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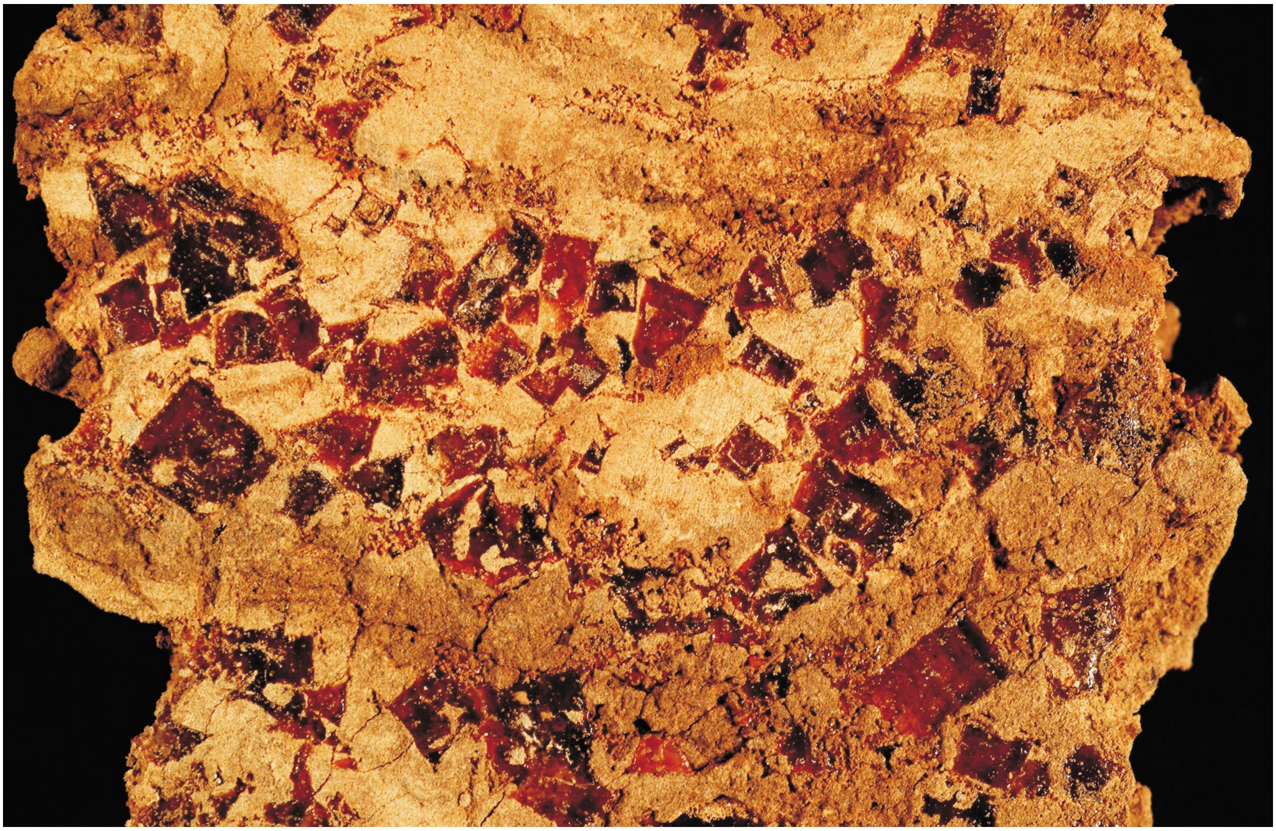
REPORT
105

THE CARRIBUDDY GROUP AND WORRAL FORMATION, CANNING BASIN, WESTERN AUSTRALIA: STRATIGRAPHY, SEDIMENTOLOGY, AND PETROLEUM POTENTIAL

by PW Haines



Geological Survey of Western Australia

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

REPORT 105

THE CARRIBUDDY GROUP AND WORRAL FORMATION, CANNING BASIN, WESTERN AUSTRALIA: STRATIGRAPHY, SEDIMENTOLOGY, AND PETROLEUM POTENTIAL

by
PW Haines

Perth 2009

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Cover photograph:
Drillcore photograph of disseminated euhedral halite within red-brown dolomitic mudstone in the upper Mallowa Salt at about 3100 m depth in Kidson 1. Core is about 9 cm in width.

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The Carribuddy Group and Worral Formation, Canning Basin, Western Australia: stratigraphy, sedimentology, and petroleum potential

by

PW Haines

Abstract

The Ordovician–Silurian megasequence of the Canning Basin comprises a lower shallow marine component overlain by restricted marginal marine to terrestrial and evaporitic facies of the Carribuddy Group. The overlying Worral Formation was previously placed in the Devonian – lower Carboniferous megasequence, but reassessment of biostratigraphic constraints and stratigraphic relationships indicate that it belongs with the Ordovician–Silurian megasequence. High frequency cycle correlation shows the lithostratigraphic boundary between the Carribuddy Group and underlying Nita Formation is mainly conformable and diachronous, but on the Barbwire Terrace this contact is unconformable, indicating local uplift along the margin of the proto-Fitzroy Trough coincident with the Rodingan movement in central Australia. Previous misunderstandings about the relationship between the Carribuddy Group and Worral Formation were due to miscorrelations and, in one case, to an incorrectly located biostratigraphic sample. Useful biostratigraphic data are rare throughout the Carribuddy Group and Worral Formation. The most reliable data shows that the Carribuddy Group ranges in age from Middle Ordovician to Llandovery (early Silurian), and the Worral Formation from Llandovery to at least the late Silurian.

In areas where massive salt units can be used as an aid to subdivision, the Carribuddy Group can be easily subdivided into five formations: Bongabinni Formation, Minjoo Salt, Nibil Formation, Mallowa Salt, and Sahara Formation (in ascending order). Where salt units are absent, subdivision of the attenuated mudstone-dominated Carribuddy Group is often problematic due to the repetitive nature of facies and rarity of useful biostratigraphic data. The Mount Troy Formation, an approximate lateral equivalent of Minjoo Salt, can be recognized locally. The Minjoo and Mallowa Salts were deposited by marine-sourced salterns surrounded by supratidal carbonate and mudflats. A thin member of the Sahara Formation, herein named the Pegasus Dolomite Member, formed during a brief basin-wide marine incursion. It forms a useful marker allowing recognition of the Sahara Formation in areas where the Mallowa Salt is absent. It is also useful for demonstrating the diachronous nature of the top of the Mallowa Salt, and assists with the recognition of the base of the Worral Formation, which lies 20–40 m above it in most sections. The Worral Formation is locally subdivided into the Dodonea (new name; formerly 'lower carbonate member'), Elsa Sandstone, and Waldecks Members. The Dodonea Member represents an early Silurian marine incursion across part of the basin and intertongues with the lower part of the Elsa Sandstone Member deposited under clastic shoreline to eolian conditions. The base of the Elsa Sandstone Member on the Barbwire Terrace may represent a supersequence boundary, but with little or no incision. This supersequence boundary likely lies within the Elsa Sandstone Member elsewhere. Contrary to some previous interpretations, the Worral Formation is older than and distinct from the Tandalgoo Formation, which belongs low in the Devonian – lower Carboniferous megasequence. The contact with the Tandalgoo Formation is sharp and probably unconformable in most areas, but may not represent a large time gap.

From a petroleum perspective, the main role of the Carribuddy Group and Worral Formation are as a regional seal to the prospective Larapintine 2 petroleum system. Along the Admiral Bay Fault Zone the Bongabinni Formation contains excellent oil-prone source rocks which can be linked to migrated oil in that area. Other local source units may be present, but are not well documented. Porous reservoir sands are locally present in the Carribuddy Group, but are more extensive in the Worral Formation, particularly in the Elsa Sandstone Member.

KEYWORDS: Canning Basin, Western Australia, Ordovician, Silurian, Devonian, Carribuddy Group, Bongabinni Formation, Minjoo Salt, Mount Troy Formation, Nibil Formation, Mallowa Salt, Sahara Formation, Worral Formation, sedimentology, stratigraphy, biostratigraphy, petroleum

Introduction

The Paleozoic to Mesozoic Canning Basin (Fig. 1) is the largest onshore basin in Western Australia. Despite containing several demonstrated petroleum systems, and six small producing oil fields, most of the basin remains underexplored or unexplored for petroleum resources. The oldest petroleum system, the Ordovician–Silurian Larapintine 2 system of Bradshaw (1993), is the most widespread but is yet to yield a commercial field. Rocks of this system can be broadly subdivided into a lower marine section of four widespread Lower to Middle Ordovician subsurface formations, and their local equivalents in outcrop on the northern margin, and the overlying marginal marine to terrestrial and evaporitic Carribuddy Group and Worral Formation of Middle Ordovician to Silurian (and possibly Devonian age).

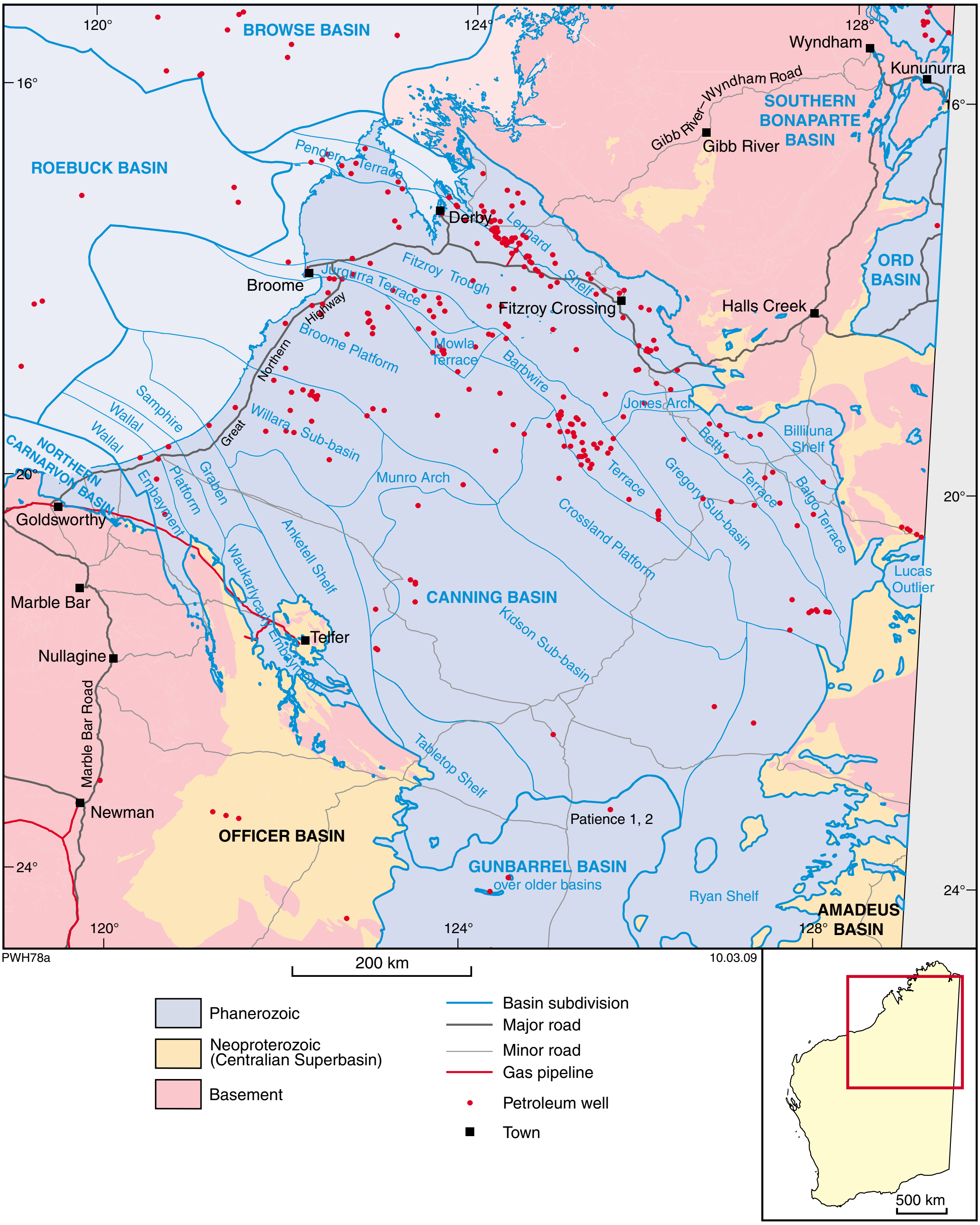


Figure 1. Principal structural elements of the Canning Basin

The Carribuddy Group and Worral Formation are widespread in the Canning Basin, intersected in 56 petroleum wells and at least 33 open file mineral exploration drillholes (Fig. 2; Appendix 1, 2), but this combined stratigraphic interval has received less attention than other Paleozoic packages in the basin. This is because of the general perception of low hydrocarbon prospectivity, and difficulties in stratigraphic subdivision and environmental interpretation of the group due in part to very poor biostratigraphic control. The underlying marine section has been traditionally considered to harbour all source, and most reservoir, potential of the Larapintine 2 system; the Carribuddy Group being regarded mainly as a regional seal. The potential of the Carribuddy Group to host very rich oil-prone source rocks has been recently documented (Edwards et al., 1997), although the known distribution of such rich source facies remains limited. The Carribuddy Group and particularly Worral Formation also locally host potential sandstone and carbonate reservoir units. A better understanding of regional facies relationships within this package is essential to predict their distribution.

This study reviews the stratigraphy, sedimentology, and petroleum potential of the Carribuddy Group and Worral Formation across the Canning Basin. The Worral Formation was previously considered to be part of the Devonian – lower Carboniferous megasequence. The reason for its inclusion in this study is that reassessment of well correlations does not support the concept of regional angular unconformity at its base as proposed by Lehmann (1986), nor the inferred interdigitation of this unit with the Devonian Tandalgoo Formation (Kennard, 1994), and the sparse biostratigraphic data are open to reinterpretation. Pending new biostratigraphic constraints, it is here concluded the Worral Formation is genetically more closely related to the Carribuddy Group than to the Middle Devonian Tandulla Group with which it was previously placed.

Regional setting

Canning Basin

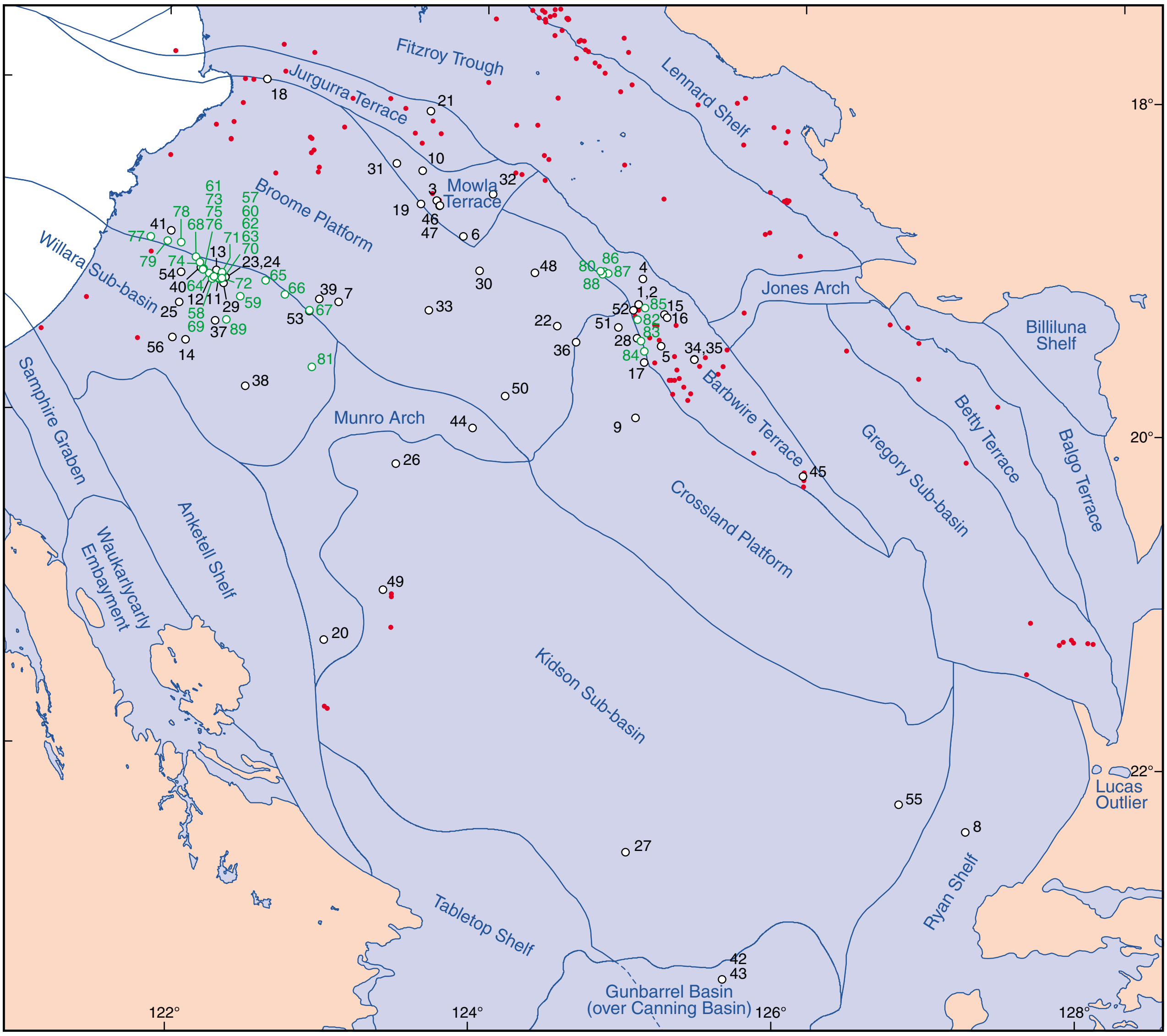
The Canning Basin extends in a southeasterly direction from offshore northern Western Australia then inland to near the Northern Territory border, covering a total area of approximately 640 000 km^2 (530 000 km^2 onshore). Surrounded by Proterozoic and Archean provinces, and underlain by basement of mostly uncertain age, the Canning Basin preserves a multi-phase depositional history ranging from Early Ordovician to Cretaceous (Forman and Wales, 1981; Brown et al., 1984; Kennard et al., 1994). In comparison to basins of similar age elsewhere in Australia, the Canning Basin is relatively little deformed, with successions close to horizontal in many areas. Surface exposures of the older basin components are rare, with Ordovician to Carboniferous rocks only exposed along and near the northern and northeastern basin margin. Many units, including the entire Carribuddy Group and Worral Formation, are not known in outcrop and all information about these come from drilling and seismic interpretation.

Tectono-stratigraphic subdivision

The Canning Basin is cut by major fault systems, typically trending southeasterly parallel to the long margins of the basin. Most major fault systems were active during various phases of deposition, thereby controlling major thickness changes, and can be used to subdivide the basin into a series of tectono-stratigraphic domains (Shaw et al., 1994; Hocking et al., 1994; Fig. 1). At a broad scale, the onshore Canning Basin displays elongate northern and southern depocentres separated by thinner successions on the contiguous Broome (northwest) and Crossland (southeast) Platforms. In the north, up to 15 km of strata is preserved in the Fitzroy Trough (northwest) and Gregory Sub-basin (southeast), whereas to the south of the central highs, thinner sequences are preserved in the Willara (northwest) and Kidson (southeast) sub-basins. The Fitzroy Trough and Gregory Sub-basin are flanked to the south by the Jurgurra, Mowla, and Barbwire terraces; transitional domains to the Broome and Crossland platforms respectively. The present northern margin of the basin is defined by the Lennard Shelf, northeast of the Fitzroy Trough, and the Billiluna Shelf and transitional Balgo and Betty terraces northeast of the Gregory Sub-basin. The southeastern margin of the basin is defined by thin successions on the Ryan Shelf flanking the Crossland Platform and Kidson Sub-basin, whereas the Tabletop and Anketell shelves likewise define the southwest margin. The Carribuddy Group and Worral Formation are only known with certainty from south of the Fenton Fault Zone which defines the southern margin of the Fitzroy Trough and Gregory Sub-basin, although they are likely to extend into these areas below the depth of well penetration. It is uncertain to what extent the Fitzroy Trough and Gregory Sub-basin were depositional and structural entities prior to Devonian tectonic events.

Paleozoic lithostratigraphy and depositional history

Paleozoic lithostratigraphy of the Canning Basin is summarized in Figure 3. Series and Stage names used in this report follow the International Stratigraphic Chart (International Commission on Stratigraphy, 2008), and where necessary Series and Stage names used in cited reports have been converted. Deposition began during a phase of subsidence (Samphire Marsh Movement) following the cessation of earlier contractional tectonic activity (Kennard et al., 1994). South of the present Fitzroy Trough and Gregory Sub-basin the succession begins with four fossiliferous marine units, the Nambeet, Willara, Goldwyer, and Nita Formations (in ascending order) ranging from late Tremadocian to late Darriwilian (Early to Middle Ordovician) (Nicoll, 1993; Nicoll et al., 1993). Apart from widespread basal siliciclastics portion of the Nambeet Formation, the remainder of the section is mostly composed of an alternation of mudstones (typically deeper water facies) and carbonates (typically shallower) on several scales, with the exception of sandy and conglomeratic facies near basin margins (Wilson Cliffs Sandstone and Carranya Formation on eastern and southeastern margins respectively; Playford et al., 1974). Local siliciclastic bodies, such as the Acacia Sandstone



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Phanerozoic

Basement

Petroleum well

28 Named petroleum well

72 Mineral exploration drill hole

100 km

1	Acacia 1	24	Great Sandy 2	47	Pictor 2	70	DD89SS15 (CRAE)		
2	Acacia 2	25	Juno 1	48	Robert 1	71	DD89SS16 (CRAE)		
3	Antares 1	26	Kemp Field 1	49	Sahara 1	72	DD89SS17 (CRAE)		
4	Barbwire 1	27	Kidson 1	50	Sally May 1	73	DD89SS18 (CRAE)		
5	Boab 1	28	Kunzea 1	51	Santalum 1A	74	DD90SS19 (CRAE)		
6	Canopus 1	29	Leo 1	52	Solanum 1	75	DD90SS20 (CRAE)		
7	Carina 1	30	Looma 1	53	Vela 1	76	DD90SS21 (CRAE)		
8	Contention Heights 1	31	Lovells Pocket 1	54	Willara 1	77	DD91SS22 (CRAE)		
9	Crossland 2	32	Matches Spring 1	55	Wilson Cliffs 1	78	DD91SS23 (CRAE)		
10	Crystal Creek 1	33	McLarty 1	56	Woods Hills 1	79	DD91SS24 (CRAE)		
11	Cudalgarra 1	34	Mirbelia 1	57	DD86SS2 (CRAE)	80	DD88CLI (CRAE)		
12	Cudalgarra 2	35	Mirbelia 2	58	DD86SS3 (CRAE)	81	Brooke 1 (BHP-Utah)		
13	Cudalgarra North 1	36	Missing 1	59	DD87SS4 (CRAE)	82	BW1 (Pasminco)		
14	Darriwell 1	37	Munda 1	60	DD87SS5 (CRAE)	83	BW3A (Pasminco)		
15	Dodonea 1	38	Munro 1	61	DD87SS6 (CRAE)	84	BW5 (Pasminco)		
16	Dodonea 2	39	Musca 1	62	DD87SS7 (CRAE)	85	BW15 (Pasminco)		
17	Drosera 1	40	Nita Downs 1	63	DD88SS8 (CRAE)	86	BW24 (Pasminco)		
18	East Crab Creek 1	41	Parda 1	64	DD88SS9 (CRAE)	87	BW26 (Pasminco)		
19	Edgar Range 1	42	Patience 1	65	DD88SS10 (CRAE)	88	BW27 (Pasminco)		
20	Frankenstein 1	43	Patience 2	66	DD88SS11 (CRAE)	89	Gingerah Hill 1 (BHP-Utah)		
21	Frome Rocks 1	44	Pegasus 1	67	DD88SS12 (CRAE)				
22	Fruitcake 1	45	Percival 1	68	DD89SS13 (CRAE)				
23	Great Sandy 1	46	Pictor 1	69	DD89SS14 (CRAE)				

Figure 2. Location of petroleum exploration wells and mineral exploration drillholes intersecting the Carribuddy Group and/or Worral Formation

Member of the Willara Formation, extended into the basin during times of relative low stand of sea level.

The Nita Formation, capping the relatively open marine section, is essentially free of any coarse siliciclastics, implying a relatively low relief hinterland (and probably dry climate) at this time. The Nita Formation has been subdivided into a lower Leo Member, with upward trend of increasing carbonate, and an overlying Cudalgarra Member, with shaling-upward trend (McCracken, 1994). Although McCracken only applied this subdivision in the Willara Sub-basin and Admiral Bay Fault Zone, it is clear from the present study that the boundary between the members can be easily picked across most of the basin and corresponds closely with the A_2–B_1 supersequence boundary of Kennard et al. (1994) and Romine et al. (1994) — see **Paleozoic sequence stratigraphy**. From a sequence stratigraphic perspective the Cudalgarra Member belongs genetically with the overlying Carribuddy Group.

The shallow cyclic carbonate and shale package of the Nita Formation is overlain conformably, in most areas, by the marginal marine and evaporitic Carribuddy Group, comprising six formations ranging in age from Middle Ordovician to early Silurian. Deposition of the Carribuddy Group took place mostly in supratidal environments, with periodic deposition of thick halite-dominated evaporite units in large salterns. Apart from the evaporites, the group is predominantly composed of redbed mudstone, which is dolomitic or calcareous in part, with minor sandstone and carbonate interbeds. What is now recognized as the Worral Formation was once (pre-1984) included in the Carribuddy 'Formation' (now Group), but later separated out on the basis of an inferred regional unconformity (Lehmann, 1984), although the stratigraphic position of this supposed break has differed between authors. This study concludes that the contact is conformable in most areas.

The Worral Formation is generally overlain by the Middle Devonian Tandalgoo Formation, typically comprising orange to reddish, well sorted, well rounded, and porous sandstone. Much of it appears to be of eolian origin, interspersed with minor fluvial or other facies. The contact is sharp, and there is evidence of erosional incision in some areas, with probable Tandalgoo Formation directly overlying the Carribuddy Group locally near the present salt edge. The Tandalgoo Formation is conformably overlain by the marginal marine to sabkha facies of the Mellinjerie Formation in the south, and carbonate reef and basin complexes in the north. Within the Fitzroy Trough and Gregory Sub-basin, and further north, deposition continued into the Carboniferous with the mixed siliciclastic–carbonate rocks of the Fairfield Group, and deltaic siliciclastic rocks of the Anderson Formation.

Upper Carboniferous to Permian rocks form a widespread predominantly siliciclastic blanket across the basin, often lying with marked angular unconformably over older depositional packages. Most widespread is the Grant Group, comprising non-marine to marine siliciclastics, which includes glacially influenced deposits near the base. The Grant Group is overlain by the marginal-marine Poole Sandstone, marine Noonkanbah Formation, and deltaic Liveringa Group. Lower Triassic marine to fluvial strata overlie the Permian, but are confined to the Fitzroy Trough in the onshore part of the basin. Younger Mesozoic and Cenozoic cover are relatively thin, and obscure the Paleozoic successions in many areas.

Paleozoic sequence stratigraphy

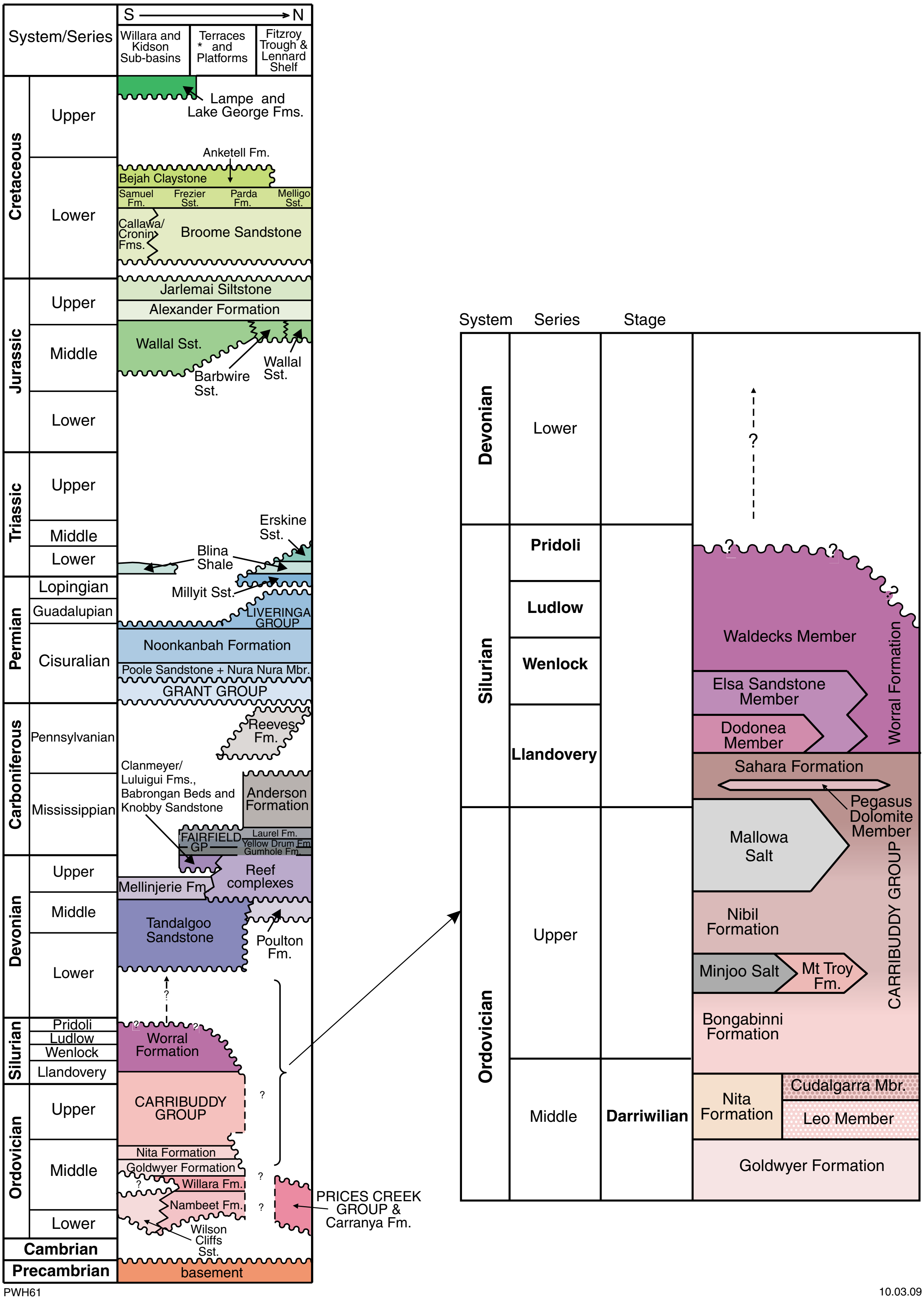
Warris (1993) subdivided the Paleozoic of the Canning Basin into three megasequences; Megasequence I: Nambeet to Worral Formations; Megasequence II: Tandalgoo to Anderson Formations; Megasequence III: Grant Group and younger. Kennard et al. (1994) recognized four first-order depositional megasequences within the entire Canning Basin succession; Ordovician–Silurian, Devonian – lower Carboniferous, upper Carboniferous – Permian (including basal Triassic), and Jurassic–Cretaceous. The older three are similar to those proposed by Warris, with the exception that under the Kennard et al. scheme the Worral Formation is grouped with the Tandalgoo Formation in the Devonian – lower Carboniferous megasequence.

Kennard et al. (1994) and Romine et al. (1994) further subdivide the Ordovician–Silurian megasequence into five supersequences; A_0, A_1, A_2, B_1, B_2 (Fig. 3). The lower and upper boundaries of this megasequence coincide with regional tectonic events: the basin-forming Samphire Marsh Movement (extensional) at the base, and the Early Devonian Prices Creek Compressional Movement that resulted in local folding and a regional unconformity at the top. This megasequence is interpreted as displaying an overall transgressive–regressive trend, with timing of peak transgression coinciding with shale deposition in supersequence A_2, corresponding to the lower Goldwyer Formation (Romine et al., 1994). Supersequence A_2 extends from the upper part of the Willara Formation to a position within the Nita Formation, here interpreted as being at or close to the boundary between the Leo and Cudalgarra Members of McCracken (1994). The upper part of the Nita Formation (Cudalgarra Member) and lower Carribuddy Group up to lower Mallowa Salt is assigned to supersequence B_1, with the remaining Carribuddy Group placed in supersequence B_2.

The Tandalgoo, Worral, and Poulton (Lennard Shelf) Formations were placed together in supersequence C (Kennard et al., 1994; Romine et al., 1994). This study concludes that the Worral Formation is genetically more closely related to the Carribuddy Group and is not a partial lateral equivalent of the Tandalgoo Formation as previously inferred. If correct, this implies that the Worral Formation belongs to the Ordovician–Silurian megasequence. There is, however, a likely sequence boundary within the lower Worral Formation corresponding to the base of the Elsa Sandstone Member on the Barbwire Terrace. To be consistent with the scheme of Kennard et al. (1994) the upper Worral Formation is here assigned to a new supersequence, B_3.

Paleozoic paleogeography

With the exception of parts of the northern margin, the basin margins are poorly delineated due to limited outcrop



Sst. Sandstone
Fm. Formation
Gp Group

Unconformity

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

Figure 3. Simplified stratigraphy of the Canning Basin (modified after Kennard et al., 1994 and D'Ercole et al., 2003), with detail of Middle Ordovician to Early Devonian stratigraphy at right

and scarcity of drilling and seismic data. For this reason it is unclear to what extent the modern basin boundary reflects the original depositional margins at any particular time in basin history. Along the northeastern margin (Lennard Shelf), good exposures of Devonian rocks clearly demark the primary basin margin at that time (Playford, 1980). There is a clear angular unconformity between the Devonian strata and eroded relics of the Ordovician succession in this area, indicating that the pre-Devonian basin margin in the northeast has been uplifted and eroded and possibly extended some distance beyond the Devonian basin margin. Based on the Larapintine Seaway concept (Webby, 1978), it is generally assumed that for early Paleozoic strata the present eastern margin of the Canning Basin is tectonic and erosional, and the basin extended further east to link, via Paleozoic basins of central Australia, to the continent margin basins of eastern Australia. This concept has been recently challenged by Haines and Wingate (2007) who questioned the strength of evidence for such a link and suggested the alternate possibility that during Ordovician time the Canning Basin may have represented a large embayment not greatly different from its modern configuration. The southwestern margin of the Canning Basin is defined by the limit of Permian strata, which generally overlies basement in this area. The established margin of Ordovician rocks in this area lies over 100 km to the north of the Permian limit, but with very poor well- and seismic-control it is possible that further Ordovician strata may be preserved under the Permian in deep embayments along this margin.

Previous studies

History of investigations and stratigraphic nomenclature

The presently recognized Carribuddy Group and Worral Formation have had a complex history of stratigraphic nomenclature and interpreted stratigraphic relationships (Fig. 4). This history is detailed below so that interpretations of varying vintages can be understood in the light of subsequent work, and to set the stage for the reinterpretations presented in this report.

Carribuddy Group

Frome Rocks 1, drilled in 1959, intersected 464 m of dolomite breccia cap rock and 532.5 m of massive halite and minor breccia to total depth beneath Jurassic sediments (Elliott, 1959; Bureau of Mineral Resources, 1962). The structure was interpreted as a salt dome and although the age of the salt in this well has never been directly determined, it is highly likely that this represents the first intersection of part of what is now recognized as the Carribuddy Group, presumably Mallowa Salt, albeit remobilized by halokinesis. The name Carribuddy 'Formation' was first used by Singleton (1965) for a succession of mudstone and bedded evaporites intersected beneath the Tandalgoo 'Red Beds' (now Formation) and continuing to total depth in Sahara 1. The name was taken from Carribuddy Springs located 16 km to the northeast. Koop (1966) published a formal definition of the Carribuddy 'Formation' and nominated the interval 1727–2120 m in Sahara 1 as the type section. This interval was further informally subdivided into an upper 'spotted shale unit A' and a lower 'interbedded evaporite unit B'. As the base of the evaporite succession was not reached, a lower boundary was not included in the original formation definition. At the time, the age was constrained to Middle Devonian or older by the biostratigraphically dated Mellinjerie Formation above the Tandalgoo Formation. However, the significance of the sharp Tandalgoo–Carribuddy contact was uncertain, and the possibility of equivalence with Proterozoic evaporite successions of the adjacent Amadeus and Officer basins was discussed (Koop, 1966).

Subsequent drilling of Willara 1 and Kidson 1 revealed that the Carribuddy 'Formation' was underlain by fossiliferous Middle and Lower Ordovician rocks, including the Goldwyer Formation, which had been earlier recognized in Goldwyer 1 and Thangoo 1/1A (Elliot, 1961) in areas of the Broome Platform where the Carribuddy Group had been eroded. By common usage the Carribuddy 'Formation' was extended down to the top of recognizable Goldwyer Formation in a number of wells drilled in the late 1960s and early 1970s, while Johnson (1966) extended the informal unit system to include units A to E, in descending order, in Kidson 1. This five fold subdivision was found to be applicable in other wells, although individual units were locally absent. In particular, Units B and D, characterized by abundant halite and other evaporite minerals, were found to be lenticular.

McTavish and Legg (1972) first referred to the Nita Formation without definition, and in the same year this term was used in the Munro 1 well completion report (Williams, 1972) to designate a carbonate unit between the Carribuddy and the Goldwyer Formations. The Nita Formation was later formalized by Playford et al. (1975), who nominated 1165–1270 m in Parda 1 as the type section. This interval correlates in whole or part with Carribuddy unit E as used in a number of well completion reports of the late 1960s and early 1970s, although the unit is apparently absent or very attenuated in the original 'unit E' of Kidson 1. At the time, a strong argument in favour of creating the new formation was the recognition of its conformable lower contact with the Goldwyer Formation and inferred disconformable or unconformable relationship with the overlying and lithologically different Carribuddy 'Formation' (Playford et al., 1975; McTavish and Legg, 1976). The Nita Formation was demonstrated to be of late Darriwilian age based on conodonts, while the sparse evidence available in the 1970s favoured an Early Devonian age for the Carribuddy 'Formation' (McTavish and Legg, 1976).

Lehmann (1984) redefined the Carribuddy 'Formation' as the Carribuddy Group comprising six named formations. The type sections of five of these are in Kidson 1, where they mostly correspond to the five previously informal units (unit E = Bongabinni Formation, 4071–4279 m; unit D = Minjoo Salt, 3905–4071 m; unit C = Nibil Formation, 3501–3905 m; unit B = Mallowa Salt, 2967–3501 m; lower part of unit A = Sahara Formation, 2688–2967 m). Although some drillcore was recovered

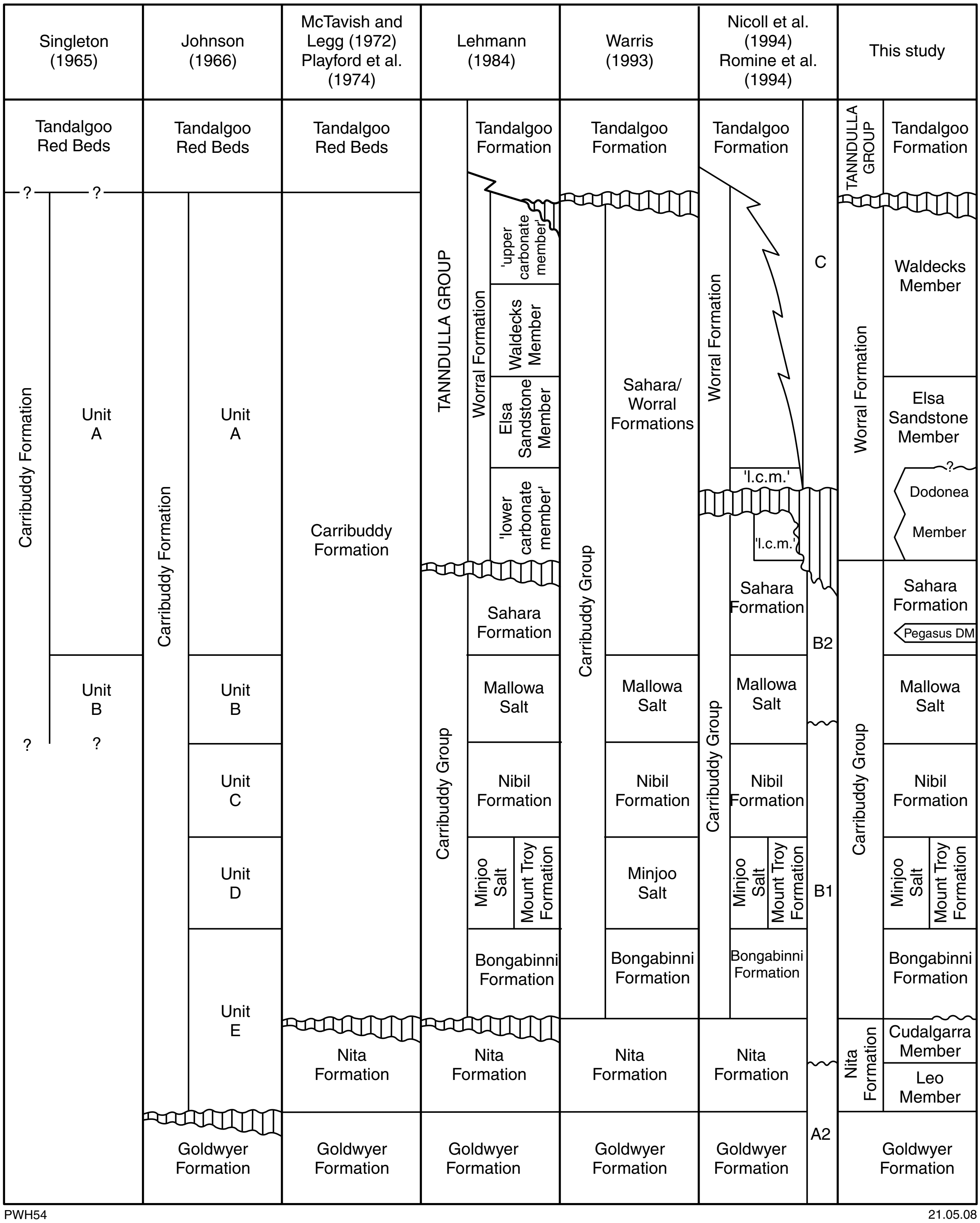


Figure 4. History of stratigraphic nomenclature and interpretations applied to the Carribuddy Group and Worral Formation. Right-hand column under Nicoll et al. (1994) and Romine et al. (1994) indicates supersequence interpretation. 'l.c.m.' = 'lower carbonate member'

from each formation in Kidson 1, only 18.24 m was cored from the entire Carribuddy Group no core intervals intersect formation boundaries. A thin dolomite and mudstone unit considered to be laterally equivalent to the Minjoo Salt was defined as the Mount Troy Formation with its type section between 701–716 m in Edgar Range 1 (Lehmann, 1984). No core was cut from the type section, and as such the definition of the Mount Troy Formation is based on wireline log data and cuttings alone.

When fully cored intersections across boundaries became available in the 1980s and 1990s it became clear that the long assumed regional stratigraphic break between the Nita Formation and Carribuddy Group was not well supported. Limited conodont data from the lower Carribuddy Group also allowed little scope for a significant time break (Nicoll, 1993). The only clear case of an erosional break involves some wells on the Barbwire Terrace; elsewhere the contact between the Nita and Bongabinni Formations is gradational.

Worral Formation

Based on seismic interpretations and well correlations, Lehmann (1984) inferred a regional angular stratigraphic break within the old unit A of the Carribuddy ‘Formation’, placing the upper part (2571–2688 m in Kidson 1) into a new unit, the Worral Formation. The formation was included in the Tandulla Group along with the Tandalgoo and Poulton Formations on the inference of at least local conformity and partial age equivalence of these units. The type section was placed in Barbwire 1 between 457–613 m, and further subdivided into a ‘lower carbonate member’ (596–613 m), Elsa Sandstone Member (577–596 m), Waldecks Member (472–577 m), and ‘upper carbonate member’ (457–577 m; Lehmann, 1984). The base of the Worral Formation was interpreted to cut down significantly into the Carribuddy Group. For example, at the type section Lehmann (1984) interpreted the Worral Formation to lie unconformably over the Nibil Formation with upper formations of the Carribuddy Group eroded. Such relationships are re-examined in this report, and previous interpretations are generally found to derive from miscorrelations.

The stratigraphic relationship between the Carribuddy Group and Worral Formation inferred by Lehmann (1984) was challenged by Warris (1993) who interpreted the relationship between the lithologically similar Worral and Sahara Formations as conformable, suggesting instead that the main unconformity is between the Worral and Tandalgoo Formations. Nicoll et al. (1994) recovered early Silurian conodonts from the ‘lower carbonate member’ (now Dodonea Member) of the Worral Formation in Boab 1 and Acacia 1, which when combined with the palynological data for a Late Ordovician to earliest Silurian age for the Mallowa Salt (Foster and Williams, 1991) leaves no scope for a significant hiatus. However, the conodont age was in apparent conflict with a previously reported mid-Devonian ostracod and foraminiferal age determination reported from a slightly higher stratigraphic level in the ‘lower carbonate member’ in Boab 1 (Jones and Nicoll; 1982). Nicoll et al. (1994) and Romine et al. (1994) reconciled the biostratigraphic age difference by suggesting that the regional unconformity inferred to be at the base of the Worral Formation lies at some indeterminate position within the ‘lower carbonate member’ in Acacia 1 and Boab 1. They suggested that the lower portion of the ‘lower carbonate member’ belongs to the Sahara Formation, with only the upper part belonging to the real Worral Formation. However, as discussed below, the depth and stratigraphic position at which the upper fossil sample was derived is now in doubt, negating the need for this interpretation.

Biostratigraphy and age

The Carribuddy Group and Worral Formation are largely devoid of age diagnostic fossils with the exception of Late Ordovician – earliest Silurian palynomorphs extracted from organic-rich layers within the Mallowa Salt (Foster and Williams, 1991) and Llandovery (early Silurian) conodonts from the basal Worral Formation (Nicoll et al., 1994). Pridoli (late Silurian) fish scales have been identified in a stratigraphic unit underlying the Tandalgoo Formation at the bottom of Kemp Field 1 (Young and Turner, cited in Romine et al., 1994). This stratigraphic unit has been inferred to be the Sahara Formation by Romine et al. (1994), but if this age and stratigraphic identification are correct the implication is that the Sahara Formation spans the Silurian. These age determinations overturned the long held view that the Carribuddy Group was most likely of Devonian age because of apparent lithological affinities with overlying fossiliferous Devonian strata and an assumed regional erosional hiatus separating it from underlying Ordovician rocks. When fully cored intersections became available in the 1980s it became clear that no obvious regional stratigraphic break exists between the Nita and Bongabinni Formations. For this reason the base of the group is now assumed to be close in age to the top of the Nita Formation, the latter being of late Darriwilian age based on conodonts (upper *Phragmodus–Plectodina* Zone) (Nicoll,1993; Nicoll et al., 1993; Jones et al., 1998). Specific identifications of conodonts recovered from the Bongabinni Formation have not been possible due to low recoveries of fragmentary material, but Nicoll (1993) indicates Ordovician rather than younger affinities.

Palynology

Attempts at palynological dating of the Carribuddy Group have been reported in a number for well completion reports from across the basin (Appendix 3). In general, samples were either reported as barren or produced a low to very low yield of organic remains, usually restricted to acritarchs. The typical acritarch assemblage from the Carribuddy Group has been informally referred to as the ‘*Pterospermopsimorpha* zone’, but does not provide any useful age constraints because the taxa are all wide ranging (Purcell, 1985, 1988a,c, 1989). This assemblage also has been reported from intervals recognized in this report as Worral Formation. Apart from acritarchs, some rare spores, miospores, chitinozoans, and taxa such as *Gloeocapsomorpha prisca* have been reported, but these are generally interpreted as being either reworked or mud contaminants.

An important exception is the report of tetrad land plant spores assigned to *Tetrahedraletes medinensis* in organic rich mudstone interbeds in drillcore from the Mallowa Salt in Gingerah Hill 1. These have been assigned an age of Late Ordovician or earliest Silurian (Foster and Williams, 1991) and provide the firmest internal age-constraint for any interval of the Carribuddy Group.

Conodonts

Conodonts have been reported from the Carribuddy Group or Worral Formation in Kunzea 1, Frankenstein 1, McLarty 1, Acacia 1, Boab 1, and Gingerah Hill 1 (Nicoll and Young, 1987; Nicoll 1993; Nicoll et al., 1994). Most occurrences are limited to few elements, often of poor quality, and with the exception of the fauna from the Dodonea Member of the Worral Formation in Acacia 1 and Boab 1, do not provide tight age constraints. Apart from variable quality age information, the presence of conodonts (except where reworked) provides evidence of marine influence.

Acacia 1 and Boab 1: Seventy conodont elements dominated by *Ozarkodina hassi* and including *Oulodus* sp. and *Icriodella*? sp. from drillcore samples of the Dodonea Member in Acacia 1 (3 samples between 511.64 – 522.53 m) and Boab 1 (2 samples between 1012.5 – 1015.32 m) indicate a Llandovery (early Silurian) age (Nicoll et al., 1994). In addition, a sample from 1009.32 – 1010.9 m in Boab 1 produced an unidentified scolecodont fauna (Nicoll et al., 1994).

Frankenstein 1: Rare conodont fragments and phosphatic ?fish fragments were reported by Nicoll (1993) from cuttings in the interval 1795–2005 m (Nibil Formation to Mallowa Salt). While the species were indeterminate, the fauna was tentatively assigned an Ordovician age.

Gingerah Hill 1: A sample from 800.5 – 801.5 m produced three conodont elements and fish scales (Nicoll and Young, 1987). The conodonts could not be identified to generic level, but the specimens were reported to display a type of apparatus known in Devonian conodonts, but not in Ordovician conodonts. The fish scales provide further support for a Devonian age (see below). The sample comes from a mudstone interval about 8 m below an unconformity at the base the Grant Group, but the stratigraphic unit to which it belongs has been disputed. Originally assigned to Carribuddy ‘unit A’, Foster and Williams (1991) suggest that the entire section above the Mallowa Salt is equivalent to the Tandalgoo Formation, which would be consistent with the Devonian age. The drillhole was not wireline logged, so there are considerable uncertainties in correlating to nearby petroleum wells (the closest, Munda 1, is 9 km to the west). Comparable depths from the surface to the base of the Grant Group, and top of the Mallowa Salt between Gingerah Hill 1 and Munda 1 suggest that the latter well may be useful as a crude proxy. If this inference is correct, the sample most likely comes from high in the Worral Formation, or a younger unit, because the Pegasus Dolomite Member and the base of the Worral Formation lie at a much lower equivalent level in Munda 1. Furthermore, it is possible that the sample comes from an elevated gamma ray unit below the Grant Group that is seen in Munda 1. Such high gamma mudstone units are not typical of the Worral Formation, but do occur at the base of the Tandalgoo Formation in a number of wells. While these fossils suggest that the Worral Formation may extend up into the Devonian, such an interpretation should be viewed with caution because of the stratigraphic uncertainties.

Kunzea 1: Conodont elements assigned to ?*Plectodina* sp. and ?*Erismodus* sp. were recovered from drillcore near the base of the Carribuddy Group at 288–290 m and 273.53 – 274.5 m, respectively; the fauna is too poor to be zoned, but indicates an Ordovician age (Nicoll, 1993). The two elements of ?*Plectodina* sp., while being too broken to be identified with confidence, are reported as looking similar to specimens from the Nita Formation (Nicoll, 1993). Given the evidence for a local erosional break between the Nita Formation and the Carribuddy Group in several nearby wells, it is possible that these elements have been reworked from the Nita Formation. During this study 6 conodont elements were recovered from a drillcore sample of dolomite at 274.55 – 275.92 m, but have not been identified.

McLarty 1: Nicoll (1993) reports conodonts from two stratigraphic levels interpreted as part of the Carribuddy Group. Elements from core 5 (464.6 – 465.9 m) ‘near the top of the Carribuddy Group’ were reported as typical of the significantly older Willara Formation. The elements are rounded and discoloured, and thus presumably reworked. The stratigraphic position of core 5 is here reinterpreted and being very close to the top of the Worral Formation. This raises an interesting question about basin tectonics — were significantly older Ordovician sediments being uplifted and eroded somewhere in the basin at this time? A small sample of conodonts from core 10 at 1496 m in the Nibil Formation contains elements of uncertain identification, but comparable to those found at a similar stratigraphic level in Frankenstein 1 (Nicoll, 1993).

Vertebrates

Fish and probable fish remains have been reported from the Carribuddy Group (or supposed Carribuddy Group) in Frankenstein 1, Gingerah Hill 1, Kemp Field 1, and are herein also reported from Kidson 1.

Frankenstein 1: Phosphatic fragments that are probable fish scales are reported by Nicoll (1993) from cuttings over the interval 1795–2005 m (Nibil Formation to Mallowa Salt), along with unzoned but tentatively Ordovician conodont fragments (see above).

Gingerah Hill 1: Nicoll and Young (1987) report that a sample from 800.5 – 801.5 m produced fish scales along with minor conodont elements (see above). The material includes about 15 thelodont scales closely resembling *Turinia australiensis*, first described from the Tandalgoo Formation in Wilson Cliffs 1 (Gross, 1971), and also known from the Cravens Peak Beds of the Georgina Basin. Also present are acanthodian scales similar to specimens described from the Georgina Basin. According to Nicoll and Young (1987) the fauna is Devonian, with a possible range of Lockovian to Frasnian. Unfortunately, as discussed above, the stratigraphic assignment of the sample is equivocal. While unlikely to be below upper Worral Formation, it could also be from a younger unit.

Kemp Field 1: Romine et al. (1994) briefly mention the discovery of Pridoli (late Silurian) fish scales in what they refer to as Sahara Formation in Kemp Field 1. Details of this discovery were never published (Young, G, 2004, ANU, written comm.). The sample came from core 8 at 1123.2 m (Trinajistic, K, 2008, written comm.), which was cut within a succession of dolomite and mudstone beneath the Tandalgoo Formation. The stratigraphic unit is uncertain because the well terminated before intersecting any regional marker horizons, however, it is here considered more likely to be Worral Formation than Sahara Formation. Such an interpretation would be more consistent with a late Silurian age, because of the early Silurian conodont age for the base of the Worral Formation in Acacia 1 and Boab 1.

Kidson 1: During this study, fish fragments were located near the base of the stratotype of the Nibil Formation in Kidson 1, core 18 (3865.2 – 3866.1 m). Fragments occur in argillaceous and sandy dolomite and fine grained sandstone. These have yet to be studied in detail and provide no age constraints at the present time. A search for conodonts in this core, and in core 17, was unsuccessful.

Ostracods and other microfossils

Boab 1: A drillcore sample reportedly from the interval 1003.6 – 1005.21 m produced a pyritized fauna of ostracod and gastropod steinkerns, foraminiferids and sponge spicules, and phosphatic shell fragments (Jones and Nicoll, 1982). Two of three recovered ostracods were considered to have close affinities with Middle Devonian (Eifelian) species described from the former USSR, while it was noted that other morphologically close taxa are known to range from Emsian to Givetian. One foraminiferid specimen was identified as *Pseudopalmula*, a genus known to range from Givetian to Frasnian. The cited depth corresponds to the upper part of the 'lower carbonate member' of the Worral Formation (as used by Lehmann, 1984), a slightly lower part of which produced Llandovery (early Silurian) conodonts in the same well (Nicoll et al., 1994). The combined age information was used to revise the stratigraphic position of the base of the Worral Formation, and provide evidence for a significant hiatus between the Sahara and Worral Formations (Romine et al., 1994; Nicoll et al., 1994).

A recent re-examination of the actual sample, as well as collection and processing notes, confirms a Devonian age (no older than Emsian, probably Eifelian), but reveals an error in depth assignment (Jones, PJ, 2007, written comm.). While it is unclear at exactly what stratigraphic level this sample was collected, it does not come from the previously published depth (1003.6 – 1005.21 m), but was probably from within the 900–1000 m depth range (Jones, PJ, 2007, written comm.). Therefore, this sample cannot be used as evidence for a base to the Worral Formation within the 'lower carbonate member', consistent with the lack of physical evidence for any stratigraphic break at this level. The interval 900–1000 m spans most of the original Worral Formation, so if the sample did come from this interval, it would provide evidence that the Worral Formation ranges to the Lower or Middle Devonian, likely requiring an hiatus within the unit. Resampling of the core would be required to confirm this. At this stage it is preferred to retain the original definition and boundary position of the Worral Formation.

Present study

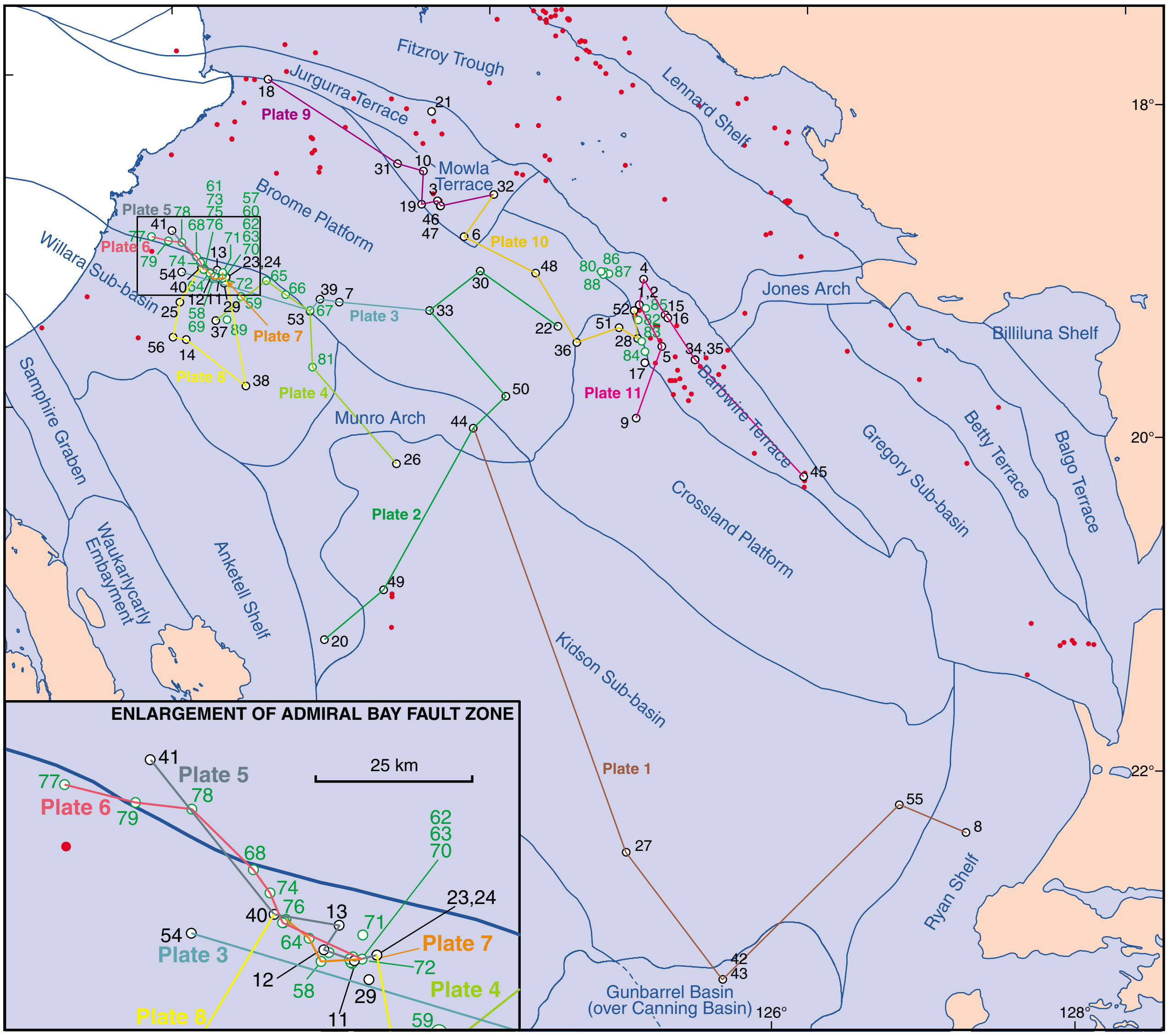
This report reviews and reassesses the stratigraphy, sedimentology, biostratigraphy and petroleum potential of the Ordovician–Silurian Carribuddy Group and overlying Worral Formation. The study is basin-wide in scope and utilizes data from all available petroleum wells, and the majority of mineral drillholes that are known to intersect these rocks.

Data sources and availability

This project relies heavily on open file data provided in well completion reports submitted to the Geological Survey of Western Australia as a statutory requirement of petroleum exploration licences. Scanned copies of well completion reports and digital well logs are freely available for download at the Department of Mines and Petroleum website (http://www.dmp.wa.gov.au/). Some online data is also available for most relevant mineral drillholes from the same web site, but is typically less comprehensive than that provided for petroleum wells. Most mineral drillholes used in this study have a limited set of digital wireline log data. Published data and interpretations from Geological Survey of Western Australia, Geoscience Australia and its precursors, and university sponsored projects are also reviewed.

Correlation charts

The correlation charts presented in Plates 1–11 represent the primary data behind this study. The location of wells used in each Plate is shown in Figure 5. Most petroleum exploration wells intersecting the Carribuddy Group or Worral Formation are presented on at least one plate. In some cases where closely spaced wells provide similar data, only one may be utilized (e.g. Pictor 1 but not 2, Dodonea 1 but not Dodonea 2, Merbelia 2 but not Merbelia 1, Great Sandy 1 but not Great Sandy 2, Patience 2 but not Patience 1). Acacia 2 is used rather than Acacia 1 because the latter does not have complete wireline logs over the interval of interest — but drillcore observations relating to this well come from Acacia 1, which was continuously cored over the Carribuddy Group and Worral Formation. Drosera 1 is omitted because the relevant interval beneath the Grant Group is very short (8 m) and of uncertain stratigraphic position. The interval of interest presented on the charts extends from the uppermost Goldwyer Formation (or to the base of wireline data if that depth was not reach) to a position approximately 50 m into the unit overlying the Carribuddy–Worral interval, typically in Devonian or



Phanerozoic

Basement

Petroleum well

28 Named petroleum well

72 Mineral exploration drill hole

100 km

1 Acacia 1
2 Acacia 2
3 Antares 1
4 Barbwire 1
5 Boab 1
6 Canopus 1
7 Carina 1
8 Contention Heights 1
9 Crossland 2
10 Crystal Creek 1
11 Cudalgarra 1
12 Cudalgarra 2
13 Cudalgarra North 1
14 Darriwell 1
15 Dodonea 1
16 Dodonea 2
17 Drosera 1
18 East Crab Creek 1
19 Edgar Range 1
20 Frankenstein 1
21 Frome Rocks 1
22 Fruitcake 1
23 Great Sandy 1
24 Great Sandy 2
25 Juno 1
26 Kemp Field 1
27 Kidson 1
28 Kunzea 1
29 Leo 1
30 Looma 1
31 Lovells Pocket 1
32 Matches Spring 1
33 McLarty 1
34 Mirbelia 1
35 Mirbelia 2
36 Missing 1
37 Munda 1
38 Munro 1
39 Musca 1
40 Nita Downs 1
41 Parda 1
42 Patience 1
43 Patience 2
44 Pegasus 1
45 Percival 1
46 Pictor 1
47 Pictor 2
48 Robert 1
49 Sahara 1
50 Sally May 1
51 Santalum 1A
52 Solanum 1
53 Vela 1
54 Willara 1
55 Wilson Cliffs 1
56 Woods Hills 1
57 DD86SS2 (CRAE)
58 DD86SS3 (CRAE)
59 DD87SS4 (CRAE)
60 DD87SS5 (CRAE)
61 DD87SS6 (CRAE)
62 DD87SS7 (CRAE)
63 DD88SS8 (CRAE)
64 DD88SS9 (CRAE)
65 DD88SS10 (CRAE)
66 DD88SS11 (CRAE)
67 DD88SS12 (CRAE)
68 DD88SS13 (CRAE)
69 DD89SS14 (CRAE)
70 DD89SS15 (CRAE)
71 DD89SS16 (CRAE)
72 DD89SS17 (CRAE)
73 DD89SS18 (CRAE)
74 DD90SS19 (CRAE)
75 DD90SS20 (CRAE)
76 DD90SS21 (CRAE)
77 DD91SS22 (CRAE)
78 DD91SS23 (CRAE)
79 DD91SS24 (CRAE)
80 DD88CLI (CRAE)
81 Brooke 1 (BHP-Utah)
82 BW1 (Pasminco)
83 BW3A (Pasminco)
84 BW5 (Pasminco)
85 BW15 (Pasminco)
86 BW24 (Pasminco)
87 BW26 (Pasminco)
88 BW27 (Pasminco)
89 Gingerah Hill 1 (BHP-Utah)

Figure 5. Location diagram for well correlations in Plates 1–11

Permian strata. The charts are based primarily around digital wireline log data and were drawn using CycloLog version 3.2 (developed by ENRES International). For simplicity and space saving, the logs displayed are restricted to natural gamma ray (GR) and sonic (DT), although other logs were used, where required, during interpretation. GR is plotted as both a colourized 'pseudolithology' plot, and more conventional wiggle trace. The graphic lithology column was generated separately using Winlog version 4 (HRH Geological Services). In most cases, the lithology column is derived primarily from the interpretation provided on composite well logs submitted to GSWA within well completion reports, often with a degree of simplification. However, generation of some lithology columns involved partial or full reinterpretation where company interpretations are not available, were considered too simplistic, or appear unreliable. Most of the presented mineral holes lack a lithology column because a suitably detailed graphic company log was not available, and in most cases the only wireline log run over the entire interval of interest was GR. Also plotted is a dynamic INPEFA curve (D-IMPEFA-GR), a derivative curve calculated from the raw GR data by CycloLog. This curve (see below) is based on changes in spectral properties of the GR log and was found to be a useful aid in regional correlations by providing a 'machine objective' tool for picking critical bounding surfaces, particularly within relatively monotonous successions.

INPEFA curve

An INPEFA curve (Nio et al., 2005, 2006; de Jong et al., 2006) can be generated by CycloLog from any wireline log, but is most useful and geologically meaningful when applied to facies specific logs such as gamma ray (GR). The program uses maximum entropy spectral analysis to first compute a prediction error filter, which then predicts new data points from the preceding data series. The filter progressively calculates a new data series (PEFA curve), each point being the numerical error between the predicted and actual value of the log in each of a series of short (~10 m) overlapping windows of data. When numerically integrated over the interval of interest, the resulting INPEFA curve, while bearing a clear resemblance to the original log from which it was derived, often reveals trends and patterns not easily visible in the raw data. These trends and patterns can highlight distinct facies changes and reveal key surfaces to aid in correlation and sequence analysis, but it is important to realise that the curve is reporting changing spectral properties rather than lithology. The INPEFA curve is typically plotted in a broader track than the raw logs curves in order to highlight positive and negative trends and turning points.

In simple clastic successions, *positive trends* (right-trending), which mathematically means that the software is persistently underestimating the real log values are typical of shaling-upward or transgressives sequences. *Negative trends* (left-trending), mathematically implying that the software is persistently overestimating the real log values, are typical of sanding-upward or regressive successions. A major *positive turning point* (negative trend changes to positive) may imply a base level rise and therefore flooding surface, while a major *negative turning point* (positive trend changes to negative) may imply an erosion surface at the base of a coarse package and thus a candidate for a sequence boundary.

Carribuddy Group lithostratigraphy

Carribuddy Group

Definition and nomenclature: The Carribuddy Group was defined by Lehmann (1984) and comprises the Bongabinni Formation, Minjoo Salt, Nibil Formation, Mallowa Salt and Sahara Formation (in ascending order). The type sections of all of these units are in Kidson 1 (2688–4279 m; Fig. 6). The Mount Troy Formation, a localized lateral equivalent of the Minjoo Salt, is separately defined in Edgar Range 1. The Carribuddy Group relaced the earlier 'Carribuddy Formation', with the exception that its upper part was separated as the Worral Formation, then considered part of the Tanndulla Group. The original type section of the 'Carribuddy Formation' (1727–2120 m in Sahara 1: Koop, 1966) is very incomplete and no longer relevant; Lehmann (1984) proposed a reference section in Kidson 1, comprising the type sections to most of its constituent formations. The name Carribuddy is derived from Carribuddy Spring, 16 km northeast of Sahara 1.

Distribution and thickness: The Carribuddy Group is widespread south of the Fenton Fault Zone, except where removed by pre-Permian erosion on the northwest Broome Platform, and around the basin margin (Fig. 7). The group presumably extends into the Fitzroy Trough and Gregory Sub-basin, but is below the depth range of all wells. It thickens towards the centre of the Kidson Sub-basin, where Lehmann (1984) estimates that it may reach or exceed 2000 m. The thickest well intersection is 1591 m in Kidson 1 in the southern Kidson Sub-basin. Isopachs of the Carribuddy Group are significantly controlled by the distribution of the massive halite formations (Fig. 8). If the group was ever present on the shelves and terraces north of the Fitzroy Trough and Gregory Sub-basin, it has been removed by erosion prior to Devonian deposition.

Lithofacies: The Carribuddy Group is a succession of fine grained clastics and evaporites, interbedded with minor sandstone and carbonate. Thick-bedded halite units serve to subdivide the group where present.

Relationships and boundary criteria: The Carribuddy Group conformably overlies the Nita Formation in most wells (for more detail see *Bongabinni Formation*). It overlies the Goldwyer Formation with uncertain contact relationship in Kidson 1. On the Barbwire Terrace the boundary between the Carribuddy Group and the Nita Formation is locally unconformable in several wells (Barbwire 1, Dodonea 1 and 2, Merbelia 2, and possibly Acacia 1 and 2, and Percival 1). Variable thicknesses of Nita Formation are eroded, and in Dodonea 1 the entire Nita and upper Goldwire Formations are missing. The contact is exposed in drillcore in Acacia 1, where it lies at the base of a one metre bed of poorly sorted sandstone and mudstone sharply overlying dolomite of the upper

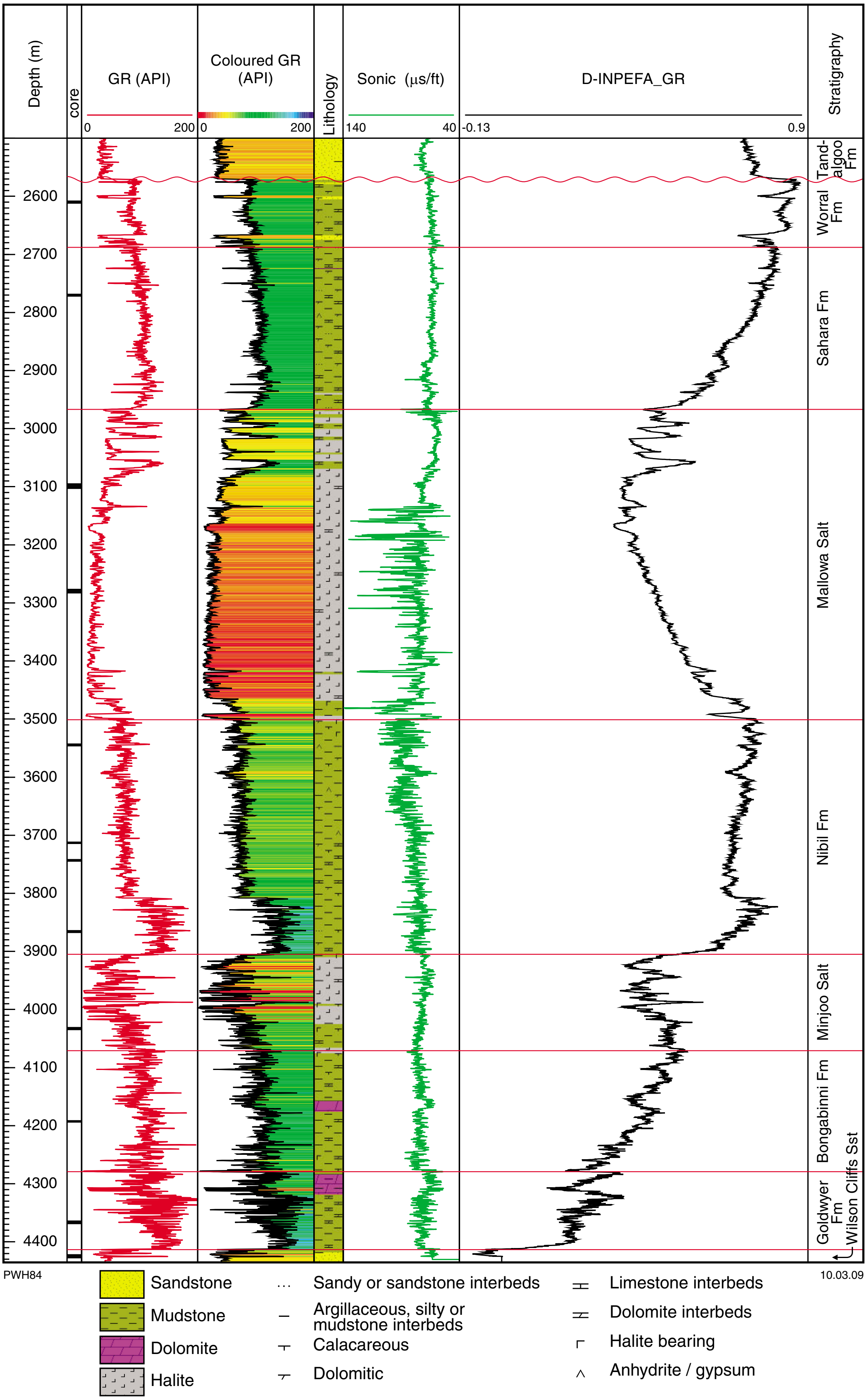


Figure 6. Carribuddy Group and Worral Formation in Kidson 1 reference section

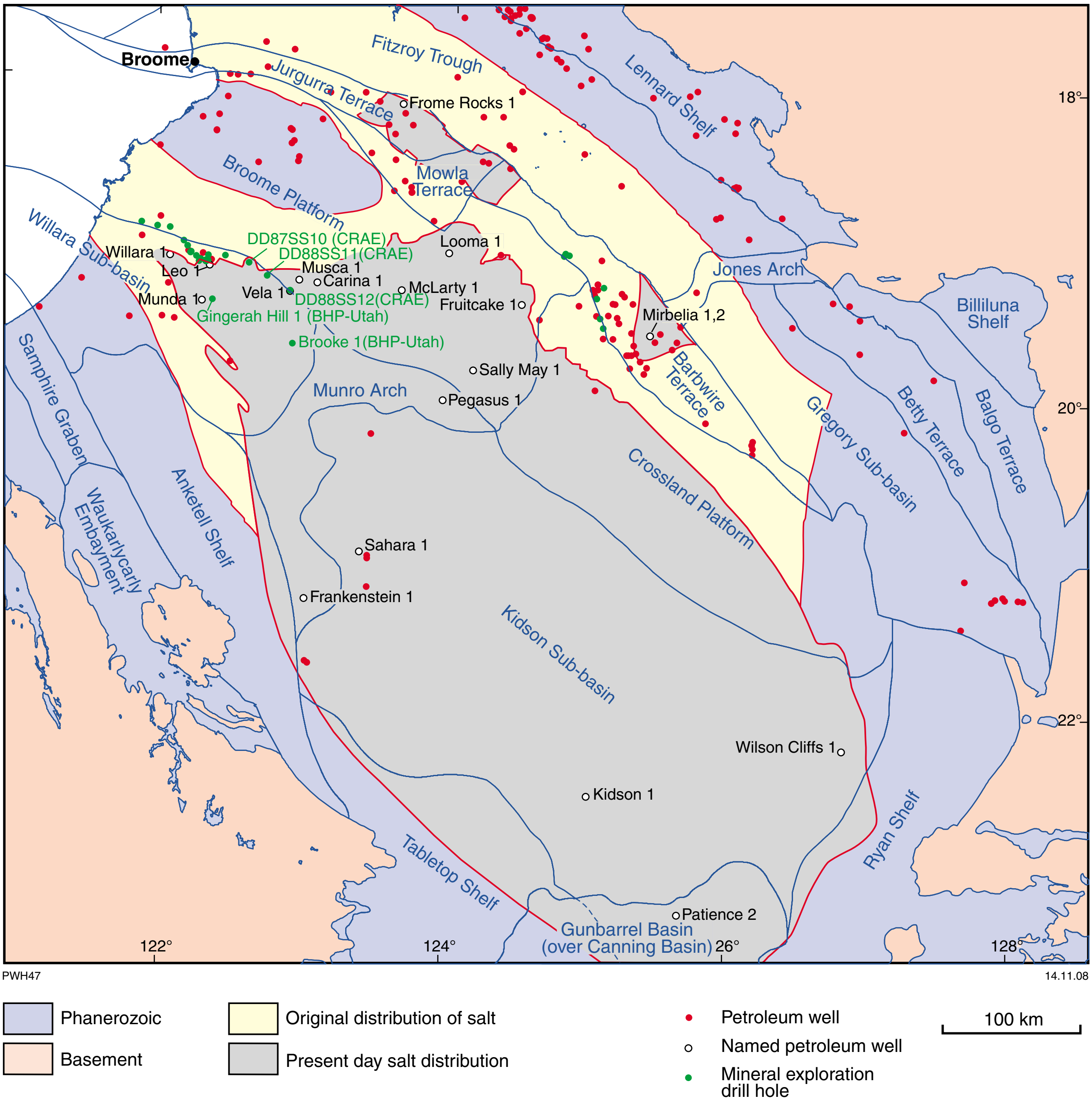


Figure 7. Total distribution and distribution of massive halite within Carribuddy Group. Petroleum wells and mineral drillholes intersecting significant halite are indicated (after Shell, 2000)

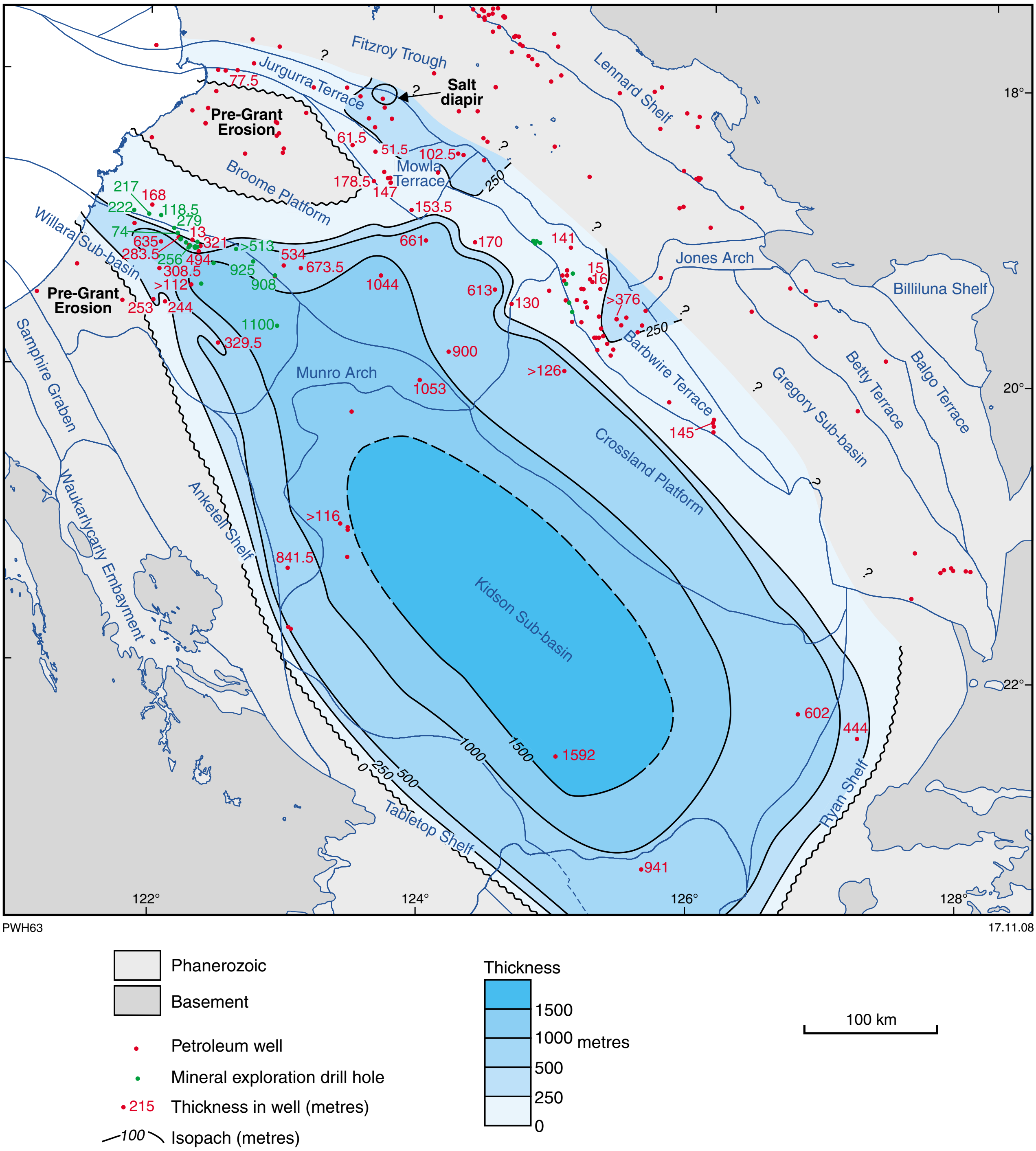


Figure 8. Isopach map of combined Carribuddy Group

Nita Formation (Scibiorski, 1982). It is unclear if the unit immediately overlying the unconformity in this area is an equivalent of the Bongabinni Formation, or lies at a higher stratigraphic level. The initiation of deposition of Mallowa Salt only about 30 m above the erosional contact in Merbelia 2 suggests that either the Bongabinni and other pre-Mallowa Salt formations are highly attenuated in this area, or the base here is younger than the Bongabinni Formation due to onlap onto a basin high. Areas of the Barbwire Terrace underwent local uplift and erosion during the early stages of Carribuddy Group deposition and the group then onlapped the unconformity surface such that the age of the base may vary from place to place. This local tectonic event is roughly coincident with the start of the Rodingan Movement (Wells et al., 1970; Haines et al., 2001) in central Australia.

The Carribuddy Group is overlain with apparent conformity by the Worral Formation, or unconformably by younger units such as the Grant Group. Possible unconformities between the Worral Formation and Carribuddy Group are present locally near the salt margins, and may be related to halotectonics or salt dissolution.

Age and correlations: The age of the Carribuddy Group ranges from Middle Ordovician to early Silurian (for details see discussions under **Biostratigraphy**).

Depositional setting: Marginal marine to supratidal with local and periodic development of lagoons and more extensive salterns. Minor local eolian influences are present, mainly in the Nibil Formation.

Bongabinni Formation

Definition and nomenclature: Lehmann (1984) named the Bongabinni Formation after Bongabinni Native Well (between Canning Stock Route Well 35 and 36), and nominated the type section as the interval 4071–4279 m in Kidson 1 to replace the earlier informal 'Carribuddy Unit E' of Johnson (1966) in that well. However, the formation does not equate directly with 'Carribuddy Unit E' as applied to a number of other wells drilled from the mid 1960s to mid 1970s that include what was later recognized as Nita Formation (Kidson 1 lacks an unequivocal Nita Formation).

Distribution and thickness: The Bongabinni Formation is widespread, with distribution similar to that of the entire Carribuddy Group, although its presence over the Barbwire Terrace is uncertain (see below). The thickest known intersection, 208 m, is in the type section in Kidson 1. Where the top of the formation can be distinguished in the Willara Sub-basin and southern Broome Platform it is typically around or less than 100 m in thickness. Average thickness decreases to the north across the Broome Platform and is typically only 30–40 m on the Mowla Terrace. In areas where neither Minjoo Salt nor Mount Troy Formation can be recognized the top of the formation and thickness cannot be determined.

Lithofacies: At its type section the Bongabinni Formation is dominated by red-brown mudstone (Fig. 9a), which is often calcareous or dolomitic, and contains interbeds of argillaceous dolomite and rare thin beds, veins, and scattered crystals of halite and anhydrite (Johnson, 1966). Although predominantly red-brown and oxidized, the mudstone does display local greenish-grey to olive-grey mottling, streaks, and reduction spots. Similar massive red-brown mudstone is a dominant component of the Bongabinni Formation in most areas, with the exception of parts of the Admiral Bay Fault Zone. In areas where the underlying Nita Formation is well developed, a lower unit of the Bongabinni Formation, transitional between the carbonate-dominated Nita Formation and the massive mudstone of the upper Bongabinni Formation, can be recognized and is distinguished informally on the stratigraphic charts. This lower unit contains sparse cyclical dolomite or limestone beds up to several metres in thickness. and typically traceable for considerable distances between wells using wireline log data.

A significant facies change is observed in petroleum wells and mineral exploration drillholes along the Admiral Bay Fault Zone. Here the Bongabinni Formation is quite calcareous or less commonly dolomitic, including beds of argillaceous limestone and minor dolomite. It is also predominantly chemically reduced as indicated by the grey-green, and grey to black colours of the mudstone when fresh. Pyrite is often present. Some of the mudstone is organic rich, and centimetre- to metre-scale beds of black coal-like material found in several cored mineral exploration drillholes in this area have excellent oil-prone source properties (McCracken, 1994; Edwards, et al., 1995; Haines and Ghori, 2006). These rocks are further described in the petroleum section. Scattered evaporite pseudomorphs are found in the Bongabinni Formation in this area, and increase in abundance up section.

Relationships and boundary criteria: The Bongabinni Formation conformably and gradationally overlies the Nita Formation (Cudalgarra Member) in most areas. The lithostratigraphic boundary is thus somewhat arbitrary. By common usage it is picked at a point were the cyclical and predominantly carbonate section of the Nita Formation gives way to predominantly mudstone up section, the actual boundary being placed at the top of the last of the closely spaced carbonate cycles. Carbonate cycles up to several metres in thickness are present in both the upper Nita Formation, and lower Bongabinni Formation (but sparser in the latter) and individual cycles can often be correlated with confidence for several hundred kilometres on wireline logs. If these cycles form approximate time markers, as seems likely, the implication is that the formation boundary, as picked by the above method, is somewhat diachronous, being slightly older in the southwest and younger towards the northeast. Boundaries used on the stratigraphic charts and in Appendix 2 have often been modified from those given in well completion reports to maximize consistency between nearby wells.

The contact between the Carribuddy Group and older successions is locally disconformable to unconformable on the Barbwire Terrace, but it is unclear if the Bongabinni Formation is present as the basal unit in these area (for more detail see **Carribuddy Group** above).

Age and correlations: No precise biostratigraphic age for the Bongabinni Formation is possible. The best age constraints come from the conformable relationship, in

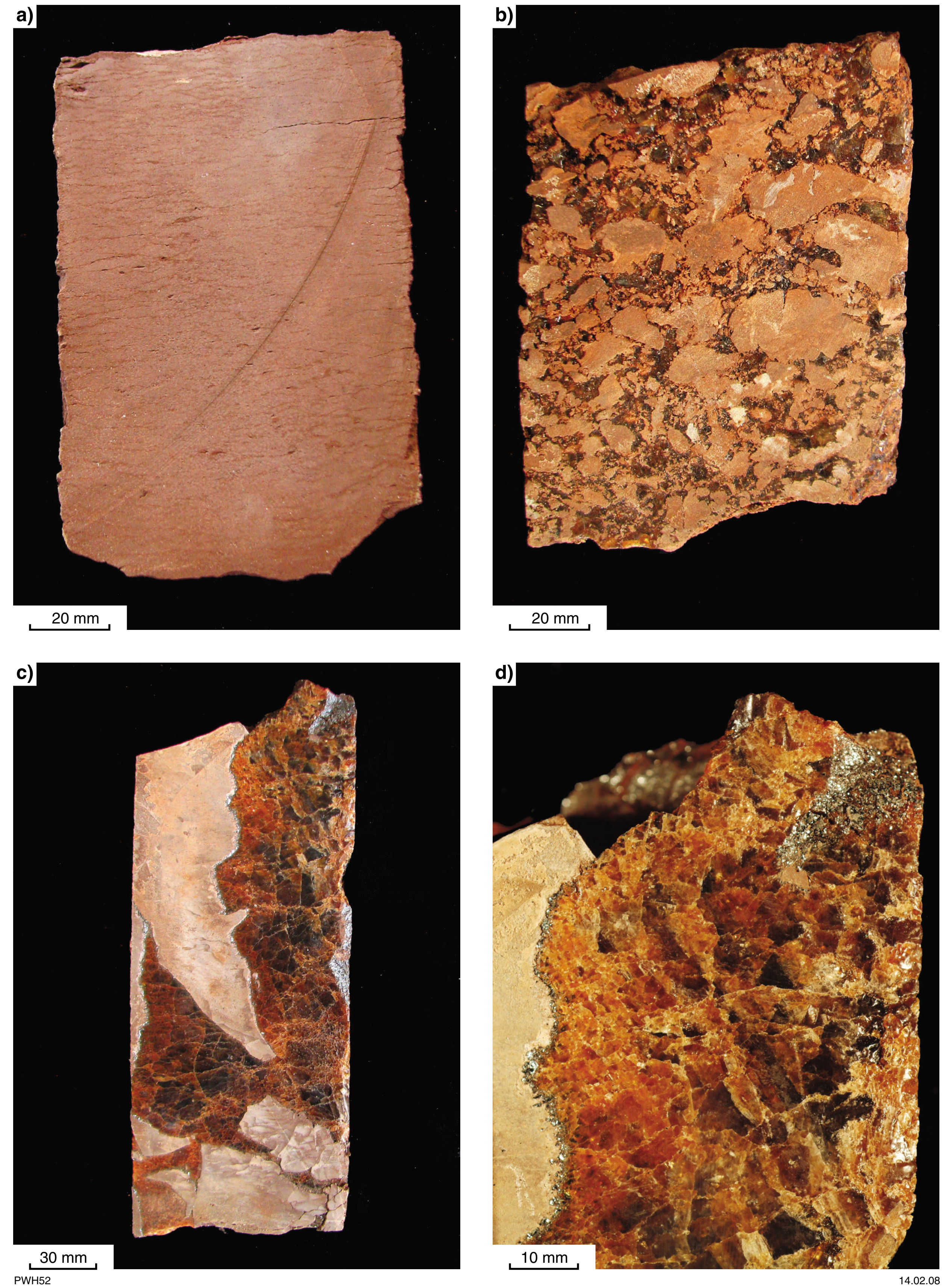


Figure 9. Drillcore photographs of Bongabinni Formation and Minjoo Salt type section in Kidson 1: a) massive red-brown dolomitic mudstone, Bongabinni Formation, core 20 (4191.6 – 4193.7 m); b) disseminated halite appearing to surround dolomitic mudstone clasts, Minjoo Salt, core 19 (4031.3 – 4034.3 m); c) cross-cutting vein of coarse recrystallized halite in massive red-brown dolomitic mudstone Minjoo Salt, core 19; d) close up of vein in c) showing specular hematite along margin

most areas, with the underlying Nita Formation that is assigned a late Darriwilian (Middle Ordovician) age based on conodonts (Nicoll, 1993).

Depositional setting: The Bongabinni Formation is mostly an oxidized marginal marine to supratidal deposit. Deposition occurred under conditions of very low relief and minimal influx of coarse siliciclastic detritus to the basin. During deposition of the Bongabinni Formation the Admiral Bay Fault Zone hosted a local system of lagoons in which chemically reduced and organic-rich sediments could accumulate in contrast to the surrounding oxidized supratidal flats. Localization of these unique deposits along the fault zone suggests fault-controlled accommodation, possibly allowing an elongate inlet from the open sea which likely lay to the west at this time. The lack of obvious marine fauna or bioturbation, and the sparse distribution of evaporite minerals suggest at least periodically hypersaline conditions that would have precluded normal marine fauna.

Minjoo Salt

Definition and nomenclature: The Minjoo Salt is the lower and generally thinner of two halite bearing intervals present within the Carribuddy Group. The formation was named by Lehmann (1984) after Minjoo Native Well (Canning Stock Route Well 35), to replace the earlier informal 'Carribuddy Unit D'. The type section is the interval 4071–3905 m in Kidson 1.

Distribution and thickness: The Minjoo Salt is more restricted in distribution than the younger Mallowa Salt. It has been intersected in some wells in the Willara Sub-basin and adjacent southern Broome Platform (Willara 1, Vela 1, Musca 1, Carina 1, McLarty 1, and mineral drillholes DD88SS12 and Brooke 1). In the Kidson Sub-basin log correlations from Kidson 1 (the type section) to Patience 2 and Wilson Cliffs 1 suggest that the single salt unit present in the latter wells is probably Minjoo rather than Mallowa Salt. The Minjoo Salt is thinnest in McLarty 1 (approximately 19 m), and if the correlation expressed above is correct, the thickest intersection is 313 m in Patience 2. Thus the depocentre of the Minjoo Salt saltern appears to be in the southern Kidson Sub-basin (Fig. 10). The lack of Minjoo Salt in Pegasus 1 at the northwest end of the Kidson Sub-basin makes it unclear if the Minjoo Salt is continuous between the two areas (as inferred in Fig. 10), or if there were two separate salterns, perhaps linked by a narrow channel.

Lithofacies: There is limited drillcore through the Minjoo Salt; most descriptions are summarized from cuttings information and log interpretations. At the type section the Minjoo Salt is composed of red-brown calcareous and dolomitic mudstone, grading to argillaceous dolomite, with interbeds of reddish-brown to brown and colourless coarsely crystalline halite (Johnson, 1966). Halite also occurs as scattered crystals between the main halite beds (Fig. 9b). Anhydrite is a minor component. In the limited cored interval from this well, veins of coarsely recrystallized and remobilized halite rimmed with specular hematite are also present (Fig. 9c,d). The halite beds increase in thickness, and the halite/mudstone ratio increases towards the middle of the formation, with these trends reversing in the upper part of the unit. From wireline logs, the thickest individual halite bed, which may be several amalgamated beds, is about 5 m in thickness. In the northern wells, halite beds in the Minjoo Salt show more regular cyclicity and a pronounced thickening upward trend right to the top of the formation. Such trends are less evident in Patience 2 and Wilson Cliffs 1, although in Patience 2 the thickest relatively massive halite beds do appear near the top.

Relationships and boundary criteria: The lower and upper contacts with the Bongabinni and Nibil Formations, respectively, appear conformable and typically gradational. The contacts are picked below and above the lowest and highest significant halite bed, respectively, but minor halite and other evaporate minerals do extend beyond the contacts. Where salt is absent, the equivalent interval, if recognized, is referred to as Mount Troy Formation (Lehmann, 1984). In practice differentiating the Mount Troy Formation from the enclosing formations depends on subtle features making the unit difficult to distinguish in many wells (see below).

Age: No internal age information is available. The unit is assumed to be of Late Ordovician age, based on the late Darriwilian age assigned to the older Nita Formation (Nicoll, 1993), and Late Ordovician to earliest Silurian age assigned to the younger Mallowa Salt (Foster and Williams, 1991).

Depositional setting: The depositional setting appears similar to that of the thicker and more widespread Mallowa Salt. Based on a detailed study of the latter unit by Cathro et al. (1992), the Minjoo Salt presumably accumulated within a saltern, with halite precipitating predominantly subaqueously from a shallow hypersaline water body, but with periodic freshening, exposure and desiccation between halite precipitation episodes, giving rise to the distinctive cyclicity of the unit seen on wireline logs.

Mount Troy Formation

Definition and nomenclature: The Mount Troy Formation is a dolomitic interval defined by Lehmann (1984) with its type section being the interval 701–716 m in Edgar Range 1. It is named after Mount Troy 5.5 km north of that well. Unfortunately the type section is not cored. Lehmann (1984) interpreted the Mount Troy Formation as a lateral equivalent to the Minjoo Salt.

Distribution and thickness: The Mount Troy Formation is best distinguished in areas marginal to deposits of the Minjoo Salt, particularly parts of the Willara Sub-basin and Broome Platform. The type section is 15 m thick, and the formation rarely exceeds 20 m in thickness.

Previous attempts at assigning the Mount Troy Formation in the Barbwire Terrace area appear to be in error. The dolomite horizon inferred by Lehmann (1984) to mark the base of the Mount Troy Formation in Barbwire 1 is here interpreted as the Pegasus Dolomite Member of the Sahara Formation. Likewise, intervals identified as Mount Troy Formation or 'Minjoo marker bed' in well

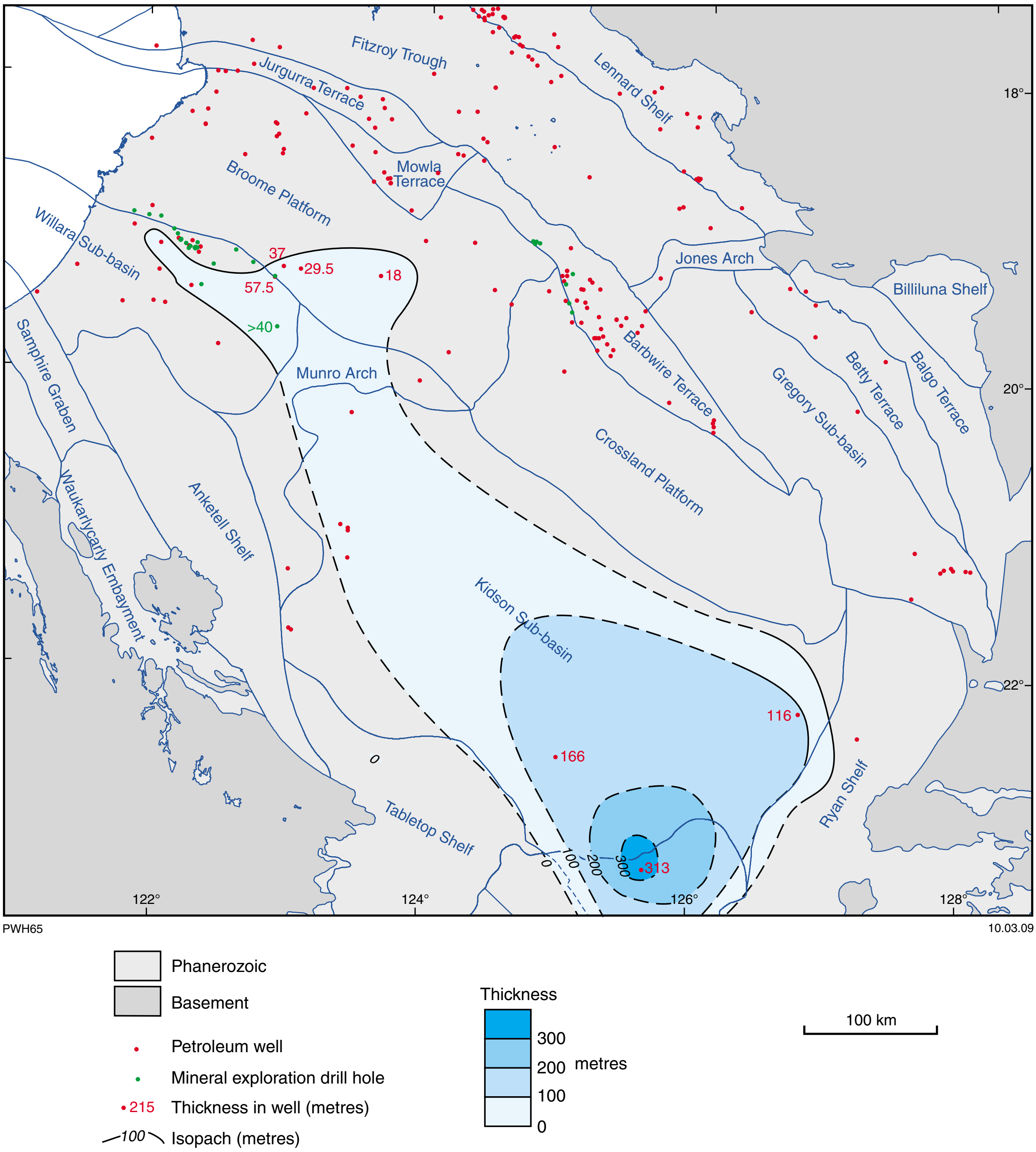


Figure 10. Isopach map of Minjoo Salt. Location of salt margin between main area of well data in northwest and southeastern Kidson Sub-basin is very uncertain

completion reports for Dodonea 1, 2, and Percival 1 are here reinterpreted as the Pegasus Dolomite Member. Such misinterpretations likely contributed to the incorrect inference of an angular unconformity at the base of the Worral Formation in this area.

Lithofacies: Based on cuttings information, the lithofacies at the type section is mainly pale grey dolomite with interbedded red, brown, and grey mudstone. Regionally the dolomite to mudstone ratio is variable and in many wells is represented by only a subtle increase in carbonate content over intervals below and above. Minor halite may be present, but its solubility makes it unlikely to survive in cuttings.

The formation is typically expressed as an interval of slightly lower gamma ray values in comparison to underlying and overlying mudstones, due to increased dolomite content. In some wells it has a spiky sonic signature, perhaps indicating dissolution of minor halite. The Cyclolog INPEFA curve often helps to distinguish the formation where it displays a subtle gamma-log response.

Relationships and boundary criteria: The Mount Troy Formation has conformable and gradational lower and upper contacts with the Bongabinni and Nibil Formations, respectively. The difference in lithology and wireline signature from the enclosing units is often subtle, making recognition of the unit difficult, or impossible, in many wells. Where recognized the gradational nature of the contacts allow only approximate formation picks.

Age and correlations: No internal age information is available. As an inferred correlative of the Minjoo Salt, the unit is assumed to be Late Ordovician.

Depositional setting: The Mount Troy Formation was likely deposited under supratidal conditions surrounding the Minjoo Salt saltern.

Nibil Formation

Definition and nomenclature: The Nibil Formation is defined as the predominantly non-evaporite interval between the Minjoo and Mallowa salts. The type section is in Kidson 1 from 3501 m to 3905 m (Lehmann, 1984), effectively replacing the earlier informal 'Carribuddy Unit C' in that well (3468–3905 m; Johnson, 1966). The formation was named after Nibil Native Well (Canning Stock Route Well 34) 40 km north-northwest of Kidson 1.

Distribution and thickness: The presence of the Nibil Formation is confirmed only where both the Mallowa and Minjoo Salt or Mount Troy Formation are present. It is assumed to be more widespread, presumably with a distribution similar to the entire Carribuddy Group, but is difficult or impossible to distinguish where one and particularly both salt units are absent, as discussed below. At 404 m, Kidson 1 has the thickest known intersection. The thickness decreases to the northwest within the combined Kidson–Willara sub-basin system (~240 m in Pegasus 1, 167 m in Vela 1, and 122 m in Willara 1), and is typically less than 100 m further north on the Broome Platform.

Lithofacies: At its type section in Kidson 1 the Nibil Formation is dominated by grey calcareous and less commonly dolomitic mudstone, locally grading to silty and argillaceous limestone and less commonly dolomite, with rare sandstone interbeds (Johnson, 1966). Minor halite is present, mainly near the base and top of the unit, implying either gradational contacts with the enclosing evaporate formations, or post-depositional remobilization of halite from those sources. Anhydrite is also common. Three short cores were cut from the type section. Core 18 from the base of the formation comprises yellow-brown to pink dolomitic mudstone and dolomite, and minor poorly sorted dolomitic sandstone (Fig. 11a,c). This interval displays fine laminae, disrupted by desiccation cracks (Fig. 11c), and scattered halite — probably remobilized from the underlying Minjoo Salt — fills vugs and small veins. Fish fragments are locally common (Fig. 11d), and are undergoing study at the time of writing. The other cores (16 and 17) are dominated by massive grey calcareous mudstone and grey to black argillaceous limestone (Fig. 11b). Organic geochemistry on samples from these cores returned low (0.11 – 0.47%) total organic carbon values (Ghori and Haines, 2006).

The expression of the Nibil Formation in Kidson 1 is similar to that seen in Frankenstein 1 and Wilson Cliffs 1, and thus may be typical of much of the central Kidson Sub-basin. In Patience 2, the southern-most well in the Kidson Sub-basin, the approximate interval of the Nibil Formation comprises red-brown to grey mudstone, which is commonly dolomitic and locally calcareous, and displays minor dolomite interbeds. In wells north of Frankenstein 1 the Nibil Formation is mostly non-calcareous and oxidized, being dominated by red-brown to varicoloured mudstone, with minor dolomite, sandstone, halite, and anhydrite. Greenish, grey, and black chemically reduced horizons may be present, but are a minor component only.

A 5–10 m thick sandstone-bearing marker unit has been intersected in several wells (Great Sandy 1, 2; Cudalgarra 1, 2; Cudalgarra North 1) and nearby mineral exploration drillholes along the Admiral Bay Fault Zone. This unit is inferred to lie within the Nibil Formation, although formation boundaries have not been determined in these wells. The unit comprises several beds of medium- to coarse-grained sandstone in a generally thickening-upward and 'cleaning-upward' (upward-decreasing gamma ray values) package, interbedded with mudstone. Sand grains are generally well rounded, well sorted, and frosted, and the friable sandstone beds are reported to have good porosity. Oil shows are reported in this unit in Cudalgarra 1 (Russell and Edwards, 1984) and Great Sandy 1 (Menzel and Norlin, 1982). An interval of interbedded sandstone and mudstone up to 35 m thick in Munro 1, Darriwell 1, Woods Hills 1, and Juno 1 in the Willara Sub-basin lies at an approximately similar stratigraphic level, but has a different wireline signature it is unclear if this unit correlates with the thinner sandstone horizon of the Admiral Bay Fault Zone.

Relationships and boundary criteria: At its type section the Nibil Formation lies conformably between the Minjoo Salt and Mallowa Salt. The contacts are picked at the last and first major salt beds respectively. Where the Minjoo

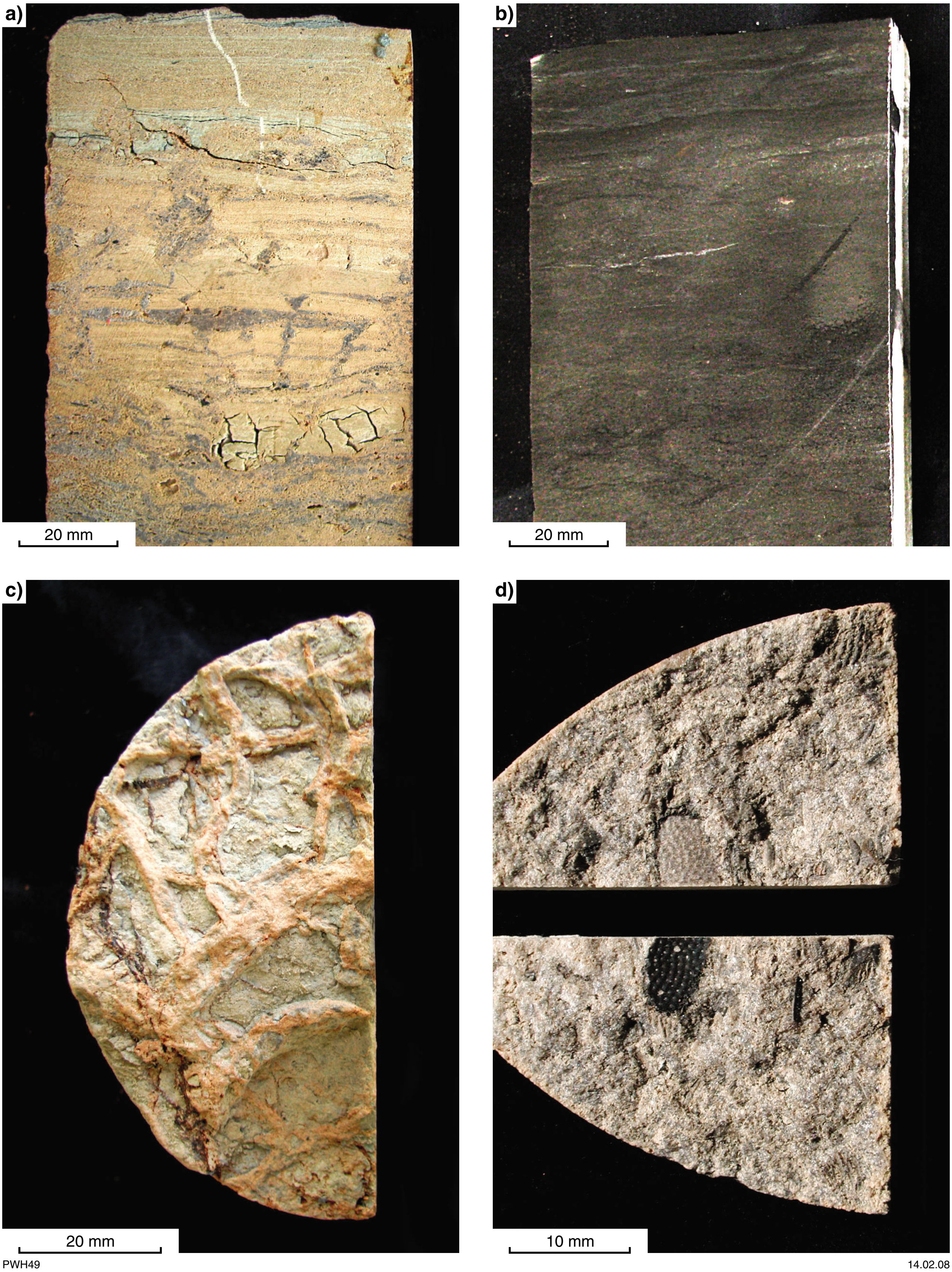


Figure 11. Drillcore photographs of Nibil Formation type section in Kidson 1: a) laminated silty and sandy dolomite, with possible desiccation cracks, core 18 (~3865.5 m); b) dark grey weakly laminated argillaceous limestone, core 17 (3742 – 3744.5 m); c) polygonal shrinkage cracks on core break, probably of desiccation origin; pink dolomitic sediment fills cracks into pale grey mudstone, core 18 (3864.3 – 3865.2 m); d) fossil fish fragments on core break of dolomitic sandstone, core 18 (~3865.5 m)

Salt is replaced by the roughly equivalent Mount Troy Formation, the Nibil Formation lies conformably above that unit, or directly above the Bongabinni Formation elsewhere. In areas where the Mallowa Salt is absent, the top of the Nibil Formation is in direct contact with the overlying Sahara Formation. In practice, Bongabinni–Nibil and Nibil–Sahara boundaries are difficult or impossible to define from present data because of the close lithological similarities of these units, and the Carribuddy Formation typically remains undifferentiated in these areas.

Age and correlations: No accurate internal age information is available, although conodonts and fish remains have been reported (see **Biostratigraphy**). The unit is inferred to be of Late Ordovician age, based on the late Darriwilian age assigned to the older Nita Formation (Nicoll, 1993), and the Late Ordovician or earliest Silurian age assigned to the upper Mallowa Salt (Foster and Williams, 1991).

Depositional setting: In most areas the Nibil Formation was probably deposited under very shallow and periodically exposed marginal marine conditions (upper intertidal to supratidal), similar to the typical deposition environments of the Bongabinni and Sahara Formations. The ephemeral nature of the water bodies and hypersaline conditions apparently precluded normal marine fauna in most cases. In parts of the Kidson sub-basin and adjacent areas, there is evidence that most of the Nibil Formation was deposited under somewhat deeper water conditions, however, the lack of a normal marine fauna and the presence of scattered evaporite minerals suggests restriction of circulation and at least periodic hypersaline conditions. A large lagoon with limited connection to the open sea, which probably lay to the northwest at the time, is suggested for the Kidson Sub-basin. The sandstone unit along the Admiral Bay Fault Zone is probably at least partly of eolian origin, but in the absence of drillcore a detailed facies analysis is not possible.

Mallowa Salt

Definition and nomenclature: The Mallowa Salt is the upper and thicker of two major halite bearing intervals within the Carribuddy Group. The formation was named by Lehmann (1984) after Mallowa Native Well (near Canning Stock Route Well 32), and replaced the earlier informal 'Carribuddy Unit B' of Koop (1966). The type section is the interval 2967–3501 m in Kidson 1. Lehmann (1984) also recognized an informal 'lower Mallowa Salt' over the interval 3419–3501 m, separated from the main unit by a widespread ~10 m shale horizon.

Apart from its implications for petroleum exploration as both a super seal and locally a control over structure in younger strata, the Mallowa Salt has been the subject of several phases of mineral exploration, particularly for potash (Peiris, 2004).

Distribution and thickness: The Mallowa Salt, with thickness up to 800 m and a present distribution of approximately 180 000 km^2 (not including potential salt in the Fitzroy Trough), is the most voluminous halite formation in Australia. The Mallowa Salt is present in the northeastern Willara Sub-basin, southeastern Broome Platform, the Munro Arch, and across most of the Kidson Sub-basin and adjacent parts of the southern Crossland Platform (Fig. 12), although well intersections and good quality seismic data are sparse in the latter areas. Wireline log correlations suggest that halite units in Wilson Cliffs 1 and Patience 2 are more likely to represent the Minjoo rather than Mallowa Salt. If correct, the distribution is somewhat less than suggested by previous authors and the eastern and southern boundaries of the Mallowa Salt must lie between Kidson 1 and Wilson Cliffs 1, and Kidson 1 and Patience 2, respectively. The salt distribution indicated in Figure 7 (after Shell, 2000) is for the combined Mallowa and Minjoo Salt, but with the exception of the aforementioned eastern Kidson Sub-basin, can be taken as the distribution of the Mallowa Salt and is used as the basis of the Mallowa Salt margin over much of Figure 12.

A salt unit present locally on the Barbwire Terrace and intersected in Merbelia 1 and 2 is inferred to be the Mallowa Salt because the top of the salt lies just below the Pegasus Dolomite Member of the Sahara Formation, but this salt lens appears to be separated from the main body of Mallowa Salt. Another separate salt lens is identified from seismic data on the Mowla and eastern Jurgurra terraces (Shell, 2000). Although in situ salt has not been reached by any wells in this area, 532.5 m of remobilized halite beneath 464 m of dolomite breccia cap rock, interpreted as a salt diapir, was penetrated in Frome Rocks 1 (Elliott, 1959; Bureau of Mineral Resources, 1962). Although not dated, this salt is assumed to be derived from the Carribuddy Group, most likely the Mallowa Salt. It is possible that related halite deposits are present at depth within the adjacent Fitzroy Trough and Gregory Sub-basin, beyond the reach of wells and too deep for distinct seismic imaging.

The present Mallowa Salt distribution may not be identical to the original depositional area. Wireline log data suggests significant halite dissolution in some wells, most notably near the present salt margins (see below). Seismic evidence for dissolution and remobilization along the present northern margin of the main Mallowa Salt body is detailed by Shell (2000). It is therefore quite likely that the present distribution has been somewhat reduced by halite dissolution, although this seems to have mainly affected relatively thin former Mallowa Salt marginal to the preserved depocentres.

The maximum intersected thickness is 800.5 m in potash exploration drillhole Brooke 1 (Fig. 12). This hole was sited to intersect the Mallowa Salt near its seismically defined depocentre and thus is probably close to the maximum (unmobilized) thickness. The thickest intersection in a petroleum well is 788.5 m in Pegasus 1, and comparable thicknesses are reported from nearby wells on the southeastern Broome Platform. The average thickness is about 400 m, including sites where the salt has clearly been reduced in thickness by partial dissolution. The thinnest complete intersection is 30 m in DDSS21, sited near the edge of salt preservation in the Admiral Bay Fault Zone.

Lithofacies: The Mallowa Salt comprises beds of halite interbedded with red, green, grey, and black mudstone, with lesser anhydrite and dolomite. The formation is

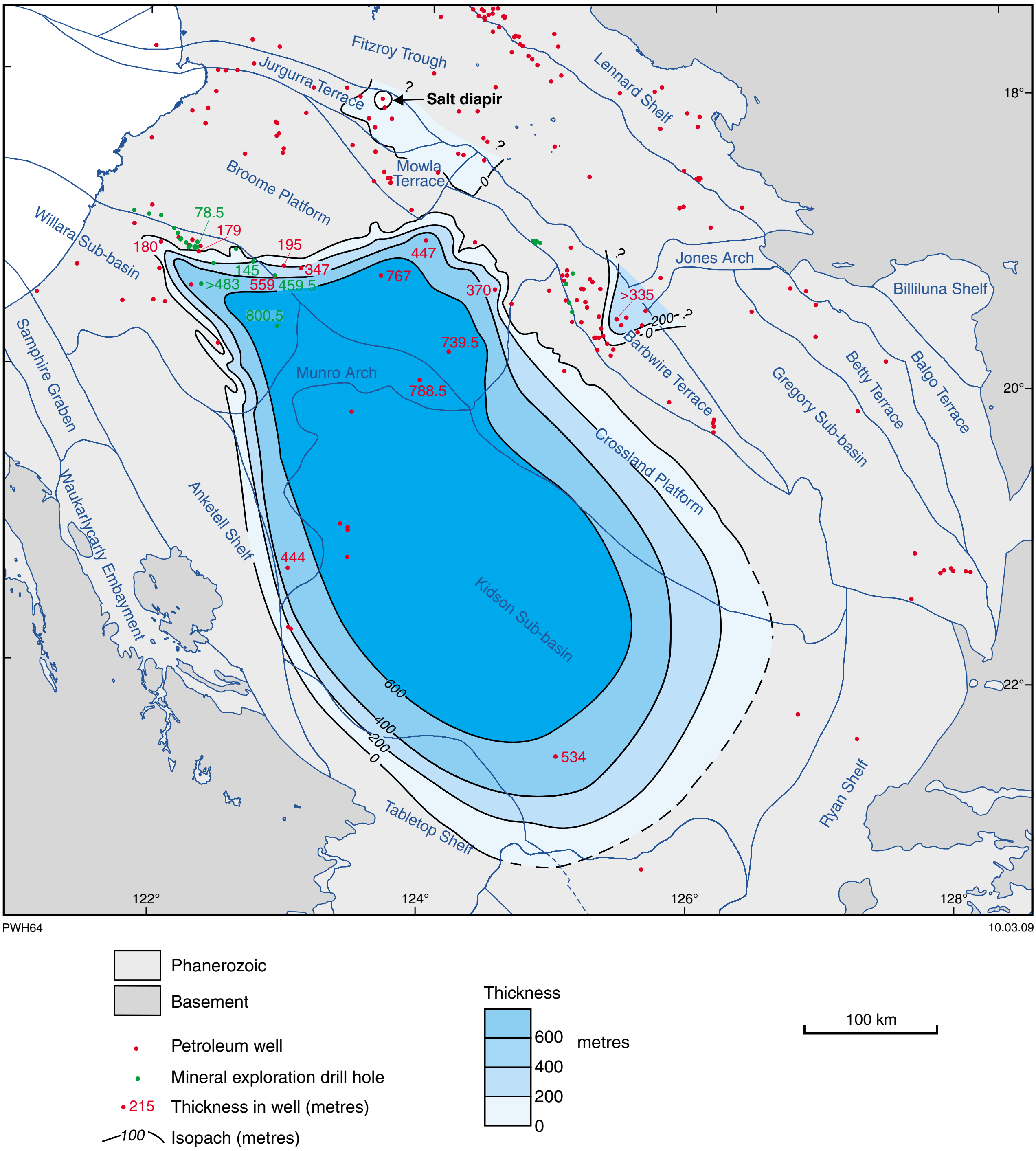


Figure 12. Isopach map of Mallowa Salt. Position of salt edge taken from Shell (2000), except around southeastern end of Kidson Sub-basin

cored in relatively few petroleum wells, so in most areas information is restricted to cuttings and wireline log data. Most of the formation is cored, however, in BHP potash exploration drillholes Gingerah Hill 1 and Brooke 1 in the Willara Sub-basin, and the following descriptions are substantially derived from these holes. Detailed descriptions are presented in BHP Minerals Exploration (1987), BHP-UTAH Minerals International (1989), Cathro (1989), and Cathro et al. (1992). Two cores (13 and 14) are available from the Kidson 1 type section (Fig. 13a–d). Halite petrography in Kidson 1 is described in Glover (1973). The halite varies in colour from clear and colourless to red-brown. Glover (1973) suggests that the red-brown colour is due to inclusions of ferric hydrate, a precursor of hematite, and appears mainly to be found in halite that has undergone reprecipitation.

The Mallowa Salt is notably cyclic; Cathro et al. (1992) recognize 2–15 m thick dolomite/anhydrite–halite–mudstone Type 1 cycles, and much more common (95% of halite sequence) 1–4 m thick halite–mudstone Type 2 cycles. The halite unit in both cycles comprises a mosaic of large random interlocking crystals, resulting mainly from recrystallization during early diagenesis. Relics of vertically elongate and chevron crystals, interpreted as primary fabrics, are preserved locally.

A typical Type 1 cycle consists of (Cathro et al., 1992):
- Terrigenous mudstone (top)
- Banded halite with variable, upwardly increasing clay content
- Clear, coarsely crystalline halite
- Massive to laminated anhydrite
- Dolomite (base)

A typical Type 2 cycle consists of (Cathro et al., 1992):
- Terrigenous mudstone (top)
- Banded halite with variable, upwardly increasing clay content
- Clear, coarsely crystalline halite (base)

The vertical Type 1 cycle approximates the theoretically predicted precipitation sequence for evaporative concentration of sea water, except that with modern seawater aragonite and gypsum, rather than dolomite and anhydrite would be expected. The Type 2 cycles are interpreted as incomplete Type 1 cycles, lacking the lower dolomite and anhydrite portions (Cathro et al, 1992).

The Mallowa Salt can be subdivided using widespread shale markers aided with the gamma ray and particularly the gamma ray-derived INPEFA curve. Two thicker markers, distinguished on the stratigraphic charts as the ‘lower shale marker’ and ‘upper shale marker’, lie stratigraphically near the base and top of the formation, respectively. The lower of these, up to 10 m in thickness was used by Lehmann (1984) to mark the top of a ‘lower Mallowa member’ in Kidson 1, McLarty 1, and Willara 1, but this horizon can now be recognized in the majority of wells intersecting the Mallowa Salt. This shale marker is at the approximate position of the B1/B2 supersequence boundary recognized by Romine et al. (1994) and Kennard et al. (1994). The ‘upper shale marker’, up to 15 m thick, is only recognized in Brooke 1, Pegasus 1, Sally May 1, and McLarty 1 where the most complete salt sections are found. Elsewhere, the inferred time equivalent of this shale interval lies either within the zone of salt dissolution or above the depositional top of the salt, and can thus not be distinguished. Thin shale markers throughout the formation can commonly be correlated between nearby and sometimes distance wells with high to moderate confidence. Three such horizons, designated ‘m1’, ‘m2’, and ‘m3’ on the stratigraphic charts, have proved to be useful markers, particularly for demonstrating progressive dissolution of salt in wells such as Vela 1, Musca 1, and Carina 1. A thin (~1 m) dolomite marker (‘d1’ on the stratigraphic charts) lies between the Pegasus Dolomite Member of the Sahara Formation and the top of the halite in a number of wells that have undergone partial salt dissolution. Where recognized it is by definition in the Sahara Formation, but where the salt section is relatively complete, this unit presumably lies within the salt.

Relationships and boundary criteria: The lower and upper boundaries of the Mallowa Salt are conformable and defined by the first and last appearance of substantial halite beds, although minor disseminated halite and other evaporate minerals may be found below and above the boundaries. The boundaries vary between primary depositional in nature, to being defined by the limit of secondary dissolution, the latter most common in the case of the upper boundary, and most noticeable close to the margin of salt distribution. It is clear for analysing well completion reports that boundary definitions have not been applies consistently, a predictable consequence of the gradational nature of the contact. Because disseminated and thin beds of halite may be found widely through the Carribuddy Group (but not necessarily detected from cuttings and logs), and halite may be remobilized as veins some distance above and below the salt formations, boundary definitions based on the first and last halite are difficult to apply meaningfully. In this report the boundaries have been reassessed and placed where massive beds of halite are first detected on logs.

Based on the assumption that the lower Mallowa Salt shale marker (see above) is essentially isochronous, the deposition of the first massive salt beds and hence lower boundary appears to have been initiated across most of the depositional area of the Mallowa Salt near synchronously. However, the upper boundary is clearly far more diachronous. In wells near the centre of the salt basin (Pegasus 1, Sally May 1, Brooke 1) the upper boundary lies just beneath the Pegasus Dolomite Member of the Sahara Formation (see below), but in wells closer to the margins the top is progressively deeper relative to this marker, suggesting that the salt basin shrank with time. This view is complicated, however, by evidence of post depositional top salt dissolution in many wells. In Mirbelia 1 and 2, intersecting an isolated body of Mallowa Salt on the Barbwire Terrace, the top of salt also reaches the Pegasus Dolomite Member.

Age and correlations: The Mallowa Salt has been assigned an age of Late Ordovician to earliest Silurian age based on the identification of early land plant spores assigned to *Tetrahedraletes medinensis* in mudstone interbeds in core from BHP mineral exploration drillhole Gingerah Hill 1

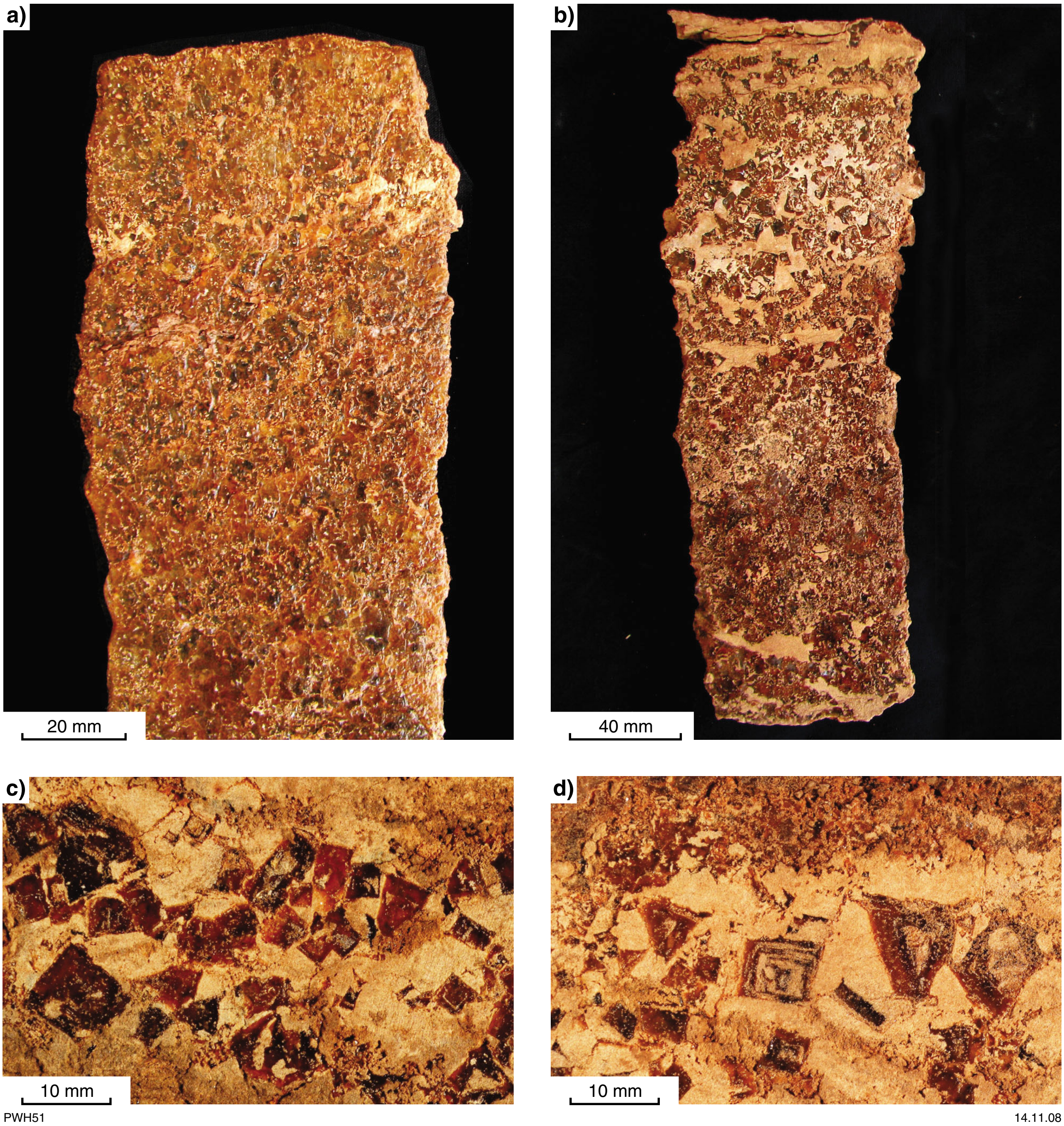


Figure 13. Drillcore photographs of Mallowa Salt type section in Kidson 1, core 13: a) massive halite with randomly interlocking crystals (3095–3096 m); b) massive halite band, overlain by disseminated euhedral halite (3098–3099 m); c) close up of disseminated euhedral halite (3099–3100 m); d) close up of disseminated euhedral halite showing well developed zoning (3099–3100 m)

(Foster and Williams, 1991). This age is consistent with the early Silurian age assigned to the Dodonea Member of the younger Worral Formation, and the broad Ordovician ages assigned to lower parts of the Carribuddy Group from conodont evidence.

Depositional setting: Cathro et al. (1992) consider that the Mallowa Salt accumulated within a saltern, with halite precipitating predominantly subaqueously from a shallow hypersaline water body, but with periodic freshening, exposure, and desiccation. Intraformational karst features observed in drillcore from Brooke 1 indicate periodic dissolution events interpreted as times of exposure. The large fluctuation in Br values from halite layers only tens of centimetres apart is evidence for the water body being shallow (probably no more than 1–2 m) and ephemeral; if the water were deeper and more permanent the water volume would act as a buffer to Br values resulting in a more consistent compositional profile (Cathro et al., 1992). Both Type 1 and 2 cycles show evidence of increasing restriction towards the top of each cycle. Considering the cumulative thickness of salt, the brine must have been replenished periodically from sea water. Presumably the saltern was separated from the open sea by a partial barrier allowing periodic influx followed by build-up of hypersaline conditions under an arid climate. A marine origin is also supported by the generally high Br content of brines in fluid inclusions (Kovalevych et al., 2006).

Kovalevych et al. (2006) attempted to provide some constraints on the composition of Late Ordovician seawater using fluid inclusions from primary Mallowa Salt halite in Gingerah Hill 1. Because the inclusion brines represent a late stage in the evaporation of the parent brine, which may have reached the point of precipitation of K and Mg salts (sylvite and carnallite are found as crystals in many inclusions), the remaining fluids cannot be used to calculate a quantitative composition for the parent seawater. However, when compared with data on Early Cambrian and late Silurian seawater, the Mallowa data suggest a similar composition in the Late Ordovician. While the K content was inferred to be similar to that of modern seawater, Ca, Mg, and SO_4 were significantly different. Late Ordovician seawater appears to have been approximately three times richer in Ca, 30% depleted in Mg, and three times depleted in SO_4 contents compared with modern seawater.

Cyclicity in the Mallowa Salt is not only evident from wireline logs, but is also expressed in salt geochemistry obtained from continuously sampled core bagged at 1 m intervals (BHP Minerals Exploration, 1987; BHP-UTAH Minerals International, 1989; Williams, 1991). Fast Fourier transform analysis of Br, MgO, and K_2O content in soluble salt extracts give principal spectral peaks at ~250, 113, 35.4, 22.1, and 19.7 m, while this method applied to Na_2O and total salts content give dominant spectral peaks at 220–259 and 109–114 m (Williams, 1991). Williams (1991) argues that the spectral peaks are consistent with Milankovitch cyclicity, if the strongest peak at 113 m is taken to represent the relatively stable eccentricity period at ~100 ka. If correct, other peaks, as exemplified by the Br spectrum, would represent 31.3 ± 3, 19.6 ± 1.1, and 17.4 ± 1.1 ka cycles, consistent with the predicted Late Ordovician to early Silurian periods for obliquity (30.5 ka) and precession (19.3 and 16.4 ka). This implies a net rate of deposition of about 1.13 m/ka for the Mallowa Salt, consistent with other Paleozoic evaporite successions (Williams, 1991).

Sahara Formation

Definition and nomenclature: The Sahara Formation was defined by Lehmann (1984) with the type section being the interval 2688–2967 m in Kidson 1. The name was derived from Sahara 1, where the unit was first encountered. The Sahara Formation at its type section equates to the lower part of the earlier informal ‘Carribuddy Unit A’ in that well (2570–2941 m; Johnson, 1966) with the upper part of that informal unit being assigned to the Worral Formation by Lehmann (1984).

Distribution and thickness: The Sahara Formation is widespread, with similar distribution to the entire Carribuddy Group, although locally removed by erosion, particularly in the west. The Sahara Formation, particularly its lower boundary, can be difficult or impossible to differentiate in areas where the Mallowa Salt is absent. However, in most such areas the distinctive wireline log signature of the Pegasus Dolomite Member (see below) indicates the presence of the formation, and serves further as a guide to identifying the Sahara–Worral contact above. The Sahara Formation is 280 m thick at its type section, but the average thickness is about 130 m.

Lithofacies: At the type section the Sahara Formation is dominated by red-brown argillaceous, silty and sandy dolomite grading to dolomitic mudstone, with minor sandstone interbeds (Fig. 14a). Anhydrite is common throughout as small nodules and vein fillings. The limited drillcore recoveries show common green reduction spots and zones. Zones of intraclastic breccia in one core (core 10) are consistent with disruption by desiccation. The Sarah Formation is similar elsewhere, but with varying carbonate content and colouration. In core from Acacia 1 on the Barbwire Terrace the formation consists of red-brown to grey-green and often mottled mudstone, in part dolomitic and calcareous, with common calcite veining. It is notably more dolomitic below the Pegasus Dolomite Member, although the base of the formation cannot be defined in this well. In core from Brooke 1 in the Willara Sub-basin the Sahara Formation consists of massive pale-green to brown mudstone with minor sandy horizons. The widespread Pegasus Dolomite Member is describe separately below.

Relationships and boundary criteria: The base of the Sahara Formation can only be confidently defined where the Mallowa Salt is present, and is taken above the last significant halite bed. Marker horizons including the Pegasus Dolomite Member and a thinner dolomite marker below, and shale markers within the Mallowa Salt, clearly demonstrate that the boundary is diachronous. The diachronaity is both a primary feature, due to shrinkage of the saltern to the northern part of its range with time, and locally a product of salt dissolution. Partial salt dissolution

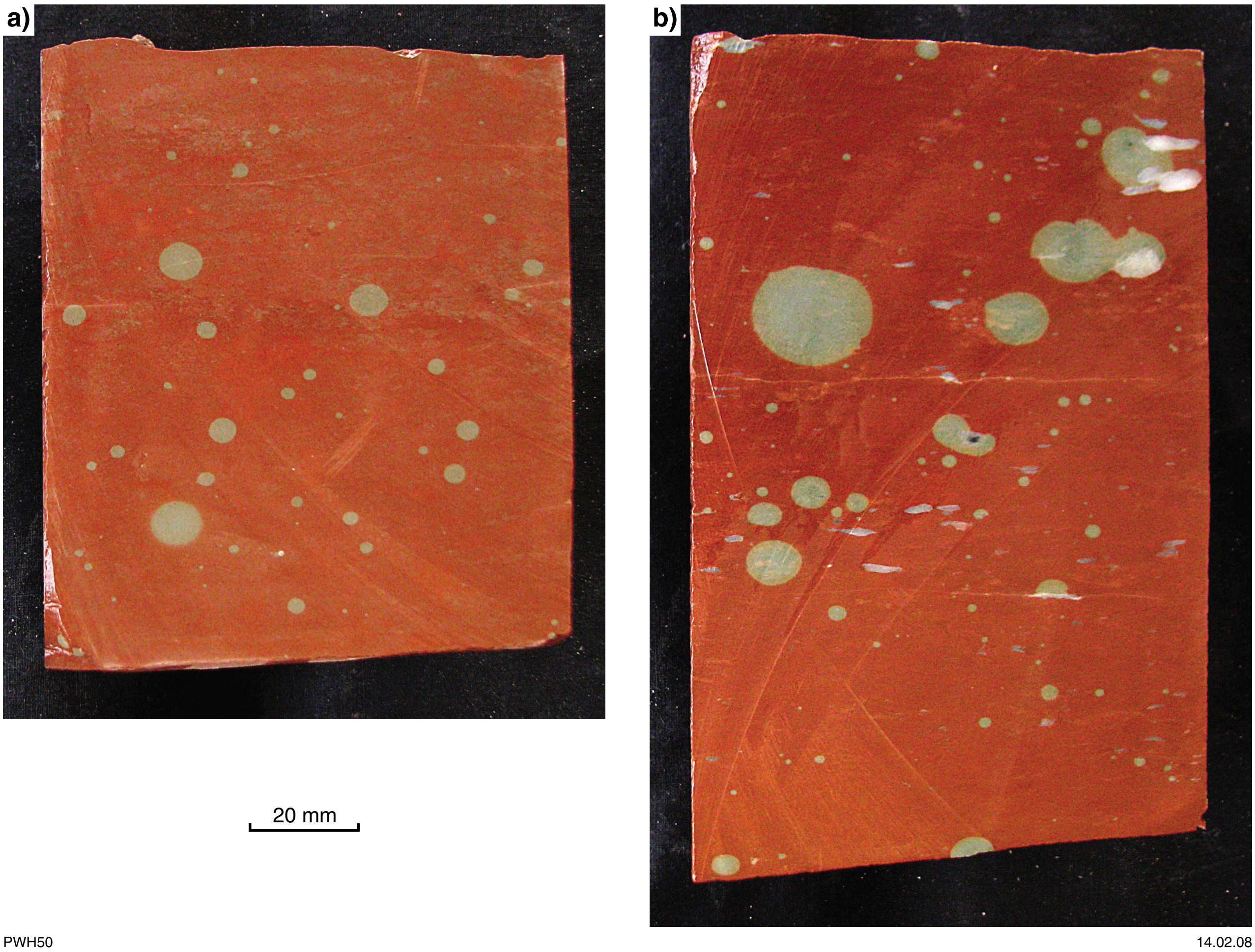


Figure 14. Drillcore photographs of Sahara Formation type section and Worral Formation in Kidson 1, showing close similarity of dominant facies: a) red dolomitic mudstone with reduction spots, Sahara Formation, core 10 (2757.8 – 2769.7 m); b) red dolomitic mudstone with reduction spots (pale green) and small anhydrite lenses (pale grey to white), Worral Formation, core 9 (2608.5 – 2611.5 m)

progresses down from the original top of the Mallowa Salt, leaving a new sharp boundary over massive recrystallized halite, overlain by a reduced stratigraphic thickness of insoluble components including carbonate and mudstone. For convenience, the insoluble debris above the new halite top surface is included in the Sahara Formation.

Age and correlations: The age of the Sahara Formation is constrained only by the Late Ordovician to earliest Silurian palynomorphs-derived age for the Mallowa Salt and the early Silurian conodont age for the base of the conformably overlying Worral Formation. As the boundary between the Mallowa Salt and Sahara Formation is notably diachronous, there is an overlap in age between the lower Sahara Formation (pre Pegasus Dolomite Member) and the Mallowa Salt.

Depositional setting: The Sahara Formation (above residue from salt dissolution) was probably deposited under very shallow, restricted, marginal marine conditions, with periodic exposure. The depositional environment was similar to other non-salt units of the Carribuddy Group such as Bongabinni Formation.

Pegasus Dolomite Member (new name, see Appendix 6)

Definition and nomenclature: The Pegasus Dolomite Member is a thin but widespread marker unit within the Sahara Formation. It is named after Pegasus 1 petroleum well, where the member is well developed. The type section is the fully cored interval 550.45 – 552.6 m in Acacia 1. A fully cored reference locality for western areas is the interval 971.75 – 975.5 m in mineral exploration drillhole Brooke 1.

This thin member is likely to represent an approximate time line across the basin. It has proved of critical importance in identifying the Sahara Formation where the Mallowa Salt is absent, and aiding in the identification of the base of the younger Worral Formation.

Distribution and thickness: The Pegasus Dolomite Member is present everywhere within the Sahara Formation, except in the southern and eastern Kidson Sub-basin where it is either absent or too thin to distinguish with certainty. It has often been removed by pre-Permian erosion in wells in the

Willara Sub-basin and southwestern Broome Platform. It is 2.15 m thick at the type section, increasing to 3.75 m at the reference section. The regional average thickness is about 2.75 m, while the maximum identified thickness is 5 m in Mirbelia 1.

Lithofacies: The type and reference section are the only known cored sections and descriptions of the unit in other wells from cuttings are sparse. At the type section the Pegasus Dolomite Member comprises light-grey, hard, massive dolomite which is stylolitic and displays infilled subvertical fractures, microfaults, calcite filled veins, and minor vuggy porosity. At the reference section in Brooke 1 the lower part of the unit consists of cream to tan and dark grey-green argillaceous, nodular and banded dolomite, capped by a metre-thick anhydrite bed at the top (Cathro, 1989; Cathro et al., 1992). At this locality there is also minor halite veining at the base which lies very close to the top of the Mallowa Salt. As a generalization from cuttings descriptions elsewhere, the unit is composed of very fine grained to microcrystalline, pale coloured hard dolomite and argillaceous to silty dolomite. The unit is typically inferred to have low or nil porosity in most wells, although Di Toro and Derrington (1987) describe very good porosity from sucrosic dolomite in Dodonea 2.

Log character: The Pegasus Dolomite Member has a distinctive signature on wireline logs, which, when taken in the context of other stratigraphic constraints, is suffice to distinguish the unit in most wells. Its character is a distinctive sharp mirror-image spike (often a double-peaked spike) on back-to-back plotted gamma ray and sonic logs. In areas of thicker development, this is often followed by a shale interval displaying high transit time on the sonic log, although this interval can not be distinguished from shales above or below on the gamma log.

Relationships and boundary criteria: In several holes (e.g. Brooke 1, Pegasus 1, Sally May 1, Mirbelia 1, 2) the Pegasus Dolomite Member lies just a few metres above the last halite bed of the Mallowa Salt, and thus lies very close to the base of the Sahara Formation in these areas. In other holes, particularly where there is evidence of considerable salt dissolution at the top of the Mallowa Salt (e.g. around Vela 1, Musca 1, and Carina 1), the marker lies several tens of metres to over 100 m above the top salt bed. Assuming that the member was deposited roughly synchronously across the basin, this relationship is important for demonstrating the diachronaiety of the preserved top of the Mallowa Salt. In contrast, the vertical distance to the base of the Worral Formation is typically fairly constant within wells in the same area, averaging 30 m across the basin and rarely ranges beyond 20–40 m. The boundaries of the member are relatively sharp but appear conformable. There is no evidence that the unit marks an unconformity, as suggested by Cathro et al. (1992).

Age: There is no internal age evidence for the Pegasus Dolomite Member and no fossils are known. An attempt to extract conodonts from the type section was unsuccessful. A Late Ordovician to early Silurian age, as for the entire Sahara Formation, is inferred with reference to the enclosing formations.

Depositional setting: The Pegasus Dolomite Member probably represents a brief and restricted marine incursion.

Worral Formation lithostratigraphy

Definition and nomenclature: The Worral Formation was defined by Lehmann (1984) with its type section covering the interval 457–613 m in Barbwire 1. It was named after nearby Worral Range. Prior to 1984 the formation was incorporated, along with the Sahara Formation, into ‘Carribuddy unit A’. Lehmann (1984) recognized the Worral Formation across much of the basin, and the term has been used, although not consistently, in many subsequent well completion reports. It is clear that there have been misunderstandings about the stratigraphic identity and relationships of the Worral Formation leading to erroneous correlations. Some of the confusion is apparently due to the close similarity of facies between the Sahara and Worral Formations.

Members: Lehmann (1984) subdivided the Worral Formation into four members at the type section, although only two received formal names. In ascending order these include the ‘lower carbonate member’ (569–613 m), Elsa Sandstone Member (577–596 m), Waldecks Member (472–577 m), and ‘upper carbonate member’ (457–472 m). During this study it was found that the Elsa Sandstone Member and Waldecks Member could be distinguished in most areas. The ‘lower carbonate member’ is herein formalized and renamed Dodonea Member. This distinctive dolomite and locally limestone unit is restricted to the Barbwire Terrace and adjacent areas, interdigitating with sandstone units at the base of the Elsa Sandstone Member. The ‘upper carbonate member’ is often indistinct, typically manifest only by an increase in carbonate cement or minor carbonate interbeds in an otherwise mudstone-dominated succession typical of the Waldecks Member. It is usually difficult to distinguish on wireline logs and no effort has been made to formalize it or distinguish it on the stratigraphic charts. Here it is included in the Waldecks Member. Discrete sandstone units are present in the upper part of the formation in the Kidson Sub-basin and adjacent areas. However, due to the scarcity of wells in this area it is unclear if these can be correlated and no attempt to define formal members is attempted.

Distribution and thickness: The Worral Formation has widespread distribution south of the Fitzroy Trough and Gregory Sub-basin, although locally removed by pre-Permian erosion, particularly in the west. The thickest development is in the northern Kidson Sub-basin and adjacent areas, with the thickest intersection being 277.5 m in Sahara 1 (Fig. 15). The average thickness is about 140 m. As the top of the formation always appears to be erosional, all thicknesses are presumably reduced from the original depositional thickness. Sections in the Willara Sub-basin and adjacent Admiral Bay Fault Zone, where preserved, are typically only a few tens of metres in thickness due to extensive pre-Permian erosion.

Lithofacies: The Worral Formation is dominated by red-brown and lesser green and grey mudstone (Fig. 14b), in part calcareous and dolomitic, with variable content of fine

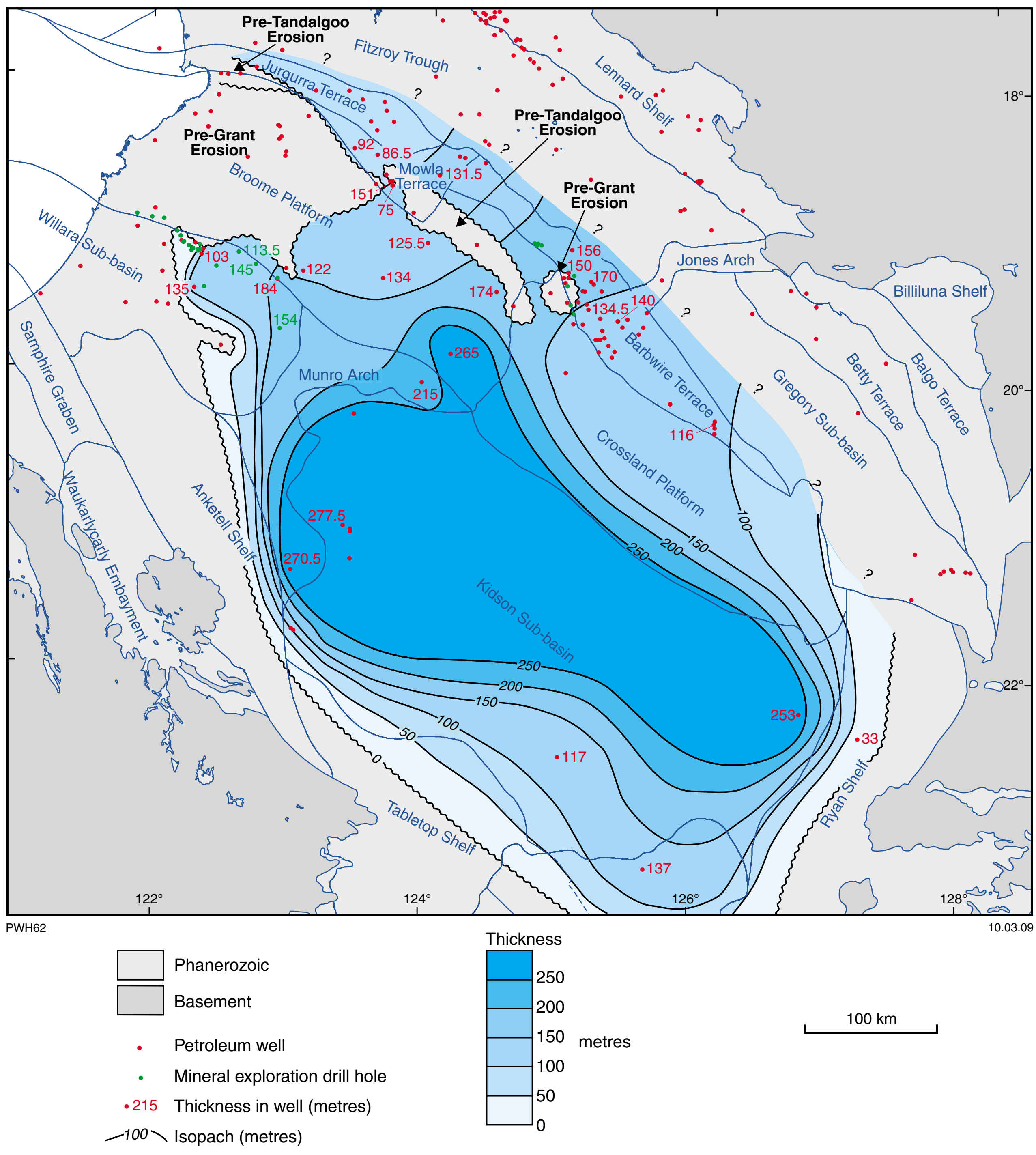


Figure 15. Isopach map of Worral Formation

to medium and less commonly coarse grained sandstone, and interbeds of dolomite and limestone. Disseminated evaporite minerals, mainly anhydrite, may be present. More detail is provided under individual member descriptions below.

Relationships and boundary criteria: Lehmann (1984) interpreted the base of the Worral Formation as an unconformity, believing that it overlies the Nibil Formation at the type section, with upper units of the Carribuddy Group removed by erosion. Lehmann equated the Worral Formation with the lower Poulton Formation (Lennard Shelf) and believed the relationship with the overlying Tandalgoo Formation to be mainly disconformable, with the possibility that the Worral Formation was in part laterally equivalent to the lower Tandalgoo Formation. Subsequent workers, such as Romine et al. (1994), Kennard et al. (1994) and Jones et al. (1998), have generally considered the Worral and Tandalgoo Formations to be at least partial lateral age equivalents with the boundary represented by a highly diachronous facies change. Nicoll et al. (1994) and Romine et al. (1994) agreed with a basal hiatus but placed it within, rather than at the base, of Lehmann's 'lower carbonate member' on biostratigraphic evidence. In contrast, Warris (1993) considered that the Worral Formation conformably overlies the Sahara Formation, with the main unconformity lying between the Worral and Tandalgoo Formations.

Although the base of the Worral Formation is relatively sharp no evidence for a regional angular unconformity was observed during this study. Conformity, or at least paraconformity, is suggested by the relatively consistent stratigraphic interval between the top of the Pegasus Dolomite Member and base of the Worral Formation in most areas. One of the leading causes of the erroneous impression of an unconformity has been mis-correlation of the Pegasus Dolomite Member. This unit was incorrectly identified as Mount Troy Formation in some areas.

A local exception to a basal conformity is noted in Lovell's Creek 1, Crystal Creek 1, and Matches Springs 1, where there is evidence of erosion beneath a unit that is probably Worral Formation. These wells are close to major growth faults and are in an area of likely salt dissolution near to the margin of the preserved salt. Local tectonic activity and/or salt dissolution shortly after cessation of salt deposition are likely causes of such local disconformities or unconformities. Alternatively, such apparent unconformities from logs could have a structural explanation, i.e. faulted contacts.

Age and correlations: Conodonts recovered from core of the Dodonea Member in Acacia 1 and Boab 1 give an age of Llandovery (early Silurian) for the lower Worral Formation based on the presence of *Ozarkodina hassi* (Nicoll et al., 1994). There is no unequivocal biostratigraphic data for the age of the top of the Worral Formation. Romine et al. (1994) reported Pridoli (late Silurian) fish remains from the Sahara Formation in Sahara 1; however it is considered here more likely to come from the upper Worral Formation. Likewise, the stratigraphic position of Devonian conodonts and fish remains in Gingerah Hill 1 (Nicoll and Young, 1987) is disputed. The depth interval of a mid-Devonian ostracod and foraminifera bearing sample in Boab 1, previously reported as derived from the upper Dodonea Member, is now indeterminate, but could come from the upper Worral Formation (see discussion under **Biostratigraphy**). The Worral Formation most likely extends in age to at least the Pridoli (late Silurian). If it does extend to the Devonian there is likely a significant hiatus within the succession.

Depositional setting: The bulk of the Worral Formation (i.e. Waldecks Member) is lithologically indistinguishable from the bulk of the Sahara Formation, and other mudstone dominated redbed units of the Carribuddy Group, and therefore is likely to have been deposited under a similar marginal marine evaporitic mud flat environment. The Dodonea Member, bearing conodonts and scolecodonts, suggests an incursion with greater marine influence, over parts of the basin. The well sorted and porous Elsa Sandstone Member is most likely at least partly or locally of eolian origin. Porous sandstone units in the upper part of the formation in the Kidson Sub-basin are also likely of eolian origin.

Dodonea Member (new name, see Appendix 6)

Definition and nomenclature: The Dodonea Member, distinguished by dominant carbonate lithology, is the basal unit at the Worral Formation type section and in nearby wells. The name is derived from Dodonea 1 which intersects the member in this area. The unit was previously referred to by Lehmann (1984) using the informal name 'lower carbonate member', and assigned a type section as the interval 596–613 m in Barbwire 1. Because the type section is not cored, the fully cored intervals 503.95–524.23 m in nearby Acacia 1 and 1002–1015 m in Boab 1 are nominated as reference sections.

Distribution and thickness: The Dodonea Member is best developed on the Barbwire Terrace (Acacia 1 and 2, Barbwire 1, Boab 1, Dodonea 1 and 2, Mirbelia 1 and 2, and Percival 1), eastern Broome Platform (Fruitcake 1), and Crossland Platform (Crossland 2). It is absent in western and southern parts of the basin, although minor carbonate interbeds may be present at the base or within the lower Elsa Sandstone Member, but it is unclear if these represent an intertounging of the members. The Dodonea Member has an average thickness of about 16 m, while the type section is 17 m thick. The thickest recorded intersection is 23.5 m in Fruitcake 1.

Lithofacies: The Dodonea Member is dominated by massive to weakly laminated and nodular carbonate, most commonly pale grey to beige dolomite, but including limestone in some wells. Massive carbonate grades to dolomitic or calcareous mudstone at the top. A minor sand component is present in some wells.

In the Boab 1 reference section (Fig. 16) the lower two thirds of the dolomite has weakly developed nodular bedding and is distinctly stylolitic. Minor vugs occur throughout, with a porous vuggy and silty intraclast horizon present near the top. Minor pyrite is also present. The top of the unit grades to sandy dolomitic siltstone with irregular bedding and evidence of soft sediment

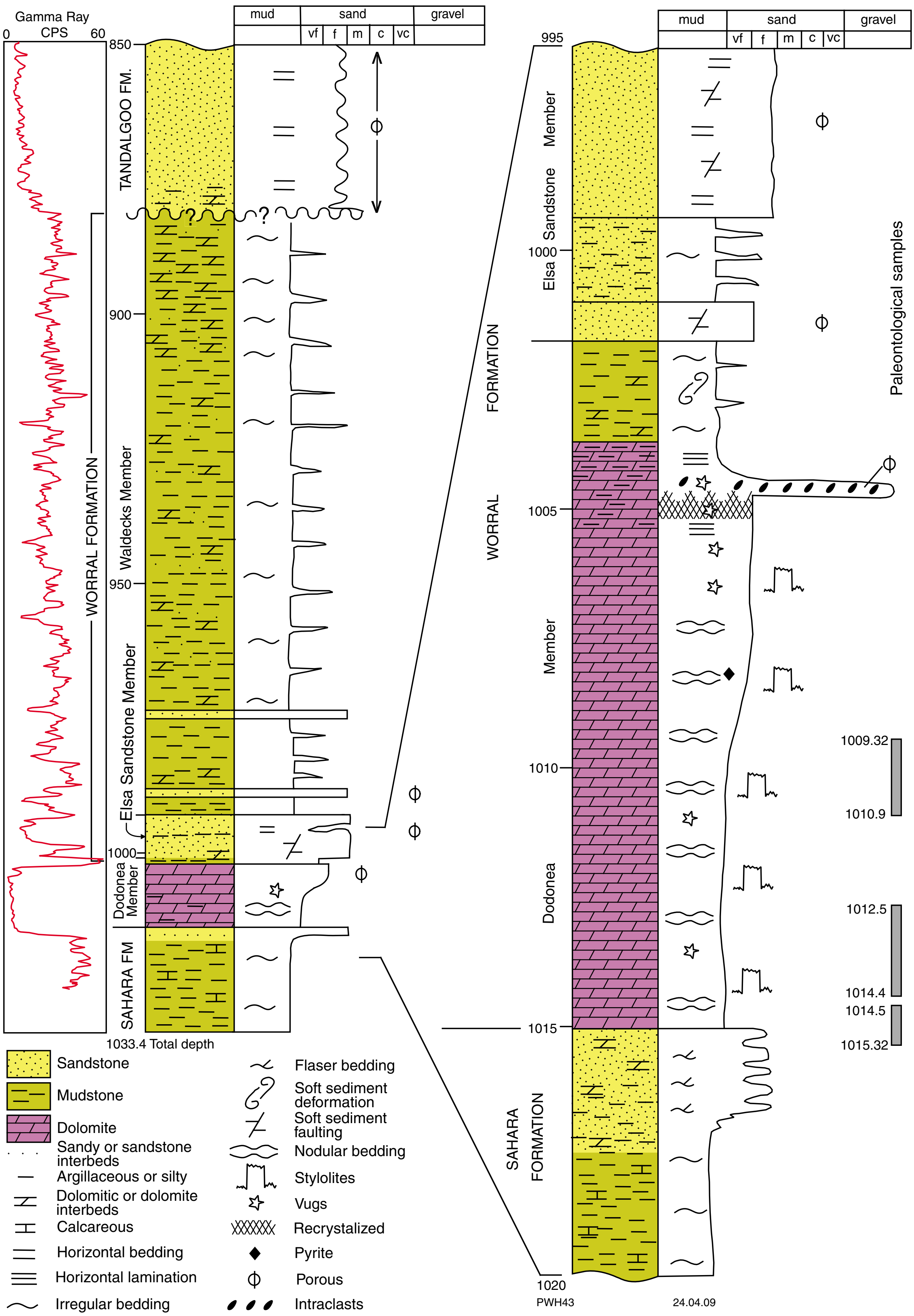


Figure 16. Graphic log of lower Worral Formation and upper Carribuddy Group in Boab 1

deformation. At Acacia 1, the base is sandy, grading up to massive very finely crystalline dolomite with abundant stylolites and common pyrite. Vuggy porosity is developed in places. The top becomes silty and laminated and includes some limestone intervals. Possible microbial laminations are also present near the top.

Relationships and boundary criteria: The Dodonea Member overlies the Sahara Formation with a relatively sharp but apparent conformable contact. It is sharply overlain by the Elsa Sandstone Member at the type section and in nearby wells, but there is no evidence of significant incision on the contact. Regionally, the member appears to interfinger with the Elsa Sandstone Member, which often contains minor carbonate interbeds in its lower part.

Age: Llandovery (early Silurian) based on the conodont *Ozarkodina hassi* recovered from drillcore in Acacia 1 and Boab 1 (Nicoll et al., 1994; see discussion under **Biostratigraphy**).

Depositional setting: The Dodonea Member was deposited under a shallow marginal marine, probably lagoonal setting. Marine influence is indicated by the presence of conodonts and scelecodonts although no macrofossils or bioturbation were seen in cores.

Elsa Sandstone Member

Definition and nomenclature: The Elsa Sandstone Member (named after Elsa Bore 25 km east of the type section) was defined by Lehmann (1984) as the interval 577–596 m in the Worral Formation type section in Barbwire 1. The type section is not cored, so the fully cored interval 480.13 – 503.95 m in nearby Acacia 1 is nominated as a reference section. It is also cored in Boab 1 (Fig. 16).

Distribution and thickness: The Elsa Sandstone Member is more widespread than the Dodonea Member, being recognized in most sections of Worral Formation. The thickest section is 58 m in Wilson Cliffs 1, with thickness generally decreasing to the west and northwest. The average thickness is about 26 m. Thicknesses of less than 10 m are the norm in the Willara Sub-basin.

Lithofacies: The Elsa Sandstone Member is characterized by well sorted porous sandstone, typically fine to medium grained, but locally including coarse and granular beds. It may be relatively massive, or contain interbeds of mudstone and minor carbonate, particularly in the lower part. Grains are dominantly quartz and are typically described as being rounded to well rounded, and displaying a frosted and pitted surface texture. Unlike the younger Tandalgoo Formation, sandstones of which typically display an orange to reddish colour, sandstone in the Elsa Sandstone Member and younger parts of the Worral Formation are typically white to pale grey or pale brown in colour. In the few cored intervals, the sandstone is massive to weakly laminated and locally displays large steep forests (~25°). Soft sediment faulting is common in Boab 1, and secondary pyrite (as veins and nodules) is common in Acacia 1.

Relationships and boundary criteria: At the type section and in wells across the Barbwire Terrace, eastern Broome Platform, Crossland Platform, and northwestern Kidson Sub-basin the Elsa Sandstone Member overlies the Dodonea Member with a sharp contact. The base is defined by the sudden appearance of clean sandstone over mudstone or argillaceous carbonate. This contact appears to represent an erosional hiatus in drillcore, although regionally there is no evidence of an angular relationship or any significant incision on this contact. Elsewhere, in the absence of a discrete Dodonea Member, the term Elsa Sandstone Member is applied to the entire lower sandy part of the Worral Formation, but relationships with the type area are unclear. The local presence of carbonate interbeds in the lower part suggests, but does not prove that the unit intertongues with the Dodonea Member. The Elsa Sandstone Member may contain a sequence or supersequence boundary; possibly at its base on the Barbwire Terrace, but within the unit elsewhere. More cored sections may resolve these issues.

Age and correlations: The Elsa Sandstone Member has no internal age constraints, but is presumed to be of Silurian age because of its relationship with the Dodonea Member.

Depositional setting: The Elsa Sandstone Member arrears to be mainly eolian in origin in the few cored intervals. Elsewhere, the high degree of sorting, roundness and frosting of grains has led other authors to similar conclusions. Small dunes may have formed around the margins of the lagoon represented by the Dodonea Member, decreasing in preservation to the west with decreasing accommodation space.

Waldecks Member

Definition and nomenclature: As originally defined by Lehmann (1984), the Waldecks Member (named after Waldecks Bore) spanned the interval 472–577 m in the Worral Formation type section in Barbwire 1, and was overlain by the informal ‘upper carbonate member’. However, the ‘upper carbonate member’ is difficult to apply in any regionally significant sense, and is here included within the Waldecks Member, now taken as the interval 457–577 m in Barbwire 1.

Distribution and thickness: The Waldecks Member is widespread, being recognized above the Elsa Sandstone Member in most areas. The average thickness is about 115 m, with the maximum thickness being 195 m in Wilson Cliffs 1.

Lithofacies: The Waldecks Member is dominated by red-brown to grey mudstone, which is often variably calcareous or dolomitic, and contains interbeds of dolomite, limestone, and fine-grained sandstone and dolomite. There is an increased carbonate content near the top in some wells (Lehmann’s ‘upper carbonate member’). Minor anhydrite is also common. Significant sandstone sub-units are present in the Kidson Sub-basin and immediately adjacent areas.

Relationships and boundary criteria: The Waldecks Member conformably overlies the Elsa Sandstone Member and is overlain by the Tandalgoo Formation with probable unconformity or disconformity. The upper contact is always sharp, and marked by the abrupt appearance of massive fine reddish porous sandstone of the Tandalgoo Formation (note that sandstone interbeds in the Waldecks Member are typically white, pale grey, or pale brown in colour).

Age: There is no unequivocal internal age evidence for the Waldecks Member. As discussed under **Biostratigraphy**, it likely ranges in age to at least the late Silurian.

Depositional setting: The Waldecks Member was deposited under marginal marine to supratidal evaporitic mud flat environments, probably with local eolian influences.

Interbasinal correlation

Depositional sequences with overlapping age ranges to the Carribuddy Group and Worral Formation are known from the Amadeus and other basins in central Australia, the Southern Carnarvon Basin, and the Petrel Sub-basin of the Bonaparte Basin. The degree of direct connection, if any, between these areas at the time of deposition is uncertain. Mory et al. (2003) made previous comparisons of the Paleozoic in Western Australian basins, but concluded that the broadly coeval Ordovician–Silurian successions have little in common, implying local rather than continental scale depositional controls.

Bonaparte Basin

Salt diapirs are common in the mainly offshore Petrel Sub-basin of the Bonaparte Basin (Edgerley and Crist, 1974; Mory, 1990). In well intersections these are composed of halite with minor gypsum and calcite. In situ evaporites have not been intersected, but inferred evaporates have been imaged on seismic data, deep in the basin. The age of this package is not concisely constrained, but must be older than the Upper Devonian successions that the diapirs intrude, while overlying even deeper reflectors that have been assigned to the Cambrian to Lower Ordovician Carlton Group that is known from outcrop (Mory, 1990). The presence of reworked Darriwilian conodonts in Carboniferous conglomerates in the Petrel Sub-basin suggest that the pre-evaporate marine succession extends up to at least the Middle Ordovician in the sub-surface, as in the Canning Basin (Nicoll, 1995), presuming that the conodonts were locally derived.

It is likely that the age of the evaporate succession in the Petrel Sub-basin is broadly similar to that of the evaporates in the Carribuddy Group, but may not be identical because of the migration of climatic belts through time. What is now Western Australia moved southward across the paleo-equator during the Ordovician and Silurian (Scotese, 2004), such that the optimal 10–20° paleolatitude for accumulation of lower Paleozoic evaporates (Evans, 2004) moved across the Canning Basin during the Late Ordovician, and across the Bonaparte Basin slightly later into the Silurian. Therefore, the peak of evaporate deposition in the Bonaparte Basin probably post-dated that in the Canning Basin.

Southern Carnarvon Basin

An early phase of deposition in the Southern Carnarvon Basin included the coarse clastic Tumblagooda Sandstone overlain by carbonates, evaporites, and fine- and coarse-grained clastics of the Dirk Hartog Group. The age of the Tumblagooda Sandstone appears to be Ordovician, based on the Llandovery (early Silurian) conodont fauna in the ?conformably overlying Ajana Formation of the Dirk Hartog Group (Iasky et al., 2003; Mory et al., 2003). The Tumblagooda Sandstone was deposited under braided fluvial to high-energy coastal settings (Hocking, 1992), while the Dirk Hartog Group was deposited under restricted marine conditions, with brief connections to open marine environments during the Silurian (Iasky et al., 2003). The basal Ajana Formation displays shoaling upward cycles in grey sandy mudstone, laminated dolomitic mudstone, and wackestone (Gorter et al., 1994). The overlying Yaringa Formation comprises dolomite, dark grey shales, and beds of halite and anhydrite. Palynomorphs and conodonts suggest a Telychian (late Llandovery) age for the upper Ajana and Yaringa Formations (Gorter et al., 1994; Mory et al., 1998). The Dirk Hartog Group is completed by the Coburn Formation, which is dominated by dolomitic carbonate and unconformably overlain by Devonian rocks.

At least in part, the Tumblagooda Sandstone would appear to correlate in age, but clearly not in facies, with the Carribuddy Group, while the Dirk Hartog Group correlates at least in part with the uppermost Carribuddy Group and Worral Formation. Evaporites are better developed in the Dirk Hartog Group than the Worral Formation, possibly because by mid- to late Silurian time the Canning Basin was more equatorial, but the Southern Carnarvon Basin would have been coming into the optimal evaporate deposition climatic belt, based on paleocontinental reconstructions of Scotese (2004).

Amadeus and other central Australian basins

In the Amadeus Basin, formations that likely overlap in time with the combined Carribuddy Group and Worral Formation are the upper Stokes Siltstone, Carmichael Sandstone, and Mereenie Sandstone (Walley et al., 1990; Cook and Totterdell, 1991; Haines and Wingate, 2007). The only reliable biostratigraphic tie, based on conodonts, is between the lower Stokes Siltstone (Amadeus Basin) and the Nita Formation, both being of late Darriwilian age (Nicoll, 1993; Nicoll and Laurie, 1997; Jones et al., 1998). Both units were deposited in a shallow marine environment, but other than a few cosmopolitan conodonts, the faunas have little else in common at the species level. The faunal differences may have several explanations including different facies, incomplete descriptions of faunas or lack of physical connection between basins (Haines and Wingate, 2007).

In the Canning Basin, the Nita Formation shallows upward and grades into the mostly supratidal mudstone-dominated Bongabinni Formation (Haines, 2004). At approximately the same time, the upper Stokes Siltstone becomes more restricted, with evidence of minor evaporate deposition (Nicoll et al., 1988).

The Stokes Siltstone is overlain with at least local disconformity by the deltaic Carmichael Sandstone, deposited in response to the Rodingan Movement, the earliest phase of the Alice Springs Orogeny in the Late Ordovician (Haines et al., 2001). In contrast, in the Canning Basin there is no obvious stratigraphic break and coarse clastic material is not a prominent feature of the Carribuddy Group. The marginal marine to eolian Mereenie Sandstone of the Amadeus Basin is poorly age constrained between latest Ordovician and Early Devonian with some paleomagnetic evidence of a Silurian age (Haines et al., 2001). The formation most likely overlaps in age with the Worral Formation, but upper parts could even overlap with deposition of the Tandalgoo Formation, which it closely resembles on lithological grounds.

In summary, probable age equivalents of the Carribuddy Group and Worral Formation in the Amadeus Basin are much sandier and less evaporitic than the Canning Basin succession, except at the base. This is mainly the result of high detrital input related to local tectonics, which do not seem to have affected the Canning Basin. While possible, there is no compelling evidence for the hypothetical Larapintine Seaway to have been operating at this time (Haines and Wingate, 2007).

Hydrocarbon potential

From the perspective of hydrocarbon potential, the Carribuddy Group and Worral Formation have received less attention than most other pre-Mesozoic components of Canning Basin stratigraphy. However, due to the dominance of mudstone, and the presence of massive bedded halite in many areas, the Carribuddy Group is generally seen as an effective regional seal over the more prospective marine Ordovician formations, except where it is absent due to erosion over the northwestern Broome Platform and southern Willara Sub-basin. This seal role has long been recognized, but more recently the Carribuddy Group has been demonstrated to locally host the richest oil-prone hydrocarbon source rocks in the basin, and both Carribuddy Group and Worral Formation also contain porous sandstone units, that although relatively thin and localized, are inferred to have excellent reservoir potential.

Source rock

In most wells the Carribuddy Group and Worral Formation are predominantly oxidized, as indicated by the common red-brown colouration, and such rocks clearly have no potential to source hydrocarbons. Chemically-reduced horizons do occur, either as thin interbeds, or within regions of more pervasive facies change, but these are generally localized. Organic geochemistry data, where available, is generally disappointing from a source rock perspective, except from the Bongabinni Formation of the Admiral Bay Fault Zone.

Bongabinni Formation of the Admiral Bay Fault Zone

In contrast to the oxidized redbed facies in most intersections of the lower Carribuddy Group, cored mineral exploration drillholes along parts of the Admiral Bay Fault Zone reveal an anomalous chemically reduced facies, best developed within the Bongabinni Formation. In this area mudstone is pyritic and typically dark green to dark grey and occasionally black in fresh core, although the core commonly oxidizes to a khaki green-brown colour after a few years of exposure. The interval is also commonly calcareous, varying to argillaceous limestone. Several drillcores have intersected black coal-like beds (Fig. 17), individually up to about 1 m in thickness, which

Figure 17. Drillcore photograph of Bongabinni Formation with coal-like source rock intervals (black), mineral exploration drillcore DD88SS9

had escaped detection in the previously drilled petroleum wells in the area. These beds have been variously referred to as algal coal (McCracken, 1994), or oil shale (Edwards et al., 1995; McCracken, 1997), and have the richest source potential of any source rocks reported from the Canning Basin. Cumulative thicknesses of the coal-like beds exceed 3 m in DD86SS3 and DD86SS9. Horizons bearing intraclasts of these coal-like rocks are also present, suggesting storm rip-up of such deposits.

Geochemical and petrological properties

The excellent source rock potential of the coal-like horizons was first noted by CRA Exploration (unpublished internal reports) and later documented by Taylor (1992), McCracken (1994, 1997), and Edwards et al. (1995, 1997), with a combined total of 13 analysed samples from three drillholes. GSWA has undertaken 19 new Rock-Eval pyrolysis determinations from four drillholes, including two holes not previously analysed (most results previously published in Ghori and Haines, 2006). The full data set is presented in Appendix 5. Total organic carbon (TOC) values range from 3.9 to 62.2%, with potential yield ($S_1 + S_2$) ranging from 4.9 to 208.2 mg/g, classifying most samples as excellent source rocks on their generating potential (Haines and Ghori, 2006). The hydrogen index varies widely, but is typically 250–650, with one exceptional sample recording a value of 926. The standard hydrogen index versus T_{max} plot indicates that samples range from oil and gas prone, to oil prone (Fig. 18). Maturity determinations from Rock-Eval data indicate that individual samples range from immature to within the oil window, but are unlikely to have generated significant hydrocarbons at the drilled locations based on low production index. This is confirmed by CAI and TAI data from the nearby petroleum wells indicating that the underlying Ordovician section is marginally mature to mature for oil generation. The current burial depth of the source unit ranges between 1300–1400 m in this area. Some of the enclosing mudstones are also believed to be organic-rich (McCracken, 1997), but this has been tested by few analyses.

Based on organic petrography, Edwards et al. (1995, 1997) reported that the coal-like beds contain two types of kerogen: unstructured irregular masses and structured tissue-like fragments. Both were reported as strongly altered by bacterial action precluding recognition of the fossil groups involved, but the broad similarity of the biomarker signature to *G. prisca*-bearing rocks was taken to suggest that *G. prisca* was probably a major component (Edwards et al., 1997). However, samples analysed for GSWA by Keiraville Konsultants were reported as containing vitrinite of higher plant origin (Keiraville Konsultants, 2005; Ghori and Haines, 2006). After further study, the new samples were reported to show no petrographic evidence of *G. prisca*, despite lacking the strong alteration identified in earlier studies, and the preserved tissue reasserted as having the appearance of a higher plant origin, but involving an unrecognizable group, with macerals referrable to vitrinite (Alan Cook, Keiraville, written comm. 2006).

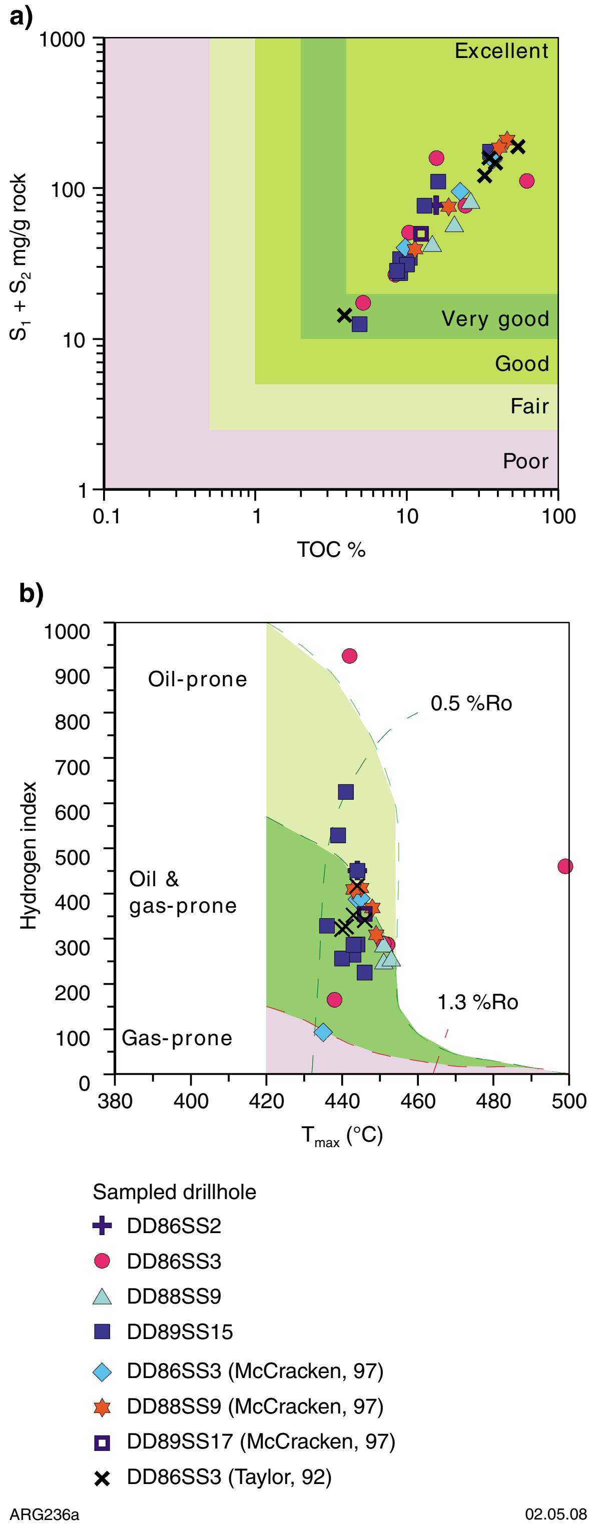


Figure 18. Summary of all available Rock-Eval data for Bongabinni Formation source rock in mineral exploration Drillcore, Admiral Bay Fault Zone: a) generating potential, indicated by organic richness (TOC) versus potential yield (S_1+S_2); b) organic facies, indicated by T_{max} verses hydrogen index (after Haines and Ghori, 2006)

Distribution and depositional setting

The distribution of the coal-like beds in the Bongabinni Formation is not well known, particularly as little information can be gleaned from the petroleum wells. Their presence is conformed by analyses from mineral drillholes DD86SS2, DD86SS3, DD87SS7, DD88SS9, DD89SS15, and DD89SS17 (Fig. 19), and thin interbeds have been visually inferred in several adjacent drillholes. These drill holes are aligned along the centre of the Admiral Bay Fault Zone, spanning a total of about 15 km. Mention of 'coal' fragments in cuttings descriptions of the Bongabinni Formation in Leo 1 (Command Petroleum, 1989) suggest that such rocks may extend to the south of the main fault zone. If they do extend to the downthrown side of the fault zone in the northern Willara Sub-basin, the deeper burial should improve the prospect of the source reaching sufficient maturity to generate significant hydrocarbons.

The environment of deposition is likely to have been a restricted lagoonal environment prone to hypersalinity (see discussion under *Bongabinni Formation*). It is suggested that subsidence along, and possibly on the downthrown side of the Admiral Bay Fault Zone controlled a local marine incursion as an elongate lagoon system. Because the open sea is inferred to have been to the west at this time, it is likely that such a lagoon system extends further west than the known intersections, potentially bearing similar source pods. It may also extend further east along the fault zone and potentially even into the Kidson Sub-basin, although this is more speculative. Although mineralization has largely destroyed potential carbonate reservoirs near the studied drillholes, sandstone units within the Nibil Formation, and fractured and vuggy dolomite in the Nita and Mount Troy Formations are present along the Admiral Bay Fault Zone, and may form suitable reservoirs.

Admiral Bay oil source?

Oil shows are common in Ordovician rocks of the Admiral Bay Fault Zone in both petroleum wells and mineral exploration drillholes, particularly in the Nita Formation, mineralized biohermal facies of the Goldwyer Formation, and the lower Carribuddy Group. The Goldwyer Formation is considered the most likely source of Ordovician shows in most parts of the basin, but available data indicates this unit has poor source potential near the Admiral Bay Fault Zone (Edwards et al., 1997). This implies than other systems capable of oil migration are operating in the area, the Bongabinni Formation being an obvious candidate.

In Leo 1, oils recovered from drillstem tests in the Willara and Nita Formations, and from cuttings in the Grant Group were geochemically characterized and compared with in situ generated oil extracted from a coal-like bed in the Bongabinni Formation in DD86SS3 (Appendix 4 *in* Command Petroleum, 1989). It was concluded that oils from the Willara and Nita Formations did have very similar source affinities to the oil extracted from the Bongabinni 'coal'; the biomarker and n-alkane distribution patterns being additionally used to infer an algal/bacterial source. While the oil from the Grant Group was slightly different, it could be explained as a mixture of oils similar to those recovered from the Willara and Nita Formations, combined with a small amount of oil from a higher plant source (Command Petroleum, 1989). Similarly, the alkane distribution of oils recovered from Cudalgarra 1, and possibly Great Sandy 1, has been used to suggest a correlation to the Bongabinni Formation source rocks (Edwards et al., 1995; McCracken, 1997).

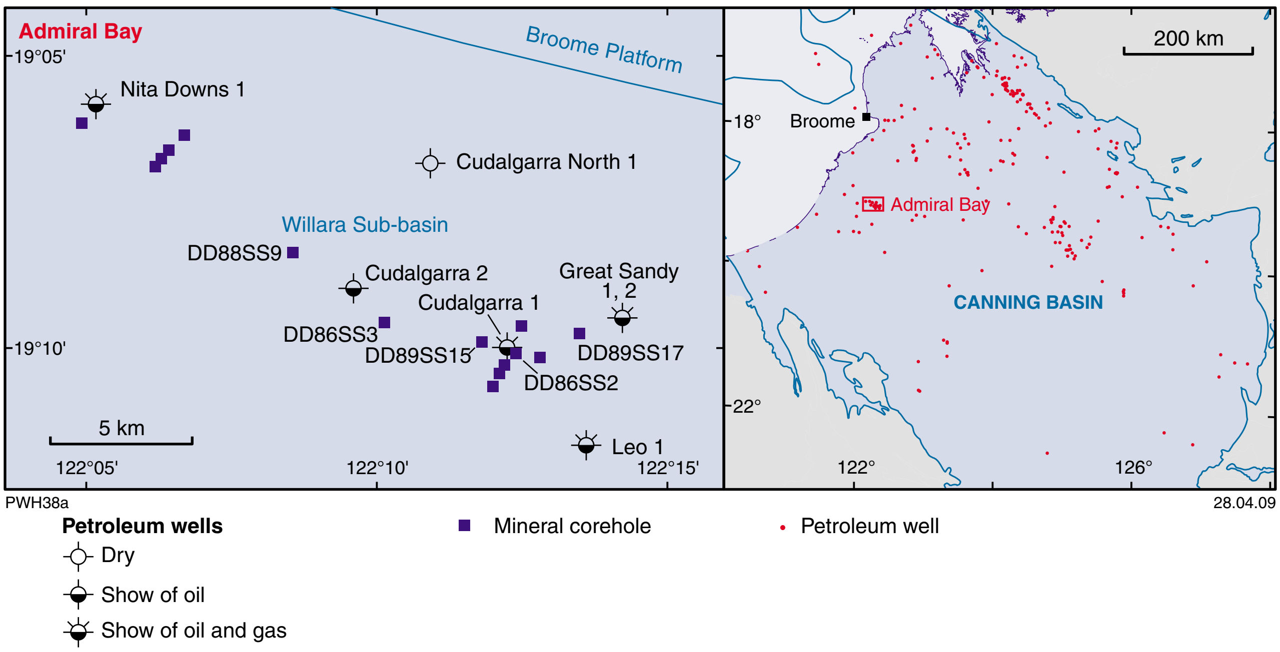


Figure 19. Admiral Bay drillholes with significant source rock intervals (from Haines and Ghori, 2006)

Nibil Formation

Although the Nibil Formation is oxidized in most wells, the sparse well data over the Kidson Sub-basin suggest that it is mainly chemically reduced with common grey to black colouration over this large area. Organic geochemistry on samples from the limited drillcore in Kidson 1 returned low (0.11 – 0.47 %) total organic carbon values (Ghori and Haines, 2006a). Unfortunately, analytical data are very sparse and no meaningful comment can be made of the source potential of the formation in this area from the present dataset.

Mallowa Salt

The Mallowa Salt locally contains interbeds of grey to black mudstone suggesting the possibility of organic rich facies, and Foster and Williams (1991) speculated on the source potential of such material in mineral exploration drillholes Gingerah Hill 1 and Brooke 1, although no analyses were reported. In Leo 1, bulk cuttings samples from the interval 1260–1320 m in the lower Mallowa Salt returned TOC values greater than 0.5% (Appendix 12 *in* Command Petroleum, 1989). The best Rock-Eval pyrolysis analyses were from the interval 1280–1300 m (TOC = 1.28%; hydrogen index = 489; potential yield $S_1 + S_2 = 8.97$ mg/g). Note that these values refer to the proportion of the sediments which are not soluble in water (i.e. not halite) and therefore an unquantified degree of concentration due to halite removal is involved.

Reservoir

The Carribuddy Group and Worral Formation have the potential to locally host both sandstone and carbonate reservoirs. Sandstone, often described as having good to excellent visual or log derived porosity in well completion reports, occurs as local interbeds within the Carribuddy Group, most notably within the Nibil Formation along the Admiral Bay Fault Zone and within the Willara Sub-basin. These sandstones may be of eolian origin, as discussed earlier. Log derived porosities of 16–33% (av. 25%) were reported in Munro 1 (Williams, 1972). In Great Sandy 1, a 10 m thick medium- to coarse-grained, well sorted, well rounded, sandstone unit with good visual porosity had common traces of dead oil (Menzel and Norlin, 1982). The same unit in DD87SS7 also displayed common oil stains (McCracken, 1997). Similar sandstone is more widespread near the base of the Worral Formation (particularly the Elsa Sandstone Member), and also locally occurs higher in that unit, particularly in the Kidson Sub-basin and adjacent areas.

Carbonates in both stratigraphic units are usually described as fine-grained and tight, but exceptions exist such as the porous dolomite beds, including the Mount Troy Formation, in Cudalgarra 1 (see below). A general problem with Carribuddy and Worral reservoirs is that they are encased within thick mudstone seals and hence may be isolated from migrating petroleum pathways, but shows within at least some potential reservoir units demonstrate that some migrating hydrocarbons have been trapped locally.

Shows

Hydrocarbon shows (oil fluorescence, bitumen, oil staining, and mud gas anomalies) within the Carribuddy Group and Worral Formation have been reported from a number of wells, but the most significant are concentrated along the Admiral Bay Fault Zone. Oil bleeds from mineral exploration drillcore have also been widely reported from this area, and on the Barbwire Terrace, but such shows are not well documented. Along the Admiral Bay Fault Zone there is a likely correlation between the presence of shows and the demonstrated occurrence of excellent source rocks in the Bongabinni Formation, as detailed above.

From petroleum wells in the Admiral Bay Fault Zone the most extensive shows in the Carribuddy Group were reported in Cudalgarra 1 (Russell and Edwards, 1984). In this well, shows started intermittently at 1207 m and increased downwards towards the lower part of the group and continued into the underlying Nita Formation. A ~10 m porous sandstone unit below 1240 m, assigned to the Nibil Formation, displayed oil stained grains and fluorescence. Log analysis of the sandstone gave water saturation (S_w) of 60%, but a drillstem test over the interval failed to recover hydrocarbons (Russell and Edwards, 1984). Good hydrocarbon indications, including fluorescence and high gas reading, were reported from 1270 m and persisted intermittently across the base of the group at 1330 m. This interval includes an unusual local development of dolomite that probably includes in part the Mount Troy Formation, although boundary positions are unclear. A second drillstem test over 1273–1286 m also failed to recover hydrocarbons. Subsequent log analysis indicated a possible 12 m net pay spanning the interval 1277–1303 m with average porosity of 22.6% and water saturation (S_w) averaging 41% (Russell and Edwards, 1984). Sidewall cores over the interval displayed 100% oil fluorescence and typically a strong petroliferous odour.

In Great Sandy 1 oil fluorescence was reported in Carribuddy Group siltstone below 1335 m (?Nibil Formation), and in dolomite below 1430 m (lower Bongabinni Formation), with pitch-like material being reported from 1415 m (Menzel and Norlin, 1982). The correlative sandstone unit to that intersected in Cudalgarra 1 displayed common traces of dead oil. Great Sandy 2 encountered shows over similar intervals (Bologna and Hillock, 1990). In the same area, mineral drillhole DD87SS7 encountered oil stained sandstone in Nibil Fm (McCracken, 1997).

In Leo 1, high gas reading (C_1–C_4) with peaks up to 100 units were reported from the lower Mallowa Salt between 1260–1330 m; considering the lack of obvious reservoir over this interval the peaks are not satisfactorily explained (Command Petroleum, 1989). The Carribuddy Group below the salt displayed numerous gas peaks (C_1–C_5), most being minor but one peak reaching 191 units, and common oil fluorescence, but the interval lacked any signs of a reservoir.

In Pasminco mineral exploration drillhole BW26 on the Barbwire Terrace, a c. 3 m zone at around 380 m in undivided Carribuddy Group contains abundant bitumen associated with contorted and brecciated silicified limestone (Fig. 20a,b). Oil staining and bitumen is also seen in porous sandstone of the Worral Formation (Fig. 20c). The bitumen zone in the Carribuddy Group is interpreted as a fault zone and demonstrates that faults cutting the Carribuddy Group may have been effective conduits for moving hydrocarbons from sources below the group, to higher reservoirs (Middleton et al., 2007).

Conclusions

This study has refined the internal lithostratigraphy of the Carribuddy Group and addressed the disputed stratigraphic position and relationships of the Worral Formation. Previous misunderstandings about these stratigraphic relationships stemmed from long standing miscorrelations and in one case from incorrect depth information applied to a critical biostratigraphic sample.

Figure 20. Drillcore photographs of bitumen in Pasminco BW26 on the Barbwire Terrace: a) bitumen impregnating bedded and brecciated carbonate, undifferentiated Carribuddy Group, 382.2 m; b) bitumen and minor bedded carbonate in fault cutting undifferentiated Carribuddy Group, 379.8 m; c) patchy bitumen impregnation of sandstone, Waldecks Member of Worral Formation, 279.7 m

The recognition of the thin Pegasus Dolomite Member in the Sahara Formation provides an important marker horizon and likely timeline that can be traced across the basin, irrespective of the presence or absence of salt units, and provides an independent check on the identification of the base of the Worral Formation in many areas. Although previously recognized as a marker above the Mallowa Salt, the long standing incorrect assignment of the same horizon to the Mount Troy Formation on the Barbwire Terrace, led in part to the spurious interpretation of a major angular unconformity at the base of the Worral Formation. In fact the upper Sahara Formation and lower Worral Formation were deposited in a remarkably 'layer cake' fashion across large areas, indicating very low paleoslopes and uniform subsidence at this time. Local unconformities at the base of, and facies changes within, the Worral Formation do occur locally along the fault controlled Jurgurra and Mowla terraces and adjacent northern Broome Platform. These areas are also close to the preserved salt edge and presumably relate to early salt dissolution and collapse or salt mobilization in this area, features previously documented from seismic interpretation.

Apart from providing a regional seal over the older Ordovician petroleum system, the basal Carribuddy Group contains excellent local oil-prone source potential. The source rocks of the Bongabinni Formation along part of the Admiral Bay Fault Zone formed within a local and probably tectonically controlled lagoonal environment. Tracing this known lagoon system laterally and finding separate occurrences, specifically in a more mature setting and in communication with reservoir beds, will be a future challenge for explorers.

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Appendix 1a

Petroleum wells intersecting the Carribuddy Group and/or Worral Formation

Well name	*UWI*	*S no.*	*Company*	*Classi-fication*	*Year spudded*	*Latitude (S)*	*Longitude (E)*	*TD (m)*
Petroleum wells								
Acacia 1	W001071	S1849	WMC	STR	1981	19°19'44.95"	124°59'43.66"	1 209
Acacia 2	W001177	S2161	WMC	NFW	1982	19°19'46.95"	124°59'43.66"	1 575
Antares 1	W001534	S3238	Bridge	NFW	1988	18°43'57.59"	123°41'42.61"	1 291
Barbwire 1	W000832	S732	WAPET	STR	1972	19°10'33.32"	125°01'04.01"	1 071
Boab 1	W001072	S379	WMC	STR	1981	19°34'36.95"	125 08'49.66"	1 033
Canopus 1	W001179	S2166	Getty	NFW	1982	18°56'47.98"	123°52'05.88"	1 779
Carina 1	W001178	S2164	Getty	NFW	1982	19°21'12.18"	123°04'48.77"	1 603
Contention Heights 1	W000875	S874	Aquitaine	NFW	1973	22°25'30.93"	127°13'35.72"	1 791
Crossland 2	W000806	S652	WAPET	STR	1971	20°00'30.43"	124°59'35.17"	914
Crystal Creek 1	W001585	S3363	Kufpec	NFW	1988	18°33'22.26"	123°36'07.99"	2 504
Cudalgarra 1	W001359	S2648	Sydney	NFW	1984	19°13'13.15"	122°19'20.25"	1 703
Cudalgarra 2	W001467	S2852	Sydney	NFW	1985	19°12'15.02"	122°16'33.95"	1 550
Cudalgarra North 1	W001629	S3626	Command	NFW	1989	19°10'10.90"	122°17'55.00"	1 220
Darriwell 1	W001569	S3337	OCA	NFW	1988	19°35'18.54"	122°06'19.14"	1 600
Dodonea 1	W001469	S2864	WMC	NFW	1985	19°23'06.15"	125°09'43.35"	2 215
Dodonea 2	W001519	S3149	WMC	NFW	1987	19°24'12.95"	125°10'45.66"	1 688
Drosera 1	W001281	S2421	WMC	STR	1984	19°40'40.95"	125°02'26.67"	450
East Crab Creek 1	W001312	S2503	Gulf	NFW	1983	18°01'01.00"	122°36'36.67"	2 813
Edgar Range 1	W000708	S435	Total	STR	1968	18°45'19.94"	123°35'43.23"	1 968
Frankenstein 1	W001594	S3417	Command	NFW	1988	21°22'50.57"	123°01'01.64"	2 803
Frome Rocks 1	W000062	S20753	WAPET	NFW	1959	18°11'46.96"	123°38'47.51"	1 220
Fruitcake 1	W002508	S20753	Hughes	NFW	2001	19°28'19.97"	124°28'51.77"	1 696
Great Sandy 1	W001087	S1911	Meridian	NFW	1981	19°12'42.73"	122°21'22.02"	1 771
Great Sandy 2	W001661	S20013	WMC	DEV	1990	19°12'42.73"	122°21'21.83"	1 576
Juno 1	W001472	S2872	Royal	NFW	1985	19°21'49.83"	122°03'47.81"	1 750
Kemp Field 1	W000710	S439	Total	STR	1968	20°19'04.79"	123°27'52.50"	1 181
Kidson 1	W000130	S244	WAPET	STR	1965	22°36'59.52"	125°00'34.93"	4 432
Kunzea 1	W001344	S2604	WMC	STR	1984	19°32'01.35"	124°59'27.56"	450
Leo 1	W001587	S3368	Command	NFW	1988	19°14'50.17"	122°20'44.31"	2 411
Looma 1	W002050	S20328	Shell	NFW	1996	19°07'24.86"	123°59'39.42"	2 535
Lovell's Pocket 1	W001662	S20014	Kufpec	NFW	1990	18°30'52.14"	123°26'13.98"	1 924
Matches Spring 1	W000741	S500	Total	NFW	1969	18°41'21.11"	124°03'06.81"	2 835
McLarty 1	W000693	S415	Total	NFW	1968	19°23'38.87"	123°39'24.40"	2 591
Mirbelia 1	W001394	S2729	WMC	NFW	1985	19°39'02.65"	125°21'41.16"	2 670
Mirbelia 2	W001595	S2729	WMC	EXT	1988	19°38'56.32"	125°21'43.91"	2 819
Missing 1	W002494	S20739	Hughes	NFW	2001	19°33'57.97"	124°36'10.67"	1 810
Munda 1	W000809	S655	WAPET	STR	1971	19°28'21.62"	122°17'38.62"	1 069
Munro 1	W000822	S698	WAPET	NFW	1972	19°51'50.15"	122°29'23.26"	2 116
Musca 1	W001180	S2168	Getty	NFW	1982	19°20'14.33"	122°57'24.97"	1 535
Nita Downs 1	W001301	S2452	Sydney	NFW	1983	19°09'15.13"	122°11'59.57"	1 849
Parda 1	W000105	S198	WAPET	NFW	1965	18°56'02.24"	122°00'33.01"	1 909
Patience 1	W001479	S2919	Sydney	NFW	1986	23°21'40.97"	125°40'11.84"	1 869
Patience 2	W002426	–	Nerdlihc	NFW	2000	23°21'40.97"	125°40'11.93"	4 184
Pegasus 1	W001570	S3338	Amoco	NFW	1988	20°05'45.60"	123°57'08.83"	2 998
Percival 1	W001458	S2819	WMC	NFW	1985	20°19'50.64"	126°04'59.97"	2 448
Pictor 1	W001346	S2607	BHP	NFW	1984	18°45'46.83"	123°42'57.68"	2 146
Pictor 2	W001716	S20049	Bridge	EXT	1990	18°45'52.15"	123°42'52.07"	1 085
Robert 1	W002480	S20728	Hughes	NFW	2001	19°09'21.96"	124°19'47.67"	1 628
Sahara 1	W000091	S128	WAPET	NFW	1965	21°04'36.23"	123°23'39.97"	2 120
Sally May 1	W002718	–	Kingsway	NFW	2004	19°44'39.00"	124°17'46.64"	1 700
Santalum 1A	W001284	S2426	WMC	STR	1983	19°28'18.12"	124°52'10.67"	629
Solanum 1	W001277	S2408	WMC	STR	1984	19°21'53.95"	124°57'46.66"	834
Vela 1	W001181	S2170	Getty	NFW	1982	19°24'37.71"	122°53'40.79"	1 908
Willara 1	W000115	S214	WAPET	NFW	1965	19°10'53.60"	122°04'21.80"	3 903
Wilson Cliffs 1	W000696	S419	WAPET	NFW	1968	22°16'33.94"	126°46'59.72"	858
Woods Hills 1	W001389	S2710	Royal	NFW	1984	19°34'28.94"	122°01'13.31"	1 978

NOTES:
TD: Total depth
NFW: New Field Wildcat
STR: Stratigraphic
DEV: Development
EXT: Extension
Amoco: Amoco Australia Petroleum Company
Aquitaine: Australian Aquitaine Petroleum Pty Ltd
BHP: BHP Petroleum Pty Ltd
Bridge: Bridge Oil Limited
Command: Command Petroleum NL
Getty: Getty Oil Development Co Ltd
Gulf: Gulf Oil Australia Pty Ltd
Hughes: Hughes & Hughes Australia Pty Ltd
Kingsway: Kingsway Resources Pty Ltd
Kufpec: Kufpec Australia Pty Ltd
Meridian: Meridian Oil NL
Nerdlihc: Nerdlihc Company
OCA: Oil Company Of Australia
Royal: Royal Resources Exploration Inc
Shell: Shell Development (Australia) Pty Ltd
Sydney: Sydney Oil Company
Total: Total Exploration Australia Pty Ltd
WAPET: West Australian Petroleum Pty Ltd
WMC: Western Mining Co Ltd

Appendix 1b

Mineral drillholes intersecting the Carribuddy Group and/or Worral Formation

Hole name	*UWI*	*I no.*	*A no.*	*Company*	*Year spudded*	*Latitude (S)*	*Longitude (E)*	*TD (m)*
Mineral exploration drillholes								
DD86SS2	M0000613	I 7215	A 22015	CRAE	1986	19°13'14.53"	122°19'24.00"	1 754
DD86SS3	M0000614	I 7215	A 22015	CRAE	1986	19°12'33.83"	122°17'13.00"	1 724
DD87SS4	M0000615	I 7215	A 22015	CRAE	1987	19°21'43.02"	122°27'18.70"	1 502
DD87SS5	M0000616	I 7215	A 28951	CRAE	1987	19°13'33.75"	122°19'14.02"	1 269
DD87SS6	M0000617	I 7215	A 26351	CRAE	1987	19°10'00.43"	122°13'03.00"	1 613
DD87SS7	M0000618	I 7215	A 26351	CRAE	1987	19°12'56.03"	122°19'25.70"	1 819
DD88SS8	M0000619	I 7215	A 26351	CRAE	1988	19°11'21.03"	122°15'23.70"	1 853
DD88SS9	M0000620	I 7215	A 26351	CRAE	1988	19°11'21.03"	122°15'21.70"	1 753
DD88SS10	M0000621	I 7215	A 26351	CRAE	1988	19°15'53.01"	122°36'57.70"	1 647
DD88SS11	M0000622	I 7215	A 26351	CRAE	1988	19°18'45.01"	122°44'25.70"	1 825
DD88SS12	M0000623	I 7215	A 28951	CRAE	1988	19°24'18.99"	122°53'56.69"	1 869
DD88SS13	M0000624	I 7215	A 28951	CRAE	1988	19°07'35.03"	122°10'16.70"	1 527
DD89SS14	M0000625	I 7215	A 28951	CRAE	1989	19°13'20.03"	122°16'32.70"	1 620
DD89SS15	M0000626	I 7215	A 28951	CRAE	1989	19°13'09.03"	122°19'05.70"	1 638
DD89SS16	M0000627	I 7215	A 28951	CRAE	1989	19°13'18.03"	122°19'45.70"	1 508
DD89SS17	M0000628	I 7215	A 28951	CRAE	1989	19°13'07.03"	122°20'14.70"	1 519
DD89SS18	M0000658	I 7215	A 28951	CRAE	1989	19°09'39.03"	122°13'18.70"	1 536
DD90SS19	M0000659	I 7215	A 31831	CRAE	1990	19°09'30.03"	122°11'49.70"	1 686
DD90SS20	M0000660	I 7215	A 31831	CRAE	1990	19°09'53.03"	122°13'07.70"	1 506
DD90SS21	M0000661	I 7215	A 31831	CRAE	1990	19°10'04.03"	122°12'59.70"	1 657
DD91SS22	M0000662	I 5846	A 34538	CRAE	1991	18°58'24.03"	121°52'51.70"	1 433
DD91SS23	M0000663	I 5846	A 34538	CRAE	1991	19°02'22.03"	122°04'31.70"	1 394
DD91SS24	M0000664	I 5846	A 34538	CRAE	1991	19°01'49.02"	121°59'25.70"	1 463
DD88CL1	M0000779	I 4654	A 27976	CRAE	1988	19°09'15.98"	124°45'03.35"	399
Brooke 1	M0000711	I 3925	A 27362	BHP	1988	19°44'52.17"	122°55'03.60"	2 035
Gingerah Hill 1	M0000712	I 3925	A 21388	BHP	1986	19°28'06.24"	122°22'04.95"	1 474
BW1	M0000665	I 9423	A 38033	Pasminco	1992	19°25'16.95"	124°59'38.66"	468
BW3A	M0000666	I 9423	A 38033	Pasminco	1992	19°32'57.95"	125°01'12.66"	362
BW5	M0000667	I 9423	A 38033	Pasminco	1992	19°36'37.95"	125°02'37.67"	678
BW15	–	I 9423	A 40680	Pasminco	1993	19°21'11.95"	125°02'28.66"	551
BW24	–	I 9423	A 49925	Pasminco	1996	19°08'18.24"	124°46'28.29"	466
BW26	M0000669	I 9423	A 49925	Pasminco	1996	19°08'56.64"	124°47'59.08"	468
BW27	–	I 9423	A 49925	Pasminco	1996	19°09'29.46"	124°27'01.94"	453

NOTES:
TD: Total depth
BHP: BHP Minerals Pty Ltd
CRAE: CRA Exploration Pty Ltd
Pasminco: Pasminco Exploration, a division of Pasminco Australia Ltd

Appendix 2a

Revised formation tops and thickness data for the Carribuddy Group and Worral Formation

Well or drillhole name	Overlying unit	Carribuddy Group Formation tops (m): Top Carribuddy Group	Top Sahara Formation	Top Pegasus Dolomite Member	Top Mallowa Salt	Top Nibil Formation	Top Minjoo Salt	Top Mount Troy Formation	Top Bongabinni Formation	Base Carribuddy Group	Top Leo Member (Nita Formation)	TD in Carribuddy Group
Petroleum wells												
Acacia 1	Worral	524.5	524.5	550.5	–	–	–	–	–	693.5	707.5	–
Acacia 2	Worral	524	524	552	–	–	–	–	–	700	714	–
Antares 1	Tandalgoo	919.5	919.5	924.5	–	–	–	999.5	1 017	1 058	1 119.5	–
Barbwire 1	Worral	613	613	638	–	–	–	–	–	754	754	–
Boab 1	Worral	1 015	1 015	–	–	–	–	–	–	–	–	1 033
Canopus 1	Tandalgoo	938	938	–	–	–	–	1 032.5	1 055	1 091.5	1 141	–
Carina 1	Worral	816.5	816.5	835	926.5	1 273.5	1 372	–	1 401.5	1 490	1 504.5	–
Contention Heights 1	Worral	944	944	–	–	–	–	–	–	1 388	–	–
Crossland 2	Worral	788	788	829	–	–	–	–	–	–	–	914
Crystal Creek 1	Worral	1 521.5	–	–	–	–	–	1 521.5	1 536.5	1 573	1 642	–
Cudalgarra 1	Grant	1 174	–	–	–	–	–	–	–	1 330	–	–
Cudalgarra 2	Grant	1 141.5	–	–	–	–	–	1 309	1 331	1 393.5	1 411	–
Cudalgarra North 1	Grant	1 173	–	–	–	–	–	–	–	–	–	1 220
Darriwell 1	Grant	1 239	–	–	–	–	–	1 362	1 392	1 483	1 504.5	–
Dodonea 1	Worral	1 411	1 411	1 441.5	–	–	–	–	–	1 527	–	–
Dodonea 2	Worral	1 419	1 419	1 451	–	–	–	–	–	1 586	–	–
Drosera 1	Grant	440.5	–	–	–	–	–	–	–	–	–	450
East Crab Creek 1	Pillara	2 663	–	–	–	2 663	–	2 696.5	2 708	2 740.5	–	–
Edgar Range 1	Grant	572	–	–	–	–	–	701	716	750.5	804	–
Frankenstein 1	Worral	1 387.5	1 387.5	1 425.5	1 580.5	2 024.5	–	–	–	2 229	2 236	–
Frome Rocks 1	Wallal	223	–	–	687.5	–	–	–	–	–	–	1 220
Fruitcake 1	Worral	498	498	522.5	638	1 008	–	1 053	1 063	1 111	1 111	–
Great Sandy 1	Worral	1 126	1 126	1 143	–	–	–	1 338	1 361.5	1 447	1 472.5	–
Great Sandy 2	Worral	1 131	1 131	1 144	–	–	–	1 335	1 357.5	1 442.5	1 468	–
Juno 1	Grant	1 340	–	–	–	–	–	1 498	1 525	1 648.5	1 675	–
Kidson 1	Worral	2 687	2 687	2 723	2 967	3 501	3 905	–	4 071	4 279	–	–
Kunzea 1	Grant	261.5	–	–	–	–	–	–	–	292	314	–
Leo 1	Worral	1 046	1 046	1 074	1 152	1 331	–	1 427	1 450	1 540	1 568	–
Looma 1	Worral	563.5	563.5	589	666	1 113	–	1 177	1 193	1 224.5	1 272.5	–
Lovell's Pocket 1	Worral	1 083.5	–	–	–	–	–	1 101	1 117	1 145	1 207	–
Matches Spring 1	Worral	1 917	–	–	–	–	–	1 962	1 976.5	2 019.5	2 085.5	–
McLarty 1	Worral	586	586	614	648	1 415	1 512	–	1 530	1 630	1 640	–
Mirbelia 1	Worral	2 294	2 294	2 328.5	2 335	–	–	–	–	–	–	2 670
Mirbelia 2	Worral	2 289.5	2 289.5	2 323.5	2 330	2 547	–	–	–	2 574	1 274	–
Missing 1	Tandalgoo	859	859	–	–	–	–	963	974	989	1 016.5	–
Munda 1	Worral	947	947	973	1 012.5	–	–	–	–	–	–	1 069
Munro 1	Grant	1 172	–	–	–	–	–	1 390	1 424	1 501.5	1 533	–
Musca 1	Grant	914	914	939	1 042	1 238	1 330	–	1 367	1 448	1 461.5	–
Nita Downs 1	Grant	1 174	1 174	1 177	–	–	–	1 353.5	1 374.5	1 457.5	1 438	–
Parda 1	Grant	980	–	–	–	–	–	1 098	1 121	1 148	1 201.5	–
Patience 2	Worral	1 940	1 940	1 975	–	–	2 424	–	2 737	2 881	–	–

Appendix 2a (continued)

Well or drillhole name	Overlying unit	Carribuddy Group Formation tops										
		Top Carribuddy Group	Top Sahara Formation	Top Pegasus Dolomite Member	Top Mallowa Salt	Top Nibil Formation	Top Minjoo Salt	Top Mount Troy Formation	Top Bongabinni Formation	Base Carribuddy Group	Top Leo Member (Nita Formation)	TD in Carribuddy Group
							(m)					
Pegasus 1	Worral	1 232	1 232	1 261	1 269.5	2 058	–	–	2 165.5	2 285	2 300	–
Percival 1	Worral	1 868	1 868	1 905.5	–	–	–	–	–	2 013	–	–
Pictor 1	Worral	732	732	753.5	–	–	–	825	845	879	945	–
Pictor 2	Worral	683	683	692	–	–	–	822.5	839	827	936.5	–
Robert 1	Tandalgoo	929	929	–	–	–	–	1 047.5	1 067.5	1 099	1 158	–
Sahara 1	Worral	2 004	2 004	2 034	2 036	–	–	–	–	–	–	2 120
Sally May 1	Worral	723	723	757	765.5	1 505	–	1 561	1 576	1 623	1 631	–
Santalum 1A	Grant	321	–	–	–	–	–	–	–	372	406	–
Solanum 1	Grant	136.5	–	–	–	–	–	–	–	223	283	–
Vela 1	Worral	875	875	901	960.5	1 519.5	1 632.5	–	1 690	1 783	1 800	–
Willara 1	Grant	1 125	1 125	–	1 280	1 460	1 588	–	1 666	1 760	1 780	–
Wilson Cliffs 1	Worral	2 036	2 036	–	–	–	2 370.5	–	2 486.5	2 638	–	–
Wood Hills 1	Grant	1 081	–	–	–	–	–	1 223	1 253.5	1 333.5	1 353	–
Mineral drillholes												
Brooke 1	Worral	935	935	964.5	971.5	1 772	1 995	–	–	–	–	2 035
Gingerah Hill 1	Worral	–	–	–	990.7	–	–	–	–	–	–	1 473.5
DD86SS3	Grant	1 220	–	–	–	–	–	–	–	1 380.5	1 402.5	–
DD88SS9	Worral	1 107	1 107	1 121.5	–	–	–	–	–	1 408	1 430	–
DD88SS10	Worral	1 134	1 134	1 157.5	1 271.5	1 350	–	–	–	–	–	1 647
DD88SS11	Worral	900	900	924	980	1 439.5	–	–	1 518	1 740	(a) nl	(a) nl
DD88SS12	Worral	896	896	922	981.5	1 488.5	1 565.5	–	1 601.5	1 686.5	1 700.5	–
DD88SS13	Grant	1 128	–	–	–	–	–	–	–	1 407	1 429	–
DD89SS14	Grant	1 174.5	–	–	–	–	–	–	–	1 424	1 445.5	–
DD89SS15	Worral	1 112	1 112	1 123	–	–	–	–	–	1 360.5	1 381.5	–
DD89SS16	Worral	1 094.5	1 094.5	1 105.5	–	–	–	–	–	1 350	1 365.5	–
DD89SS17	Worral	1 122	1 122	1 134.5	–	–	–	–	–	1 358	1 377.5	–
DD89SS18	Grant	1 160	–	–	–	–	–	–	–	1 419.5	1 446	–
DD90SS19	Worral	1 179.5	1 179.5	1 201	–	–	–	–	–	1 571	1 529.5	–
DD90SS20	Worral	1 123.5	1 123.5	1 137.5	–	–	–	–	–	1 390.5	1 409.5	–
DD90SS21	Worral	1 178	1 178	1 194.5	1 283.5	1 313.5	–	–	–	1 551	1 577	–
DD91SS22	Grant	1 043	–	–	–	–	–	–	–	1 265	1 298	–
DD91SS23	Grant	1 096	–	–	–	–	–	–	–	1 284.5	1 308	–
DD91SS24	Grant	1 138	–	–	–	–	–	–	–	1 355	1 378	–

NOTES: (a) not logged

Appendix 2b

Revised formation tops and thickness data for the Carribuddy Group and Worral Formation

Well or drillhole name	Thickness Carribuddy Group	Thickness Sahara Formation	Thickness Pegasus Dolomite Member	Thickness Mallowa Salt	Thickness Nibil Formation	Thickness Minjoo Salt	Thickness Mount Troy Formation	Thickness Bongabinni Formation	Thickness Cudalgarra Member (Nita Formation)
	Carribuddy Group thicknesses (m)								
Petroleum wells									
Acacia 1	169	–	2	–	–	–	–	–	14
Acacia 2	176	–	2	–	–	–	–	–	14
Antares 1	138.5	–	2	–	–	–	17.5	41	61.5
Barbwire 1	141	–	2.5	–	–	–	–	–	–
Boab 1	(a)18	(a)18	–	–	–	–	–	–	–
Canopus 1	153.5	–	–	–	–	–	22.5	36.5	49.5
Carina 1	673.5	110	2.5	347	98.5	29.5	–	88.5	14.5
Contention Heights 1	444	–	–	–	–	–	–	–	–
Crossland 2	(a)126	(a)126	2	–	–	–	–	–	–
Crystal Creek 1	51.5	–	–	–	–	–	15	36.5	69
Cudalgarra 1	156	–	–	–	–	–	–	–	–
Cudalgarra 2	252	–	–	–	–	–	22	62.5	17.5
Cudalgarra North 1	47	–	–	–	–	–	–	–	–
Darriwell 1	244	–	–	–	–	–	30	91	21.5
Dodonea 1	116	–	4	–	–	–	–	–	–
Dodonea 2	167	–	–	–	–	–	–	–	–
Drosera 1	(a,b)9.5	–	–	–	–	–	–	–	–
East Crab Creek 1	77.5	–	–	–	–	–	11.5	32.5	–
Edgar Range 1	178.5	–	–	–	–	–	15	34.5	53.5
Frankenstein 1	841.5	193	2.5	444	–	–	–	–	7
Frome Rocks 1	(a)997	–	–	–	–	–	–	–	–
Fruitcake 1	613	140	3	370	45	–	10	48	–
Great Sandy 1	321	–	3	–	–	–	23.5	85.5	25.5
Great Sandy 2	311.5	–	3	–	–	–	22.5	85	25.5
Juno 1	308.5	–	–	–	–	–	27	123.5	26.5
Kidson 1	1 592	280	2	534	404	166	–	208	–
Kunzea 1	30.5	–	–	–	–	–	–	–	22
Leo 1	494	106	3	179	96	–	23	90	28
Looma 1	661	102.5	2	447	64	–	16	31.5	48
Lovell's Pocket 1	61.5	–	–	–	–	–	16	28	62
Matches Spring 1	102.5	–	–	–	–	–	14.5	43	66
McLarty 1	1 044	62	3	767	97	18	–	100	10
Mirbelia 1	(a)376	41	5	(a)335	–	–	–	–	–
Mirbelia 2	284.5	40.5	2.5	217	–	–	–	–	–
Missing 1	130	–	–	–	–	–	11	15	27.5
Munda 1	(a)122	65.5	3	(a)56.5	–	–	–	–	–
Munro 1	329.5	–	–	–	–	–	34	77.5	31.5
Musca 1	534	128	2.5	196	92	37	–	81	13.5

Appendix 2b (continued)

Well or drillhole name	Thickness Carribuddy Group	Thickness Sahara Formation	Thickness Pegasus Dolomite Member	Thickness Mallowa Salt (m)	Thickness Nibil Formation	Thickness Minjoo Salt	Thickness Mount Troy Formation	Thickness Bongabinni Formation	Thickness Cudalgarra Member (Nita Formation)
	Carribuddy Group thicknesses (m)								
Nita Downs 1	283.5	–	3.5	–	–	–	21	83	25.5
Parda 1	168	–	–	–	–	–	23	27	53.5
Patience 2	941	–	2	–	–	313	–	144	–
Pegasus 1	1 053	37.5	4.5	788.5	107.5	–	–	119.5	15
Percival 1	145	–	2.5	–	–	–	–	–	–
Pictor 1	147	–	1.5	–	–	–	20	34	66
Pictor 2	189	–	1	–	–	–	16.5	33	64.5
Robert 1	170	–	–	–	–	–	20	31.5	59
Sahara 1	(a)116	32	2	(a)84	–	–	–	–	–
Sally May 1	900	42.5	4.5	739.5	56	–	15	47	8
Santalum 1A	51	–	–	–	–	–	–	–	34
Solanum 1	86.5	–	–	–	–	–	–	–	60
Vela 1	908	85.5	3	559	113	57.5	–	93	17
Willara 1	635	155	–	180	128	78	–	94	20
Wilson Cliffs 1	602	–	–	–	–	116	–	151.5	–
Wood Hills 1	253	–	–	–	–	–	30.5	80	19.5
Mineral drillholes									
Brooke 1	(a)1 100	36.5	3.5	800.5	223	(a)40	–	–	–
Gingerah Hill 1	–	–	–	(a)483	–	–	–	–	–
DD86SS3	160.5	–	–	–	–	–	–	–	22
DD88SS9	301	–	2	–	–	–	–	–	22
DD88SS10	(a)513	137.5	3	(a)78.5	–	–	–	–	–
DD88SS11	925	80	3.5	459.5	78.5	–	–	–	–
DD88SS12	790.5	85.5	2.5	507	77	36	–	85	14
DD88SS13	279	–	–	–	–	–	–	–	22
DD89SS14	249.5	–	–	–	–	–	–	–	21.5
DD89SS15	248.5	–	3	–	–	–	–	–	21
DD89SS16	255.5	–	2.5	–	–	–	–	–	15.5
DD89SS17	236	–	2	–	–	–	–	–	19.5
DD89SS18	259.5	–	–	–	–	–	–	–	26.5
DD90SS19	391.5	–	3	–	–	–	–	–	21.5
DD90SS20	267	–	3	–	–	–	–	–	19
DD90SS21	373	105.5	3	30	–	–	–	–	26
DD91SS22	222	–	–	–	–	–	–	–	33
DD91SS23	188.5	–	–	–	–	–	–	–	23.5
DD91SS24	217	–	–	–	–	–	–	–	23

NOTES (a) Incomplete intersection
(b) undifferentiated Carribuddy Group or Worral Formation

Appendix 2c

Revised formation tops and thickness data for the Carribuddy Group and Worral Formation

Well or drillhole name	Overlying unit	Worral Formation tops and thicknesses (m): Top Worral Formation	Top Waldecks Member	Top Elsa Sandstone	Top Dodonea Member	Top Carribuddy Group Member	TD in Worral Formation	Thickness Worral Formation	Thickness Waldecks Member	Thickness Elsa Sandstone Member	Thickness Dodonea Member
Petroleum wells											
Acacia 1	Tandalgoo	372	372	480	504	524.5	–	152.5	108	24	20.5
Acacia 2	Tandalgoo	373	373	483	506	524	–	151	110	23	18
Barbwire 1	Tandalgoo	458	458	577	596	613	–	155	119	19	17
Boab 1	Tandalgoo	880.5	880.5	989	1 001	1 015	–	134.5	108.5	12	14
Carina 1	Tandalgoo	694	694	792	–	816	–	122	98	24	–
Contention Heights 1	Tandalgoo	911	–	–	–	944	–	33	–	–	–
Crossland 2	Grant	659.5	659.5	746.5	774.5	788	–	128.5	87	28	13.5
Crystal Creek 1	Tandalgoo	1 435	–	–	–	1 521.5	–	86.5	–	–	–
Dodonea 1	Tandalgoo	1 246	1 246	1 366	1 392.5	1 411	–	165	120	26.5	18.5
Dodonea 2	Tandalgoo	1 249	1 249	1 377	1 400	1 419	–	170	128	23	19
Drosera 1	Grant	440.5	–	–	–	–	–	[a,b]9.5	–	–	–
Frankenstein 1	Tandalgoo	1 117	1 214	1 338	–	1 387.5	–	270.5	124	49.5	–
Fruitcake 1	Tandalgoo	315	315	437	465.5	489	–	174	122	28.5	23.5
Great Sandy 1	Grant	1 098	–	–	–	1 126	–	28	–	–	–
Great Sandy 2	Grant	1 100.5	–	–	–	1 131	–	30.5	–	–	–
Kemp Field 1	Tandalgoo	1 115	1 115	–	–	–	1181	[a]66	[a]66	–	–
Kidson 1	Tandalgoo	2 570	2 570	2 666.5	–	2 687	–	117	96.5	20.5	–
Leo 1	Grant	943	–	–	–	1 046	–	103	–	–	–
Looma 1	Grant	438	438	514	–	563.5	–	125.5	76	49.5	–
Lovell's Pocket 1	Dominic	991.5	–	–	–	1 083.5	–	92	–	–	–
Matches Spring 1	Tandalgoo	1 780	1 780	1 884.5	–	1 917	–	137	104.5	32.5	–
McLarty 1	Grant	452	452	550	–	586	–	134	98	36	–
Mirbelia 1	Tandalgoo	2 156	2 156	2 255	2 283.5	2 294	–	138	99	28.5	10.5
Mirbelia 2	Tandalgoo	2 150	2 150	2 249	2 273.5	2 289.5	–	139.5	99	24.5	16
Munda 1	Grant	800.5	800.5	937	–	947	–	146.5	136.5	10	–
Patience 1	Tandalgoo	1 796	–	–	–	–	1869	[a]73	–	–	–
Patience 2	Tandalgoo	1 803	–	1 895.5	–	1 940	–	137	–	44.5	–
Pegasus 1	Tandalgoo	1 017	1 017	1 197.5	–	1 232	–	215	180.5	34.5	–
Percival 1	Tandalgoo	1 752	1 752	1 812	1 858	1 868	–	116	60	46	10
Pictor 1	Tandalgoo	581	581	695	–	732	–	151	114	37	–
Pictor 2	Tandalgoo	608	608	–	–	683	–	75	–	–	–
Sahara 1	Tandalgoo	1 726.5	1 792	1 955	–	2 004	–	277.5	163	49	–
Sally May 1	Tandalgoo	458	501	684.5	–	723	–	265	183.5	38.5	–
Vela 1	Grant	691	691	862.5	–	875	–	184	171.5	12.5	–
Wilson Cliffs 1	Tandalgoo	1 783	1 783	1 978	–	2 036	–	253	195	58	–
Mineral drillholes											
Brooke 1	Tandalgoo	781	781	925	–	935	–	154	144	10	–
Gingerah Hill 1	Grant	792.5	–	–	–	uncertain	–	–	–	–	–
SS9	Grant	1 097	–	–	–	1 107	–	10	–	–	–

Appendix 2c (continued)

Well or drillhole name	Overlying unit	Worral Formation tops and thicknesses (m)									
		Top Worral Formation	Top Waldecks Member	Top Elsa Sandstone	Top Dodonea Member	Top Carribuddy Group Member	TD in Worral Formation	Thickness Worral Formation	Thickness Waldecks Member	Thickness Elsa Sandstone Member	Thickness Dodonea Member
SS10	Grant	1 020.5	1 020.5	1 128	–	1 134	–	113.5	108.5	6	–
SS11	Grant	755	755	895	–	900	–	145	140	5	–
SS12	Grant	714	714	882.5	–	896	–	182	168.5	13.5	–
SS15	Grant	1 066.5	–	–	–	1 112	–	45.5	–	–	–
SS16	Grant	1 045	–	–	–	1 094.5	–	49.5	–	–	–
SS17	Grant	1 086	–	–	–	1 122	–	36	–	–	–
SS19	Grant	1 157	–	–	–	1 179.5	–	22.5	–	–	–
SS20	Grant	1 090	–	–	–	1 123.5	–	33.5	–	–	–
SS21	Grant	1 169	–	–	–	1 178	–	9	–	–	–

NOTES: (a) Incomplete intersection
(b) undifferentiated Carribuddy Group or Worral Formation

Appendix 3

Biostratigraphic data for the Carribuddy Group and Worral Formation

Well/depth (m)	*Sample type*	*Stratigraphy*	*Fossil type*	*Zone/association*	*Yield*	*TAI*	*CAI*	*Environment*	*Age*	*Comments*	*Reference*
Acacia 1											
456.7, 471.1	core	Waldecks Member	miospores association	*Pterospermella*	very low	–	–	marine	indeterminate	–	Foster (1982)
511.6 – 522.5	core	Dodonea Member	conodonts	–	seven elements	–	1	marine	Llandovery	–	Nicoll and Jones (1982)
673.4	core	undivided Carribuddy	miospores	?*Pterospermella* association	very low	–	–	?	indeterminate	–	Foster (1982)
Antares 1											
1005–1041	cuttings	undivided Carribuddy	acritachs	'*Pterospermopsimorpha*'	low	–	–	very shallow marine	indeterminate	–	Purcell (1988a)
1017–1041	cuttings	undivided Carribuddy	Acritachs, *G. prisca*, chitinozoans	'*Pterospermopsimorpha*'	low	–	–	very shallow marine	indeterminate	*G. prisca* and chitinozoans probably reworked	Purcell (1988a)
Boab 1											
?900–1000	core	?Worral	ostracods, gastropods, foraminiferids, sponge spicules,phosphatic shell fragments	–	three pyritized steinkerns	–	–	marine	Devonian (Emsian–Eifelian)	depth in doubt (Jones, PJ, 2007, written comm.)	Jones and Nicoll (1982); Nicoll et al. (1994); Jones, PJ (2007, written comm.)
1009.32 – 1010.9	core	Dodonea Member	scolecodonts	–	–	–	–	marine	indeterminate	–	Nicoll et al. (1994)
1012.5 – 1014.4	core	Dodonea Member	conodonts	–	31 elements	–	1	marine	Llandovery	–	Nicoll et al. (1994)
1014.5 – 1015.3	core	Dodonea Member	conodonts	–	23 elements	–	1	marine	Llandovery	–	Nicoll et al. (1994)
Canopus 1											
952, 992	SWC	undivided Carribuddy	palynology	–	–	–	–	oxidized	indeterminate	–	Ingram (1982a)
1075	cuttings	Bongabinni	conodonts	–	one element	–	1.5	marine	indeterminate	–	Savage (1982)
Carina 1											
708 – 1402.5	SWC	Bongabinni to Worral	acritarchs	–	–	–	–	Aqueous, not open marine	indeterminate	*Micrhystridium*, *Leiospaeridia*	Purcell (1982)
1211	SWC	Mallowa	miospores	–	–	–	–	–	?Devonian	?*Stenozonotriletes*: possibly contaminant	Ingram (1982b)
East Crab Creek 1											
2670.8 – 2763.3	SWC	undivided lower Carribuddy	acritachs	'*Pterospermopsimorpha*'	very low	–	–	Shallow marine	indeterminate	*Asketopalla* sp., *Pterospermopsimorpha* sp, *Leiospaeridia* spp	Purcell (1985)
2676–2697	cuttings	undivided lower Carribuddy	acritachs	'*Pterospermopsimorpha*'	very low	–	–	Shallow marine	indeterminate	*Pterospermopsimorpha* sp	Purcell (1987)

Appendix 3 (continued)

Well/depth (m)	*Sample type*	*Stratigraphy*	*Fossil type*	*Zone/association*	*Yield*	*TAI*	*CAI*	*Environment*	*Age*	*Comments*	*Reference*
2722–2763.3	cuttings, SWC	undivided lower Carribuddy	acritachs	–	very low	–	–	–	indeterminate	*Leiospaeridia voighti*	Purcell (1987)
2748–2751	cuttings	undivided lower Carribuddy	acritachs	–	very low	–	–	–	indeterminate	*Pterospermopsimorpha* sp	Purcell and Ingram (1985)
Frankenstein 1											
1795–2005	cuttings	Nibil to Mallowa	conodonts, phosphatic fish fragments	–	low	–	1	–	?Ordovician	–	Nicoll (1993)
1379.3 – 2027.0	SWC	Nibil to Worral	acritachs	–	low	–	–	–	indeterminate	*Leiospaeridia* sp, *Lophosphaeridium* sp	Purcell (1989)
2100.9, 2166.7	SWC	undivided lower Carribuddy	acritachs	'*Pterospermopsimorpha*'	medium	3	–	–	indeterminate	*Leiospaeridia* sp, *Lophosphaeridium* sp; *Pterospermopsimorpha* sp	Purcell (1989)
2203.2	SWC	lower Bongabinni	acritachs	–	low	3	–	–	indeterminate	*Leiospaeridia* sp	Purcell (1989)
Gingerah Hills 1											
800.5 – 801.5	core	?Worral (or Tandalgoo)	conodonts	–	three elements	–	1.5	marine	?Devonian	'definitely not Ordovician, almost certainly not Silurian'	Nicoll (1993)
800.5 – 801.5	core	?Worral (or Tandalgoo)	fish	–	–	–	–	–	Devonian	acanthodian and Turiniid fish scales	Nicoll and Young (1987)
841.6	core	?Sahara	acritachs, spores	–	–	–	–	–	–	–	Foster and Williams (1991)
1038.1	core	Mallowa	acritarchs	–	–	–	–	–	–	–	Foster and Williams (1991)
1138.5	core	Mallowa	acritachs, spores	–	–	–	–	–	Late Ordovician – earliest Silurian	–	Foster and Williams (1991)
1271.1 – 1306.5	core	Mallowa	acritachs, ?spores	–	–	–	–	–	?Devonian	–	Foster and Williams (1991)
Kemp Field 1											
1123.2 – ?1181.1	?core	?Worral	fish	–	–	–	–	–	Late Silurian (Pridoli)	cites Young and Turner (unpublished)	Romine et al. (1994)
Kidson 1											
3865.2 – 3866.1	core	Nibil	fish	–	–	–	–	–	indeterminate	–	this report
Kunzea 1											
273.5 – 274.5	core	Bongabinni	conodonts	–	16 elements	–	?1	–	Ordovician	?*Erismodus* sp.	Nicoll (1993)
274.6–274.9	core	Bongabinni	conodonts	–	six elements	–	–	–	–	–	this report
288–290	core	Bongabinni	conodonts	–	two elements	–	1	–	Ordovician	?*Plectodina* sp.	Nicoll (1993)
Leo 1											
992–1513	SWC	Bongabinni to Worral	acritachs	–	low	–	–	–	indeterminate	*Leiosphaeridia* spp, *Micrhystridium* spp, samples 995.5, 1003 (Worral) and 1501.5 m	Purcell (1988b)

Appendix 3 (continued)

Well/depth (m)	*Sample type*	*Stratigraphy*	*Fossil type*	*Zone/association*	*Yield*	*TAI*	*CAI*	*Environment*	*Age*	*Comments*	*Reference*
										(base Bongabinni) additionally containing *Dictyotidium* spp, *Lophosphaeridium* spp, *Saharidia* sp., *Filisphaeridium* sp.	
Lovells Pocket 1											
1140	SWC	basal Bongabinni	acritachs, chitinozoans, *G. prisca*	–	low	–	–	–	Middle Ordovician	'Goldwyer-type' assemblage; reworked?	Purcell (1990)
McLarty 1											
464.6 – 465.9	core	Worral	conodonts	*O. communis* zone	53 elements	–	1	–	Ordovician (Arenig)	'Willara-type' assemblage; reworked	Nicoll (1993)
1496.3 – 1497.5	core	Nibil	conodonts	–	two elements	–	1	–	?Ordovician	–	Nicoll (1993)
Munda 1											
1065.3	core	Mallowa	palynology	–	low	–	–	–	indeterminate	Bisaccate indet, *Punctatisporites* sp., *Leiotriletes* sp	Williams (1972)
Musca 1											
926.2	SWC	Sahara	acritachs	–	–	–	–	–	indeterminate	–	Purcell (1983a)
Parda 1											
1032.1	SWC	undivided mid Carribuddy	spores, acritachs	–	low	–	–	–	?post Silurian	*Retusotriletes* suggest not older than Devonian, but could be contaminants	Balme (1965)
1178.7	SWC	Nita–Bongabinni transition	possible acritachs	–	low	–	–	–	indeterminate	possible leiospheres	Balme (1965)
Pegasus 1											
1500–2300	cuttings	upper Nita to Mallowa	acritachs	'*Pterospermopsimorpha*'	low	–	–	restricted shallow marine	indeterminate	*Pterospermopsimorpha* sp, *Leiospaeridia* spp, *Micrhystridium* spp, *Lophosphaeridium* spp	Purcell (1988c)
Pictor 1											
765.3	SWC	Sahara	acritachs	'*Pterospermopsimorpha*'	low	–	–	–	indeterminate	*Leiospaeridia* spp, *Pterospermopsimorpha* sp\	Purcell (1985)
874.5	SWC	Bongabinni	acritachs	'*Pterospermopsimorpha*'	low	–	–	–	indeterminate	*Leiospaeridia* spp, *Pterospermopsimorpha* sp, *Baltisphaeridium* spp	Purcell (1985)
Vela 1											
769.5 – 1703.0	SWC	Bongabinni to Worral	acritachs	–	–	–	–	–	indeterminate	*Micrhystridium* sp, *Pterospermopsimorpha* sp *Leiosphaeridia* sp, et al.	Purcell (1983b)

NOTES:
SWC — Side wall core
TAI — Thermal alteration index
CAI — Conodont alteration index
undivided — Undivided at formation level

Appendix 4

Drillcore intervals in Carribuddy Group and Worral Formation

Well or drillhole name	Worral Formation		Sahara Formation		Mallowa Salt		Nibil Formation		Minjoo Salt		Mount Troy Formation		Bongabinni Formation		Undifferentiated Carribuddy Group	
	top	*base*	*top*	*base*	*top*	*base*	*top*	*base*	*top*	*base*	*top*	*base*	*top*	*base*	*top*	*base*
Petroleum wells																
Acacia 1	372	524.5	–	–	–	–	–	–	–	–	–	–	–	–	524.5	693.5
Barbwire 1	481.9	491	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Boab 1	880.5	1 015	1 015	1 033.4	–	–	–	–	–	–	–	–	–	–	–	–
Crossland 2	684.6	691	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cudalgarra 2	–	–	–	–	–	–	1 308	1 309	–	–	1 309	1 313.5	1 345	1 354	–	–
Drosera 1	440.5	450	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Edgar Range 1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	640.1	643.1
Frome Rocks 1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	313.9	318.8
Frome Rocks 1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	389.2	392.3
Frome Rocks 1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	512.1	515.1
Frome Rocks 1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	634	635.4
Frome Rocks 1	–	–	–	–	755.9	759	–	–	–	–	–	–	–	–	–	–
Frome Rocks 1	–	–	–	–	835.2	838.2	–	–	–	–	–	–	–	–	–	–
Frome Rocks 1	–	–	–	–	894.9	897.9	–	–	–	–	–	–	–	–	–	–
Frome Rocks 1	–	–	–	–	957.7	960.7	–	–	–	–	–	–	–	–	–	–
Frome Rocks 1	–	–	–	–	1 021.1	1 024.1	–	–	–	–	–	–	–	–	–	–
Frome Rocks 1	–	–	–	–	1 085.1	1 088.1	–	–	–	–	–	–	–	–	–	–
Frome Rocks 1	–	–	–	–	1 149.1	1 152.1	–	–	–	–	–	–	–	–	–	–
Frome Rocks 1	–	–	–	–	1 211.6	1 214.6	–	–	–	–	–	–	–	–	–	–
Juno 1	–	–	–	–	–	–	–	–	–	–	–	–	1 644	1 648.5	–	–
Kemp Field 1	1 123.2	1 126.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Kemp Field 1	1 178.1	1 181.1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Kidson 1	2 608.5	2 611.5	2 768.8	2 771.9	3 095.2	3 102.9	3 543	3 556	4 031.3	4 034.3	–	–	4 191.6	4 193.7	–	–
Kidson 1	–	–	2 929.4	2 932.5	3 276.6	3 282.7	3 711.9	3 714.9	–	–	–	–	–	–	–	–
Kidson 1	–	–	–	–	–	–	3 742	3 744.5	–	–	–	–	–	–	–	–
Kidson 1	–	–	–	–	–	–	3 864.3	3 867.3	–	–	–	–	–	–	–	–
Kunzea 1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	261.5	292
McLarty 1	463.3	466.3	–	–	735.8	744.9	1 496	1 499	–	–	–	–	–	–	–	–
McLarty 1	577.6	580.6	–	–	1 288.4	1 291.4	–	–	–	–	–	–	–	–	–	–
Munda 1	–	–	–	–	1 060.7	1 066.8	–	–	–	–	–	–	–	–	–	–
Musca 1	–	–	965	969.3	–	–	–	–	–	–	–	–	1 443.3	1 448	–	–
Nita Downs 1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1 333	1 342.6
Pictor 1	–	–	–	–	–	–	–	–	–	–	–	–	844.5	845	–	–
Sahara 1	1 851.1	1 853.8	–	–	2 118.7	2 120.2	–	–	–	–	–	–	–	–	–	–
Sahara 1	1 999.8	2 003.1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Santalum 1A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	321	372
Solanum 1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	136.5	223
Willara 1	–	–	1 147	1 150.6	1 284.7	1 287.8	1 460	1 462.2	1 602	1 605.1	–	–	1 739.2	1 743.8	–	–
Willara 1	–	–	–	–	1 459.1	1 460	–	–	–	–	–	–	–	–	–	–
Wilson Cliffs 1	1 814.8	1 819.4	–	–	–	–	–	–	2 434.1	2 437.2	–	–	2 568.5	2 572.2	2 211.6	2 215
	1 992.5	1 997.4	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Appendix 4 (continued)

Well or drillhole name	Worral Formation		Sahara Formation		Mallowa Salt		Nibil Formation		Minjoo Salt		Mount Troy Formation		Bongabinni Formation		Undifferentiated Carribuddy Group	
	top	*base*	*top*	*base*	*top*	*base*	*top*	*base*	*top*	*base*	*top*	*base*	*top*	*base*	*top*	*base*
Mineral drillholes																
Brooke 1	863.2	935	935	971.5	971.5	1 662.2	–	–	–	–	–	–	–	–	–	–
Gingerah Hill 1	792.5	nd	nd	990.7	990.7	1 473.5	–	–	–	–	–	–	–	–	–	–
DD86SS2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	[a]1 167	[a]1 324
DD86SS3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1 220	1 380.5
DD87SS4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	[a]1 200.5	[a]1 357
DD87SS5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	[a]1 231.4	[a]1 269.4
DD87SS6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	[a]1 203	[a]1 469
DD87SS7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	[a]1 238	[a]1 463
DD88SS8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	[a]1 363.1	[a]1 492
DD88SS9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1 295.7	1 408
DD88SS10	–	–	1 224.3	1 271.5	1 271.5	1 350	–	–	–	–	–	–	–	–	1 350	1 647
DD88SS11	–	–	–	–	–	–	–	–	–	–	–	–	1 559.8	1 740	–	–
DD88SS12	–	–	–	–	–	–	–	–	–	–	–	–	1 644	1 686.5	–	–
DD89SS14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1 352	1 424
DD89SS15	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1 278	1 360.5
DD89SS16	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1 304	1 350
DD89SS17	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1 315.5	1 358
DD89SS18	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1 333	1 419.5
DD90SS19	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1 366.1	1 571
DD90SS20	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1 275	1 390.5
DD90SS21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1 388.9	1 551
DD91SS22	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1 198.4	1 265
DD91SS23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1 238	1 284.5
DD91SS24	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1 253.8	1 355
DD88CL1	?362.9	395.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–
BW1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	[a]208	[a]246.6
BW3A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	[a]244.9	[a]312.4
BW5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	[a]300	[a]419
BW15	–	–	–	–	–	–	–	–	–	–	–	–	–	–	[a]498	[a]550.5
BW24	[a]296	[a]383	–	–	–	–	–	–	–	–	–	–	–	–	[a]383	[a]466.4
BW26	[a]159	[a]347	–	–	–	–	–	–	–	–	–	–	–	–	[a]347	[a]423.5
BW27	[a]416	[a]446	–	–	–	–	–	–	–	–	–	–	–	–	[a]446	[a]452.5

NOTES: (a) Company picks only; not reassessed
nd not determined

Appendix 5

Organic geochemistry data for the Bongabinni Formation, Admiral Bay Fault Zone

Drillhole	*Depth (m)*	*Sample*	*Tmax*	S_1	S_2	S_3	S_1+S_2	S_2/S_3	*PI*	*TOC*	*HI*	*OI*	*Reference*
DD86SS2	1 295.7	Core	444	6.76	70.49	2.84	77.25	24.82	0.09	15.63	451	18	GSWA, unpublished
DD86SS3	1 330.5	Core	444	7.58	87.41	0	94.99	0	0.08	22.60	387	0	McCracken (1997)
DD86SS3	1 330.5	Core	443	11.20	135.93	0.87	147.13	156.24	0.08	38.60	352	2	Taylor (1992)
DD86SS3	1 335.2	Core	442	12.96	145.55	4.44	25.92	32.78	0.08	15.72	926	28	Ghori and Haines (2006)
DD86SS3	1 335.4	Core	438	9.21	102.54	8.82	18.42	11.63	0.08	62.18	165	14	Ghori and Haines (2006)
DD86SS3	1 335.4	Core	440	13.75	174.79	0.83	188.54	210.59	0.07	54.30	321	1	Taylor (1992)
DD86SS3	1 335.6	Core	445	9.79	144.48	0	154.27	0	0.06	37.10	389	0	McCracken (1997)
DD86SS3	1 337.9	Core	499	3.11	47.63	3.97	6.22	12.00	0.06	10.35	460	38	Ghori and Haines (2006)
DD86SS3	1 338.4	Core	435	31.28	9.10	3.49	40.38	2.61	0.77	9.77	93	36	McCracken (1997)
DD86SS3	1 338.4	Core extract	441	0.91	4.03	3.18	4.94	1.27	0.18	–	–	–	McCracken (1997)
DD86SS3	1 338.5	Core	452	2.52	14.79	1.27	5.04	11.65	0.15	5.15	287	25	Ghori and Haines (2006)
DD86SS3	1 352.1	Core	452	6.60	70.00	5.47	13.20	12.80	0.09	24.39	287	22	Ghori and Haines (2006)
DD86SS3	1 352.1	Core	446	9.59	111.53	0.91	121.12	122.56	0.08	32.70	341	2	Taylor (1992)
DD86SS3	1 355.2	Core	444	12.54	146.17	0.68	158.71	214.96	0.08	35.00	417	1	Taylor (1992)
DD86SS3	1 355.4	Core	451	2.32	24.31	1.59	4.64	15.29	0.09	8.40	289	19	Ghori and Haines (2006)
DD86SS3	1 359.4	Core	441	1.62	12.70	0.32	14.32	39.69	0.11	3.88	327	8	Taylor (1992)
DD87SS6	1 415.8	Core	408	0.20	0.25	0.07	0.45	3.57	0.45	0.92	27	7	Taylor (1992)
DD86SS9	1 360.1	Core	451	6.86	76.26	4.17	13.72	18.29	0.08	26.39	289	16	Ghori and Haines (2006)
DD86SS9	1 356.2	Core	448	5.80	69.46	0	75.26	0	0.08	18.90	368	0	McCracken (1997)
DD86SS9	1 356.2	Core extract	448	0.08	63.84	0	63.92	0	0.00	–	–	–	McCracken (1997)
DD86SS9	1 359.6	Core	445	18.50	189.71	0	208.21	0	0.09	46.00	412	0	McCracken (1997)
DD86SS9	1 379.4	Core	449	4.27	35.03	0	39.30	0	0.11	11.32	309	0	McCracken (1997)
DD86SS9	1 380.4	Core	451	6.37	51.72	2.75	12.74	18.81	0.11	20.60	251	13	Ghori and Haines (2006)
DD86SS9	1 390.6	Core	453	5.00	37.93	2.75	10.00	13.79	0.12	14.74	257	19	Ghori and Haines (2006)
DD86SS9	1 391.3	Core	443	18.26	167.43	0	185.69	0	0.10	40.90	409	0	McCracken (1997)
DD89SS15	1 280.6	Core	436	4.11	29.70	1.86	33.81	15.97	0.12	9.04	329	21	GSWA, unpublished
DD89SS15	1 296.6	Core	439	7.15	69.21	2.54	76.36	27.25	0.09	13.09	529	19	GSWA, unpublished
DD89SS15	1 334.2	Core	444	4.30	30.20	2.30	34.50	13.13	0.12	10.50	288	22	GSWA, unpublished
DD89SS15	1 335.5	Core	446	1.55	10.97	2.33	12.52	4.71	0.12	4.87	225	48	GSWA, unpublished
DD89SS15	1 338.1	Core	443	3.46	23.86	2.07	27.32	11.53	0.13	9.03	264	23	GSWA, unpublished
DD89SS15	1 340.9	Core	441	9.20	101.18	3.06	110.38	33.07	0.08	16.19	625	19	GSWA, unpublished
DD89SS15	1 344.0	Core	440	5.44	25.64	3.06	31.08	8.38	0.18	10.01	256	31	GSWA, unpublished
DD89SS15	1 346.0	Core	444	14.85	159.80	5.04	174.65	31.71	0.09	35.45	451	14	GSWA, unpublished
DD89SS15	1 348.0	Core	443	3.46	24.75	3.06	28.21	8.09	0.12	8.63	287	35	GSWA, unpublished
DD89SS17	1 347.8	Core	446	5.69	44.16	0	49.85	0	0.11	12.43	355	0	McCracken (1997)
DD89SS17	1 347.8	Core extract	446	0.12	43.69	0	43.81	0	0.00	–	–	–	McCracken (1997)

NOTES:
Tmax — Temperature of maximum pyrolitic yield (°C)
S_1 — Volatile hydrocarbons (mg/g rock)
S_2 — Pyrolitic yield or hydrocarbon-generating potential (mg/g rock)
S_3 — Organic carbon dioxide (mg/g rock)
S_1+S_2 — Potential yield
PI — Production index $\{S_1/(S_1+S_2)\}$
TOC — Total organic carbon (wt% of rock)
HI — Hydrogen index
OI — Oxygen index

Appendix 6

New and revised lithostratigraphic definitions

Dodonea Member (new name for previously defined but invalidly named unit)

***Derivation of name*:** Dodonea 1 petroleum exploration well (19°23'6.15"S 125°9'43.35"E, CROSSLAND*), in which the member is intersected close to the type and reference sections.

***Synonymy*:** Previously referred to as the 'lower carbonate member' (Lehmann, 1984).

***Constituent units*:** None.

***Parent unit*:** Worral Formation.

***Distribution/extent*:** Best developed on the Barbwire Terrace, eastern Broome Platform and Crossland Platform of the Canning Basin, Western Australia. Absent in western and southern parts of the basin. Only known from the sub-surface.

***Geomorphic expression*:** Sub-surface only.

***Type locality*:** The interval 596–613 m in Barbwire 1 (19°10'33.32"S 125°1'4.01"E; CROSSLAND), as nominated by Lehmann (1984) for the 'lower carbonate member'. Reference localities: Because the type section is not cored, the fully cored intervals 503.95 – 524.23 m in Acacia 1 (19°19'44.95"S 124°59'43.66"E) and 1002–1015 m Boab 1 (19°34'36.95"S 125°8'49.66"E) are nominated as reference sections. Core is stored in Geological Survey of Western Australia Perth core library.

***Description at type locality*:** Off-white to pale green-grey finely crystalline dolomite; hard, brittle, pyritic, non-porous, calcite veining.

***Thickness*:** 17 m at type section, 20.28 m and 13 m at the Acacia 1 and Boab 1 reference sections, respectively. These thicknesses are typical for the unit throughout its distribution.

***Lithology*:** Dominated by massive carbonate, most commonly pale grey to beige dolomite, but including limestone in some wells. Grades to dolomitic or calcareous mudstone at the top. Minor sandy component in some wells.

***Depositional environment*:** Shallow marginal marine, probably lagoonal.

***Fossils*:** Conodonts and scelecodonts recovered from drillcore from Boab 1 and Acacia 1 (Nicoll et al., 1994).

***Diastems or hiatuses*:** None known.

***Relationships and boundary criteria*:** Overlies the Sahara Formation (Carribuddy Group) with apparent conformity. Sharply, but probably conformably overlain by the Elsa Sandstone Member at the type section and in nearby wells. Appears to interfinger with the Elsa Sandstone Member to the west.

***Age and evidence*:** The conodont *Ozarkodina hassi* provides a Llandovery (Early Silurian) age (Nicoll et al., 1994). The earlier report of a Devonian ostracod and foraminifera fauna in this unit in Boab 1 (Jones and Nicoll, 1982; Nicoll et al., 1994) is no longer valid as the sample depth has been shown to be in error.

***Correlation with other units*:** Appears to interfinger with the Elsa Sandstone Member to the west.

Pegasus Dolomite Member (new name)

***Derivation of name*:** Pegasus 1 petroleum exploration well (20°5'45.60"S 123°57'8.83"E, JOANNA SPRING), in which the member is intersected close to the centre of its known distribution.

***Synonymy*:** None.

***Constituent units*:** None.

***Parent unit*:** Sahara Formation.

***Distribution/extent*:** Widespread in the Canning Basin in wells south of the Fenton Fault Zone, although apparently absent (or thin) in the southern and eastern Kidson Sub-basin. Commonly removed by pre-Permian erosion in wells near the west coast. Only known from the sub-surface.

***Geomorphic expression*:** Sub-surface only.

***Type locality*:** The fully cored interval 550.45 – 552.6 m in petroleum exploration well Acacia 1 (19°19'44.95"S 124°59'43.66"E; CROSSLAND). Wireline log data is available for nearby Acacia 2 (552–554 m). Reference locality for western area: Fully cored interval 971.75 – 975.5 m in mineral exploration drillhole Brooke 1 (19°44'52.17"S 122°55'3.60"E). Both cores are stored in Geological Survey of Western Australia Perth core library.

***Description at type locality*:** Light grey, hard, massive dolomite; stylolitic, with infilled subvertical fractures, microfaults, calcite filled veins and minor vuggy porosity.

***Thickness*:** Thickness at type section 2.15 m. Average thickness estimated at 2.75 m. Maximum thickness 4.5 m in petroleum explorations wells Pegasus 1 and Sally May 1.

***Lithology*:** Typically hard, massive to nodular and laminated, fine grained, cream to pale grey and brown dolomite and argillaceous to silty dolomite. Local

* Capitalized names refer to standard 1:250 000 unless otherwise indicated.

anhydrite. The member has a distinctive signature on wireline logs (a sharp and often double spike on gamma and sonic logs) allowing it to be easily recognized in numerous petroleum exploration wells.

***Depositional environment*:** Shallow or marginal marine incursion.

***Fossils*:** None known.

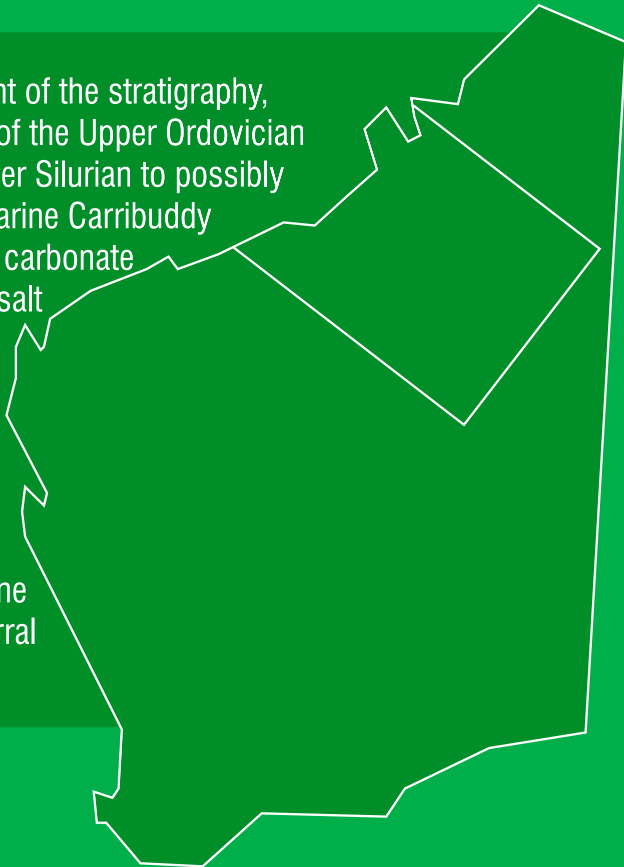
***Diastems or hiatuses*:** None known.

***Relationships and boundary criteria*:** A conformable member within or occasionally at the base the Sahara Formation of the Carribuddy Group. Boundaries are relatively sharp with mudstone below and above. Although this thin marker was probably deposited approximately synchronously across the basin, its position relative to the base of the Sahara Formation varies because of the diachronous nature of the salt-defined lower boundary of the formation. In several wells it lies at the base of the Sahara Formation.

***Age and evidence*:** No internal evidence for age. The age is inferred to be Late Ordovician to Early Silurian based on biostratigraphic ages from the underlying Mallowa Salt (Foster and Williams, 1991) and overlying basal Worral Formation (Nicoll et al., 1994).

***Correlation with other units*:** None.

***Comments*:** A valuable stratigraphic marker aiding well correlations across the basin.



This Report provides a detailed reassessment of the stratigraphy, sedimentology, age and petroleum potential of the Upper Ordovician to Lower Silurian Carribuddy Group and Lower Silurian to possibly Devonian Worral Formation. The marginal marine Carribuddy Group is dominated by mudstone and minor carbonate lithofacies, and includes two thick lenticular salt formations that provide a seal over the Ordovician petroleum system. The Worral Formation includes similar facies, but lacks significant evaporites. The Bongabinni Formation, basal unit of the Carribuddy Group, locally contains excellent quality oil-prone source rocks, while minor sandstone units in the upper Carribuddy Group and Worral Formation have good reservoir properties.

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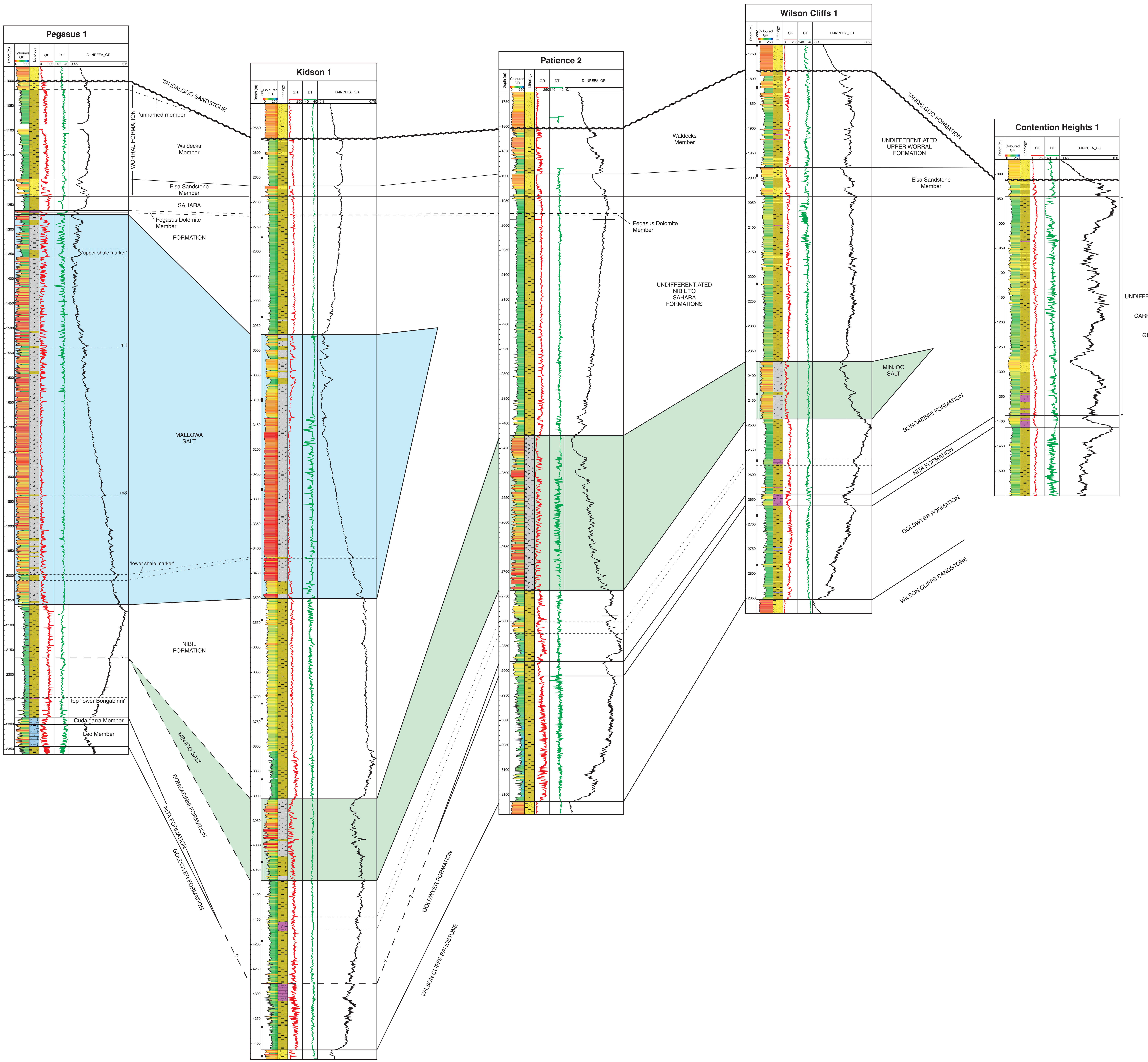

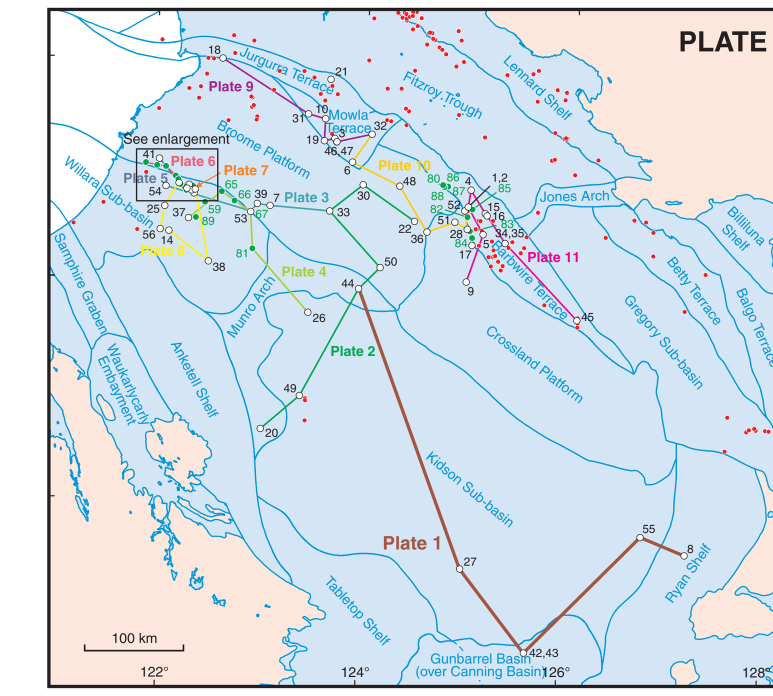

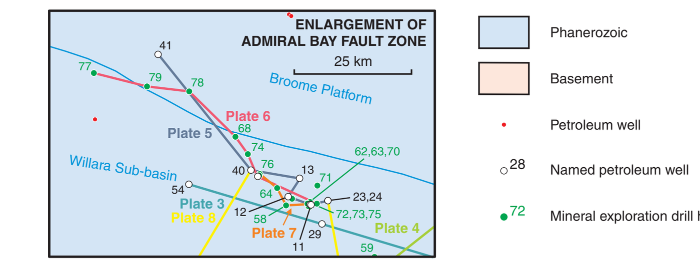

Phanerozoic
Basement
Petroleum well
Named petroleum well
Mineral exploration drill hole

PLATE 1

STRATIGRAPHIC CORRELATIONS

PEGASUS 1 TO CONTENTION HEIGHTS 1
(MUNRO ARCH TO RYAN SHELF)

1	Acacia 1	24	Great Sandy 2	47	Pictor 2	70	DD89SS15 (CRAE)
2	Acacia 2	25	Juno 1	48	Robert 1	71	DD89SS16 (CRAE)
3	Antares 1	26	Kemp Field 1	49	Sahara 1	72	DD89SS17 (CRAE)
4	Barbwire 1	27	Kidson 1	50	Sally May 1	73	DD89SS18 (CRAE)
5	Boab 1	28	Kunzea 1	51	Santalum 1A	74	DD90SS19 (CRAE)
6	Canopus 1	29	Leo 1	52	Solanum 1	75	DD90SS20 (CRAE)
7	Carina 1	30	Looma 1	53	Vela 1	76	DD90SS21 (CRAE)
8	Contention Heights 1	31	Lovells Pocket 1	54	Willara 1	77	DD91SS22 (CRAE)
9	Crossland 2	32	Matches Spring 1	55	Wilson Cliffs 1	78	DD91SS23 (CRAE)
10	Crystal Creek 1	33	McLarty 1	56	Woods Hills 1	79	DD91SS24 (CRAE)
11	Cudalgarra 1	34	Mirbelia 1	57	DD86SS2 (CRAE)	80	DD88CLI (CRAE)
12	Cudalgarra 2	35	Mirbelia 2	58	DD86SS3 (CRAE)	81	Brooke 1 (BHP-Utah)
13	Cudalgarra North 1	36	Missing 1	59	DD87SS4 (CRAE)	82	BW1 (Pasminco)
14	Darriwell 1	37	Munda 1	60	DD87SS5 (CRAE)	83	BW3A (Pasminco)
15	Dodonea 1	38	Munro 1	61	DD87SS6 (CRAE)	84	BW5 (Pasminco)
16	Dodonea 2	39	Musca 1	62	DD87SS7 (CRAE)	85	BW15 (Pasminco)
17	Drosera 1	40	Nita Downs 1	63	DD88SS8 (CRAE)	86	BW24 (Pasminco)
18	East Crab Creek 1	41	Parda 1	64	DD88SS9 (CRAE)	87	BW26 (Pasminco)
19	Edgar Range 1	42	Patience 1	65	DD88SS10 (CRAE)	88	BW27 (Pasminco)
20	Frankenstein 1	43	Patience 2	66	DD88SS11 (CRAE)	89	Gingerah Hill 1 (BHP-Utah)
21	Frome Rocks 1	44	Pegasus 1	67	DD88SS12 (CRAE)		
22	Fruitcake 1	45	Percival 1	68	DD88SS13 (CRAE)		
23	Great Sandy 1	46	Pictor 1	69	DD89SS14 (CRAE)		

ROCK TYPES

- Conglomerate
- Sandstone
- Mudstone
- Limestone
- Dolomitic limestone
- Dolomite
- Halite

MODIFIERS

- Pebbly
- Breccia
- Sandy or sandstone interbeds
- Argillaceous, silty, or mudstone interbeds
- Calcareous
- Dolomitic
- Limestone interbeds
- Dolomitic interbeds
- Halite bearing
- Anhydrite / gypsum

LITHOSTRATIGRAPHIC BOUNDARIES

- Unconformity / Disconformity
- Formation boundary
- Formation boundary (approx.)
- Member boundary
- Member boundary (approx.)
- Minor tie point
- Boundary of inferred salt dissolution or disseminated salt

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
REPORT 105 PLATE 1

STRATIGRAPHIC CORRELATIONS
PEGASUS 1 TO CONTENTION HEIGHTS 1
(MUNRO ARCH TO RYAN SHELF)

Compiled by PW Haines
Edited by N Tetlaw
Cartography by C Schroder and S Dowsett

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REPORT 105
PLATE 1

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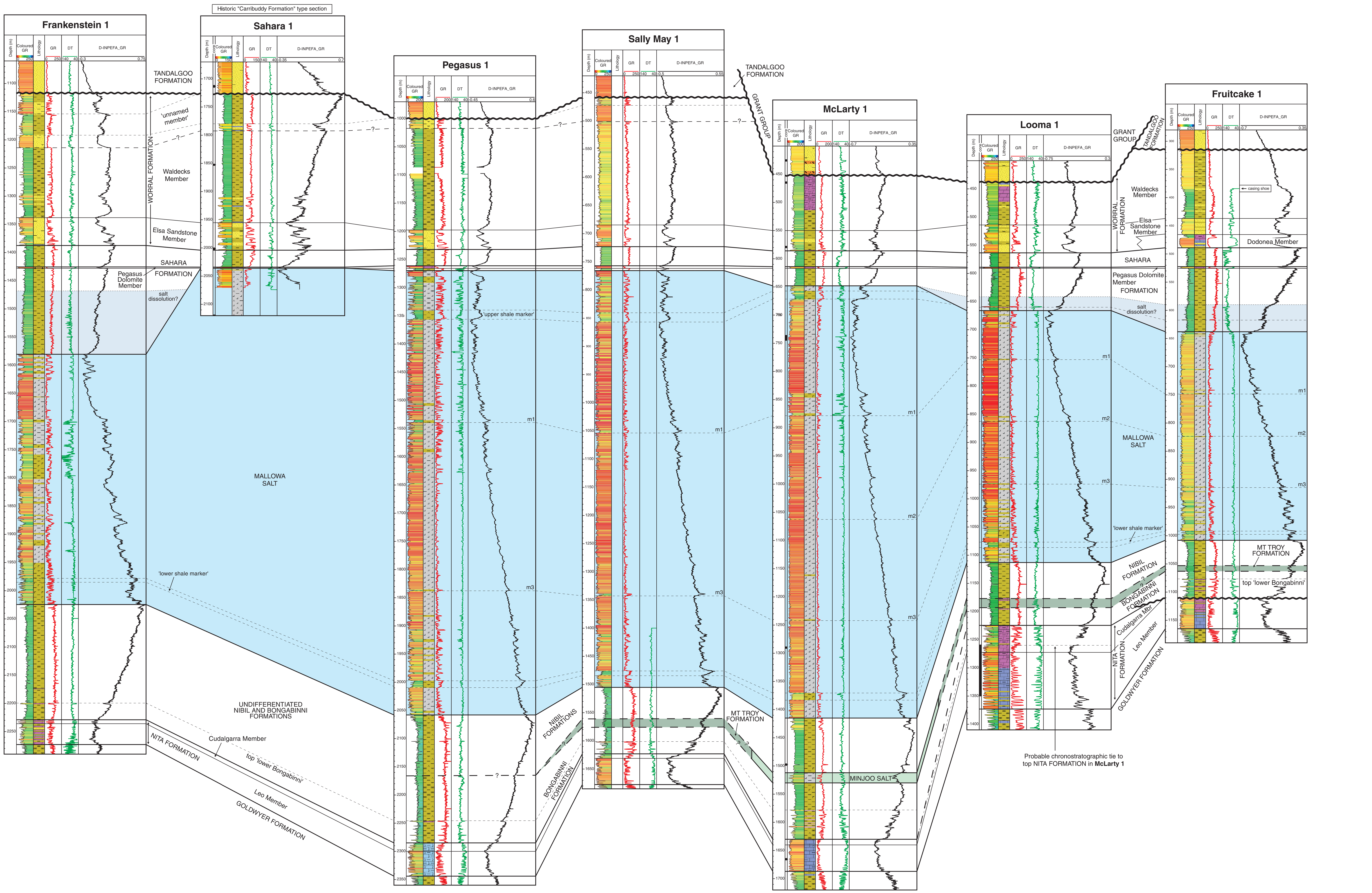

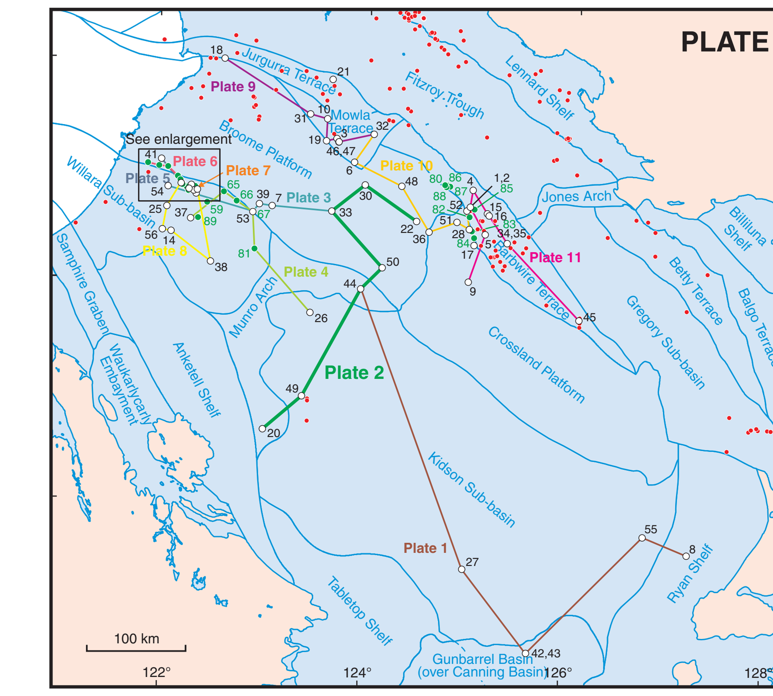

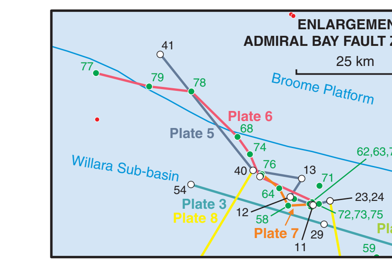

Phanerozoic
Basement
Petroleum well
Named petroleum well
Mineral exploration drill hole

PLATE 2
STRATIGRAPHIC CORRELATIONS
FRANKENSTEIN 1 TO FRUITCAKE 1
(MUNRO ARCH TO BROOME PLATFORM)

1 Acacia 1
2 Acacia 2
3 Antares 1
4 Barbwire 1
5 Boab 1
6 Canopus 1
7 Carina 1
8 Contention Heights 1
9 Crossland 2
10 Crystal Creek 1
11 Cudalgarra 1
12 Cudalgarra 2
13 Cudalgarra North 1
14 Darriwell 1
15 Dodonea 1
16 Dodonea 2
17 Drosera 1
18 East Crab Creek 1
19 Edgar Range 1
20 Frankenstein 1
21 Frome Rocks 1
22 Fruitcake 1
23 Great Sandy 1
24 Great Sandy 2
25 Juno 1
26 Kemp Field 1
27 Kidson 1
28 Kunzea 1
29 Leo 1
30 Looma 1
31 Lovells Pocket 1
32 Matches Spring 1
33 McLarty 1
34 Mirbelia 1
35 Mirbelia 2
36 Missing 1
37 Munda 1
38 Munro 1
39 Musca 1
40 Nita Downs 1
41 Parda 1
42 Patience 1
43 Patience 2
44 Pegasus 1
45 Percival 1
46 Pictor 1
47 Pictor 2
48 Robert 1
49 Sahara 1
50 Sally May 1
51 Santalum 1A
52 Solanum 1
53 Vela 1
54 Willara 1
55 Wilson Cliffs 1
56 Woods Hills 1
57 DD86SS2 (CRAE)
58 DD86SS3 (CRAE)
59 DD87SS4 (CRAE)
60 DD87SS5 (CRAE)
61 DD87SS6 (CRAE)
62 DD87SS7 (CRAE)
63 DD88SS8 (CRAE)
64 DD88SS9 (CRAE)
65 DD88SS10 (CRAE)
66 DD88SS11 (CRAE)
67 DD88SS12 (CRAE)
68 DD88SS13 (CRAE)
69 DD89SS14 (CRAE)
70 DD89SS15 (CRAE)
71 DD89SS16 (CRAE)
72 DD89SS17 (CRAE)
73 DD89SS18 (CRAE)
74 DD90SS19 (CRAE)
75 DD90SS20 (CRAE)
76 DD90SS21 (CRAE)
77 DD91SS22 (CRAE)
78 DD91SS23 (CRAE)
79 DD91SS24 (CRAE)
80 DD88CLI (CRAE)
81 Brooke 1 (BHP-Utah)
82 BW1 (Pasminco)
83 BW3A (Pasminco)
84 BW5 (Pasminco)
85 BW15 (Pasminco)
86 BW24 (Pasminco)
87 BW26 (Pasminco)
88 BW27 (Pasminco)
89 Gingerah Hill 1 (BHP-Utah)

ROCK TYPES

- Conglomerate
- Sandstone
- Mudstone
- Limestone
- Dolomitic limestone
- Dolomite
- Halite

MODIFIERS

- Pebbly
- Breccia
- Sandy or sandstone interbeds
- Argillaceous, silty, or mudstone interbeds
- Calcareous
- Dolomitic
- Limestone interbeds
- Dolomitic interbeds
- Halite bearing
- Anhydrite / gypsum

LITHOSTRATIGRAPHIC BOUNDARIES

- Unconformity / Disconformity
- Formation boundary
- Formation boundary (approx.)
- Member boundary
- Member boundary (approx.)
- Minor tie point
- Boundary of inferred salt dissolution or disseminated salt

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
REPORT 105 PLATE 2
STRATIGRAPHIC CORRELATIONS
FRANKENSTEIN 1 TO FRUITCAKE 1
(MUNRO ARCH TO BROOME PLATFORM)

Compiled by PW Haines
Edited by N Tetlaw
Cartography by C Schroder and S Dowsett

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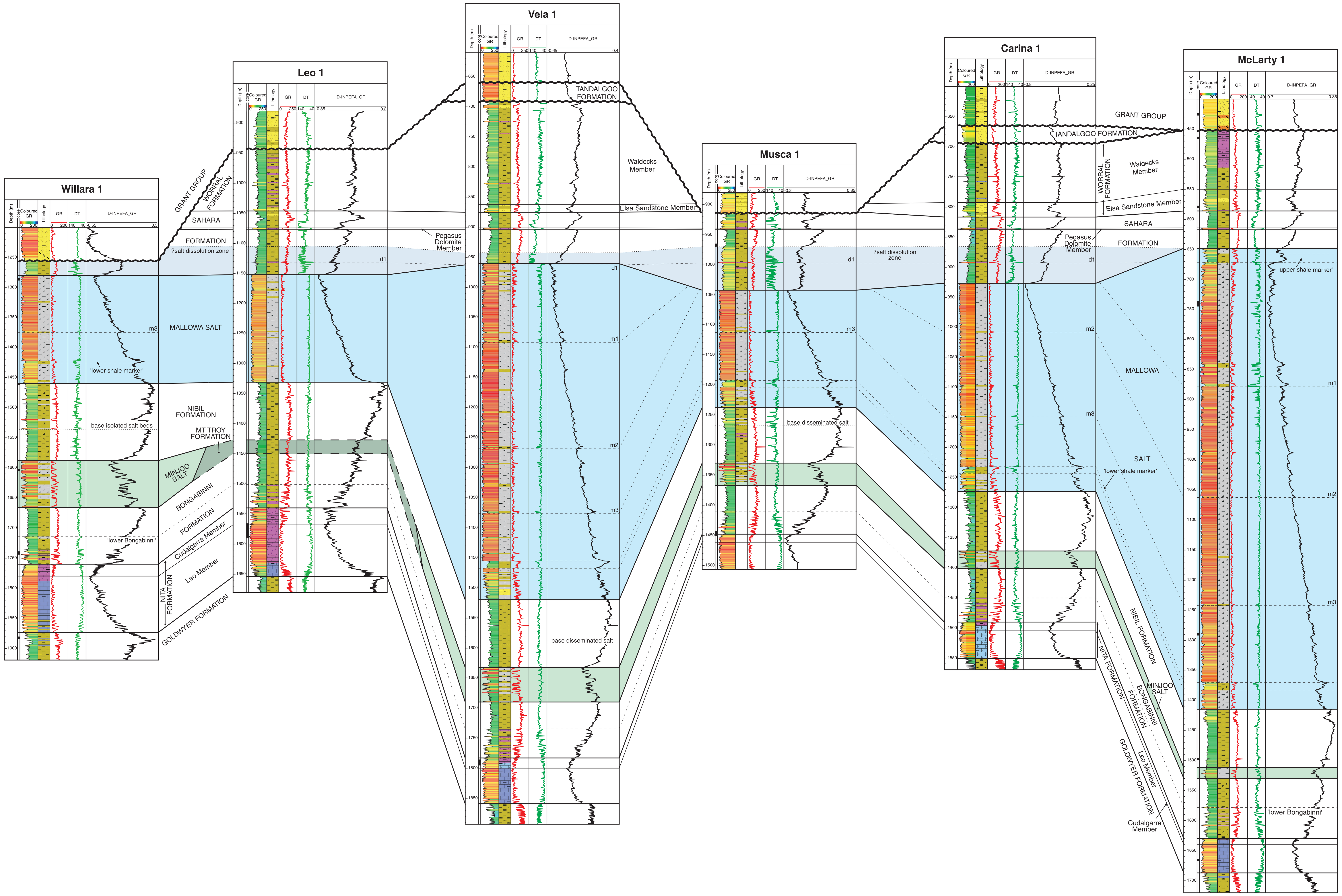

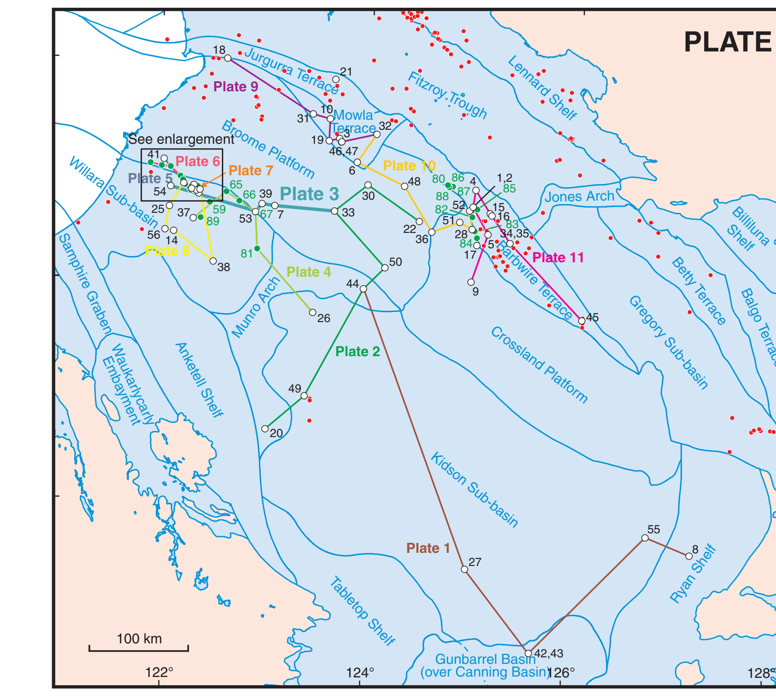

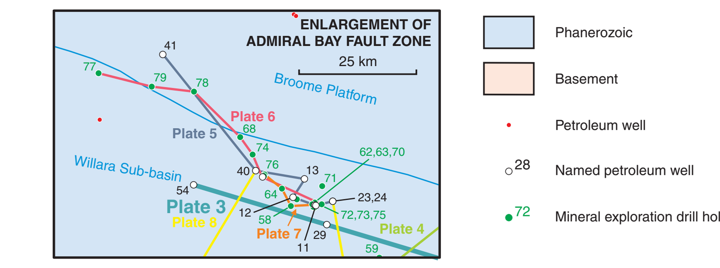

PLATE 3

STRATIGRAPHIC CORRELATIONS

WILLARA 1 TO MCLARTY 1
(WILLARA SUB-BASIN TO BROOME PLATFORM)

1	Acacia 1	24	Great Sandy 2	47	Pictor 2	70	DD89SS15 (CRAE)
2	Acacia 2	25	Juno 1	48	Robert 1	71	DD89SS16 (CRAE)
3	Antares 1	26	Kemp Field 1	49	Sahara 1	72	DD89SS17 (CRAE)
4	Barbwire 1	27	Kidson 1	50	Sally May 1	73	DD89SS18 (CRAE)
5	Boab 1	28	Kunzea 1	51	Santalum 1A	74	DD90SS19 (CRAE)
6	Canopus 1	29	Leo 1	52	Solanum 1	75	DD90SS20 (CRAE)
7	Carina 1	30	Looma 1	53	Vela 1	76	DD90SS21 (CRAE)
8	Contention Heights 1	31	Lovells Pocket 1	54	Willara 1	77	DD91SS22 (CRAE)
9	Crossland 2	32	Matches Spring 1	55	Wilson Cliffs 1	78	DD91SS23 (CRAE)
10	Crystal Creek 1	33	McLarty 1	56	Woods Hills 1	79	DD91SS24 (CRAE)
11	Cudalgarra 1	34	Mirbelia 1	57	DD86SS2 (CRAE)	80	DD88CLI (CRAE)
12	Cudalgarra 2	35	Mirbelia 2	58	DD86SS3 (CRAE)	81	Brooke 1 (BHP-Utah)
13	Cudalgarra North 1	36	Missing 1	59	DD87SS4 (CRAE)	82	BW1 (Pasminco)
14	Darriwell 1	37	Munda 1	60	DD87SS5 (CRAE)	83	BW3A (Pasminco)
15	Dodonea 1	38	Munro 1	61	DD87SS6 (CRAE)	84	BW5 (Pasminco)
16	Dodonea 2	39	Musca 1	62	DD87SS7 (CRAE)	85	BW15 (Pasminco)
17	Drosera 1	40	Nita Downs 1	63	DD88SS8 (CRAE)	86	BW24 (Pasminco)
18	East Crab Creek 1	41	Parda 1	64	DD88SS9 (CRAE)	87	BW26 (Pasminco)
19	Edgar Range 1	42	Patience 1	65	DD88SS10 (CRAE)	88	BW27 (Pasminco)
20	Frankenstein 1	43	Patience 2	66	DD88SS11 (CRAE)	89	Gingerah Hill 1 (BHP-Utah)
21	Frome Rocks 1	44	Pegasus 1	67	DD88SS12 (CRAE)		
22	Fruitcake 1	45	Percival 1	68	DD88SS13 (CRAE)		
23	Great Sandy 1	46	Pictor 1	69	DD89SS14 (CRAE)		

ROCK TYPES

- Conglomerate
- Sandstone
- Mudstone
- Limestone
- Dolomitic limestone
- Dolomite
- Halite

MODIFIERS

- Pebbly
- Breccia
- Sandy or sandstone interbeds
- Argillaceous, silty, or mudstone interbeds
- Calcareous
- Dolomitic
- Limestone interbeds
- Dolomitic interbeds
- Halite bearing
- Anhydrite / gypsum

LITHOSTRATIGRAPHIC BOUNDARIES

- Unconformity / Disconformity
- Formation boundary
- Formation boundary (approx.)
- Member boundary
- Member boundary (approx.)
- Minor tie point
- Boundary of inferred salt dissolution or disseminated salt

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
REPORT 105 PLATE 3

STRATIGRAPHIC CORRELATIONS
WILLARA 1 TO MCLARTY 1
(WILLARA SUB-BASIN TO BROOME PLATFORM)

Compiled by PW Haines
Edited by N Tetlaw
Cartography by C Schroder and S Dowsett

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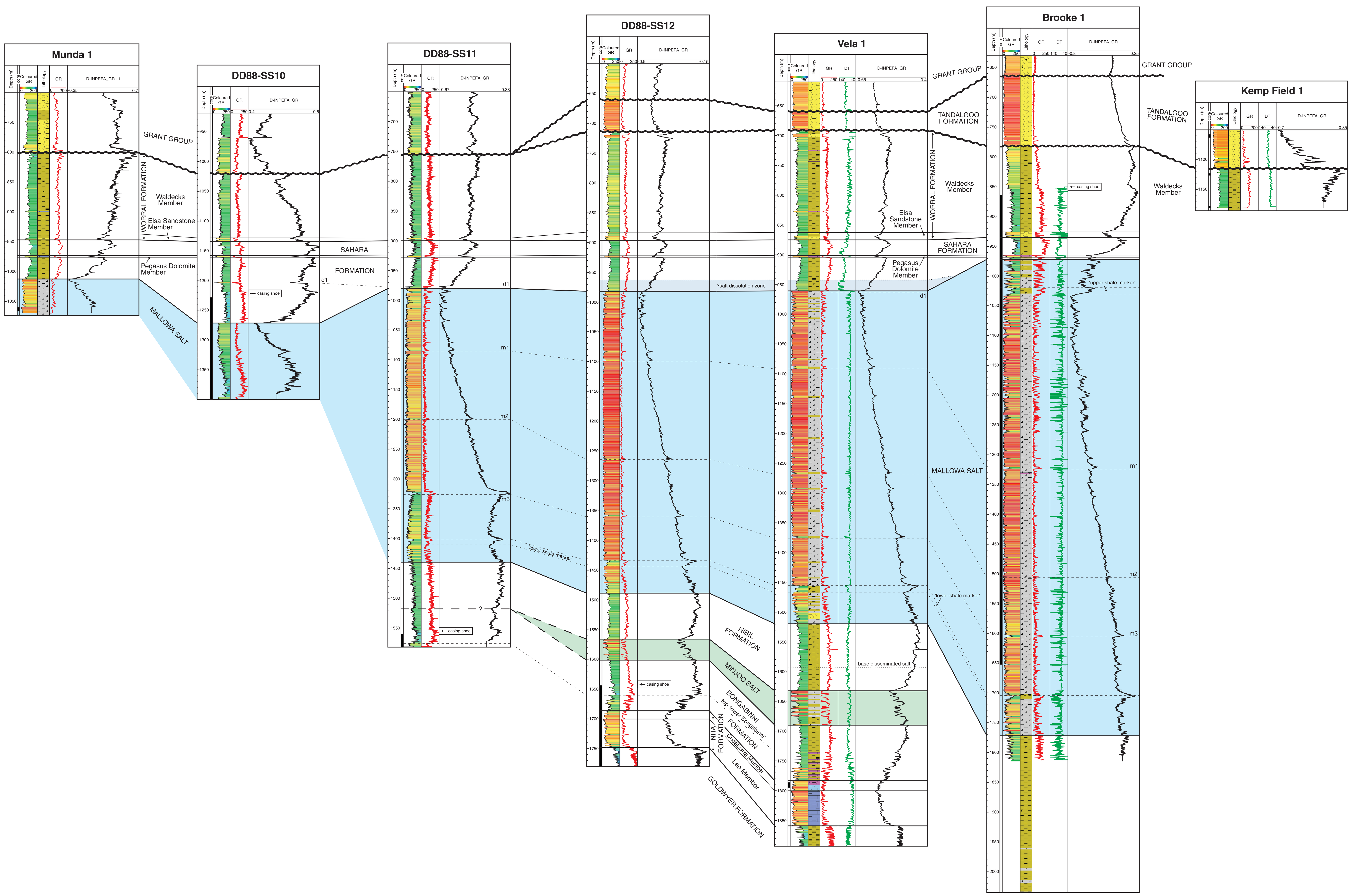

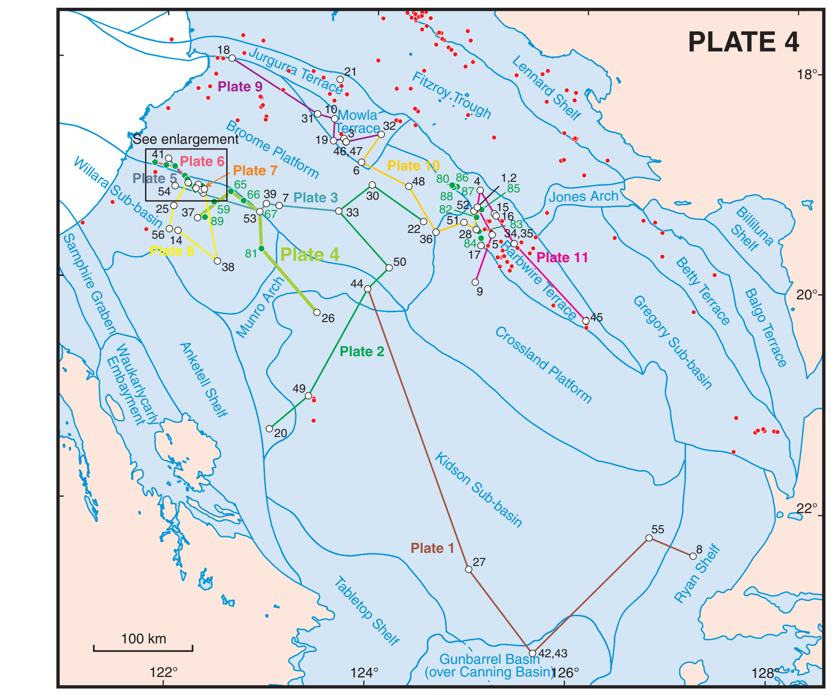

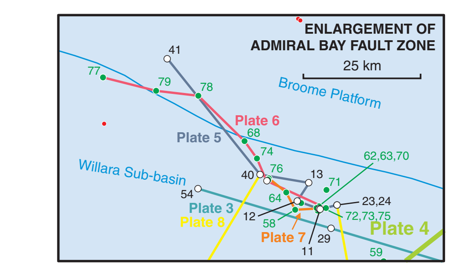

- Phanerozoic
- Basement
- Petroleum well
- Named petroleum well
- Mineral exploration drill hole

PLATE 4

STRATIGRAPHIC CORRELATIONS

MUNDA 1 TO KEMP FIELD 1

(WILLARA SUB-BASIN TO KIDSON SUB-BASIN)

1	Acacia 1	24	Great Sandy 2	47	Pictor 2	70	DD89SS15 (CRAE)
2	Acacia 2	25	Juno 1	48	Robert 1	71	DD89SS16 (CRAE)
3	Antares 1	26	Kemp Field 1	49	Sahara 1	72	DD89SS17 (CRAE)
4	Barbwire 1	27	Kidson 1	50	Sally May 1	73	DD89SS18 (CRAE)
5	Boab 1	28	Kunzea 1	51	Santalum 1A	74	DD90SS19 (CRAE)
6	Canopus 1	29	Leo 1	52	Solanum 1	75	DD90SS20 (CRAE)
7	Carina 1	30	Looma 1	53	Vela 1	76	DD90SS21 (CRAE)
8	Contention Heights 1	31	Lovells Pocket 1	54	Willara 1	77	DD91SS22 (CRAE)
9	Crossland 2	32	Matches Spring 1	55	Wilson Cliffs 1	78	DD91SS23 (CRAE)
10	Crystal Creek 1	33	McLarty 1	56	Woods Hills 1	79	DD91SS24 (CRAE)
11	Cudalgarra 1	34	Mirbelia 1	57	DD86SS2 (CRAE)	80	DD88CLI (CRAE)
12	Cudalgarra 2	35	Mirbelia 2	58	DD86SS3 (CRAE)	81	Brooke 1 (BHP-Utah)
13	Cudalgarra North 1	36	Missing 1	59	DD87SS4 (CRAE)	82	BW1 (Pasminco)
14	Darriwell 1	37	Munda 1	60	DD87SS5 (CRAE)	83	BW3A (Pasminco)
15	Dodonea 1	38	Munro 1	61	DD87SS6 (CRAE)	84	BW5 (Pasminco)
16	Dodonea 2	39	Musca 1	62	DD87SS7 (CRAE)	85	BW15 (Pasminco)
17	Drosera 1	40	Nita Downs 1	63	DD88SS8 (CRAE)	86	BW24 (Pasminco)
18	East Crab Creek 1	41	Parda 1	64	DD88SS9 (CRAE)	87	BW26 (Pasminco)
19	Edgar Range 1	42	Patience 1	65	DD88SS10 (CRAE)	88	BW27 (Pasminco)
20	Frankenstein 1	43	Patience 2	66	DD88SS11 (CRAE)	89	Gingerah Hill 1 (BHP-Utah)
21	Frome Rocks 1	44	Pegasus 1	67	DD88SS12 (CRAE)		
22	Fruitcake 1	45	Percival 1	68	DD88SS13 (CRAE)		
23	Great Sandy 1	46	Pictor 1	69	DD89SS14 (CRAE)		

ROCK TYPES

- Conglomerate
- Sandstone
- Mudstone
- Limestone
- Dolomitic limestone
- Dolomite
- Halite

MODIFIERS

- Pebbly
- Breccia
- Sandy or sandstone interbeds
- Argillaceous, silty, or mudstone interbeds
- Calcareous
- Dolomitic
- Limestone interbeds
- Dolomitic interbeds
- Halite bearing
- Anhydrite / gypsum

LITHOSTRATIGRAPHIC BOUNDARIES

- Unconformity / Disconformity
- Formation boundary
- Formation boundary (approx.)
- Member boundary
- Member boundary (approx.)
- Minor tie point
- Boundary of inferred salt dissolution or disseminated salt

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

REPORT 105 PLATE 4

STRATIGRAPHIC CORRELATIONS

MUNDA 1 TO KEMP FIELD 1

(WILLARA SUB-BASIN TO KIDSON SUB-BASIN)

Compiled by PW Haines
Edited by N Tetlaw
Cartography by C Schroder and S Dowsett

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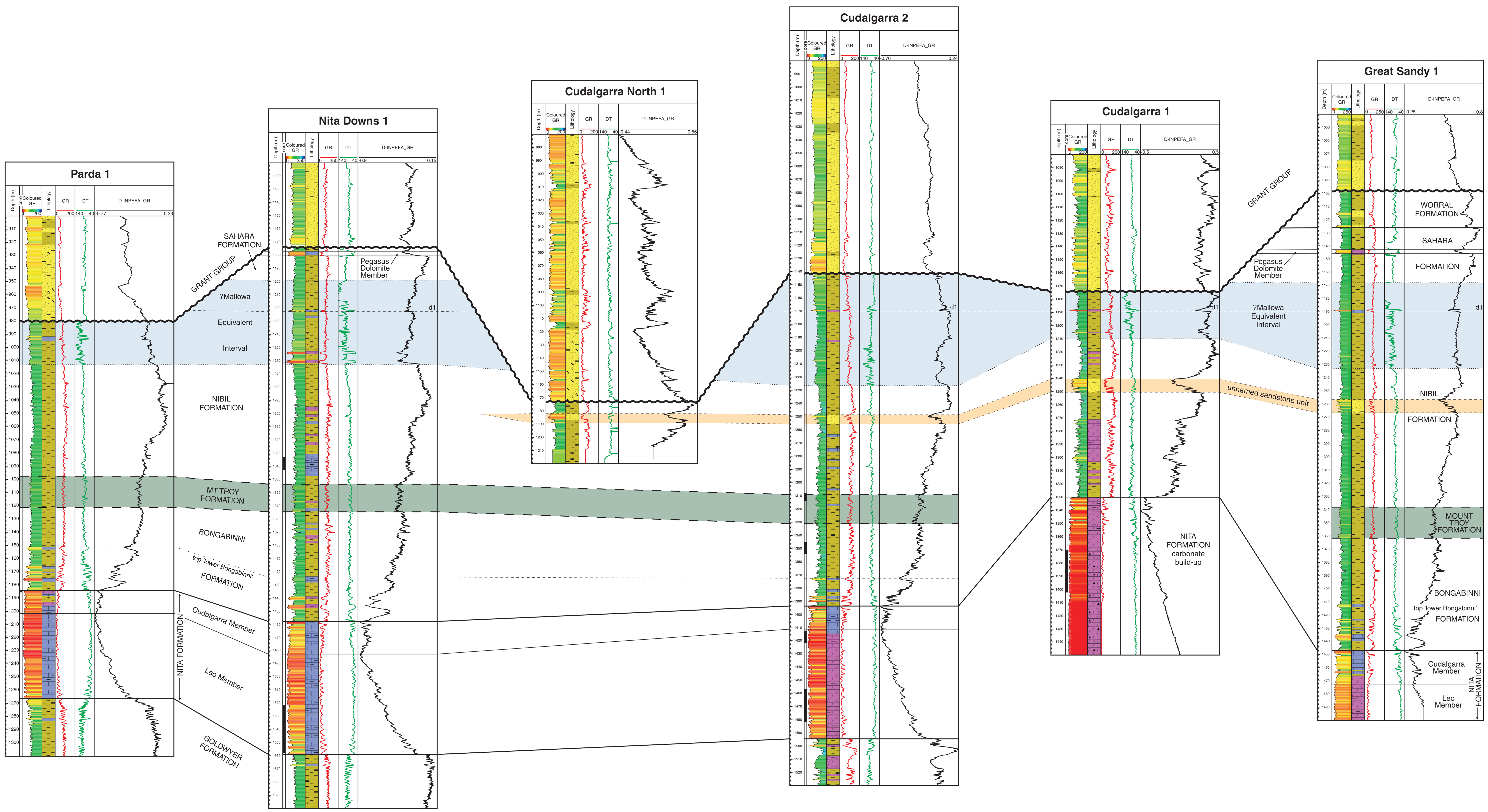
PWH69
09.06.09



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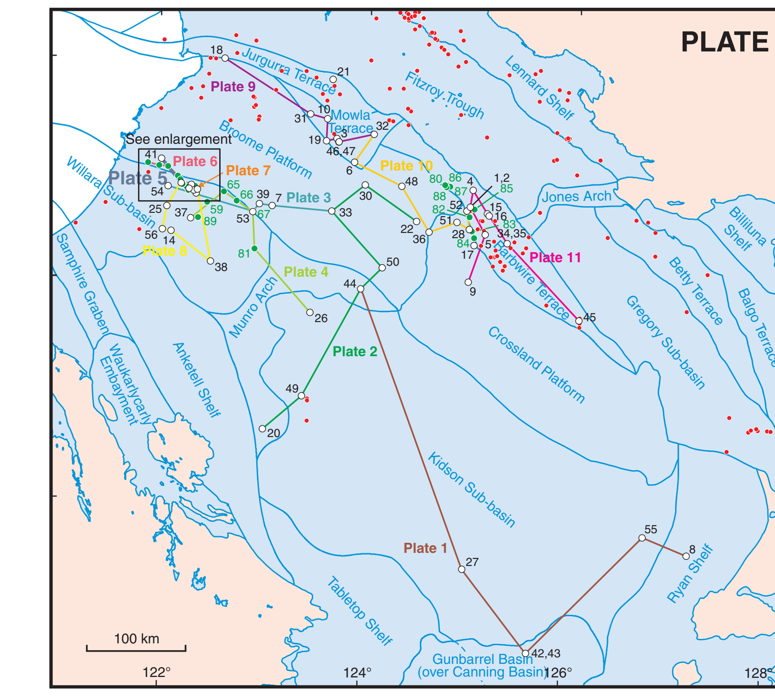

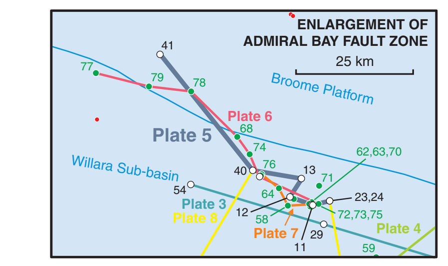

Phanerozoic

Basement

Petroleum well

Named petroleum well

Mineral exploration drill hole

PLATE 5
STRATIGRAPHIC CORRELATIONS
PARDA 1 TO GREAT SANDY 1
(BROOME PLATFORM TO WILLARA SUB-BASIN)

1 Acacia 1
2 Acacia 2
3 Antares 1
4 Barbwire 1
5 Boab 1
6 Canopus 1
7 Carina 1
8 Contention Heights 1
9 Crossland 2
10 Crystal Creek 1
11 Cudalgarra 1
12 Cudalgarra 2
13 Cudalgarra North 1
14 Darriwell 1
15 Dodonea 1
16 Dodonea 2
17 Drosera 1
18 East Crab Creek 1
19 Edgar Range 1
20 Frankenstein 1
21 Frome Rocks 1
22 Fruitcake 1
23 Great Sandy 1
24 Great Sandy 2
25 Juno 1
26 Kemp Field 1
27 Kidson 1
28 Kunzea 1
29 Leo 1
30 Looma 1
31 Lovells Pocket 1
32 Matches Spring 1
33 McLarty 1
34 Mirbelia 1
35 Mirbelia 2
36 Missing 1
37 Munda 1
38 Munro 1
39 Musca 1
40 Nita Downs 1
41 Parda 1
42 Patience 1
43 Patience 2
44 Pegasus 1
45 Percival 1
46 Pictor 1
47 Pictor 2
48 Robert 1
49 Sahara 1
50 Sally May 1
51 Santalum 1A
52 Solanum 1
53 Vela 1
54 Willara 1
55 Wilson Cliffs 1
56 Woods Hills 1
57 DD86SS2 (CRAE)
58 DD86SS3 (CRAE)
59 DD87SS4 (CRAE)
60 DD87SS5 (CRAE)
61 DD87SS6 (CRAE)
62 DD87SS7 (CRAE)
63 DD88SS8 (CRAE)
64 DD88SS9 (CRAE)
65 DD88SS10 (CRAE)
66 DD88SS11 (CRAE)
67 DD88SS12 (CRAE)
68 DD88SS13 (CRAE)
69 DD89SS14 (CRAE)
70 DD89SS15 (CRAE)
71 DD89SS16 (CRAE)
72 DD89SS17 (CRAE)
73 DD89SS18 (CRAE)
74 DD90SS19 (CRAE)
75 DD90SS20 (CRAE)
76 DD90SS21 (CRAE)
77 DD91SS22 (CRAE)
78 DD91SS23 (CRAE)
79 DD91SS24 (CRAE)
80 DD88CLI (CRAE)
81 Brooke 1 (BHP-Utah)
82 BW1 (Pasminco)
83 BW3A (Pasminco)
84 BW5 (Pasminco)
85 BW15 (Pasminco)
86 BW24 (Pasminco)
87 BW26 (Pasminco)
88 BW27 (Pasminco)
89 Gingerah Hill 1 (BHP-Utah)

ROCK TYPES

- Conglomerate
- Sandstone
- Mudstone
- Limestone
- Dolomitic limestone
- Dolomite
- Halite

MODIFIERS

- Pebbly
- Breccia
- Sandy or sandstone interbeds
- Argillaceous, silty, or mudstone interbeds
- Calcareous
- Dolomitic
- Limestone interbeds
- Dolomitic interbeds
- Halite bearing
- Anhydrite / gypsum

LITHOSTRATIGRAPHIC BOUNDARIES

- Unconformity / Disconformity
- Formation boundary
- Formation boundary (approx.)
- Member boundary
- Member boundary (approx.)
- Minor tie point
- Boundary of inferred salt dissolution or disseminated salt

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
REPORT 105 PLATE 5
STRATIGRAPHIC CORRELATIONS
PARDA 1 TO GREAT SANDY 1
(BROOME PLATFORM TO WILLARA SUB-BASIN)

Compiled by PW Haines
Edited by N Tetlaw
Cartography by C Schroder and S Dowsett

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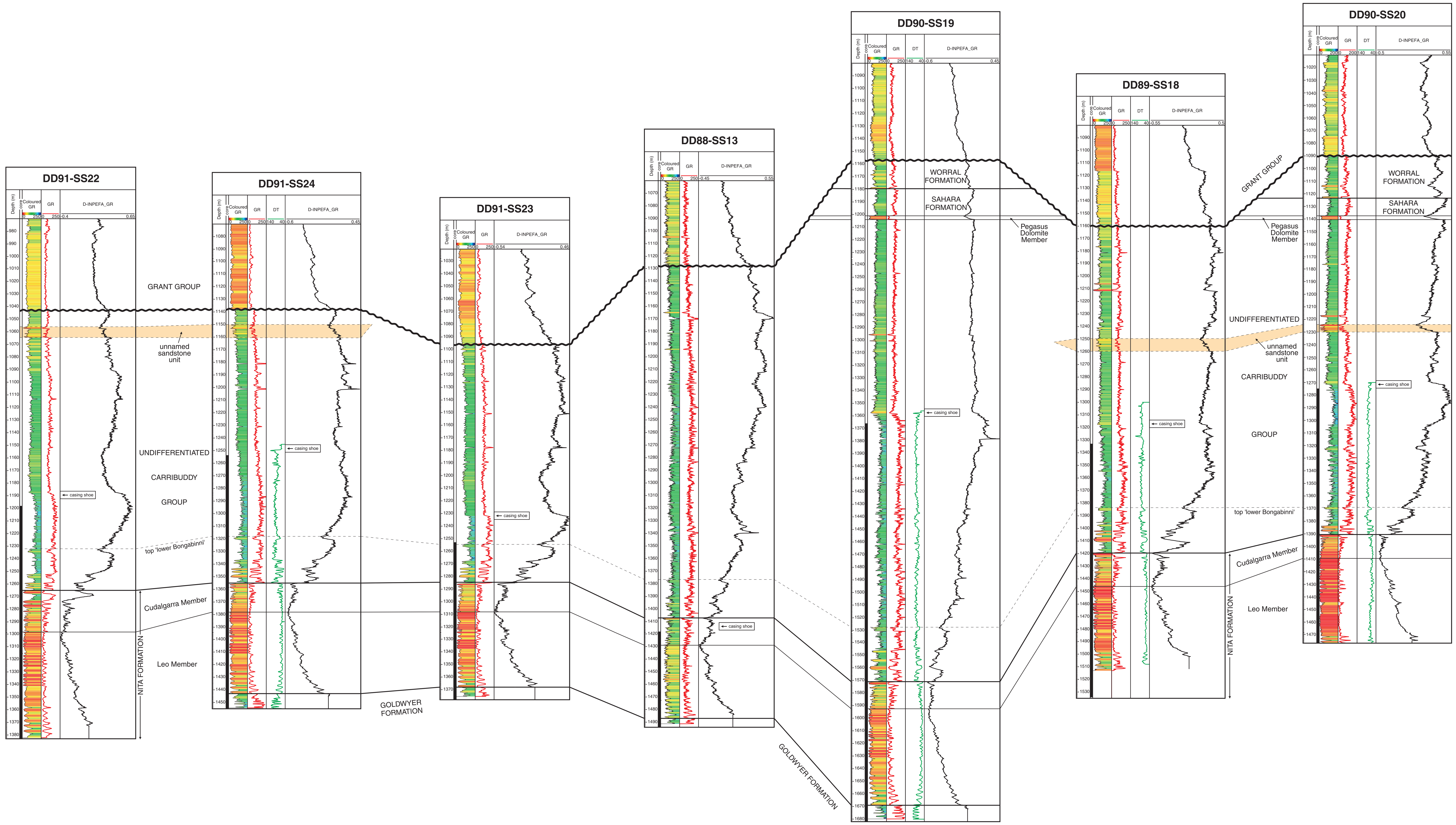

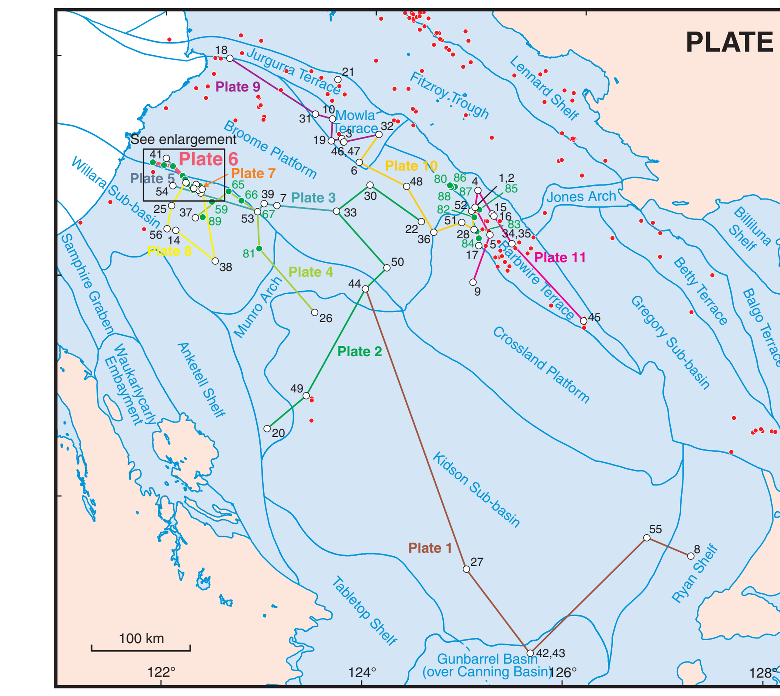

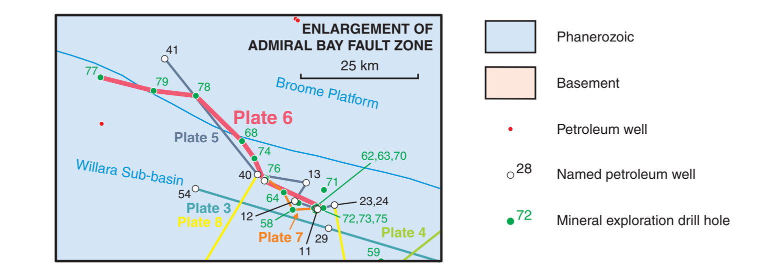

Phanerozoic

Basement

Petroleum well

28 Named petroleum well

72 Mineral exploration drill hole

PLATE 6

STRATIGRAPHIC CORRELATIONS

DD91-SS22 (CRAE) TO DD90-SS20 (CRAE)

(WILLARA SUB-BASIN)

1 Acacia 1
2 Acacia 2
3 Antares 1
4 Barbwire 1
5 Boab 1
6 Canopus 1
7 Carina 1
8 Contention Heights 1
9 Crossland 2
10 Crystal Creek 1
11 Cudalgarra 1
12 Cudalgarra 2
13 Cudalgarra North 1
14 Darriwell 1
15 Dodonea 1
16 Dodonea 2
17 Drosera 1
18 East Crab Creek 1
19 Edgar Range 1
20 Frankenstein 1
21 Frome Rocks 1
22 Fruitcake 1
23 Great Sandy 1
24 Great Sandy 2
25 Juno 1
26 Kemp Field 1
27 Kidson 1
28 Kunzea 1
29 Leo 1
30 Looma 1
31 Lovells Pocket 1
32 Matches Spring 1
33 McLarty 1
34 Mirbelia 1
35 Mirbelia 2
36 Missing 1
37 Munda 1
38 Munro 1
39 Musca 1
40 Nita Downs 1
41 Parda 1
42 Patience 1
43 Patience 2
44 Pegasus 1
45 Percival 1
46 Pictor 1
47 Pictor 2
48 Robert 1
49 Sahara 1
50 Sally May 1
51 Santalum 1A
52 Solanum 1
53 Vela 1
54 Willara 1
55 Wilson Cliffs 1
56 Woods Hills 1
57 DD86SS2 (CRAE)
58 DD86SS3 (CRAE)
59 DD87SS4 (CRAE)
60 DD87SS5 (CRAE)
61 DD87SS6 (CRAE)
62 DD87SS7 (CRAE)
63 DD88SS8 (CRAE)
64 DD88SS9 (CRAE)
65 DD88SS10 (CRAE)
66 DD88SS11 (CRAE)
67 DD88SS12 (CRAE)
68 DD88SS13 (CRAE)
69 DD89SS14 (CRAE)
70 DD89SS15 (CRAE)
71 DD89SS16 (CRAE)
72 DD89SS17 (CRAE)
73 DD89SS18 (CRAE)
74 DD90SS19 (CRAE)
75 DD90SS20 (CRAE)
76 DD90SS21 (CRAE)
77 DD91SS22 (CRAE)
78 DD91SS23 (CRAE)
79 DD91SS24 (CRAE)
80 DD88CLI (CRAE)
81 Brooke 1 (BHP-Utah)
82 BW1 (Pasminco)
83 BW3A (Pasminco)
84 BW5 (Pasminco)
85 BW15 (Pasminco)
86 BW24 (Pasminco)
87 BW26 (Pasminco)
88 BW27 (Pasminco)
89 Gingerah Hill 1 (BHP-Utah)

ROCK TYPES

Conglomerate
Sandstone
Mudstone
Limestone
Dolomitic limestone
Dolomite
Halite

MODIFIERS

Pebbly
Breccia
Sandy or sandstone interbeds
Argillaceous, silty, or mudstone interbeds
Calcareous
Dolomitic
Limestone interbeds
Dolomitic interbeds
Halite bearing
Anhydrite / gypsum

LITHOSTRATIGRAPHIC BOUNDARIES

Unconformity / Disconformity
Formation boundary
Formation boundary (approx.)
Member boundary
Member boundary (approx.)
Minor tie point
Boundary of inferred salt dissolution or disseminated salt

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

REPORT 105 PLATE 6

STRATIGRAPHIC CORRELATIONS

DD91-SS22 (CRAE) TO DD90-SS20 (CRAE)

(WILLARA SUB-BASIN)

Compiled by PW Haines
Edited by N Tetlaw
Cartography by C Schroder and S Dowsett

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Geological Survey of Western Australia, Report 105, Plate 6

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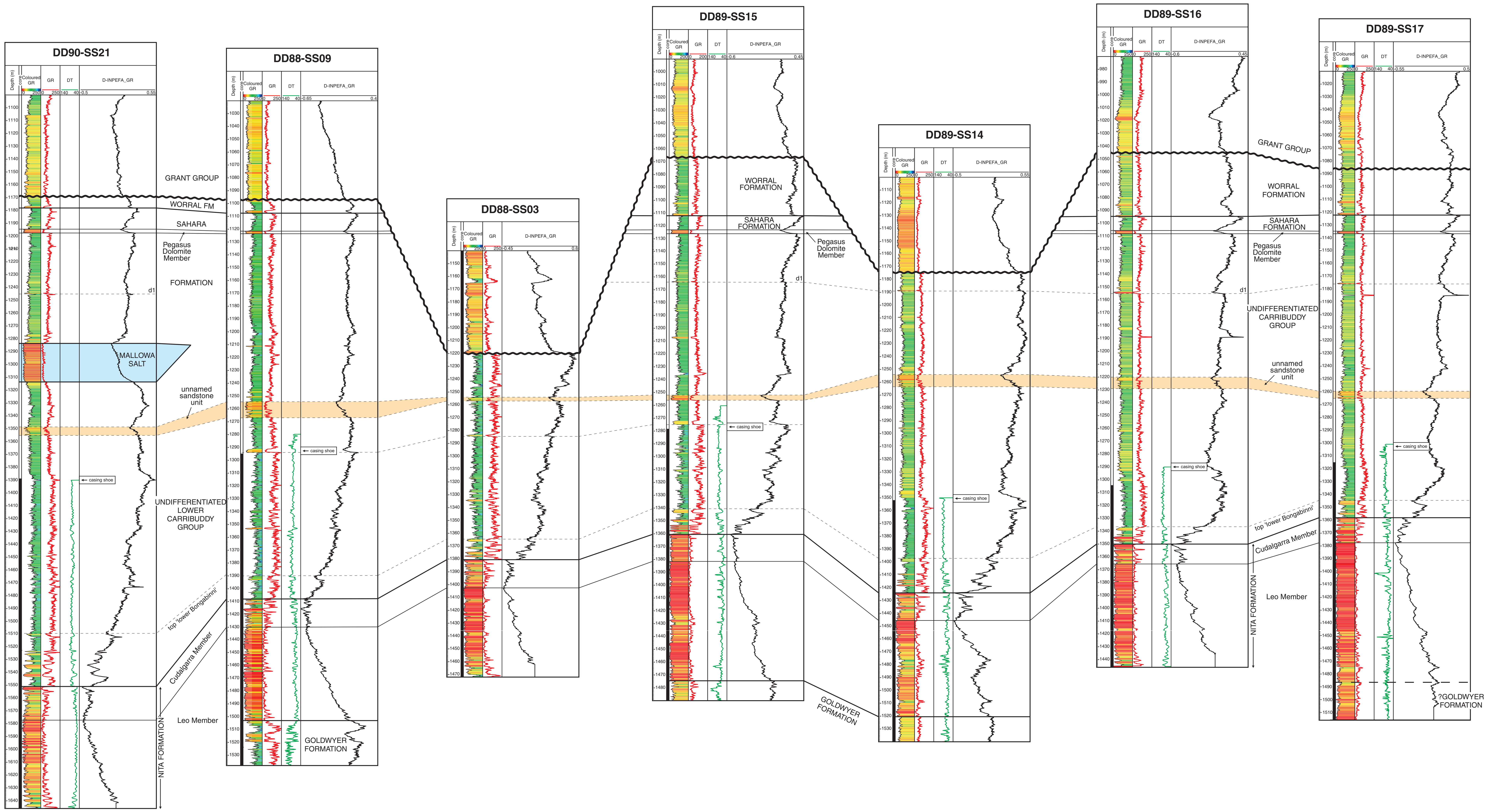

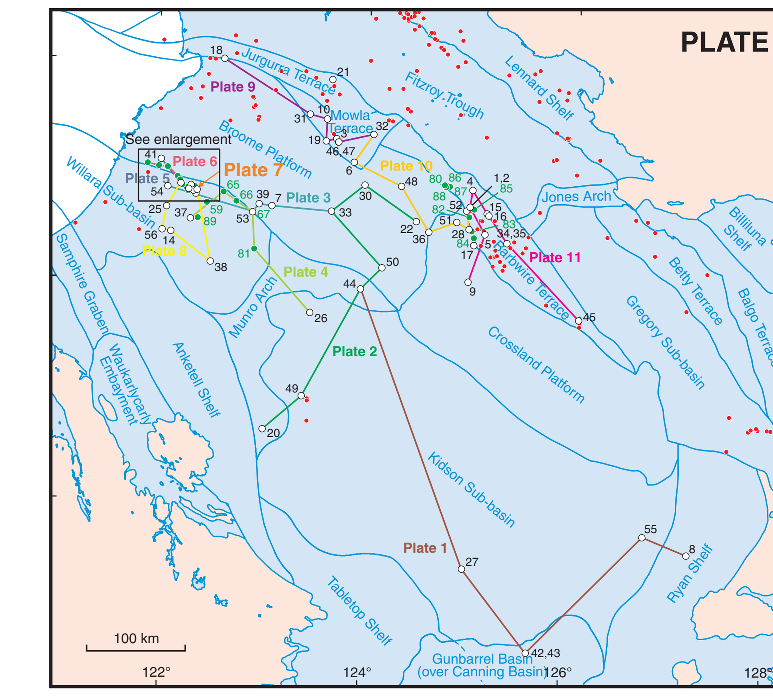

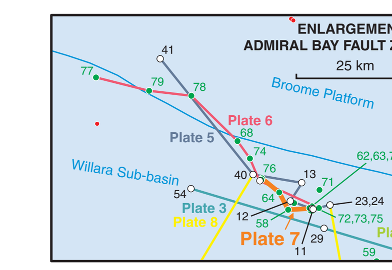

Phanerozoic
Basement
Petroleum well
Named petroleum well
Mineral exploration drill hole

PLATE 7
STRATIGRAPHIC CORRELATIONS
DD90-SS21 (CRAE) TO DD89-SS17 (CRAE)
(WILLARA SUB-BASIN)

1	Acacia 1	24	Great Sandy 2	47	Pictor 2	70	DD89SS15 (CRAE)
2	Acacia 2	25	Juno 1	48	Robert 1	71	DD89SS16 (CRAE)
3	Antares 1	26	Kemp Field 1	49	Sahara 1	72	DD89SS17 (CRAE)
4	Barbwire 1	27	Kidson 1	50	Sally May 1	73	DD89SS18 (CRAE)
5	Boab 1	28	Kunzea 1	51	Santalum 1A	74	DD90SS19 (CRAE)
6	Canopus 1	29	Leo 1	52	Solanum 1	75	DD90SS20 (CRAE)
7	Carina 1	30	Looma 1	53	Vela 1	76	DD90SS21 (CRAE)
8	Contention Heights 1	31	Lovells Pocket 1	54	Willara 1	77	DD91SS22 (CRAE)
9	Crossland 2	32	Matches Spring 1	55	Wilson Cliffs 1	78	DD91SS23 (CRAE)
10	Crystal Creek 1	33	McLarty 1	56	Woods Hills 1	79	DD91SS24 (CRAE)
11	Cudalgarra 1	34	Mirbelia 1	57	DD86SS2 (CRAE)	80	DD88CLI (CRAE)
12	Cudalgarra 2	35	Mirbelia 2	58	DD86SS3 (CRAE)	81	Brooke 1 (BHP-Utah)
13	Cudalgarra North 1	36	Missing 1	59	DD87SS4 (CRAE)	82	BW1 (Pasminco)
14	Darriwell 1	37	Munda 1	60	DD87SS5 (CRAE)	83	BW3A (Pasminco)
15	Dodonea 1	38	Munro 1	61	DD87SS6 (CRAE)	84	BW5 (Pasminco)
16	Dodonea 2	39	Musca 1	62	DD87SS7 (CRAE)	85	BW15 (Pasminco)
17	Drosera 1	40	Nita Downs 1	63	DD88SS8 (CRAE)	86	BW24 (Pasminco)
18	East Crab Creek 1	41	Parda 1	64	DD88SS9 (CRAE)	87	BW26 (Pasminco)
19	Edgar Range 1	42	Patience 1	65	DD88SS10 (CRAE)	88	BW27 (Pasminco)
20	Frankenstein 1	43	Patience 2	66	DD88SS11 (CRAE)	89	Gingerah Hill 1 (BHP-Utah)
21	Frome Rocks 1	44	Pegasus 1	67	DD88SS12 (CRAE)		
22	Fruitcake 1	45	Percival 1	68	DD88SS13 (CRAE)		
23	Great Sandy 1	46	Pictor 1	69	DD89SS14 (CRAE)		

ROCK TYPES
- Conglomerate
- Sandstone
- Mudstone
- Limestone
- Dolomitic limestone
- Dolomite
- Halite

MODIFIERS
- Pebbly
- Breccia
- Sandy or sandstone interbeds
- Argillaceous, silty, or mudstone interbeds
- Calcareous
- Dolomitic
- Limestone interbeds
- Dolomitic interbeds
- Halite bearing
- Anhydrite / gypsum

LITHOSTRATIGRAPHIC BOUNDARIES
- Unconformity / Disconformity
- Formation boundary
- Formation boundary (approx.)
- Member boundary
- Member boundary (approx.)
- Minor tie point
- Boundary of inferred salt dissolution or disseminated salt

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
REPORT 105 PLATE 7
STRATIGRAPHIC CORRELATIONS
DD90-SS21 (CRAE) TO DD89-SS17 (CRAE)
(WILLARA SUB-BASIN)

Compiled by PW Haines
Edited by N Tetlaw
Cartography by C Schroder and S Dowsett

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Geological Survey of Western Australia, Report 105, Plate 7

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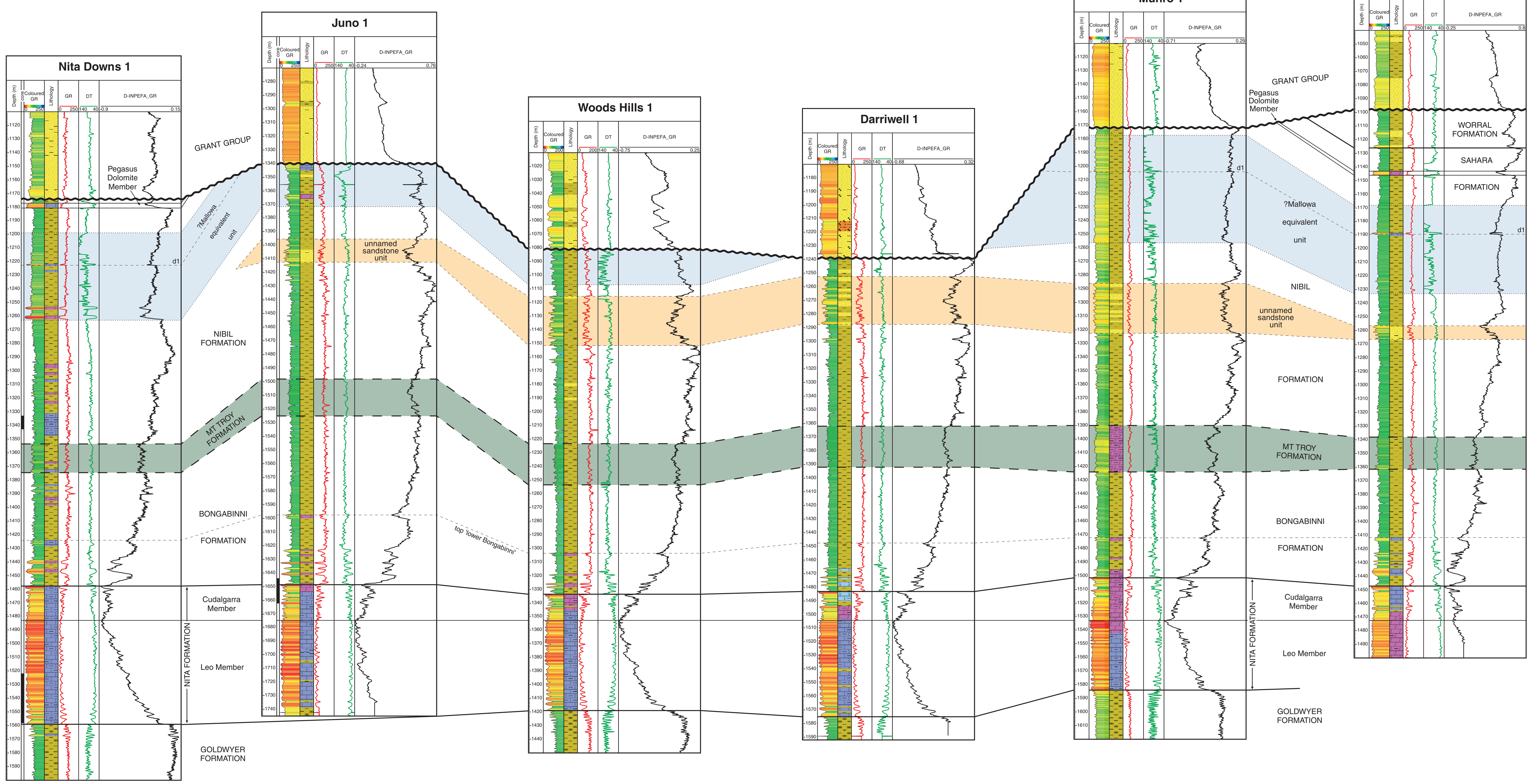

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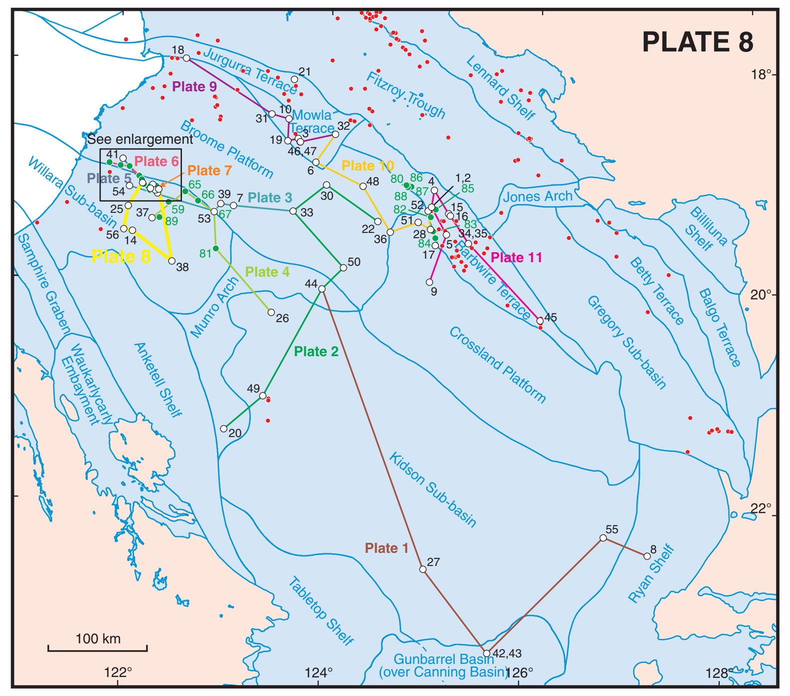

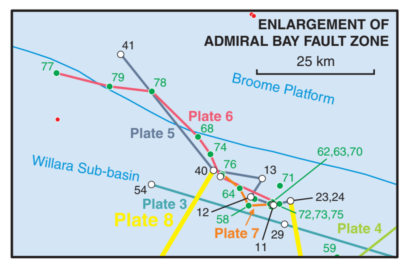

- Phanerozoic
- Basement
- Petroleum well
- 28 Named petroleum well
- 72 Mineral exploration drill hole

PLATE 8
STRATIGRAPHIC CORRELATIONS
NITA DOWNS 1 TO GREAT SANDY 1
(WILLARA SUB-BASIN)

1 Acacia 1	24 Great Sandy 2	47 Pictor 2	70 DD89SS15 (CRAE)
2 Acacia 2	25 Juno 1	48 Robert 1	71 DD89SS16 (CRAE)
3 Antares 1	26 Kemp Field 1	49 Sahara 1	72 DD89SS17 (CRAE)
4 Barbwire 1	27 Kidson 1	50 Sally May 1	73 DD89SS18 (CRAE)
5 Boab 1	28 Kunzea 1	51 Santalum 1A	74 DD90SS19 (CRAE)
6 Canopus 1	29 Leo 1	52 Solanum 1	75 DD90SS20 (CRAE)
7 Carina 1	30 Looma 1	53 Vela 1	76 DD90SS21 (CRAE)
8 Contention Heights 1	31 Lovells Pocket 1	54 Willara 1	77 DD91SS22 (CRAE)
9 Crossland 2	32 Matches Spring 1	55 Wilson Cliffs 1	78 DD91SS23 (CRAE)
10 Crystal Creek 1	33 McLarty 1	56 Woods Hills 1	79 DD91SS24 (CRAE)
11 Cudalgarra 1	34 Mirbelia 1	57 DD86SS2 (CRAE)	80 DD88CLI (CRAE)
12 Cudalgarra 2	35 Mirbelia 2	58 DD86SS3 (CRAE)	81 Brooke 1 (BHP-Utah)
13 Cudalgarra North 1	36 Missing 1	59 DD87SS4 (CRAE)	82 BW1 (Pasminco)
14 Darriwell 1	37 Munda 1	60 DD87SS5 (CRAE)	83 BW3A (Pasminco)
15 Dodonea 1	38 Munro 1	61 DD87SS6 (CRAE)	84 BW5 (Pasminco)
16 Dodonea 2	39 Musca 1	62 DD87SS7 (CRAE)	85 BW15 (Pasminco)
17 Drosera 1	40 Nita Downs 1	63 DD88SS8 (CRAE)	86 BW24 (Pasminco)
18 East Crab Creek 1	41 Parda 1	64 DD88SS9 (CRAE)	87 BW26 (Pasminco)
19 Edgar Range 1	42 Patience 1	65 DD88SS10 (CRAE)	88 BW27 (Pasminco)
20 Frankenstein 1	43 Patience 2	66 DD88SS11 (CRAE)	89 Gingerah Hill 1 (BHP-Utah)
21 Frome Rocks 1	44 Pegasus 1	67 DD88SS12 (CRAE)	
22 Fruitcake 1	45 Percival 1	68 DD88SS13 (CRAE)	
23 Great Sandy 1	46 Pictor 1	69 DD89SS14 (CRAE)	

ROCK TYPES

- Conglomerate
- Sandstone
- Mudstone
- Limestone
- Dolomitic limestone
- Dolomite
- Halite

MODIFIERS

- Pebbly
- Breccia
- Sandy or sandstone interbeds
- Argillaceous, silty, or mudstone interbeds
- Calcareous
- Dolomitic
- Limestone interbeds
- Dolomitic interbeds
- Halite bearing
- Anhydrite / gypsum

LITHOSTRATIGRAPHIC BOUNDARIES

- Unconformity / Disconformity
- Formation boundary
- Formation boundary (approx.)
- Member boundary
- Member boundary (approx.)
- Minor tie point
- Boundary of inferred salt dissolution or disseminated salt

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
REPORT 105 PLATE 8
STRATIGRAPHIC CORRELATIONS
NITA DOWNS 1 TO GREAT SANDY 1
(WILLARA SUB-BASIN)

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Edited by N Tetlaw
Cartography by C Schroder and S Dowsett

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Geological Survey of Western Australia, Report 105, Plate 8

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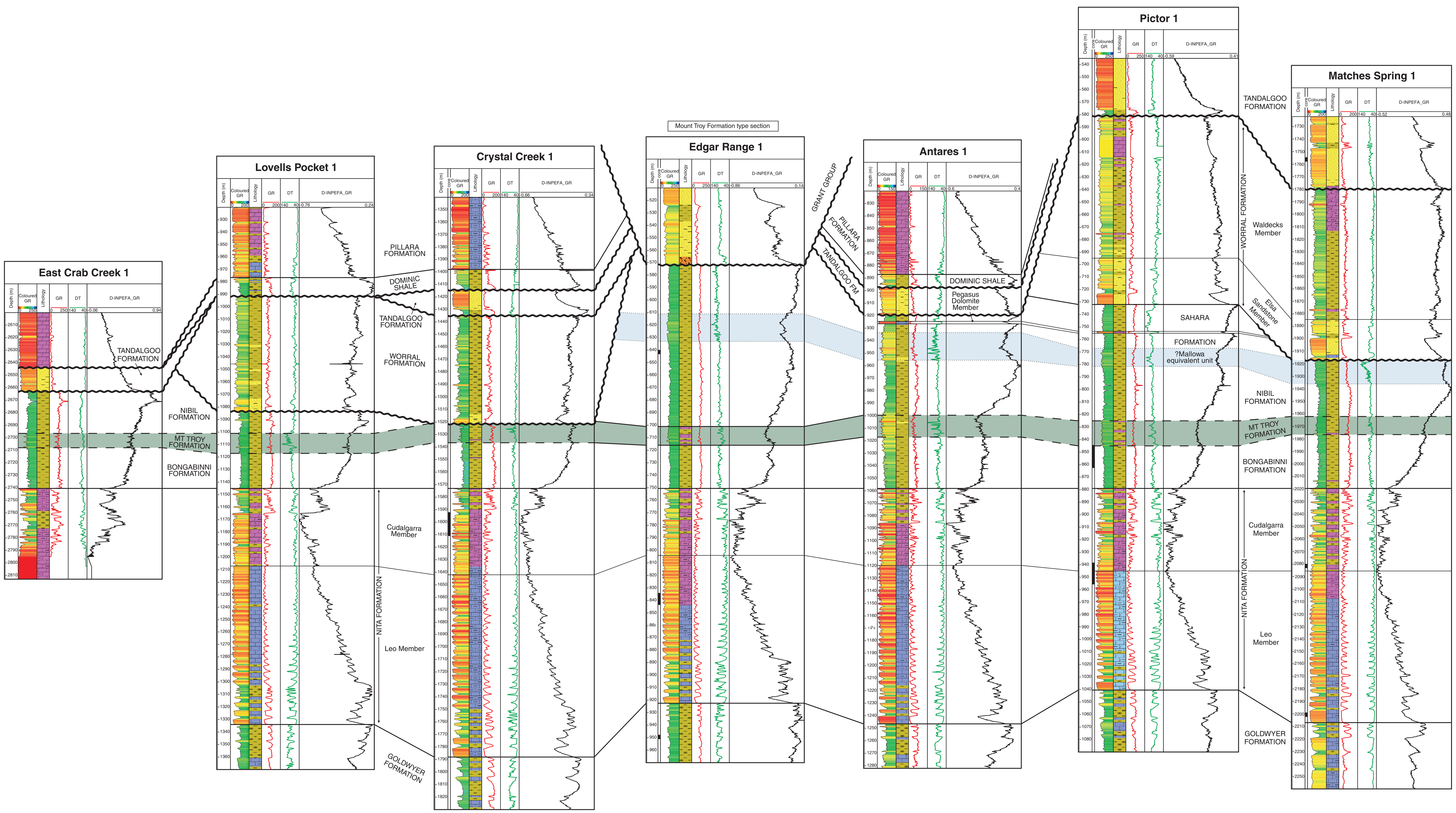
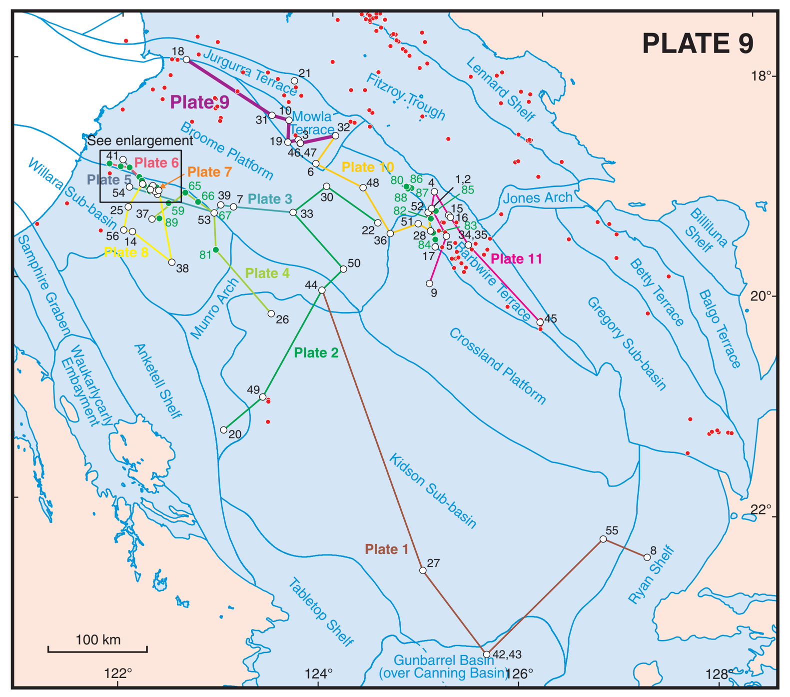
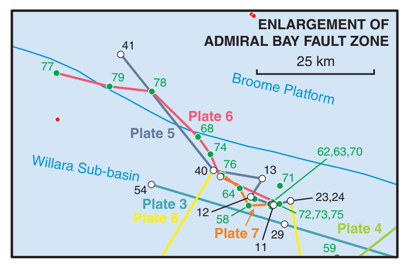
REPORT 105
PLATE 8







Phanerozoic
Basement
Petroleum well
Named petroleum well
Mineral exploration drill hole

PLATE 9

STRATIGRAPHIC CORRELATIONS

EAST CRAB CREEK 1 TO MATCHES SPRING 1
(JURGURRA TERRACE TO MOWLA TERRACE)

1 Acacia 1	24 Great Sandy 2	47 Pictor 2	70 DD89SS15 (CRAE)
2 Acacia 2	25 Juno 1	48 Robert 1	71 DD89SS16 (CRAE)
3 Antares 1	26 Kemp Field 1	49 Sahara 1	72 DD89SS17 (CRAE)
4 Barbwire 1	27 Kidson 1	50 Sally May 1	73 DD89SS18 (CRAE)
5 Boab 1	28 Kunzea 1	51 Santalum 1A	74 DD90SS19 (CRAE)
6 Canopus 1	29 Leo 1	52 Solanum 1	75 DD90SS20 (CRAE)
7 Carina 1	30 Looma 1	53 Vela 1	76 DD90SS21 (CRAE)
8 Contention Heights 1	31 Lovells Pocket 1	54 Willara 1	77 DD91SS22 (CRAE)
9 Crossland 2	32 Matches Spring 1	55 Wilson Cliffs 1	78 DD91SS23 (CRAE)
10 Crystal Creek 1	33 McLarty 1	56 Woods Hills 1	79 DD91SS24 (CRAE)
11 Cudalgarra 1	34 Mirbelia 1	57 DD86SS2 (CRAE)	80 DD88CLI (CRAE)
12 Cudalgarra 2	35 Mirbelia 2	58 DD86SS3 (CRAE)	81 Brooke 1 (BHP-Utah)
13 Cudalgarra North 1	36 Missing 1	59 DD87SS4 (CRAE)	82 BW1 (Pasminco)
14 Darriwell 1	37 Munda 1	60 DD87SS5 (CRAE)	83 BW3A (Pasminco)
15 Dodonea 1	38 Munro 1	61 DD87SS6 (CRAE)	84 BW5 (Pasminco)
16 Dodonea 2	39 Musca 1	62 DD87SS7 (CRAE)	85 BW15 (Pasminco)
17 Drosera 1	40 Nita Downs 1	63 DD88SS8 (CRAE)	86 BW24 (Pasminco)
18 East Crab Creek 1	41 Parda 1	64 DD88SS9 (CRAE)	87 BW26 (Pasminco)
19 Edgar Range 1	42 Patience 1	65 DD88SS10 (CRAE)	88 BW27 (Pasminco)
20 Frankenstein 1	43 Patience 2	66 DD88SS11 (CRAE)	89 Gingerah Hill 1 (BHP-Utah)
21 Frome Rocks 1	44 Pegasus 1	67 DD88SS12 (CRAE)	
22 Fruitcake 1	45 Percival 1	68 DD88SS13 (CRAE)	
23 Great Sandy 1	46 Pictor 1	69 DD89SS14 (CRAE)	

ROCK TYPES

- Conglomerate
- Sandstone
- Mudstone
- Limestone
- Dolomitic limestone
- Dolomite
- Halite

MODIFIERS

- Pebbly
- Breccia
- Sandy or sandstone interbeds
- Argillaceous, silty, or mudstone interbeds
- Calcareous
- Dolomitic
- Limestone interbeds
- Dolomitic interbeds
- Halite bearing
- Anhydrite / gypsum

LITHOSTRATIGRAPHIC BOUNDARIES

- Unconformity / Disconformity
- Formation boundary
- Formation boundary (approx.)
- Member boundary
- Member boundary (approx.)
- Minor tie point
- Boundary of inferred salt dissolution or disseminated salt

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
REPORT 105 PLATE 9

STRATIGRAPHIC CORRELATIONS
EAST CRAB CREEK 1 TO MATCHES SPRING 1
(JURGURRA TERRACE TO MOWLA TERRACE)

Compiled by PW Haines
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REPORT 105
PLATE 9

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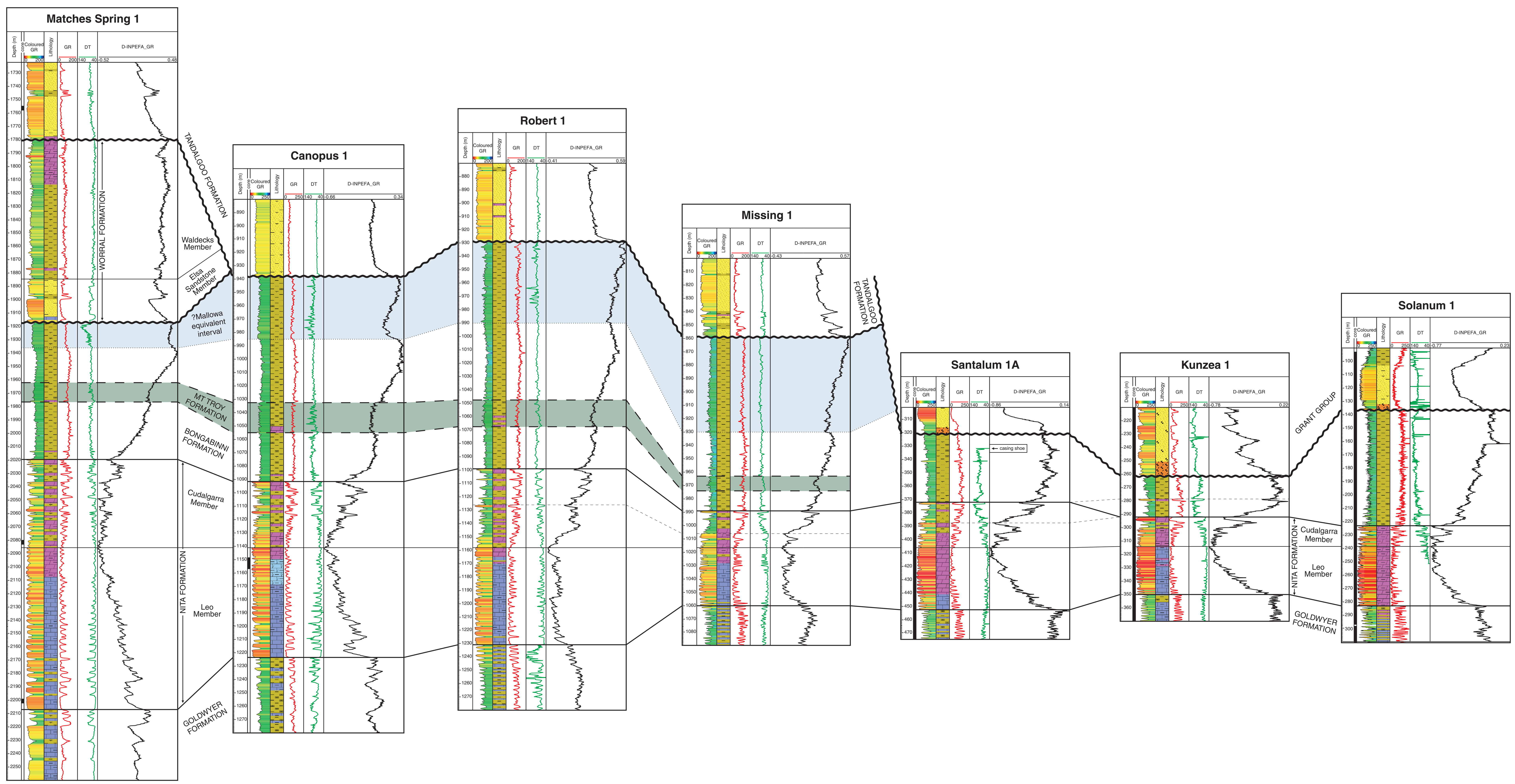

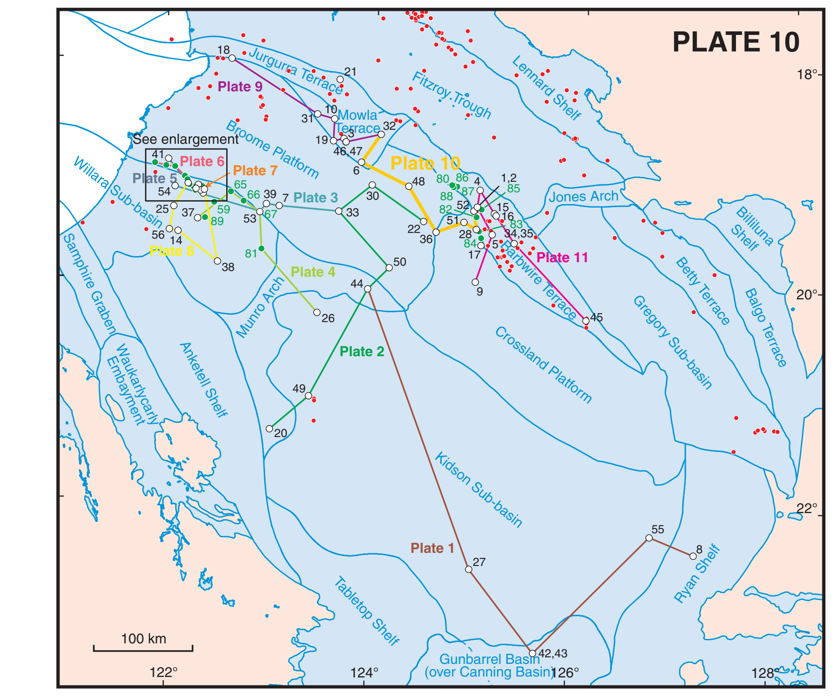

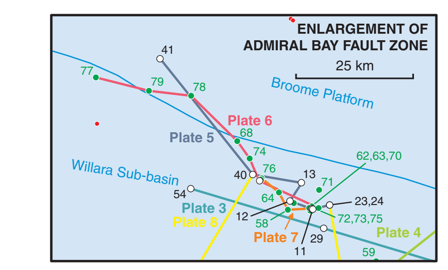

Phanerozoic
Basement
Petroleum well
28 Named petroleum well
72 Mineral exploration drill hole

PLATE 10

STRATIGRAPHIC CORRELATIONS

MATCHES SPRING 1 TO SOLANUM 1

(MOWLA TERRACE TO BARBWIRE TERRACE)

1 Acacia 1
2 Acacia 2
3 Antares 1
4 Barbwire 1
5 Boab 1
6 Canopus 1
7 Carina 1
8 Contention Heights 1
9 Crossland 2
10 Crystal Creek 1
11 Cudalgarra 1
12 Cudalgarra 2
13 Cudalgarra North 1
14 Darriwell 1
15 Dodonea 1
16 Dodonea 2
17 Drosera 1
18 East Crab Creek 1
19 Edgar Range 1
20 Frankenstein 1
21 Frome Rocks 1
22 Fruitcake 1
23 Great Sandy 1
24 Great Sandy 2
25 Juno 1
26 Kemp Field 1
27 Kidson 1
28 Kunzea 1
29 Leo 1
30 Looma 1
31 Lovells Pocket 1
32 Matches Spring 1
33 McLarty 1
34 Mirbelia 1
35 Mirbelia 2
36 Missing 1
37 Munda 1
38 Munro 1
39 Musca 1
40 Nita Downs 1
41 Parda 1
42 Patience 1
43 Patience 2
44 Pegasus 1
45 Percival 1
46 Pictor 1
47 Pictor 2
48 Robert 1
49 Sahara 1
50 Sally May 1
51 Santalum 1A
52 Solanum 1
53 Vela 1
54 Willara 1
55 Wilson Cliffs 1
56 Woods Hills 1
57 DD86SS2 (CRAE)
58 DD86SS3 (CRAE)
59 DD87SS4 (CRAE)
60 DD87SS5 (CRAE)
61 DD87SS6 (CRAE)
62 DD87SS7 (CRAE)
63 DD88SS8 (CRAE)
64 DD88SS9 (CRAE)
65 DD88SS10 (CRAE)
66 DD88SS11 (CRAE)
67 DD88SS12 (CRAE)
68 DD88SS13 (CRAE)
69 DD89SS14 (CRAE)
70 DD89SS15 (CRAE)
71 DD89SS16 (CRAE)
72 DD89SS17 (CRAE)
73 DD89SS18 (CRAE)
74 DD90SS19 (CRAE)
75 DD90SS20 (CRAE)
76 DD90SS21 (CRAE)
77 DD91SS22 (CRAE)
78 DD91SS23 (CRAE)
79 DD91SS24 (CRAE)
80 DD88CLI (CRAE)
81 Brooke 1 (BHP-Utah)
82 BW1 (Pasminco)
83 BW3A (Pasminco)
84 BW5 (Pasminco)
85 BW15 (Pasminco)
86 BW24 (Pasminco)
87 BW26 (Pasminco)
88 BW27 (Pasminco)
89 Gingerah Hill 1 (BHP-Utah)

ROCK TYPES

- Conglomerate
- Sandstone
- Mudstone
- Limestone
- Dolomitic limestone
- Dolomite
- Halite

MODIFIERS

- Pebbly
- Breccia
- Sandy or sandstone interbeds
- Argillaceous, silty, or mudstone interbeds
- Calcareous
- Dolomitic
- Limestone interbeds
- Dolomitic interbeds
- Halite bearing
- Anhydrite / gypsum

LITHOSTRATIGRAPHIC BOUNDARIES

- Unconformity / Disconformity
- Formation boundary
- Formation boundary (approx.)
- Member boundary
- Member boundary (approx.)
- Minor tie point
- Boundary of inferred salt dissolution or disseminated salt

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

REPORT 105 PLATE 10

STRATIGRAPHIC CORRELATIONS

MATCHES SPRING 1 TO SOLANUM 1

(MOWLA TERRACE TO BARBWIRE TERRACE)

Compiled by PW Haines
Edited by N Tetlaw
Cartography by C Schroder and S Dowsett

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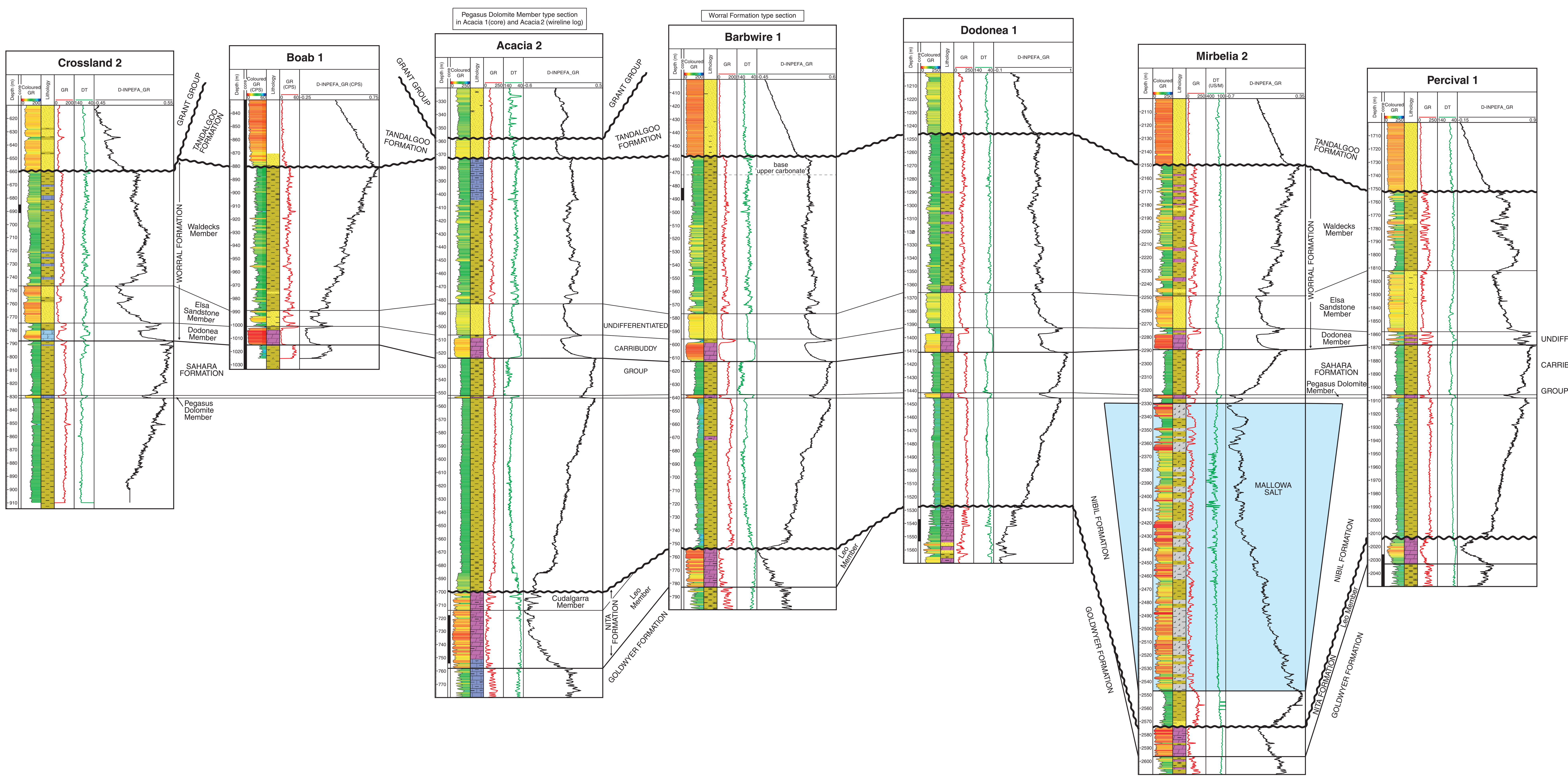

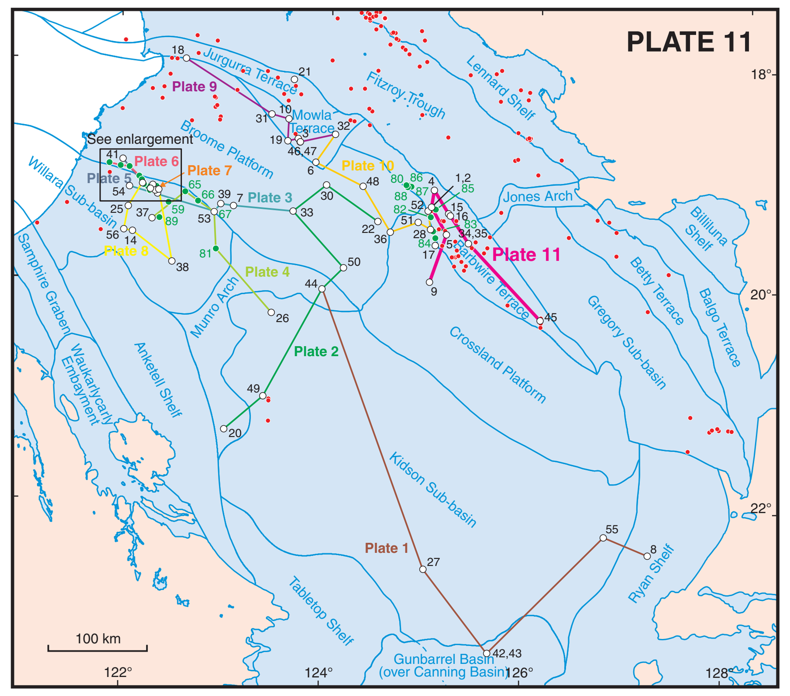

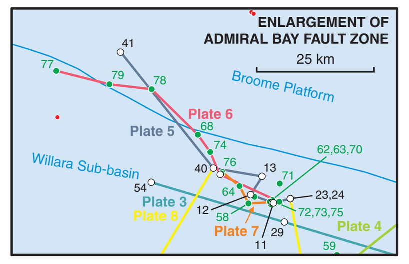

Phanerozoic

Basement

Petroleum well

Named petroleum well

Mineral exploration drill hole

PLATE 11
STRATIGRAPHIC CORRELATIONS
CROSSLAND 2 TO PERCIVAL 1
(CROSSLAND PLATFORM TO BARBWIRE TERRACE)

1	Acacia 1	24	Great Sandy 2	47	Pictor 2	70	DD89SS15 (CRAE)
2	Acacia 2	25	Juno 1	48	Robert 1	71	DD89SS16 (CRAE)
3	Antares 1	26	Kemp Field 1	49	Sahara 1	72	DD89SS17 (CRAE)
4	Barbwire 1	27	Kidson 1	50	Sally May 1	73	DD89SS18 (CRAE)
5	Boab 1	28	Kunzea 1	51	Santalum 1A	74	DD90SS19 (CRAE)
6	Canopus 1	29	Leo 1	52	Solanum 1	75	DD90SS20 (CRAE)
7	Carina 1	30	Looma 1	53	Vela 1	76	DD90SS21 (CRAE)
8	Contention Heights 1	31	Lovells Pocket 1	54	Willara 1	77	DD91SS22 (CRAE)
9	Crossland 2	32	Matches Spring 1	55	Wilson Cliffs 1	78	DD91SS23 (CRAE)
10	Crystal Creek 1	33	McLarty 1	56	Woods Hills 1	79	DD91SS24 (CRAE)
11	Cudalgarra 1	34	Mirbelia 1	57	DD86SS2 (CRAE)	80	DD88CLI (CRAE)
12	Cudalgarra 2	35	Mirbelia 2	58	DD86SS3 (CRAE)	81	Brooke 1 (BHP-Utah)
13	Cudalgarra North 1	36	Missing 1	59	DD87SS4 (CRAE)	82	BW1 (Pasminco)
14	Darriwell 1	37	Munda 1	60	DD87SS5 (CRAE)	83	BW3A (Pasminco)
15	Dodonea 1	38	Munro 1	61	DD87SS6 (CRAE)	84	BW5 (Pasminco)
16	Dodonea 2	39	Musca 1	62	DD87SS7 (CRAE)	85	BW15 (Pasminco)
17	Drosera 1	40	Nita Downs 1	63	DD88SS8 (CRAE)	86	BW24 (Pasminco)
18	East Crab Creek 1	41	Parda 1	64	DD88SS9 (CRAE)	87	BW26 (Pasminco)
19	Edgar Range 1	42	Patience 1	65	DD88SS10 (CRAE)	88	BW27 (Pasminco)
20	Frankenstein 1	43	Patience 2	66	DD88SS11 (CRAE)	89	Gingerah Hill 1 (BHP-Utah)
21	Frome Rocks 1	44	Pegasus 1	67	DD88SS12 (CRAE)		
22	Fruitcake 1	45	Percival 1	68	DD88SS13 (CRAE)		
23	Great Sandy 1	46	Pictor 1	69	DD89SS14 (CRAE)		

ROCK TYPES

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- Mudstone
- Limestone
- Dolomitic limestone
- Dolomite
- Halite

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GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
REPORT 105 PLATE 11
STRATIGRAPHIC CORRELATIONS
CROSSLAND 2 TO PERCIVAL 1
(CROSSLAND PLATFORM TO BARBWIRE TERRACE)

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