04	455	Goldwyer Formation
Solanum 1	319	1.25	436	0.23	5.96	0.04	477	Goldwyer Formation
Solanum 1	320	0.86	436	0.15	3.64	0.04	423	Goldwyer Formation
Solanum 1	326	0.85	441	0.17	3.44	0.05	405	Goldwyer Formation
Solanum 1	327	1.88	440	0.31	11.60	0.03	617	Goldwyer Formation
Solanum 1	505	1.06	435	0.41	2.58	0.14	243	Goldwyer Formation
Solanum 1	515	1.16	435	0.42	2.57	0.14	222	Goldwyer Formation
Solanum 1	520	1.17	437	0.67	2.52	0.21	215	Goldwyer Formation
Solanum 1	526	1.34	433	0.48	2.82	0.15	210	Goldwyer Formation

NOTES: HC: hydrocarbons; HI: hydrogen index; PI: production index; S_1: volatile hydrocarbon (HC); S_2: pyrolytic yield (HC); T_{max}: temperature of maximum pyrolytic yield (S_2); TOC: total organic carbon

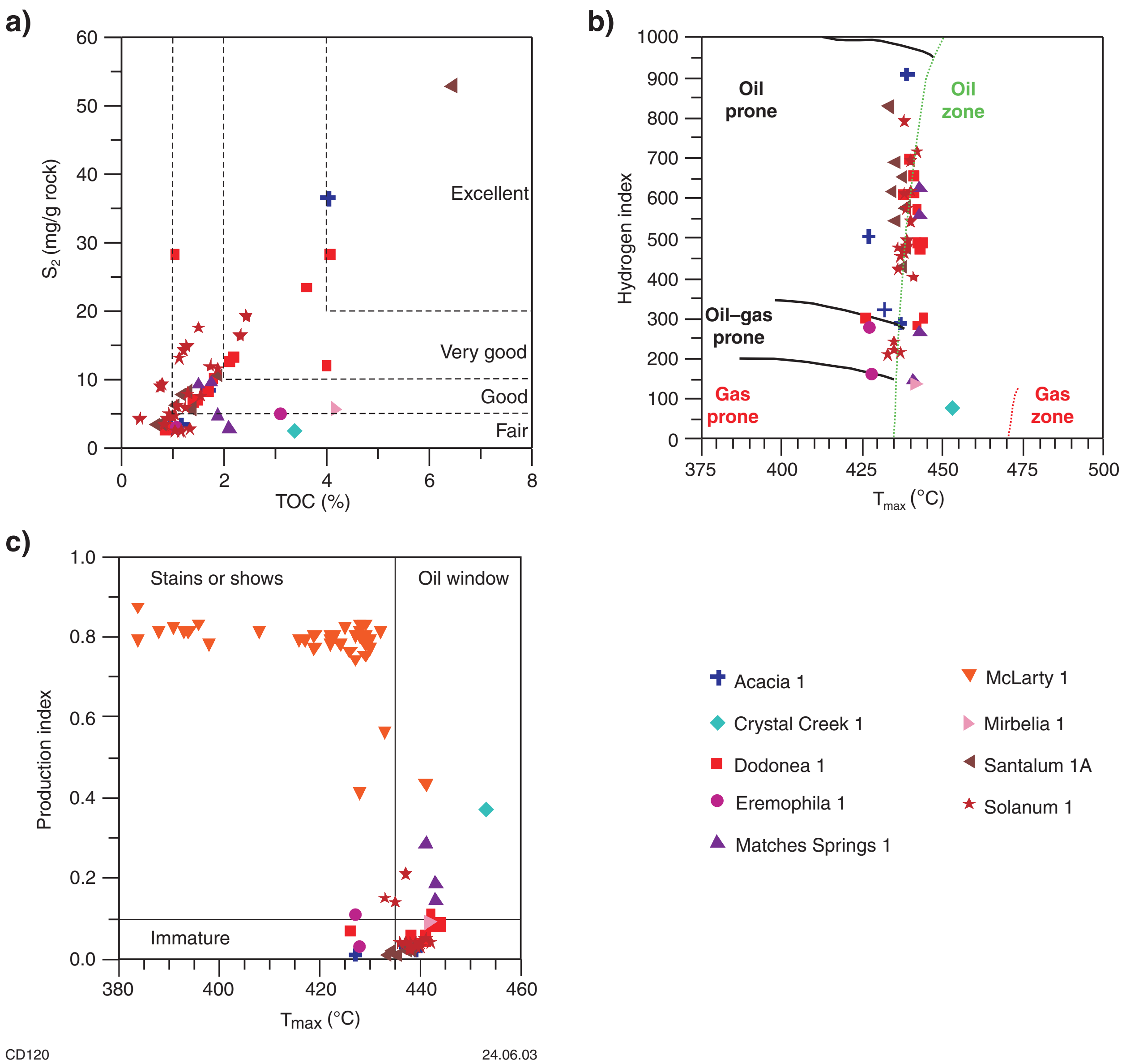


Figure 16. **Rock-Eval source-rock characterization of selected wells from the central Canning Basin: a) petroleum-generating potential; b) kerogen typing; and c) maturity**

recorded is 12% (Fig. 25a). Because few permeability measurements are available, it is possible that these results, of which the majority are mostly poor, are not truly representative of the formation. For example, Dodonea 1 produced 85 m^3/day of gas from the Nambeet Formation, indicating that it can be an effective reservoir. The Nambeet Formation has extensive porosity reduction caused by diagenetic cementation, which may explain the poor reservoir qualities seen in most of the formation.

Dolomite intervals in the Willara Formation have variable porosity (0.5 – 15%; average 4.46%), but very low permeability (0.06 – 0.8 mD; Fig. 25). In comparison, the 'Acacia sandstone member' of the Willara Formation has much better reservoir characteristics (porosities of 0.4 – 19.3%, permeabilities of 0.02 – 385 mD; Fig. 25). The best reservoir qualitiy was recorded in Acacia 2 (1174.13 – 1180.91 m) by a drill-stem test (DST; 1164.6 – 1182 m), which flowed water at 279.82 kL/day (1760 bbl/day) and indicated a permeability of 291 mD. Good porosity values are recorded from Solanum 1 (614 – 699.32 m), where log-derived values ranged from 8.9 to 16.5%, and from Setaria 1 (452.11 – 455.93 m), where core-derived values range from 8 to 13.2%. Live oil was recorded from this member in Looma 1. The 'Acacia sandstone member' has only been identified in six holes on the Barbwire Terrace, but the presence of this unit has not been assessed in older wells, as it was not named until the mid-1980s (by WMC). Other sandstone units have been noted within the Willara Formation elsewhere, and could possibly belong to this member.

The Goldwyer Formation has poor to excellent porosity and permeability (Fig. 25). The best results were from Acacia 1, with porosities of up to 20.6% and permeabilities of up to 505 mD, although the formation typically has an average porosity of 8.36% and permeability of 43.96 mD. A DST (1525–1553 m) over the Goldwyer Formation in Dodonea 1 produced just 10 L of oil (Appendix 1), probably because the porosity (0.6 – 4%) and permeability (0.002 – 58 mD) were low. Live oil bled from the Goldwyer Formation in Acacia 1, Canopus 1, and Dodonea 2 (Appendix 1).

The Nita Formation is considered one of the better potential carbonate reservoirs in the Ordovician section, despite being uniformly tight and showing little or no sign of porosity and permeability, except in vugs within the dolomite. In the vuggy dolomite, the overall porosity is low to good (0.4 – 20.9%), and permeability is very low or not developed (0.001 – 38 mD), although some high values are noted (Fig. 25b). The maximum-recorded porosity value of 20.9% is from Pictor 1, however, permeability was low (1.7 mD). Acacia 2 had an anomalously high permeability value of 238 mD with a corresponding 14.8% porosity value. This is not typical of the formation in this well, which has commonly low permeability values (0.25 – 35 mD). Better reservoir quality was recorded in the Nita Formation west of the acreage release area in Aquila 1, which also had anomalously high permeability values of up to 3310 mD with porosity values of up to 15% (Karajas and Kernick, 1984). Primary porosity and permeability is preserved in some areas where hydrocarbons were entrapped in the reservoir rocks or the pores have been infilled by marine cement (Manzanita Alliances Incorporated, 1996). Oil was produced from the Nita Formation in Pictor 1 and 2, and live oil bled from vugs and fractured surfaces in Acacia 1 and 2, Canopus 1, Dodonea 2, and Looma 1 (Table 1; Appendix 1). Elsewhere, porosity and permeability have

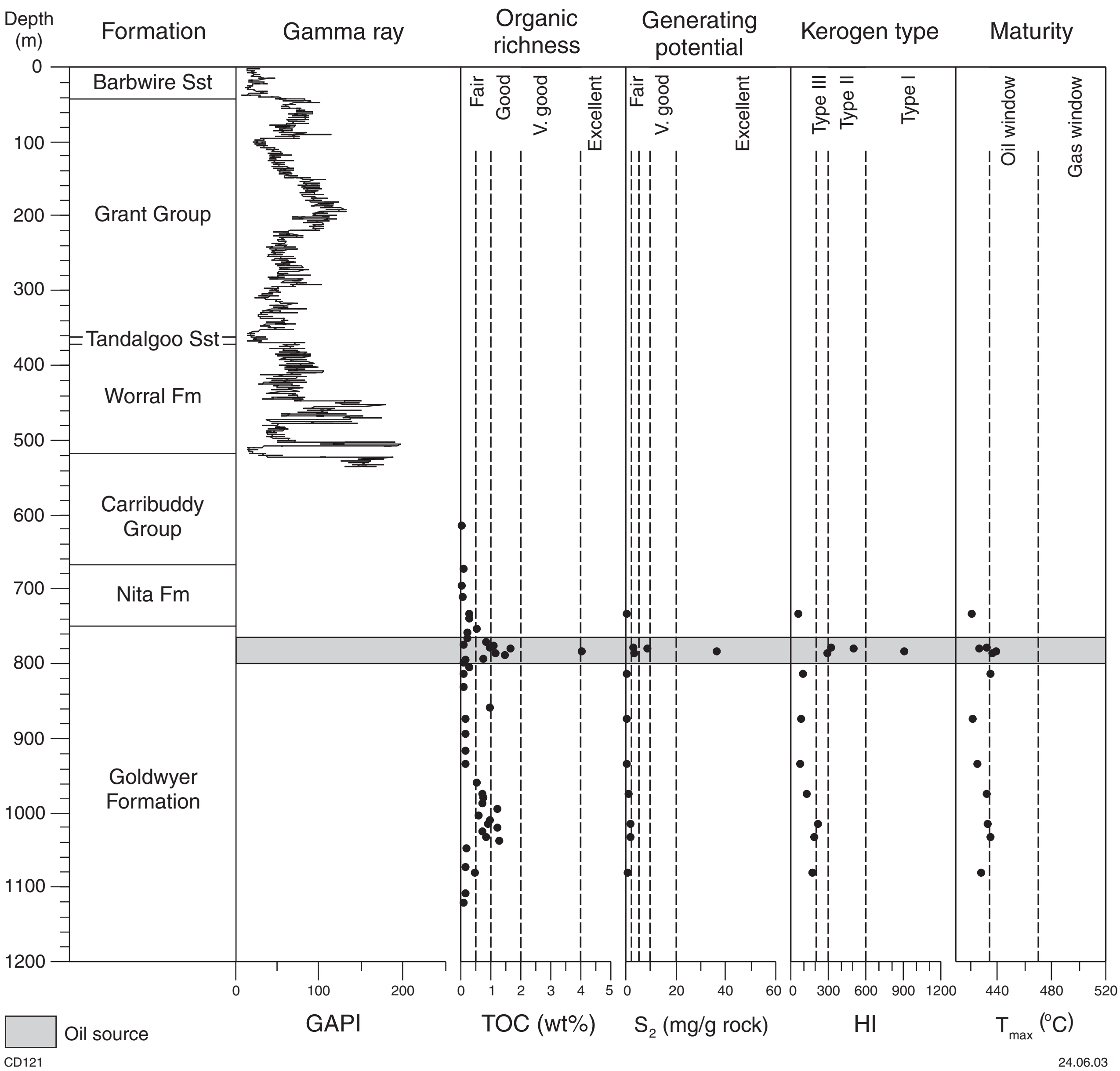


Figure 17. Source-rock potential of rocks in Acacia 1

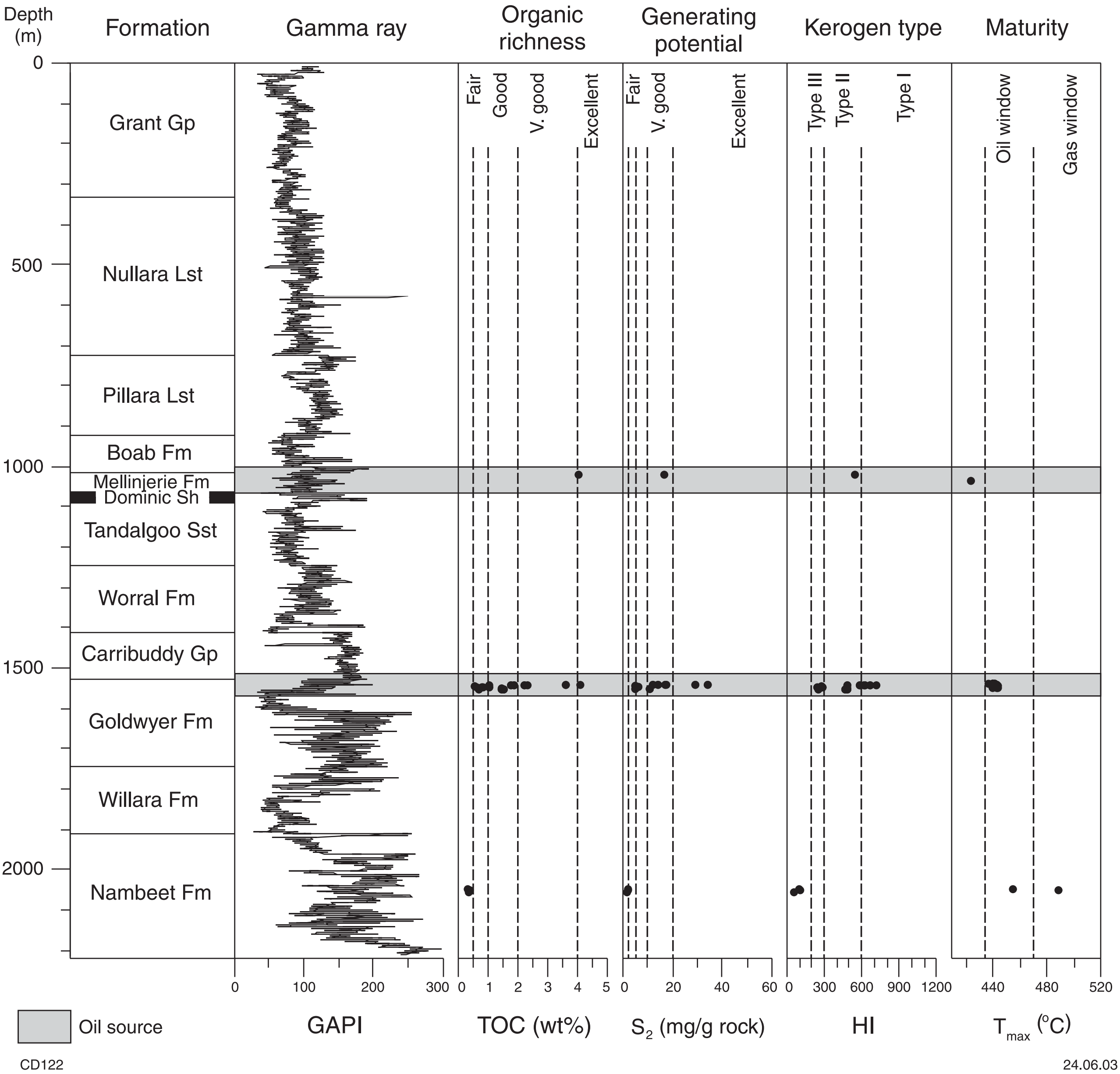


Figure 18. Source-rock potential of rocks in Dodonea 1

been destroyed by late-stage evaporite invasion or diagenetic processes. Dolomitization of original limestones in the Nita Formation took place during shallow to deep burial (Manzanita Alliances Incorporated, 1996), which produced secondary porosity. Oil residues noted in some wells are mostly associated with horizons of intercrystalline, vuggy, mouldic, and fracture porosity (i.e. secondary porosity). The best porosity and permeability within the Nita Formation form preferentially in these intensively dolomitized horizons. The porosity significantly decreases with depths greater than 970 m (Fig. 25a).

Dolomite and sandstone intervals in the Sahara and Nibil Formations of the Carribuddy Group are possible potential reservoirs. They represent the highest risk reservoirs in the area as they are not laterally extensive and are typically fine grained. Good porosity (1.9 – 26%) but very low permeability (0.1 – 5.3 mD, average of 0.16 mD) values were recorded from the group (Fig. 25). Of these results, the Sahara Formation yielded log-derived porosities of 16–26% in Carina 1 and 12–15% in Musca 1, and core-derived porosities of 14–15% in McLarty 1, and the Nibil Formation yielded one core-derived porosity value of 10% in McLarty 1. The other values were from undifferentiated Carribuddy Group.

Likely reservoir intervals within the Devonian section include the Tandalgoo Sandstone, Worral and Mellinjerie Formations, Upper Devonian reef complexes (e.g. Pillara

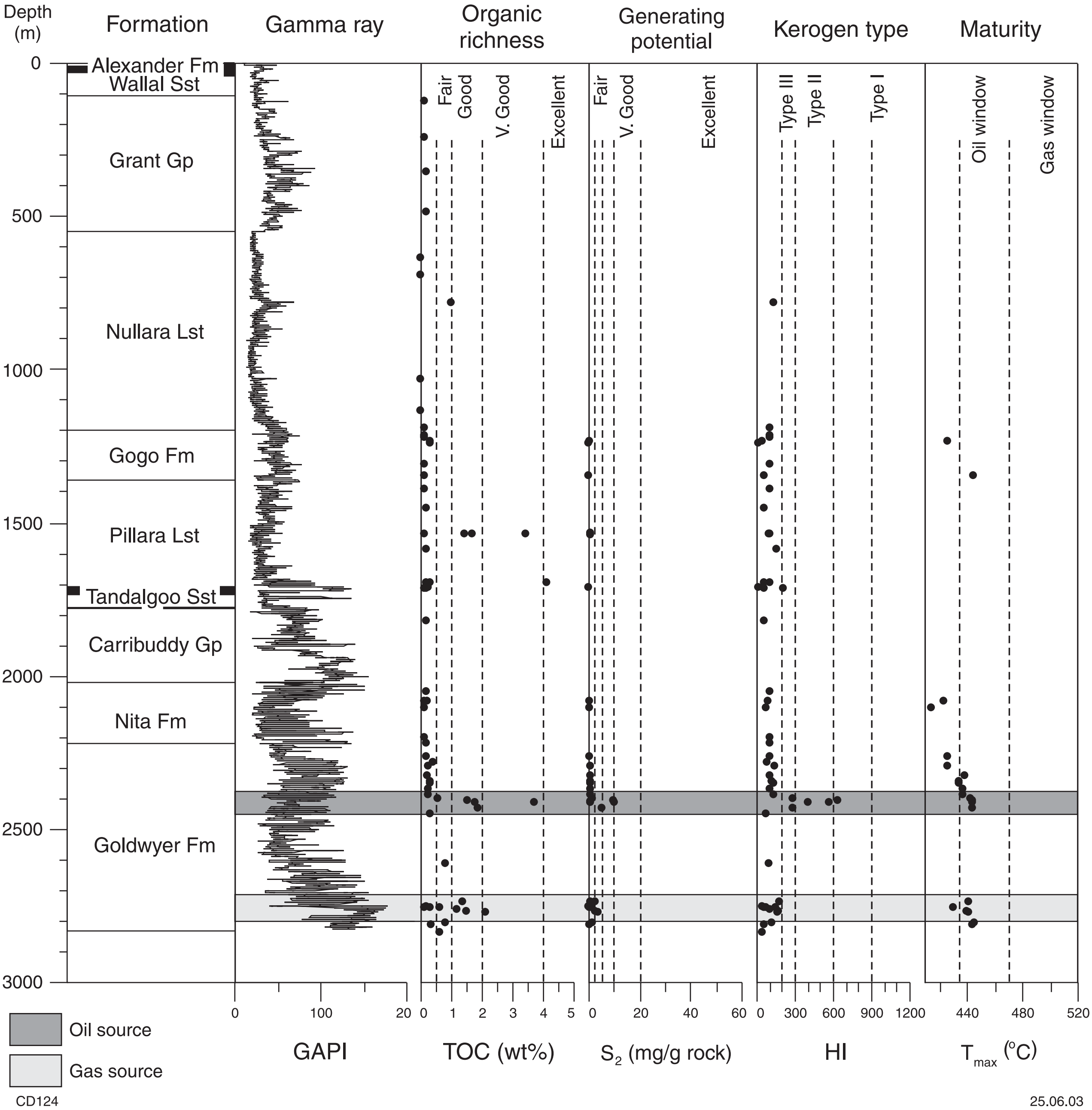


Figure 19. Source-rock potential of rocks in Matches Springs 1

and Nullara Limestones), Upper Devonian quartz arenites (e.g. Luluigui Formation, Boab Sandstone), and the Fairfield Group.

The Tandalgoo Sandstone has excellent reservoir characteristics (porosities of 2–35%; permeabilities of 66–2700 mD; Fig. 25). Measured porosities of up to 30.3% compare well with log-derived values of up to 35%. The unit is a proven aquifer, from which about 458.19 kL/day (2884 bbl/day) of water flowed in Matches Springs 1. Porosity values decrease with depth, with the highest values less than 1000 m below surface (Fig. 25a). Bridge Oil Ltd (1987) suggested that economically significant porosities for the Tandalgoo Sandstone could be expected above 2800 m, with the possibility of redeveloped porosity via secondary processes below 3500 m. The Worral Formation also has excellent reservoir characteristics (porosities of 10.7 – 29.3%; permeabilities of 0.1 – 3950 mD), but the dataset is small. The highest recorded values (porosity of 29.3% and permeability of 3950 mD) are from a sample at 488.7 m in Acacia 1.

The Mellinjerie Formation shows highly variable reservoir characteristics (Fig. 25). Porosity (0.1 – 20.8%) and permeability (0.001 – 195 mD) values range from low to high, although they are typically close to the average (porosity of 6.29% and permeability of 7.30 mD). The best values are recorded from Dodonea 1 (Fig. 25). In Mirbelia 1, moderate porosity values (4 – 15.7%) are recorded from the upper part of the formation (1836 –

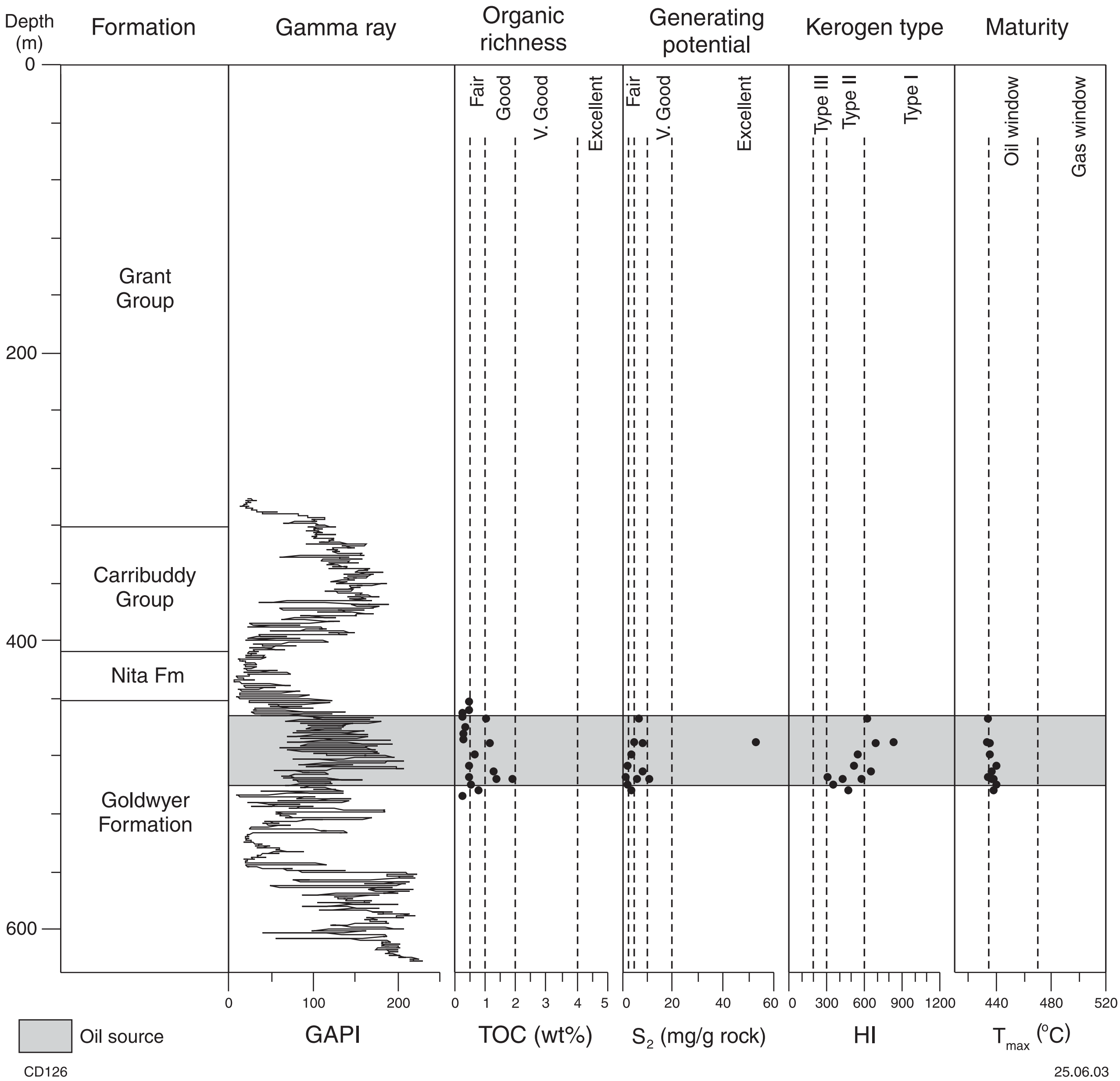


Figure 20. Source-rock potential of rocks in Santalum 1A

1847.64 m), but the lower part (>1847.64 m) has very low values (<0.8%; Fig. 25a). Live oil and gas were recorded in Mirbelia 1 from the Mellinjerie Formation (Table 1). DST 2 (1837 – 1846.5 m) yielded 20 m of oil mud and 1.5 L of 22.4° API oil, whereas DST 3 (1855.5 – 1892.5 m) yielded 1.25 L of gas (Appendix 1).

The Pillara and Nullara Limestones are the best-quality reservoirs within the Devonian reef complexes. These units are typically uniformly tight, but porosity and permeability have developed within vugs, molds, intercrystalline pores, and fractures within dolomite. The Pillara Limestone has low to very high porosities (0.3 – 29.1%) and permeabilities (0.01 – 2630 mD), with an average porosity of 9.11% and permeability of 216 mD. The best reservoir values are from intervals with mouldic, vuggy, and intercrystalline porosity at shallow depths (<590 m, e.g. Boab 1), but values rapidly decrease below this depth (Fig. 25a). For example, in Crossland 1 excellent porosity values (9.3 – 21.4%, average of 17.2%) are seen in vuggy dolomite down to 340 m, but they dramatically decrease (0.7 – 7.4%, average 2.64%) at depths greater than 900 m. The Nullara Limestone also has fair to excellent reservoir characteristics (porosities of 0.3 – 28.2%, permeabilities of 0.01 – 14570 mD; Fig. 25). The highest measured permeability is in Cassia 1 (14 570 mD at 1521.9 m), where it is associated with large vugs and fractures in the dolomite. The maximum porosity of 28.2% is in Nollamara 1, where karst fabrics give the unit an average permeability value of 3117.2 mD. Water flowed

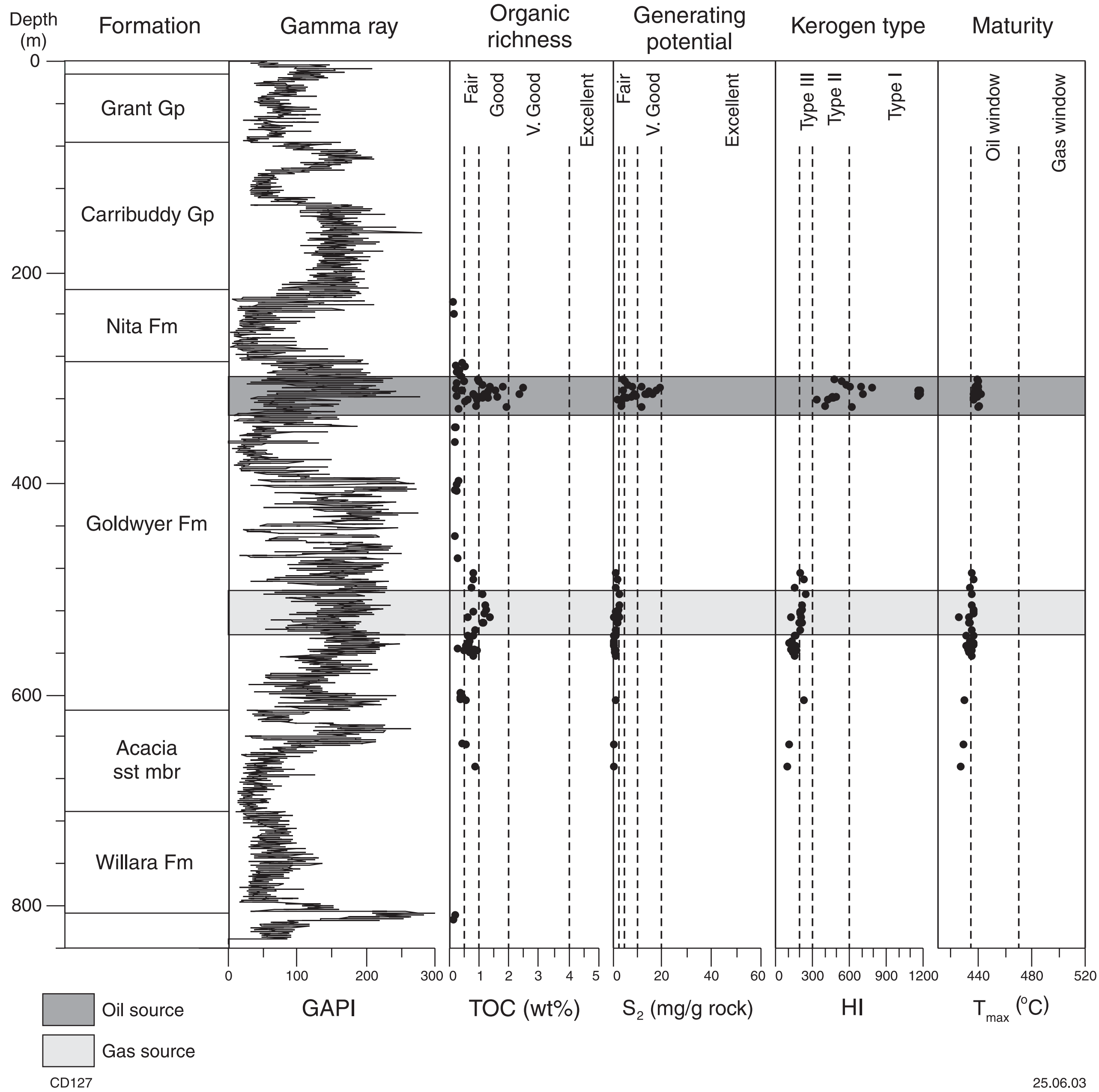


Figure 21. Source-rock potential of rocks in Solanum 1

from the Nullara Limestone in Ficus 1, indicating that the vugs and fractures are interconnected. Good porosity values are retained at greater depths in the Nullara Limestone than for the Pillara Limestone (Fig. 25a). All significant porosity and permeability values in both the Pillara and Nullara Limestones are directly related to pervasive secondary dolomitization or leaching in shallow burial regimes, or a combination of both (Bridge Oil Ltd, 1987; Manzanita Alliances Incorporated, 1996). In some cases where the Upper Devonian dolomites are overlain by Permian sedimentary rocks, the dolomites are vuggy and fractured directly below the unconformity. This may be a product of solution by acidic subglacial meltwater (Playford, 2002). Oil has been produced from the Nullara Limestone in the Blina oilfield (Table 2). Live oil bled from the Nullara Limestone in Aristida 1/1A and from a Nullara/Pillara Limestone equivalent in Eremophila 1 (Table 1; Appendix 1).

Thin sandstone beds within the Luluigui Formation may also be potential reservoirs, although limited well data show that these beds have low permeability (one sample of 5.3 mD in Doran 1). In Frome Rocks 2, the log-derived porosity of the sandstone is up to 25%, compared with log-derived porosity values of 6–10% for fossiliferous limestone. In Doran 1, log-derived values of 6–12% were noted in interbedded sandstone, shale, and siltstone of the Luluigui Formation. Globules of oil were noted in both sandstone and limestone units within the Luluigui Formation in Frome Rocks 2 (Table 1; Appendix 1).

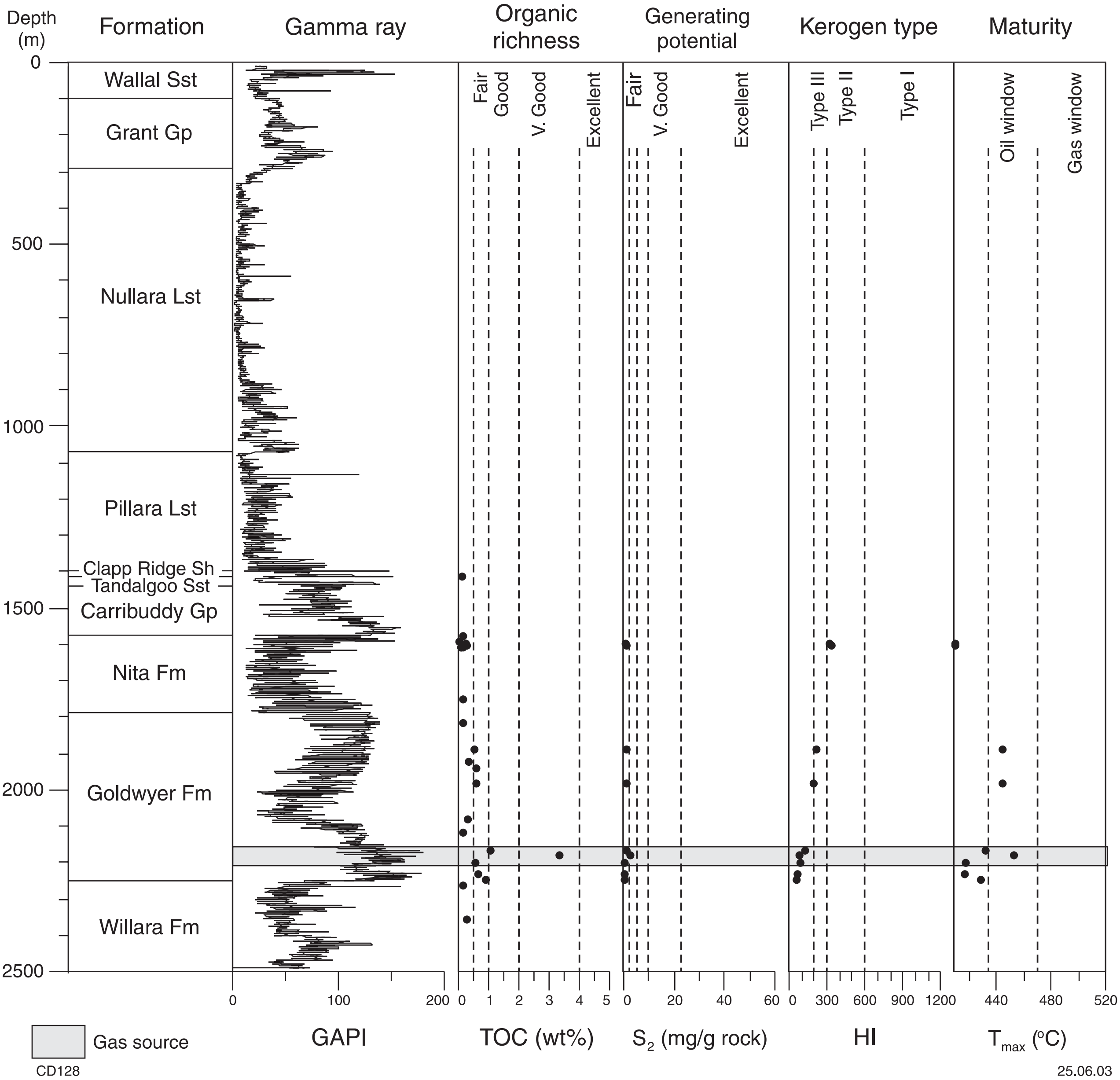


Figure 22. Source-rock potential of rocks in Crystal Creek 1

Samples of shale, siltstone, limestone, and dolomite from the Clanmeyer Formation in Babrongan 1 show low porosities and permeabilities, with some exceptions (Fig. 25). Based on the available data, this formation is not considered a potential reservoir.

The Fairfield Group exhibits highly variable reservoir characteristics (Fig. 25). The best reservoirs within the group are the Laurel and Yellow Drum Formations. Porosity values range from 0.3 to 29.8% (average of 10.55%), with permeability values ranging from 0.003 to 3438 mD (average 305.5 mD). The best porosity and permeability values are associated with vuggy, intergranular, or fracture porosity in the shallower part of the section (Fig. 25b). In Cassia 1, the upper part of the Fairfield Group (<549.9 – 750 m; Yellow Drum Formation) has an average porosity of 26.6%, with corresponding high permeability values, but the lower part (750 – 1036.1 m) has an average porosity of 5.45% with lower permeability values. Oil has been produced from the Yellow Drum Formation in the Blina oilfield (Table 2). Live oil bled from the Fairfield Group in Goodenia 1 and Fitzroy River 1 (Laurel Formation). Minor oil shows were recorded in Nuytsia 1 and Placer Camelgooda 1, and minor gas was noted in Fitzroy River 1 from the Laurel Formation (Table 1; Appendix 1).

Limited porosity values are available for the Anderson Formation in the acreage release areas. In Grant Range 1, porosities range from 6.5 to 6.7%. However, in other parts of the Canning Basin, porosities of up to 19.7% are recorded from this unit. Water flowed from the Anderson Formation in Grant Range 1, proving it has good reservoir characteristics, even though data are limited. Oil has been

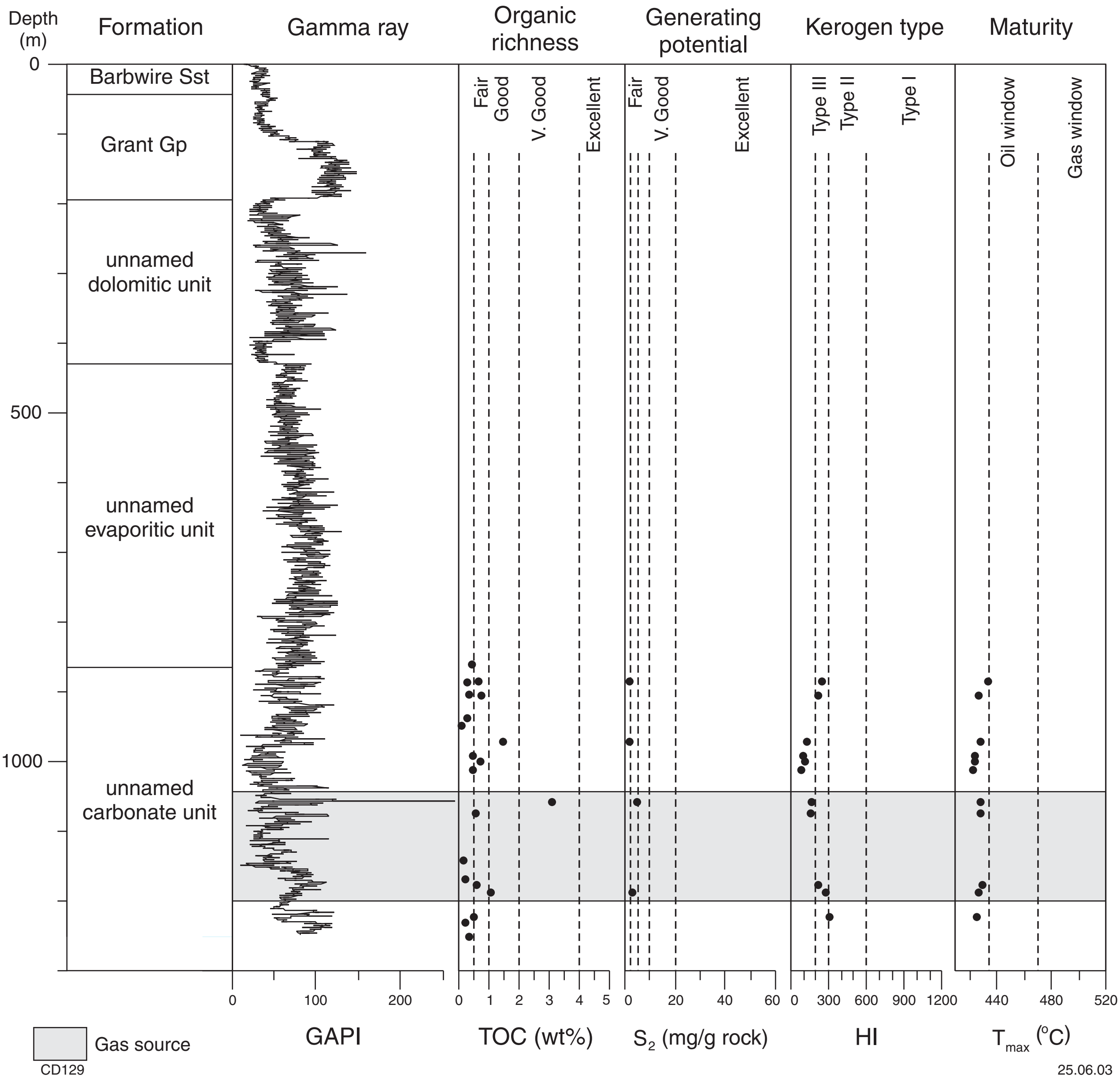


Figure 23. Source-rock potential of rocks in Eremophila 1

produced from this unit in the Lloyd and West Kora oilfields (Table 2), and minor light oil was recorded from this unit in Fitzroy River 1 (Table 1; Appendix 1).

The Reeves Formation is an untested reservoir in the central Canning Basin, but shows good to excellent porosity and permeability (Fig. 25). Log-derived porosity values range from 11 to 27% in Notabilis 1, compared with core-derived values of 6 to 23.3% in Ficus 1 and Grant Range 1. Permeability values of up to 1463 mD have been recorded from Ficus 1.

The most favourable potential reservoir characteristics in the study area are in the Permian Grant Group. Reservoir quality for the Grant Group throughout the area, based on both log-derived and core-derived results, is variable, with commonly good to excellent values (Fig. 25). The basal units of the group are poorly sorted and have low permeability, whereas the best porosity values recorded from sandstone beds range from 1.2 to 40% (average 19.94%). The porosity values are fairly consistent across the entire acreage release area. Only a few permeability measurements were recorded for the unit, and these range from 0.03 to 5520 mD, with an average of 604.85 mD. The best permeability values were recorded on the Barbwire (4225 mD in Ficus 1 at 388.05 m, and 5520 mD in Cassia 1 at 390.43 m) and Mowla Terraces (1569 mD in Matches Springs 1 at 166.5 m). Oil has been produced from this group in the Boundary, Sundown, and West Terrace oilfields (Table 2). Live oil was recorded from Aristida 1/1A, Eremophila 1 and 2, Goodenia 1, Mount Wynne 3, and Nerrima 1 (AFO) in the Grant Group (Table 1; Appendix 1). Other hydrocarbon shows were recorded in Babrongan 1, Dampiera 1/1A, and Mount Wynne 1 (Table 1; Appendix 1).

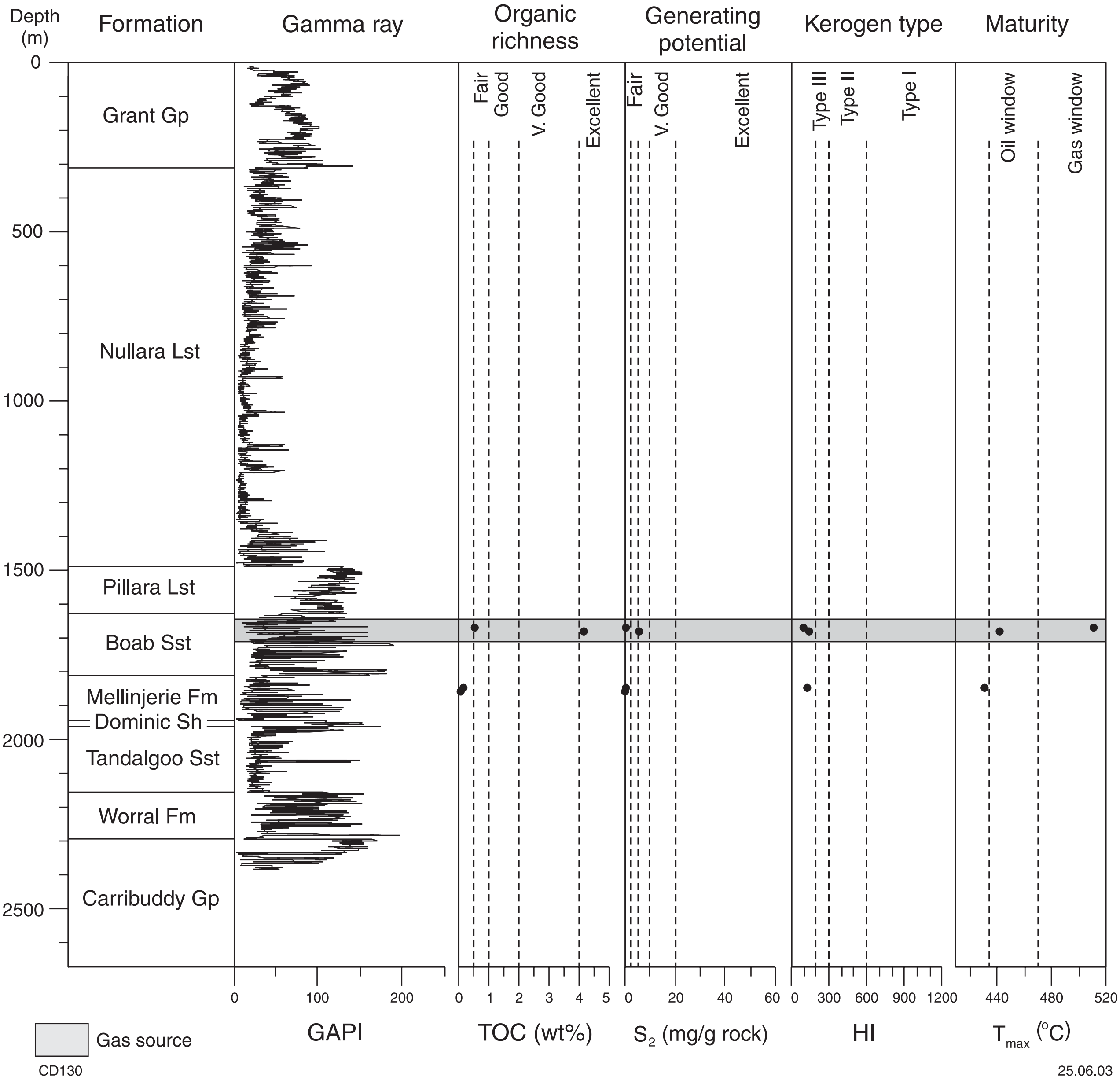


Figure 24. Source-rock potential of rocks in Mirbelia 1

Based on wireline logging, the Poole Sandstone has good reservoir characteristics. The Noonkanbah Formation has low to moderate porosity, and very low to low permeability. Oil stains and background gas were recorded from the Poole Sandstone, Noonkanbah Formation, and Liveringa Group.

Seals

There are several potential Palaeozoic sealing sections within the central Canning Basin (Fig. 3 and Table 3). Intraformational shale, mudstone, and tight, impermeable limestone within most of the Ordovician section (Nambeet, Willara, and Goldwyer Formations) could form good seals for any hydrocarbons within the same formation, or for the formations directly below them.

Where mid-Carboniferous erosion has not removed the Carribuddy Group, it could form the top seal for the Nita Formation. Seals within the Carribuddy Group consist of shale, impermeable carbonate, and evaporite facies, and are either intraformational or entire formations within the group (i.e. shale of the Bongabinni and Nibil Formations, and evaporite of the Mallowa and Minjoo Salt). Based on drillhole data, these seals are typically widespread, fairly thick, and of good quality. The group can be up to 1500 m thick, of which around one-third is massive evaporites (e.g. within the southwestern part of the region on the Broome Platform).

Impermeable Upper Devonian limestone, together with basin facies of the Gogo Formation and Devonian evaporites, are good possible seals. The tight, fine-grained Clanmeyer and Luluigui Formations are potential sealing units for the underlying Devonian reservoirs. The Dominic Shale and a middle shale unit within the Tandalgoo Sandstone are potential seals, although in most areas in the central Canning Basin they are too thin to be effective. In some areas, Permian erosion has removed this top seal (and much of the Tandalgoo Sandstone), but in some locations, sufficient section has been preserved to form an effective seal. The Worral Formation contains intraformational shale horizons (Waldecks Member), which have very variable seal qualities. In places the member is absent, but elsewhere it has the potential to be a very good quality seal.

The Gumhole Formation and intraformational marine shale horizons of the Laurel Formation from the Fairfield Group form effective top seals within the Blina oilfield. Thin, intraformational shale beds in the Anderson Formation form effective seals within the Lloyd and West Kora oilfields. The Anderson Formation is a possible regional seal over the Fairfield Group within the Fitzroy Trough.

Intraformational shale and claystone in the Grant Group could form sealing intervals, but there is a high risk that they may be thin and laterally discontinuous, very sandy, or even absent in some areas. Shale and claystone intervals from this group form effective seals in the Boundary, Sundown, and West Terrace oilfields. The Sundown oilfield also relies on the thin, basal, siltstone-dominated Nura Nura Member of the Poole Sandstone as a seal. Marine shale of the Noonkanbah Formation is also a potential seal for exploration plays in the central Canning Basin. Any unit that lies directly below the Wallal Sandstone will not be sealed, unless intraformational seals are present within the underlying unit.

Traps

The following summary of play types within the Palaeozoic section of the central Canning Basin (Table 5) is based on detailed work undertaken by Goldstein (1989); Bradshaw et al. (1994), Kennard et al. (1994), Manzanita Alliances Incorporated (1996), Shell Development (Australia) Pty Ltd (1991, 2000), and SRK Consulting (1998).

The most prospective play types in the central Canning Basin are pre-salt plays (below the Mallowa Salt, Carribuddy Group) with Ordovician objectives, and overlying post-salt plays with Devonian to Lower Permian objectives. To date no viable plays have been identified in Upper Permian or younger sedimentary rocks. Key risks in all these plays are charge, timing, migration, and trap integrity.

Kennard et al. (1994) postulated oil generation between the Late Devonian and Early Carboniferous, from virtually all Ordovician source-rock intervals. This implies that such generation preceded several of the basin-wide trap-forming and reactivation events (see **Tectonic evolution**). Russell (1998) noted that in a pulsed heat-flow model, rather than a prolonged single-event model as used by Kennard et al. (1994), hydrocarbon generation could have extended into the Triassic in the central Canning Basin. This model implies that Lower Carboniferous source rocks of the Fairfield Group and Anderson Formation also passed into the oil-generation window, along with possible source intervals of the Grant Group, in the Triassic.

Pre-salt plays

On the Jurgurra, Mowla, and Barbwire Terraces and southern flank of the Fitzroy Trough, the most common traps within the pre-salt plays are low-amplitude anticlines, fault-controlled structures, and stratigraphic traps. The fault-controlled traps include faulted anticlines, inversion structures (rollover features), tilted fault traps, basement drapes, and minor salt diapirs. Stratigraphic traps include mound- or reef-like structures within carbonate rocks, and truncation traps. Wells drilled on the Jurgurra Terrace have not penetrated pre-salt strata, so development of a pre-salt fairway is speculative. Pre-salt source rocks within the Fitzroy Trough may be too deeply buried to source the flanking areas, but the source for pre-salt plays could be from the terraces (SRK Consulting, 1998).

The pre-salt reservoirs consist of the Nambeet, Willara, Goldwyer, and Nita Formations. Where sealing intervals within the Carribuddy Group are preserved, these reservoirs are a primary target, especially around basement highs and the basement margin, provided that secondary porosity has developed. If the Ordovician reservoirs are overlain by the Grant Group, top seals and traps are dubious as, for example, in Setaria 1. Stratigraphically, the Nita Formation is favourably situated to trap hydrocarbons generated in the Goldwyer Formation. The 'Acacia sandstone member' play relies on northward migration of Ordovician oil charge from a source pod in the Kidson Sub-basin.

The pre-salt structures (with Ordovician objectives) could have formed as early as the Late Carboniferous. The primary risks in pre-salt plays are the timing of generation relative to trap formation (generally during compressional events), trap integrity, and the lack of knowledge of Palaeozoic basin geometry.

Post-salt plays

On the Jurgurra, Mowla, and Barbwire Terraces, Broome Platform, and southern flank of the Fitzroy Trough, the most common traps within post-salt plays are similar to the pre-salt plays, with the addition of sombrero features (Jenyon, 1986) caused by salt dissolution. The sombreros are either cored by the Worral Formation with the Grant Group draped over them, or are entirely within the Grant Group. Stratigraphic traps include Upper Devonian reefal facies localized on anticlinal palaeohighs, truncation of reservoirs against the Permian unconformity, and incised channels at the unconformity surface. The rugged relief of the base Permian unconformity, combined with

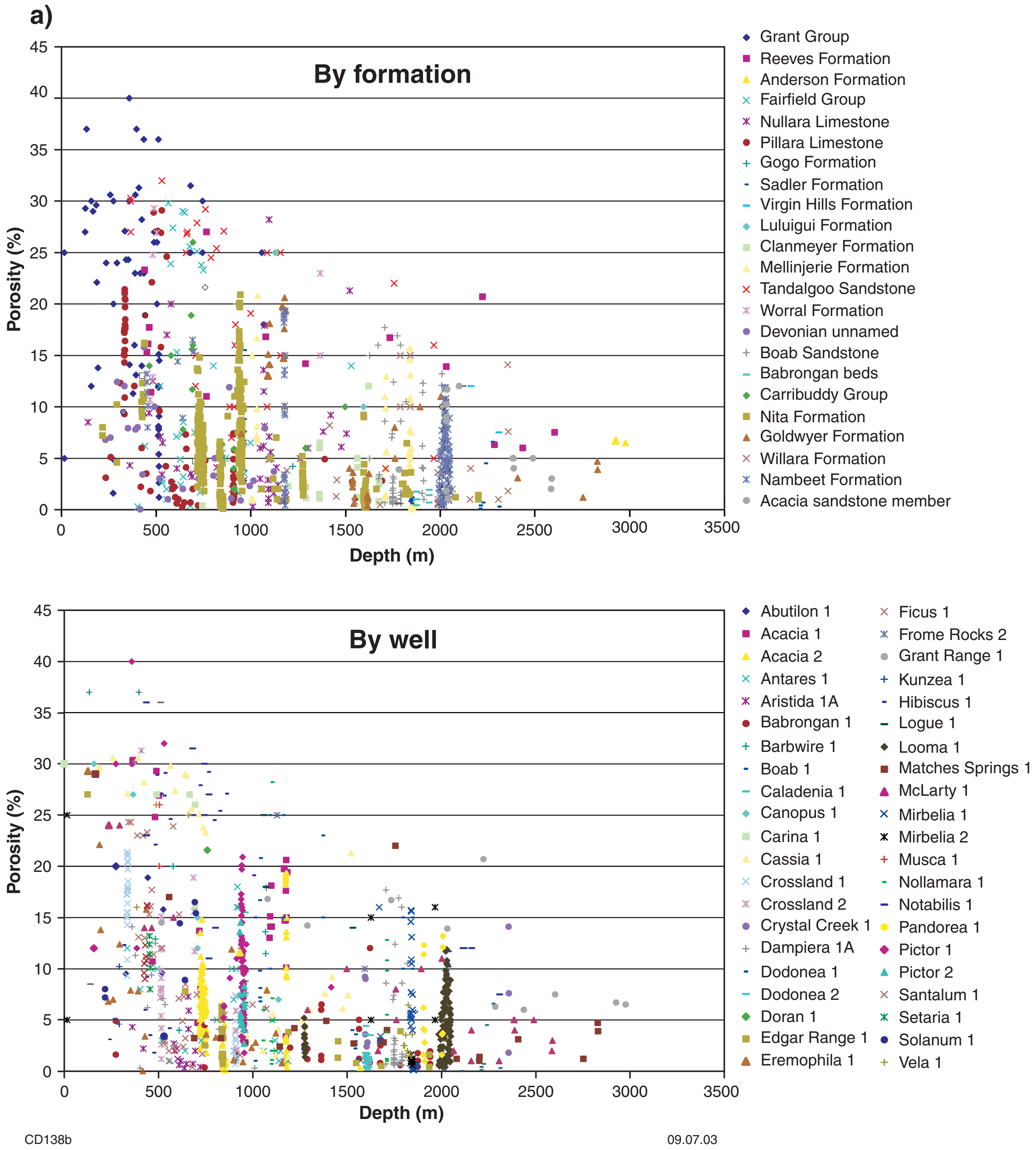


Figure 25. a) Porosity versus depth for potential reservoirs

overstepping seal strata, provides numerous prospective mound targets, but these are extremely high-risk plays.

The most widely distributed post-salt reservoirs are reefal carbonate facies of the Pillara and Nullara Limestones, which rim the Fitzroy Trough, and sandstone of the Grant Group. Other potential reservoirs are the Tandalgoo Sandstone, Worral Formation, Mellinjerie Formation, Boab Sandstone, Fairfield Group (Laurel and Yellow Drum Formations), and Anderson Formation. Several of these units have a restricted distribution and are only present in a few wells.

The post-salt plays depend largely on a pre-salt source and breaching of the Mallowa Salt along the sub-basin margins to allow 'back-spill' migration into them, as well as updip migration directed to the southeast, prior to the Meda Transpressional Event (SRK Consulting, 1998; Shell Development (Australia) Pty Ltd, 2000). The dominant risk is breaching of traps during the Late Triassic to Early

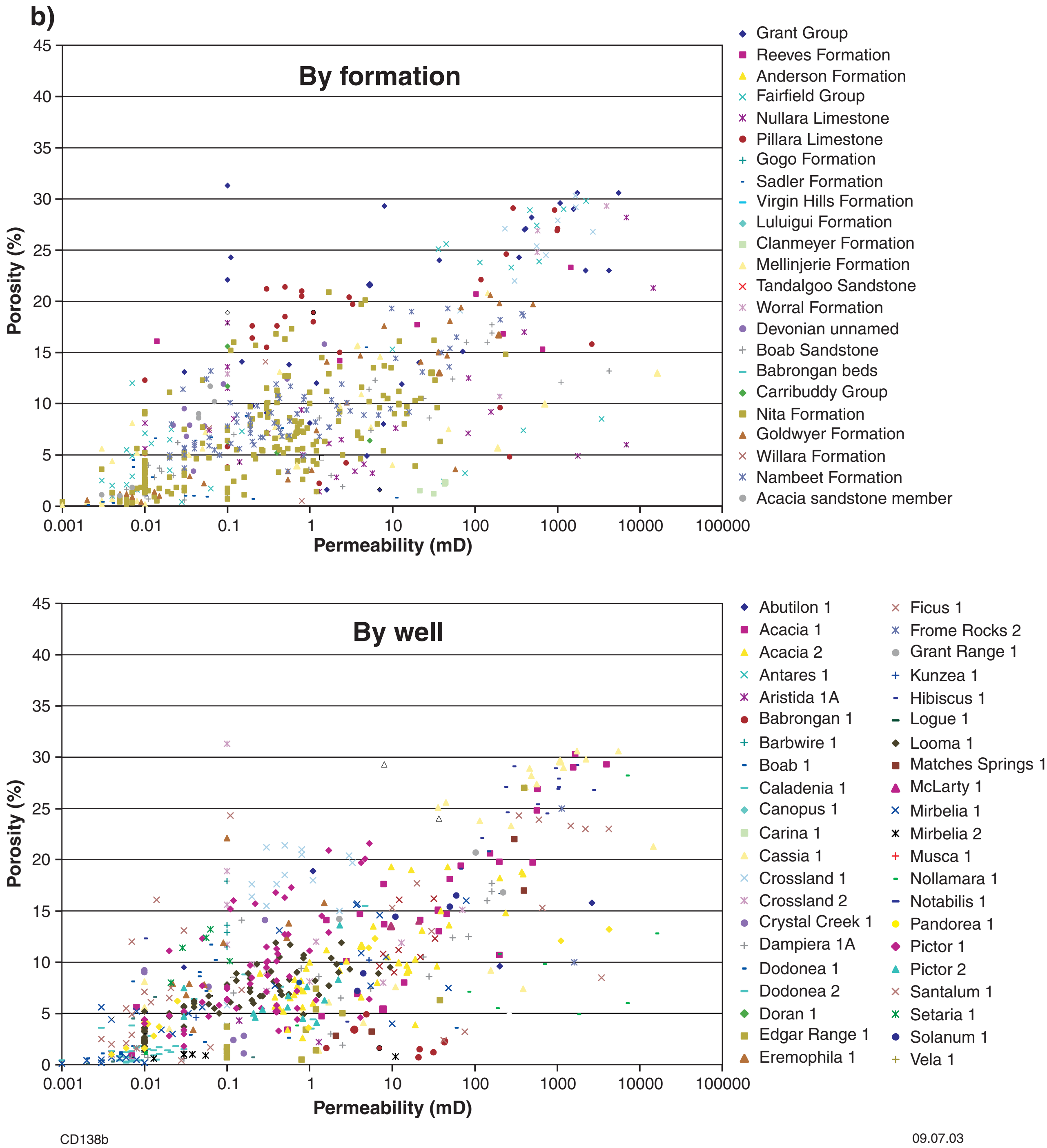


Figure 25. b) Porosity versus permeability for potential reservoirs

Jurassic Fitzroy Transpressional Movement, particularly near major strike-slip faults and the larger anticlines. Inversion at this time created most of the post-salt structures, and was responsible for the last significant salt-dissolution event (Shell Development (Australia) Pty Ltd, 2000).

The post-salt plays rely mainly on the same charge system as pre-salt plays. Migration of hydrocarbons into the post-salt structures requires fault conduits and migration from a pre-salt source or pre-salt temporary accumulations (e.g. 'Acacia sandstone member'), or both, in Devonian and younger reservoirs (see **EP 353 R1**).

The primary risks in the post-salt plays are oil biodegradation (as the reservoirs are fairly shallow), seal integrity, charge, and reservoir quality and extent. With respect to lateral seals across faults, the thin and discontinuous nature of intraformational shales in the Grant Group, and the local erosion of the Nura Nura

Table 5. Play types in the central Canning Basin

Reservoir	*Seal*	*Source*	*Structure*	*Location*	*Key risks*
Permian–Carboniferous					
Poole Sandstone	Noonkanbah Fm	Grant Gp shales	Drape over fault related or reefal highs; wrench anticlines; salt related traps	Adjacent to margins of Fitzroy Trough, Jurgurra and Mowla Terrace, Crossland Platform	Reservoir quality and presence, shallow oil biodegradation; small trap sizes
Grant Group	Intraformational shales and claystones	Laurel Fm shales, Goldwyer Fm	Drape over fault related or reefal highs, wrench anticlines, salt related traps (sombreros)	Central Canning Basin (entire), associated with salt edge	Reservoir presence, top and lateral seal quality, oil degradation
Reeves Formation	Grant Gp, ?Nura Nura Member, ?Noonkanbah Fm	?Upper Devonian shales or Goldwyer Fm	Drape over fault related or reefal highs, simple anticlines	Fitzroy Trough, Barbwire, Mowla, and Jurgurra Terraces, ?Broome Platform	New, untested play; ?oil degradation, reservoir quality and presence, small trap sizes
Anderson Formation	Intraformational shales, Grant Gp, Noonkanbah Fm, Nura Nura Member	Laurel Fm shales, Goldwyer Fm	Stratigraphic turbidite traps enhanced by Triassic inversion, simple anticlines	Fitzroy Trough, Mowla Terrace, Broome Platform	New, untested play; reservoir and seal distribution uncertain, oil degradation, small trap sizes
Fairfield Group (Laurel and Yellow Drum Formations)	Intraformational siltstones and shales (Laurel and Gumhole Fms)	Intraformational shales (Laurel Fm)	Drape over fault-related or reefal highs; wrench anticlines, salt related structures	Fitzroy Trough, Barbwire and Jurgurra Terrace, northern part of Mowla Terrace	Seal breach reservoir presence and quality, small trap sizes
Devonian					
Nullara Limestone	Fairfield Gp, intraformational shales and tight limestones, Clanmeyer and Luluigui Fms	Boab Sandstone, Pillara Limestone, Mellinjerie Fm, or Gogo Fm	Biohermal build-ups, anticlinal drapes controlled by transverse faulting	Southern flank of Fitzroy Trough, Barbwire Terrace, thinner on Jurgurra and Mowla Terraces	Reservoir quality and development, migration, immaturity of Gogo Fm source, gas flushing
Pillara Limestone	Intraformational shales and tight limestones, Napier Fm, tight Nullara Limestone, Clanmeyer and Luluigui Fms, Fairfield Gp	Boab Sandstone, Pillara Limestone, Mellinjerie Fm, or Gogo Fm	Biohermal build-ups, anticlinal drapes controlled by transverse faulting	Southern flank of Fitzroy Trough, Barbwire Terrace, thinner on Jurgurra and Mowla Terraces	Reservoir quality and development, migration, immaturity of Gogo Fm source, gas flushing
Tandalgoo Sandstone	Dominic Shale, intraformational shales, ?basin facies of the Nullara/ Pillara Limestones	Goldwyer Fm, Boab Sandstone, or Gogo Fm	Salt related structures (sombreros), drape over sombreros, 4-way dip and fault-bounded anticlines	Southern flank of Fitzroy Trough, Jurgurra and Barbwire Terraces, Broome Platform, associated with salt edge	Requires migration through Carribuddy Gp, removal of thin top seal by erosion, reservoir facies change, oil degradation
Boab Sst	Gogo Fm	Intraformational, Gogo Fm	4-way dip and fault-bounded anticlines	Barbwire Terrace	Not widespread, reservoir facies change
Worral Formation (Elsa Sandstone Member)	Intraformational shales (Waldecks Member)	Goldwyer Fm, ?Willara, Gogo, ?Bongabinni, and Nambeet Fms	Salt related structures (sombreros), 4-way dip and fault-bounded anticlines, rotated fault blocks	Southern flank of Fitzroy Trough, Jurgurra and Barbwire Terraces, associated with salt edge	Sealing potential and thickness not proven, oil degradation

Table 5 (continued)

Reservoir	*Seal*	*Source*	*Structure*	*Location*	*Key risks*
Ordovician					
Nita Formation	Evaporites and shales of the Carribuddy Gp (Bongabinni and Nibil Fms, Mallowa Salt), mudstones and tight limestones of the Goldwyer and Willara Fms	Goldwyer Formation, ?minor Willara Fm, ?Bongabinni	4-way dip and fault bounded anticlines, rotated fault blocks	Southern flank of Fitzroy Trough, Jurgurra, Mowla, and Barbwire Terraces, and Broome Platform	Variable reservoir quality and development, depth conversion, base Permian unconformity may have eroded the top seal
Goldwyer Formation	Intraformational shales, ?Carribuddy Gp	Goldwyer Fm	4-way dip and fault-bounded anticlines	Jurgurra, Mowla, and Barbwire Terraces	Variable reservoir quality and development
Willara Formation ('Acacia sandstone member')	Goldwyer Fm, intraformational shales and limestones	Goldwyer Fm, ?minor Willara Fm	4-way dip and fault-bounded anticlines, tilted fault blocks	Jurgurra, Mowla, and Barbwire Terraces, and Broome Platform	Variable reservoir quality and development, depth conversion
Nambeet Formation	Intraformational shales or Goldwyer Fm, ?Mallowa Salt	Intraformational shales, or Goldwyer Fm	4-way dip and fault-bounded anticlines, basement drapes	Broome Platform and Barbwire Terrace	Reservoir quality; trap integrity, gas versus oil

NOTES: Fm: Formation
Gp: Group
Sst: Sandstone

SOURCE: modified from Shell Development (Australia) Pty Ltd (2000)

Member, in particular, are deemed key risks for some of these plays.

Hydrocarbons shows

The most significant hydrocarbon shows recorded in the area are within the Nita, Goldwyer, and Willara formations, and Upper Devonian units on the Barbwire and Mowla Terraces, from both petroleum and mineral exploration wells. Oil saturated mineral cores have also been reported along the Admiral Bay Fault Zone (McCracken, 1994, 1997). Only minor shows are recorded on the Jurgurra Terrace, and one show on the Broome Platform (Table 1). Hydrocarbon shows in the Fitzroy Trough are within the Carboniferous–Permian section (Table 1), whereas fields in the Lennard Shelf span the Upper Devonian to Lower Permian sections (Table 2).

Oil has been recovered from Dodonea 1, Mirbelia 1, and Pictor 1 and 2 within the Ordovician section. Live oil shows have been recorded from Acacia 1, Aristida 1/1A, Canopus 1, Dodonea 2, Edgar Range 1, Eremophila 1 and 2, Goodenia 1, and Looma 1 (Table 1). The hydrocarbon shows from the Nita and Goldwyer Formations consist of: live oil (trace to minor quantities recovered on testing, evident in vugs and fracture surfaces in cores and bleeding from tight core sections); fluorescence, commonly with cut and residue; minor oil staining; and some hydrocarbon odour (Table 1; Appendix 1). Hydrocarbon shows from fractured and vuggy Upper Devonian dolomites and Permian conglomerates consist of heavy, biodegraded oil with fluorescence (Table 1; Appendix 1). In some cases, gas shows are associated with dead-oil stains, but these lack fluorescence (e.g. Fitzroy River 1).

All shows in Eremophila 1 and 2, Goodenia 1, and Aristida 1A are at the base of the Permian section in structural highs adjacent to the Dummer Range Fault System, and represent oils or seeps migrated from depth (Western Mining Corporation Ltd, 1982, 1987). The hydrocarbons are biodegraded, restricted to fractures and vugs in the Permian section as shallow as 96 m, and are absent from pre-Permian dolomite intercrystalline pores (Western Mining Corporation Ltd, 1982, 1987).

The lack of shows in the remaining wells of the acreage release area could be attributed to lack of adequate source horizons or migration pathways, wells not being a valid structural test, lack of thermal maturity, or a combination of these three factors. Oil-saturated mineral cores and live oil recovered in the region suggest multiple oil source rocks in the area (Western Mining Corporation Ltd, 1982, 1987).

Prospects and leads inventory

The following inventory summarizes post-1980 exploration prospects and leads for the four gazetted areas L03-4, L03-5, L03-6, and L03-7 (Fig. 26). All information on the prospects and leads in the historic permits within and immediately adjacent to these release areas has been obtained from published reports or open-file statutory petroleum exploration reports held by DoIR. All the permits discussed below are no longer current. Their positions relative to the acreage release areas are shown in Figure 26.

Much of the subsurface mapping in the central Canning Basin is of low reliability due to poor seismic quality or inadequate seismic coverage. Seismic data in the region are of variable quality: data of post-1984 vintage are generally good quality, 1982–84 data are average quality, and pre-1982 data are typically poor quality. Because of the poor-quality seismic data, misties in much of the company mapping were up to 35 ms. Although numerous wells have been drilled in the region, many were based on inaccurate mapping or were stratigraphic tests. With improved seismic data and revised mapping, the structural validity of many of the early targets will probably be disproved.

There is no reassessment, based on seismic data, for any of the prospects and leads discussed in this Record. All well information has come from unpublished well completion reports; relevant wells and the corresponding reports are summarized in Appendices 1 and 2. No commercial considerations are included here. The volumetrics used in this Record are as provided by the permit operators from the open-file data.

EP 103 R1

EP 103 R1 was operated by Kufpec Australia Pty Ltd from 1982 to 1990. During this time, 2597 line-km of 2D seismic data were acquired (Fitzroy Basin seismic surveys) and six new-field wildcats were drilled (Crystal Creek 1, Hakea 1, Lovell's Pocket 1, Notabilis 1, Nollamara 1, and Nuytsia 1). The total depths (TD) of these wells range from 1350 to 2811 m, with Crystal Creek 1 and Lovell's Pocket 1 terminating in the Ordovician Willara Formation, and the remainder terminating in Devonian or younger rocks. This region was largely covered by the subsequent permit EP 377 (see **EP 377**).

EP 143 (now EP 373)

Permit EP 143 was operated by WMC from 1979 to 1989. During this time, WMC acquired 2764 line-km of 2D seismic data (Acacia (1981), Bongabinni, Dora 1983, Minjoo, Nibil, and Nita 1982 (Phase 1 and 2) seismic surveys) and drilled 24 wells (Abutilon 1, Acacia 1 and 2, Aristida 1/1A, Boab 1, Capparis 1, Cassia 1, Dampiera 1/1A, Dodonea 1 and 2, Frankenia 1, Ficus 1, Halgania 1, Hibiscus 1, Melaleuca 1, Mirbelia 1 and 2, Pandorea 1, Panicum 1, Pratia 1, Setaria 1, Solanum 1, Triodia 1, and Typha 1; Appendices 1 and 2). Of these, 15 were stratigraphic wells, eight were new-field wildcats, and one was an extension well (Appendix 2). Acacia 1 and 2, Dodonea 1 and 2, Mirbelia 2, Setaria 1, and Solanum 1 intersected Lower–Middle Ordovician rocks, Boab 1 and Mirbelia 1 were terminated in the Ordovician–Silurian Carribuddy Group, Melaleuca 1 was terminated in the Permian, and the remaining wells were completed in Devonian strata. The region covered by EP 143 now falls

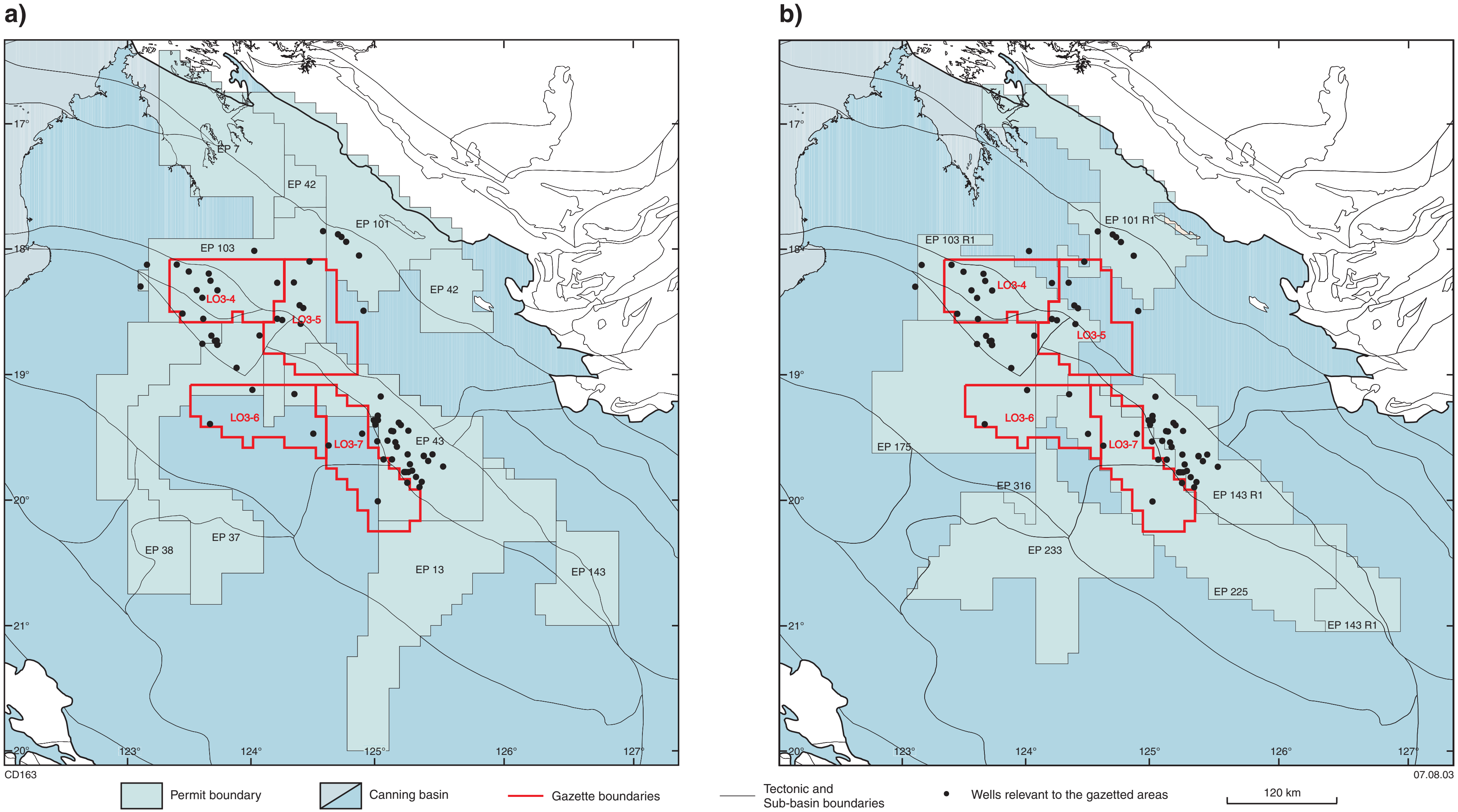


Figure 26. The four gazetted areas L03-4, L03-5, L03-6, and L03-7, showing: a) pre-1980 permits and b) 1980–85 permits (continued over page)

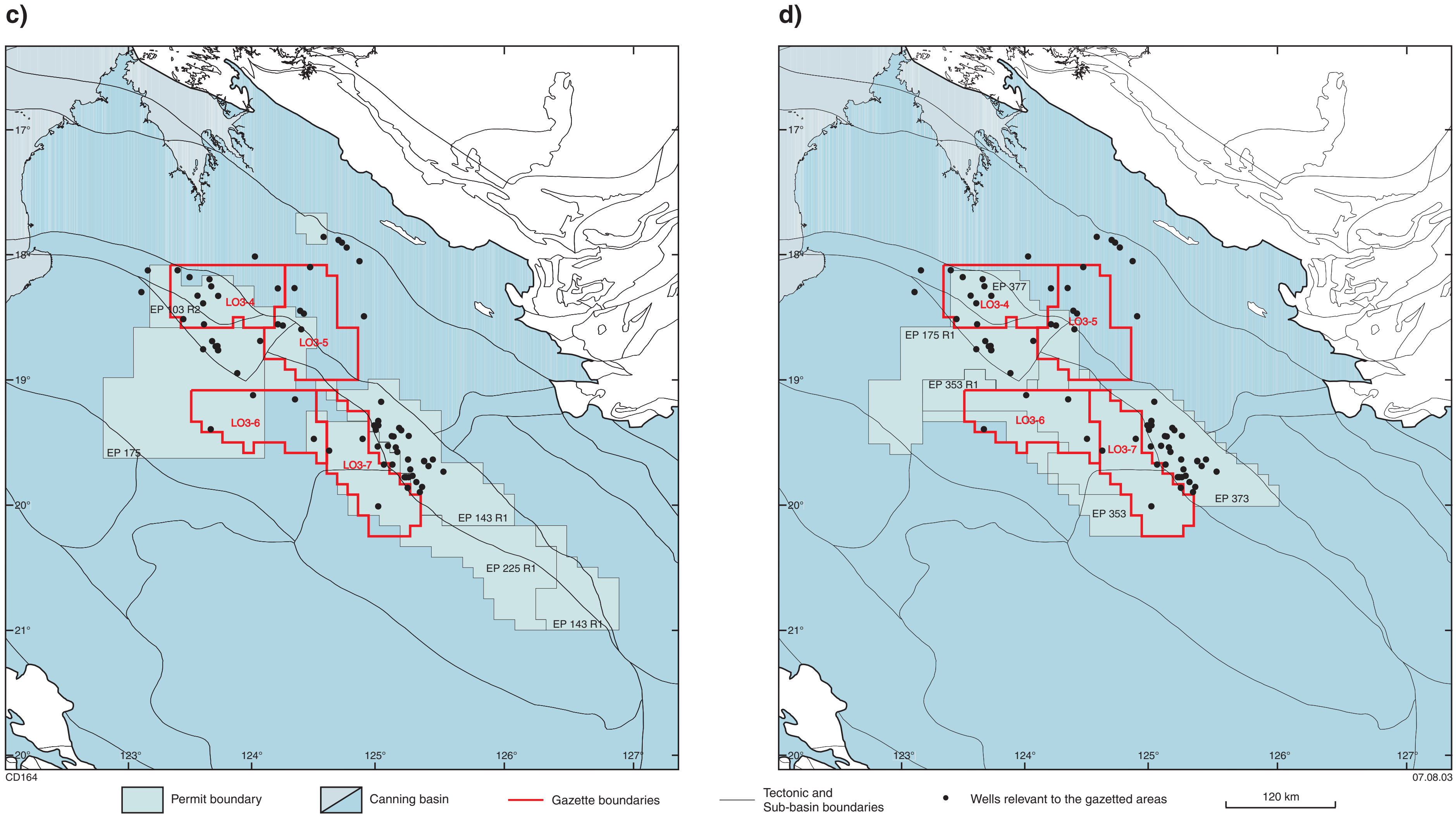


Figure 26 (continued). The four gazetted areas L03-4, L03-5, L03-6, and L03-7, showing: c) 1985–90 permits; and d) post-1990 permits

within EP 373, which was granted from 1993 to 1998 and operated by Pasminco Australia Ltd, and later granted to Black Rock Petroleum NL in 1998 for another five years. Black Rock Petroleum NL are currently (July 2003) reprocessing existing seismic data and evaluating the prospectivity of the region.

The majority of EP 143 is situated on the Barbwire Terrace. The permit is dominated by the Dummer Range Fault System in the southwest, and by the Fenton Fault System in the northeast (Fig. 27). The Barbwire Terrace consists of a series of complexly faulted blocks. There are several prospects and leads within the permit (Figs 27 and 28; Table 6) ranging from anticlines to fault-related traps, as well as carbonate build-ups. Black Rock Petroleum NL have reassessed some of these prospects and leads, and renamed some of them (Fig. 29). Additional prospects and leads in EP 373 are not discussed due to a confidentiality agreement with Black Rock Petroleum NL.

Acacia prospect

Hydrocarbon type	Oil
Play type	Anticline
Primary objective	Nita Formation
Secondary objective	Goldwyer Formation
Key strengths	Proximity to known reservoir rocks and migration pathway
Key weaknesses	Small areal extent and structural integrity
Seismic coverage	7 seismic lines of 1982 and 1984 vintage

Summary

The Acacia prospect is located in the northwestern part of EP 143, east of the Dummer Range Fault. The Boab

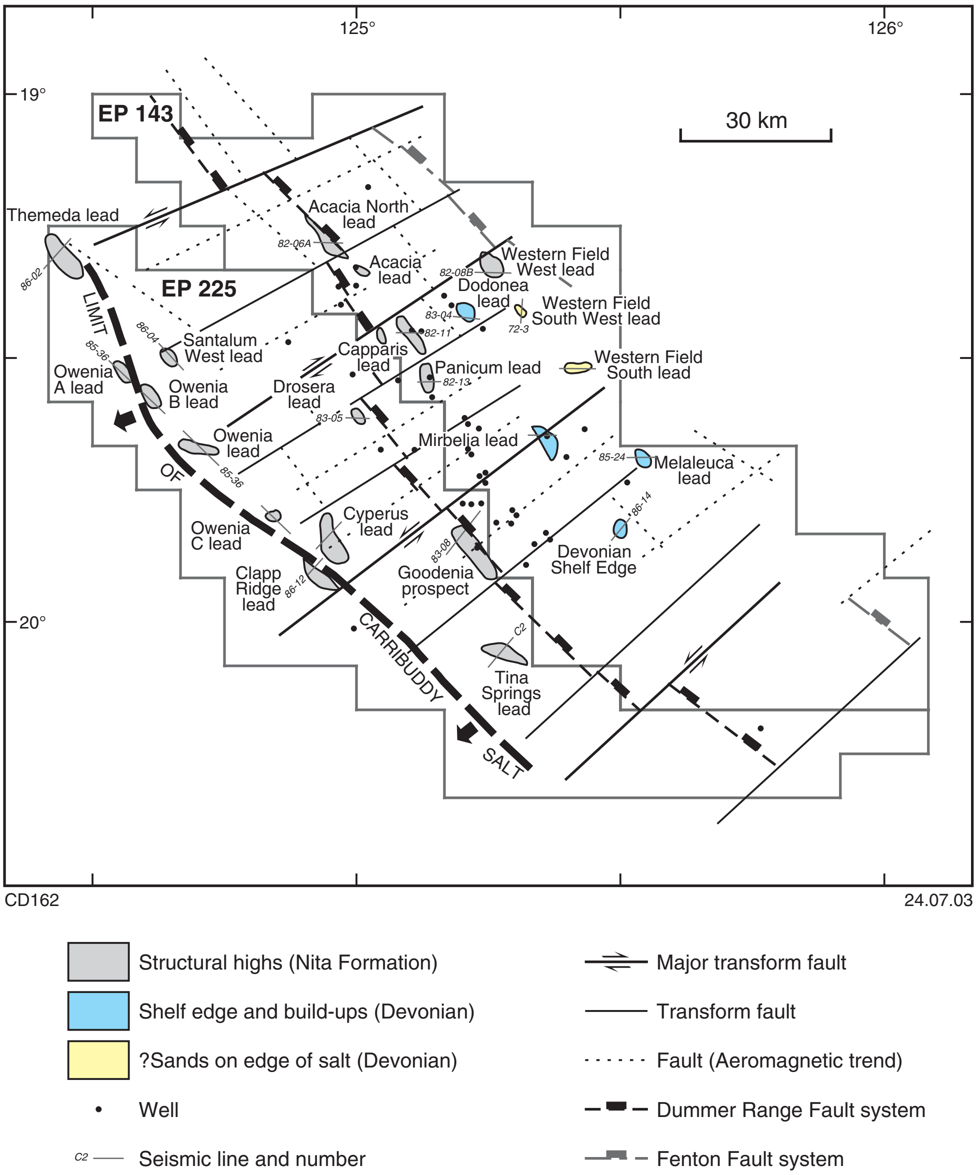


Figure 27. Prospects and leads of EP 143 and 225 (after Western Mining Corporation, 1990)

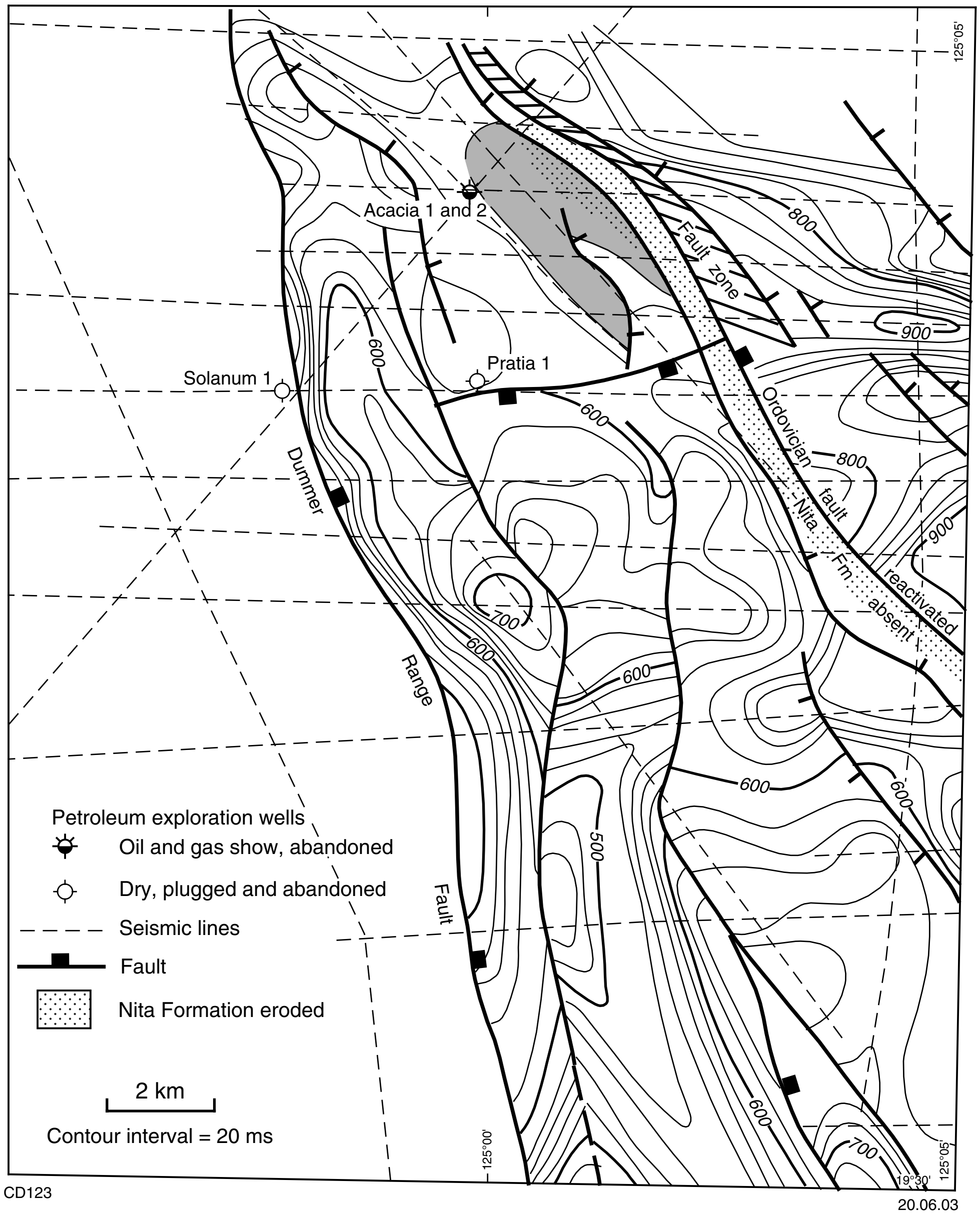


Figure 28. Two-way-time contours to the top Nita Formation, Acacia prospect (after Jones, 1986)

and Nita 1982 (Phase 1 and 2) seismic surveys showed potential closure of the Acacia prospect updip and to the southeast of Acacia 1 and 2 (Fig. 28). Non-commercial oil shows were recorded from the Nita Formation in Acacia 1, whereas only fluorescence was detected in Acacia 2 (98 m south of Acacia 1) in the same unit. Both wells displayed good to excellent porosity and permeability values in the Nita Formation, suggesting the trap was breached.

The seismic data show complex faulting in the area, but given the poor to average quality of the data, the uncertainty of the structural integrity is a major risk for this prospect. The other main risk is the small areal extent.

Nearby wells

Acacia 1 and 2, Pratia 1, Setaria 1, and Solanum 1.

Trap

The Acacia prospect is a northwesterly trending faulted anticline with small areal extent on a titled fault block. At Nita Formation level, the structural high lies just east of Acacia 1 and 2 on the downthrown side of the Dummer Range Fault (Fig. 28). It has fault closure to the east, and dip closure to the west (Fig. 28). The Nita Formation has been eroded and truncated on the upthrown side of the bounding fault (Jones, 1986). A local erosional surface within the Carribuddy Group, which directly overlies the Nita Formation, was seen in the seismic data.

Where the Carribuddy Group is not eroded, evaporitic rocks or shale within the group are expected to seal the Nita and Goldwyer Formations. Alternative seals include mudstone and tight limestone horizons in the Goldwyer and Willara Formations.

Table 6. Leads in EP 143

Lead name (WMC)	*Lead name (Black Rock)*	*Seismic line*	*Reservoir (WMC)*	*Reservoir (Black Rock)*	*Recoverable resources[(a)] (GL)*	*Structure*
Acacia	–	–	Nita Formation	–	–	Faulted anticline
Acacia North	–	N-W82-06A	Nita Formation	–	–	Faulted anticline
Capparis	Axel	N-W82-11	Nita Formation	'Acacia sst mbr'	9.79	Faulted anticline
Devonian shelf edge	–	NIB86-14	Devonian	–	–	Carbonate mound
Dodonea	Dodonea North	D83-04	Devonian	'Acacia sst mbr'	3.50	Carbonate mound
				Goldwyer Formation	1.27	
Melaleuca	?Pryde	BONG-85-24	Devonian	'Acacia sst mbr'	2.23	Carbonate mound
Mirbelia	Mirbelia		Devonian	'Acacia sst mbr'	–	Carbonate mound
Panicum	–	W82-13	Nita Formation	–	–	Faulted anticline
Western Field West	–	W82-08B	Nita Formation	–	–	?Anticline
Western Field Southwest	–	72-3	Devonian sandstones	–	–	Salt edge dissolution
Western Field South	–	W82-13	Devonian sandstones	–	–	Salt edge dissolution

NOTES: (a) Source from Department of Industry and Resources (2003)

Source

The upper part of the Goldwyer Formation should provide oil-prone source rocks for the area, as it is currently within the oil-generative window. Live-oil shows were recorded in Acacia 1 and to the east in Dodonea 1 and 2, with the Goldwyer Formation providing the source (see **Source rock and maturity**). The presence of oil shows implies that a migration pathway operated in the region.

Reservoir

The leads are close to wells in which the Ordovician section has fair to excellent reservoir quality. Based on Acacia 1 and 2, average porosities for the Nita Formation should be 4–8%, with average permeabilities ranging from 5.44 to 11.91 mD. The Goldwyer Formation could be a possible secondary reservoir target, as porosity values of up to 20.6% were recorded in Acacia 1.

Capparis and Panicum leads

Hydrocarbon type	Oil
Play type	Faulted anticline
Primary objective	Nita Formation
Key strengths in the area	Reservoir and proven source
Key weaknesses	Structural integrity
Seismic coverage	Panicum lead has 6 seismic lines and Capparis has 4 seismic lines of 1982 and 1984 vintage

Summary

The Capparis and Panicum leads are located in the central part of EP 143, east of the Dummer Range Fault (Fig. 27). Both leads target the Middle Ordovician Nita Formation, whereas Capparis 1 and Panicum 1 had Upper Devonian objectives, and were terminated in the Tandalgoo Sandstone and Boab Sandstone respectively. The Capparis lead has been renamed the Axel prospect by Black Rock Petroleum NL (Fig. 29), who have retargeted it to the 'Acacia sandstone member' of the Willara Formation.

The main risk involved with this prospect is the uncertainty of the structural integrity, given that the seismic lines are of poor to average quality. Additional seismic data are needed to improve the definition of the crestal high and closure of the structures.

Nearby wells

Abutilon 1, Boab 1, Capparis 1, Panicum 1, and Typha 1.

Trap

The Panicum and Capparis structures are compressional structural highs on the Barbwire Terrace. The structures are interpreted to have dip and fault closure with possible fault-drag rollover, and may be sealed against the downthrown formations. The Panicum lead has dip closure to the northwest, south, and southeast, and fault closure to the west and northeast (Fig. 30). The Capparis lead has dip closure to the northwest and southeast, and fault closure to the southwest and northeast (Fig. 30).

Mapping of the structures is based on seismic data of variable quality and is therefore questionable. The structural highs at the Nita Formation level in the Capparis and Panicum leads lie north of Capparis 1 and Panicum 1.

Seals to these leads could be provided by either evaporitic rocks or shale horizons within the Carribuddy Group, if the group has not been eroded, or the mudstones and tight limestones of the Goldwyer and Willara Formations.

Source

Oil-prone source rocks in the upper part of the Goldwyer Formation currently within the oil-generative window are the most likely source, as demonstrated by live-oil shows recorded updip in Acacia 1 and Dodonea 1 and 2 from the Goldwyer Formation. The oil shows also indicate that a good migration pathway has operated in the region.

Reservoir

The leads are close to wells in which the Ordovician section has fair to excellent reservoir quality. Based on these wells, average porosities for the Nita Formation are estimated at 3–8%. For the 'Acacia sandstone member', Black Rock Petroleum NL estimated porosities of 15 to 20%, and permeabilities of about 250 mD (Department of Industry and Resources, 2003) from the surrounding wells (Acacia 2, Setaria 1, and Solanum 1). The 'Acacia sandstone member' is reasonably thick in the area and should provide an adequate reservoir.

EP 175

Permit EP 175 was operated by Getty Oil Development Company Ltd from 1980 to 1983, and then taken over by

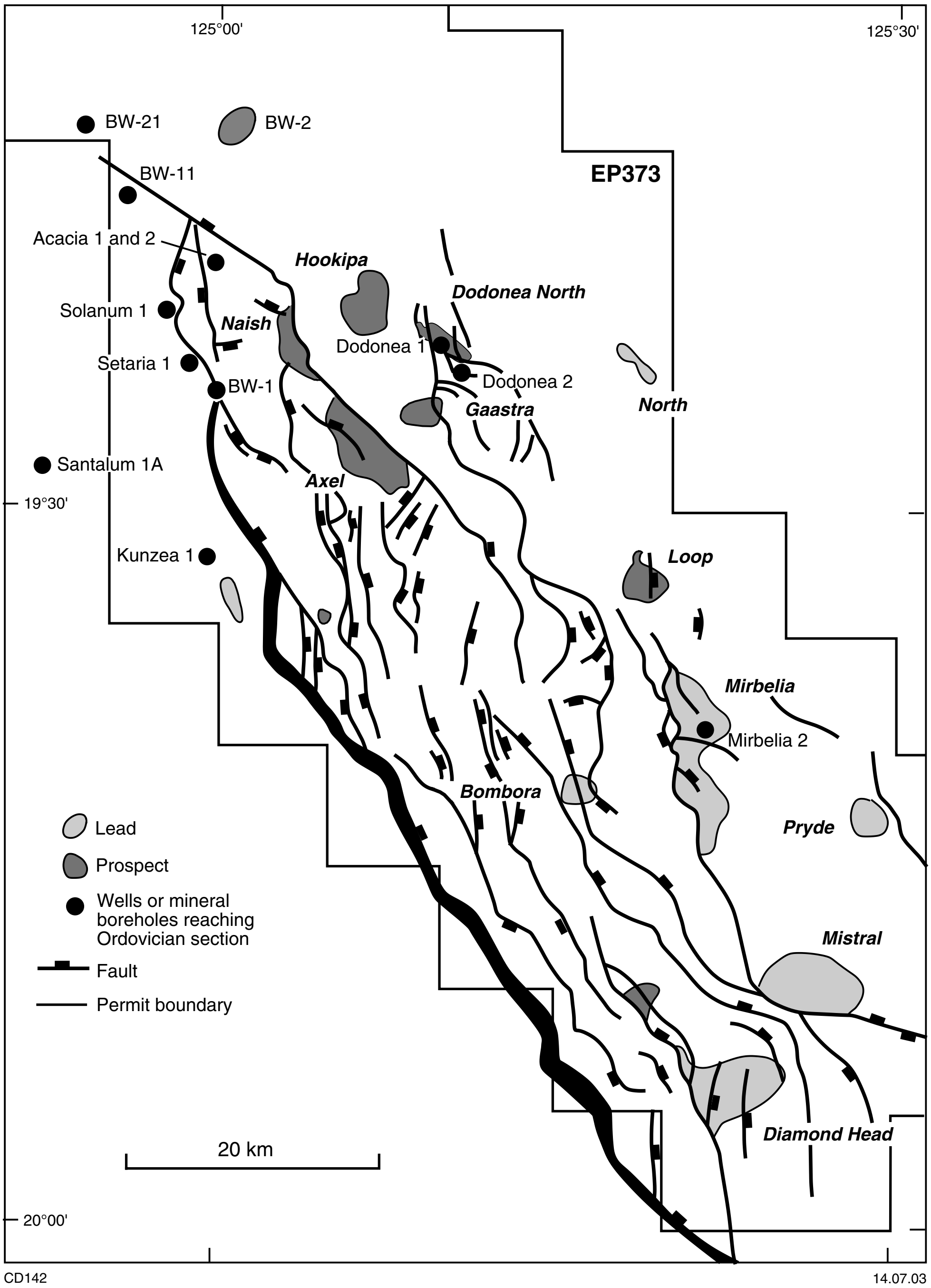


Figure 29. Prospects and leads on EP 373 at the top 'Acacia sandstone member', intra Willara Formation (after Department of Industry and Resources, 2003)

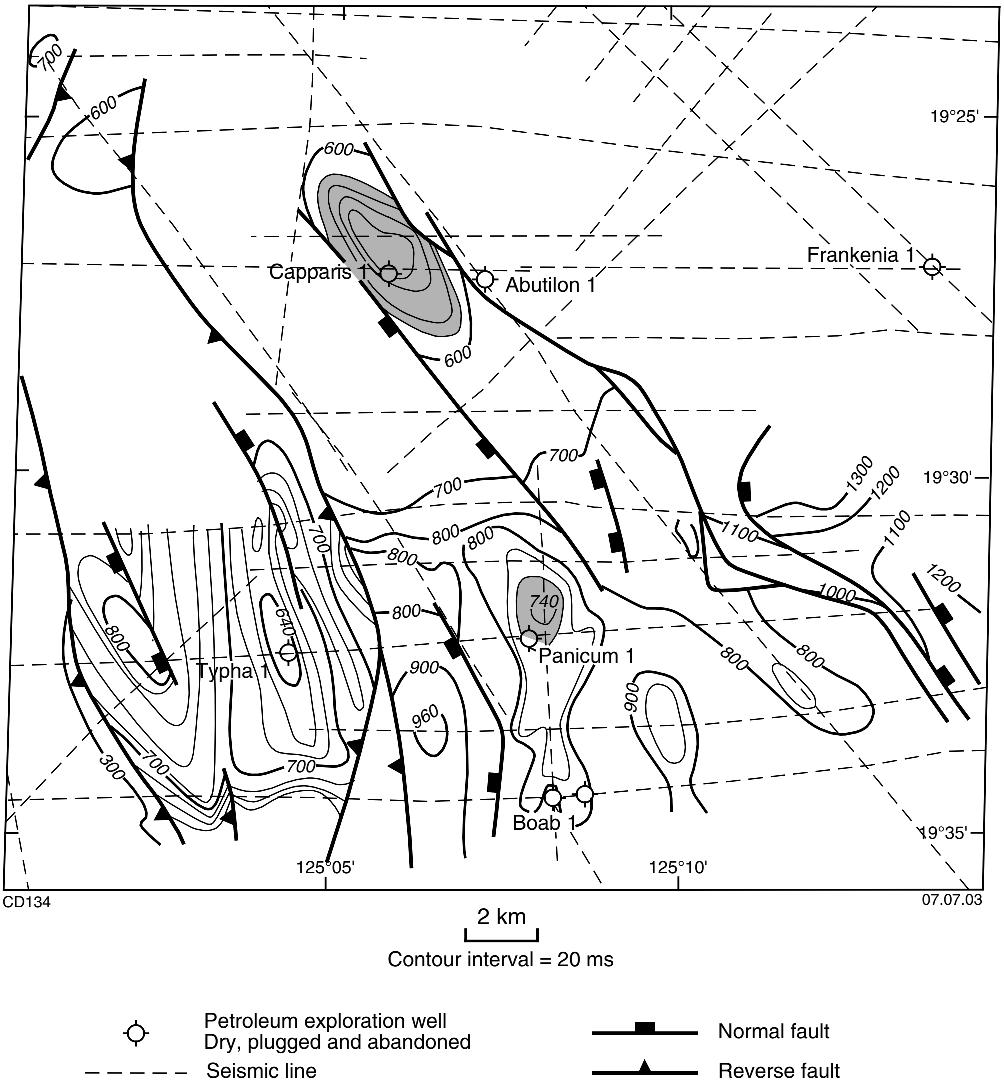


Figure 30. Two-way-time contours to the top Nita Formation, Panicum and Capparis leads (after Jones, 1986)

BHP Petroleum from 1983 to 1990. Bridge Oil Ltd (now Parker and Parsley Australasia Limited) renewed the permit from 1990 to 1995. Over the period 1980–85, 1839 line-km of 2D seismic data (Carribuddy, Cuncudgerie, and Nambeet 1981 seismic surveys) were acquired, and five new-field wildcats (Canopus 1, Carina 1, Musca 1, Pictor 1, and Vela 1; Appendices 1 and 2) were drilled into Ordovician rocks. From 1985 to 1990, 784 line-km of 2D seismic data (Jarlemai, Geegully, and Mowla Experimental seismic surveys) were acquired, and one new-field wildcat (Antares 1) and one extension well (Pictor 2) were drilled.

EP 175 covers part of the Broome Platform and Mowla Terrace. The Admiral Bay Fault Zone extends through the southwestern part of the permit, and the Collins Fault extends through the northeastern part. The permit was subdivided into four regions by Getty Oil Development Company Ltd: the northeast, northwest, southwest, and central EP 175 quadrants.

Potential reservoirs within EP 175 extend from the Lower Ordovician section up to the Permian section, with the best-quality reservoirs being sandstone intervals of the Permian Grant Group and Devonian Tandalgoo Sandstone. Upper Devonian carbonate facies may potentially contain the thickest reservoirs in this area, as either reefal facies or fracture enhanced reservoirs, or a combination of both (Bellis, 1987). Nearby wells that intersect the Nita Formation indicate that the greatest thickness, and porosity development due to dolomitization, is in the northwest quadrant (Bridge Oil Ltd, 1993a). Good seals are expected in the northeast, southwest, and central quadrants of the permit for Ordovician to Silurian reservoirs, but are risky in the northwest quadrant. Seals for Devonian units are of variable quality but high risk, and those for the Permian units are good in the northwest but risky in the northeast quadrant. Figure 31 and Table 7 show all the prospects and leads within EP 175. Only the prospects and leads for which detailed information is available are discussed below.

Northeast EP 175 prospects and leads

Hydrocarbon type	Oil and gas
Operator	Bridge Oil Ltd
Depth to objective	400–3500 m SS (subsea)
Play type	Faulted anticlinal structures
Primary objective	Nita Formation
Secondary objectives	Sandstone within the Grant Group, Pillara Limestone, Tandalgoo Sandstone, and Mount Troy, Willara, and Nambeet Formations
Key strengths	Known source and presence of migration pathway
Key weaknesses	Structure and reservoir
Seismic coverage	Numerous lines of various vintages and quality

Summary

A group of prospects and leads was mapped northeast of the Collins Fault in EP 175 on the Mowla Terrace (Fig. 31). The area is dominated by northeasterly trending faults. Most of the plays target the Middle Ordovician Nita Formation, with Permian, Devonian, and Ordovician sandstone and dolomite as secondary objectives. Fracturing caused by wrench movement has probably induced good porosity and permeability within the reservoirs. Four of these structures are discussed in more detail below (see **Centaurus lead**, **North Pictor prospect**, **Pictor prospect**, and **Pointers lead**). The quality of seismic data within northeast EP 175 is fair to poor, with the poorest-quality data below the Grant Group in the northeastern corner in the Moose/Elk area. The seals in this same corner are risky for the Permian units, and fault seals around the Collins Fault area are questionable.

Nearby wells

Antares 1, Canopus 1, Crystal Creek 1, Edgar Range 1, Looma 1, Lovell's Pocket 1, Matches Springs 1, Mowla 1, Mount Alexander 1, and Pictor 1 and 2.

Trap

These structures are tightly folded, northwesterly trending, faulted anticlines that were modified by steep-angle reverse faults associated with strike-slip movement along the Collins Fault (Fig. 31). They are expected to have fault and dip closure at the top of the Ordovician objectives (Nita and Nambeet Formations). These features are probably the result of the Fitzroy Transpressional Movement, which was a major period of structural development during the Late Triassic to Early Jurassic (see **Tectonic evolution**).

Various seals should be present. The Nita Formation should be sealed by shale intervals in the Carribuddy Group (i.e. the Bongabinni and Nibil Formations), which are of good quality in the area. Shale in the Goldwyer Formation is expected to provide a fair to good quality seal for the Willara Formation. Sandstone in the Grant Group could be sealed by intraformational shale and claystone, but are a high risk in the region as they may be locally absent, discontinuous, or thief zones if sandy. The Tandalgoo Sandstone frequently grades upwards to a thin shale unit or contains interbedded shale. Therefore, an intraformational seal is expected for this reservoir. Where mid-Carboniferous erosion has not removed sealing facies within the Carribuddy Group and the uppermost Nita Formation, oil shows within the latter unit are common in the area.

Source

The upper part of the Goldwyer Formation is expected to provide the major source in this area, with minor input from the Willara Formation. TOC values are up to 6.4% in these units. Source-rock maturity studies indicate that generation from these units, which are still within the oil window, peaked in the Late Jurassic to Late Cretaceous (Bridge Oil Ltd, 1993a).

Reservoir

The main reservoir unit in northeast EP 175 is the Nita Formation, which consists of 1–5 m-thick, fining-upward carbonate cycles. These facies may have undergone fracturing in the tightly folded anticlinal structures, inducing porosity and permeability. The formation displays good lateral continuity and can be correlated in wells across EP 175. Porosity within the Nita Formation in surrounding wells is fair to good, with a range of 7–20%, but commonly with an average of 10%. Permeability values range from 1 to 40 mD, with an average of 5 to 10 mD.

Sandstone intervals within the Willara Formation in the region are up to 60 m thick, averaging 15 m, but are discontinuous. Porosity values average 11% with a range of 8–20%. Permeability is variable, ranging on average from 10 to 100 mD, but in places up to 500 mD. Fractured Willara Formation reservoir net thickness ranges from 0 to 200 m, with porosity values averaging 2–3% (range of 1 to 20%), and permeability values ranging from 0.1 mD to 1 D (Bellis, 1987). Fracture-enhanced reservoirs may be present in the Nambeet Formation near the major faults within northeast EP 175.

Potential reservoir intervals within the Mount Troy Formation (Carribuddy Group) are 10–20 m thick (Bellis, 1987). Porosity and permeability values from this unit in Pictor 1 range from 5.2 to 6.4% and 0.1 to 5 mD respectively. The Tandalgoo Sandstone comprises clean quartzose sandstone in this area and averages about 60 m in thickness, but is anomously thick in the southeastern part of the area, as shown by Canopus 1 (342 m; Bellis, 1987). Log-derived and core-derived porosities range from 2 to 32% in the nearby wells, and permeabilities range from 302 mD to 3 D (Bellis, 1987). A DST over this unit in Matches Springs 1 produced 464 kL/day (2920 bbl/day) of fresh water, demonstrating that it is a good aquifer.

Log-derived porosities of up to 12% have been noted from the Pillara Limestone. Sandstone intervals within the Grant Group range in thickness from 10 to 75 m with an average of 50 m. Porosity values from the group average about 30%, and permeability ranges from 0.5 mD to 2 D.

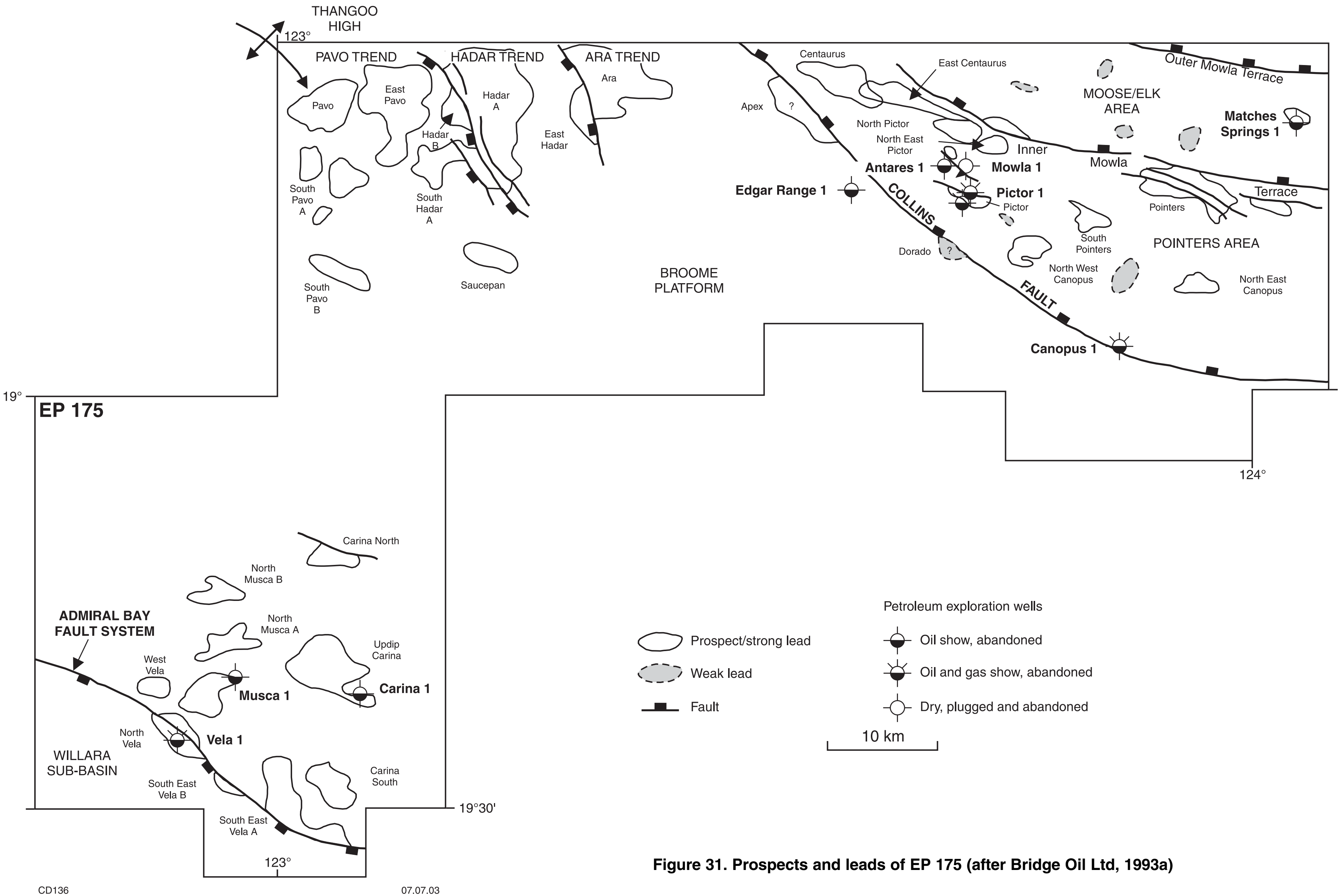


Figure 31. Prospects and leads of EP 175 (after Bridge Oil Ltd, 1993a)

Table 7. Prospects and leads in EP 175

Prospect/lead name	*Nearest well*	*Seismic line*	*Shot point*	*Reservoir*	*Time depth (ms)*	*Structure*
Apex	Edgar Range 1	HCG-205	900	Grant Group	300	Faulted anticline
				Nita Formation	450	
				Willara Formation	1100	
Ara	Edgar Range 1	HCG-103	500	Nita Formation	500	Simple faulted anticline
				Willara Formation	840	
Canopus Northeast	Canopus 1	B88-619	1800	Grant Group	500	
				Nita Formation	800	
				Willara Formation	1100	
Canopus Northwest	Canopus 1	83-567	240	Nita Formation	750	
				Willara Formation	950	
Carina North	Carina 1	80-522	450	Nita Formation	900	Faulted anticline
				Willara Formation	1210	
Carina South	Carina 1	80-518	500	Nita Formation	1050	
				Willara Formation	1240	
Carina Updip	Carina 1	80-516	440	Nita Formation	1100	
Centaurus	Antares 1	B88-606	500	Grant Group	300	Faulted anticline
				Nita Formation	750	
Centaurus West	Antares 1	HCG-207	450	Willara Formation	1150	Faulted anticline
Hadar A	Edgar Range 1	80-515	180	Grant Group	500	Faulted anticline
				Nita Formation	540	
				Willara Formation	860	
Hadar B	Edgar Range 1	80-548	220	Grant Group	500	Faulted anticline
				Nita Formation	560	
				Willara Formation	910	
Hadar East	Edgar Range 1	HCG-108	3000	Grant Group	520	Faulted anticline
				Willara Formation	910	
Hadar South A	Edgar Range 1	83-548	400	Grant Group	510	Faulted anticline
				Nita Formation	600	
				Willara Formation	940	
Musca North A	Musca 1	81-532	150	Nita Formation	1050	
				Willara Formation	1210	
Musca North B	Musca 1	81-532	220	Nita Formation	1000	
				Willara Formation	1270	
North Pictor	Antares 1	HCG-301	1000	Grant Group	250	Faulted anticline
				Nita Formation	850	
				Willara Formation	1100	
Pavo	Edgar Range 1	80-512	240	Grant Group	500	Faulted anticline
				Nita Formation	550	
				Willara Formation	870	
Pavo East	Edgar Range 1	HCG-106	1700	Grant Group	500	Faulted anticline
				Willara Formation	890	
Pavo South	Edgar Range 1	80-514	280	Grant Group	520	Faulted anticline
				Nita Formation	580	
				Willara Formation	910	
Pavo South B	Carina 1	B88-603	1000	Willara Formation	950	Faulted anticline
Pictor	Pictor 1 and 2	–	–	Nita Formation	–	Faulted anticline
Pictor Northeast	Mowla 1	80-505	360	Grant Group	450	Faulted anticline
Pointers	Canopus 1	HCG-401	750	Nita Formation	800	Faulted anticline
				Willara Formation	1100	
Pointers South	Canopus 1	80-506	900	Nita Formation	800	Faulted anticline
				Willara Formation	1100	
Saucepan	Edgar Range 1	80-514	700	Grant Group	600	Anticline
				Nita Formation	670	
				Willara Formation	990	
Vela North	Vela 1	80-521	310	Nita Formation	1150	Faulted anticline
				Willara Formation	1220	
Vela Southeast A	Vela 1	81-529	224	Nita Formation	1100	Faulted anticline
				Willara Formation	1240	
Vela Southeast B	Vela 1	81-529	160	Nita Formation	1200	Faulted anticline
Vela West	Vela 1	80-516	190	Nita Formation	1050	
				Willara Formation	1220	

NOTES: The depths are based on two-way-time contours

SOURCE: modified from Bridge Oil Ltd (1993a)

Centaurus lead

Hydrocarbon type	Oil
Play type	Faulted anticline
Primary objectives	Basal Grant Group and Nita Formation
Key strengths	Known reservoir in the area
Key weaknesses	Structural integrity
Seismic coverage	8 seismic lines of 1980 and 1988 vintage

Summary

The Centaurus lead is situated in the central-northeastern part of EP 175 and is about 10 km north of Edgar Range 1 (Fig. 31). It is an elongate, faulted anticline on a tilted fault block at all reservoir levels (Figs 32 and 33). Preliminary mapping indicated closure greater than 60 km^2 (BHP Petroleum Pty Ltd, 1985), but later mapping suggests it is smaller (6 × 3 km; Bridge Oil Ltd, 1989). The main risk with this lead is structural integrity of the trap. The Grant Group is known to have thin, discontinuous seals in the area, and the lead is cut by several small faults.

Nearby wells

Antares 1, Crystal Creek 1, Edgar Range 1, Lovell's Pocket 1, Mowla 1, Mount Alexander, and Pictor 1 and 2.

Trap

The Centaurus lead is an elongate, north-northwesterly trending, faulted anticline on the downthrown side of the Collins Fault. At the base Grant Group level, the lead has dip closure in most directions, but is dissected by several small, northwesterly trending faults (Fig. 32). Shale and claystone within the Grant Group should seal this lead at this level. Vertical seals juxtaposed to, and within, this group tend to be thin, laterally discontinuous, and even sandy in some areas (Bridge Oil Ltd, 1993a), which raises a seal risk.

At the top Nita Formation level, the lead has fault closure to the northeast, and dip closure in all other directions (Fig. 33). These features are probably associated with wrench movement along the Collins Fault (BHP Petroleum Pty Ltd, 1985). Evaporites or shale within the Carribuddy Group are expected to be seals at this level.

Source

Oil and gas shows were recorded from Pictor 1 and 2, with the upper part of the Goldwyer Formation being the sole source in the region. Oil shows from Antares 1, Crystal Creek 1, and Edgar Range 1, as well as oil and gas from Pictor 1 and 2, indicate a migration pathway in the region.

Reservoir

Sandstone intervals within the Grant Group typically display good to excellent reservoir characteristics in

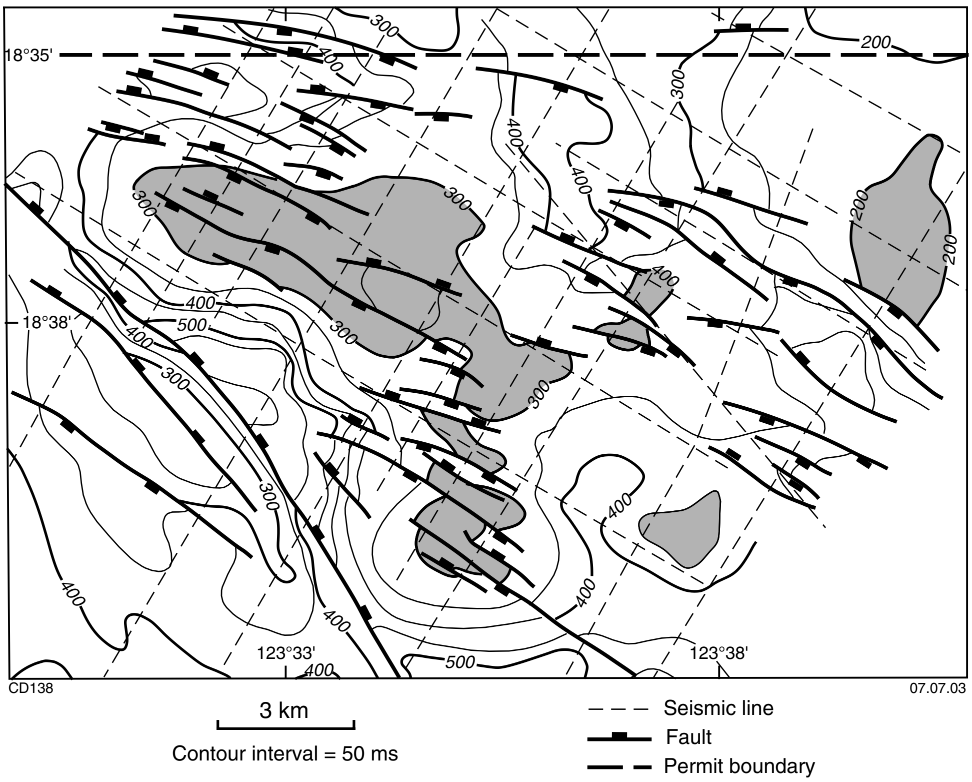


Figure 32. Two-way-time contours to the base Grant Group, Centaurus lead (after Bridge Oil Ltd, 1993a)

nearby wells. Log-derived porosity values from Pictor 1 range from 20 to 40%, compared with a core-derived value of 27% from Edgar Range 1, with a corresponding permeability of 400 mD. Fair to excellent porosities were also noted in Antares 1. By analogy, the Centaurus lead is expected to have good-quality Permian sandstone reservoirs.

Porosity of the Nita Formation in the surrounding wells is poor to good, with a range of 0.1 – 20.9% and average values between 3.5 and 9.58%. Permeability values range from 0.01 to 38 mD, with averages of 0.59 to 1.08 mD. The highest porosity and permeability values were noted in fairly clean dolomite horizons, but these are unpredictable and not continuous.

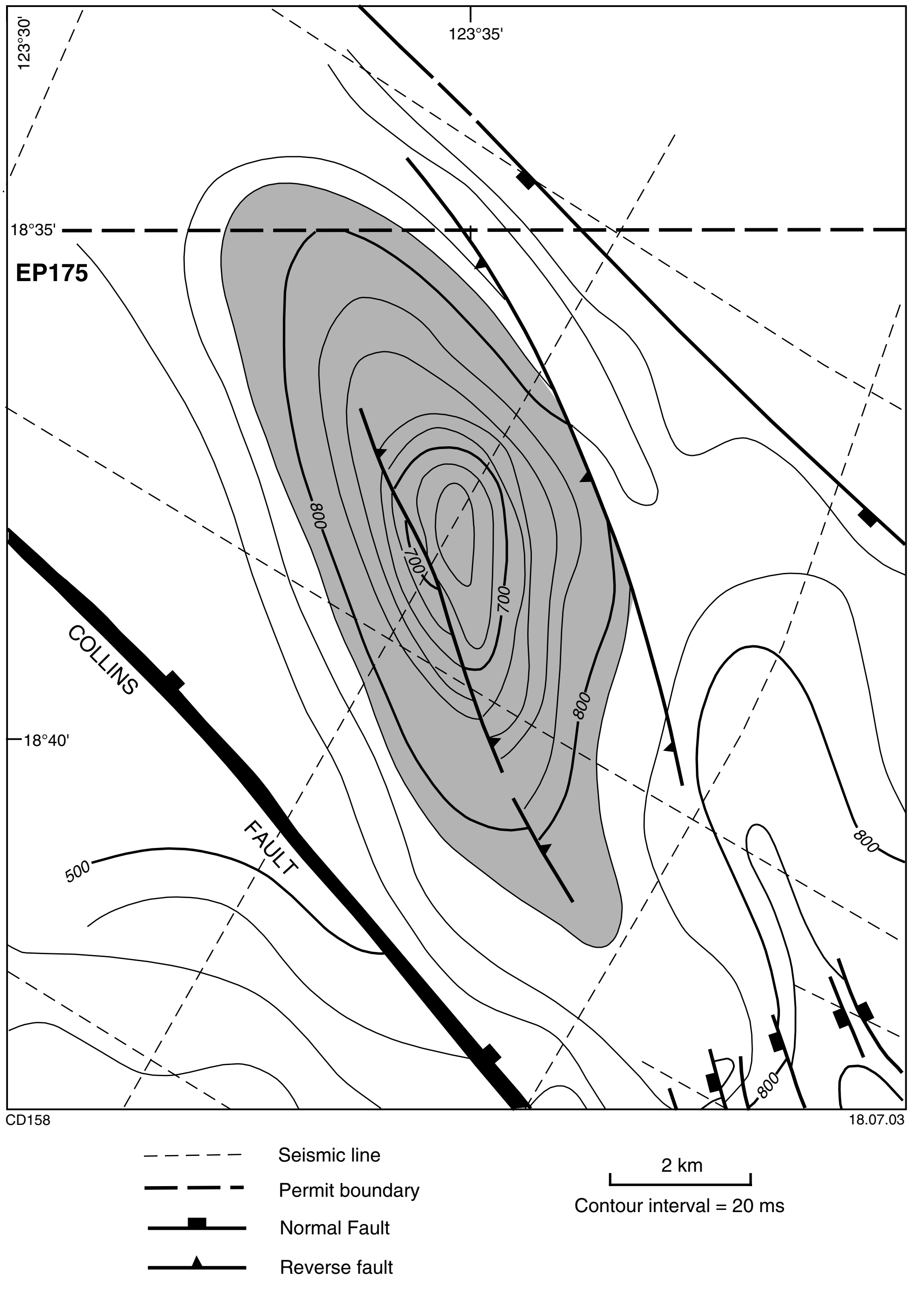


Figure 33. Two-way-time contours to the top Nita Formation, Centaurus lead (after BHP Petroleum Pty Ltd, 1985)

North Pictor prospect

Hydrocarbon type	?Gas, minor oil
Depth to objective	1018 m SS
Total depth	2450 m SS
Surface area	7.7 km^2
Play type	Faulted anticline
Primary objective	Nita Formation
Key strengths	Reservoir and proven source in the area
Key weaknesses	Structural integrity
Seismic coverage	7 seismic lines of 1981 vintage

Summary

The North Pictor prospect is located in the northern central part of northeast EP 175, about 5 km north of Pictor 1 (Fig. 31). The structure is a faulted anticline on the upthrown side of a down-to-the-east fault (Fig. 34). The structure is analogous to that in Pictor 1 and 2, but is about 280 m structurally lower. Small quantities of oil and gas were produced from the nearby Pictor 1 and 2 wells (Table 1). Both wells recorded fair to excellent porosity values for the Nita Formation, but the trap was probably breached.

Nearby wells

Antares 1, Crystal Creek 1, Edgar Range 1, Lovell's Pocket 1, Mowla 1, Mount Alexander, and Pictor 1 and 2.

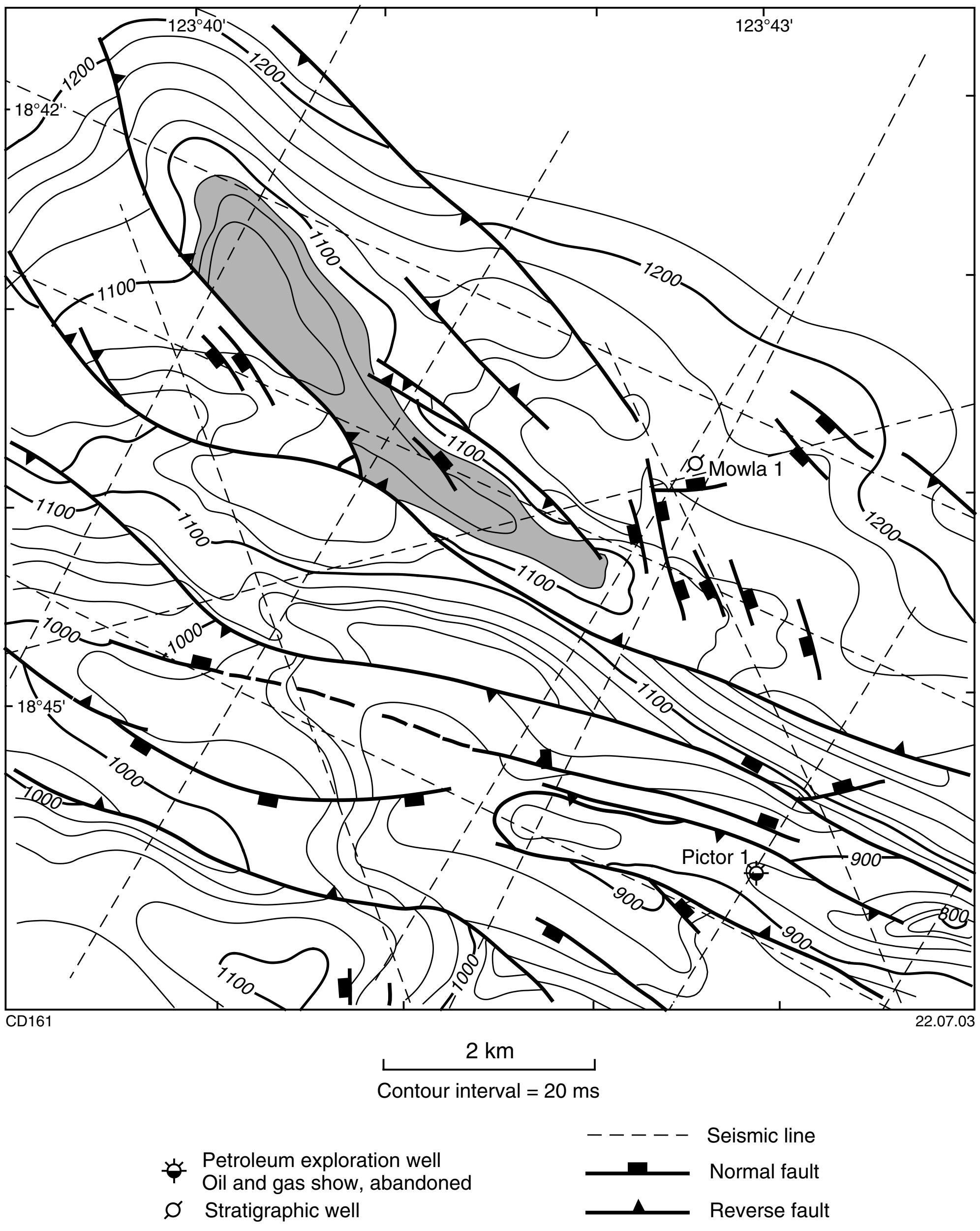


Figure 34. Two-way-time contours to the top Nita Formation, North Pictor prospect (after BHP Petroleum Pty Ltd, 1985)

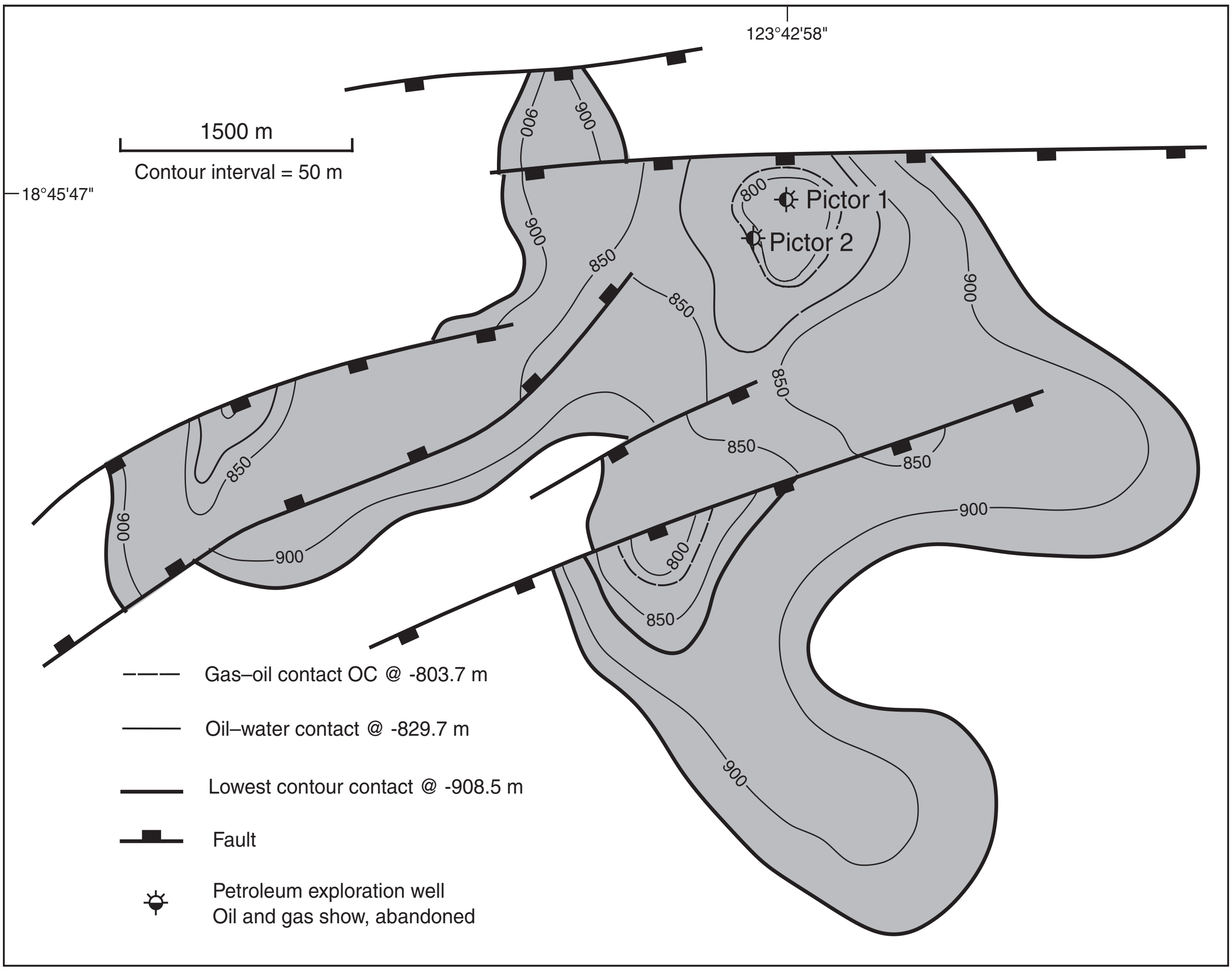


Figure 35. Depth contours to the top Nita Formation, Pictor prospect (after Bridge Oil Ltd, 1993a)

Trap

The structure is a northwesterly trending, faulted anticline (Fig. 34) associated with wrench movement along the Collins Fault. The structure has fault closure to the west, southwest, and over a limited distance to the northeast. The faults are interpreted as high-angle reverse faults (BHP Petroleum Pty Ltd, 1985).

Source

Analysis of samples from the Goldwyer Formation in Pictor 1 indicated poor TOC values of 0.83 – 1.54% and low potential yields (S_1+S_2) of 0.51 – 1.31 mg/g rock. The Willara Formation is thermally immature in this area. However, oil and gas shows from the nearby wells indicate a migration pathway in the region.

Reservoir

Porosity values in Pictor 1 were up to 20.9%, whereas the highest value in Pictor 2 was 14.5%. Permeability values in these two wells were poor (0.01 – 4.7 mD). The carbonate reservoirs within Pictor 1 and 2 proved to be thin, unpredictable, and of low permeability. Porosity and permeability values from the Nita Formation in the surrounding wells are poor to good.

Pictor prospect

Hydrocarbon type	Gas, minor oil
Depth to objective	730–740 m SS
Volumetrics	P_{50} case: 0.099 Gm^3 (3.49 Bcf) recoverable reserves; P_{90} case: 0.066 Gm^3 (2.33 Bcf); P_{10} case: 0.20 Gm^3 (7.18 Bcf)
Surface area	P_{50} case: 0.49 km^2 (120 acres) P_{90} case: 0.32 km^2 (80 acres); P_{10} case: 1 km^2 (247.1 acres)
Play type	Faulted anticline
Primary objective	Nita Formation
Key strengths	Proven source in the area
Key weaknesses	Structure and reservoir
Seismic coverage	Several seismic lines of various vintages

Summary

The Pictor prospect is situated in the centre of the northeastern quadrant of EP 175, east of the Collins Fault (Fig. 31). The prospect is a large, westerly trending regional high on the downthrown side of the Collins Fault. The Middle Ordovician Nita Formation is the primary objective. It was partially tested by Pictor 1 and 2, which produced oil and gas (Fig. 35, Table 1).

Pressure–volume–temperature (PVT) analyses confirmed that both Pictor 1 and 2 intersected the same oil leg (Bridge Oil Ltd, 1993a,b), but it is uncertain if the oil leg extends over in the rest of the structure; the success of the prospect requires that it does. The objectives in nearby wells have only modest-quality reservoir characteristics, so reservoir quality could be a problem within the prospect.

Nearby wells

Antares 1, Edgar Range 1, Mowla 1, Mount Alexander 1, and Pictor 1 and 2.

Trap

The Pictor prospect is a large, complexly faulted anticline at the Nita Formation level (Fig. 35) that is reasonably constrained by seismic data. The structure is on the downthrown side of a down-to-the-south fault, and has dip closure to the south and east, and fault closure to the north and west (Fig. 35). Antithetic and synthetic faulting has compartmentalized the structure. The Nita Formation was intersected at 738.7 m SS and 730.1 m SS in Pictor 1 and Pictor 2 respectively. The Carribuddy Group forms the top seal within the prospect.

The current structure-depth map at the top Nita Formation is inadequate to delineate the areal extent of the Pictor accumulation (Bridge Oil Ltd, 1993a). Further studies may lead to more confident mapping, and upgrading of the prospect.

Source

Analyses of Goldwyer Formation source rocks from Pictor 1 indicate poor TOC values (0.18 – 1.54%) and low potential yields (0.51 – 1.31 mg/g rock). The Willara Formation is thermally immature in the area. Oil and gas shows in the nearby wells indicate a migration pathway in the region.

Reservoir

The main reservoir characteristics pertinent to the Nita Formation for the Pictor prospect are shown in Table 8. Porosity of the Nita Formation from the surrounding wells is fair to good. Core-porosity values in Pictor 1 are up to 20.9%, whereas the highest value in Pictor 2 is 14.5%. Permeability values in these two wells are very poor: Pictor 1 had an average of 0.59 mD, with a range of 0.01 – 4.7 mD; and Pictor 2 had an average of 1.08 mD, with a range of 0.03 – 4.26 mD. Potential carbonate reservoirs within Pictor 1 and 2 are thin, unpredictable, and have low permeability.

Table 8. Reservoir parameters for the Nita Formation, Pictor prospect

Reservoir parameters	*Pictor 1*	*Pictor 2*	*Pictor prospect (mean)*
Net pay	19.5 m	11.1 m	15.3 m
Estimated average permeability	<5 mD	<5 mD	<5 mD
Estimated average pay porosity	10.75%	9.56%	10.15%
Estimated average pay Sw	30%	30%	30%

NOTES: Sw: water saturation **SOURCE:** after Bridge Oil Ltd (1993b)

Pointers lead

Hydrocarbon type	?Oil
Surface area	30 km^2
Play type	Faulted anticline
Primary objective	Nita Formation
Secondary objective	Willara Formation
Key strengths	Known reservoir in the area
Key weaknesses	Structure and reservoir
Seismic coverage	8 seismic lines of 1973, 1980, 1981, and 1986 vintage

Summary

The Pointers lead lies 10 km southwest of Matches Springs 1 on the upthrown side of a major fault on the Mowla Terrace (Fig. 31). The lead contains two parallel compartments in the northeastern corner of EP 175. The structure is analogous to that of the Pictor prospect, and its proximity to that prospect implies that it is at the same stratigraphic level and has similar reservoir characteristics, seals, and source rocks. The primary risk element is the potential for leakage across faults, due to the complex pattern of faulting across the lead.

Nearby wells

Matches Springs 1.

Trap

The Pointers lead consists of two elongate, tight, west-northwesterly trending anticlines (Fig. 31) bounded by high-angle reverse faults. The lead has dip closure to the southwest and east, and fault closure in other directions. The mapped closure is about 10 × 3 km, with a vertical relief of about 100 ms (BHP Petroleum Pty Ltd, 1985).

Source

The Goldwyer Formation is expected to provide the main source rock in this area.

Reservoir

The quality of the reservoir rocks in this area is expected to be enhanced by fractures. However, based on Matches Springs 1, the Nita and Willara Formations in this area are of low reservoir quality (porosity values of 1 – 4.7%).

Northwest EP 175 prospects and leads

Hydrocarbon type	Oil
Operator	Bridge Oil Ltd
Depth to objective	400–1400 m SS
Play type	Tilted fault traps
Primary objectives	Nita and Willara Formations
Secondary objectives	Sandstone within the Grant Group, and Mount Troy and Nambeet Formations
Key strengths	Known source and presence of migration pathway
Key weaknesses	Seal quality
Seismic coverage	Numerous lines of various vintages and quality

Summary

A group of prospects and leads has been mapped west of the Collins Fault in EP 175 on the Broome Platform (Fig. 31). The area is dominated by northerly trending, down-to-the-west tilted fault blocks. Most of the structures have objectives in the Ordovician Nita and Willara Formations, with Permian and Ordovician sandstone and dolomite as secondary targets. Fracturing caused by wrench movement has probably induced good porosity and permeability within the reservoirs. Three of these structures are discussed in more detail (see **Ara lead**, **Hadar A prospect**, and **Pavo lead**). The quality of the seismic data in the area is fair to poor. The primary risk is leakage across the seals, as potential sealing intervals in the Carribuddy Group are thin in this area, and may not seal the fault blocks.

Nearby wells

Crystal Creek 1, Edgar Range 1, Goorda 1, Lovell's Pocket 1, and Twin Buttes 1.

Trap

The prospects and leads in this area are all situated within a series of northerly trending, tilted fault blocks, which may be related to an extensional regime associated with isostatic adjustment following compression along the Collins Fault (BHP Petroleum Pty Ltd, 1985). Most are fault dependent and have closure at the top of the Ordovician objectives (Nita and Willara Formations). Three main trends identified are the Ara trend, which contains the Ara lead, the Hadar trend, which contains four prospects and leads, and the Pavo trend, which contains six leads (Fig. 31). The structures in this region are commonly broad, low-relief features.

The prospects and leads require either intraformational shale (in the case of the Permian reservoirs), or overlying limestone and shale to provide top and cross-fault seals within the mapped closures. The Nita Formation is sealed by shale intervals of the Carribuddy Group, which are believed to be of good quality. However, the seal risk increases towards the Thangoo high (Fig. 31) due to a potential lack of the Carribuddy Group in this area (Bellis, 1987). Fault seals for the Nita Formation within upthrown fault blocks are risky, but those in downthrown traps are more attractive due to the juxtaposition of the Nita Formation against shale of the Goldwyer Formation (Bellis, 1987).

Willara Formation reservoirs are sealed by shale in the Goldwyer Formation, which is thought to be of fair quality, and good to very good quality over fractured Willara Formation reservoirs. The Grant Group reservoirs are sealed by intraformational shale units, which are believed to be of fair to good quality. Within the upthrown traps, sealing potential is very risky, as fault throws may exceed 50 m, and Grant Group shale horizons within the area are about 50 m thick (Bellis, 1987).

Source

The most likely hydrocarbon type in this region is oil, since oil-prone source rocks of the Goldwyer Formation in the area are slightly immature to just past peak oil maturity (Bellis, 1987). Structural mapping indicates that northwest EP 175 is a regional migration focal point for hydrocarbons from the Jurgurra and Mowla Terraces, Thangoo high, and southern-central EP 175 (Bellis, 1987).

Reservoir

The Nita Formation contains numerous reservoirs ranging from 4 to 60 m thick, with an average of 18 m. Porosity averages 11% with a range of 7–24%, and permeability averages 1–40 mD, but in places is as high as 3 D. Where intersected and evaluated, potential Willara Formation reservoirs in this region are believed to be associated with karst development or fracturing, or both. The karst reservoirs within this unit have a net thickness of up to 20 m (average of 6.5 m), porosity values that average 20%, but can be as low as 5%, and permeability values that range from 10 mD to 1 D, but have an average of 200 mD (Bellis, 1987). The fractured reservoirs have a net thickness of up to 200 m, porosities averaging 2–3% (range of 1–20%), and permeabilities that range from 0.1 mD to 1 D (Bellis, 1987).

The Nambeet Formation is quite deep in the region (>1700 m), and all of the wells that intersected it were terminated within 10 m (average of 6 m) of the top of the unit. Porosity of the formation ranges from 6 to 12% (average of 8%), and permeability is believed to be low, unless the formation is fractured.

The Grant Group is up to 75 m thick, with an average of 50 m, but is locally absent. Porosity averages 30%, and permeability ranges from 0.5 mD to 2 D (Bellis, 1987). These reservoirs are the best and shallowest reservoirs (200–700 m) in the area, and in some places, sandstone in the Grant Group overlies the porous Nita Formation, which is the most prospective reservoir for hydrocarbons from an Ordovician source. These reservoirs are also updip from the Thangoo high, where permeable Grant Group strata directly overlie source rocks of the Goldwyer Formation (Bellis, 1987).

Ara lead

Hydrocarbon type	Oil
Play type	Faulted anticline
Primary objective	Nita Formation
Key strengths	Proximity to known hydrocarbon shows
Key weaknesses	Poorly constrained by seismic data
Seismic coverage	1 seismic line, and the end of 2 seismic lines, all of 1980 vintage

Summary

Within the north-northwesterly Ara trend, in the northwestern part of EP 175, one culmination (the Ara lead) has been identified (Fig. 31). The Ara lead is about 21 km northwest of Edgar Range 1, and appears to be a relatively simple faulted anticline on the upthrown side of a down-to-the-west fault. The lead is defined by the ends of two seismic lines, and a single line over the centre of the structure. Additional seismic data are required to adequately delineate the structure and upgrade it to a prospect status.

Nearby wells

Crystal Creek 1, Edgar Range 1, and Lovell's Pocket 1.

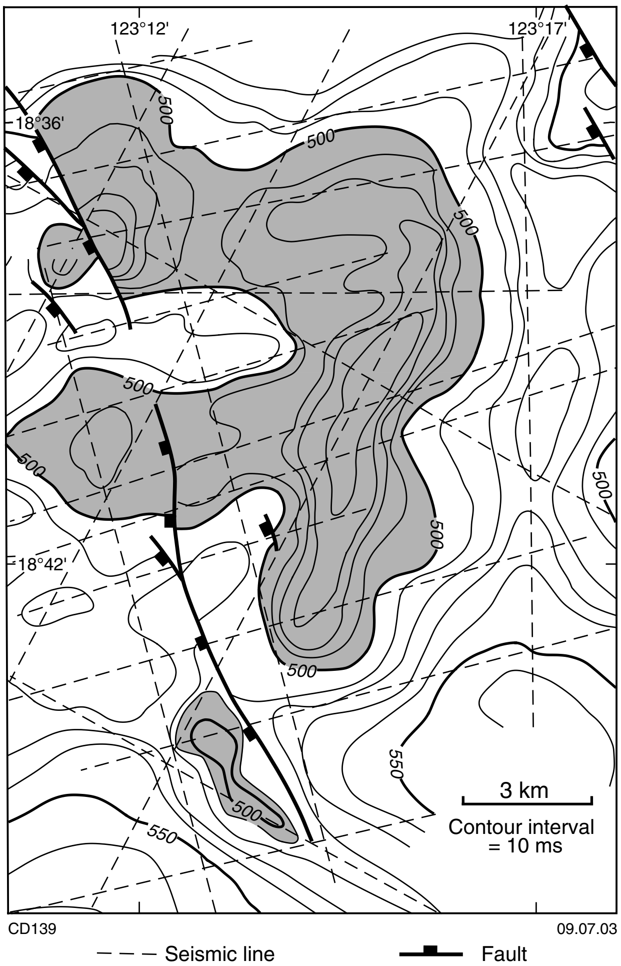


Figure 36. Two-way-time contours to the base Grant Group, Hadar A prospect (after Bridge Oil Ltd, 1993a)

Trap

The Ara lead is a low-relief, fault-dependent structure. Preliminary mapping indicates a closure of about 50 ms with north–south rollover. It has fault closure to the west, and dip closure in all other directions (Fig. 31). Preliminary mapping of the area showed that the Edgar Range 1 structure was open to the northwest, with its crest northwest of the well and east of the Ara lead (BHP Petroleum Pty Ltd, 1985). Any hydrocarbons that were present in the Edgar Range 1 structure may have migrated updip into the Ara lead. Live oil bled from the Nita Formation in Edgar Range 1, and oil stains and fluorescence from the same formation were noted in Crystal Creek 1 and Lovell's Pocket 1, which suggests that this trap is likely to have been charged.

Source

The Goldwyer Formation is the primary source in the immediate area. Oil shows recorded in nearby wells suggest that there is a migration pathway in the region.

Reservoir

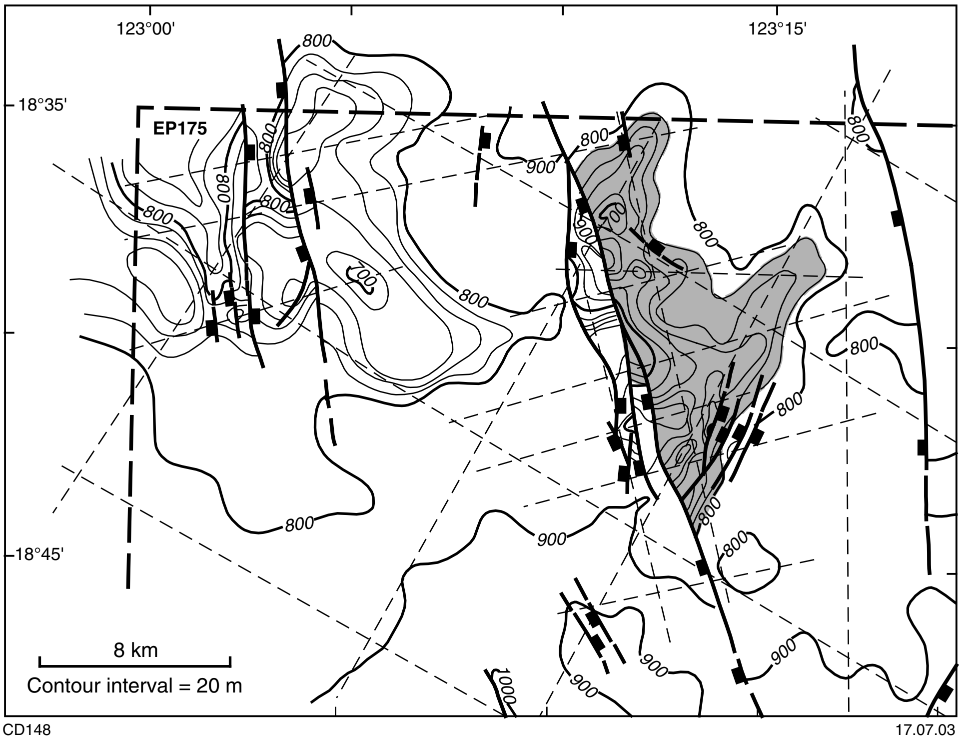
The Nita Formation in the surrounding wells is a very tight to fair reservoir rock. Porosity ranges from 0.7 to 9.2% in Edgar Range 1 and Crystal Creek 1. Permeability averages 0.09 – 0.78 mD, but in places is as high as 38 mD.

Hadar A prospect

Hydrocarbon type	Oil
Depth to objective	800 m (Nita Formation), 400 m (Grant Group sandstones)
Total depth	2130 m
Surface area	47 km^2
Play type	Faulted anticline
Primary objectives	Nita and Willara Formations
Secondary objective	Sandstone within the Grant Group and Nambeet Formation
Key strengths	Prospect closes on 2D seismic grid
Key weaknesses	Seal and reservoir quality
Seismic coverage	11 seismic lines of 1980, 1983, and 1986 vintage

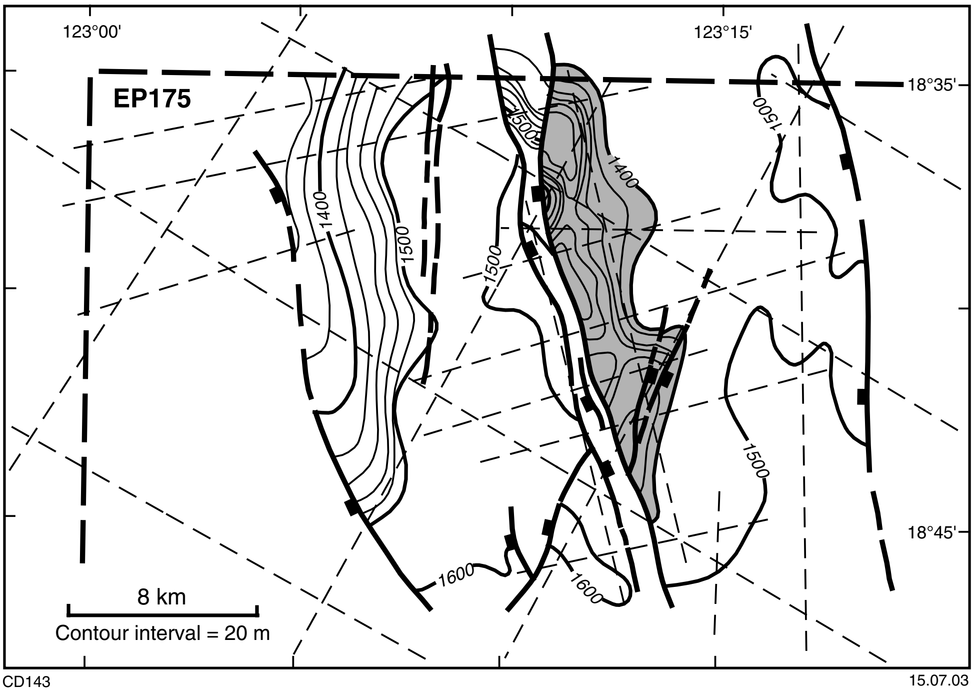
Summary

The north-northwesterly Hadar trend is situated in the northwestern part of EP 175 and contains four culminations: Hadar A, Hadar B, Hadar East, and Hadar South A (Fig. 31). All of these prospects have Ordovician objectives, with the possibility of a Lower Permian trap where the top Nita Formation has been truncated by the Permian unconformity. The Hadar A prospect is the largest and probably the lowest risk prospect within the Hadar trend. The structure is analogous to that of Pictor 1 and 2. The prospect is about 32 km east-northeast of Edgar Range 1 within an elongate, tilted, faulted block on the upthrown side of a down-to-the-west fault at all reservoir levels (Figs 36–38). The prospect is reasonably well constrained by 11 2D seismic lines of variable quality. The



Seismic line
Permit boundary
Fault

Figure 37. Depth contours to the top Nita Formation, Hadar A prospect (after BHP Petroleum Pty Ltd, 1985)



Seismic line
Permit boundary
Fault

Figure 38. Depth contours to the top Willara Formation, Hadar A prospect (after BHP Petroleum Pty Ltd, 1985)

primary risks are the potential for leakage across the major fault, and the reservoir quality of the Willara Formation in this area.

Nearby wells

Crystal Creek 1, Goorda 1, Lovell's Pocket 1, and Twin Buttes 1.

Trap

At all reservoir levels, the trap is on the eastern side of a north-northwesterly trending fault. Along this fault, throw increases with depth from 10 ms at base Grant Group level, to about 100 ms at top Nita and Willara Formation levels. The Hadar A prospect is a fault-dependent anticline with fault closure to the west, and dip closure in all other directions (Figs 36–38). At the Nita and Willara Formation levels, the prospect is much narrower than at Grant Group level, and has additional fault closure in the southeastern corner (Figs 37 and 38). The closure across the Hadar A prospect is about 100 m, and at top Nita Formation level the structure has an aerial extent of about 47 km^2 (BHP Petroleum Pty Ltd, 1985). The northern edge of the structure shows possible breaching at top Nita Formation level, possibly due to erosion of the Carribuddy Group, which would allow for the migration of hydrocarbons into the Grant Group (Fig. 39; BHP Petroleum Pty Ltd, 1985).

Shale units within the Carribuddy Group are expected to be 110 m thick, and may provide vertical and lateral seals across the fault at Lower–Middle Ordovician levels to the north and south, as this thickness exceeds the fault throw at this level by 10 m. Near the central part of the prospect, the fault throw exceeds the likely seal thickness, making fault seal in that part of the prospect dubious (BHP Petroleum Pty Ltd, 1985). Shale intervals within the Grant Group are expected to seal intraformational sandstone reservoirs where they onlap the Permian unconformity.

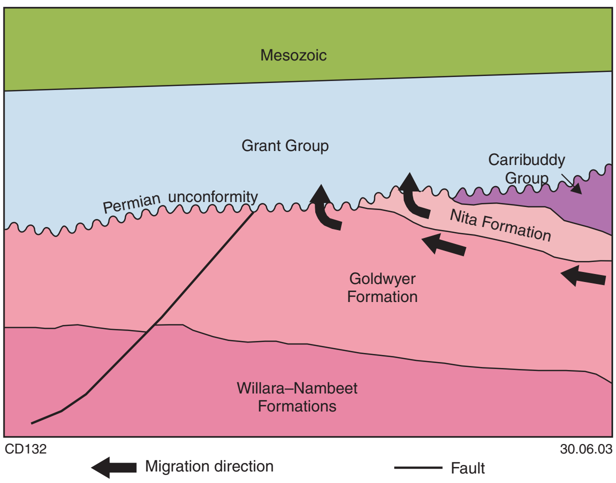


Figure 39. Schematic diagram of the possible migration of hydrocarbons into the Grant Group from a breached Nita Formation and eroded Carribuddy Group section

Source

The main source for the Ordovician and Permian reservoirs in the Hadar A prospect is the Goldwyer Formation. Fluorescence in Twin Buttes 1 from the Nita, Goldwyer, and Willara Formations, and hydrocarbon shows in other nearby wells, indicate that there is a source in the region or a migration pathway has been active.

Reservoir

Log-derived porosities of up to 20% were recorded in Twin Buttes 1, with an average of 13%, in vuggy dolomites of the Nita Formation probably related to karst weathering. Based on the regional information on the Nita Formation, the following reservoir parameters were estimated for the Hadar A prospect: a gross rock volume of 180 to 990 Mm^3, porosity of 13–17%, an oil saturation of 70–80%, a net to gross ratio of 30–38%, and a formation volume factor of 1.05 – 1.15 (BHP Petroleum Pty Ltd, 1985). The Willara Formation is either tight or water bearing in nearby wells. Log-derived porosities of up to 5% were recorded for this unit in Twin Buttes 1, compared with core-derived porosities of 1.8 – 14.1% in Crystal Creek 1. Recorded permeabilities were very low (0.06 – 0.29 mD).

Pavo lead

Hydrocarbon type	Oil
Play type	Faulted anticline
Primary objectives	Nita and Willara Formations
Key strengths	Known migration pathway in the area
Key weaknesses	Seal and reservoir quality
Seismic coverage	5 seismic lines of 1980 and 1983 vintage

Summary

The northerly Pavo trend is situated in the northernmost part of northwest EP 175 and contains six leads: East Pavo, Pavo, South Pavo A (which contains three leads), and South Pavo B (Fig. 31). The Pavo lead is about 42 km west-northwest of Edgar Range 1 and appears to be a relatively simple faulted anticline south of the Thangoo high (Fig. 31). The lead is analogous to the Ara lead and Hadar A prospect, implying similar reservoirs and seals. The structure is covered by five 2D seismic lines. Additional modern seismic data are required to adequately delineate the structure.

Nearby wells

Goorda 1 and Twin Buttes 1.

Trap

The structure is bounded by a normal fault downthrown to the southeast, and has four-way dip closure at both the top Nita and Willara Formation levels. The Pavo lead has an estimated 80 m of fault-dependent closure. Based on the current seismic data, the lead could be a possible carbonate build-up towards the base of the Nita Formation (BHP Petroleum Pty Ltd, 1985).

Source

The Goldwyer Formation is the primary source in the immediate area. Fluorescence in Twin Buttes 1 from the Nita, Goldwyer, and Willara Formations indicates that there is a source in the region or a migration pathway has been active.

Reservoir

Log-derived porosities of up to 20% were recorded in Twin Buttes 1, with an average of 13%, in vuggy dolomites of the Nita Formation probably due to karstic weathering. The Willara Formation is tight with log-derived porosities of up to 5% in Twin Buttes 1.

Southwest EP 175 prospects and leads

Hydrocarbon type	Oil and gas
Operator	Bridge Oil Ltd
Depth to objective	600–3000 m
Play type	Faulted anticlinal structures
Primary objectives	Worral and Nita Formations
Secondary objectives	Sandstone in the Grant Group, Tandalgoo Sandstone, and Willara Formation
Key strengths	Reservoir
Key weaknesses	Structure and seal
Seismic coverage	Several seismic lines of 1980 to 1982 vintage

Summary

A group of leads have been mapped in the southwestern part of EP 175 on the Broome Platform and Willara Sub-basin (Fig. 31), in an area dominated by the northwesterly trending Admiral Bay Fault Zone. The primary objectives are within the Middle Ordovician Nita Formation and Devonian Worral Formation, with Permian and Devonian sandstone and Lower–Middle Ordovician carbonate rocks as secondary targets. The quality of the seismic data in the area is fair to poor, and wells drilled in the area were poorly located structurally due to insufficient seismic coverage. Hydrocarbon potential is limited in this region, compared to the northern part of the permit, primarily due to the potential for leakage across the faults, and migration of any trapped hydrocarbons northward after late, regional southerly tilting in the area.

Nearby wells

Carina 1, Musca 1, and Vela 1.

Trap

The main leads in this area involve large, roughly northwesterly trending, broad anticlinal closures on the upthrown side of the Admiral Bay Fault Zone, with only two leads on the downthrown side (Fig. 31). They are expected to have fault and dip closure at the top of the Ordovician (Nita Formation) and Devonian (Worral Formation) objectives. Numerous salt diapir structures are also present. The Fitzroy Transpressional Movement (Late Triassic – Early Jurassic) reactivated the Ordovician faults with reverse movement along the Admiral Bay Fault Zone. These events have largely been accommodated within the Mallowa Salt of the Carribuddy Group, which led primarily to gentle flexuring of the overlying formations.

A thick halite succession, the Mallowa Salt, is present in the Kidson and Willara Sub-basins to the south, and numerous structural anomalies, especially salt pillows and salt-solution features known as sombreros, are believed to be associated with the edge of this unit. Recent drilling has downgraded this play due to a lack of access to the Goldwyer Formation source rocks.

The Nita Formation reservoirs are sealed by shale in the Carribuddy Group, which is of good quality. The Willara Formation is sealed by shale within the Goldwyer Formation, which is thought to be of fair quality over the karstified Willara Formation reservoirs, and good to very good quality over the fractured reservoirs. The Worral Formation has variable seal quality. In places, the seal is absent, but elsewhere is potentially very good quality. The Tandalgoo Sandstone and Grant Group are likely to be sealed by intraformational shale intervals in the Grant Group, which are fair to good quality in the region.

Source

The main source for the Ordovician and Devonian reservoirs is type I/II kerogen in the Goldwyer Formation. In this area, the formation is past peak oil generation and is presently at, or just below, the base of the oil window, thereby generating light oil and gas (Bellis, 1987). Carina 1 and Musca 1 recorded minor fluorescence and oil stains within the Nita Formation and Carribuddy Group. Cudalgarra 1, Great Sandy 1, and Nita Downs 1, which are located more than 50 km northwest of the southwestern corner of this permit, lie along the Admiral Bay Fault Zone and had oil and minor gas shows within the Nita, Goldwyer, and upper Willara Formations. The Admiral Bay Fault Zone is believed to provide a conduit for oil generated in the deeper, adjacent basinal areas (Purcell, 1984a).

Reservoir

The Elsa Sandstone Member of the Worral Formation is the best potential reservoir in the area due to its shallow depth, good reservoir qualities, and seal. The unit ranges in thickness from 5 to 20 m with an average of 8 m, and has porosity values of 18–25%, and average permeability values of 0.25 D (Bellis, 1987). The Nita Formation ranges in thickness from 2 to 40 m with an average of 15 m. Based on the three wells in the area, the formation is fairly tight. Log-derived porosities of up to 8.5% were recorded in Vela 1.

The only potential Willara Formation reservoirs proposed to date within EP 175 are fractured zones, but these have not been intersected in wells drilled in southwest EP 175; therefore, the development of these reservoirs in this area is highly conjectural (Bellis, 1987). The Tandalgoo Sandstone has excellent reservoir qualities, with log-derived porosities of up to 27% calculated for

Carina 1. The unit ranges in thickness from 20 to 40 m (Bellis, 1987). The Grant Group also has excellent reservoir qualities, with log-derived porosities from Carina 1, Musca 1, and Vela 1 ranging from 16 to 35%. The unit ranges in thickness from 20 to 100 m, with an average of 25 m (Bellis, 1987).

Central EP 175 prospects and leads

Hydrocarbon type	Oil and gas
Operator	Bridge Oil Ltd
Depth to objective	400–2400 m
Play type	Salt-related structure
Primary objectives	Nita, Goldwyer, and Willara Formations
Secondary objectives	Sandstone within the Grant Group
Key strengths	Possible fracture-enhanced reservoirs
Key weaknesses	Poorly defined by seismic data of 1970s vintage

Summary

The central part of EP 175 is characterized by a number of broad, low-relief structures from which only one lead has been delineated. These structures are associated with salt solution, salt movement, and possible carbonate development along the salt-basin margin. The region covered by central EP 175 now partially falls within EP 353, and that portion of the permit is discussed in detail within that section (see **EP 353 R1**). This area has less potential than the other areas of EP 175, but does have one possible play: fractured Lower Ordovician reservoirs in the vicinity of a northeasterly trending lineament and related fault trends (Bellis, 1987). The central part of the region comprises an undeformed platform, apparently lacking structural leads.

EP 225

Permit EP 225 was operated by WMC from 1981 to 1990. During this time, WMC acquired 2197 line-km of 2D seismic data (Boab, Bongabinni, Dora 1983, Minjoo, Nibil, and Nita 1982 (Phase 1 and 2) seismic surveys; Appendix 3) and drilled 12 wells (Caladenia 1, Calytrix 1, Clianthus 1, Drosera 1, Eremophila 1, 2, and 3, Goodenia 1, Kunzea 1, Hoya 1, Percival 1, and Santalum 1/1A; Appendices 1 and 2). All of these are shallow stratigraphic wells with total depths averaging less than 600 m, with the exception of Percival 1, which was drilled as a new-field wildcat to a TD of 2447.6 m, and is the only well in the region that reached the Lower–Middle Ordovician section. The southeastern part of this permit was subsequently covered by EP 353.

The majority of EP 225 lies within the Broome and Crossland Platforms, but the southeastern corner lies on the Barbwire Terrace (Fig. 26). EP 225 is dominated by the northwesterly trending Dummer Range Fault to the northeast, with other smaller, northwesterly and northeasterly trending faults elsewhere (Fig. 27). The Crossland and Broome Platforms are generally unfaulted, broad, regional ramps dipping to the west and southwest, whereas on the Barbwire Terrace, complex faulting separates numerous fault blocks of variable size and structural dip. Most of the traps in the permit are 'pop-up' features related to compressional faulting. The majority of these structures are associated with northeasterly trending faults (Fig. 27). One prospect (Goodenia; Fig. 40) and 10 leads (Table 9; Fig. 27) have been delineated in the permit.

Reservoir

The most prospective exploration target in the permit is the Nita Formation (Table 10). Based on a review of core and wireline logs from Acacia 2, Dodonea 2, Kunzea 1, Santalum 1A, and Solanum 1, Western Mining Corporation (1990) concluded that the reservoir quality of

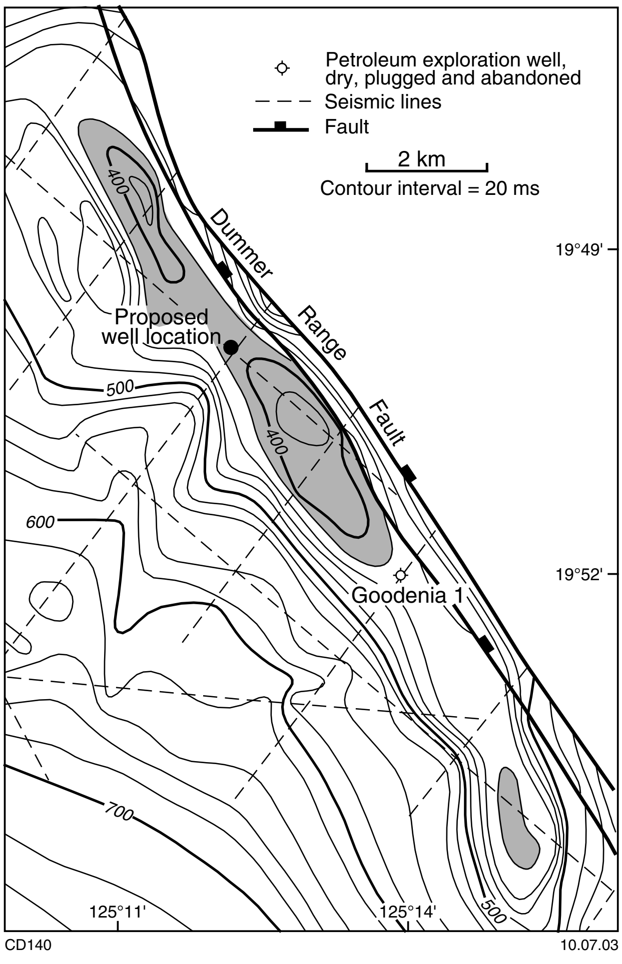


Figure 40. Two-way-time contours to the top Nita Formation, Goodenia prospect (after Western Mining Corporation, 1990)

Table 9. Leads in EP 225 with Nita Formation reservoirs

Lead	*Seismic line*	*Shot point*	*Time depth (ms)*	*Structure*
Clapp Ridge	NIB86-12	1130	630	Strike-slip fault pop-up
Cyperus	NIB86-11	1400	620	Strike-slip fault pop-up
Drosera North	D83-05	500	350	Fault trap
Owenia	BONG-85-36	2720	700	Strike-slip fault pop-up
Owenia A	BONG-85-36	720	800	Strike-slip fault pop-up
Owenia B	BONG-85-36	1260	670	Strike-slip fault pop-up
Owenia C	BONG-85-36	4880	700	Strike-slip fault pop-up
Santalum West	NIB86-04	1600	670	Reverse faulted graben
Tina Springs	C2	279	700	Strike-slip fault pop-up
Themeda	NIB86-02	240	800	Reverse faulted graben with rollover

SOURCE: modified from Western Mining Corporation Ltd (1990)

Table 10. Evaluation of reservoir objectives in EP 225

Formation	*Seal*	*Reservoir*	*Source*	*Maturation*
Grant Group	very good	very good	unknown	unknown
Fairfield Group	good	very good	poor	unknown
Nullara Limestone	unknown	very poor	good	unknown
Pillara Limestone	very good	fair–poor	fair	unknown
Boab Sandstone	very good	very good	poor	good
Mellinjerie Formation	very good	fair	good	very good
Tandalgoo Sandstone	fair–poor	very good	very poor	very poor
Nita Formation	good–fair	very good	very good	very good
Goldwyer Formation	very good	unknown	very good	good
'Acacia sandstone member'	fair–poor	very good	fair	unknown
Nambeet Formation	very good	good	poor	good

SOURCE: modified from Western Mining Corporation Ltd (1990)

the Nita Formation decreases to the south of the permit, with an associated decrease in dolomitization to the southwest. Correlation of lithology based on gamma logs indicates that the Nita Formation consists of a series of depositional cycles, which can be grouped into three main sequences, ranging from a basal grainstone and mudstone or argillaceous wackestone (subtidal environment), to predominantly bioturbated dolomite (intertidal to subtidal environment), to interbedded dolomite with siltstone and mudstone (supratidal to intertidal environment). Reservoir porosity development is confined to the predominantly bioturbated dolomite sequence ('sequence B'; Western Mining Corporation, 1990).

Porosity of the Nita Formation within EP 225 is greatest within the middle 'sequence B' and ranges from 4 to 16%, but is typically less than 10%; permeability averages less than 30 mD, but in places is as high as 238 mD (Western Mining Corporation, 1990).

Goodenia prospect

Hydrocarbon type	Oil
Depth to objective	1350 m SS
Volumetrics P_{50}	0.48 GL (3 MMbbl) recoverable reserves
Surface area	2 km^2
Play type	Faulted anticline
Primary objective	Nita Formation
Secondary objective	Willara Formation
Key strengths	Proven source in the area
Key weaknesses	Reservoir quality and structural integrity
Seismic coverage	7 seismic lines of 1982, 1983, 1984, and 1985 vintage

Summary

Although Goodenia 1 had an Upper Devonian objective, the Goodenia prospect targets the Middle Ordovician Nita Formation, which is considered the most prospective reservoir in the area. Goodenia 1 was a very shallow stratigraphic well (TD 163.3 m) and intersected non-commercial oil shows within the Grant and Fairfield Groups. Large-scale faulting was noted in the core, which was responsible for secondary hydrocarbon migration out of the region. Goodenia 1 was drilled off structure (Fig. 40; Western Mining Corporation, 1990).

Remapping of the structure at the top Nita Formation level in the Goodenia prospect places the crest of the structure just to the north of Goodenia 1 (Fig. 40) on the upthrown side of the Dummer Range Fault. This prospect is the only one delineated within EP 225, as elsewhere seismic data are insufficient. The main risks involved with this prospect are the reservoir quality of the main objective and the uncertainty of the structural integrity, given that the seismic lines are of average quality and faulting was noted in Goodenia 1. The prospect is some distance away from known good porosity in the Nita Formation.

Nearby wells

Aristida 1/1A, Dampiera 1/1A, Eremophila 1, 2, and 3, and Goodenia 1.

Trap

The Goodenia prospect is a northwesterly trending, elongate, faulted anticline at the top Nita Formation level with fault closure to the northeast, and dip closure in all other directions (Fig. 40). The centre of the northern part of the prospect has four-way dip closure. The rollover closure was probably the result of dextral movement on the main fault, with additional structural complexity from strike-slip movement along northeasterly trending transform faults in the area (Western Mining Corporation, 1990). Oil shows in surrounding wells imply that this trap has a reasonable chance of been charged.

The Carribuddy Group, if not eroded, is expected to seal the Nita Formation, and impermeable limestone and mudstone facies of the Goldwyer and Willara Formations are expected to provide a seal to reservoirs within the Willara Formation.

Source

Microbial mudstone facies in the Goldwyer Formation are expected to be effective oil-prone source rocks, as this formation is currently within the oil-generative window in the vicinity of this prospect. The presence of the oil shows demonstrates at least a good migration pathway in the region.

Reservoir

The primary objective for the Goodenia prospect is the Nita Formation, with the Willara Formation (possibly the ‘Acacia sandstone member’) as a secondary objective. Based on surrounding wells from EP 143, about 10 m of oil pay is estimated to be present with 10% porosity and 70% hydrocarbon saturation (Western Mining Corporation, 1990).

EP 353 R1

Hydrocarbon type	Oil
Depth to objective	500–1500 m SS
Play type	Faulted-anticlinal and salt-related structures
Primary objectives	‘Acacia sandstone member’ of the Willara Formation, Worral Formation, Grant Group
Secondary objectives	Tandalgoo Sandstone, and Nita and Nambeet Formations
Key strengths	Known source and presence of migration pathway
Key weaknesses	Structural integrity (seal, trap), reservoir quality, charge
Seismic coverage	Numerous lines of good quality from 1991, 1992, and 1998, roughly forming a 5 × 10 km grid

Summary

Permit EP 353 was operated by Shell Development (Australia) Propriety Limited (SDA) from 1991 to 1996. During this period, 1539 line-km of 2D seismic data (S91C and S92C seismic surveys) were acquired and one new-field wildcat (Looma 1) was drilled to Precambrian basement. Hughes and Hughes Australia Pty Ltd renewed the permit from 1998 to 2002, with SDA still acting as operator. During this period, 1758 line-km of 2D seismic data (Great Sandy (1988) seismic survey) and 5519 line-km of aeromagnetic data were acquired, and three new-field wildcats were drilled (Robert 1, Fruitcake 1, and Missing 1). The permit was relinquished in 2002.

The majority of EP 353 lies within the Broome and Crossland Platforms (Fig. 26) and is dominated by the northwesterly trending Dummer Range Fault to the northeast, with other smaller, northwesterly and northerly trending faults, and a salt edge to the southwest (Fig. 41). The Mallowa Salt thins northward because of dissolution, leaving a salt edge. Faulting in the area is relatively minor. Twenty-one prospects and leads targeting 35 objectives have been identified (Table 11; Fig. 41): eight objectives target the ‘Acacia sandstone member’ of the Willara Formation, 15 the Worral Formation, 11 the Grant Group, and one the Tandalgoo Sandstone.

The prospectivity of EP 353 is relatively high-risk, but potentially offers large rewards. There are similarities with the south Oman oil province, which has more than 1908 GL (12 Bbbl) of proven oil in place. In Oman (Department of Minerals and Energy and Petroventures Pty Ltd, 2000; Shell Development (Australia) Pty Ltd, 2000), oil shows are seen around the salt-basin edge, which are typed as Ordovician oils, and there is a lack of post-salt shows within the thick salt-basin area.

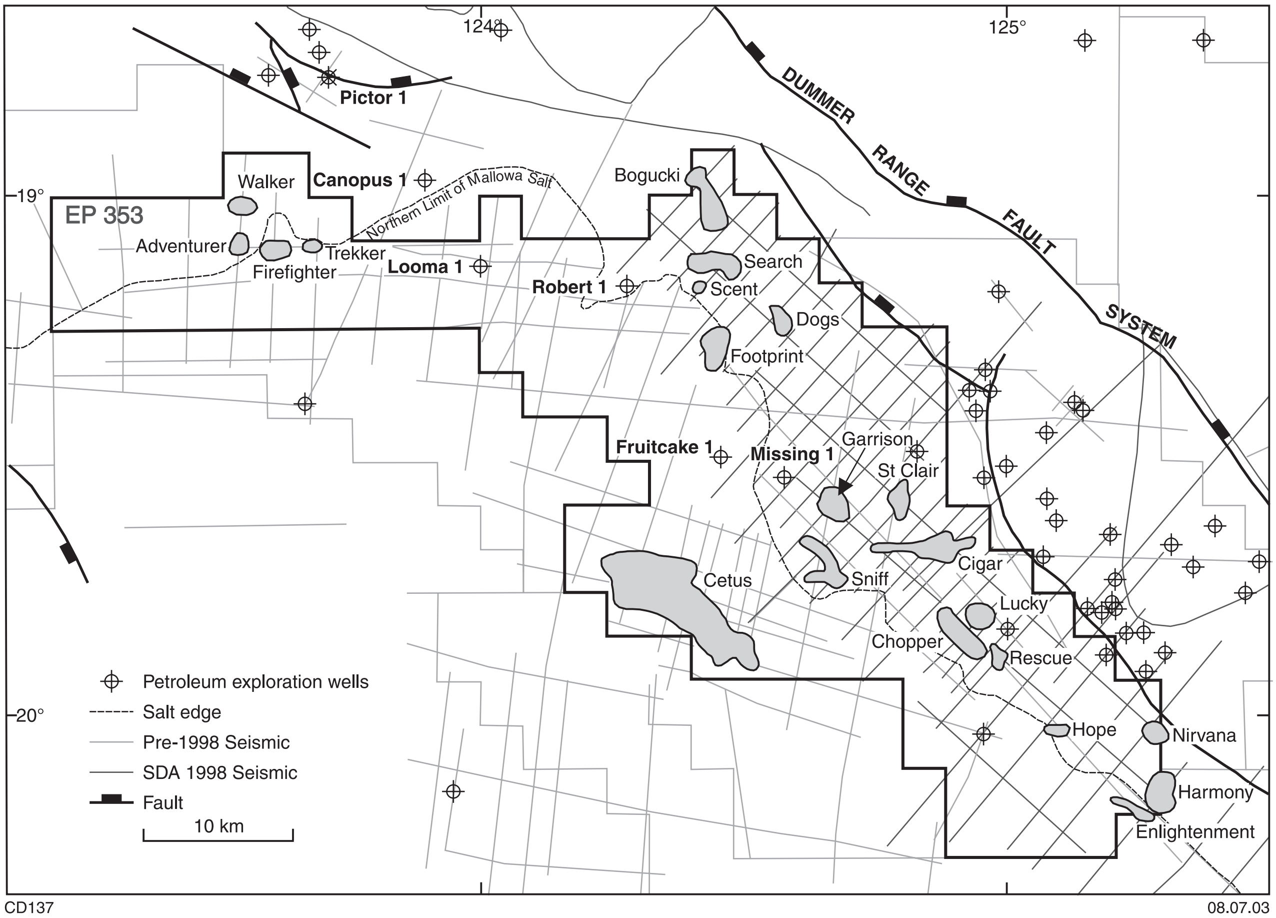


Figure 41. Prospects and leads of EP 353 (after Shell Development (Australia) Pty Ltd, 2000)

Fruitcake 1, Missing 1, and Robert 1 were drilled in 2001 by Hughes and Hughes Australia Pty Ltd. All three recorded traces of hydrocarbons in the Lower Ordovician section, but none tested a valid trap, and all the reservoirs were flushed. A closer look at the seismic data in the area is required.

Nearby wells

Aristida 1/1A, Caladenia 1, Canopus 1, Crossland 2, Dampiera 1/1A, Drosera 1, Edgar Range 1, Eremophila 1, 2, and 3, Fruitcake 1, Goodenia 1, Kunzea 1, Looma 1, McLarty 1, Missing 1, Pictor 1 and 2, Robert 1, and Santalum 1/1A.

Trap

Six major petroleum plays were identified in EP 353 (Fig. 42), of which four were considered attractive. The pre-salt plays (below the Mallowa Salt) target the 'Acacia sandstone member', and post-salt plays target the Worral Formation, Tandalgoo Sandstone, and Grant Group. The success of the post-salt plays depends on their proximity to the edge of the Mallowa Salt. The more risky plays are pre-salt plays targeting the Nambeet and Nita Formations, both of which are downgraded due to tight reservoirs in both formations in nearby wells. Oil charge from the Goldwyer Formation source rocks is expected to have migrated northward beneath the Mallowa Salt into the Ordovician reservoirs, or into the younger, post-salt reservoirs at the edge of the salt via faults and fractures (Shell Development (Australia) Pty Ltd, 2000). The plays are discussed in **Traps** under the **Petroleum prospectivity** section.

Prospects span three types of traps: a) simple structures with or without fault dependency; b) sombreros cored by the Worral Formation and draped by the Grant Group; and c) sombreros cored by the Grant Group. The volumetric estimates of all of these prospects are given in Table 11. Prospects within the Tandgaloo Sandstone, 'Acacia sandstone member', and Nita and Nambeet Formations form the first trap type. The Nambeet Formation and 'Acacia sandstone member' prospects could be sealed intraformationally by shale, the overlying Goldwyer Formation, or both. The Bongabinni Formation and Mallowa Salt would provide an effective top seal for the Nita Formation. Prospects with Ordovician objectives are critically dependent on reservoir quality and charge. Shell Development (Australia) Pty Ltd (2000) concluded that depth conversion of low-relief traps within the Ordovician section also contributes towards their risk. All Nita

Table 11. Prospects and leads in EP 353

Prospect/ lead name	*Mean success volume (GL)*	P_{15} *(GL)*	*Reservoir*
Adventurer	1.59	2.70	Worral Formation
	1.75	3.18	Grant Group
Bogucki	8.74	15.10	Worral Formation
	3.50	6.20	'Acacia sst mbr'
	6.84	12.08	Grant Group
Cetus	100.48	176.48	Worral Formation
Chopper	2.54	4.13	Worral Formation
	0.79	1.43	'Acacia sst mbr'
	2.07	3.82	Grant Group
Cigar	11.13	20.83	Worral Formation
Dogs	3.34	5.72	Worral Formation
Enlightenment	2.54	4.61	'Acacia sst mbr'
Firefighter	0.64	1.11	Worral Formation
	0.16	0.48	Grant Group
Footprint	2.07	3.66	Worral Formation
	1.43	2.54	'Acacia sst mbr'
Garrison	3.97	6.84	Worral Formation
	2.07	4.29	Grant Group
Harmony	2.07	3.82	Grant Group
	2.86	4.77	'Acacia sst mbr'
Hope	2.70	4.93	Worral Formation
	6.68	12.08	Tandalgoo Sandstone
Lucky	1.59	2.86	Worral Formation
	0.48	0.79	'Acacia sst mbr'
	0.32	0.64	Grant Group
Nirvana	7.47	15.26	'Acacia sst mbr'
Rescue	1.11	2.07	'Acacia sst mbr'
Scent	0.32	0.64	Grant Group
Search	3.97	7.15	Worral Formation
	2.70	5.09	Grant Group
Sniff	3.02	5.09	Worral Formation
St Clair	2.23	3.97	Worral Formation
Trekker	0.64	1.11	Grant Group
Walker	1.43	2.54	Worral Formation
	0.64	1.27	Grant Group

NOTES: P_{15}: volume exceeded by 15% of success cases
sst mbr: sandstone member

SOURCE: Shell Development (Australia) Pty Ltd (2000)

Formation features within the area appear to be associated with velocity anomalies in the shallower Grant Group, and as a result, the observed time features may not be present at depth (Shell Development (Australia) Pty Ltd, 1991).

Localized thickening of the Worral Formation and Grant Group, caused by deformation of the salt, as well as two or more phases of salt dissolution, forms the centre of sombrero structures. Grant Group prospects rely on sandstones sealed intraformationally by shales, which are present over the majority of the permit. The Elsa Sandstone Member is considered the best reservoir interval within the Worral Formation, the prospectivity of which relies on intraformational seals by shale of the Waldecks Member. The risks associated with both the Worral Formation and Grant Group prospects include integrity and quality of the intraformational shales, charge, and oil quality in shallow to very shallow reservoirs. Reservoir quality of the Elsa Sandstone Member is also a risk for Worral Formation prospects. The Tandalgoo Sandstone prospects are sealed by the Dominic Shale, where present. In some areas, Permian erosion has removed this top seal and much of the Tandalgoo Sandstone, but elsewhere, sufficient Devonian section has been preserved (Shell Development (Australia) Pty Ltd, 2000).

Based on seismic data, Shell Development (Australia) Pty Ltd (2000) concluded that Late Triassic to Early Jurassic inversion associated with the Fitzroy Transpressional Movement created most of the post-salt structures, and was also responsible for the last significant salt-dissolution event. The pre-salt structures (with Ordovician objectives) could therefore be as old as Late Carboniferous.

Source

The upper part of the Goldwyer Formation is expected to be the major source in this area, as it is rich in oil-prone kerogen. TOC values typically range from 0.7 to 1.5% in this area, but are locally as much as 6% (Shell Development (Australia) Pty Ltd, 1991). Maturity studies concluded that these source rocks reached peak generation in the Late Jurassic to Late Cretaceous, and are still within the oil window. Live-oil shows were recorded in Canopus 1 and Looma 1 from the Nita Formation, and in Aristida 1/1A, Eremophila 1 and 2, and Goodenia 1 from the Permian and Upper Devonian sections. Acacia 1 and 2, and Dodonea 1 and 2 (updip to the east), and Pictor 1 and 2 (updip to the northwest) recorded live-oil shows from the Nita and Goldwyer Formations. The shows indicate that a migration pathway has been active in the region.

The timing of peak charge generation is accepted as Middle Devonian to Early Carboniferous (Kennard et al., 1994; Shell Development (Australia) Pty Ltd, 2000), but post-salt structures in EP 353 date from the Late Triassic to Early Jurassic. SDA suggested that EP 353 is an analogue to the Eastern Flank province in southern Oman. In Oman, oil generation preceded trap formation, but the oil remained reservoired in low porosity and permeability pre-salt strata until it was released by salt dissolution. Oil charge within EP 353 may also be pooled within low porosity and permeability rocks sealed beneath the Mallowa Salt layer before being released into post-salt reservoirs during phases of salt dissolution (Department of Minerals and Energy and Petroventures Pty Ltd, 2000; Shell Development (Australia) Pty Ltd, 2000). The last significant phase of salt dissolution in the southern Canning Basin was during the Fitzroy Transpressional Movement, so there may have been an oil charge post-dating trap formation.

Reservoir

The presence of a suitable reservoir within the Ordovician section is a significant risk within EP 353. The Ordovician reservoirs rely on secondary porosity; where the reservoirs are fractured, leached, or dolomitized, about 5–15% porosity is expected. Elsewhere, typically less than 5% porosity is seen. The quality of the Nita Formation improves updip towards the northern and eastern parts of the permit: porosity values vary from 2% in the southwest

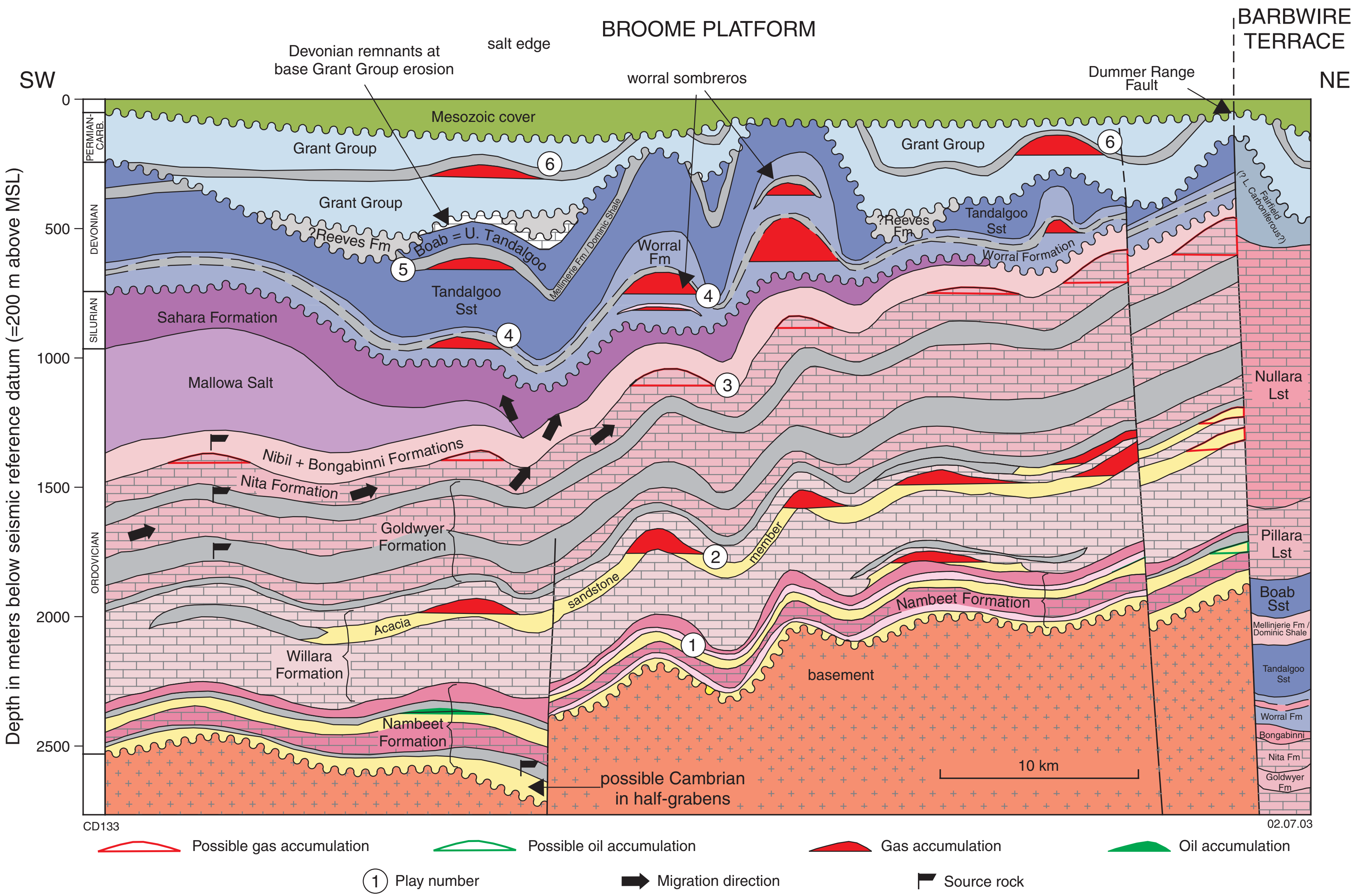


Figure 42. Schematic cross section of EP 353 showing the possible plays present (after Shell Development (Australia) Pty Ltd, 2000)

(McLarty 1), to 7–15% in the north (Canopus 1), to 9 – 16.2% in the east (Santalum 1). The higher porosity values are on the flanks of the salt basin, updip from the salt edge. The 'Acacia sandstone member' displays good log-derived porosities in Fruitcake 1 (9–11%) and Missing 1 (11–18%, with an average of 15%), which compares with core-derived porosities of 0.4 – 11.9% in Looma 1. These porosity values approach those of the 'Acacia sandstone member' in Acacia 1 and 2, Dodonea 1, Setaria 1, and Solanum 1. Permeability values range from 0.01 to 9.5 mD in the permit area. Where intersected and evaluated, the Nambeet Formation has low porosities (2–5% in McLarty 1).

The Tandalgoo Sandstone has excellent reservoir qualities. In Canopus 1, log-derived porosities of 27–30% were calculated for the section between 365.5 and 707 m, compared with 12–15% between 707 and 938 m. Where intersected and evaluated, the Elsa Sandstone Member shows excellent reservoir qualities. An average porosity of 23% was recorded for the Elsa Sandstone Member in Acacia 1. In the Grant Group, porosities range from 14 to 24% in the southwest (McLarty 1, permeability of 21–37 mD), to 12–30 % in the north (Canopus 1). Variable values are seen in the southeast on the Crossland Platform (porosity of 1.3 – 31.3% and permeability of 0.1 71 mD in Crossland 2).

EP 377

EP 377 was operated by Lonman Pty Ltd from 1993 to 1997 when it was surrendered. During this time Lonman reprocessed seismic data in the permit and conducted a radiometric and geochemical soil survey. This region is currently vacant. The leads delineated within this permit are considered dubious.

Conclusions

Oil-saturated mineral cores and live oil recovered from stratigraphic and petroleum exploration wells suggest the presence of a number of oil-prone source-rock intervals within the central Canning Basin. These shows are widespread throughout almost the entire stratigraphic column, from Lower Ordovician right up to the Permian, across the Barbwire, Jurgurra, and Mowla Terraces, Broome Platform, and Fitzroy Trough, indicating good migration pathways. Within the acreage release area in the central Canning Basin, the most significant oil shows are associated with the Ordovician to Upper Devonian section on the Barbwire and Mowla Terraces and Broome Platform, whereas shows in the Fitzroy Trough are probably sourced from the Carboniferous–Permian section.

Based on the geochemical data available, the best source rocks are microbial-rich, oil-prone argillaceous rocks within the upper part of the Ordovician Goldwyer Formation, which ranges from immature to within the oil-generative window in the acreage release areas. The source rock intervals within the lower part of the Goldwyer Formation are gas prone. Oil-prone (Mellinjerie Formation) and gas-prone (unnamed carbonate unit and Boab Sandstone) source rocks are present in the Upper Devonian section, but are of much poorer quality than the Ordovician source rocks.

The main objectives for petroleum exploration in the central Canning Basin have been Ordovician rocks within pre-salt plays, and Upper Devonian to Permian rocks within post-salt plays. The 'Acacia sandstone member' of the Willara Formation and Nita Formation are considered to have the best reservoir characteristics in the Lower Ordovician section. The 'Acacia sandstone member' has porosities of up to 19.3% and permeabilities of up to 385 mD, compared with porosities of up to 20.9% and permeabilities of up to 238 mD in the Nita Formation. However, the Nita Formation is commonly tight and oil residues noted from this formation in most wells are associated with horizons of intercrystalline, vuggy, mouldic, or fracture porosity. The highest porosity and permeability values within the Nita Formation correspond to these intensively dolomitized horizons. The thickest sections of the Ordovician Nita and Willara Formations are on the Mowla Terrace. The 'Acacia sandstone member' of the Willara Formation has only been recognized in the southern part of the area on the Barbwire Terrace, but this does not discount it from being present elsewhere within the acreage release area.

The most likely clastic reservoirs are within the Devonian Tandalgoo Sandstone and Worral Formation, whereas the best-quality carbonate reservoirs are in the Devonian reef complexes (Pillara and Nullara Limestones). Oil has been produced from the reef complexes, whereas no known hydrocarbon shows are associated with the Tandalgoo Sandstone and Worral Formation. Additionally, these two units are stratigraphically remote from the source rocks of the Goldwyer Formation. All significant porosity and permeability values in both the Pillara and Nullara Limestones are a direct result of pervasive secondary dolomitization, subsequent leaching in shallow burial regimes, or a combination of both (Bridge Oil Ltd, 1987; Manzanita Alliances Incorporated, 1996). The Devonian reef complexes are thickest on the Barbwire Terrace, with thinner sections on the Mowla and Jurgurra Terraces. The Tandalgoo Sandstone thins from the east to the west within the area. Within the Carboniferous–Permian section, the Fairfield and Grant Groups have the best reservoir characteristics. Overall, the Grant Group is the most favourable reservoir unit, with porosity values of up to 40% (average of 19.94%) and permeability values of up to 5520 mD (average 604.85 mD), but it is only a proven reservoir on the Lennard Shelf to the north. The Permian Grant Group has a moderately uniformly thickness in the central part of the area, but thickens dramatically towards the Fitzroy Trough.

There are two main play types in the central Canning Basin: pre-Mallowa Salt plays with Ordovician objectives that could be as old as the Late Carboniferous; and post-salt plays with Devonian to Lower Permian objectives, which overlie the Carribuddy Group and formed during the Late Triassic to Early Jurassic. The timing of peak charge is probably Middle Devonian to Early Carboniferous, with a possible extension into the Triassic (Kennard et al., 1994; Russell, 1998; Shell Development (Australia) Pty Ltd, 2000).

The main problem in the area for post-salt traps is that they may have formed after peak hydrocarbon expulsion. SDA proposed that secondary migration into younger traps was possible, mainly by oil pooling within low porosity and permeability Ordovician rocks sealed beneath the Mallowa Salt, which would then be released after salt dissolution into the post-salt reservoirs (Department of Minerals and Energy and Petroventures Pty Ltd, 2000; Shell Development (Australia) Pty Ltd, 2000).

Wells drilled to date in the acreage release area have been unsuccessful for a variety of reasons, which as a whole include lack of structural closure, poor reservoir and seal quality, and the absence of effective source rocks or migration pathways (Appendix 1). One or more of these factors apply for any one well. Numerous undrilled leads have been identified that may have none of these drawbacks. Source rocks, potential reservoir rocks, and seals have been identified in areas where there is the potential for adequate structural closure, effective migration pathways, and appropriate timing of trap development. Limited infrastructure is in place for when an economic discovery is made, and could easily be upgraded.

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Appendix 1

Summaries of selected wells in the central Canning Basin

Well name	*Year drilled*	*Company*	*Structure drilled*	*Stratigraphic objective*	*Results*	*Comments*
Abutilon 1	1981	WMC	Carbonate mound	Primary objectives: Fairfield Group and Pillara Limestone. Secondary objectives: Devonian sandstones and carbonate rocks	No hydrocarbons were detected. The Pillara Limestone had varying, but typically good permeability (max. 2630 mD) and secondary fracture, vuggy, and moldic porosity (up to 15%)	A stratigraphic test of a Palaeozoic seismic anomaly without structural closure. No source rocks or good seals were found within the well
Acacia 1	1981	WMC	Carbonate mound (?Worral Formation – Carribuddy Group, as well as Nita Formation reefal mound)	Devonian–Ordovician section	Fluorescence, free oil in mud, live and dead oil, bitumen, and minor gas were noted in the Nita and top part of the Goldwyer Formations (694.65 – 869.3 m). Further fluorescence, residual oil, and solvent cut were noted to TD. Oil bled from vugs, veins, and fractures in the Nita Formation (744 – 783.25 m). The Grant Group and Tandalgoo Sandstone had the best porosities and permeabilities. The Nita Formation was mainly tight, but there were three intervals between 713 and 841 m of enhanced vuggy and moldic porosity (4.7 – 13.7%; 1.4 – 14 mD). Dolomites in the Goldwyer Formation were tight, but the sandstones had very good porosity (13 – 20.6%) and fair to excellent permeability (1.56 – 505 mD)	A stratigraphic test of a Palaeozoic seismic anomaly. There were not enough seismic data to determine if the structure has complete closure
Acacia 2	1982	WMC	Carbonate mound	Nita Formation	No significant hydrocarbons were detected. Fluorescence, residual oil, and minor gas were noted in the Nita Formation. A DST (700–754 m) flowed salt water and showed moderate permeability. Fluorescence, residual oil, and bitumen were noted in the Goldwyer Formation. DSTs over this unit flowed saline water and showed good permeabilities. A minor gas kick was noted in the Nambeet Formation. The average porosities in the well were 6.4% for the dolomites (with average permeability of 4.65 mD), 0.97% for the limestones (average permeability of 0.22 mD), and 8.9% for the sandstones (average permeability of 50.7 mD)	No stratigraphic or structural trap can be proved at this site; the well probably did not test a valid trap
Antares 1	1988	Bridge Oil Ltd	Complexly faulted anticline	Nita Formation	Trace residual oil and gas were detected in the Nita Formation (1110–1218 m). A DST over this formation was dry. Fair to excellent reservoir quality sandstones are present in the Grant Group, but the objective had fairly poor reservoir quality (average 2% porosity)	The well failed as the seal and reservoir were not adequate

Appendix 1 (continued)

Well name	*Year drilled*	*Company*	*Structure drilled*	*Stratigraphic objective*	*Results*	*Comments*
Aristida 1/1A	1983	WMC	Broad anticline	Permian – Upper Devonian section	Tarry asphaltic oils were recorded between 195 and 218 m (Grant Group and Nullara Limestone) in Aristida 1. Similar oils were noted at 545 and 558–560 m (Nullara Limestone) in small fractures associated with possible fault zones in Aristida 1A. Asphalt was also noted from the Grant Group	A stratigraphic test of the Permian to Upper Devonian strata. Potential reservoir units were tight, and there were no source facies intersected
Babrongan 1	1962	WAPET	Anticline on the down-thrown side of the Dampier Fault and updip from Frome Rocks 2 (near a salt dome)	Primary objective: lower part of the Luluigui Formation. Secondary objective: upper part of the Grant Group	Minor gas shows (methane) in the Dora Member (Grant Group) are probably associated with highly carbonaceous material in this unit. Bitumen inclusions were recorded in the Babrongan Formation (1835–1841 m; 1929–1932 m; and 1936–1939 m). High porosity and permeability were noted in the Mesozoic and Permian sections	The well did not test a valid trap. The objective was missing due to an unconformity between the upper part of the Luluigui Formation and lower part of the Clanmeyer Siltstone. All units intersected were thicker than anticipated
Barbwire 1	1972	WAPET	Anticline with four-way dip closure	Permian–Ordovician section	No hydrocarbons were detected. An oil show noted at 466 m was due to contamination in the drilling mud. The Ordovician carbonates had low to very low porosities (2–10%, average 4%) and negligible permeabilities. Rare vuggy porosity was seen. Sandstones in the Tandalgoo Sandstone and Carribuddy Group had good porosity values (37% and 20% respectively)	A stratigraphic test of the Permian to Ordovician section located in an area of poor seismic control. Pores within the Nita Formation were cemented, preventing the entrapment of any hydrocarbons
BMR 01 Mount Anderson	1955	BMR	Stratigraphic	Palaeozoic section	No hydrocarbons were detected. The Grant Group and Noonkanbah Formation had low to moderate porosity and very low to low permeability. The Poole Sandstone had excellent porosity and permeability	The well was a stratigraphic test of the Palaeozoic, with no structural closure
Boab 1	1981	WMC	Carbonate mound	Ordovician and Permian section	No hydrocarbons were detected. The Grant Group had low porosity. Devonian dolomites had fair to excellent secondary porosity, but the limestones had very low porosity. The Devonian sandstones had excellent porosity (25–30%) and permeability (up to 2700 mD)	The well was a stratigraphic test away from seismic control. The Ordovician section was not penetrated. No source or seal rocks were intersected
Caladenia 1	1983	WMC	Broad anticline on the Barbwire Terrace	Permian and Devonian section	No hydrocarbons were detected. The Nullara Limestone was tight (very poor porosity with minor vuggy zones). There was no visible porosity below 274.6 m	The well was a stratigraphic test to provide velocity data for the Permian and Devonian section. No reservoir rocks were intersected
Canopus 1	1982	Getty Oil	Pinnacle reef within a large anticlinal feature	Primary objectives: Pillara Limestone, Tandalgoo Sandstone, and Nita Formation. Secondary objectives: Carribuddy Group, and Goldwyer and Willara Formations	Minor gas was recorded from the Carribuddy Group. Traces of free oil in the drilling fluid, the presence of gas, and minor fluorescence were noted in the Nita, Goldwyer, and Willara Formations. The Grant Group and Tandalgoo Sandstone had excellent porosity, but very little porosity was seen below the Carribuddy Group	The well failed as there were no good seals for the reservoirs and no structure. The Pillara Limestone was absent; instead an anomalously thick section of the Tandalgoo Sandstone was intersected, rather than a reef as predicted

Appendix 1 (continued)

Well name	*Year drilled*	*Company*	*Structure drilled*	*Stratigraphic objective*	*Results*	*Comments*
Capparis 1	1984	WMC	Broad anticline	Silurian–Devonian and Ordovician section	No hydrocarbons were recorded. There may be some source potential in the Grant Group, but none in the older section. The reservoir in the Grant Group is thin and of poor quality. The Mellinjerie Formation had very poor reservoir quality rocks, but the Tandalgoo Sandstone had good to excellent reservoir quality rocks	A stratigraphic test of the Silurian to Ordovician strata. There was no potential source facies in the pre-Permian, and no closure
Carina 1	1982	Getty Oil	Anticline	Primary objectives: Tandalgoo Sandstone and Nita Formation. Secondary objectives: Grant and Carribuddy Groups	Minor fluorescence was noted in the Nita Formation, which was also very tight. Minor fluorescence was also seen in the Carribuddy Group (Sahara Formation and Minjoo Salt) and Goldwyer Formation	The well was poorly located due to insufficient seismic coverage, and probably did not test a valid trap. Reservoir, source, and sealing quality were very poor
Crossland 1	1971	WAPET	Stratigraphic	Permian section	No hydrocarbons shows were recorded. Sandstones in the Grant Group were tight. Porosity in the Devonian section varied from 1 to 21% (average 2.5%) and permeability was poor (<0.1 to 3.3 mD)	A stratigraphic test of the Permian section in an area of no seismic control
Crossland 2	1971	WAPET	Diapir	Permian section	No hydrocarbons shows were recorded. The sandstones in the Grant Group were porous and permeable	A stratigraphic test of the Permian section in an area with no seismic control
Crystal Creek 1	1988	Kufpec	Northerly trending, faulted anticline with four-way dip closure	Primary objectives: Nita and Willara Formations, and Tandalgoo Sandstone. Secondary objectives: Goldwyer Formation, Carribuddy Group, and Nullara and Pillara Limestones	Fair to a few good oil shows in the Nita Formation below 1583 m. A DST below this depth (1583–1593 m) flowed mud, indicating that the carbonates were tight. The Willara Formation had patchy bituminous stains, but a DST over the formation (2375.5 – 2386.5 m) flowed water. Gas peaks were recorded throughout the Goldwyer and Willara Formations	The well failed, as reservoir quality in the Nita Formation was poor, and all other potential reservoirs were water-wet
Dampiera 1/1A	1982	WMC	Carbonate build-up	Primary objectives: Pillara and Nullara Limestones, Tandalgoo Sandstone, and Worral Formation. Secondary objective: Laurel Formation	Dubious fluorescence at 1471.7 m, but other reliable shows (fluorescence and residual oil) from 1747 to 1801 m within Devonian limestones and sandstones with low porosity and permeability	A stratigraphic test of the Silurian–Permian section located in an area of poor seismic control
Dodonea 1	1985	WMC	Faulted anticline on a tilted fault block	Primary objectives: Nita Formation and ‘Acacia sandstone member’. Secondary objectives: Devonian sandstones, Mellinjerie Formation, and Tandalgoo Sandstone	A DST (1525–1553 m) over the Goldwyer Formation produced 10 L of 18.5° API oil and 60 m of oil-cut mud. DST 2 (2014.03 – 2033.42 m) over the Nambeet Formation produced gas at 85 m^3/day. Minor oil stains were noted in the Devonian sandstones. All the secondary objectives were water-wet	The primary objective was completely eroded, with no updip closure
Dodonea 2	1987	WMC	Pinchout on tilted fault block	Nita Formation downdip of Dodonea 1	No significant hydrocarbons were recorded. Trace heavy oil, fluorescence, and solvent cut were noted in the Nita and Goldwyer	The well failed, as the reservoir quality in the Ordovician section was poor, and all other reservoirs were flushed

Appendix 1 (continued)

Well name	*Year drilled*	*Company*	*Structure drilled*	*Stratigraphic objective*	*Results*	*Comments*
Dodonea 2 (cont.)					Formations,with minor live oil bleeding from vugs and fractures in the latter unit. Intercrystalline porosity is poor to absent in the Ordovician section. These units are tight, but all other reservoirs were water-wet	The well was drilled downdip of the Dodonea 1 structure, and did not test a valid trap
Doran 1	1968	WAPET	Broad, asymmetric, domal anticline	Primary objective: Grant Group. Secondary objective: sand bodies in the Luluigui Formation	No significant hydrocarbons were intersected. A bituminous residue was noted in the lower part of the Grant Group. Log-derived porosities for the Grant Group ranged from 0 to 30%. The Luluigui Formation had fair porosity (6–12%) and low permeability (5 mD)	A stratigraphic well designed to investigate Permian and pre-Permian strata. The well was not located within a structure
Drosera 1	1984	WMC	Broad anticline	Ordovician and Silurian–Devonian section	No hydrocarbons were detected. The Grant Group had good to very good porosity	A stratigraphic well designed to test the Ordovician and Silurian–Devonian strata. Potential source rocks were absence, and the objectives were not reached
Edgar Range 1	1968	Total Exploration	Faulted anticline bounded to the north by the Dampier Fault	Thangoo Limestone (now Willara Formation)	Minor hydrocarbons were detected. Trace oil was noted in the Nita Formation, trace pinpoint fluorescence in the Willara Formation, and a minor gas show in the Nambeet Formation. Both DSTs were dry. Porosity was very good in the Permian section, but poor to nil in the pre-Permian section (minor porous zones were noted)	A stratigraphic well drilled without seismic data
Eremophila 1	1982	WMC	Devonian carbonate mound	Upper Devonian section	No significant hydrocarbons were recorded. Fluorescence and oil stains were noted in the basal Grant Group and Devonian dolomites (193.8 – 209.7 m). A DST over this zone produced only salty water. Minor fluorescence and oil residues were noted from 900–1190 m. The Grant Group had good porosity and permeability, the Devonian dolomites had low porosity and permeability, and the Devonian carbonate unit had very poor porosity and permeability	A stratigraphic test in an area with no structural control. There were very few intervals of good reservoir quality units, but excellent seals
Eremophila 2	1983	WMC	Devonian carbonate mound	Lower Permian and Upper Devonian sections	Minor fluorescence and free oil from two zones in the Grant Group were recorded. Porosity in the hole was poor	The well did not test a valid trap. There were no source rocks in the well
Eremophila 3	1983	WMC	Devonian carbonate mound	Upper Devonian section	No hydrocarbons were detected	The well did not test a valid trap
Ficus 1			Carbonate build-up	Primary objective: Fairfield Group (Laurel Formation). Secondary objective: sandstones in the Grant Group	No hydrocarbons were detected. The Nullara Limestone has good porosity (0.4 – 15.3%) and low permeability (mostly <0.1 mD). Water flowed from this unit, showing that the fractures and vugs are interconnected. Excellent reservoir quality was noted in the sandstones of the Grant Group	The well did not test a valid trap. There was no closure to the north in this poorly seismically defined structure. No source rocks were noted in the well

Appendix 1 (continued)

Well name	*Year drilled*	*Company*	*Structure drilled*	*Stratigraphic objective*	*Results*	*Comments*
Fitzroy River 1	1980	Amax Petroleum	Broad anticline, containing possible carbonate build-up anomalies, in the central part of a graben within the Fitzroy Trough	Fairfield Group (Anderson and Laurel Formations)	Hydrocarbon shows were noted intermittently from 1715 m to TD (Anderson and Laurel Formations), with a minor light oil show at 1869 m with a gas kick, and minor gas shows below 2075 m. The gas shows to 2600 m are heavier and are associated with oil stains and fluorescence; those below are dry gas associated with dead oil stains but no fluorescence. A DST over the Laurel Formation produced traces of light condensate and gas. The reservoirs above 2075 m are saturated with fresh-water and those below saturated with more-saline water. Traces of ?bituminous residue and fluorescence were noted in the lower part of the Grant Group, which is saturated with fresh water . Porosities of the Fairfield Group were up to 15% (average 10% in the oil show related zones)	The well did not test a valid trap and source rock potential is low. The lack of permeability in the reservoir rocks (low to nil over the hydrocarbon-bearing zones) also contributed to the scarcity of hydrocarbons
Frome Rocks 1	1959	WAPET	Strongly faulted anticline	Pre-Permian section	No hydrocarbons were detected. The well intersected a salt dome	The well did not reach its objective and did not test a valid trap
Frome Rocks 2	1959	WAPET	Anticline on the southern flank of a salt dome	Ordovician section	Fluorescence and oil staining were noted throughout the Luluigui Formation. The reservoir was water saturated and porosity and permeability were low. The well demonstrated that part of the Devonian section was petroliferous	The well did not reach its objective. Any oil that was present was either lost or has migrated into a fault trap against the salt intrusion. The well was the first to core a pre-Permian section in this area
Fruitcake 1	2001	Hughes & Hughes	Salt-related structure	Worral (Elsa Sandstone Member) and Willara (‘Acacia sandstone member’) Formations	No significant hydrocarbons were detected. Trace gas was noted in the Nita, Goldwyer, and Willara Formations. All reservoirs were water-wet and had low porosities and permeabilities. The ‘Acacia sandstone member’ had an estimated net sand section of 29 m with 9–11% porosity	The well did not test a valid trap
Goodenia 1	1983	WMC	Stratigraphic	Permian–Devonian section	Hydrocarbon shows in the basal part of the Grant Group and in the immediately underlying the Fairfield Group consist of stained core, asphalt on fractured surfaces, rare globules of heavy oil, and fluorescence. A DST flowed salty water. Porosity in the Permian section is low, but there is excellent fracture porosity and permeability in the Devonian carbonates	The well was a stratigraphic test. Large-scale faulting was seen in the core, so any hydrocarbons that were present have probably migrated elsewhere. No source-rock potential was demonstrated
Grant Range 1	1955	WAPET	Complex, faulted anticline separated into two parts by a graben	Devonian and Ordovician section	No hydrocarbons were detected. Traces of bituminous material and spotty fluorescence were noted. DSTs produced water and mud. The Grant Group had very good porosity (6.3 – 20.7%) and permeability and the Upper Carboniferous section had good porosity (6 – 7.5%)	The well failed as it did not penetrate the objectives, and the Grant Group contains predominantly reservoir facies

Appendix 1 (continued)

Well name	*Year drilled*	*Company*	*Structure drilled*	*Stratigraphic objective*	*Results*	*Comments*
Kunzea 1	1984	WMC	Stratigraphic	Goldwyer Formation	Fluorescence and oil staining (310.7 – 375.5 m) were noted in the Nita and Goldwyer Formations. Nil to poor porosity was seen in these units, but excellent porosity and permeability was noted in the Grant Group	A stratigraphic test of the Lower Permian to Ordovician section. Reservoir facies were very tight
Logue 1	1972	WAPET	Anticline	Primary objective: Mellinjerie Formation. Secondary objectives: Tandalgoo Sandstone and sandstones in the Permian section	No significant hydrocarbons were detected. There was a poor hydrocarbon show at the top of the lower Grant Group. The pre-Permian section was thicker than expected	Poor seismic control led to the mis-identification of the objective, which was not reached. The well failed as it was drilled downdip from the crest of the structure and the Permian reservoirs were flushed and not sealed
Looma 1	1996	Shell Development	Broad anticline	Primary objectives: Nita Formation and Willara Formation (‘Acacia sandstone member’). Secondary objective: Nambeet Formation	Oil bled from the Nita Formation and ‘Acacia sandstone member’, but DSTs over these intervals showed them to be tight. Gas shows were noted from the Nambeet Formation. No hydrocarbon shows were noted above1262 m. Very low porosity (average 6%) and permeability were recorded from the Nita Formation. Primary porosity in the ‘Acacia sandstone member’ was very low to 11%, and secondary porosity was very low to 4%	The well failed due to poor reservoir quality. The oil is probably residual
Lovell’s Pocket 1	1990	Kufpec	Faulted anticline with four-way dip closure	Primary objectives: Nita, Willara, and Tandalgoo Formations. Secondary objectives: Goldwyer Formation, Carribuddy Group, and Nullara and Pillara Limestones	Oil stains and fluorescence were noted in the Nita Formation below 1149 m, and only fluorescence in the upper part of the Goldwyer Formation. Traces of rare, bituminous oil stains were seen in the Willara Formation. Minor gas shows were recorded throughout the Ordovician and Upper Devonian section. There are no effective reservoir present in the Nita Formation and all other reservoirs were water-wet	The Tandalgoo Formation was not recognized (or was missing) in the well. There was evidence of residual or fossil hydrocarbons or a migration pathway. The well failed as the objectives were flushed and reservoir quality was nil to poor (average <5% for all reservoirs)
Matches Springs 1	1969	Total Exploration	Anticline, fault dependent closure to the east, on a fault-bounded block	Primary objectives: Middle–Upper Devonian carbonates facies and anhydritic dolomite of the Carribuddy Group. Secondary objective: Thangoo Limestone (now Willara Formation)	Minor shows were noted in the Carribuddy Group (mainly weak fluorescence). DSTs over various intervals produced muddy water or rathole mud. The Permian section was much thinner than expected, but the Devonian section was much thicker and more calcareous. Most of the reservoirs had very good to excellent porosity and moderate to excellent permeability. However, both the Carribuddy Group and Goldwyer Formation were tight	The well did not test a valid trap. The Permian section was deeply eroded and there was no seal. The secondary objective was not reached. There was no anhydritic dolomite in this well
McLarty 1	1968	Total Exploration	Eastern flank of a faulted anticline	Pre-Permian section	No hydrocarbons were detected. Trace fluorescence and bituminous material were noted in the Goldwyer Formation. The Grant Group had excellent porosity (up to 35%) and	The well did not test a valid trap. No reservoirs were present below the Permian unconformity

Appendix 1 (continued)

Well name	*Year drilled*	*Company*	*Structure drilled*	*Stratigraphic objective*	*Results*	*Comments*
McLarty 1 (cont.)					high permeability, but all other reservoirs were very tight (porosity of 1–3%)	
Mirbelia 1	1985	WMC	Faulted anticline	Primary objectives: Boab and Tandalgoo Sandstones, and Nita Formation. Secondary objectives: basal Grant Group and Pillara Limestone	Fluorescence, free oil and gas, oil stains, and a strong odour were recorded in the Mellinjerie Formation. Asphalt and bitumen were noted at the base of this unit. DST 1 produced 2 m^3 of oil and gas-cut mud, DST 2 produced 20 m^3 oil and gas mud and 1.5 L 22.4° API oil, and DST 3 produced 2 m^3 gas-cut mud and 1.25 L gas cut. The Mellinjerie Formation was very tight and preliminary analyses gave a 17 m gross pay and 1 m net pay with good porosity (10–15%) and low permeability (1–10 mD)	No hydrocarbon shows were noted in the primary objectives. The Nita Formation was not reached due to bad hole conditions associated with the salt in the area. The potential pay zone is not economic at this location
Mirbelia 2	1988	WMC	Faulted anticline	Primary objective: Mellinjerie Formation. Secondary objective: Nita Formation	No significant hydrocarbons were recorded. Minor fluorescence was noted in the Mellinjerie Formation (1835–1859 m) and in the Nambeet Formation. The good dolomite reservoir from Mirbelia 1 was not intersected in Mirbelia 2. Instead, the dolomite was tight (porosity <3%)	The well did not test a valid trap. There was no reservoir continuity of the dolomite between Mirbelia 1 and 2. Therefore, the reservoir is of limited extent and much thinner than expected
Missing 1	2001	Hughes & Hughes	Salt-related structure	Primary objectives: Elsa Sandstone Member (Worral Formation) and 'Acacia sandstone member' (Willara Formation). Secondary objective: Nita Formation	No significant hydrocarbons were detected. Trace gas was noted in the Willara Formation. All reservoirs were water-wet above 930 m, but had low porosities and permeabilities below that depth	The well did not test a valid trap. All reservoirs were flushed
Mowla 1	1969	Total Exploration	Anticline on a fault-bounded block	Carribuddy Group sandstones	No hydrocarbons were recorded. A DST (482–593 m) over the Devonian limestones produced rathole mud and salty formation water. All reservoirs had good porosity and permeability, but were water saturated. The Jurassic section was thinner and the Permian section thicker than expected	The well failed as it did not penetrate the objective and all other reservoirs were flushed
Mount Wynne 1	1923	Freney Kimberley	Regional anticline	Devonian limestones	Asphalt and bitumen were noted in sandstones of the Grant Group	The well did not reach the objective, or test a valid trap
Mount Wynne 3	1925	Freney Kimberley	Regional anticline	Devonian limestones	Globular oil and bitumen were noted in sandstones of the Grant Group	The well did not reach the objective, or test a valid trap
Musca 1	1982	Getty Oil	Anticline	Primary objectives: Nita Formation, Tandalgoo Sandstone, and sandstones of the Carribuddy Group. Secondary objectives: Carribuddy Group and Goldwyer Formation	Minor fluorescence and oil was noted in muds from the Carribuddy Group (Sahara Formation and Minjoo Salt). Gas readings, trace fluorescence, and oil stains were recorded from the Nita Formation. DSTs over these intervals failed. Good porosity was noted in the Grant Group, but it was water-wet. All other units were tight	The well was poorly located structurally due to insufficient seismic coverage, implying it was not a valid trap. Possible source rocks were organically lean

Appendix 1 (continued)

Well name	*Year drilled*	*Company*	*Structure drilled*	*Stratigraphic objective*	*Results*	*Comments*
Myroodah 1	1956	Associated Freney	Anticline, minor faulting at the eastern end. Closure was not determined at depth due to poor seismic control	Permian (Liveringa Group, Noonkanbah Formation, Poole Sandstone, and Grant Group)	No hydrocarbons were detected. A DST (454–454.1 m) produced 1.04 m^3 (36.8 cf) of water	The well probably did not test a valid trap. A full section of the Grant Group was not penetrated. The unconformity intersected in the well indicates that erosion in the area was more severe than previously thought
Nerrima 1 (AFO)	1955	Associated Freney	Anticline with fault closure on the western and northern flank, and dip closure elsewhere	Devonian limestones	There were traces of oil in the Grant Group. When tested, the rocks proved to be water-wet. Low to fair porosity was noted in the Permian units. The well failed to reach its objective as the Permian and Upper Carboniferous sections were unexpectedly thick	The well did not test a valid trap or reach its Devonian objective, and was drilled downdip from the main structure. The oil residues are remnants of either an earlier oil pool that migrated elsewhere or migration through the area
Nerrima 1 (FKO)	1941	Freney Kimberley	Regional anticline	Devonian limestones	Very minor gas was noted in sandstones of the Grant Group	The well did not reach the objective or test a valid trap
Nollamara 1	1985	IEDC Australia	Faulted anticline with possible drape closure on a fault-bounded block basinward of a carbonate edge	Primary objectives: Nullara and Pillara Limestones. Secondary objective: Grant Group	Bitumen was recorded in the Nullara Limestone (trace to 5%). DSTs over the unit produced rathole mud and formation water at a high flow rate. A DST over the Virgin Hills Formation produced a water cushion and mud. All reservoirs had good porosity and permeability	The well failed because there was no seal across the fault, implying any hydrocarbons migrated updip. The Pillara Limestone was not intersected
Notabilis 1	1984	IEDC Australia	Faulted, dip closure over a salt-related structure	Primary objectives: Tandalgoo Sandstone and uppermost Carribuddy Group. Secondary objectives: Fairfield Group, basal Clanmeyer Siltstone, and Frasnian units	No hydrocarbons were detected. There was a questionable minor oil show in the Clanmeyer Siltstone (1025 – 1027.5 m). All reservoirs above the Fairfield Group had very good log-derived porosities (23–36%), all reservoirs below had poor porosities. The Fairfield Group had fair porosities (up to 14%)	The well did not reach its primary objectives. The well failed as there was no valid trap. No mature source rocks were intersected
Nuytsia 1	1984	IEDC Australia	Faulted anticline	Primary objective: Nullara Limestone. Secondary objectives: Fairfield Group and basal Grant Group	Trace bitumen residues were noted at 785 m (basal Grant Group), 987–1050 m (Fairfield Group), and 1325–1340 m (Nullara Limestone). The Grant Group has good porosity (10–21%), Fairfield Group has very poor porosity (<5%, one small interval up to 12.7%), and the Nullara Limestone also has very poor porosity (average 3–5%, rarely up to 10%)	The well did not test a valid trap. The oil has either migrated up the faulted flank of the structure (lack of lateral seal across the fault) or there was insufficient hydrocarbons generated to charge the reservoirs. No adequate source rock was intersected
Pandorea 1	1985	WMC	Faulted anticline on the upthrown side of a major fault	Primary objectives: Tandalgoo Sandstone and Boab Sandstone. Secondary objectives: Nullara and Pillara Limestones and Worral Formation	No significant hydrocarbons were recorded. Minor fluorescence and bitumen were noted in the Boab Sandstone and Tandalgoo Sandstone. A DST over this interval flowed mud and water. Very good porosity and permeability were noted in the Devonian sandstones, but low porosity in the Devonian carbonates	The well did not test a valid trap. Major faulting in the area breached the structure

Appendix 1 (continued)

Well name	*Year drilled*	*Company*	*Structure drilled*	*Stratigraphic objective*	*Results*	*Comments*
Panicum 1	1984	WMC	Broad anticline on the Barbwire Terrace	Devonian section	No hydrocarbons were detected. There were fair reservoir-quality sandstones in the Grant Group. Poor porosity was noted in the Pillara Limestone but fair to good porosity in the Devonian sandstones	The well was a stratigraphic test to provide velocity data for the Devonian section. No source rocks were present. The well did not reach the anticipated TD as the drill string was accidentally cemented in the hole
Petaluma 1	1987	Ultramar	Fault-dependent closure on the easternmost crest of the Deep Well Anticline, which is cut by northerly trending faults on the east and west limbs	Primary objective: Grant Group ('Member C'). Secondary objective: Grant Group ('Member A') and Poole Sandstone	No significant hydrocarbons were detected. Minor oil shows and background gas were noted in the Liveringa Group, Noonkanbah Formation, and uppermost Poole Sandstone. Excellent reservoir-quality sandstones in the uppermost Grant Group and Poole Sandstone were water-wet	The well failed as the source rock in the area was lean, the section is immature, reservoirs were flushed, and there probably was leakage along the faults
Pictor 1	1984	BHP Petroleum	Compressional antilcine bounded by high angle, reverse faults	Primary objectives: Tandalgoo Sandstone, and the Nita and Willara Formations. Secondary objectives: Grant Group, Carribuddy Group, Nambeet Formation, and Pillara Limestone	High gas readings were recorded throughout the Carribuddy, Nita, and Willara Formations. Oil stains were noted in the Nita Formation and fluorescence in the Willara Formation. A DST (905–955 m) over the Nita Formation flowed gas at 5380 m^3/day (0.19 MMcf/day). A production test (940–965 m) over the same unit flowed 62 300 m^3/day (2.2 MMcf) and 3.8 kL (24 bbl) of 45° API oil. Porosity of the Nita Formation was poor (average 6% for limestone; 12% for dolomites), as was the permeability (0.2 – 4 mD). Fair to poor porosity was observed in the Willara Formation	The well did not test a valid trap and was drilled downdip of the main structure. Thick shales from the Carribuddy Group could provide an adequate seal, however, the porosity and permeability of the reservoir facies in the area are generally poor. The company noted that the oil leg in the Nita Formation was overlain by a gas cap, but the gas/oil contact could not be seen in the logs
Pictor 2	1990	Bridge Oil Ltd	Faulted anticline similar to Pictor 1	Nita Formation	A production test (929–959 m) over the Nita Formation produced 7391 m^3/day (0.261 MMcf /day) of gas, 1.67 kL/day (10.5 bbl/day) of oil/ condensate, and 1.45 kL (9.1 bbl) of salty formation water. The flow rates did not improve on those from Pictor 1, so the well was abandoned	There is a high level of uncertainty regarding the structural integrity of the trap due to the poor tie with seismic data in the area. The well did not intersect the predicted oil leg
Placer Camelgooda 1	1989	Placer	Fault trap	Nullara Limestone	This mineral hole recorded minor oil staining and fluorescence in the Fairfield Group. Fresh water flowed from the Poole Sandstone and Nullara Limestone	The hole was drilled for lead–zinc exploration in Devonian carbonates and was not a valid hydrocarbon test
Pratia 1	1984	WMC	Carbonate build-up	Lower–Middle Devonian sandstones	No hydrocarbons were detected. The Mellinjerie Formation has very poor reservoir quality, but the Devonian sandstones had good reservoir characteristics. The Grant Group had good reservoir quality. The facies intersected in the Mellinjerie Formation do not support a reef interpretation	A stratigraphic test of Permian to Devonian strata. The well failed due to lack of structure and there were no source rocks

Appendix 1 (continued)

Well name	*Year drilled*	*Company*	*Structure drilled*	*Stratigraphic objective*	*Results*	*Comments*
Robert 1	2001	Hughes & Hughes	Salt-related structure (sombrero development)	Primary objectives: Upper Grant Group and Worral (Elsa Sandstone Member). Secondary objectives: Willara ('Acacia sandstone member') and Nita Formations	No significant hydrocarbons were detected. There was an oil show at 1537 m in the 'Acacia sandstone member'. Trace gas was noted in the Nita and Goldwyer Formations. All reservoirs were water-wet and had low to moderate porosities and permeabilities. The 'Acacia sandstone member' had a net sand of 23 m with 11–18% porosity (average 15%)	The well did not test a valid trap. The secondary objective was not reached due to a sheared-off drill string
Santalum 1A	1983	WMC	Broad anticline	Permian–Ordovician section	Minor fluorescence and some oil staining were noted from the Goldwyer Formation (459–504 and 579–580 m). Good porosity was noted in the Permian section, but the Ordovician was tight with few vugs and fractures	The well was a stratigraphic test to provide velocity data for the Permian and Ordovician sections. The well probably did not test a valid trap
Setaria 1	1989	WMC	Regional culmination of the Crossland Platform. Dip closure to west and southwest, fault closure to east and northeast	Primary objective: 'Acacia sandstone member'. Secondary objectives: Goldwyer, Willara, and Nambeet Formations	Minor fluorescence and oil stains were recorded from the Permian and Ordovician sections. These hydrocarbon shows are interpreted to be residual. A DST (440 – 447.5 m) over the 'Acacia sandstone member' produced only water	The well was not located within a structural closure, but oil shows were noted directly under seals in the Willara and Nambeet Formations. This indicates that the well intersected a migration pathway rather than the pool. There was no significant seal from the overlying Permian section and poor porosity and permeability in the Goldwyer Formation
Solanum 1	1984	WMC	Fault block	Ordovician section	No significant hydrocarbons were recorded. Minor fluorescence and oil staining were noted in the Nita and Goldwyer Formations. A DST over this zone flowed formation water, mud, and mud filtrate. The Nita and Goldwyer Formations had poor reservoir quality, but the Grant Group had moderate reservoir quality	A stratigraphic test of the Lower Permian to Ordovician section. The reservoir quality of the objectives was poor
Triodia 1	1988	WMC	Broad anticline	Devonian section	No hydrocarbons were recorded. There were no reservoir rocks in the Grant Group, and poor porosity and permeability in the Nullara and Pillara Limestones. However, good to excellent fracture porosity was seen at 225–229 m	A stratigraphic test of Permian strata. The reservoir quality of the objectives was poor
Typha 1	1984	WMC	Rollover onto fault	Lower Permian – Upper Devonian section	No hydrocarbons were detected. The Devonian sandstones had good porosity and permeability, the Devonian limestones had fair visual porosity, and the Grant Group had fair to good porosity and fair permeability	A stratigraphic test of Permian and Devonian strata. The well is located on on a plunging anticline that spills to the north and is not a valid test

Appendix 1 (continued)

Well name	*Year drilled*	*Company*	*Structure drilled*	*Stratigraphic objective*	*Results*	*Comments*
Vela 1	1982	Getty Oil	Anticline on the down-thrown side of the Admiral Bay Fault Zone	Primary objectives: Nita, Formation, Tandalgoo Sandstone, and sandstones of the Grant Group. Secondary objective: Carribuddy Group sandstones	Minor fluorescence was recorded from the Minjoo Salt. The Grant Group and Tandalgoo Sandstone were water-wet. The Nita Formation and Carribuddy Group were tight	The well did not test a valid trap as it was poorly located in an area with insufficient seismic coverage. The source facies were organically lean

NOTES:

av.:	Average
DST:	Drill-stem test
TD	total depth

COMPANY:

Amax Petroleum	Amax Petroleum (Australia) Incorporated
Associated Freney:	Associated Freney Oilfields NL
BHP Petroleum:	BHP Petroleum (Australia) Pty Ltd
BMR:	Bureau of Mineral Resources
Freney Kimberley:	Freney Kimberley Oil Company NL
Getty Oil:	Getty Oil Development Company Ltd
Hughes & Hughes:	Hughes and Hughes Australia Pty Ltd
IEDC Australia:	IEDC Australia Pty Ltd
Kufpec:	Kufpec Australia Pty Ltd
Placer:	Placer Exploration Ltd
Shell Development:	Shell Development (Australia) Pty Ltd
Total Exploration:	Total Exploration Australia Pty Ltd
Ultramar:	Ultramar Australia Incorporated
WAPET:	West Australian Petroleum Pty Ltd
WMC:	Western Mining Corporation Ltd

Appendix 2

Petroleum exploration and stratigraphic wells in the central Canning Basin

Well name	*S no.*	*Type*	*Latitude (S)*	*Longitude (E)*	*Elevation from drillers datum (m AHD)*	*Total depth (m)*	*Bottomed in*	*Year*	*Operator*	*Production status*	*Completion status*	*Gas show*	*Oil show*
Abutilon 1	1846	STR	19°27'13"	125°07'05"	233	850.3	Upper Devonian	1981	WMC	Dry	P&A	Nil	Nil
Acacia 1	1847	STR	19°19'45"	124°59'44"	211.4	1208.7	Middle Ordovician	1987	WMC	Oil	P&A	Poor	Excellent
Acacia 2	2161	NFW	19°19'47"	124°59'44"	223	1575	Precambrian	1982	WMC	Oil	P&A	Poor	Good
Antares 1	3238	NFW	18°43'58"	123°41'43"	130.3	1298.5	Middle Ordovician	1988	Bridge Oil Ltd	Dry	P&A	Nil	Nil
Aristida 1A	2399	STR	19°53'50"	125°19'41"	179	734	Upper Devonian	1983	WMC	Dry	P&A	Nil	Fair
Babrongan 1	20	NFW	18°23'20"	123°35'46"	109.73	1949	Upper Devonian	1962	WAPET	Dry	P&A	Poor	Nil
Barbwire 1	723	STR	19°10'34"	125°01'04"	218.54	1071.37	Upper Devonian	1972	WAPET	Dry	P&A	Nil	Nil
BMR 01 Mount Anderson	3044	STR	18°19'48"	123°42'56"	71	512	Permian	1955	BMR	Dry	P&A	Nil	Nil
Boab 1	1848	STR	19°34'37"	125°08'50"	202	1033.4	?Silurian	1981	WMC	Dry	P&A	Nil	Nil
Caladenia 1	2423	STR	19°40'41"	125°06'31"	170	296.5	Upper Devonian	1983	WMC	Dry	P&A	Nil	Nil
Canopus 1	2166	NFW	18°56'48"	123°52'06"	179.5	1779	Lower Ordovician	1982	Getty Oil	Dry	P&A	Nil	Nil
Capparis 1	2398	STR	19°27'02"	125°06'09"	222	521	Upper Devonian	1984	WMC	Dry	P&A	Nil	Nil
Carina 1	2164	NFW	19°21'12"	123°04'49"	116.2	1603	Middle Ordovician	1982	Getty Oil	Dry	P&A	Nil	Poor
Cassia 1	1849	STR	19°44'05"	125°30'59"	194.7	1576.6	Upper Devonian	1981	WMC	Dry	P&A	Nil	Nil
Crossland 1	652	STR	19°42'57"	125°15'06"	183.79	913.2	Devonian	1971	WAPET	Dry	P&A	Nil	Nil
Crossland 2	652	STR	20°00'41"	124°59'43"	177.7	914.4	?Silurian	1971	WAPET	Dry	P&A	Nil	Nil
Crystal Creek 1	3363	NFW	18°33'22"	123°36'08"	139	2504	Middle Ordovician	1988	Kufpec	Dry	P&A	Poor	Poor
Dampiera 1/1A	1851	STR	19°46'01"	125°16'11"	184	1856.9	Upper Devonian	1985	WMC	Dry	P&A	Nil	Poor
Dodonea 1	2864	NFW	19°23'06"	125°09'44"	218.89	2215	Lower Ordovician	1985	WMC	Dry	P&A	Fair	Poor
Dodonea 2	3149	NFW	19°24'13"	125°10'46"	213	1688	Middle Ordovician	1987	WMC	Dry	P&A	Nil	Poor
Doran 1	430	STR	18°10'49"	123°29'16"	65.23	763.22	Upper Devonian	1968	WAPET	Dry	P&A	Nil	Nil
Drosera 1	2421	STR	19°40'41"	125°02'27"	165	450	Silurian	1984	WMC	Dry	P&A	Nil	Nil
Edgar Range 1	435	STR	18°45'20"	123°35'43"	136.25	1968	Precambrian	1968	Total Exploration	Dry	P&A	Nil	Poor
Eremophila 1	2107	STR	19°46'45"	125°12'18"	173.6	1252	Upper Devonian	1982	WMC	Dry	P&A	Nil	Fair
Eremophila 2	2418	STR	19°46'44"	125°13'10"	173	360	Upper Devonian	1983	WMC	Dry	P&A	Nil	Fair
Eremophila 3	2419	STR	19°46'41"	125°14'18"	176	464	Upper Devonian	1983	WMC	Dry	P&A	Nil	Nil
Ficus 1	1852	STR	19°49'03"	125°17'58"	185	1083.7	Upper Devonian	1982	WMC	Dry	P&A	Nil	Nil
Fitzroy River 1	1523	NFW	18°29'34"	124°52'55"	80.75	3133.8	Lower Carboniferous	1980	Amax Petroleum	Dry	P&A	Poor	Poor
Frankenia 1	2406	STR	19°26'54"	125°14'22"	192	479	Upper Devonian	1984	WMC	Dry	P&A	Nil	Nil
Frome Rocks 1	97	NFW	18°11'47"	123°38'48"	70.1	1220.1	?Upper Devonian	1959	WAPET	Dry	P&A	Nil	Nil
Frome Rocks 2	96	NFW	18°15'14"	123°39'41"	90.2	2287.2	Upper Devonian	1959	WAPET	Dry	P&A	Nil	Poor
Fruitcake 1	20753	NFW	19°28'20"	124°28'52"	144.2	1696	Middle Ordovician	2001	Hughes & Hughes	Dry	P&A	Nil	Nil
Goodenia 1	2415	STR	19°51'47"	125°13'49"	171	163.3	Upper Devonian	1983	WMC	Dry	P&A	Nil	Fair
Goorda 1	202	STR	18°34'21"	122°56'24"	–	152	?Cretaceous	1963	WAPET	Dry	P&A	Nil	Nil
Grant Range 1	92	NFW	18°00'54"	124°00'33"	72.24	3936.5	Upper Carboniferous	1955	WAPET	Dry	P&A	Nil	Nil
Halgania 1	2403	STR	19°41'23"	125°23'49"	200	500	?Carboniferous	1983	WMC	Dry	P&A	Nil	Nil
Hibiscus 1	3179	NFW	19°38'12"	125°25'54"	220.7	2394	Upper Devonian	1987	WMC	Dry	P&A	Poor	Poor
Kunzea 1	2604	STR	19°32'02"	124°59'28"	180	450	Upper Ordovician	1984	WMC	Dry	P&A	Nil	Poor
Logue 1	656	NFW	18°07'28"	123°23'29"	58.82	2698.7	Upper Devonian	1972	WAPET	Dry	P&A	Nil	Nil
Looma 1	20358	NFW	19°07'25"	123°59'40"	181	2535	Precambrian	1996	Shell Development	Dry	P&A	Poor	Poor
Lovell's Pocket 1	20014	NFW	18°30'52"	123°26'14"	117.4	1924	Lower Ordovician	1990	Kufpec	Dry	P&A	Poor	Poor

Appendix 2 (continued)

Well name	*S no.*	*Type*	*Latitude (S)*	*Longitude (E)*	*Elevation from drillers datum (m AHD)*	*Total depth (m)*	*Bottomed in*	*Year*	*Operator*	*Production status*	*Completion status*	*Gas show*	*Oil show*
Mangaloo 1	2817	NFW	19°35'12"	125°34'06"	219.7	3100	Upper Devonian	1985	IEDC Australia	Dry	P&A	Nil	Nil
Matches Springs 1	500	NFW	18°41'21"	124°03'07"	148.44	2834.6	Middle Ordovician	1969	Total Exploration	Dry	P&A	Nil	Poor
McLarty 1	415	NFW	19°23'39"	123°39'25"	174.35	2590.8	Lower Ordovician	1968	Total Exploration	Dry	P&A	Nil	Nil
Melaleuca 1	2573	STR	19°41'13"	125°32'49"	199.5	450	Permian	1984	WMC	Dry	P&A	Nil	Nil
Mirbelia 1	2729	NFW	19°39'03"	125°21'41"	205	2670	Silurian	1985	WMC	Oil	P&A	Poor	Excellent
Mirbelia 2	3430	EXT	19°38'56"	125°21'44"	205.15	2818.6	Lower Ordovician	1988	WMC	Dry	P&A	Nil	Nil
Missing 1	20739	NFW	19°33'58"	124°36'11"	153.4	1810	Lower Ordovician	2001	Hughes & Hughes	Dry	P&A	Nil	Nil
Mowla 1	528	NFW	18°43'45"	123°42'40"	127.4	762.91	Upper Devonian	1969	Total Exploration	Dry	P&A	Nil	Nil
Mount Wynne 1	1355	NFW	18°06'00"	124°27'00"	–	273	Lower Permian	1923	Freney Kimberley	Dry	P&A	Nil	Poor
Mount Wynne 3	1355	NFW	18°06'00"	124°27'00"	–	657	Lower Permian	1925	Freney Kimberley	Dry	P&A	Nil	Poor
Musca 1	2168	NFW	19°20'14"	122°57'25"	114.2	1535	Middle Ordovician	1982	Getty Oil	Dry	P&A	Nil	Poor
Myroodah 1	592	NFW	18°16'10"	124°11'32"	124.97	1829.1	Permian	1956	Associated Freney	Dry	P&A	Nil	Nil
Nerrima 1 (AFO)	593	NFW	18°26'55"	124°22'17"	118.87	2765.2	Upper Carboniferous	1955	Associated Freney	Dry	P&A	Nil	Nil
Nerrima 1 (FKO)	1355	NFW	18°28'16"	124°24'02"	116	1302	Lower Permian	1939	Freney Kimberley	Dry	P&A	Nil	Nil
Nollamara 1	2812	NFW	18°33'58"	124°13'57"	133.8	1719	Middle Devonian	1985	IEDC Australia	Dry	P&A	Nil	Poor
Notabilis 1	2581	NFW	18°19'44"	123°33'05"	119.7	2811	Middle Devonian	1984	IEDC Australia	Dry	P&A	Nil	Nil
Nuytsia 1	2681	NFW	18°33'23"	124°11'35"	156.7	1350	Upper Devonian	1984	IEDC Australia	Dry	P&A	Nil	Nil
Pandorea 1	2693	NFW	19°51'23"	125°20'42"	185	2274.5	Middle Devonian	1985	WMC	Dry	P&A	Nil	Poor
Panicum 1	2405	STR	19°32'23"	125°08'04"	201	278	Upper Devonian	1984	WMC	Dry	P&A	Nil	Nil
Petaluma 1	3241	NFW	18°16'01"	124°19'35"	88.39	2086	Carboniferous	1987	Ultramar	Dry	P&A	Poor	Poor
Pictor 1	2607	NFW	18°45'47"	123°42'58"	140.3	2146	Precambrian	1984	BHP Petroleum	Gas & oil	Susp.	Excellent	Excellent
Pictor 2	20049	EXT	18°45'52"	123°42'52"	142.2	1085	Middle Ordovician	1990	Bridge Oil Ltd	Gas & oil	Susp.	Good	Good
Placer Camelgooda 1	20256	MIN	18°35'48"	124°22'49"	99	1170	Upper Devonian	1989	Placer	Dry	P&A	Nil	Nil
Pratia 1	2407	STR	19°21'50"	124°59'46"	204	464	Upper Devonian	1984	WMC	Dry	P&A	Nil	Nil
Robert 1	20728	NFW	19°09'22"	124°19'48"	207.2	1628	Middle Ordovician	2001	Hughes & Hughes	Dry	P&A	Nil	Nil
Santalum 1	2426	STR	19°28'18"	124°52'11"	200	629.2	Middle Ordovician	1983	WMC	Dry	P&A	Nil	Fair
Setaria 1	3433	NFW	19°24'03"	124°58'33"	203.73	955.5	Lower Ordovician	1989	WMC	Dry	P&A	Nil	Fair
Solanum 1	2408	NFW	19°21'54"	124°57'47"	196	834	Lower Ordovician	1984	WMC	Dry	P&A	Nil	Nil
Triodia 1	2404	STR	19°38'12"	125°14'02"	178	631	Upper Devonian	1984	WMC	Dry	P&A	Nil	Nil
Typha 1	2425	STR	19°31'41"	125°04'23"	184	395	Upper Devonian	1984	WMC	Dry	P&A	Nil	Nil
Twin Buttes 1	3135	NFW	18°32'37"	122°56'47"	216.6	1600.3	Lower Ordovician	1987	Santos Australia Ltd	Dry	P&A	Nil	Poor
Vela 1	2170	NFW	19°24'38"	122°53'41"	117.2	1908	Middle Ordovician	1982	Getty Oil	Dry	P&A	Nil	Nil

NOTES:
EXT: Extension
MIN: Mineral hole
NFW: New-field wildcat
P&A: Plugged and abandoned
STR: Stratigraphic
Susp.: Suspended

Amax Petroleum: Amax Petroleum (Australia) Incorporated
Associated Freney: Associated Freney Oilfields NL
BHP Petroleum: BHP Petroleum (Australia) Pty Ltd
BMR: Bureau of Mineral Resources
Freney Kimberley: Freney Kimberley Oil Company NL
Getty Oil: Getty Oil Development Company Ltd
Hughes & Hughes: Hughes and Hughes Australia Pty Ltd
IEDC Australia: IEDC Australia Pty Ltd

Kufpec: Kufpec Australia Pty Ltd
Placer: Placer Exploration Ltd
Shell Development: Shell Development (Australia) Pty Ltd
Total Exploration: Total Exploration Australia Pty Ltd
Ultramar: Ultramar Australia Incorporated
WAPET: West Australian Petroleum Pty Ltd
WMC: Western Mining Corporation Ltd

Appendix 3

Surveys conducted for petroleum exploration in the central Canning Basin to June 2003

Survey name	*Company*	*Year*	*Tenement*	*Survey type*	*Line prefix*	*Total kilometres*	*No. of lines*	*S. number*
1985–1986 Amoco Canning Basin S.S.	Amoco Australia Petroleum Company	1985–86	EP 311 EP 312 EP 313 EP 316	Gravity 2D reflection	– TPP; TQI	– 3601.4	– 76	2896
Acacia (1981) S.S.	Western Mining Corporation Ltd	1981	EP 143	2D reflection	AX	30	–	10051
Airborne Geophysical Survey – Canning Basin	Aerodata Holdings Ltd	1986	–	Aeromagnetic	–	16240	–	2525
Babrongen Reconnaissance S.S.	West Australian Petroleum Pty Ltd	1960	PE-30-H	2D reflection	B60	44	5	1244
Babrongen Refraction Line AR S.S.	West Australian Petroleum Pty Ltd	1962	PE-30-H	2D refraction	BR62	33	1	1281
Babrongen South Detail S.S.	West Australian Petroleum Pty Ltd	1961	PE-30-H	2D reflection	B61	16.1	3	1225
Barbwire Range Semi Detail S.S.	Continental Oil Company of Australia Ltd	1965	PE-227-H	2D reflection	BR65	178	5	246
Barbwire Terrace S.S.	West Australian Petroleum Pty Ltd	1972	EP 13 EP 17 EP 19 EP 43 EP 44	2D reflection	C72	637	17	711
Boab S.S.	Western Mining Corporation Ltd	1984	EP 143 R1	2D reflection	B84	593	41	2617
Bongabinni S.S.	Western Mining Corporation Ltd	1985	EP 143 R1 EP 225	2D reflection	BONG	1028	39	2779
Broome Swell S.S.	Continental Oil Company of Australia Ltd	1965	PE-227-H	?2D reflection	BS65	90.5	7	213
Camelgooda S.S.	West Australian Petroleum Pty Ltd	1960	PE-30-H	2D reflection	C60	32	4	1244
Canning Basin 1988 S.S.	Bureau of Mineral Resources	1988	–	2D reflection	BMR88	645.3	3	10231
Canning Basin Aeromagnetic Survey	Shell Development (Australia) Pty Ltd	1997	EP 353	Aeromagnetic	–	15000	–	10366
Canning Basin Aeromagnetic Reconnaissance Survey	Bureau of Mineral Resources	1954	–	Aeromagnetic	–	–	–	3033
Canning Basin Airborne Geochemical Microwave Survey	Amoco Australia Petroleum Company	1987	EP 311 EP 312 EP 316	Geochemical	–	3278	–	3247
Canning Basin South Aeromagnetic Survey	West Australian Petroleum Pty Ltd	1963	PE-30-H	Aeromagnetic	–	29006	–	56
Canning Fitzroy Basin Aeromagnetic Survey	West Australian Petroleum Pty Ltd	1955	PE-30-H	Aeromagnetic	–	–	–	1280
Canning Refraction S.S.	West Australian Petroleum Pty Ltd	1958	PE-30-H	2D refraction	CR58	523.7	8	563
Carribuddy S.S.	Getty Oil Development Company Ltd	1980	EP 175	2D reflection	C80	1060	23	1621
Collins S.S.	West Australian Petroleum Pty Ltd	1972	EP 37 EP 42 EP 43 EP 7	2D reflection	C72	256	3	734
Collins 2 S.S.	West Australian Petroleum Pty Ltd	1973	EP 37	2D reflection	C73	56	2	910
Crossland 3 S.S.	West Australian Petroleum Pty Ltd	1973	EP 18	2D reflection	C73	110	4	898
Crossland 4 S.S.	West Australian Petroleum Pty Ltd	1974	EP 18	2D refraction	C74	56	2	1001
Crossland Area S.S.	Continental Oil Company of Australia Ltd	1965	PE-227-H	2D reflection	CA65	370	10	178
Crossland D1 S.S.	West Australian Petroleum Pty Ltd	1972	EP 18 EP 43	2D reflection	C72	118.5	4	711

Appendix 3 (continued)

Survey name	*Company*	*Year*	*Tenement*	*Survey type*	*Line prefix*	*Total kilometres*	*No. of lines*	*S. number*
Crossland Platform Reconnaissance S.S.	West Australian Petroleum Pty Ltd	1971	EP 13 EP 18 EP 19 EP 43	2D reflection	CROSS71	572	8	642
Crossland Reconnaissance S.S.	West Australian Petroleum Pty Ltd	1970	EP 18 EP 43 EP 44	2D reflection	CR70	136	1	591
Cuncudgerie S.S.	Getty Oil Development Company Ltd	1983	EP 175	2D reflection	C83	302	25	2352
Dampier Downs S.S.			EP 14 EP 37 EP 38 EP 42 EP 43 EP 6 EP 7	2D reflection	C72	174.1	2	734
Dampier Downs Refraction S.S.	West Australian Petroleum Pty Ltd	1956	PE-30-H	2D refraction	DDR56	7	2	1265
Dampier Fault (Edgar) S.S.	West Australian Petroleum Pty Ltd	1960	LP-56-H PE-30-H	2D reflection	DF60	224.9	–	585
Deep Well Anticline-Myroodah S.S.	Bureau of Mineral Resources	1954	LP-30-H	2D reflection	–	26	–	3038
Dora 1983 S.S.	Western Mining Corporation Ltd	1983	EP 143 EP 225	2D reflection	D83	400	10	2374
Doran S.S.	West Australian Petroleum Pty Ltd	1973	EP 7	2D reflection	C73	73	4	911
Elsa S.S.	Western Mining Corporation Ltd	1989	EP 335 EP 336	2D reflection	89	153	6	3614
EP 373 Geophysical Survey	Pasminco Exploration	1995	EP 373	Velocity	–	–	–	10255
Erskine 1981 S.S.	IEDC Australia Pty Ltd	1981	EP 103	2D reflection	W81	518.5	22	1786
Fenton Refraction S.S.	West Australian Petroleum Pty Ltd	1958	PE-30-H	2D refraction	F58	457	4	566
Fitzroy Basin 1981 S.S.	Amax Petroleum (Australia) Inc	1981	EP 101 EP 102 EP 103 EP 97	2D reflection	ED81	1491.5	66	1816
Fitzroy Basin 1982 (Phase 3) S.S.	IEDC Australia Pty Ltd	1982	EP 103	2D reflection	ED82	814	17	2205
Fitzroy Basin 1983 (Phase 2) S.S.	IEDC Australia Pty Ltd	1983	EP 101 R1 EP 102 R1 EP 97 R1	2D reflection	ED83	596	24	2377
Fitzroy Basin 1984 S.S.	IEDC Australia Pty Ltd	1984	EP 101 R1 EP 102 R1 EP 103 R1 EP 97 R1	2D reflection	ED84	244	113	2578
Fitzroy Basin 1985 (Phase 3) S.S.	IEDC Australia Pty Ltd	1985	EP 103 R1	2D reflection	ED85	556	32	2806
Fitzroy Basin 1987 (Phase 4) S.S.	Kufpec Australia Pty Ltd	1987	EP 103 R2	2D reflection	ED87	305	22	3152
Frome Rocks 1958 S.S.	West Australian Petroleum Pty Ltd	1958	PE-30-H	2D reflection	FR58	39	6	1250
Frome Rocks Gravity Survey	West Australian Petroleum Pty Ltd	1959	PE-30-H	Gravity	–	–	–	532
Frome Rocks Refraction S.S.	West Australian Petroleum Pty Ltd	1958	PE-30-H	2D refraction	FR58	141	4	566
Frome Rocks S.S.	West Australian Petroleum Pty Ltd	1956	PE-30-H	2D reflection	FR56	117	5	1245

Appendix 3 (continued)

Survey name	*Company*	*Year*	*Tenement*	*Survey type*	*Line prefix*	*Total kilometres*	*No. of lines*	*S. number*
Frome West S.S.	West Australian Petroleum Pty Ltd	1963	PE-30-H	2D reflection	FW63	168	15	158
Geegully S.S.	Bridge Oil Ltd	1989	EP 175 R1	2D reflection	B88	314.9	20	3419
Great Sandy (1998) S.S.	Shell Development (Australia) Pty Ltd	1998	EP 353	2D reflection	S98C	1758	38	10372
Hall Range S.S.	West Australian Petroleum Pty Ltd	1973	EP 43	2D reflection	C73	104	5	908
Jarlemai 1986 S.S.	BHP Petroleum (Australia) Pty Ltd	1986	EP 175 R1	2D reflection	HCG	459	27	2940
Jarlemai S.S.	West Australian Petroleum Pty Ltd	1960	PE-30-H	2D reflection	J60	39	4	1244
Jarlemai South Detail S.S.	West Australian Petroleum Pty Ltd	1961	PE-30-H	2D refraction	JSD61	46.7	6	1225
Jones Range S.S.	West Australian Petroleum Pty Ltd	1973	EP 43 EP 44	2D reflection	C73	47	2	909
Jurgurra Creek Refraction S.S.	West Australian Petroleum Pty Ltd	1956	PE-30-H	2D refraction	JCR56	23	6	1247
Jurgurra Terrace Gravity Survey	West Australian Petroleum Pty Ltd	1962	PE-30-H	Gravity	–	426.5	–	75
Jurgurra Terrace S.S.	West Australian Petroleum Pty Ltd	1969	PE-270-H	2D reflection	JT69	44	2	525
Liveringa S.S.	Whitestone Petroleum Australia Ltd	1978	EP 103	2D reflection	W78	142	5	1437
Liveringa 2 S.S.	West Australian Petroleum Pty Ltd	1973	EP 5	2D reflection	C73	31	1	913
Liveringa Ridge S.S.	West Australian Petroleum Pty Ltd	1972	EP 5 EP 6 EP 7	2D reflection	C72	150	3	768
Logue S.S.	West Australian Petroleum Pty Ltd	1960	PE-30-H	2D reflection	LOG59	42	6	585
Manguel Refraction S.S.	West Australian Petroleum Pty Ltd	1958	PE-30-H	2D refraction	M58	287.1	9	566
Matches Springs S.S.	Total Exploration Australia Pty Ltd	1969	PE-259-H	2D reflection	MS69	410	18	476
McLarty S.S.	French Petroleum Company (Australia) Pty Ltd	1967	PE-259-H	2D reflection 2D refraction	M67 –	1125 211	39 –	361
McLarty Spec S.S.	Baker Atlas	1987	SI 1/87-88	2D reflection	W87	271.1	8	3229
Mellingerie S.S.	French Petroleum Co (Australia) Pty Ltd	1967	PE-259-H	2D reflection 2D refraction	M67 –	92 76	– –	361
Millijiddee S.S.	Pasminco Exploration	1995	–	2D reflection	P95	39.8	5	–
Minjoo S.S.	Western Mining Corporation Ltd	1987	EP 143 R1 EP 225 R1	2D reflection	MIN87	195.5	14	3197
Mount Anderson Refraction S.S.	West Australian Petroleum Pty Ltd	1958	PE-30-H	2D refraction	MA58	82.6	2	566
Mount Anderson–Luluigui area Reconnaissance S.S.	West Australian Petroleum Pty Ltd	1953	PE-30-H	2D reflection	MAL53	123.8	15	1259
Mowla S.S.	West Australian Petroleum Pty Ltd	1965	PE-30-H	2D reflection	M65	42	5	241
Mowla Experimental S.S.	Bridge Oil Ltd	1987	EP 175 R1	2D reflection	B87	10	1	3271
Nambeet 1981 S.S.	Getty Oil Development Company Ltd	1981	EP 175	2D reflection	P81	451	23	1780
Nibil S.S.	Western Mining Corporation Ltd	1986	EP 143 R1 EP 225 R1	2D reflection	NIB86	389.1	19	2973
Nita 1982 (Phase 1) S.S.	Western Mining Corporation Ltd	1982	EP 143 EP 225	2D reflection	W82	1287	49	2047
Nita 1982 (Phase 2) S.S.	Western Mining Corporation Ltd	1982	EP 143	2D reflection	N-W82	422	17	2048
Noonkanbah Gravity Survey	Continental Oil Company of Australia Ltd	1967	PE-227-H	Gravity	–	766	–	391
Noonkanbah S.S.	Whitestone Petroleum Australia Ltd	1976	EP 97	2D reflection	N76	168	22	588
Poole Range Detail Vibroseis S.S.	Continental Oil Company of Australia Ltd	1965	PE-227-H	2D reflection	PR65	246.7	14	211
Primus Aeromagnetic Survey	Black Rock Resources Australia NL	1997	EP 373	Aeromagnetic	–	11500	–	10357

Appendix 3 (continued)

Survey name	*Company*	*Year*	*Tenement*	*Survey type*	*Line prefix*	*Total kilometres*	*No. of lines*	*S. number*
Quonga S.S.	Petroleum Securities Australia Ltd	1985	EP 306	2D reflection	P85	197	10	2769
S91C S.S.	Shell Development (Australia) Pty Ltd	1991	EP 353	2D reflection	S91C	819.2	14	10065
S92C S.S.	Shell Development (Australia) Pty Ltd	1992	EP 353	2D reflection	S92C	720	15	10122
Skinners Pool S.S.	Petroleum Securities Australia Ltd	1985	EP 306	2D reflection	P85	257	14	2904
SPA 4/1996-97	Shell Development (Australia) Pty Ltd	1997	SPA 4/96-97	Aeromagnetic	–	5000	–	10365
St Georges Range Reconnaissance S.S.	Continental Oil Company of Australia Ltd	1964	PE-227-H	2D reflection	SGR64	540.4	10	172
Wilson Refraction S.S.	West Australian Petroleum Pty Ltd	1958	PE-30-H	2D refraction	W58	30.7	1	566

NOTES: S. number: Western Australia Geological Survey statutory petroleum exploration report number
S.S.: seismic survey
–: not applicable

Appendix 4

Formation tops and thicknesses of selected wells in the Canning Basin

Well name	Formation top/(thickness)														
	Jj	*Ja*	*Jb*	*Jw*	*Pl*	*Pn*	*Pp*	*Ppn*	*Pg*	*Cr*	*Ca*	*Cf*	*Dl*	*Dc*	*Db*
Abutilon 1	–	–	7.13 (40.14)	–	–	–	–	–	47.27 (280.03)	–	–	–	–	–	–
Acacia 1	–	–	7.5 (34)	–	–	–	–	–	41.5 (320.1)	–	–	–	–	–	–
Acacia 2	–	–	–	–	–	–	–	–	56 (301)	–	–	–	–	–	–
Antares 1	–	–	–	7.6 (48.9)	–	–	–	–	56.5 (269.5)	–	–	–	–	–	–
Aristida 1/1A	–	–	–	–	–	–	–	–	90 (115)	–	–	–	–	–	–
Babrongan 1	–	–	–	–	–	–	178 (99)	247 (30)	277 (392)	–	–	–	669 (44)	713 (1236)	1736 (213)
Barbwire 1	–	–	–	–	–	–	–	–	0 (143)	–	–	–	–	–	–
BMR 01 Mount Anderson	–	–	–	–	–	4 (264)	268 (137)	–	427 (85)	np	np	np	np	np	np
Boab 1	–	–	–	23 (41)	–	–	–	–	64 (145.5)	–	–	–	–	–	–
Caladenia 1	–	–	–	–	–	–	–	–	40 (99.9)	–	–	–	–	–	–
Canopus 1	–	–	10 (147.2)	–	–	–	–	–	157.2 (208.3)	?365.5 (341.5)	?707 (231)	–	–	–	–
Capparis 1	–	–	–	–	–	–	–	–	51 (161.35)	–	–	–	–	–	–
Carina 1	–	–	0 (367)	–	–	–	–	–	367 (297.2)	–	–	–	–	–	–
Cassia 1	–	–	–	15.8 (30)	–	–	–	–	45.8 (504.1)	–	–	549.9 (486.2)	–	–	–
Crossland 1	–	–	–	–	–	–	–	–	0 (300)	–	–	–	–	–	–
Crossland 2	–	–	–	–	–	9 (135)	144 (64)	–	208 (452)	–	–	–	–	–	–
Crystal Creek 1	–	–	10 (86.5)	–	–	–	–	–	96.5 (193)	–	–	–	–	–	–
Dampiera 1/1A	–	–	–	3 (46)	–	–	–	–	49 (328.95)	–	–	377.95 (74.05)	–	–	–
Dodonea 1	–	–	–	–	–	–	–	–	22 (312)	–	–	–	–	–	–
Dodonea 2	–	–	–	–	–	–	–	–	35 (298)	–	–	–	–	–	–
Doran 1	19 (11)	30 (75)	105 (77)	–	–	–	–	–	182 (384)	566 (175)	–	–	741 (22)	np	np
Drosera 1	–	–	–	–	–	–	–	–	0 (111)	?111 (330)	–	–	–	–	–
Edgar Range 1	–	–	9 (104)	–	–	–	–	–	113 (458)	–	–	–	–	–	–
Eremophila 1	–	–	–	8 (35)	–	–	–	–	43 (153)	–	–	–	–	–	–
Eremophila 2	–	–	–	–	–	–	–	–	33 (?195.16)	–	–	–	–	–	–
Eremophila 3	–	–	–	–	–	–	–	–	19 (278)	–	–	–	–	–	–
Ficus 1	–	–	–	8 (59)	–	–	–	–	67 (357)	424 (51)	–	475 (608)	np	np	np
Fitzroy River 1	–	–	–	–	–	4 (373)	377 (121)	–	498 (1217)	–	1715 (360)	2075 (1761)	np	np	np
Frankenia 1	–	–	–	–	–	–	–	–	42 (206)	–	–	–	–	–	–
Frome Rocks 1	12 (82)	94 (73)	167 (57)	–	–	–	–	–	–	–	–	–	–	–	–
Frome Rocks 2	–	–	9 (54)	–	63 (70)	133 (413)	546 (97)	610 (33)	643 (387)	–	–	–	1030 (879)	1909 (378)	np
Fruitcake 1	–	–	0 (96)	–	–	–	–	–	96 (179)	?275 (40)	–	–	–	–	–
Goodenia 1	–	–	–	–	–	–	–	–	90 (15.2)	–	–	105.2 (57.8)	np	np	np
Grant Range 1	–	–	–	–	–	–	–	–	0 (?800)	?800? (?1805)	2605 (1331.49)	np	np	np	np
Halgania 1	–	–	–	–	–	–	–	–	26 (284)	–	–	310 (190)	np	np	np
Hibiscus 1	–	–	–	–	–	–	–	–	50 (375)	–	–	–	–	–	–
Kunzea 1	–	–	–	–	–	–	–	–	29.4 (232.1)	–	–	–	–	–	–

Formation top/(thickness)																TD
Drc	*Dm*	*Dt*	*Dw*	*Sc*	*Scs*	*Scm*	*Scn*	*Scmm*	*Scb*	*On*	*Og*	*Ow*	*Owa*	*Oa*	*pC*	*(m)*
327.3 (523)	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	850.3
–	–	361.6 (10.7)	372.3 (151.7)	524 (161)	–	–	–	–	–	685 (71)	747 (284)	1031 (177.7)	1087 (105)	np	np	1208.7
?unnamed (357–508)	–	–	–	508 (192)	–	–	–	–	–	700 (58)	758 (284)	1042 (235)	1095 (101)	1277 (225.5)	1502.5	1573
326 (561)	–	887 (33)	–	920 (138)	–	–	–	–	–	1058 (188.6)	1246.6 (51.9)	np	np	np	np	1298.5
205 (529)	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	734
np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	1949
143 (928)	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	1071
np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	512
209.5 (806.5)	–	–	–	1016 (17.4)	np	np	np	np	np	np	np	np	np	np	np	1033.4
139.9 (156.7)	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	296.5
–	–	–	–	938 (154)	–	–	–	–	–	1092 (132)	1224 (398)	1622 (157)	np	np	np	1779
–	212.35 (79.35)	291.7 (229.3)	np	np	np	np	np	np	np	np	np	np	np	np	np	521
–	–	664.2 (29.8)	–	694 (778.8)	694	926.3 (305.7)	1323	1364.7	–	1472.8 (78)	1550.8 (52.2)	np	np	np	np	1603
1036.1 (540.5)	np	np	np		np	np	np	np	np	np	np	np	np	np	np	1576.6
300 (613.2)	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	913.2
–	–	–	–	660 (254.4)	np	np	np	np	np	np	np	np	np	np	np	914.4
289.5 (1125.2)	–	1414.7 (15.6)	–	1437 (136)	?1437	?1508 (17)	?1525	–	–	1573 (215.6)	1788.6 (460.9)	2249.5 (254.5)	np	np	np	2504
452 (1404.9)	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	1856.9
334 (681)	1015 (55)	1085 (161)	1246 (165)	1411 (116)	–	–	–	–	–	–	1527 (219)	1746 (164)	1789 (121)	1910 (305)	2180	2215
333 (723)	–	1056 (193)	1249 (170)	1419 (167)	–	–	–	–	–	1586 (29)	1615 (73)	np	np	np	np	1688
np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	763
–	–	–	–	441 (9)	np	np	np	np	np	np	np	np	np	np	np	450
–	–	–	–	571 (195)	–	–	–	–	–	766 (156)	922 (431)	1353 (401)	–	1754 (167)	1921	1968
?196 (1056)	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	1252
?228.16 (131.84)	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	360
297 (167)	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	464
np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	1083
np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	3134
248 (231)	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	479
224 (464)	–	–	–	?688 (535)	–	?688 (535)	np	np	np	np	np	np	np	np	np	1220
np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	2287
–	–	–	315 (151)	466 (645)	–	638 (370)	–	–	–	1111 (57)	1168 (409)	1577 (119)	1635 (36)	np	np	1696
np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	163
np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	3936.49
np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	500
425 (1898)	–	2350 (44)	np	np	np	np	np	np	np	np	np	np	np	np	np	2394
–	–	–	–	261.5 (30.8)	–	–	–	–	–	292.3 (57.7)	350 (100)	np	np	np	np	450

Appendix 4 (continued)

Well name	*Jj*	*Ja*	*Jb*	*Jw*	*Pl*	*Pn*	*Pp*	*Ppn*	*Pg*	*Cr*	*Ca*	*Cf*	*Dl*	*Dc*	*Db*
	Formation top/(thickness)														
Logue 1	–	–	5 (160)	–	–	165 (240)	405 (59)	–	464 (463)	927 (636)	–	–	–	1563 (1067)	2630 (68.7)
Looma 1	–	–	–	–	–	–	–	–	0 (557)	–	–	–	–	–	–
Lovell's Pocket 1	–	–	41 (184.5)	–	–	–	–	–	225.5 (220.2)	–	–	–	–	–	–
Mangaloo 1	–	–	–	–	–	105 (21)	126 (129)	255 (43)	298 (496)	–	–	794 (827)	–	1621 (800)	–
Matches Springs 1	–	9 (13)	22 (82)	–	–	–	–	–	104 (442)	–	–	–	–	–	–
McLarty 1	–	4 (19.5)	23.5 (102.1)	–	–	–	–	–	125.6 (326.4)	–	–	–	–	–	–
Melaleuca 1	–	–	–	–	–	–	–	–	50 (400)	np	np	np	np	np	np
Mirbelia 1	–	–	–	–	–	–	–	–	38 (271)	–	–	–	–	–	–
Mirbelia 2	–	–	–	–	–	–	–	–	15.5 (285.5)	–	–	–	–	–	–
Missing 1	–	–	4.2 (85.8)	–	–	–	–	–	90 (158)	?248 (63)	–	–	–	–	–
Mowla 1	–	–	–	–	–	–	12 (14)	12 (14)	26 (448)	–	–	–	–	–	–
Mt Wynne 1	–	–	–	–	–	–	–	–	5 (268)	np	np	np	np	np	np
Mt Wynne 3	–	–	–	–	–	–	–	–	5 (652)	np	np	np	np	np	np
Musca 1	–	–	0 (504.8)	–	–	–	–	–	504.8 (409)	–	–	–	–	–	–
Myroodah 1	–	–	–	–	0 (435)	435 (370)	805 (356)	1151 (10)	1161 (627)	–	–	1788 (41.11)	np	np	np
Nerrima 1 (AFO)	–	–	–	–	–	0 (274)	274 (385.9)	–	659.9 (1578.9)	?2238.8 (?202.2)	?2441 (?324.2)	np	np	np	np
Nerrima 1 (FKO)	–	–	–	–	–	5 (239)	244 (398)	–	642 (660)	np	np	np	np	np	np
Nollamara 1	–	–	10 (40)	–	–	50 (72)	122 (110)	196 (36)	232 (358)	590 (277)	–	867 (182)	np	np	np
Notabilis 1	–	–	12.4 (125.6)	–	–	138 (201.5)	339.5 (96.5)	405 (31)	436 (331)	767 (36)	–	803 (52)	–	855 (1265)	–
Nuytsia 1	–	–	0 (60)	–	–	60 (79)	139 (113)	224 (28)	252 (573)	–	–	825 (226)	–	–	–
Pandorea 1	–	–	–	–	–	–	–	–	12 (375)	–	–	387 (59)	–	–	–
Panicum 1	–	–	–	–	–	–	–	–	34 (145)	–	–	–	–	–	–
Petaluma 1	–	–	–	–	3 (271)	274 (447.6)	721.6 (316.1)	916 (121.7)	1037.7 (1048.3)	np	np	np	np	np	np
Pictor 1	–	–	0 (108)	–	–	–	–	–	108 (277.5)	–	–	–	–	–	–
Pictor 2	–	–	7.6 (99.9)	–	–	–	–	–	170.5 (223.6)	–	–	–	–	–	–
Placer Camelgooda 1	–	–	14 (36)	–	–	50 (70)	120 (97)	170 (47)	217 (543)	–	–	760 (184)	–	–	–
Pratia 1	–	–	–	–	–	–	–	–	60 (240)	–	–	–	–	–	–
Robert 1	–	–	4.2 (46.3)	–	–	–	–	–	50.5 (107.5)	?158 (302)	?460 (469)	–	–	–	–
Santalum 1A	–	–	–	–	–	–	–	–	6 (315)	–	–	–	–	–	–
Setaria 1	–	–	–	–	–	–	–	–	41.5 (104)	–	–	–	–	–	–
Solanum 1	–	–	–	–	–	–	–	–	12 (125)	–	–	–	–	–	–
Triodia 1	–	–	–	–	–	–	–	–	17 (178.9)	–	–	–	–	–	–
Typha 1	–	–	–	–	–	–	–	–	30 (195.5)	–	–	–	–	–	–
Vela 1	–	–	0 (302.2)	–	–	–	–	–	302.2 (357.2)	–	–	–	–	–	-

NOTES: Formation thicknesses are shown in brackets under the formation top; formation tops are relative to KB/DF/RT

Jj: Jarlemai Sandstone
Ja: Alexander Formation
Jw: Wallal Sandstone
Jb: Barbwire Sandstone
Pl: Liveringa Group
Pn: Noonkanbah Formation
Pp: Poole Sandstone
Ppn: Nura Nura Member
Pg: Grant Group
Cr: Reeves Formation
Ca: Anderson Formation
Cf: Fairfield Group
Dl: Luluigui Formation
Dc: Clanmeyer Formation
Db: Babrongan beds
Drc: Devonian reef complexes
Dm: Mellinjerie Formation
Dt: Tandalgoo Sandstone
Dw: Worral Formation

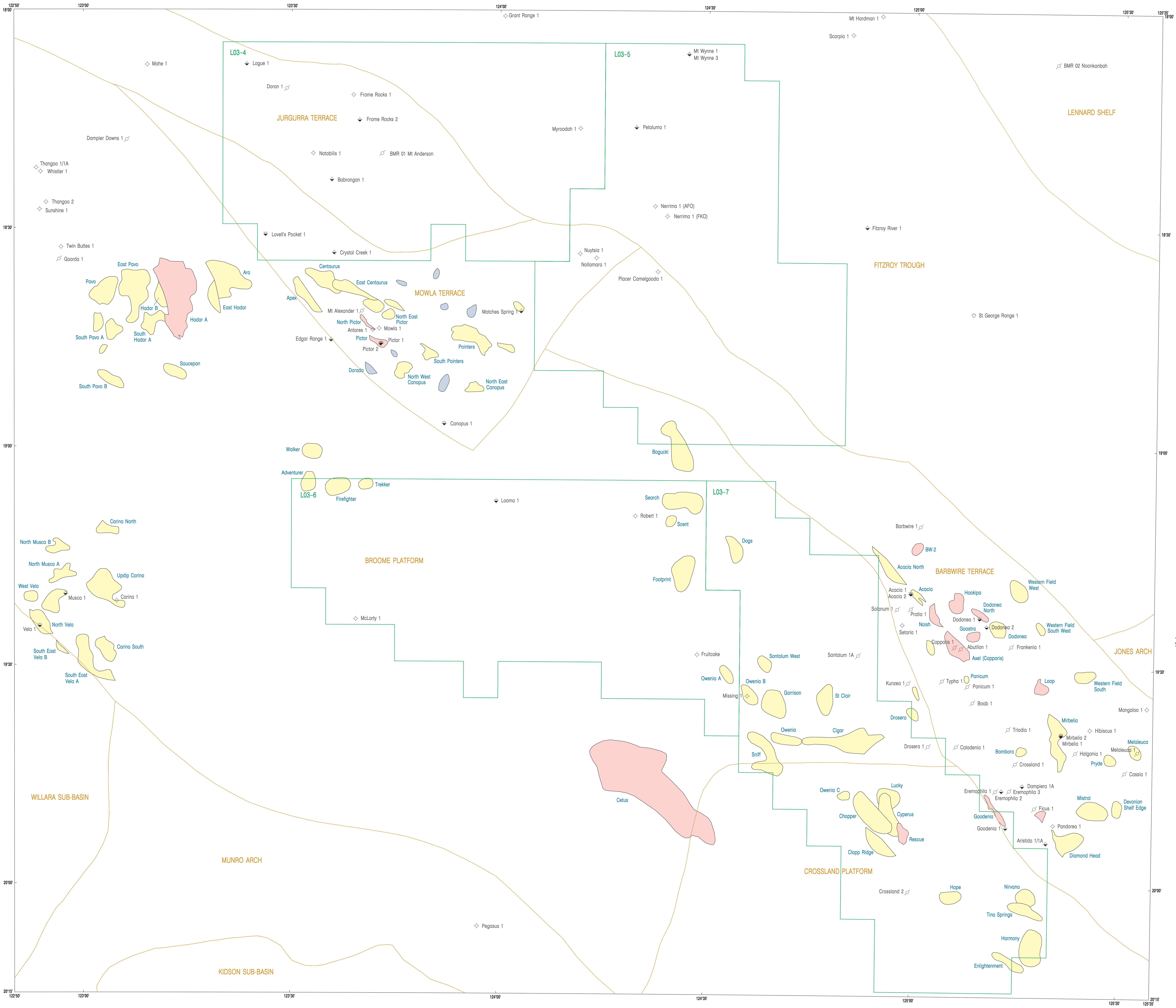
Formation top/(thickness)																TD
Drc	*Dm*	*Dt*	*Dw*	*Sc*	*Scs*	*Scm*	*Scn*	*Scmm*	*Scb*	*On*	*Og*	*Ow*	*Owa*	*Oa*	*pC*	*(m)*
np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	2698.7
–	–	–	–	557 (668)	557	660 (461)	1121	1167	1196	1225 (148)	1373 (561)	1934 (377)	1992 (64)	2311 (183)	2494	2535
445.7 (545.8)	–	–	–	991.5 (153.5)	–	–	–	–	–	1145 (189.5)	1334.5 (434.5)	1769 (155)	np	np	np	1924
2421 (679)	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	3100
546 (1174)	–	1700 (78)	–	1778 (241)	–	–	–	–	–	2019 (189)	2208 (626.6)	np	np	np	np	2834.6
–	–	–	–	452 (1179)	452	675 (740)	1415	1512	1578	1631 (56)	1687 (373)	2060 (281)	–	2341 (249.8)	np	2590.8
np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	450
309 (1498.5)	1807.5 (135)	1958.3 (197.7)	2156 (138)	2294 (376)	–	–	2294	2335	2530	np	np	np	np	np	np	2670
301 (1506)	1807 (128)	1966 (184)	2150 (139)	2289 (258)	–	–	2289	2324	–	–	–	–	–	2547 (271.6)	np	2818.6
–	–	–	311 (528)	839 (163)	–	–	–	–	–	1002 (55)	1057 (383)	1440 (306)	1494 (44)	1746 (64)	np	1810
474 (288.91)	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	762.91
np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	273
np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	657
–	–	–	–	913.8 (517)	913.8	1041.9 (150.5)	1192.4	1323.5	–	1430.8 (75.4)	1506.2 (28.8)	np	np	np	np	1535
np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	1829.11
np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	2765.2
np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	1302
1049 (670)	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	1719
2120 (519)	–	2639 (172)	np	np	np	np	np	np	np	np	np	np	np	np	np	2811
1051 (299)	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	1350
446 (1659)	2105 (98)	2228 (46.5)	np	np	np	np	np	np	np	np	np	np	np	np	np	2274.5
179 (99)	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	278
np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	2086
385.5 (131.5)	–	517 (216)	–	733 (146)	–	–	–	–	–	879 (162)	1041 (464)	1505 (427)	–	1932 (189)	2121	2146
394.1 (153.7)	–	547.8 (198.8)	–	746.6 (125.7)	–	–	–	–	–	872.3 (183.7)	1056 (29.5)	np	np	np	np	1085.5
944 (226)	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	1170
–	300 (164)	np	np	np	np	np	np	np	np	np	np	np	np	np	np	464
–	–	–	–	929 (170)	–	–	–	–	–	1099 (132)	1231 (397)	np	np	np	np	1628
–	–	–	–	321 (85)	–	–	–	–	–	406 (35)	441 (188.2)	np	np	np	np	629.2
–	–	–	–	–	–	–	–	–	–	–	145.5 (242.5)	388 (239.5)	439 (113)	627.5 (327.5)	np	955
–	–	–	–	137 (80)	–	–	–	–	–	217 (67)	284 (279)	563 (242.9)	615 (96)	805.9 (28.1)	np	834
195.9 (435.1)	np	np	np	np	np	np	np	np	np	np	np	np	np	np	np	631
225.5 (37.1)	262.6 (93.2)	355.8 (39.2)	np	np	np	np	np	np	np	np	np	np	np	np	np	395
–	–	659.4 (31.6)	–	691 (1071)	691	960.8 (494.7)	1455.5	1622.7	–	1762 (97.1)	1859.1 (48.9)	np	np	np	np	1908

NOTES:

Sc: Carribuddy Group
Scs: Sahara Formation
Scm: Mallowa Salt
Scn: Nibil Formation
Scmm: Minjoo Salt/Mount Troy Formation
Scb: Bongabinni Formation

On: Nita Formation
Og: Goldwyer Formation
Ow: Willara Formation
Owa: 'Acacia sandstone member'
Oa: Nambeet Formation
pC: Precambrian basement

np: not penetrated
–: not present or not identified
KB: Kelly bushing
DF: Drill floor
RT: Rotary table

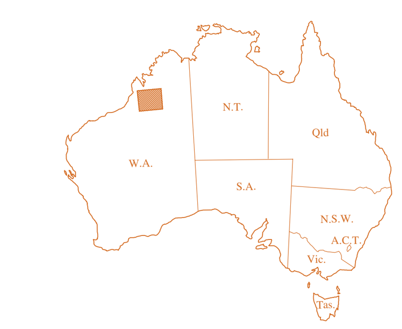


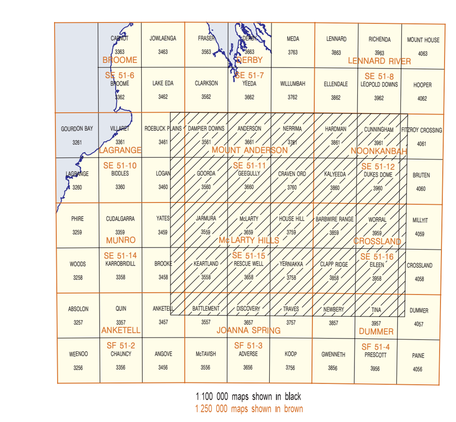
SYMBOLS

- Prospect
- Lead
- Weak lead
- Gazette area
- Sub-basin boundary

PETROLEUM EXPLORATION WELLS

- Show of oil, abandoned
- Show of gas, abandoned
- Show of oil and gas, abandoned
- Dry, abandoned
- Stratigraphic





Department of Industry and Resources

CLIVE BROWN, M.L.A.
MINISTER FOR STATE DEVELOPMENT

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Geological Survey of Western Australia

TIM GRIFFIN
DIRECTOR

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
REPORT 2003/14 PLATE 1

WELLS, LEADS, AND PROSPECTS OF THE CENTRAL CANNING BASIN WESTERN AUSTRALIA, 2003

SCALE 1: 500 000

5000 0 5 10 15 20
Metres Kilometres

UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 51
HORIZONTAL DATUM: GEOCENTRIC DATUM OF AUSTRALIA 1994
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM

Compiled by C. D'Ercole and L. Gibbons
Edited by K. Blundell
Cartography by A. Francois

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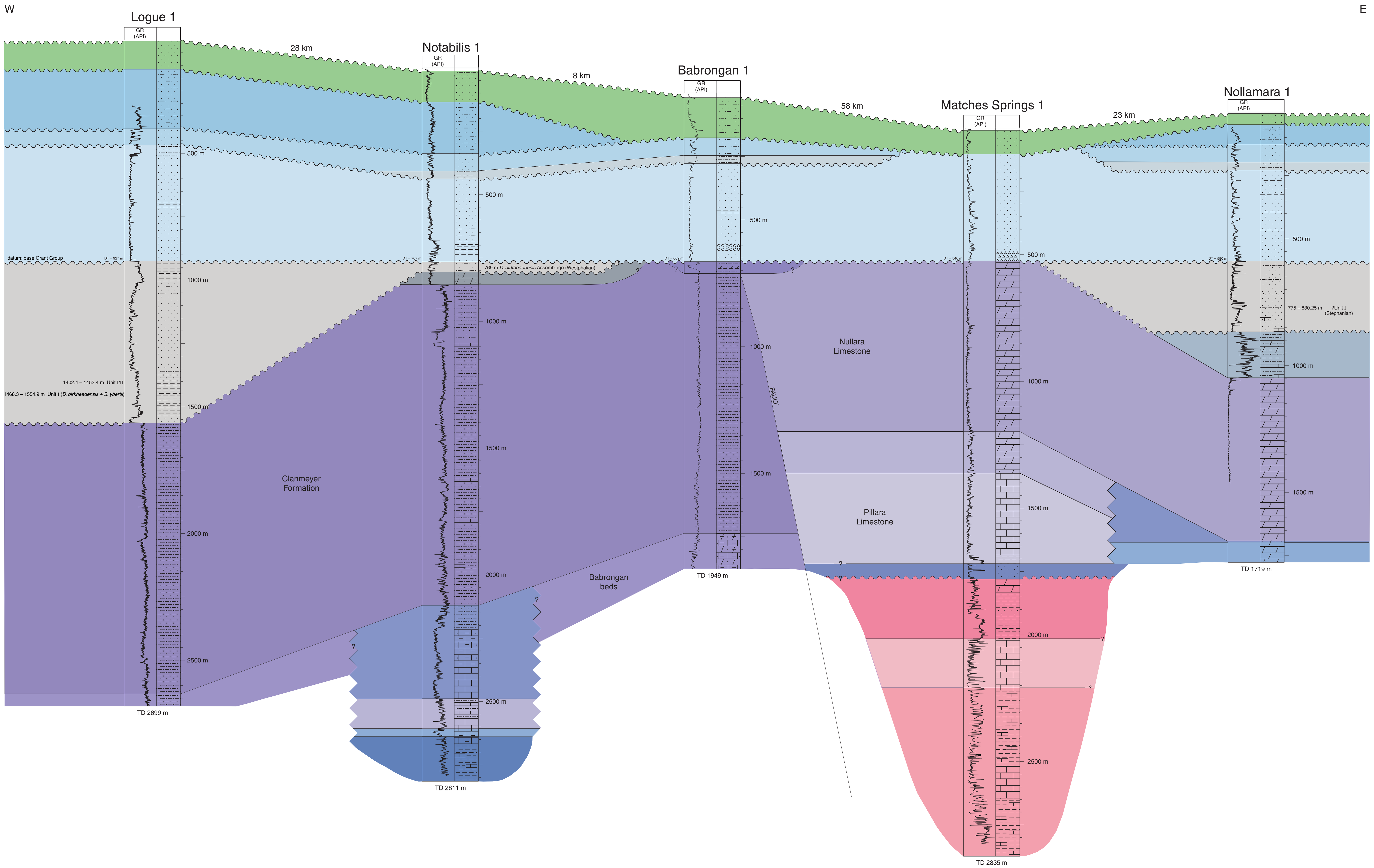


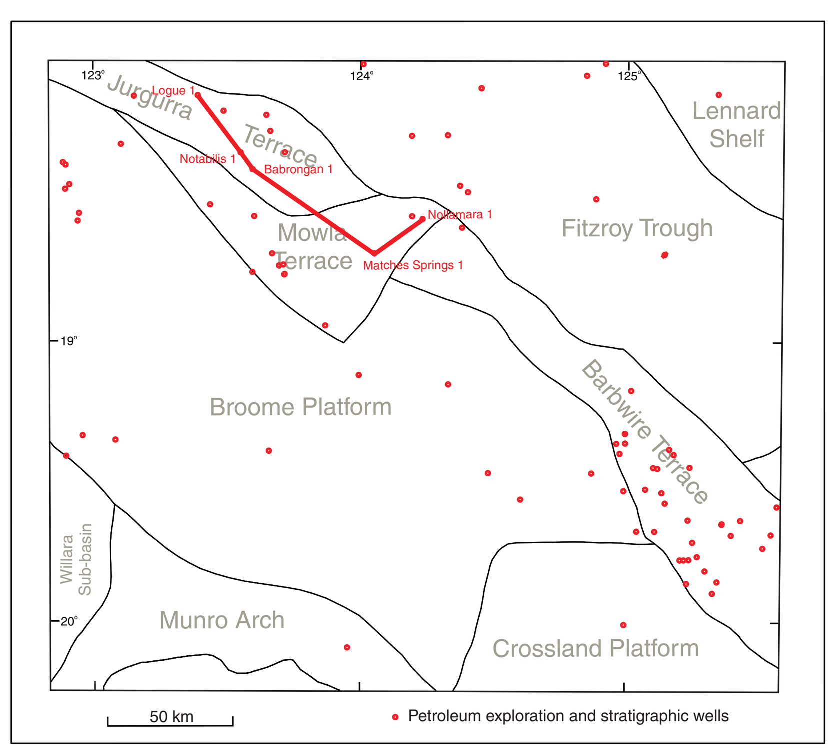
AGE	STRATIGRAPHIC UNITS
MESOZOIC	Undifferentiated
PERMIAN	Noonkanbah Formation
	Poole Sandstone; Nura Nura Member
	Grant Group
CARBONIFEROUS	Reeves Formation
	Fairfield Group

DEVONIAN:
- Luluigui Formation
- Clanmeyer Formation
- Babrongan beds
- Reef complexes: Nullara Limestone, Virgin Hills Formation, Gogo Formation, Pillara Limestone, Sadler Limestone
- Tandalgoo Sandstone

ORDOVICIAN–SILURIAN:
- Carribuddy Group
- Nita Formation
- Goldwyer Formation

Lithology:
- Sandstone
- Siltstone and claystone
- Conglomerate
- Calcilutite
- Shale
- Limestone
- Dolomite
- Polymictic diamictite

DT datum (base Grant Group)



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Edited by K. Blundell
Cartography by T. Pizzi

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The recommended reference for this plate is:
D'ERCOLE, C., 2003, Simplified stratigraphic correlation across the Jurgurra and Mowla Terraces, central Canning Basin, Western Australia, *in* Prospects and leads, central Canning Basin, Western Australia, 2003 *by* C. D'ERCOLE, L. GIBBONS, and K. A. R. GHORI (compilers): Western Australia Geological Survey, Record 2003/14, Plate 2.

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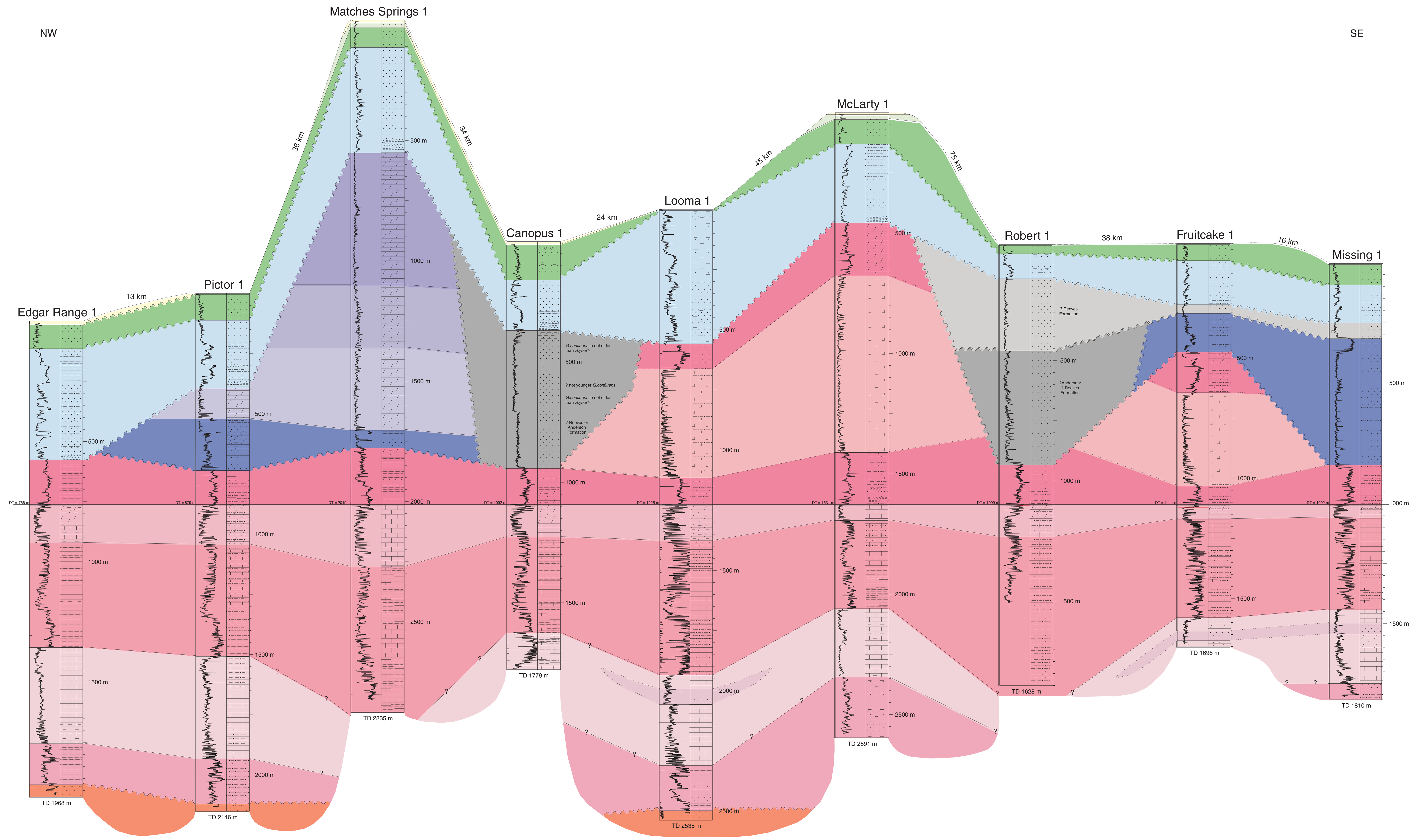
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
RECORD 2003/14 PLATE 2

SIMPLIFIED STRATIGRAPHIC CORRELATION ACROSS THE JURGURRA AND MOWLA TERRACES CENTRAL CANNING BASIN WESTERN AUSTRALIA

CD115 13.06.03

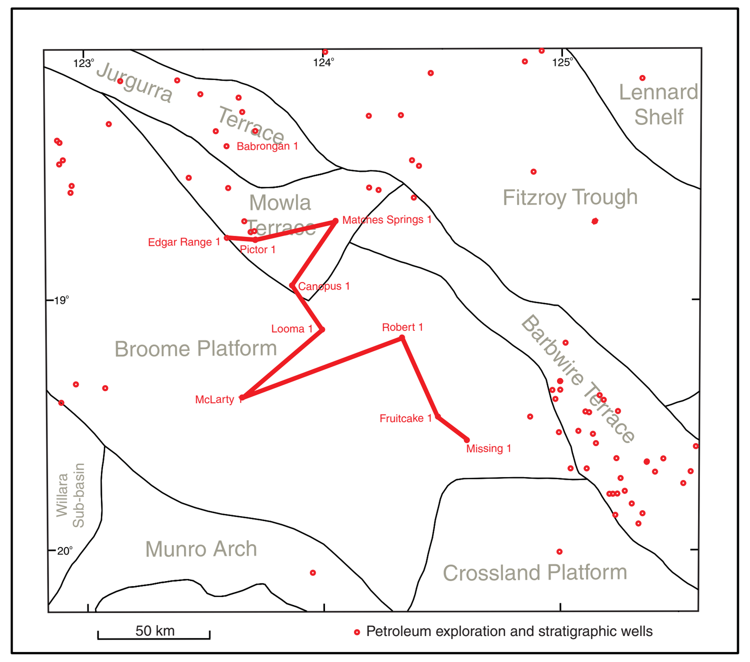


AGE — STRATIGRAPHIC UNITS

- Quaternary
- JURASSIC: Alexander Formation; Wallal Sandstone
- PERMIAN: Grant Group
- CARBONIFEROUS: ? Reeves Formation; ? Anderson/ ? Reeves Formation
- DEVONIAN: Nullara Limestone; Gogo Formation; Pillara Limestone; Tandalgoo Sandstone
- ORDOVICIAN–SILURIAN: Carribuddy Group (Mallowa Salt); Nita Formation; Goldwyer Formation; Willara Formation (Acacia sandstone member); Nambeet Formation
- Basement

DT datum (top Nita Formation)

- Conglomerate
- Siltstone and claystone
- Shale
- Sandstone
- Limestone
- Dolomite
- Polymictic diamictite
- Schist
- Salt (halite)
- Anhydrite



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GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
RECORD 2003/14 PLATE 3

SIMPLIFIED STRATIGRAPHIC CORRELATION ACROSS THE MOWLA TERRACE AND BROOME PLATFORM CENTRAL CANNING BASIN WESTERN AUSTRALIA

CD116 13.06.03