Geology and mineral resources of the Northern Territory

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Chapter 41: Eromanga Basin

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Chapter 41: EROMANGA BASIN

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INTRODUCTION

The Cambrian–?Devonian Warburton Basin, Carboniferous–Triassic Pedirka Basin and Jurassic–Cretaceous Eromanga Basin are three stacked basins in the southeastern corner of the Northern Territory that also extend over areas of adjoining Queensland, South Australia and New South Wales (**Figure 41.1**). The Eromanga, Surat and Carpentaria basins together form the bulk of the Great Australian Basin[1] (Green 1997, Draper 2002b) of central and northeastern Australia. Other interconnected eastern Australian basins (eg Clarence-Moreton, Nambour and Laura basins) could also be considered to be a part of this vast depositional system. The Northern Territory part of the Eromanga Basin contains about 2300 m of Jurassic to Cretaceous strata overlying Proterozoic (Aileron Province and Musgrave Province), Palaeozoic (Amadeus/Warburton and Georgina basins, Irindina Province) and Permian–Triassic (Pedirka Basin) successions. Elsewhere, the Eromanga Basin also overlies the Bowen, Cooper, Galilee, Arckaringa and older basins, and crystalline basement rocks. Most of the succession is in the subsurface and in the NT is largely overlain by Cenozoic and Recent sedimentary rocks of the Lake Eyre Basin and other surficial deposits (see **Cenozoic geology and regolith**). However, the southwestern margins of the basin are exposed in SA and the northeastern part of the basin in central Qld is also exposed and has been eroding since the Late Cretaceous. The surface elevation of the basin is highest over central Qld, where it is ca 300 m above present-day sea-level, but elevations decrease towards the southwest to below present-day sea level (Waschbusch *et al* 2009).

The stratigraphic nomenclature of the Eromanga Basin is complex and has evolved over a century. Units of the same lithology and in the same stratigraphic position have been given different names in different parts of the basin. The stratigraphic succession in the Northern Territory is summarised in **Table 41.1** and a correlation chart that includes successions from other portions of the Great Australian Basin is presented in **Figure 41.2**. The Jurassic succession is mainly terrestrial and comprises fluviatile quartz sandstone interbedded with carbonaceous shale. The Early Cretaceous succession is largely marine, whereas late Early Cretaceous strata were deposited in a regressive sea. The early Late Cretaceous part of the Eromanga Basin succession was laid down in a mix of environments, including shallow marine, paralic, lacustrine, paludal and fluviatile.

Numerous studies have been published on the Eromanga Basin, of which some of the more significant include Whitehouse (1955), Day (1964, 1966, 1967, 1968, 1969), Vine and Day (1965), Vine *et al* (1967), Senior *et al* (1969, 1978), Casey (1970), Exon and Senior (1976), Haig and Barnbaum 1978, Burger and Senior (1979), Habermehl

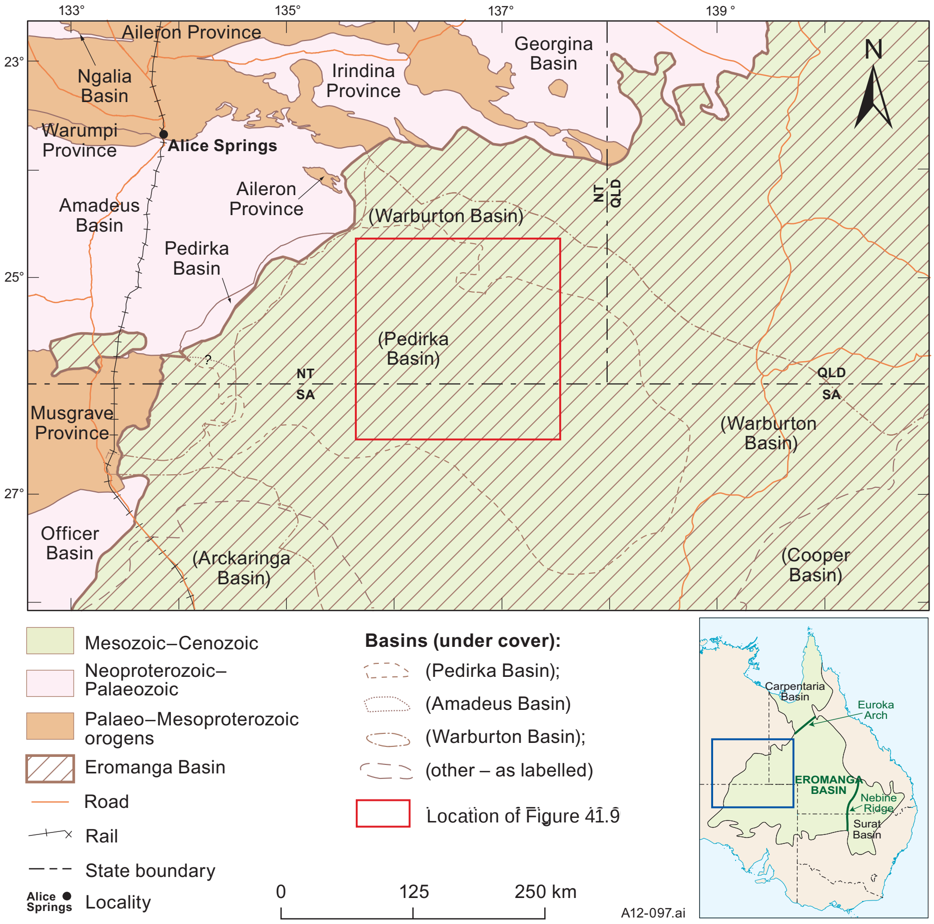

Figure 41.1. Regional geological setting of Eromanga Basin. NT geological regions slightly modified from NTGS 1:2.5M geological regions GIS dataset. Queensland geological regions simplified and slightly modified from Denaro and Dhnaram (2009) and Geoscience Australia (GA) Geological Regions National Geoscience Dataset. SA geological regions simplified and slightly modified from Department for Manufacturing, Innovation, Trade, Resources and Energy (DMITRE), South Australia Resources Information Geoserver (SARIG: **http://www.sarig.dmitre.sa.gov.au/**) and from GA Geological Regions National Geoscience Dataset. Cenozoic covering strata (eg Lake Eyre Basin) not shown.

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[1] These basins were originally defined by Mott (1952) as portions of the Great Artesian Basin, a term best restricted to hydrogeology as portions of the artesian system are within sedimentary rocks of other basins (eg Bowen, Galilee basins).

(1980, 1986), papers in Moore and Mount (1982), Burger (1986), papers in Gravestock *et al* (1986), John and Almond (1987), papers in O'Neil (1989), Questa (1990), Green *et al* (1991, 1992), Krieg *et al* (1995), Draper (2002a, b), Gray *et al* (2002), Gray and Draper (2002), McKellar (2002), Ambrose *et al* (2002, 2007), Ambrose (2006), Cotton *et al* (2006), Waschbusch *et al* (2009) and Ambrose and Heugh (2010, 2011). The distribution of outcrops in the NT portion of the basin is shown in **Figure 41.3**.

JURASSIC–EARLY CRETACEOUS

In the NT portion of the Eromanga Basin, the Jurassic and older part of the Early Cretaceous succession is divided into two units (**Figure 41.2**, **Table 41.1**), the Poolowanna Formation and Algebuckina Sandstone.

Poolowanna Formation

The entirely subsurface Poolowanna Formation (Moore 1986b; 'Poolowanna beds' of Wiltshire 1978) is the basal unit in the Eromanga Basin succession in the NT in the Poolowanna, Madigan and Eringa troughs. However, it thins to the west and is absent along the western flanks of the latter two depocentres, where it is overlapped by the Algebuckina Sandstone (**Figure 41.4**). The Poolowanna Formation unconformably overlies Permian and Triassic sedimentary rocks of the Pedirka Basin in the NT and SA and the Cooper Basin in SA and Qld. In the Cooper Basin, it also unconformably overlies the Late Triassic Cuddapan Formation, which is the lowermost unit of the Eromanga Basin in that area (Gray *et al* 2002). Elsewhere, it unconformably overlies earlier Palaeozoic sedimentary and metasedimentary basement rocks. In the western Eromanga Basin in the NT and northern SA, the Poolowanna Formation intertongues with and is conformably overlain by the Algebuckina Sandstone. To the east on the Birdsville Track Ridge, it is conformably overlain by the Hutton Sandstone, which is a lateral equivalent of the lower Algebuckina Sandstone, and in the Cooper Basin area further to the east, it intertongues with and is conformably overlain by the Hutton Sandstone (Krieg *et al* 1995, Gray *et al* 2002). The Poolowanna Formation is a lateral equivalent of the Precipice Sandstone and overlying Evergreen Formation of the northeastern Eromanga Basin and Surat Basin (McKellar 2002). The main depocentre for the formation is the Poolowanna Trough, where it reaches a maximum thickness of 206 m in drillhole Poolowanna-1 in SA (Krieg *et al* 1995). Thick sections are also present to the east and northeast of the trough in southwestern Qld, where the formation reaches a thickness of 165 m in drillhole DIO Curalle-1 (Gray *et al* 2002). In the NT, the Poolowanna Formation reaches maximum thicknesses of 205 m in Thomas-1 (Wiltshire 1982) and 193 m in Poeppels Corner-1 (Arco Australia 1985), but it thins to the north and west to be 109.4 m thick in Colson-1 (Beach Petroleum 1979), 39 m in Simpson-1 (Central Petroleum 2009a) and less than 10 m in Blamore-1 (Central Petroleum 2008, **Figure 41.5**).

An informal two-fold division of the Poolowanna Formation is recognised in Qld, where a lower interval of medium to very coarse sandstone, grading in places to

Unit, max thickness	Lithology	Depositional environment	Stratigraphic relationship
Cretaceous			
ROLLING DOWNS GROUP			
MANUKA SUBGROUP			
Winton Formation 620 m	Claystone, siltstone and mudstone with interbedded sandstone and minor coal seams.	Fluviatile to paludal to lacustrine. Paralic, estuarine, deltaic and fluviatile near base.	Conformable on Mackunda Formation. Unconformable beneath Cenozoic sediments, including those of Lake Eyre Basin.
Mackunda Formation 144 m	Labile lithic sandstone, siltstone and mudstone, lesser mud-clast intraformational conglomerate.	Shallow marine and paralic.	Conformable on Allaru Mudstone.
WILGUNYA SUBGROUP			
Allaru Mudstone 306 m	Partly pyritic mudstone with calcareous siltstone interbeds, cone-in-cone limestone, minor sandstone and limestone.	Shallow marine.	Conformable on Toolebuc Formation or Wallumbilla Formation.
Toolebuc Formation 65 m	Mudstone with thin layers of siltstone, subordinate labile sandstone, limestone, marl and conglomerate.	Shallow marine.	Conformable on Wallumbilla Formation.
Wallumbilla Formation 237 m	Mudstone and siltstone, minor thin interbeds of fine sandstone and limestone.	Shallow marine, nearshore to marginal marine, minor non-marine.	Conformable on Cadna-owie Formation; unconformable/disconformable on Algebuckina Sandstone in west.
UNGROUPED			
Cadna-owie Formation 81 m	Sandstone, siltstone, silty mudstone and mudstone, minor claystone.	Lacustrine to restricted/marginal marine, minor fluviatile and subtidal shallow marine.	Conformable on Algebuckina Sandstone.
Jurassic–Early Cretaceous			
Algebuckina Sandstone 757 m	Quartzic sandstone, with granule and pebble layers, minor shale and siltstone.	Fluviatile.	Disconformable/unconformable on Poolowanna Formation or basement rocks.
Poolowanna Formation 205 m	Sandstone, siltstone and coaly shale, arranged in two upward-fining cycles. Thin discontinuous coal seams.	Fluviatile and lacustrine.	Unconformable on Permian and Triassic rocks of Pedirka Basin or basement rocks.

Table 41.1. Summary of Jurassic–Cretaceous stratigraphic succession of NT portion of Eromanga Basin.

granule conglomerate, is overlain by an aerially extensive interval of mudstone, siltstone and lesser sandstone and coal arranged in fining-upward cycles (Almond 1983, Green 1997). These represent cyclical fluviatile–lacustrine sedimentation (Gray *et al* 2002), with the finer upper interval marking a rise in the base level of erosion that has been correlated with a global rise in sea level (Passmore and Burger 1986, Gray *et al* 2002). An informal twofold division is also recognised in the NT and northern SA, where the formation is typically arranged in two transgressive, upward-fining fluviatile-lacustrine cycles. Each of these is 50–100 m in thickness and consists of interbedded sheet-like sandstone that fines upwards to coaly shale and siltstone (Ambrose *et al* 2007, Ambrose and Heugh 2010). Sandstone is planar cross-bedded, horizontally bedded and ripple cross-laminated; siltstone and shale are laminated and massive; and coal seams are usually thin (<0.5 m thick) and discontinuous (Krieg *et al* 1995). The lower parts of these two cyclic successions are interpreted to have been deposited under fluviatile conditions, whereas overlying finer-grained strata were laid down in overbank environments related to progressive ponding of drainage lines. This was followed by lacustrine conditions at the top of each cycle (Ambrose and Heugh 2010). These two cycles are regionally extensive and progressively onlap the basin margins and local palaeo-highs, where the upper cycle

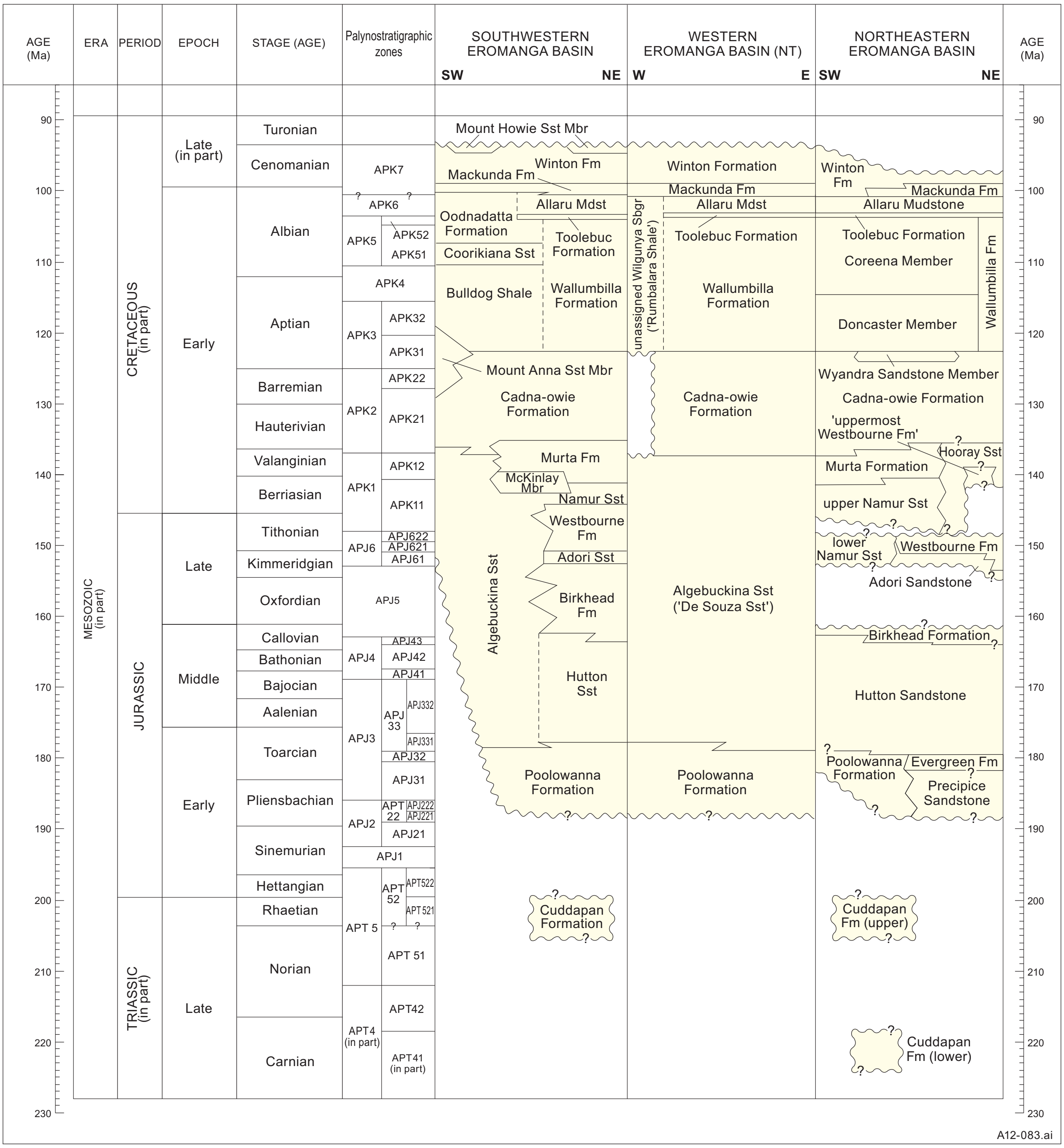

Figure 41.2. Simplified Late Triassic–Cretaceous stratigraphic correlation chart for Eromanga, Carpentaria and northern Surat basins in Qld, SA and NT. Timescale after Gradstein *et al* (2004). Stratigraphic succession for northeastern Eromanga Basin derived from Draper (2002a) and unpublished stratigraphic chart kindly supplied by J McKellar (Geological Survey of Queensland). Stratigraphic succession for SA slightly modified from Krieg *et al* (1995). Palynostratigraphic zones after Price *et al* (1985), Filatoff and Price (1988) and Price (1997). Position of palynostratigraphic zones against timescale derived from Geoscience Australia's Timescale project (see Monteil 2006) and J McKellar (*in litt* 2012).

(cycle 2) overlaps cycle 1. Cycle 2 appears to be generally sandier than the equivalent upper interval in the northeast and east of the basin, which suggests a more proximal depositional environment. The Poolowanna Formation is assigned (Draper 2002a, **Figure 41.2**) to the Early Jurassic (Pliensbachian–Toarcian) APJ221–APJ331 palynofloral zones of Price (1997).

Algebuckina Sandstone

The Algebuckina Sandstone (Wopfner *et al* 1970) is widely distributed along the western portion of the Eromanga Basin in the NT and SA. The upper parts of this thick unit are exposed along the western margins of the basin in SA and the NT, mostly in southeastern KULGERA[1], eastern FINKE and southeastern RODINGA; **Figure 41.3**, where it was described under the local name 'De Souza Sandstone' (Wells 1969, Edgoose *et al* 1993), and in southeastern ILLOGWA CREEK, where it was described as Hooray Sandstone (Shaw and Freeman 1985). In southern TOBERMOREY and northern HAY RIVER, outliers of the Eromanga Basin, mapped as Hooray Sandstone by Mond and Harrison in Senior *et al* (1978), but subsequently described as undifferentiated Jurassic–Cretaceous by Kruse *et al* (2002), may be Algebuckina Sandstone at least in part (see **Undifferentiated** below). Exposures of the Algebuckina Sandstone in the NT consists mostly of mesas and buttes, or ledges on the flanks of mesas beneath exposures of Early Cretaceous rocks. The formation extends in the subsurface from these areas into the Eringa, Madigan and Poolowanna troughs. The Algebuckina Sandstone is considered to be laterally equivalent to a thick succession in the eastern and northeastern portions of the basin, in the Cooper Basin area and in Qld, consisting of the Hutton Sandstone, Birkhead Formation, Adori Sandstone, Westbourne Formation, Namur Sandstone and Murta Formation (Nugent 1969, **Figure 41.2**). The formation is disconformable/unconformable on the Poolowanna Formation, with basal massive sandstone beds locally eroding deeply into coaly shale capping cycle 2 at the top of the underlying unit (Ambrose *et al* 2007, Ambrose and Heugh 2010). It is also unconformable on other pre-Mesozoic units, including Permian–Triassic strata of the Pedirka Basin along the

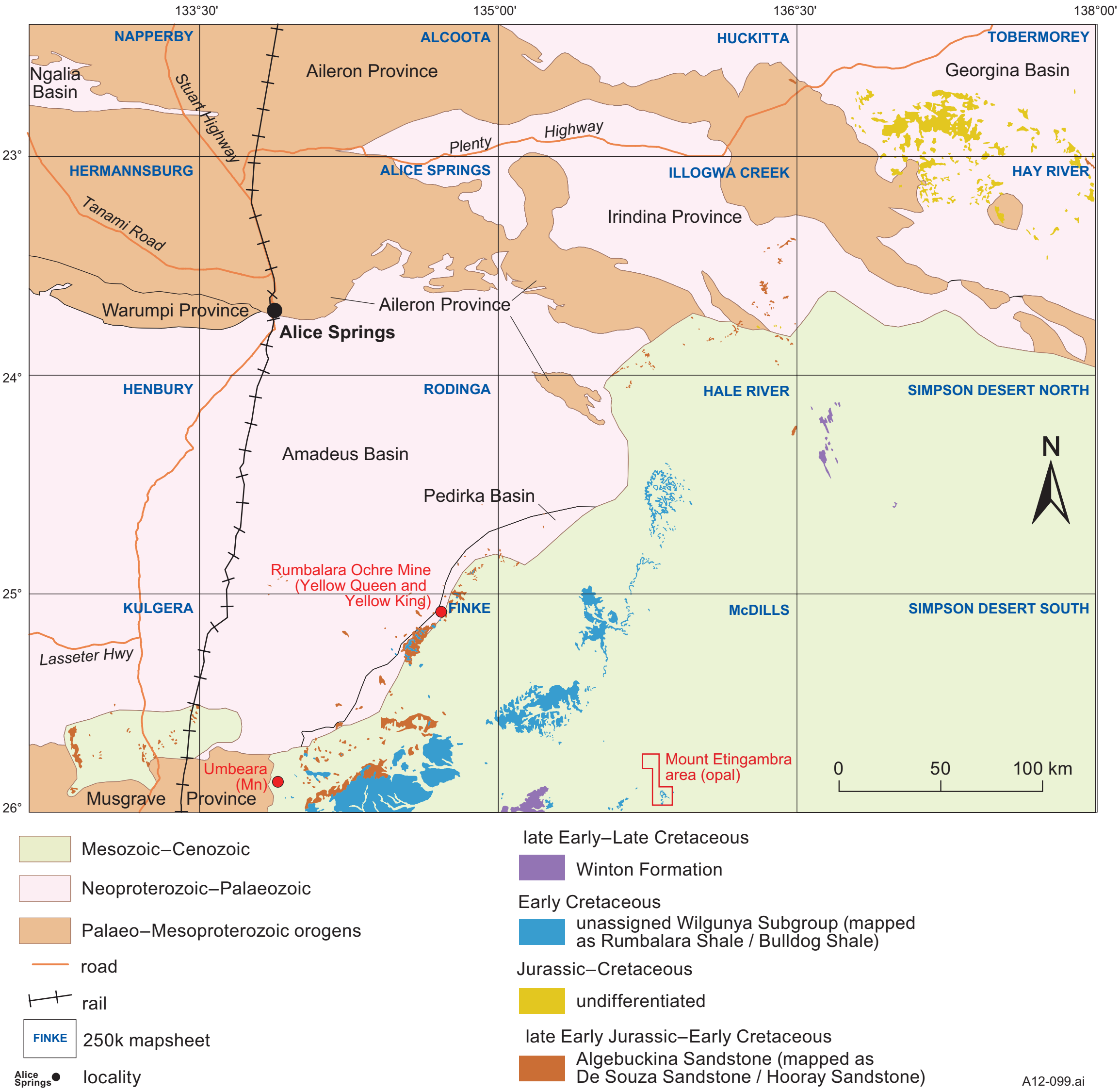

Figure 41.3. Simplified geology of Eromanga Basin in Northern Territory, derived from GA 1:1M geology and NTGS 1:2.5M geological regions GIS datasets. Unit names are as originally mapped with current interpretation included (see text). Mineral occurrences other than coal are also shown, from NTGS MODAT database.

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[1] Names of 1:250 000 mapsheets are in capital letters, eg KULGERA.

western flanks of the Madigan and Eringa troughs and on the western margins of the basin. The formation is conformably overlain and in places overlapped by the Early Cretaceous Cadna-owie Formation (Krieg *et al* 1995), except in FINKE, where the equivalent 'De Souza Sandstone' is overlain, apparently disconformably, by Early Cretaceous rocks assigned to the 'Bulldog Shale?' (Wells 1969, Edgoose *et al* 2002). However, it is possible that rocks equivalent to the Cadna-owie Formation, which is yet to be identified in this area, may be present within this interval. In the main depocentre in the Poolowanna Trough, the Algebuckina Sandstone reaches a maximum thickness of 757 m in Poolowanna-1 (Moore 1986b). In the southeast of the NT, the formation is 581 m thick in Colson-1 (Beach Petroleum 1979), 620 m in Thomas-1 (Wiltshire 1982) and 598.3 m in Poeppels Corner-1 (Arco Australia 1985), but it thins to the north and west to be 458.4 m thick in Simpson-1 (Central Petroleum 2009a), 254.2 m in McDills-1 (Amerada Petroleum 1965), 282.7 m in Blamore-1 (Central Petroleum 2008) and 198 m in CBM 93-002, which is located towards the western margins of the basin (Central Petroleum 2011a, **Figure 41.5**). The equivalent succession in the Cooper Basin area (Hutton Sandstone–Murta Formation) reaches a maximum thickness of about 850 m (Krieg *et al* 1995).

The Algebuckina Sandstone is a thick succession of fine- to coarse-grained, quartzic continental sandstone, with granule and pebble layers. Minor lenses of shale and siltstone are locally present and shale intraclasts are common in coarser beds. Sedimentary structures include large- and medium-scale tabular-planar or trough cross-beds (Krieg *et al* 1995, Ambrose and Heugh 2010). Near the basin margins in SA, a twofold subdivision of the formation into a lower, kaolinitic poorly sorted interval and an upper clean and well sorted interval, separated by an erosional unconformity is recognised (Wopfner *et al* 1970). This subdivision does not appear to be present in more central portions of the basin (Krieg *et al* 1995). Macrofossils recorded from exposures of the formation along the margins of the basin include leaves, stems, reproductive structures and pieces of wood up to 4 m long of ferns, cycads, bennettites, seed ferns and conifers (Harris 1962, Hopgood 1987). Palynofloras indicate that the formation ranges in age from late Early Jurassic (Toarcian) to Early Cretaceous (Berriasian; Price 1978, Moore 1986b),

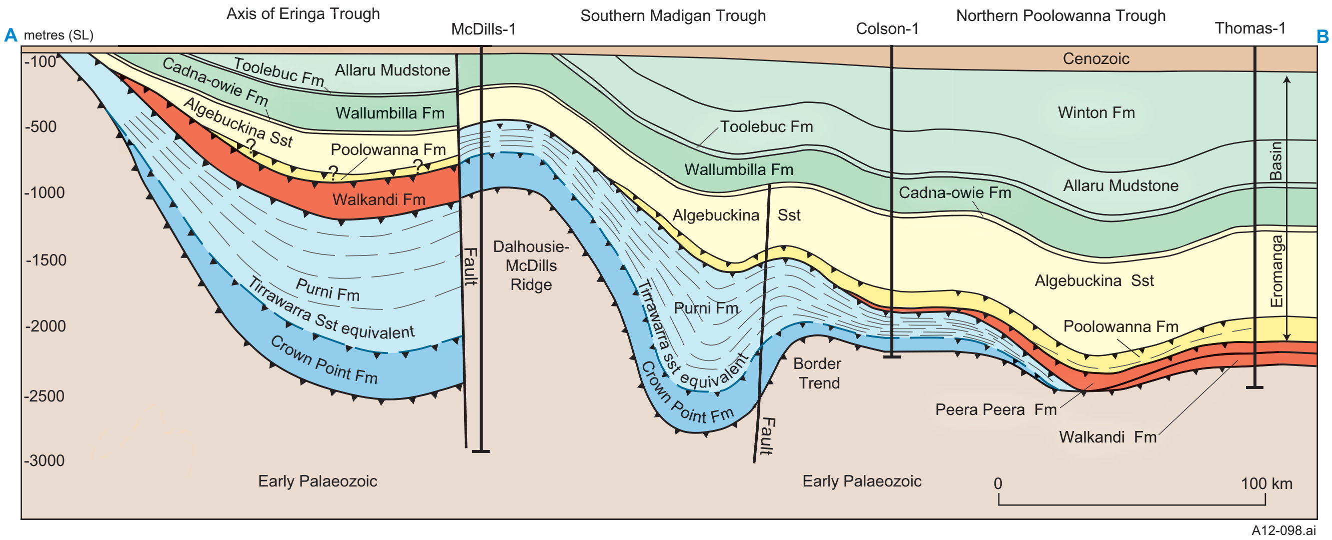

Figure 41.4. Schematic west–east structural cross-section across Pedirka and Eromanga basins (modified from Ambrose *et al* 2002) with additional data from Amerada Petroleum (1965), Beach Petroleum (1979) and Wiltshire (1982). Position of section shown in **Figure 41.5**.

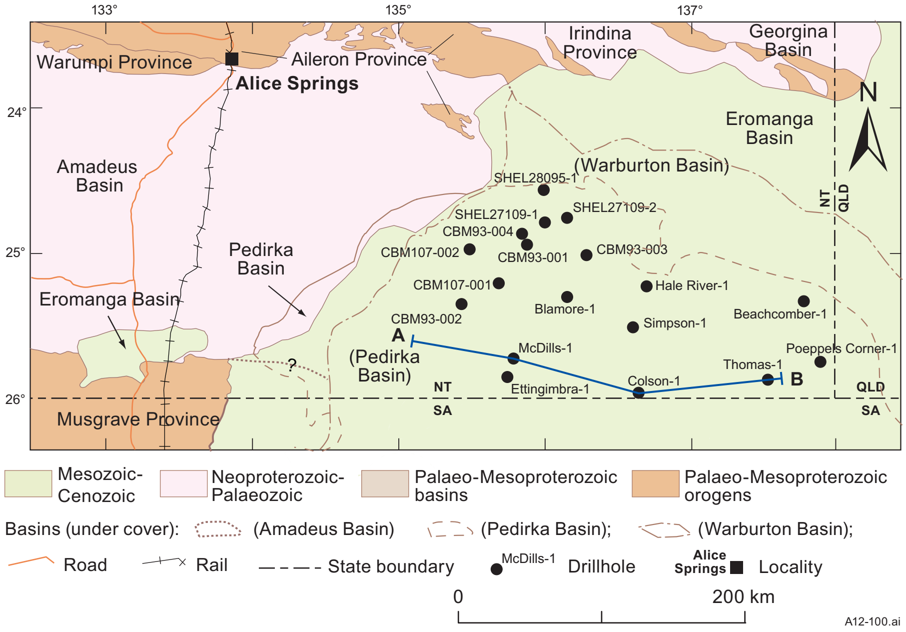

Figure 41.5. Location of drillholes within the NT portion of the Eromanga Basin.

but a slightly younger Valanginian age was indicated in Krieg *et al* (1995).

The absence of marine fauna and the presence of a more-or-less unidirectional cross-stratification indicate a fluviatile origin for the Algebuckina Sandstone. There have been a number of differing interpretations of the environment of deposition. Wopfner *et al* (1970) suggested that the setting was a senile and deeply weathered landscape with low-gradient rivers, episodic sheet flooding and an arid to seasonally arid climate, which was followed by wetter conditions with stronger more uniform flow and lacustrine bar as well as fluviatile deposition. Moore (1986b) interpreted a braided fluviatile environment for the formation with possible development of alluvial facies near cratonic source areas in SA and the NT. Wiltshire (1989) interpreted an environment that ranged from a mixed aeolian and receding scarp setting in the hinterland to quartz sand-dominated lacustrine, and Krieg *et al* (1991) interpreted a wet, cool to temperate conifer-forested setting with marked seasonal snow melt causing variable river flow.

Undifferentiated

Outliers of Eromanga Basin strata in southern TOBERMOREY and northern HAY RIVER (**Figure 41.3**) were originally described as Tarlton Formation, Longsight Sandstone or Hooray Sandstone (Smith 1963, 1965, Mond and Harrison in Senior *et al* 1978), but were remapped (in Tobermorey) as undifferentiated Jurassic–Cretaceous by Kruse *et al* (2002). The outliers consist of mesa-forming planar to cross-bedded, medium–coarse sandstone, and minor mudstone, siltstone and conglomerate (Smith 1963, Kruse *et al* 2002). These rocks are most likely to be equivalents of the Algebuckina Sandstone and possibly the Cadna-owie Formation, rather than the overlying, generally finer-grained Wilgunya Subgroup.

CRETACEOUS

The Cretaceous succession of the Eromanga Basin has been established independently in the southwestern and northeastern portions of this large depositional area, resulting in a complex nomenclature that is confusing and difficult to correlate (**Figure 41.2**). In the northeast of the basin, the Cretaceous succession above the widespread Cadna-owie Formation (Wopfner *et al* 1970) is included within the Rolling Downs Group (Whitehouse 1955), which comprises the Wilgunya Subgroup (Casey 1959, Australian Water Resources Council 1975) and overlying Manuka Subgroup (Vine *et al* 1967). The Wilgunya Subgroup includes, in ascending stratigraphic order, the Wallumbilla Formation (Vine *et al* 1967), Toolebuc Formation (Casey 1959) and Allaru Mudstone (Vine and Day 1965, Vine *et al* 1967). The Manuka Subgroup comprises the Mackunda Formation (Vine and Day 1965) and overlying Winton Formation (Whitehouse 1955), both of which are recognised over most parts of the basin. In the southwest of the basin, the Marree Subgroup (Forbes 1966, Thomson 1980) is equivalent to the Wilgunya Subgroup and, in ascending stratigraphic order, comprises the Bulldog Shale (Freytag 1966), Coorikiana Sandstone (Thomson 1980, Moore and Pitt 1982) and Oodnadatta Formation (Freytag 1966).

Wopfner *et al* (1970) defined the Neales River Group in the southwest of the basin to embrace the entire succession from the Cadna-owie Formation to the Winton Formation, including the Marree Subgroup. However, this group equates to the same interval as the previously defined Rolling Downs Group, except for inclusion in it of the underlying Cadna-owie Formation (which is presently excluded from the latter group). Furthermore, the Mackunda and Winton formations were already included within the Rolling Downs Group, so the concept of the Neales River Group was flawed from the outset and the name has not been widely used. In order to reconcile the group-level Cretaceous nomenclature of the basin, WM Cowley (Convenor, SA Stratigraphy Subcommission, *in litt* 2012) has proposed a number of recommendations that are followed herein:

- The name 'Neales River Group' is abandoned, and the name Rolling Downs Group is applied to the succession in the southwestern Eromanga Basin from top Cadna-owie Formation to top Winton Formation.
- The name Marree Subgroup is retained for the interval Bulldog Shale to Oodnadatta Formation, but is included within the Rolling Downs Group.
- The name Manuka Subgroup is adopted for use throughout the basin to encompass the Mackunda and Winton formations.
- The Cadna-owie Formation, which is a transitional terrestrial to marine unit that is generally conformable between the fluviatile succession below and the marine succession above, remains ungrouped pending a better determination of its affinities.

The nomenclature of formation-level units from the interval between the Cadna-owie and Mackunda formations (Marree and Wilgunya subgroups) is also complicated and difficult to reconcile. The presence or absence of the Coorikiana Sandstone and Toolebuc Formation determines which of the subgroup-level nomenclatures has been applied to successions within the basin (Questa 1990). The two formations generally occur in different parts of the basin, but in areas where they are both present, they have been shown to be at different stratigraphic levels (Krieg *et al* 1995, **Figure 41.6**). Overlying and underlying units therefore cannot be directly correlated; the Wallumbilla Formation is equivalent to the Bulldog Shale, Coorikiana Sandstone and lower part of the Oodnadatta Formation, whereas the Toolebuc Formation and Allaru Mudstone are equivalent to the middle and upper part of the Oodnadatta Formation. The nomenclature becomes complicated in areas where the Coorikiana Sandstone and Toolebuc Formation are both present, and also in areas where these formations are either absent or poorly defined; in these areas, the fine-grained units of the Marree and Wilgunya subgroups are difficult to distinguish from one another (Questa 1990).

In the NT, the nomenclature is particularly confusing and poorly defined. Questa (1990) noted that the Toolebuc Formation, which distinguishes the Qld succession, was generally absent over most of the NT portion of the basin except in the far southeast, where it had been described from a few drillholes. As a result of this perception, the SA nomenclature (Bulldog Shale/Oodnadatta Formation) has been generally used to describe the succession in the NT part of the basin. Notably, the Coorikiana Sandstone, which serves to define the succession in SA, has not been recognised in the NT, although it is possibly present in the subsurface in southerly areas near the SA border. Recent drilling by petroleum and mineral explorers has now established that the Toolebuc Formation is much more widespread than previously recognised, and it is present in drillholes across the NT portion of the basin, including the Eringa Trough and areas further to the west (Ambrose and Heugh 2011, **Figure 41.6**). The Wilgunya Subgroup nomenclature is therefore more applicable to the NT than that of the Marree Subgroup, and the names Wallumbilla Formation/Allaru Mudstone are more appropriate to describe the succession, as first suggested by Moore (1986a). This nomenclature is followed herein (**Figure 41.2**, **Table 41.1**).

Ungrouped

Cadna-owie Formation

The Cadna-owie Formation (Wopfner *et al* 1970; equivalent to ‘Transition beds’ of Whitehouse 1955) is a thin, mainly fine-grained unit that represents a transition from terrestrial to marine depositional environments during a widespread Early Cretaceous transgression. The formation extends throughout the Eromanga Basin, mostly in the subsurface except for exposures along the southwestern margin of the basin in SA. It is possibly equivalent to the upper part of the locally named ‘De Souza Sandstone’, which outcrops in the western part of the basin in the NT, mostly in KULGERA and FINKE (Wells 1969, Edgoose *et al* 1993), although the unit is yet to be recognised in these areas. The Cadna-owie Formation contains the fluviatile–deltaic *Mount Anna Sandstone Member* (Wopfner *et al* 1970) and fluviatile–tidal *Trinity Well Sandstone Member* (Forbes 1966) near the top of the formation in SA, and the transitional (?beach setting) *Wyandra Sandstone Member* (Senior *et al* 1975), which occupies a similar stratigraphic position at the top of the unit in Qld. The formation is conformable on the Algebuckina Sandstone in the west and southwest of the basin, although an erosional contact can be present (Krieg *et al* 1995), and on the Murta Formation and Hooray Sandstone in the east and northeast of the basin. A shale at the base of the Cadna-owie Formation in the west of the basin, commonly referred to as uppermost ‘Murta Formation’[1] shale by petroleum explorers (eg Ambrose and Heugh 2010), was referred to the basal Cadna-owie Formation by Gray *et al* (2002). The formation is conformably overlain by the Bulldog Shale in the southwest of the basin and by the laterally equivalent Wallumbilla Formation, in areas to the north and east (**Figure 41.4**). Over most of the basin, the unit is generally 60–90 m thick; it is only 10–20 m thick where it is exposed along the southwestern basin margin (Moore and Pitt 1985) and it reaches a maximum of >100 m thick in the Cooper Basin area. In general, the formation thins towards the flanks of the basin and across many prominent structural highs (Questa 1990). In the Northern Territory, the unit is thickest towards the central parts of the basin in the east and south, and thins towards the flanks of the basin in the northwest; it is 81 m thick in Poeppels Corner-1 (Arco Australia 1985), 59.5 m in Thomas-1 (Wiltshire 1982),

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[1] Murta Formation and underlying Namur Sandstone in the Cooper Basin are equivalent to the upper Algebuckina Sandstone in the Poolowanna Trough (Krieg *et al* 1995).

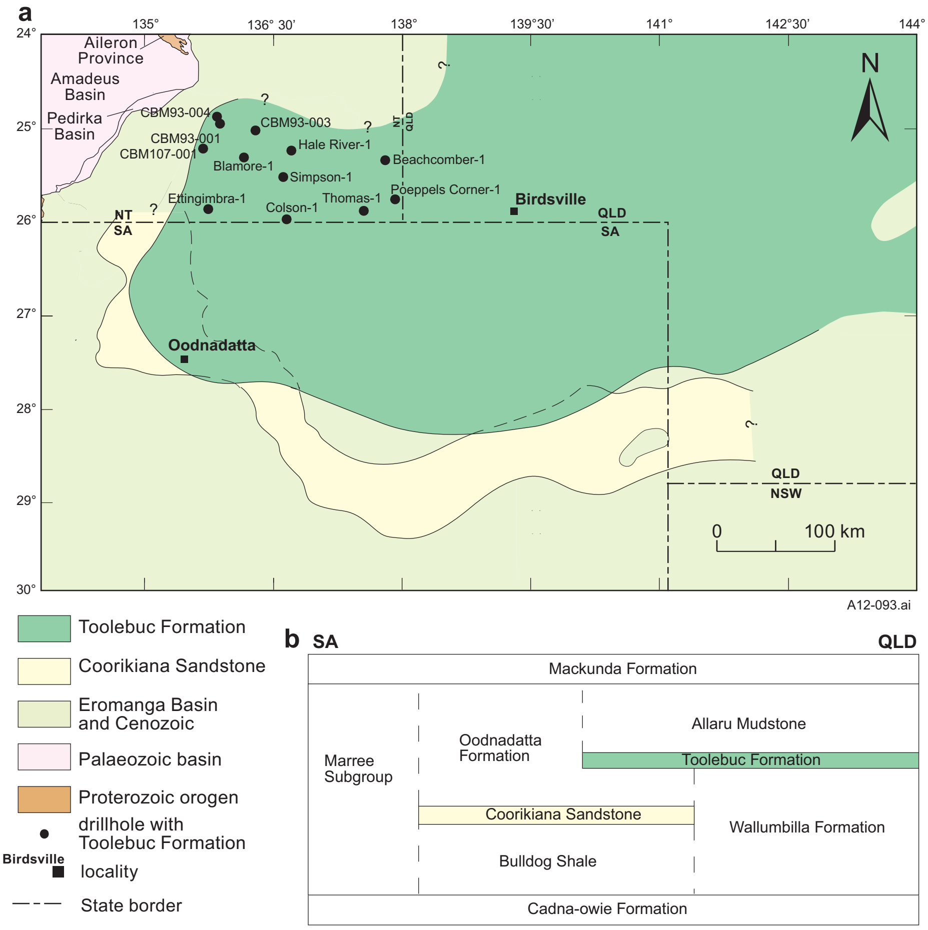

Figure 41.6. (**a**) Geographical extent of Coorikiana and Toolebuc formations in SA, NT and southwestern Qld, based on drillhole information. Distribution in SA after Krieg *et al* (1995, figure 9.20). Distribution in NT drillholes after Ambrose and Heugh (2011). Distribution in Qld simplified after Gray *et al* (2002, figure 72). (**b**) Schematic cross-section showing stratigraphic relationships between units from interval between Cadna-owie and Mackunda formations. Not to scale (derived from Krieg *et al* 1995, figure 9.20).

42.1 m in Colson-1 (‘Transition Beds’; Beach Petroleum 1979), 82 m in McDills-1 (‘Transition Beds’; Amerada Petroleum 1965), 35.6 m in Simpson-1 (including 20.6 m identified as ‘Murta Member’; Central Petroleum 2009a), 35.3 m in Blamore-1 (including 30.3 m identified as ‘Murta Member’; Central Petroleum 2008) and 23 m in CBM 93-02 (Central Petroleum 2011a, **Figure 41.5**).

The Cadna-owie Formation consists predominantly of thinly to thickly interbedded sandstone, siltstone, silty mudstone and mudstone, and minor claystone, typically with parallel bedding and upward-coarsening intervals. Pebbly layers, diamictites and coarse breccia layers occur locally, and large rounded dropstones, up to boulder size, are widely distributed around the basin margin in SA (Krieg *et al* 1995). Sandstone is lithic to quartzic and sublabile, and is generally very fine- to fine-grained, although laterally extensive or locally developed medium- to very coarse-grained sandstone interbeds also occur (Gray *et al* 2002, Krieg *et al* 1995). Some sandstone, particularly towards the top of the unit, may be carbonate cemented. Finer-grained beds may be laminated or occasionally cross-laminated, and coarser beds are sometimes trough cross-bedded at small to medium scales. Other sedimentary structures present within the formation include dewatering structures, ripple and hummocky cross-strata, tidal-bundle successions and minor bioturbation (Krieg *et al* 1995). An informal twofold division of the formation is recognised in many parts of the basin, particularly in the east and northeast (John 1985, Questa 1990, Gray *et al* 2002), although only a single coarsening-upward interval has been described from central parts of the basin (Moore and Pitt 1984, 1985, Krieg *et al* 1995). The lower interval consists of upward-coarsening silty mudstone, mudstone and very fine to fine sandstone, whereas the upper interval, which includes the named sandstone members, consists of fine- to medium-grained thickly bedded sandstone and minor siltstone.

The Cadna-owie Formation contains low-diversity microplankton (dinocyst and spinose- and non-spinose-acritarch) assemblages at various levels, suggesting depositional conditions ranging from fresh- to brackish-water lacustrine to restricted/marginal marine, with the marine influence increasing upsection (Gray *et al* 2002 and references therein). In areas around the basin margins, subtidal to peritidal to fluviatile facies are indicative of an irregularly advancing, possibly oscillating shoreline with extended intervals of stillstand (Krieg *et al* 1995). In deeper parts of the basin, Moore and Pitt (1985) interpreted lacustrine, followed by paralic, then shoreface and beach environments for the formation. Frakes and Francis (1988) interpreted a very seasonal climate at the time of deposition, with winters cold enough to allow rivers and basin shorelines to freeze; these cold conditions resulted in the formation of periglacial features within the formation, such as dropstones and diamictite. The palynoflora has been assigned to the upper APK12 to APK31 Early Cretaceous palynostratigraphic zones (late Valanginian–early Aptian, **Figure 41.2**).

Rolling Downs Group

The Rolling Downs Group (Whitehouse 1955) is a thick (up to about 1700 m) sedimentary succession that extends throughout the Eromanga Basin. It has been subdivided into the Marree and laterally equivalent Wilgunya subgroups (Casey 1959, Forbes 1966, Australian Water Resources Council 1975, Thomson 1980), which are overlain by the widespread Manuka Subgroup (Vine *et al* 1967, **Table 41.1**). Isopach maps showing the principal depocentres of the group in southwestern Qld and northeastern SA are presented in **Figure 41.7**.

Wilgunya Subgroup

Wallumbilla Formation

The Wallumbilla Formation (Vine *et al* 1967) is widespread in Qld, northeastern SA, northwestern NSW and the southeastern area of the NT, in the Eromanga, Carpentaria and Surat basins. It is laterally equivalent to the Bulldog Shale, Coorikiana Sandstone and lower part of the Oodnadatta Formation in SA, and the fine-grained units within this succession are lithologically very similar to, and not easily distinguished from the Wallumbilla Formation. The name ‘Bulldog Shale’ has been previously used to describe the formation in the NT (eg Questa 1990, Ambrose and Heugh 2010), but this name is inappropriate due to the widespread occurrence in NT drillholes across the basin (Ambrose and Heugh 2011, **Figure 41.6**) of the Toolebuc Formation, which defines the top of the Wallumbilla Formation in Qld and NSW. In the western part of the basin, the local name ‘Rumbalara Shale’ (Wells 1969) has been used for fine-grained exposures at a similar stratigraphic level that, in southern FINKE, were subsequently assigned to the Bulldog Shale? by Edgoose *et al* (2002, **Figure 41.3**). The Coorikiana Sandstone, which defines the SA nomenclature, and Toolebuc Formation are both apparently absent in this area, so the true affinities of these exposures are unclear and the succession might therefore represent any or all of the fine-grained units from the interval above the Algebuckina Sandstone. These rocks form a belt of outcrops extending from southeastern FINKE, through northwestern McDILLS to southern HALE RIVER and are here referred to as unassigned Wilgunya Subgroup. The Wallumbilla Formation is equivalent to the former ‘Roma Formation’ and lower part of the overlying former ‘Tambo Formation’ of Whitehouse (1955) of the northern Surat Basin, and the name ‘Roma Formation’ has sometimes also been used for the Wallumbilla Formation in the NT (eg Beach Petroleum 1979). Both of these names were abandoned following a revision by Vine *et al* (1967), which adopted the current Surat Basin nomenclature.

In the NT, the Wallumbilla Formation is conformable, generally with a sharp boundary, on the Cadna-owie Formation, except in FINKE, where the Cadna-owie Formation has not been recognised and the ‘Rumbalara Shale’ was described by Wells (1969) as being unconformable/disconformable on the ‘De Souza Sandstone’ (now Algebuckina Sandstone; Edgoose *et al* 2002). The formation is conformably overlain by the Toolebuc Formation (Alexander *et al* 2006), or where this is absent, is conformably overlain by the Allaru Mudstone (Gray *et al* 2002). The Wallumbilla Formation is mostly subsurface in the NT, except for areas in the western part of the basin, where the formation or a probably equivalent unit is exposed as mesas, buttes or low rounded duricrusted hills (Wells 1969, Edgoose *et al* 2002). The formation is 200 to >350 m thick in the Eromanga Basin in Qld and up to maximum of 375 m thick in a depocentre to the south, where it overlies Permian rocks of the Cooper Basin (Gray *et al* 2002, **Figure 41.7**). In the Northern Territory, the formation thins to the north and northwest from ca 237 m thick in Thomas-1 (Wiltshire 1982) and 220 m in Colson-1 ('Roma Formation': Beach Petroleum 1979) to 143 m in Simpson-1 (Central Petroleum 2009a) and 125 m in Blamore-1 in the Madigan Trough area (Central Petroleum 2008). To the west of the Eringa Trough, a thinner succession described as

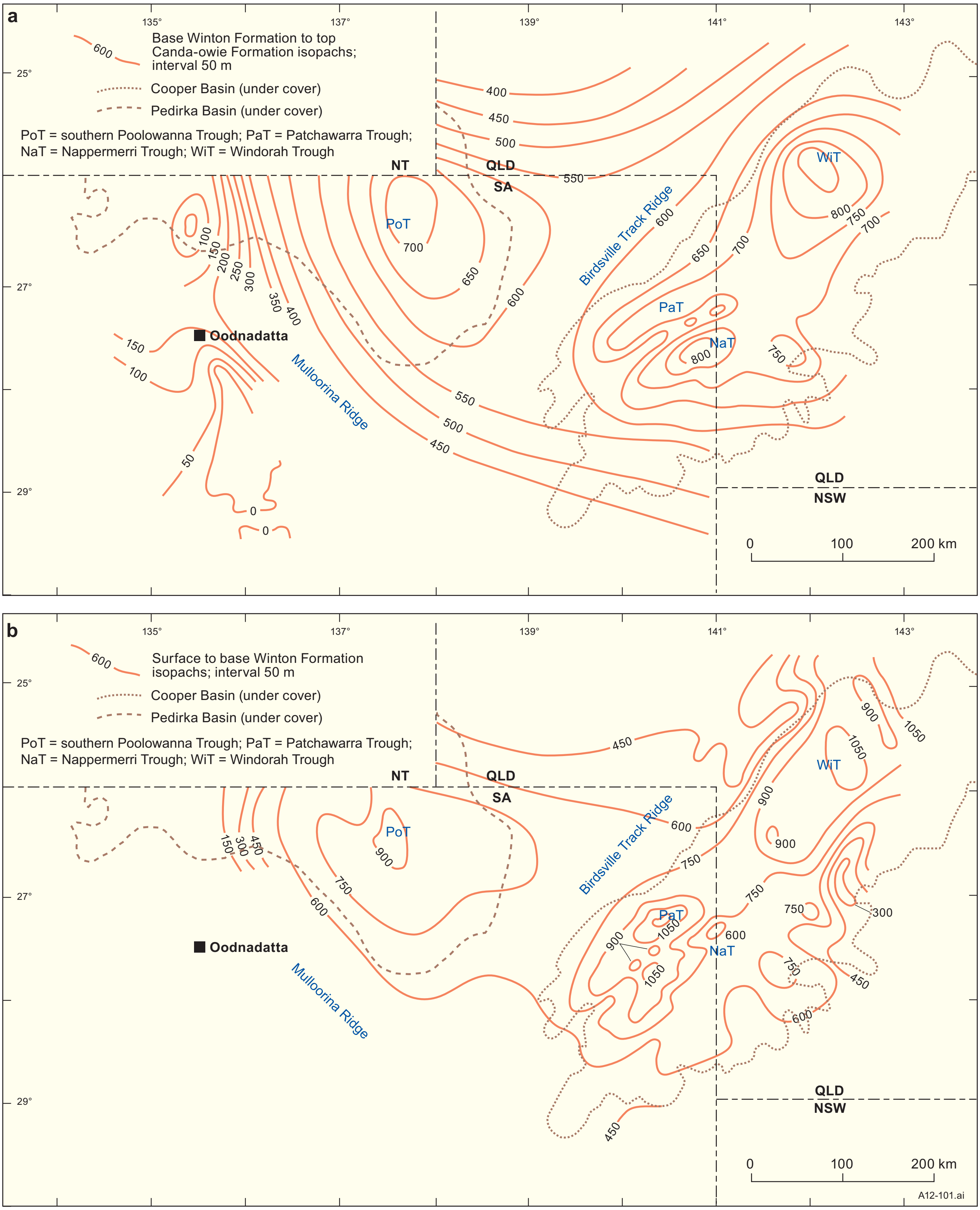

Figure 41.7. Isopach maps for northeastern SA and southwestern Qld, showing (**a**) interval from top Cadna-owie Formation to base Winton Formation, and (**b**) interval from base Winton Formation to surface (redrawn after Moore and Pitt 1985, figures 10, 12). Note that principal depocentres for Eromanga Basin overlie those of Permian–Triassic Pedirka and Cooper basins (labelled).

'Mackunda Formation/Bulldog Shale' is about 93 m thick in CBM 93-002 (Central Petroleum 2011a). A thickness of ca 275 m has been estimated for the 'Rumbalara Shale' in southern FINKE (Wells 1969).

A number of members are recognised within the Wallumbilla Formation in the east and north of the basin in Qld (Doncaster, Coreena, Jones Valley and Ranmoor members), and a thin coarse-grained interval occurs at the base of the equivalent Bulldog Shale in the south of the basin in SA. However, none of these units is recognised in the central portions of the basin, where Gray *et al* (2002) divided the Wallumbilla Formation into informal lower and upper units. The lower unit typically consists of a 30 m-thick interval of mudstone and limestone overlain by interbedded and laminated mudstone, sandstone and sandy mudstone. The very fine-grained sandstone increases up-section and carbonaceous material and shell fragments occur throughout. The upper unit typically consists of a lower interval of laminated and thinly bedded mudstone, siltstone and sandy mudstone, and subordinate sandstone, that is overlain by an interval of sandstone with some interbedded siltstone and mudstone. Carbonaceous material occurs throughout, but shell fragments and marine macrofossils are restricted to the lower finer-grained part of the upper unit (Gray *et al* 2002). In the NT, this informal subdivision is not recognised and the formation has typically been described as a relatively homogenous unit of mudstone and siltstone (Questa 1990), with minor thin interbeds of fine sandstone and limestone. In these areas, the formation is calcareous in part, may contain glauconite, and shell fragments that are common in places. In southern FINKE, the finer lithologies of the probably equivalent unit in this area have been silicified to porcellanite in places (Wells 1969, Edgoose *et al* 2002). The Wallumbilla Formation and correlative Bulldog Shale both contain diverse fossil assemblages, including bivalve molluscs, gastropods, ammonites, belemnites, scaphopods, brachiopods, crinoids, bryozoans, a poriferan, foraminifera, radiolarians, ostracods, diatoms, fish fragments, insects, marine reptiles, plant fragments, including large pieces of fossil wood, dinoflagellates, acritarchs, and spores and pollen (Moore and Pitt 1985 and references therein, Krieg *et al* 1995 and references therein, McKenzie 1999, Gray *et al* 2002, Kear 2003, Oosting 2004, Jell 2004, Jell *et al* 2011). Palynofloras have been assigned to the APK31–APK5 Early Cretaceous palynostratigraphic zones (early Aptian–late Albian; Price *et al* 1985, Filatoff and Price 1988, Price 1997, **Figure 41.2**). The environment of deposition is interpreted to have included marine, nearshore to marginal marine, and occasionally terrestrial settings (Gray *et al* 2002). Krieg *et al* (1995) noted the presence of glendonite nodules and dropstones in the Bulldog Shale, particularly towards the base of this unit and towards the margins of the basin in SA; these are indicative of a seasonal, relatively cold climate, at least during the earlier stages of deposition of this unit.

Toolebuc Formation

The sheet-like Toolebuc Formation (Casey 1959) is widespread across the central, eastern and northern Eromanga Basin, in Qld, northeastern SA, northwestern NSW and the southeastern NT, and also extends into the contiguous Carpentaria Basin in northern Australia. In the NT, it was previously considered to be restricted to the subsurface in the far southeast, but has since been shown to be widespread in drillholes across the NT portion of the basin (Ambrose and Heugh 2011, **Figure 41.6**). In SA, the unit extends no further south than the Moomba–Oodnadatta area (Krieg *et al* 1995). The thickness of the formation is generally in the range 20–45 m, with a maximum thickness of 65 m recorded in drillholes Poeppels Corner-1 in the southeastern NT and Teedeeldee-1 in southwestern Qld (Arco Australia 1985, Gray *et al* 2002). In the NT, the formation thins to the north and northwest towards the margins of the basin, to less than 15 m in drillhole CBM 107-001 (Ambrose and Heugh 2011). The Toolebuc Formation is conformable between the Wallumbilla Formation and Allaru Mudstone, and has a very distinct and strong gamma signature that enables it to be readily distinguished from these formations in wireline logs (Senior *et al* 1975, Ozimic 1986, Gray *et al* 2002).

The Toolebuc Formation is a fine-grained unit consisting predominantly of mudstone with thin layers of siltstone and subordinate labile sandstone, limestone, marl and conglomerate (Moore *et al* 1986, Questa 1990, Krieg *et al* 1995, Gray *et al* 2002). The mudstone is dark grey to black, poorly to well laminated, commonly clayey or silty, and may be carbonaceous, calcareous and/or pyritic. It typically has a high total organic content (TOC) generally in the range 9–20%, although ranging up to 35% in some areas (Henderson 2004, Ambrose and Heugh 2011), making this unit an attractive oil shale exploration target. The organic matter has been derived mainly from planktonic algae and cyanobacterial mats (Sherwood and Cook 1986, Glikson and Taylor 1986). Limestone is more common in northerly parts of the basin (Senior *et al* 1975) and is nodular or coquinitic, or occurs as calcitic laminae interbedded in mudstone. Where limestone is absent, the formation can be difficult to distinguish from under- and overlying fine-grained units (Questa 1990). The Toolebuc Formation contains a diverse Early Cretaceous fossil assemblage of bivalves, ammonites, belemnites and vertebrates, including numerous species of sharks, bony fish, rare pterosaurs, pterodactyloids and marine reptiles, less common plant remains, including rare coalified wood in some areas, and spore-pollen assemblages (Haig 1979, Shafik 1985, Moore and Pitt 1985 and references therein, Krieg *et al* 1995 and references therein, Henderson and Kennedy 2002, Gray *et al* 2002 and references therein, Kear 2003, Henderson 2004, Oosting 2004, Kellner *et al* 2010, Rich *et al* 2010). Palynomorphs are indicative of the late Albian APK5.2 and APK6 palynostratigraphic zones (of Price *et al* 1985, Filatoff and Price 1988, Price 1997, **Figure 41.2**). The formation was deposited under wholly marine conditions in an epeiric sea at the peak of an Early Cretaceous transgression. The abundance of organic matter, lack of bioturbation and general absence of diverse benthic faunas indicates dysoxic to anoxic benthic conditions, and the regular lamination of mudstone indicates deposition in relatively quiet, stratified water, probably with a permanent halocline below a layer of fresher water (Krieg *et al* 1995, Gray *et al* 2002). The coquinitic limestone layers commonly consist of the bivalves *Inoceramus* and *Aucellina*, which are interpreted to have been relatively tolerant of low oxygen levels (Ozimic 1986, Henderson 2004). Henderson interpreted the interlayering of coquina and organic-rich shale to be due to the alternation of suitable and unsuitable conditions for bivalve communities. This was attributed to an autocyclic process, whereby the sea-floor accumulation of shelly debris progressively isolated bivalve communities from trophic support, causing their periodic demise.

Allaru Mudstone

The Allaru Mudstone (Vine and Day 1965, Vine *et al* 1967) is widely distributed in Qld, northeastern SA, northwestern NSW and southeastern NT, in the central, eastern and northern Eromanga Basin, and also extends into the Carpentaria Basin in northern Australia. It is laterally equivalent to the middle and upper parts of the Oodnadatta Formation in the southern and southwestern Eromanga Basin in SA, and these fine-grained units are virtually indistinguishable lithologically (Moore and Pitt 1985). The name 'Oodnadatta Formation' has been previously used to describe the formation in the NT (eg Questa 1990, Ambrose and Heugh 2010), but this name is inappropriate due to the widespread occurrence in drillholes across the NT portion of the basin (Ambrose and Heugh 2011, **Figure 41.6**) of the Toolebuc Formation, which defines the base of the Allaru Mudstone in Qld and NSW. The Allaru Mudstone, along with the underlying Toolebuc Formation and overlying Mackunda Formation, are also equivalent to the upper part of the former 'Tambo Formation' of Whitehouse (1955) of the northern Surat Basin, and the name 'Tambo Formation' has sometimes also been used for the Allaru Mudstone in the NT (eg Beach Petroleum 1979). The name 'Tambo Formation' was abandoned following a revision by Vine *et al* (1967), which adopted the current Surat Basin nomenclature. The Allaru Mudstone conformably overlies the Toolebuc Formation or, where it is absent, the Wallumbilla Formation, and is conformably overlain by the Mackunda Formation (Gray *et al* 2002). However, Questa (1990) noted that the succession between the Toolebuc and Winton formations is not easily differentiated into distinct formations in the Northern Territory part of the Eromanga Basin, as the lithologies of the Oodnadatta Formation/Allaru Mudstone and Mackunda Formation are very similar. The boundaries between these units are therefore often determined from their gamma signatures in wireline logs (Senior *et al* 1975, Ozimic 1986, Gray *et al* 2002), rather than from a distinctive lithological change. The Allaru Mudstone is generally 200–300 m thick over most of its area of distribution, but it reaches a maximum thickness of 350–400 m in a northeast-trending depocentre, up to 100 km wide, to the north of the northern Permian zero edge of the underlying Cooper Basin (Gray *et al* 2002). This depocentre is further to the north than that of the underlying Wallumbilla Formation, which generally overlies the Permian succession of this basin. The Allaru Mudstone is an entirely subsurface unit in the NT, where significant thicknesses in the range 200–300 m have been recorded in a number of drillholes; this includes 303 m in Poeppels Corner-1 (Arco Australia 1985), 306 m in Simpson-1 (Central Petroleum 2009a) and 200 m in Blamore-1 (Central Petroleum 2008).

The Allaru Mudstone consists mostly of blue-grey mudstone, in part pyritic, with thin interbeds of calcareous siltstone, cone-in-cone limestone and minor very fine-grained sandstone and concretionary limestone (Moore and Pitt 1985, Questa 1990, Gray *et al* 2002). The correlative Oodnadatta Formation in SA was described by Krieg *et al* (1995) as consisting of claystone and siltstone with interbeds of fine-grained sandstone, calcareous and ferruginous concretions, and cone-in-cone limestone. The two formations contain a rich late Early Cretaceous fossil assemblage of ammonites, bivalves, dominated by *Inoceramus* and *Aucellina*, a scleractinian coral, teuthid squids, vertebrates, including turtles, fish, dinosaurs, and marine and terrestrial reptiles, and microfossils, including spore-pollen assemblages, dinocysts- and spinose-acritarch assemblages (Moore and Pitt 1985 and references therein, Wade 1993, Krieg *et al* 1995 and references therein, Molnar 1996, Henderson and Kennedy 2002, Gray *et al* 2002 and references therein, Thulborn and Turner 2003, Kear 2003, Jell *et al* 2011, Molnar 2011). Palynofloras are indicative of the APK6 palynostratigraphic zone (of Price *et al* 1985, Filatoff and Price 1988, Price 1997, **Figure 41.2**), although the basal part of unit APK7 may be represented in some areas and it is possible that the base of the formation may extend into unit APK52 (Gray *et al* 2002). These zones indicate a late Albian–?early Cenomanian age for the formation. The depositional environment is interpreted to have been quiet-water shallow marine from the abundant marine fauna, including well preserved whole shells, and from the uniform, mudstone-dominated lithology (Gray *et al* 2002).

Manuka Subgroup

Mackunda Formation

The Mackunda Formation (Vine and Day 1965) is widely distributed across the central and southern Eromanga Basin in Qld, SA and the NT, but is recognised neither in the southeastern parts of the basin in NSW, nor in the northernmost parts of the basin in Qld. The formation conformably overlies the Allaru Mudstone and Oodnadatta Formation, and is conformably overlain by the Winton Formation (Krieg *et al* 1995, Gray *et al* 2002). It is distinguished from these units by having a higher proportion of sandstone and by its distinctive signature in wireline logs, being also further differentiated from the Winton Formation by its marine depositional environment and lack of coal (Moore and Pitt 1985, Gray *et al* 2002). In southwestern Qld, the formation averages 74 to >100 m in thickness, with a maximum of 120 to >150 m in areas overlying Permian–Triassic rocks of the northern Cooper Basin (Gray *et al* 2002). In the southwestern Eromanga Basin in SA, the average thickness of the formation is about 100 m (Moore and Pitt 1985). The formation is not well described from the NT, where it occurs entirely in the subsurface, and it has not been clearly differentiated from underlying units in many drillholes. However, it reaches thicknesses of 144 m in Simpson-1 (Central Petroleum 2009a) and 120 m in Blamore-1 (Central Petroleum 2008), where it overlies Permian–Triassic rocks of the Pedirka Basin.

In most areas of the basin, the Mackunda Formation consists of thinly interbedded labile lithic sandstone, siltstone and mudstone, and lesser mud-clast intraformational conglomerate (Moore and Pitt 1985, Gray *et al* 2002). The sandstone is laminated and very fine- to fine-grained, and has an argillaceous and calcareous matrix. Carbonaceous partings are common. Siltstone and mudstone are laminated, calcite-cemented in part, and contain numerous plant remains. Fragments of marine shells, including the bivalve *Inoceramus*, and cone-in-cone limestone occur throughout the unit, and lode casts, calcite-filled fractures, disturbed bedding and minor nodular pyrite have also been reported (Gray *et al* 2002). The formation contains a diverse fossil assemblage of bivalves, belemnites, scaphopods, gastropods, rare ammonites and vertebrates, including common marine turtles, fish, shark teeth, a dinosaur, rare pterosaurs and marine reptiles, and microfossils, including benthonic foraminifera, and spore-pollen, spinose-acritarch and dinocyst assemblages (Bartholomai and Molnar 1981, Moore and Pitt 1985 and references therein, Krieg *et al* 1995 and references therein, Henderson and Kennedy 2002, Gray *et al* 2002 and references therein, Kear 2003). Occasional fluviatile/lacustrine algae have also been noted (Dettmann and Jones 1985). Spore-pollen assemblages are consistent with (Gray *et al* 2002) the late Albian–early Cenomanian APK6 and APK7 palynostratigraphic zones (of Price *et al* 1985, Filatoff and Price 1988, Price 1997, **Figure 41.2**). In the NT, the Mackunda Formation appears to be dominated by shale with lesser interbedded sandstone, and it is more difficult to distinguish the unit from the underlying Allaru Mudstone than it is in other parts of the basin. The succession between the Toolebuc and Winton formations occurring in drillholes in this region was described by Questa (1990) as comprising carbonaceous, pyritic, silty shale with traces of fossil fragments and *Inoceramus* prisms, common siltstone beds, minor sandstone, rare argillaceous limestone and occasional calcareous stringers.

The abundance of sandstone and presence of marine macrofossils and benthonic foraminifera indicate that the Mackunda Formation was probably deposited in shallow marine and paralic environments. The presence of intraformational mud-clast conglomerate and the paucity of planktonic organisms suggest shallowing and restriction of the sea (Exon and Senior 1976, Krieg *et al* 1995, Gray *et al* 2002), and very fine to medium-grained sandstones near the margins of the basin in SA are interpreted as probable shoreface sand bodies (Krieg *et al* 1995). Alternating shoreface sand, subtidal sand and mud, and marine mudstone in this part of the basin reveal that several cycles of regression and transgression occurred during deposition of the unit. These regressive-transgressive cycles are superimposed on a general falling trend in sea level at the time of deposition, and the formation therefore represents a transition from the underlying fully marine succession (Oodnadatta Formation/Allaru Mudstone) to the overlying freshwater Winton Formation (Krieg *et al* 1995).

Winton Formation

The Winton Formation (Whitehouse 1955) forms the upper part of the Rolling Downs Group and is the uppermost unit of the Eromanga Basin. The formation is widespread throughout much of the basin in SA, NT, NSW and Qld, and it forms thick sections in two major depocentres (Krieg *et al* 1995, Gray *et al* 2002, **Figure 41.7**). An elongate northeast-trending depocentre overlies the Permian–Triassic Cooper Basin and extends for about 500 km from northeastern SA into Qld. The formation is generally 400–1000 m thick in this region and it attains its maximum thickness of about 1200 m in the centre of the Patchawarra Trough in the southwest of this depocentre in SA. A smaller depocentre, where the formation is >900 m thick, is in the southern Poolowanna Trough in northern SA, just south of the NT–Qld border. The formation thins markedly away from these principal areas of deposition. In the NT, the Winton Formation reaches a maximum thickness of ca 620 m in drillholes Poeppels Corner-1 and Thomas-1 (Wiltshire 1982, Arco Australia 1985), but it thins to the north and northwest to be 444 m thick in Simpson-1, 370 m thick in Blamore-1 (Central Petroleum 2008, 2009a) and 178 m thick in CBM 93-02, near the western margins of the basin. The formation is widespread in outcrop and shallow subcrop throughout much of southwestern Qld, but mostly occurs in the subsurface elsewhere. In the NT, the formation is poorly exposed in western SIMPSON DESERT NORTH as highly weathered outcrops around dry lakes (Mond 1974), and in southwestern MCDILLS (**Figure 41.3**). The Winton Formation is conformable and transitional on the Mackunda Formation and the boundary between these lithologically similar units is often difficult to distinguish. However, it can usually be picked from wireline logs and the Winton Formation can also be distinguished by the presence of coal seams, which are absent in the Mackunda Formation (Gray *et al* 2002). In some successions where coal seams are lacking and these two formations are therefore more difficult to differentiate, the superseded name Blanchewater Formation (Forbes 1966) was used in the past for the combined undifferentiated interval (Moore and Pitt 1985). The Winton Formation is unconformably overlain by Cenozoic sediments, including those of the Lake Eyre Basin (see **Cenozoic geology and regolith**).

In the Queensland portion of the Eromanga Basin, the Winton Formation consists of interbedded sandstone, sandy siltstone, siltstone, mudstone and coal with minor intraformational conglomerate (Gray *et al* 2002). The well sorted, very fine- to fine-grained labile lithic sandstone is laminated to thinly bedded and has an argillaceous, partly calcareous matrix. It contains common plant fragments, finely disseminated carbonaceous material and coalified wood fragments. Finer lithologies are carbonaceous and contain interlaminated coaly material and rootlets. Coal is generally interbedded with carbonaceous mudstone. In the central and southern portions of the basin in SA and the NT, the formation is apparently finer grained and consists of claystone, siltstone and mudstone, with interbedded very fine- to fine- to occasionally medium-grained sandstone and minor coal seams (Moore and Pitt 1985, Questa 1990, Krieg *et al* 1995). Plant fragments and fossil wood are present within the succession. Finer lithologies were described as being massive in the NT (Questa 1990) and laminated to medium bedded in SA (Krieg *et al* 1995). Sandstone is quartzic and lithic, with a silica and calcite cement (Questa 1990), and has varying amounts of carbonaceous material and clay intraclasts. It contains a significant proportion of feldspar and ferromagnesian minerals, indicating derivation from a volcanic source. Sedimentary structures listed by Krieg *et al* (1995) include small-scale (ripple) cross-beds, lamination, penecontemporaneous slump structures, microfaults and bioturbation. The Winton Formation contains an abundant micro- and macroflora (Gray *et al* 2002 and references therein, Dettmann *et al* 2009 and references therein, McLoughlin *et al* 2010), and a macrofauna that includes freshwater bivalves, fish, lungfish, reptiles, insects, dinosaurs and dinosaur ichnites (Moore and Pitt 1985 and references therein, Krieg *et al* 1995 and references therein, Coombs and Molnar 1981, Dettmann *et al* 1992, Hocknull 1997, Kemp 1997, Jell 2004, Hocknull *et al* 2009, Salisbury *et al* 2007, Romilio and Salisbury 2011, Molnar 2011). Palynofloras are indicative (Gray *et al* 2002) of the late Albian–early Cenomanian APK6 and APK7 palynostratigraphic zones (of Price *et al* 1985, Filatoff and Price 1988, Price 1997, **Figure 41.2**). The fossil assemblages indicate a mostly low-energy, non-marine setting for the bulk of the Winton Formation, and the various rock types, including coal, and sedimentary structures indicate an environment of deposition ranging from fluviatile to paludal to lacustrine (Moore and Pitt 1985, Gray *et al* 2002). Towards the base of the formation, a more heterogeneous environment of deposition has been interpreted, ranging from paralic, estuarine and deltaic to fluviatile (Questa 1990, Fielding 1992).

STRUCTURE AND TECTONIC HISTORY

The structural fabric of the Eromanga Basin was largely inherited from pre-existing terranes and the basin has an overall broad synclinal structure that mirrors the underlying Permian–Triassic basins. The overall structural grain trends north-northeast, although some significant northwesterly structures are also present throughout the basin (Krieg *et al* 1995, Gray *et al* 2002). In the central and western Eromanga Basin, the main depocentres broadly coincide with underlying Triassic depocentres of the Pedirka and Cooper basins (**Figure 41.7**), which in the NT, are separated or segmented by a number of northeast- to north-trending, anticlinal basement ridges (trends), including the prominent Birdsville Track Ridge between the Cooper and Pedirka basins. These and other basement features are shown in **Pedirka Basin: figure 38.2** and are described in more detail in that chapter. The principal depocentre in the NT, which extends into northernmost SA, is the Poolowanna Trough (**Figure 41.4**); it accumulated a thick Early Jurassic to early Late Cretaceous succession. A regional basin tilt to the southeast was maintained during deposition of Eromanga Basin strata (Ambrose *et al* 2002).

Models to explain the origin and subsidence history of the Eromanga and Surat basins were summarised in Krieg *et al* (1995) and Waschbusch *et al* (2009). Both basins formed on a generally stable craton and were generally fluviatile in nature until the Early Cretaceous. Middleton (1980) considered that the initial subsidence and subsequent development of the Eromanga Basin resulted from deep crustal metamorphism, followed by increased subsidence in the mid-Cretaceous due to thermal contraction of the lithosphere. Initial subsidence may have been accompanied by igneous underplating and coeval compression (Zhou 1993). Gallagher and Lambeck (1989) suggested that subsidence was driven by thermal decay of the lithosphere and that an increase in the subsidence rate in the Early Cretaceous was due to sediment influx greater than that predicted to fill the accommodation space produced by thermal decay. This sediment influx was largely volcanigenic and has been related to increased volcanic activity associated with the development of a contemporaneous volcanic arc (Whitsunday Volcanic Province) to the east of the present-day Qld coastline (Veevers 1984, Moore *et al* 1986, Bryan *et al* 1997, Korsch *et al* 1998). The easternmost parts of Australia experienced continental extension in a backarc setting from this time until the Late Cretaceous, when seafloor spreading commenced in the southern Tasman Sea. Waschbusch *et al* (2009) proposed that tectonic subsidence in the Eromanga and Surat basins had at least three components: (1) sea-level changes; (2) long-wavelength tilting due to subduction-related corner-flow in the mantle (as per Mitrovica *et al* 1989); and (3) 'intracratonic' subsidence, possibly due to mantle downwelling, or avalanche, events (as per Pysklywec and Mitrovica 1997), which is a more passive mechanism that occurs when a continent passes over sinking detached lithospheric slabs in the mantle (Russell and Gurnis 1994), or the dynamic topography of a mantle plume is removed. In the western Eromanga Basin in the NT and SA, Waschbusch *et al* (2009) suggested that intracratonic subsidence might be due to remnant thermal subsidence over the Cooper Basin, or to a mantle-downwelling event beneath the continental interior, or possibly to the removal of a mantle plume. In the Late Cretaceous, subsidence ceased in the Surat and Eromanga basins as a result of tectonic-plate realignment and cessation of subduction, or a jump in the subduction zone well to the east of Australia (Waschbusch *et al* 2009). Rebound of the lithosphere after the cessation of subduction resulted in both basins becoming inverted, with subsequent denudation of about 1–2 km (Raza *et al* 2009).

Questa (1990) noted that the inception and subsequent growth of structural features in the western Eromanga Basin have been in response to plate-margin behaviour, but because of the large distances from plate margins, the transmitted stresses were relatively weak. Post-Triassic deformation, except for that of the Cenozoic, has therefore been relatively small scale. Most structures in the region are related to episodes of basement fault reactivation in the Late Cretaceous and Cenozoic (Carne and Alexander 1997, Gray *et al* 2002, Ambrose and Heugh 2010), although some new features were also formed at these times. Several significant episodes of Cenozoic structuring were the result of east–west compressional tectonism in response to the rotational stress applied to the Australian Plate by its oblique convergence with the Pacific Plate (Questa 1990). This included Oligocene uplift and folding, post-Miocene tilting and folding, and further structural rejuvenation during the Pleistocene to Recent (Ambrose *et al* 2002).

MINERAL RESOURCES

The few known mineral occurrences in the NT portion of the Eromanga Basin are shown in **Figure 41.3**. The mineral prospectivity of this part of the basin is yet to be assessed in any detail. The basin has attracted some exploration interest for its sandstone-hosted uranium potential, particularly in SA, although no systematic exploration for uranium has been undertaken in the NT portion of the basin. Ochre was mined at the Rumbalara Ochre Mine in northeastern FINKE in the mid-1900s and minor coal, manganese and opal occurrences have also been recorded. The petroleum potential of the basin is better studied and the southwestern part of the basin in southwestern Qld and northeastern SA, along with the underlying Cooper Basin, forms the best known and most significant onshore petroleum province in Australia. The Eromanga Basin is predominantly oil bearing with minor gas, whereas the Cooper Basin is mostly gas prone with a substantial light liquid component (Gray and Draper 2002).

Ochre

Yellow ochre was mined for use as a paint pigment between 1939 and 1951 at the *Rumbalara Ochre Mine* (includes the *Yellow Queen* and *Yellow King* mines) near Mount De Souza in northeastern FINKE on the western margins of the Eromanga Basin (Sullivan and Öpik 1951, **Figures 41.3**, **41.8**). The ochre forms a tabular stratiform ore body at the base of the 'Rumbalara Shale' (Bulldog Shale/Wallumbilla Formation), which unconformably overlies the 'De Souza Sandstone' (Algebuckina Sandstone). Ochre deposits are exposed on the flanks of isolated mesas and chains of mesas of 'Rumbalara Shale' that are capped by Cenozoic silcrete. At the Rumbalara mines, the ochre forms a tabular stratiform bed from ca 0.5 to 1.2 m thick (average 0.75 m) that contains pebbles and boulders of sandstone similar to the

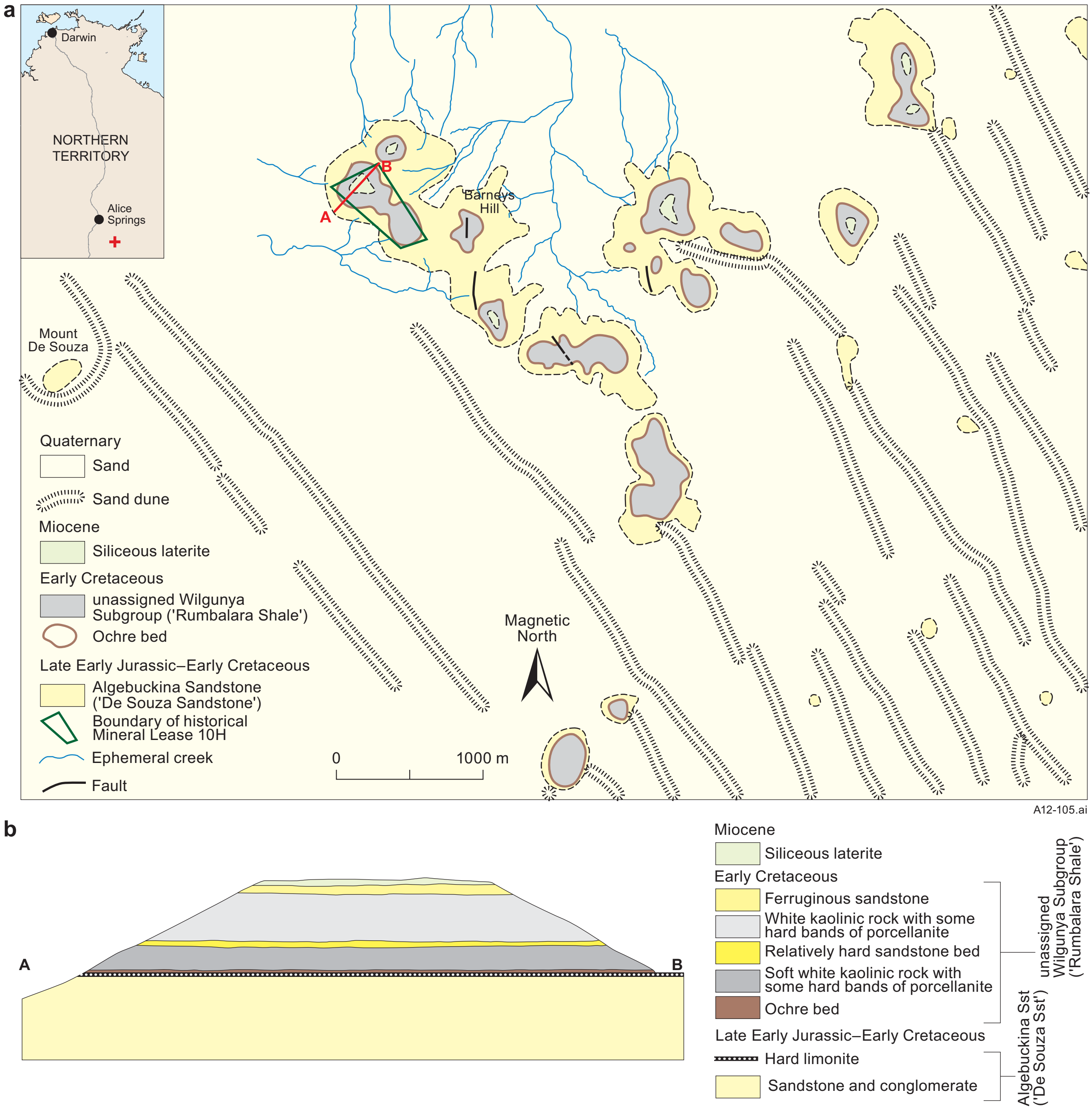

Figure 41.8. Rumbalara Ochre Mine. (**a**) Geological map of area surrounding mine and (**b**) schematic cross-section through mine deposit (redrawn after Sullivan and Öpik 1951). Rumbalara Mine area incorporates Yellow King and Yellow Queen mines, but these were not distinguished in original map.

underlying Algebuckina Sandstone. It is underlain by a thin (30–45 cm-thick) layer of limonite and is overlain by a much thicker (ca 11.5 m-thick) layer of soft white kaolinitic rock, apparently formed by leaching, that contains hard bands of porcellanite and poorly preserved pelecypods and radiolaria. Sullivan and Öpik (1951) considered the ochre to have been formed as a sedimentary iron ore, probably as a bacterial sediment. High-quality ochre is porous, bright golden-yellow and consists of 45–55% Fe_2O_3, kaolin and minor amounts of quartz and muscovite. Total recorded production from the Rumbalara mines was 7875 tons (ca 8000 t) and Sullivan and Öpik estimated possible remaining reserves to be 25 000–30 000 tons (ca 25 400–30 500 t) if the ochre layer maintains its thickness through the mesa hosting the mines. A chain of ochre-bearing mesas extends for over 30 km in the Rumbalara area, suggesting that total reserves could be considerably greater, but the quality of the ochre in these other deposits is not known.

Coal

Minor thin uneconomic coal seams have been reported from the Jurassic Poolowanna and Cretaceous Winton formations in the western and southwestern parts of the basin (Moore and Pitt 1985, Questa 1990, Krieg *et al* 1995, Ambrose *et al* 2007, Ambrose and Heugh 2010). Poolowanna Formation coal seams are rarely more than 0.5 m thick and are often discontinuous. The coal is black, dull and shaly (Questa 1990). Winton Formation coal is poorly described in the NT portion of the basin, but was described by Gray *et al* (2002) as being brown to black and interbedded with carbonaceous mudstone in the central and northern parts of the basin in Qld. Thin coal seams are more common in the lower part of the formation in these areas.

Manganese

A zone of manganese enrichment occurs within the Algebuckina Sandstone at *Umbeara* in southwestern FINKE (Edgoose *et al* 2002, **Figure 41.3**). It forms a brecciated vein, 800 m long and 100 m wide, that has a pyrolusite cement. There is no definitive evidence to indicate whether this occurrence is due to surface enrichment, but it seems most likely to be secondary, perhaps a fault infilling.

Opal

An area in the vicinity of and to the north of Mount Etingambra in southern McDILLS (**Figure 41.3**) was briefly prospected for opal in the early 1990s (Ward 1992a, b), after precious opal was rumoured to have been recovered from a borrow pit in the area. Samples of Cretaceous 'Rumbalara Shale' (Bulldog Shale/Wallumbilla Formation), described by Ward (1992a, b) as consisting of deeply weathered labile sandstone and claystone, were considered to be similar to lithologies encountered in opal-bearing areas of Queensland and New South Wales. Samples of ironstone also found in the area resembled the "Ironstone Boulders of southwest Queensland". These contained 'patch' opal, but no traces of precious or noble opal. Ward considered the area to be "quite favourable for the occurrence of 'Boulder' or 'Sandstone' precious opal deposits", but no further exploration was undertaken.

Petroleum

Stacked basins in the southeastern corner of the NT and adjacent areas are prospective for both conventional and unconventional petroleum at a number of stratigraphic levels. Possible plays in this region are associated with fractured basement rocks (Central Petroleum 2011b), early and mid Palaeozoic rocks of the Warburton Basin, Permian and Triassic rocks of the Pedirka Basin, and Mesozoic rocks of the Eromanga Basin. These basins have structures and depocentres in common and petroleum systems are not necessarily confined to any one basin succession.

The Eromanga Basin contains elements of the Murta petroleum supersystem of Bradshaw (1993) and Draper (2000) and is a significant oil/gas producer in both Qld and SA. Hydrocarbons reservoired in the basin have also been derived from source rocks associated with the underlying Permian–Triassic Gondwanan supersystem.

The petroleum prospectivity of the Eromanga Basin has been discussed in numerous publications, the more significant of which include Moore (1986a, b), Pitt 1986, Questa (1990), Alexander *et al* (1996), Michaelsen and McKirdy (1996a, b), Carne and Alexander (1997), Gray and Draper (2002), Ambrose *et al* (2002, 2007), Cotton *et al* (2006), Ambrose (2006), Central Petroleum (2009b), Radke (2009) and Ambrose and Heugh (2010, 2011).

Conventional petroleum

The NT potion of the Eromanga Basin has only been sparsely explored for conventional petroleum, although there is good potential for commercial accumulations. The succession has been penetrated by 18 drillholes (**Figure 41.5**) and there is about 3500 line km of modern seismic data over a relatively large prospective area of 70 000 km^2 (Ambrose *et al* 2002). So far, only non-commercial conventional hydrocarbon accumulations have been found in this area, in basal Jurassic sandstones of the basin. Of particular significance is a breached oil pool in a subtle Jurassic structure probably formed by drape and compaction that was intersected in drillhole Poolowanna-1 in SA, and the presence of residual oil columns in drillholes Colson-1 and Blamore-1 (Ambrose *et al* 2002, 2007, Ambrose and Heugh 2010). These are indicative of hydrocarbon migration to pre-Cenozoic structures in the region.

Source rocks

Source rocks of the western Eromanga Basin have been discussed in a number of publications including Moore (1986), Questa (1990), Carne and Alexander (1997), Ambrose *et al* (2002, 2007), Radke (2009) and Ambrose and Heugh (2011). The two best source rocks in this part of the basin are the Poolowanna and Toolebuc formations. The *Poolowanna Formation* has confirmed oil source rocks, particularly exinite-rich (sporinite, cutinite) shaly coal facies near the top of cycle 1 and to a lesser extent, cycle 2 (Ambrose *et al* 2007). TOCs are up to 15% and reflect common coal seams and abundant dispersed organic matter present in intraformational shale (Ambrose *et al* 2002). Questa (1990) noted that Mid-Poolowanna Formation sandstone in Poolowanna-1 was oil saturated, the source most likely being intraformational coal and dispersed organic matter in fine-grained clastic rocks. The *Toolebuc Formation* is a rich oil/gas source rock that in the western Eromanga Basin sometimes has minor, probably biogenic gas shows, with a minor component of heavy hydrocarbon molecules. In the eastern Eromanga Basin, TOCs in the range 9–20% have been recorded from this formation (Ambrose and Heugh 2011) and the unit has been described as an oil shale in the northern basin (Gray and Draper 2002). However, Boreham and Powell (1987) indicated that in a general sense, the unit probably should be regarded as an immature petroleum source rock.

Other Eromanga Basin rocks have subordinate source-rock potential, as discussed in Questa (1990). Although it is predominantly a coarse-grained interval, Questa considered the *Algebuckina Sandstone* to have significant source potential. Total Organic Carbon (TOC) values as high as 10% have been reported from samples of the unit, with vitrinite the dominant maceral and exinite comprising up to 30% of organic content. The *Wallumbilla Formation/Bulldog Shale* interval was not considered by Questa to be a significant hydrocarbon source in the western Eromanga Basin, but elsewhere in the basin, the formation has fair to occasionally excellent source intervals with mixed marine and terrigenous exinitic and vitrinitic organic matter (Kantsler *et al* 1986). Similarly, the *Cadna-owie Formation* was assessed by Questa as having some source potential for both oil and gas, with a locally high exinite content (eg up to 35% of organic content in Colson-1). Ambrose and Heugh (2010) reported that thin silty shale of the basal Cadna-owie Formation (commonly referred to by petroleum geologists as ‘Murta Member’) may be the source rock for residual oil recorded in the underlying Algebuckina Sandstone. However, Questa (1990) commented that the Cadna-owie Formation generally appears to contain predominantly poor-quality, gas-prone type III (vitrinite) kerogen. Low Hydrogen Indices suggest the presence of inertinite-rich and/or oxidised organic matter.

See **Pedirka Basin** for a brief discussion of underlying, fair to good Permian–Triassic source rocks (Purni Formation, Peera Peera Formation) that might have supplied hydrocarbons to reservoirs in the western Eromanga Basin succession.

Reservoirs and seals

Potential reservoirs in the Eromanga Basin are mainly in the lower part of the succession below thick Early Cretaceous marine strata, which constitute a widespread regional seal, commencing with the Wallumbilla Formation. The Eromanga Basin typically has vertically stacked hydrocarbon pools, and about 50% of the known fields in Qld and SA contain more than one pool (Gray and Draper 2002). This indicates that seals in the lower half of the succession are not wholly effective due to limited areal extent and variations in thickness and shale mineralogy (Carne and Alexander 1997). In the western part of the basin in the NT, where the succession overlies the Pedirka Basin, the best potential reservoir/seal couplets occur in: (a) the Poolowanna Formation, where lacustrine shale at the top of cycle 1 might form a regional seal to underlying braided fluviatile sandstone reservoirs; (b) the Algebuckina Sandstone, where reservoirs in the uppermost sandstone units might be sealed by thin silty shale of the basal Cadna-owie Formation (‘Murta Member’); and (c) Cadna-owie Formation shoreline sandstone reservoirs sealed by ubiquitous shale of the Wallumbilla Formation (Ambrose and Heugh 2010); these shoreline sandstone reservoirs form more significant regional targets where the basal Cadna-owie Formation shale is thin or absent. Ambrose and Heugh noted that all three seals have regional extent in the western Eromanga Basin and that the latter two reservoir/seal configurations are common to both the Pedirka Basin and Cooper Basin areas.

The *Poolowanna Formation* contains the deepest reservoir units in the Eromanga Basin succession, up to 2226 m in the Poolowanna Trough. Porosity averages 13%, with deeper samples showing the lowest average porosities due to the formation of quartz overgrowths, whereas permeability is in the range 0.001–3674 md (Carne and Alexander 1997). The *Algebuckina Sandstone* has good to excellent porosity and permeability, and forms a major artesian aquifer (Krieg 1985). In Blamore-1, the Algebuckina Sandstone contained a 15 m residual oil column beneath a basal Cadna-owie Formation seal (Ambrose and Heugh 2010). The *Cadna-owie Formation* forms the uppermost potential reservoir in the basin, below the regional seal of the Early Cretaceous marine succession. Carne and Alexander (1997) commented that the formation is generally poorly permeable in SA and not considered to be a potential reservoir unit, but Questa (1990) and Ambrose and Heugh (2010) noted that excellent porosities and permeabilities are present within the uppermost part of the unit in the NT.

Thermal maturity

Based on vitrinite reflectance values and spore colouration (Thermal Alteration Indices), Questa (1990) reported that Middle–Late Jurassic and Cretaceous successions of the western Eromanga Basin in the NT are predominantly immature to marginally mature for effective oil generation and expulsion (Ro <0.7%). However, the Early Jurassic Poolowanna Formation has reached the main oil generative window, with a peak maturity of 0.9% Ro in the Poolowanna Trough. Elsewhere in the region, the Poolowanna Formation is marginally mature (Michaelsen and McKirdy, 1996a, b). The Toolebuc Formation is not known to be thermally mature for oil/gas generation anywhere in the NT and hence sparse weak gas shows reported from the formation are probably biogenic in origin (Ambrose and Heugh 2011).

The thermal maturity of underlying Permian–Triassic source rocks that may have supplied hydrocarbons to Eromanga Basin reservoirs in the NT is discussed in **Pedirka Basin**.

Prospectivity

The stacked Warburton, Pedirka and Eromanga basins in the southeastern NT have an abundance of organically rich source rocks, porous and permeable reservoirs with effective vertical seals at a number of levels, and closed anticlinal structures. Late Palaeozoic Pedirka Basin and Mesozoic Eromanga Basin rocks remain the primary exploration targets. At least one unnamed petroleum system is present in the Eromanga Basin, which incorporates rocks of the Early Jurassic Poolowanna Formation, and there are a number of possible reservoir/seal configurations.

Most exploration activity in the Eromanga Basin has targeted strata overlying the Cooper Basin, on the basis that Eromanga reservoirs may have been charged as a result of vertical migration from Permian source rocks (Heath *et al* 1989). However, Michaelsen and McKirdy (1989, 1996a, b) concluded that there has been little appreciable migration from Permian source rocks into Eromanga Basin reservoirs in the southern Cooper Basin region and that many of the oils reservoired in the Eromanga Basin in that area were generated *in situ*. Long-distance lateral migration towards the basin margin has also been proposed in the southwestern Eromanga Basin in SA (McKirdy and Willink 1988), but in the western portion of the basin in the NT, relatively short migration pathways are more likely in the absence of gas displacement of early-reservoired oil (Ambrose and Heugh 2010, **Figure 41.9**). Most hydrocarbon generation is believed to have occurred as a result of sediment loading by the Winton Formation, either at the time of deposition of this unit in the Late Cretaceous (Ambrose and Heugh 2010), or afterwards in the Cenozoic (Questa 1990). In both cases, pre-Cenozoic structural and stratigraphic traps in the basin might have been effective trapping mechanisms prior to any significant oil migration, and structures that formed during the Cenozoic are therefore less favourable prospects (Carne and Alexander 1997, Ambrose and Heugh 2010). It is also possible that some oil may have been generated in major depocentres during the Early Cretaceous or earlier times from the Permian Purni Formation and older source rocks (Questa 1990, Ambrose and Heugh 2010, see **Pedirka Basin**).

Figure 41.9 shows the known distribution of Jurassic prospects and leads and Poolowanna Formation source kitchens in the Eromanga Basin in the NT. Possible traps include numerous four-way dip closures, combination structural-stratigraphic plays on the flanks of reactivated basement highs involving onlap of sandstone reservoirs, hangingwall fault plays, eg on the southern, fault-bounded margin of the Hale River High, and pinchout plays towards the basin margins (Ambrose *et al* 2002, Ambrose and Heugh 2010). Many of the more significant prospects and leads mirror those of the underlying Pedirka Basin and these and are discussed in that chapter.

The major risk for the preservation of early-formed oil pools is the breaching of traps by the reactivation of faults in the Cenozoic. Oil-bearing structures may survive mild reactivation, but those displaying catastrophic Cenozoic faulting are largely non-prospective (Ambrose and Heugh 2010).

Unconventional petroleum

Ambrose and Heugh (2011) reported on the unconventional potential of Mesozoic rocks in the western Eromanga Basin. The two most prospective intervals are the Toolebuc Formation and overlying basal Allaru Mudstone (referred to as Oodnadatta Formation by Ambrose and Heugh). Boreham and Powell (1987) indicated that the *Toolebuc Formation* should generally be regarded as an immature petroleum source rock, but the unit is considered to be an oil shale in the northeastern part of the basin in Qld, with “excellent

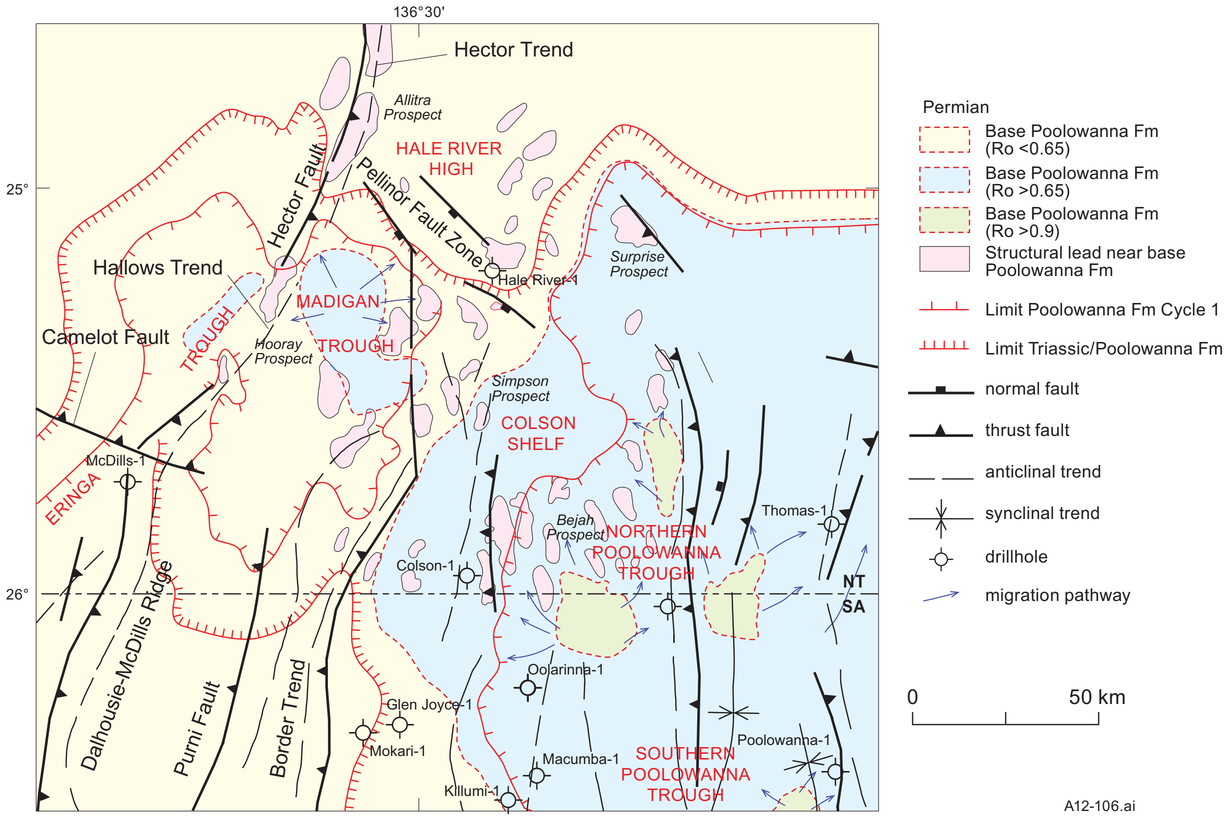

Figure 41.9. Distribution of Jurassic prospects and leads, and thermal maturity (isoreflectance contours) of Poolowanna Formation (modified from Ambrose *et al* 2002). Location of map shown in **Figure 41.1**.

potential" to generate hydrocarbon liquids and a source rock component that has generated gas (Exoma Energy Ltd, ASX Announcement 27 February 2012). Exoma is investigating the unconventional petroleum potential of the formation in this part of the basin, with an exploration program that may include laboratory studies, lateral drilling and staged fracture stimulation. In the western part of the basin in the NT, the Toolebuc Formation has yielded probably biogenic gas and is also prospective for unconventional petroleum (Ambrose and Heugh 2011), although it has yet to be investigated in detail. The overlying basal *Allaru Mudstone* contains a 40 m-thick gross interval of tight, very fine- to fine-grained glauconitic sandstone that appear to be gas charged, probably from underlying Toolebuc Formation source rocks. This gas play appears to be structural formed in a four-way dip closure with thick shale providing vertical seal and also has untested unconventional petroleum potential (Ambrose and Heugh 2011).

REFERENCES

Alexander EM, Pegum D, Tingate P, Staples C, Michaelsen BH and McKirdy PM, 1996. Petroleum potential of the Eringa Trough in SA and the NT. *APPEA Journal* 36(1), 322–348.

Alexander EM, Sansome A and Cotton TB, 2006. Chapter 5 – Lithostratigraphy and environments of deposition: in Cotton TB, Scardigno MF and Hibbert JE (editors) *Petroleum geology of South Australia, Volume 2, Eromanga Basin*. South Australia Department of Primary Industries and Resources. Petroleum Geology of South Australia Series.

Almond CS, 1983. Stratigraphic Drilling Report – GSQ Eromanga 1. *Queensland Government Mining Journal* 84, 359–368.

Ambrose GJ, 2006. Pedirka/Simpson Desert/Eromanga basins: in Northern Territory of Australia, onshore hydrocarbon potential, 2006. *Northern Territory Geological Survey, Record* 2006-003.

Ambrose GJ and Heugh J, 2010. *Petroleum geology of the Simpson Desert area: the Eromanga, Simpson, Pedirka and Warburton basins.* Central Petroleum Ltd, internal report.

Ambrose GJ and Heugh J, 2011. Unconventional hydrocarbons – new exploration targets in the Amadeus and Eromanga basins, the Wiso Basin (the Lander Trough) and the Pedirka Basin (Eringa and Madigan troughs). *Central Petroleum Ltd, Technical Note11.12.01* (Central Petroleum Ltd, ASX Announcement 01 December 2011).

Ambrose GJ, Liu K, Deighton I, Eadington PJ and Boreham CJ, 2002. New models in the Pedirka Basin, Northern Territory, Australia: in *'Australian Petroleum Production and Exploration Association conference, Adelaide, 21–24 April 2002'. APPEA Journal* 42, 259–286'.

Ambrose GJ, Scardigno M and Hill AJ, 2007. Petroleum geology of Middle-Late Triassic and Early Jurassic sequences in the Simpson Basin and northern Eromanga Basin of central Australia. *APPEA Journal* 47, 127–143.

Amerada Petroleum, 1965. Well completion report, Amerada McDills No 1. Amerada Petroleum Corporation of Australia Ltd. *Northern Territory Geological Survey, Open File Petroleum Report* PR1965-0012.

Arco Australia, 1985. Well completion report, Poeppels Corner No 1, OP-184, Northern Territory, Australia, February, 1985. Arco Australia Ltd. *Northern Territory Geological Survey, Open File Petroleum Report* PR1985-0029.

Australian Water Resources Council, 1975. *Groundwater resources of Australia.* Australian Government Publishing Service, Canberra.

Bartholomai A and Molnar RA, 1981. Muttaburrasaurus, a new iguanodontid (Ornthischia: Ornithopoda) dinosaur from the Lower Cretaceous of Queensland. *Memoirs of the Queensland Museum* 20, 319–349.

Beach Petroleum, 1979. Colson No. 1 Final well report, incorporating results of all analyses and laboratory studies. Beach Petroleum NL, North Broken Hill Ltd. *Northern Territory Geological Survey, Open File Petroleum Report* PR1979-0001.

Boreham CJ and Powell TJ, 1987. Sources and preservation of organic matter in the Cretaceous Toolebuc Formation, eastern Australia. *Organic Geochemistry* 11(6), 433 –449.

Bradshaw MT, 1993. Australian petroleum systems. *PESA Journal* 21, 43–53.

Bryan SE, Constantine AE, Stephens CJ, Ewart A, Schön RW and Parianos J, 1997. Early Cretaceous volcano-sedimentary successions along the eastern Australian continental margin: implications for the break-up of eastern Gondwana. *Earth and Planetary Science Letters* 153, 85–102.

Burger D, 1986. Palynology, cyclic sedimentation, and palaeo-environments in the Late Mesozoic of the Eromanga Basin. *Geological Society of Australia, Special Publication* 12, 53–70.

Burger D and Senior BR, 1979. A revision of the sedimentary and palynological history of the northeastern Eromanga Basin, Queensland. *Journal of the Geological Society of Australia* 26, 121–132.

Carne GE and Alexander EM, 1997. Eromanga Basin prospects inventory, blocks ER 97–A to C. *Department of Mines and Energy Resources, South Australia, Report* 44/94.

Casey D, 1970. Northern Eromanga Basin. *Geological Survey of Queensland, Report* 41.

Casey JN, 1959. New names in Queensland stratigraphy. *Australasian Oil and Gas Journal* 5, 31–36.

Central Petroleum, 2008. Blamore 1 well completion report. Basic data. EP 93, Pedirka Basin, Northern Territory. Central Petroleum Ltd. *Northern Territory Geological Survey, Open File Petroleum Report* PR2009-0225.

Central Petroleum, 2009a. Simpson 1 well completion report. Basic data. EP 97, Northern Territory. Central Petroleum Ltd. *Northern Territory Geological Survey, Open File Petroleum Report* PR2009-0226.

Central Petroleum, 2009b. Residual oil columns in the Eromanga sequence in Blamore-1 and Simpson-1 enhance the oil prospectivity of the Simpson Desert area. *Central Petroleum Ltd, Technical Note 220409* (ASX announcement 04 September 2009).

Central Petroleum, 2011a. CBM93-02 well completion report. Interpretive. EP 93, Northern Territory. 22nd May 2010–10th Jun 2010. Central Petroleum Ltd. *Northern Territory Geological Survey, Closed File Petroleum Report* PR2011-0128 (used with permission).

Central Petroleum, 2011b. Fractured basement hydrocarbon plays and “buried hill” plays in central Australia. *Central Petroleum Ltd, Technical note 11.07.15* (Central Petroleum Ltd, ASX announcement 18 July 2011).

Coombs WP Jr and Molnar RE, 1981. Sauropoda (Reptilia, Saurischia) from the Cretaceous of Queensland. *Memoirs of the Queensland Museum* 20, 351–373.

Cotton TB, Scardigno MF and Hibburt JE (editors), 2006. *‘Petroleum Geology of South Australia, volume 2: Eromanga Basin (Second Edition)’. Petroleum Geology of South Australia Series.* South Australia, Department for Manufacturing, Innovation, Trade, Resources and Energy. Available for download at **http://www.pir.sa.gov.au/petroleum/access_to_data/petroleum_publications/petroleum_geology_of_south_australia/vol_2_-_eromaga_basin_2nd_edition** (accessed February 2012).

Day RW, 1964. Stratigraphy of the Roma–Wallumbilla area. *Geological Survey of Queensland, Publication* 318.

Day RW, 1966. Lower Cretaceous macrofossils from the Tambo and Augathella 1:250 000 Sheet areas. *Bureau of Mineral Resources, Australia, Record* 1966/89.

Day RW, 1967. A mixed Roma-Tambo fauna from the Tambo area. *Queensland Government Mining Journal* 68, 10–12.

Day RW, 1968. *Biostratigraphy and taxonomy of Lower Cretaceous molluscan faunas from the Queensland portion of the Great Artesian Basin*. PhD thesis, Department of Geology, Australian National University, Canberra.

Day RW, 1969. The Lower Cretaceous of the Great Artesian Basin: in Campbell KSW (editor) *Stratigraphy and palaeontology: essays in honour of Dorothy Hill.* Australian National University Press, Canberra, 140–173.

Denaro TJ and Dhnaram C (compilers), 2009. *Queensland Minerals 2009. A summary of major mineral resources, mines and prospects*. Queensland Department of Mines and Energy.

Dettmann ME, Clifford HT and Peters M, 2009. *Lovellea wintonensis* gen. et sp. nov. – Early Cretaceous (late Albian), anatomically preserved, angiospermous flowers and fruits from the Winton Formation, western Queensland, Australia. *Cretaceous Research* 30(2), 339–355.

Dettmann ME and Jones MJ, 1985. Palynology report on DIO Jackson 1, PL 23, Qld. *CSR Oil & Gas Division, Palynology Facility, Palynological Laboratory Report* 13/141. [*Department of Employment, Economic Development and Innovation (DEEDI), Open File Company Report* CR14327].

Dettmann ME, Molnar RE, Douglas JG, Burger D, Fielding C, Clifford HT, Francis J, Jell P, Rich T, Wade M, Rich PV, Pledge N, Kemp A and Rozefelds A, 1992. Australian Cretaceous terrestrial faunas and floras: biostratigraphic and biogeographic implications. *Cretaceous Research* 13(3), 207–262.

Draper JJ, 2000. Petroleum supersystems in Queensland: a key to undiscovered petroleum resources. *Queensland Oil and Gas* 6(4), 42–47 (in *Queensland Government Mining Journal* 98).

Draper JJ, 2002a. Geological setting: in Draper JJ (editor) *‘Geology of the Cooper and Eromanga basins, Queensland’. Queensland Government, Natural Resources and Mines, Queensland Mineral and Energy Review Series, DVD*, 57–59.

Draper JJ, 2002b. Eromanga Basin tectonics: in Draper JJ (editor) *‘Geology of the Cooper and Eromanga basins, Queensland’. Queensland Government, Natural Resources and Mines, Queensland Mineral and Energy Review Series, DVD*, 57–59.

Edgoose CE, Camacho A, Wakelin-King GA and Simons BA, 1993. *Kulgera, Northern Territory (Second Edition). 1:250 000 geological map series explanatory notes, SG 53-05.* Northern Territory Geological Survey, Darwin.

Edgoose CE, Close DF, Stewart AJ and Duncan N, 2002. *Umbeara, Northern Territory (First Edition). 1:100 000 geological map series explanatory notes, 5646.* Northern Territory Geological Survey, Darwin and Geoscience Australia, Canberra (National Geoscience Mapping Accord).

Exon NF and Senior BR, 1976. The Cretaceous of the Eromanga and Surat basins. *BMR Journal of Australian Geology and Geophysics* 1(1) 33–50.

Fielding CR, 1992. A review of Cretaceous coal-bearing sequences in Australia. *Geological Society of America, Special Paper* 267, 303–324.

Filatoff J and Price PL, 1988. A pteridacean spore lineage in the Australian Mesozoic: in Jell PA and Playford G (editors) *‘Palynological and palaeobotanical studies in honour of Basil E Balme’. Association of Australasian Palaeontologists, Memoir* 5, 89–124.

Forbes BG, 1966. The geology of the Marree 1:250 000 map area. *South Australia Geological Survey, Report of Investigations* 28.

Frakes LA and Francis JE, 1988. A guide to Phanerozoic cold polar climates from high-latitude ice-rafting in the Cretaceous. *Nature* 333, 547–549.

Freytag IB, 1966. Proposed rock units for marine lower Cretaceous sediments in the Oodnadatta region of the Great Artesian Basin. *South Australia Geological Survey, Quarterly Geological Notes* 18, 3–7.

Gallagher K and Lambeck K, 1989. Subsidence, sedimentation and sea-level changes in the Eromanga Basin, Australia. *Basin Research* 2, 115–131.

Glikson M and Taylor GH, 1986. Cyanobacterial mats: major contributors to the organic matter in Toolebuc Formation oil shales: in Gravestock DI, Moore PS and Pitt GM (editors) *‘Contributions to the geology and hydrocarbon potential of the Eromanga Basin.’ Geological Society of Australia, Special Publication* 12, 273–286.

Gradstein FM, Ogg JG, Smith AG, Agterberg FP, Bleeker W, Cooper RA, Davydov V, Gibbard P, Hinnov L, House MR, Lourens L, Luterbacher H-P, Mcarthur J, Melchin MJ, Robb LJ, Shergold J, Villeneuve M, Wardlaw BR, Ali J, Brinkhuis H, Hilgen FJ, Hooker J, Howarth RJ, Knoll AH, Laskar J, Monechi S, Powell J, Plumb KA, Raffi I, Röhl U, Sanfilippo A, Schmitz B, Shackelton NJ, Shields GA, Strauss H, Van Dam J, Veizer J, Van Kolfschoten TH and Wilson D, 2004. *A geologic time scale 2004.* Cambridge University Press.

Gravestock DI, Moore PS and Pitt GM (editors), 1986. *‘Contributions to the geology and hydrocarbon potential* *of the Eromanga Basin'. Geological Society of Australia, Special Publication* 12.

Gray ARG and Draper JJ, 2002. Petroleum geology: in Draper JJ (editor) *'Geology of the Cooper and Eromanga basins, Queensland'. Queensland Government, Natural Resources and Mines, Queensland Mineral and Energy Review Series, DVD*, 63–74.

Gray ARG, McKillop M and McKellar JL, 2002. Eromanga Basin stratigraphy: in Draper JJ (editor) *'Geology of the Cooper and Eromanga basins, Queensland'. Queensland Government, Natural Resources and Mines, Queensland Mineral and Energy Review Series, DVD*, 30–56.

Green PM, 1997. Cooper–Eromanga basins project progress report. *Queensland Oil and Gas* July 1997, 39 (in *Queensland Government Mining Journal* 98).

Green PM, Carmichael DC and Brain TJ, 1991. Stratigraphic evolution of the northern Eromanga Basin. *Queensland Resource Industries, Record* 1991/26.

Green PM, Hawkins PJ, Carmichael DC, Brain TJ, Smith RJ, Quarantotto P, Genn DLP, Hoffmann KL, McKellar JL, John BH and Shield CJ, 1992. An assessment of the hydrocarbon potential of the northern Eromanga Basin, Queensland. *Queensland Government Mining Journal* 92, 25–41.

Habermehl MA, 1980. The Great Artesian Basin, Australia. *BMR Journal of Australian Geology and Geophysics* 5, 9–38.

Habermehl MA, 1986. Regional groundwater movement, hydrochemistry and hydrocarbon migration in the Eromanga Basin: in Gravestock DI, Moore PS and Pitt GM (editors) *'Contributions to the geology and hydrocarbon potential of the Eromanga Basin'. Geological Society of Australia, Special Publication* 12, 353–376.

Haig DW, 1979. Cretaceous foraminiferal biostratigraphy of Queensland. *Alcheringa* 3, 171–187.

Haig DW and Barnbaum D, 1978. Early Cretaceous microfossils from the type Wallumbilla Formation, Surat Basin, Queensland. *Alcheringa* 2, 159–178.

Harris WK, 1962. Plant remains of Upper Jurassic to Lower Cretaceous age from Cadlereena military sheet, South Australia. *South Australia Department of Mines, Report Book* 55/128.

Heath RS, McIntyre S and Gibbins N, 1989. A Permian origin for Jurassic reservoired oil in the Eromanga Basin, Australia: in O'Neil BJ (editor) *The Cooper and Eromanga Basins, Australia. Proceedings of the Cooper and Eromanga Basins Conference, Adelaide 1989.* Petroleum Exploration Society of Australia, Society of Petroleum Engineers, Australian Society of Exploration Geophysicists (SA Branches), 405–416.

Henderson RA, 2004. A Mid-Cretaceous association of shell beds and organic-rich shale: Bivalve exploitation of a nutrient-rich, anoxic sea-floor environment. *Palaios* 19, 156–169.

Henderson RA and Kennedy WJ, 2002. Occurrence of the ammonite *Goodhallites goodhalli* (J. Sowerby) in the Eromanga Basin, Queensland: an index species for the late Albian (Cretaceous). *Alcheringa* 26(2), 233–247.

Hocknull SA, 1997. Cretaceous freshwater bivalves from Queensland. *Memoirs of the Queensland Museum* 42, 223–226.

Hocknull SA, White MA, Tischler TR, Cook AG, Calleja ND, Sloan T and Elliot DA, 2009. New Mid-Cretaceous (Latest Albian) Dinosaurs from Winton, Queensland, Australia. *PLOS ONE* 4(7): e6190. doi:10.1371/journal.pone.0006190.

Hopgood LS, 1987. *The taxonomy and palaeoclimatic interpretation of late Mesozoic fossil floras from the southwestern Eromanga Basin*. BSc (Hons) thesis, Department of Geology and Geophysics, University of Adelaide, Adelaide.

Jell JS, Cook AG and Jell PA, 2011. Australian Cretaceous Cnidaria and Porifera. *Alcheringa* 35, 241–284.

Jell PA, 2004. The fossil insects of Australia. *Memoirs of the Queensland Museum* 50.

John BH, 1985. Stratigraphic drilling report – GSQ Wyandra 1 and GSQ Quilpie 1. *Queensland Government Mining Journal* 87, 29–43.

John BH and Almond CS, 1987. Lithostratigraphy of the lower Eromanga Basin sequence in south-west Queensland. *APEA Journal* 27, 196–214.

Kantsler AJ, Cook AC and Zwigulis M, 1986. Organic maturation in the Eromanga Basin: in Gravestock DI, Moore PS and Pitt GM (editors) *'Contributions to the geology and hydrocarbon potential of the Eromanga Basin'. Geological Society of Australia, Special Publication* 12, 305–322.

Kear BP, 2003. Cretaceous marine reptiles of Australia: a review of taxonomy and distribution. *Cretaceous Research* 24, 277–303.

Kellner AWA, Rich TH, Costa FR, Vickers-Rich P, Kear BP, Walters M and Kool L, 2010. New isolated pterodactyloid bones from the Albian Toolebuc Formation (western Queensland, Australia) with comments on the Australian pterosaur fauna. *Alcheringa* 34, 219–230.

Kemp A, 1997. Four species of Metaceratodus (Osteichthyes: Dipnoi, Family Ceratodontidae) from Australian Mesozoic and Cenozoic deposits. *Journal of Vertebrate Paleontology* 17(1), 26–33.

Korsch RJ, Boreham CJ, Totterdell JM, Shaw RD and Nicoll MG, 1998. Development and petroleum resource evaluation of the Bowen, Gunnedah and Surat Basins, Eastern Australia. *APPEA Journal* 38, 199–237.

Krieg GW, 1985. *Dalhousie, South Australia. 1:250 000 geological map series, explanatory notes, SG 53-11.* South Australia Geological Survey, Adelaide.

Krieg GW, Alexander EM and Rogers PA, 1995. Eromanga Basin: in Drexel JF and Priess WV (editors) *'The geology of South Australia. Volume 2, The Phanerozoic, Chapter 8 Late Palaeozoic'. Geological Survey of South Australia, Bulletin* 54, 101–127.

Krieg GW, Rogers PA, Callen RA, Freeman PJ, Alley NF and Forbes BG, 1991. *Curdimurka, South Australia. 1:250 000 geological map series, explanatory notes, SH 53-08.* South Australia Geological Survey, Adelaide.

Kruse PD, Brakel AT, Dunster JN and Duffett ML, 2002. *Tobermory, Northern Territory (Second Edition). 1:250 000 geological map series explanatory notes, SF 53-12.* Northern Territory Geological Survey, Darwin and Geoscience Australia, Canberra.

McKellar JL, 2002. Palynological biostratigraphy and age of the Cooper and Eromanga basins: in Draper JJ (editor) *'Geology of the Cooper and Eromanga basins, Queensland'. Queensland Government, Natural Resources and Mines, Queensland Mineral and Energy Review Series, DVD*, 7–8.

McKenzie ED, 1999. A new early to middle Albian (Cretaceous) ammonite fauna from the Great Artesian Basin, Australia. *Proceedings of the Royal Society of Queensland* 108, 57–88.

McKirdy DM and Willink RJ, 1988. Migration of hydrocarbons and groundwater towards PEL 31 southwestern Eromanga Basin, South Australia. Adelaide Petroleum NL. *South Australia Department of Mines and Energy, Open file Envelope* 6116.

McLoughlin S, Pott C and Elliot D, 2010. The Winton Formation flora (Albian–Cenomanian, Eromanga Basin): implications for vascular plant diversification and decline in the Australian Cretaceous. *Alcheringa* 34(3), 303–323.

Michaelsen BH and McKirdy DM, 1989. Organic facies and petroleum geochemistry of the lacustrine Murta Member (Mooga Formation) in the Eromanga Basin, Australia: in O'Neil BJ (editor) *The Cooper and Eromanga Basins, Australia. Proceedings of the Cooper and Eromanga Basins Conference, Adelaide 1989.* Petroleum Exploration Society of Australia, Society of Petroleum Engineers, Australian Society of Exploration Geophysicists (SA Branches), 541-558.

Michaelsen BH and McKirdy DM, 1996a. Source rock distribution and hydrocarbon geochemistry: in Alexander EM and Hibburt JH (editors) *The Petroleum Geology of South Australia. Volume 2, Eromanga Basin.* South Australia Department of Mines and Energy (unpublished).

Michaelsen BH and McKirdy DM, 1996b. Source rock and petroleum geochemistry of the Simpson Desert Basin and superjacent western Eromanga basin. *South Australia Department of Mines and Energy, Envelope* 8880 (unpublished).

Middleton MF, 1980. A model of intracratonic basin formation entailing deep crustal metamorphism. *Geophysical Journal of the Royal Astronomical Society* 62, 1–14.

Mitrovica JX, Beaumont C and Jarvis GT, 1989. Tilting of continental interiors by the dynamical effects of subduction. *Tectonics* 8, 1079–1094.

Mond A, 1974. *Simpson Desert North, Northern Territory (First Edition). 1:250 000 geological map series explanatory notes, SG 53-04.* Bureau of Mineral Resources, Australia, Canberra.

Monteil E (coordinator), 2006. Australian Mesozoic and Cenozoic palynology zonations – updated to the 2004 Geologic Time Scale. *Geoscience Australia, Record* 2006/23.

Molnar RE, 1996. Preliminary report on a new ankylosaur from the Early Cretaceous of Queensland, Australia. *Memoirs of the Queensland Museum* 39, 653–668.

Molnar RE, 2011. New morphological information about Cretaceous sauropod dinosaurs from the Eromanga Basin, Queensland, Australia. *Alcheringa* 35, 329–339.

Moore PS, 1986a. An exploration overview of the Eromanga Basin: in Gravestock DI, Moore PS and Pitt GM (editors) *'Contributions to the geology and hydrocarbon potential of the Eromanga Basin.' Geological Society of Australia, Special Publication* 12, 1–8.

Moore PS, 1986b. Jurassic and Triassic stratigraphy and hydrocarbon potential of the Poolowanna Trough (Simpson Desert region) northern South Australia: in Gravestock DI, Moore PS and Pitt GM (editors) *'Contributions to the geology and hydrocarbon potential of the Eromanga Basin.' Geological Society of Australia, Special Publication* 12, 39–51.

Moore PS and Mount TJ (compilers), 1982. *Summary papers, Eromanga Basin symposium, Adelaide, South Australia, Australia, November 9–11, 1982.* Petroleum Exploration Society of Australia and Geological Society of Australia (SA branches).

Moore PS and Pitt GM, 1982. Cretaceous of the southwestern Eromanga Basin: stratigraphy, facies variations and petroleum potential: in Moore PS and Mount TJ (compilers) *Summary papers, Eromanga Basin symposium, Adelaide, South Australia, Australia, November 9–11, 1982.* Petroleum Exploration Society of Australia and Geological Society of Australia (SA branches), 127–144.

Moore PS and Pitt GM, 1984. Cretaceous of the Eromanga Basin – implications for hydrocarbon exploration. *APEA Journal* 24, 358–376.

Moore PS and Pitt GM, 1985. Cretaceous subsurface of the southwestern Eromanga Basin: a review: in Lindsay JM (editor) *'Stratigraphy, Palaeontology, Malacology – papers in honour of Dr Nell Ludbrook'. South Australia Department of Mines and Energy, Special Publication* 5, 269–286.

Moore PS, Pitt GM and Dettmann ME, 1986. The Early Cretaceous Coorikiana Sandstone and Toolebuc Formation: their recognition and stratigraphic relationship in the south-western Eromanga Basin: in Gravestock DI, Moore PS and Pitt GM (editors) *'Contributions to the geology and hydrocarbon potential of the Eromanga Basin'. Geological Society of Australia, Special Publication* 12, 97–114.

Mott WD, 1952. Oil in Queensland. *Queensland Government Mining Journal* 53(7), 848–861.

Nugent OW, 1969. Sedimentation and petroleum potential of the Jurassic sequence in the south-western Great Artesian Basin. *APEA Journal* 9, 97–107.

O'Neil BJ (editor), 1989. *The Cooper and Eromanga Basins, Australia. Proceedings of the Cooper and Eromanga Basins Conference, Adelaide 1989.* Petroleum Exploration Society of Australia, Society of Petroleum Engineers, Australian Society of Exploration Geophysicists (SA Branches).

Oosting A, 2004. Palaeoenvironmental and climatic changes in Australia during the Early Cretaceous. *Laboratory of Palaeobotany and Palynology, Utrecht University, Contributions Series Number* 17.

Ozimic S, 1986. The geology and petrophysics of the Toolebuc Formation and its time equivalents, Eromanga and Carpentaria Basins: in Gravestock DI, Moore PS and Pitt GM (editors) *'Contributions to the geology and hydrocarbon potential of the Eromanga Basin'. Geological Society of Australia, Special Publication* 12, 119–137.

Passmore VL and Burger D, 1986. Effects of eustatic sea-level changes on Early Jurassic deposition in the eastern Eromanga Basin: in *Sediments Down Under: 12th International Sedimentological Congress, Canberra, Australia, 24–30 August 1986*, *Abstracts*, 237.

Pitt GM, 1986. Geothermal gradients, geothermal histories and the timing of thermal maturation in the Eromanga-Cooper Basins: in Gravestock DI, Moore PS and Pitt GM (editors) *'Contributions to the geology and hydrocarbon potential of the Eromanga Basin.' Geological Society of Australia, Special Publication* 12, 323–351.

Price PL, 1978. Core samples from Pandieburra No. 1, Poonarunna No. 1, Witcherrie No. 1 and Mokari No. 1, western Eromanga Basin, South Australia. Mines Administration Pty Ltd palynological report 13/105. *South Australia Department of Mines and Energy, Open File Envelope* 8607, 3–31.

Price PL, 1997. Permian to Jurassic palynostratigraphic nomenclature of the Bowen and Surat Basins: in Green PM (editor) *The Surat and Bowen Basins, south-east Queensland. Queensland Minerals and Energy Review Series*, 137–178.

Price PL, Filatoff J, Williams AJ, Pickering SA and Wood GR, 1985. Late Palaeozoic and Mesozoic palynostratigraphical units. *CSR Oil & Gas Division, Palynology Facility, Palynological Laboratory Report* 274/25. [*Department of Employment, Economic Development and Innovation (DEEDI), Open File Company Report* CR14012].

Pysklywec RN and Mitrovica JX, 1997. Mantle avalanches and the dynamic topography of continents. *Earth and Planetary Science Letters* 148, 447–455.

Questa, 1990. *Eromanga Basin*. Northern Territory Geological Survey, Petroleum Basin Study. Questa Australia Pty Ltd.

Radke B, 2009. Hydrocarbon and geothermal prospectivity of sedimentary basins in central Australia. Warburton, Cooper, Pedirka, Galilee, Simpson and Eromanga basins. *Geoscience Australia, Record* 2009/25.

Raza A, Hill KC and Korsch RJ, 2009. Mid-Cretaceous uplift and denudation of the Bowen and Surat Basins, eastern Australia; relationship to Tasman Sea rifting from apatite fission-track and vitrinite-reflectance data. *Australian Journal of Earth Sciences* 56, 501–531.

Romilio A and Salisbury SW, 2011. A reassessment of large theropod dinosaur tracks from the mid-Cretaceous (late Albian–Cenomanian) Winton Formation of Lark Quarry, central-western Queensland, Australia: A case for mistaken identity. *Cretaceous Research* 32(2), 135–142.

Russell M and Gurnis M, 1994. The planform of epeirogeny: vertical motions of Australia during the Cretaceous. *Basin Research* 6, 63–76.

Salisbury SW, Agnolin F, Ezcurra M and Pais D, 2007. A critical reassessment of the Cretaceous non-avian dinosaur faunas of Australia and New Zealand. *Journal of Vertebrate Paleontology* 27 (supplement to number 3), 138A.

Senior BR, Exon NF and Burger D, 1975. The Cadna-owie and Toolebuc Formations in the Eromanga Basin, Queensland. *Queensland Government Mining Journal* 76, 445–455.

Senior BR, Ingram JA, Thomas BM and Senior D, 1969. The geology of the Quilpie, Charleville, Toompine, Wyandra, Eulo and Cunnamulla 1:250 000 sheet areas, Queensland. *Bureau of Mineral Resources, Australia, Record* 1969/23.

Senior BR, Mond A and Harrison, 1978. Geology of the Eromanga Basin. *Bureau of Mineral Resources, Australia, Bulletin* 167.

Shafik S, 1985. Calcareous nannofossils from the Toolebuc Formation, Eromanga Basin, Australia. *BMR Journal of Geology and Geophysics* 9, 171–181.

Shaw RD and Freeman MJ, 1985. Illogwa Creek, Northern Territory (Second Edition). *1:250 000 geological map series explanatory notes, SF 53-15.* Bureau of Mineral Resources, Australia, Canberra.

Sherwood NR and Cook AC, 1986. Organic matter in the Toolebuc Formation: in Gravestock DI, Moore PS and Pitt GM (editors) *'Contributions to the geology and hydrocarbon potential of the Eromanga Basin.' Geological Society of Australia, Special Publication* 12, 255–265.

Smith KG, 1963. Hay River, Northern Territory (First Edition). *1:250 000 geological map series explanatory notes, SF 53-16*. Bureau of Mineral Resources, Australia, Canberra.

Smith KG, 1965. Tobermory, Northern Territory (First Edition). *1:250 000 geological map series explanatory notes, SF 53-12*. Bureau of Mineral Resources, Australia, Canberra.

Sullivan CJ and Öpik AA, 1951. Ochre deposits, Rumbalara, Northern Territory. *Bureau of Mineral Resources Australia, Bulletin* 8.

Thomson BP (compiler), 1980. *Geological Map of South Australia, 1:1 000 000 scale*. South Australia Department of Mines and Energy, Adelaide.

Thulborn T and Turner S, 2003. The last dicynodont: an Australian Cretaceous relict. *Proceedings of the Royal Society of London B* 270, 985–993.

Veevers JJ, 1984. *Phanerozoic earth history of Australia*. Clarendon Press Oxford.

Vine RR, 1964. *Mackunda, Queensland (First Edition). 1:250 000 geological map series explanatory notes, SF 54-11.* Bureau of Mineral Resources, Australia, Canberra.

Vine RR and Day RW, 1965. Nomenclature of the Rolling Downs Group, northern Eromanga Basin, Queensland. *Queensland Government Mining Journal* 66, 416–421.

Vine RR, Day RW, Casey DJ, Milligan EN, Gallaway MC and Exon NF, 1967. Revised nomenclature of the Rolling Downs Group, Eromanga and Surat Basins. *Queensland Government Mining Journal* 68, 144–151.

Wade M, 1993. New Kelaenida and Vampyromorpha: Cretaceous squid from Queensland. *Memoirs of the Association of Australasian Paleontologists* 15, 353–374.

Ward DF, 1992a. Annual Report EL 7290. Don F Ward & Associates Pty Ltd. *Northern Territory*

Geological Survey, Open File Company Report CR 1992-0672.

Ward DF, 1992b. Annual Report EL 7243. Don F Ward & Associates Pty Ltd. *Northern Territory Geological Survey, Open File Company Report* CR 1992-0673.

Waschbusch P, Korsch RJ and Beaumont C, 2009. Geodynamic modelling of aspects of the Bowen, Gunnedah, Surat and Eromanga Basins from the perspective of convergent margin processes: in Korsch RJ and Totterdell JM (editors) *'Evolution of the Bowen, Gunnedah and Surat Basins, eastern Australia'. Australian Journal of Earth Sciences (Thematic issue)* 56(3), 309–334.

Wells AT, 1969. *Finke, Northern Territory (First Edition). 1:250 000 geological map series explanatory notes, SG 53-06*. Bureau of Mineral Resources, Australia, Canberra.

Wiltshire MJ, 1978. Poolowanna No 1 well completion report. *South Australia Department of Mines and Energy, Open File Envelope* 317.

Wiltshire MJ, 1982. Well completion report, Thomas No 1. Argonaut International Corporation. *Northern Territory Geological Survey, Open File Petroleum Report* PR1983-0010.

Wiltshire MJ, 1989. Mesozoic stratigraphy and palaeogeography, eastern Australia: in O'Neil BJ (editor) *The Cooper and Eromanga Basins, Australia. Proceedings of the Cooper and Eromanga Basins Conference, Adelaide 1989.* Petroleum Exploration Society of Australia, Society of Petroleum Engineers, Australian Society of Exploration Geophysicists (SA Branches), 279–291.

Whitehouse FW, 1955. The geology of the Queensland portion of the Great Australian Artesian Basin: in Department of the Co-ordinator General of Public Works. *Artesian Water Supplies in Queensland*, *Appendix* G. Government Printer, Brisbane (imprinted 1954).

Wopfner H, Freytag IB and Heath GR, 1970. Basal Jurassic–Cretaceous rocks of the western Great Artesian Basin, South Australia: stratigraphy and environment. *AAPG Bulletin* 54, 383–416.

Zhou S, 1993. A 3-D backstripping method and its application to the Eromanga Basin in central and eastern Australia. *Geophysical Journal International* 112, 225–243.