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Ahmad M and Munson TJ (compilers)

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Chapter 22: Centralian Superbasin

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Chapter 22: CENTRALIAN SUPERBASIN

TJ Munson, PD Kruse and M Ahmad

INTRODUCTION

In the Neoproterozoic and early Palaeozoic, large, polyphase sedimentary basins covered extensive areas of northern, central and southern Australia. Neoproterozoic successions of the Amadeus, Georgina, Ngalia, Officer and former Savory basins were interpreted by Walter *et al* (1995) as comprising a single, extensive intracratonic depositional system, the Centralian Superbasin, contiguous with the Adelaide Rift (now Adelaide Fold Belt) in southern South Australia (**Figure 22.1**). A number of other Neoproterozoic terranes have been subsequently added to the superbasin, increasing its geographic extent (see below). As originally defined and subsequently interpreted, the Centralian Superbasin encompassed all Neoproterozoic successions of these basins prior to disruption of the superbasin by the 580–530 Ma Petermann Orogeny, which was followed by a widespread earliest Cambrian hiatus. During the Petermann orogeny, the Officer Basin was separated from more northerly components of the Centralian Superbasin as a result of the exhumation of the Musgrave Province by a central uplift and associated thrusts (Walter and Veevers 1997, Camacho and McDougall 2000).

In the mid–late early Cambrian, extensive sedimentary deposition was re-established over large parts of central Australia, including the Amadeus, Ngalia, southern Georgina and Warburton basins (**Figure 22.2a**). These were probably linked, via the Arrowie and Stansbury basins in South Australia, with Cambrian basins that stretched along the Transantarctic Mountains as far as the Weddell Sea in Antarctica, so as to form a vast quasi-contiguous depositional system. Following emplacement of the late early Cambrian Kalkarindji Large Igneous Province (see **Kalkarindji Province**) an early middle Cambrian marine transgression extended sedimentary deposition over large parts of northern Australia, including the central and northern Georgina, Wiso, Daly, Ord and southern Bonaparte basins (**Figure 22.2b**). This early Palaeozoic depositional tract can be considered to be a large-scale but relatively short-lived superbasin, overlapping the Centralian Superbasin as originally defined and of similar areal extent. The Neoproterozoic to early Palaeozoic depositional history of the central-northern parts of Australia can thus be considered as consisting of a series of stacked and overlapping superbasins and basins of varying extent and duration. A series of compressional deformation events, collectively denoting the 450–300 Ma Alice Springs Orogeny, dismembered this depositional system, although synorogenic deposition continued in some component basins (**Figure 22.2c–f**), until deposition was finally terminated in most areas during the mid-Carboniferous Eclipse Event.

For descriptive purposes, the Neoproterozoic Centralian Superbasin of Walter *et al* (1995) up to the time of the Petermann Orogeny is here referred to as the *Centralian A*

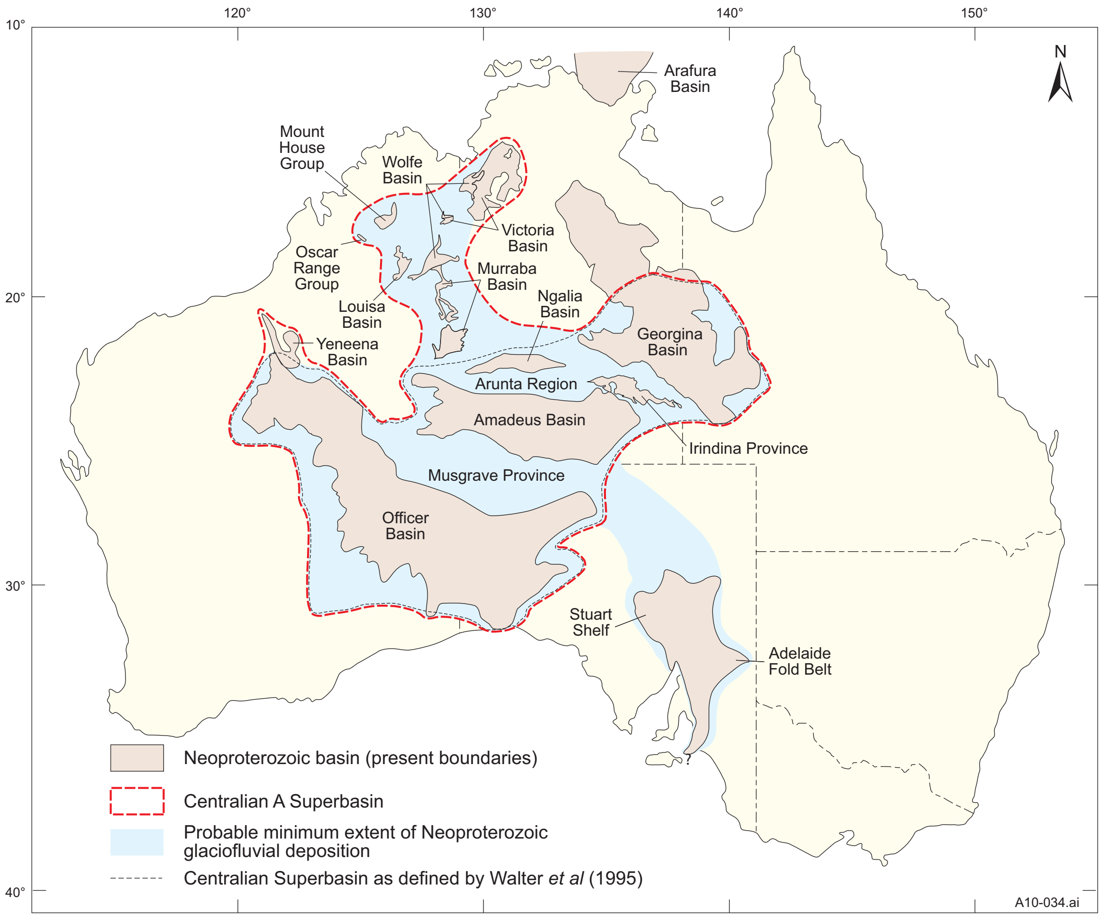

Figure 22.1. Areal extent of Centralian A Superbasin and its constituent and correlative basins in mainland Australia (data from Walter *et al* 1995, Tyler and Hocking 2001, Lindsay 2002, Bagas 2004). Location of Adelaide Fold Belt also shown.

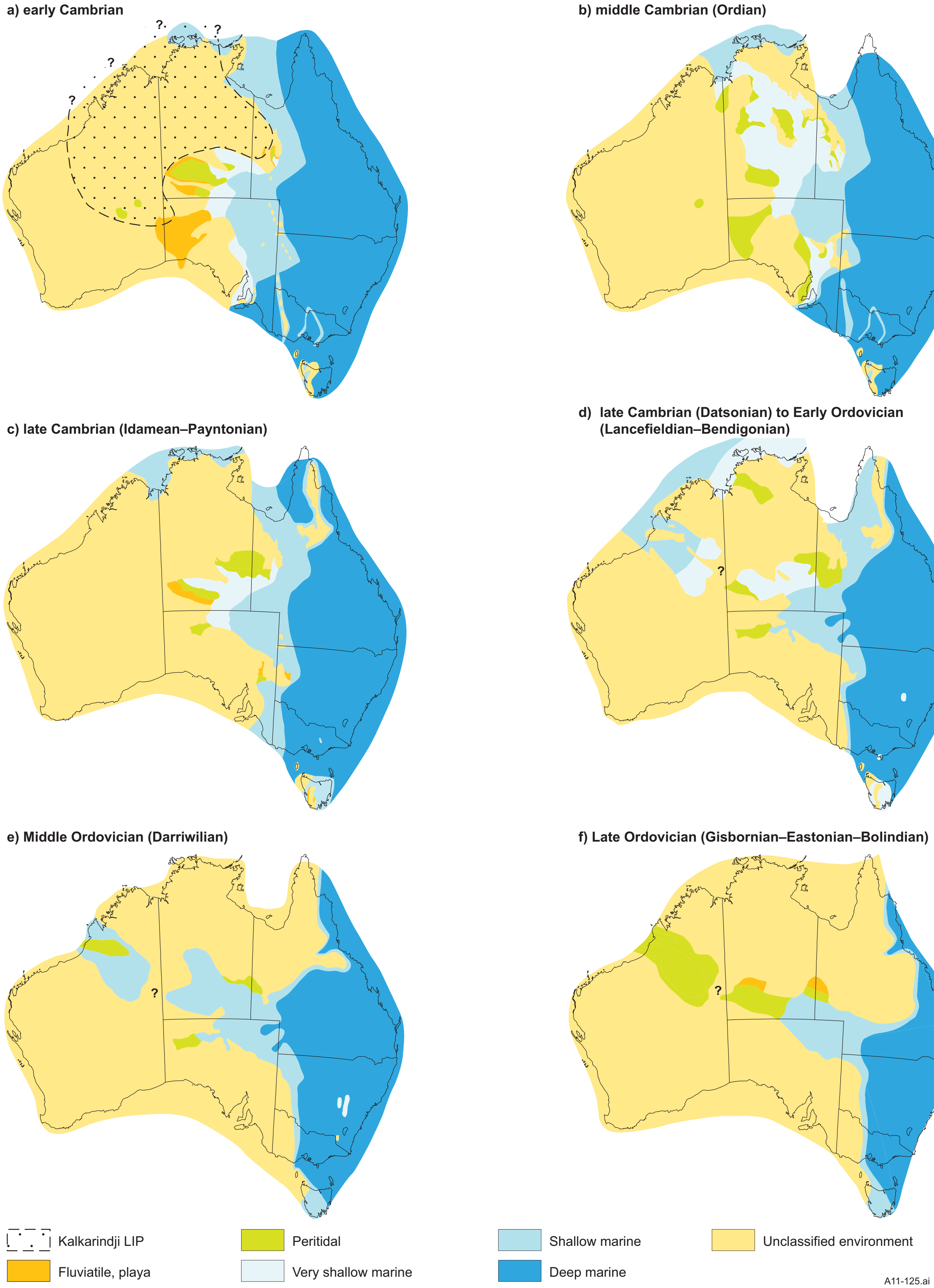

Figure 22.2. Simplified Cambrian–Ordovician palaeogeography of Australia for selected time slices, showing extent of Centralian B Superbasin, redrawn with minor modifications from Cook (1987), Cook and Totterdell (1991) and Haines and Wingate (2007). (**a**) Early Cambrian, showing probable maximum extent of late early Cambrian Kalkarindji Large Igneous Province (LIP). (**b**) Early middle Cambrian (Ordian), showing maximum extent of early middle Cambrian marine transgression. (**c**) Late Cambrian (Idamean–Payntonian). (**d**) Late Cambrian–Early Ordovician (Datsonian–Lancefieldian–Bendigonian). (**e**) Middle Ordovician (Darriwilian). (**f**) Late Ordovician (Gisbornian–Eastonian–Bolindian). Ordovician reconstructions follow Haines and Wingate (2007) in not depicting a marine connection (Larapintine Seaway; Webby 1978) between central Australian basins and Canning Basin in Western Australia.

Superbasin, and the previously unnamed early Palaeozoic depositional system in northern and central Australia that followed the Petermann Orogeny is here referred to as the *Centralian B Superbasin*[1]. These superbasins are now represented by deposits within several remnant structural basins, separated by uplifted and exhumed basement terranes. The total thickness of the sedimentary succession within the superbasins prior to the Alice Springs Orogeny was generally >7 km (McLaran *et al* 2009) and possibly as much as 10–15 km in the deeper troughs (Lindsay 2002).

CENTRALIAN A SUPERBASIN

NEOPROTEROZOIC

The Centralian A Superbasin (Centralian Superbasin of Walter *et al* 1995) was a large Neoproterozoic intracratonic depositional tract which has since been dismembered into several constituent structural basins related by age, common tectonic styles and closely comparable sedimentary successions. It was originally defined by Walter *et al* (1995) to include Neoproterozoic strata of the Amadeus, Ngalia, southern Georgina, Officer, Murraba and former 'Savory'[2] basins, which are now separated by uplifted and exhumed older Proterozoic terranes that include the Musgrave Province, and the Aileron and Warumpi provinces of the Arunta Region (**Figure 22.1**). Tyler (2000), Tyler and Hocking (2001) and Bagas (2004) also included a number of other terranes in northern Western Australia and the NT within the superbasin; these include Neoproterozoic strata of the Victoria, Wolfe, Yeneena and Louisa basins, and the Mount House and Oscar Range groups, which are not within named basins. The metamorphosed Irindina Province, currently included in the Arunta Region, has protoliths that have been dated as Neoproterozoic and Cambrian (Buick *et al* 2005, Maidment 2005), indicating that older strata of this terrane were probably also originally a part of the superbasin. In Queensland, metamorphosed Neoproterozoic rocks are present in the Thomson Fold Belt (Draper 2006), Anakie Inlier (Withnall *et al* 1996, Fergusson *et al* 2001) and the Charters Towers area (Fergusson *et al* 2007), but the relationships of these terranes with the Centralian A Superbasin, as defined herein, are unclear. As defined by Walter *et al* (1995), the superbasin extended over an area of about 2 million km^2, but if the additional terranes are included, the extent of the superbasin would be somewhat greater.

Figure 22.3 summarises stratigraphic correlations across the various structural basins that originally comprised the Centralian A Superbasin in the Northern Territory. Walter *et al* (1995) grouped the stratigraphic units of the then-defined superbasin into four supersequences separated by major unconformities; the supersequences correspond to the Ꝑ10$_1$ to Ꝑ10$_4$ subdivisions of Ahmad and Scrimgeour (2006) and to Megasequences 1–3 of Lindsay and Leven (1996) and Lindsay (2002). This lithostratigraphic succession has been further refined in a number of subsequent publications (eg Walter and Veevers 1997, 2000). The spatial distribution of the supersequences within the southern Northern Territory is shown in **Figure 22.4**. Supersequence 1 comprises a widespread basal sandstone/quartzite, followed by carbonate, evaporite and fine siliciclastic rocks. Supersequence 2 is marked by basal glaciogenic sedimentary rocks, followed by silt and shale with interbedded carbonate and sandstone. Supersequence 3 also includes glaciogenic sedimentary rocks at its base, succeeded by siltstone, shale, sandstone and carbonate rocks. Supersequence 4 represents a dominantly sandstone succession. The two major periods of glaciation in Supersequences 2 and 3 can be correlated with Neoproterozoic glacial intervals in the Adelaide Fold Belt and on other continents (Preiss *et al* 1978). Individual stratigraphic units of these supersequences in the Northern Territory are more fully discussed elsewhere, in the chapters on the constituent basins, but a brief summary is presented below.

The age of the sedimentary succession of the Centralian A Superbasin has been refined via a number of methods, as summarised by Grey (2008), including limited geochronology, carbon isotope chemostratigraphy, palynology, stromatolite biostratigraphy and lithostratigraphic correlation. Deposition of Supersequence 1 probably occurred in the interval 840–745 Ma (Walter and Veevers 2000), but the top of this succession is apparently strongly diachronous; in the Officer Basin, Supersequence 1 was followed by a hiatus of up to 45 million years (Grey *et al* 2005), whereas in more northerly basins, the corresponding time gap is up to 100 million years (**Figure 22.3**). Deposition of Supersequences 2–3 occurred in the interval 700–550 Ma, but due to poor age controls, there is some uncertainty as to the age of the boundary between these supersequences, which could be greater than ca 635 Ma (**Figure 22.3a**) or considerably younger (ca 580 Ma, **Figure 22.3b**, see **Supersequence 3**). The age of Supersequence 4 is regarded as 550–544 Ma (Walter and Veevers 2000).

Supersequence 1

Supersequence 1 consists of a thick basal sandstone/quartzite overlain by an equally thick interval of dolostone, limestone, evaporite and fine siliciclastic rocks. This succession averages 600–1000 m in thickness and exceeds 3000 m in some sub-basins (Walter *et al* 1995, Lindsay 2002). The supersequence is widespread and is recognised over most of the superbasin, extending from the western Officer Basin to the limits of known deposition in the east and south. It also has lithostratigraphic affinities to and is correlated with deposits in the Victoria Basin in the northwestern Northern Territory (Walter *et al* 1995) and southern parts of the Wolfe Basin in northeastern Western Australia (Grey and Blake 1999). More southerly parts of the supersequence (Officer and Amadeus basins) were intruded by the ca 825 Ma Gairdner and coeval Amata dyke swarms of the Gairdner Large Igneous Province (Claoué-Long and Hoatson 2010; see below).

In the Amadeus Basin, the basal sandstone interval of Supersequence 1 is represented by the Heavitree Quartzite

[1] Letter designated 'A' and 'B' to avoid confusion with supersequences 1–4 of Walter *et al* (2005) and Centralian 1–3 tectonic events of de Vries *et al* (2008).

[2] The former 'Savory Basin' (Williams 1992) is now considered to be a northwestern extension of the Officer Basin and use of this name has been discontinued (Tyler and Hocking 2001).

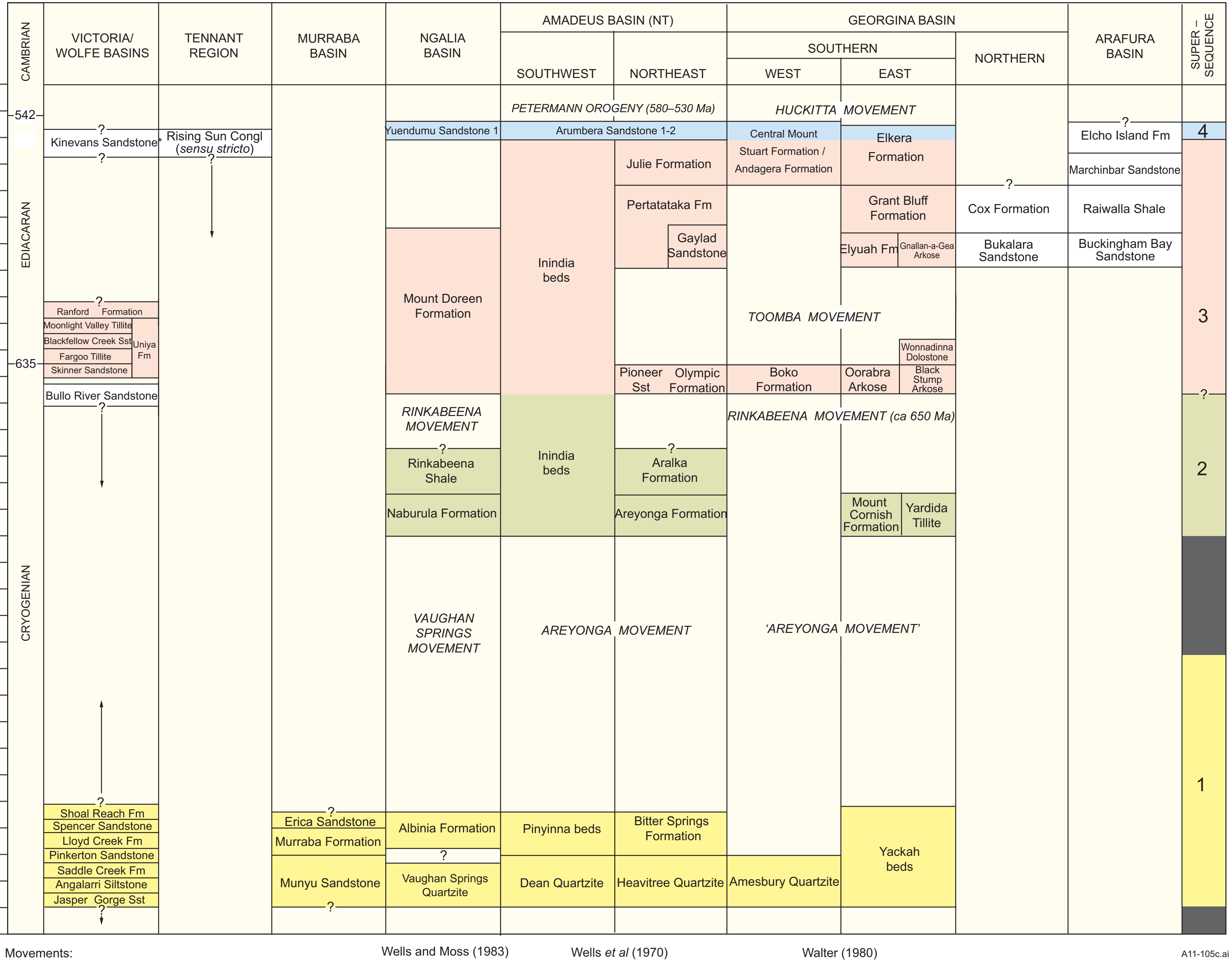

Figure 22.3. **(a)** Northern Territory Neoproterozoic correlation chart, assuming age of base of Ediacaran period to be ca 635 Ma (see discussion under **Supersequence 3**). Units of Centralian A Superbasin shaded according to assignment to Supersequences 1–4 of Walter *et al* (1995). Unshaded units are either of uncertain age and affinities, or are not included in Centralian A Superbasin successions (eg Arafura Basin units). Conformity within Inindia beds is assumed. Temporal positions of major tectonic movements are approximate and should be considered a guide only. *Kinevans Sandstone is undated and unassigned to group or basin; it is possibly equivalent to Mount Forster Sandstone (Albert Edward Group) of Wolfe Basin in Western Australia. Abbreviations: Congl = Conglomerate; Dlst = Dolostone; Fm = Formation; Sst = Sandstone **(continued next page)**.

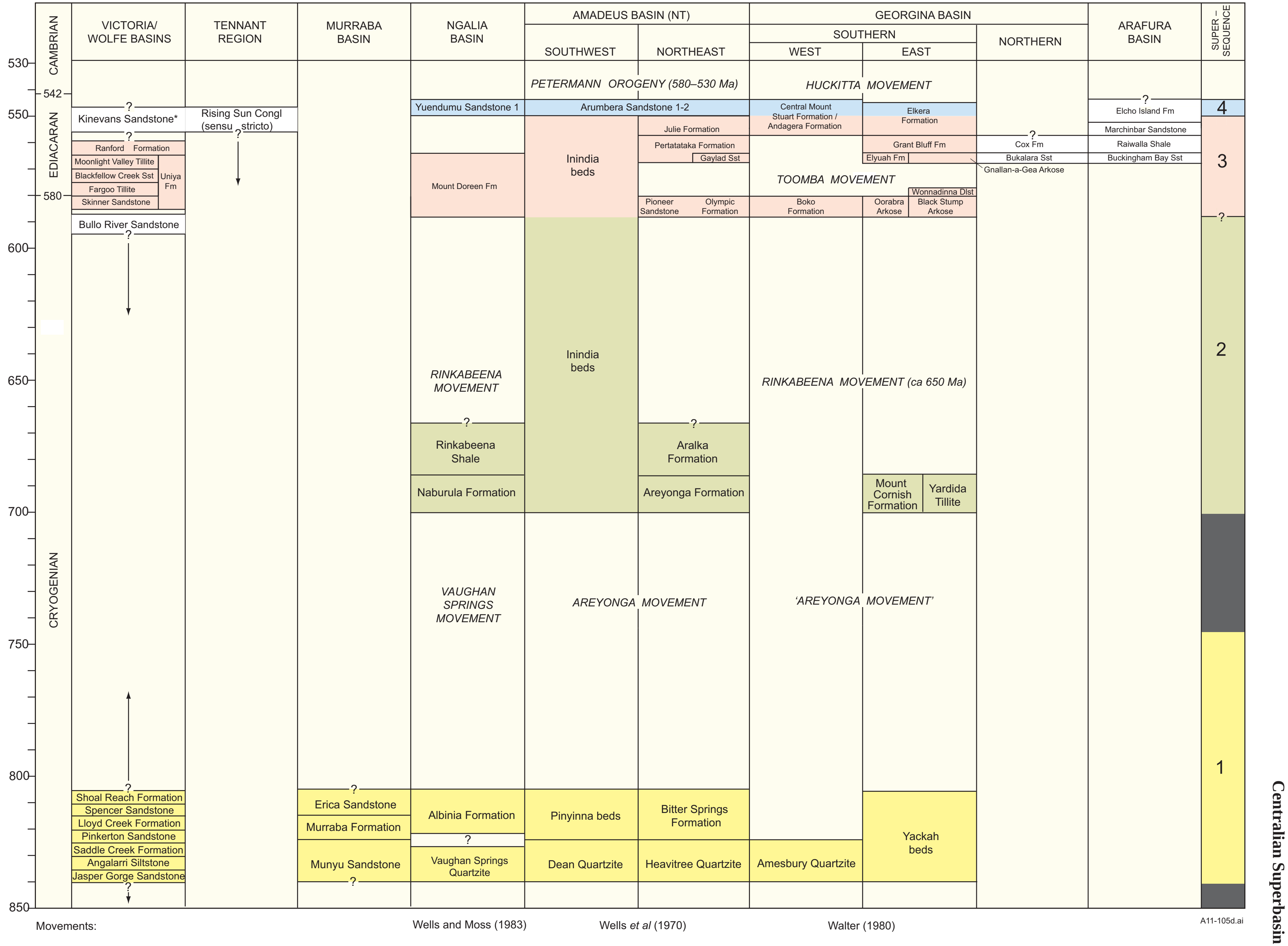

Figure 22.3 (b) Northern Territory Neoproterozoic correlation chart, assuming age of base of Ediacaran period to be ca 580 Ma **(continued from previous page)**.

and the correlative Dean Quartzite (**Figure 22.3**). These formations are overlain by widespread carbonate and evaporitic units of the Bitter Springs Formation and its lateral equivalent, the Pinyinna beds, that represent the upper interval of the supersequence. In the southern Georgina Basin, Supersequence 1 is represented by the Plenty Group, which includes the Yackah beds in the southeast and Amesbury Quartzite in the southwest. A thin succession of sandstone (Vaughan Springs Quartzite) and siltstone, shale and dolostone (Albinia Formation) are representative of Supersequence 1 in the Ngalia Basin. In the Murraba Basin, the basal sandstone interval of Supersequence 1 is represented by the Redcliff Pound Group (Munyu Sandstone, Murraba Formation, Erica Sandstone), which is composed almost exclusively of siliciclastic sedimentary rocks. Representatives of the other supersequences (2–4) are not recognised in this latter basin. The equivalent succession in the Victoria Basin is at least the upper part and perhaps all of the poorly dated Auvergne Group. In the Irindina Province, highly metamorphosed quartzite and carbonate rock of the Stanovos Gneiss Member of the Irindina Gneiss have been tentatively correlated with Supersequence 1 on the basis of similar lithology and detrital zircon age populations (Maidment 2005).

The basal sandstone interval of Supersequence 1 was probably deposited in fluviatile and lesser intertidal and shallow subtidal environments (Lindsay 1991, Walter *et al* 1995, Young *et al* 1995, Walter and Veevers 1997, Dunster *et al* 2007). Lindsay (1999, 2002) noted that it is difficult to explain the deposition of such an extensive immature sand sheet, but suggested that it was related to regional uplift and peneplanation, followed by broad regional subsidence that resulted in the deposition of sands that were redistributed by fluviatile and tidal processes. The upper interval of Supersequence 1 was probably deposited in shallow marine, lacustrine and alluvial floodplain environments (Lindsay 1987, 1991, Walter *et al* 1995, Young *et al* 1995, Walter and Veevers 1997, Dunster *et al* 2007, Vandenberg *et al* in press). Lindsay (1987) suggested that the interbedded evaporite, stromatolitic dolostone and fine siliciclastic rocks from the lower part of this upper interval were probably deposited on a marine platform in poorly circulated anoxic sub-basins of the 'saline giant' type, with carbonates and sulfates developed around basin margins and halite and potassium salts deposited in basin centres. Alternatively, Walter *et al* (1995) interpreted the depositional environment for these rocks to have been a mosaic of carbonate banks and intervening evaporitic lagoons, with distant rivers providing sources of silt.

Supersequence 2

This supersequence is characterised by basal glacial deposits, deposited during the Sturtian glaciation, followed by siltstone, shale and interbedded carbonate and sandstone deposited during subsequent widespread flooding of the Australian plate (Walter *et al* 1995). Supersequence 2 sedimentary rocks are present in the Amadeus, Ngalia, Officer (including the former 'Savory Basin') and southern

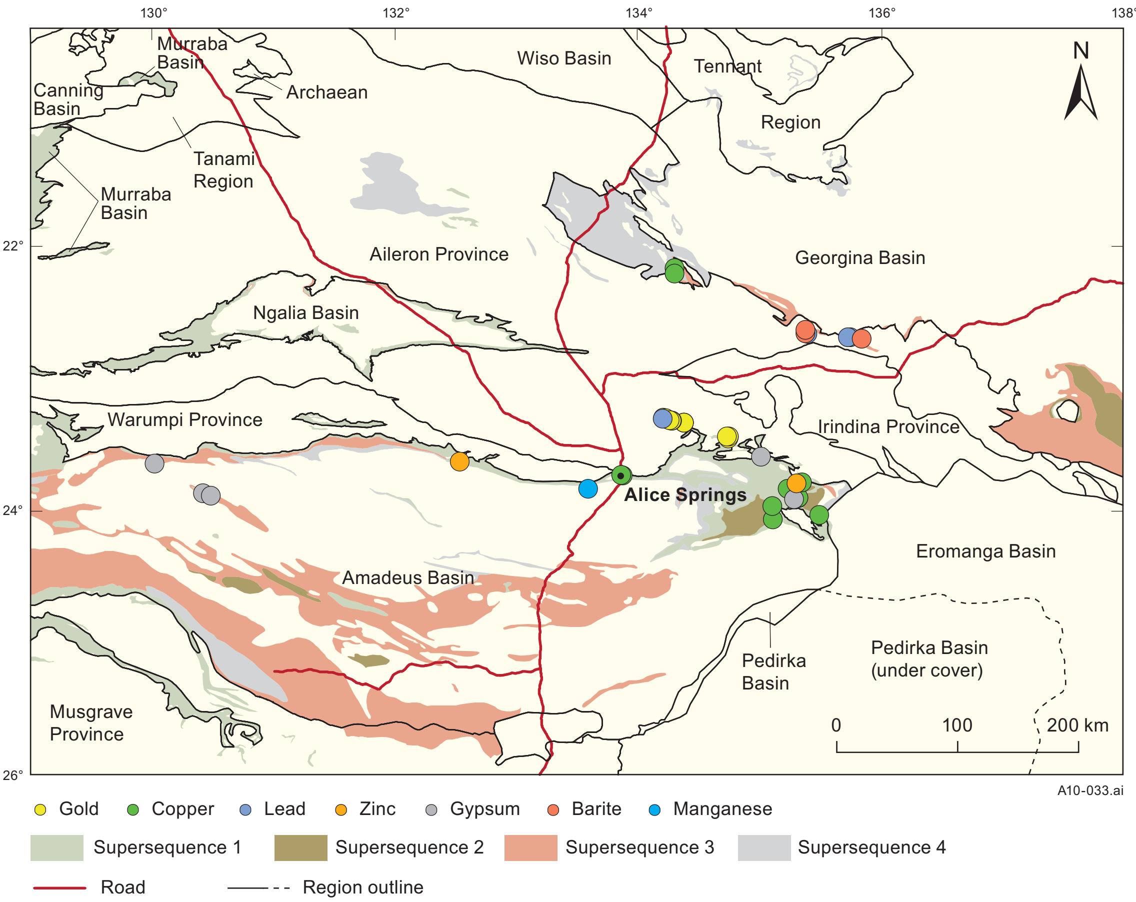

Figure 22.4. Distribution of component supersequences of Centralian A Superbasin in central–southern Northern Territory, showing Neoproterozoic mineral occurrences (data from NTGS MODAT database).

Georgina basins of the Centralian A Superbasin. They reach a total thickness of 1600–2100 m in the Amadeus Basin and are up to 2900 m thick in the southern Georgina Basin. Thicknesses in other basins are much less and in the Ngalia Basin, the supersequence reaches a maximum thickness of just 100 m.

Supersequence 2 is represented in the northern Amadeus Basin by tillite of the Areyonga Formation and by sandstone and shale of the overlying Aralka Formation, and in the southern and western Amadeus Basin by diamictite, sandstone and siltstone of the lower part of the Inindia beds (**Figure 22.3**). In the southern Georgina Basin, the succession consists of glacial sedimentary rocks of the Yardida Tillite and Mount Cornish Formation, assigned to the Aroota Group. In the Ngalia Basin, Supersequence 2 is represented by the Naburula Formation, consisting of a basal diamictite succeeded by shale and dolomudstone at the top of the formation, which is in turn overlain by shale and minor siltstone of the Rinkabeena Shale.

The Sturtian glaciation was regionally widespread (Priess and Forbes 1981) and was probably a relatively long-lived global event (Evans 2000). After deglaciation, flooding due to eustatic sea level rise might have resulted in the thick shale that overlies the basal glacial deposits. Shallow water carbonate rocks and sandstone in the middle and upper parts of the supersequence might be due to isostatic rebound (Walter *et al* 1995).

Supersequence 3

Supersequence 3 includes glacial and post-glacial transgressive deposits somewhat similar to those of Supersequence 2. The glacial strata have been correlated with similar deposits throughout the Australian continent (Priess and Forbes 1981) and are generally attributed to the latest Cryogenian Elatina glaciation[1]. As originally defined by Walter *et al* (1995), Supersequence 3 sedimentary rocks are present in the Amadeus, Ngalia, Officer and southern Georgina basins. They are also present in the Wolfe Basin and other successions in the Kimberley region of Western Australia (Grey and Corkeron 1998). In the Amadeus Basin, Supersequence 3 is greater than 2000 m in thickness and it is over 2600 m thick in deeper troughs of the Georgina Basin. A very much thinner succession of 100–350 m thickness is present in the Ngalia Basin, but to the northwest, over 900 m of Supersequence 3-equivalent strata are present in the Wolfe Basin.

In the northeastern Amadeus Basin, the Supersequence 3 succession comprises, in ascending stratigraphic order: diamictite, siliciclastic rocks and dolostone of the Olympic Formation, and conglomerate and sandstone of the equivalent Pioneer Sandstone; sandstone and conglomerate of the Gaylad Sandstone; siltstone and shale of the Pertatataka Formation; and dolostone, limestone and siltstone with sandstone lenses of the Julie Formation. In the south of the Amadeus Basin, sandstone and siltstone of the upper Inindia beds are equated with this succession (**Figure 22.3**). In the western part of the basin in Western Australia, equivalent carbonate and siliciclastic rock units are included within the Boord Formation (Haines *et al* 2009, 2010). In the Ngalia Basin, Supersequence 3 is represented by diamictite, dolomudstone and shale of the Mount Doreen Formation. In the southern Georgina Basin, a succession of lower Supersequence 3 glacial outwash deposits is included in the Keepera Group (Black Stump Arkose, Sun Hill Arkose, Oorabra Arkose, Boko Formation, Little Burke Tillite), which is in part overlain by the Wonnadinna Dolostone. The upper part of Supersequence 3 is represented by the Mopunga Group, which includes the lower part of the Elkera Formation and the marine siliciclastic Gnallan-a-Gea Arkose, Elyuah Formation and Grant Bluff Formation. The terminal Ediacaran, terrestrial to deltaic Central Mount Stuart Formation and equivalent Andagera Formation are partial lateral equivalents of the peritidal to shallow marine Elkera Formation (Dunster *et al* 2007), and the lower parts of these units are also assigned to Supersequence 3 (Walter and Veevers 1997). In the northern Georgina Basin, units of the fluviatile to shallow marine Kiana Group (Bukalara Sandstone and Cox Formation) were attributed an Ediacaran age by Kruse in Rawlings *et al* (2008) and are probable correlatives of this supersequence. However, there are no known Neoproterozoic rocks in intervening areas of the Georgina Basin and a direct connection with the Centralian A Superbasin in more southerly areas of the basin has not been established. In the Wolfe Basin, units assigned to Supersequence 3 include the Skinner Sandstone, Fargoo Tillite, Blackfellow Creek Sandstone, Moonlight Valley Tillite and Ranford Formation of the Duerdin Group and glaciogene sedimentary rocks of the ungrouped Uniya Formation.

Supersequence 3 was deposited in very similar settings to those of Supersequence 2, in that basal glaciogene deposits are overlain by mostly marine sedimentary rocks that mark an extensive transgression related to eustatic sea-level rise following deglaciation; these are capped by shallow-water carbonate rocks that might be the result of isostatic rebound (Walter *et al* 1995). There is considerable uncertainty as to the age of the Elatina glaciation. In the Adelaide Fold Belt, the base of the Ediacaran period has been defined at the boundary between glacial deposits of the Elatina Formation and overlying cap carbonate rocks of the Nuccaleena Formation; the Elatina glaciation is therefore latest Cryogenian in age. The base of the Ediacaran has been generally regarded as being about 635 Ma, based on correlations with relatively well dated glaciogene deposits in Namibia (Hoffmann *et al* 2004) and China (Condon *et al* 2005), but a much younger age of about 580 Ma is suggested by dating of possibly correlative glacial successions in King Island and elsewhere in Tasmania (Calver *et al* 2004). This younger date implies a correlation between the Elatina glaciation and the Canadian Gaskiers glaciation, which has been radiometrically dated at about 580 Ma (Bowring *et al* 2003). Alternatively, the younger age of the Tasmanian glacial deposits may be indicative of a third Ediacaran glacial event in Australia and elsewhere, which is younger than the Elatina glaciation, a possibility suggested by Grey and Corkeron (1998) from studies of glacial deposits of the Egan Formation of the Louisa Basin in Western Australia.

[1] Formerly referred to as the ‘Marinoan glaciation’, a term now regarded as invalid (Priess 2000, Williams *et al* 2008).

Supersequence 4

This succession is dominated by synorogenic sandstone deposited at the time of the 580–530 Ma Petermann Orogeny. Supersequence 4 sedimentary rocks are present in the Amadeus, Ngalia, Officer and southern Georgina basins of the Centralian A Superbasin. The supersequence ranges up to 800 m in thickness in the Amadeus Basin (Ambrose 2006) and is up to 700 m thick in the Ngalia Basin. The lower part of the succession includes the 'Ediacara fauna' (Glaessner 1984) of soft-bodied metazoans.

In the Amadeus Basin, Supersequence 4 is represented by sandstone, siltstone, shale and minor conglomerate of the lower part of the Arumbera Sandstone (**Figure 22.3**), which is probably equivalent to the Carnegie Formation in the Western Australian portion of the basin (Haines *et al* 2009, 2010). In the Georgina Basin, the supersequence is represented by sandstone and siltstone of the upper part of the Central Mount Stuart Formation, which is correlated with the lower Arumbera Sandstone, and by sandstone of the upper part of the Elkera Formation. In the Ngalia Basin, the lower part of the Yuendumu Sandstone is a probable correlative of the lower Arumbera Sandstone and is also included within the supersequence.

Supersequence 4 was deposited in response to tectonic uplift of the Musgrave Province as a result of the Petermann Orogeny. This uplifted area become a major source of sandy sediment for deltas building out into northern areas of the superbasin. Only the northernmost parts of the superbasin were marine at this time, whereas much of the southern area was likely to have been emergent (Walter *et al* 1995).

CENTRALIAN B SUPERBASIN

The Centralian B Superbasin is here interpreted to encompass interlinked and probably contiguous early Palaeozoic intracratonic sedimentary basins that developed in northern and central Australia (**Figures 22.2**, **22.5**) following the Petermann Orogeny. It includes interconnected basins stretching from the Carlton Sub-basin of the southern Bonaparte Basin in northern Australia, through the Ord, Daly, Wiso, Georgina and Ngalia basins, to the Amadeus and Warburton basins in central Australia. The highly metamorphosed Irindina Province in central Australia is also included within the superbasin, as it contains metamorphosed sedimentary protoliths of probable Cambrian age (Buick *et al* 2005, Maidment 2005) that are probably equivalent to Cambrian successions in the adjacent Georgina and Amadeus/Warburton basins. The eastern Officer Basin in northern South Australia, to the south of the uplifted and presumably emergent Musgrave Province, contains early Cambrian and latest Cambrian?–Ordovician successions (see Gravestock *et al* 1995) that are also tentatively included within the superbasin. Interconnectivity between all of these now mostly separate basins during the Cambrian is indicated by the presence of common invertebrate faunas, as summarised by Kruse *et al* (2009). The onshore Arafura Basin in northern Australia is not included within the superbasin, as it is unlikely to have had a direct southerly connection with other component basins. However, indirect links are suggested by the presence of common faunal elements (Laurie 2006a). The southern limits of the Centralian B Superbasin are difficult to define, but are here interpreted to exclude rift-related epicontinental Cambrian basins in central-eastern South Australia (Arrowie

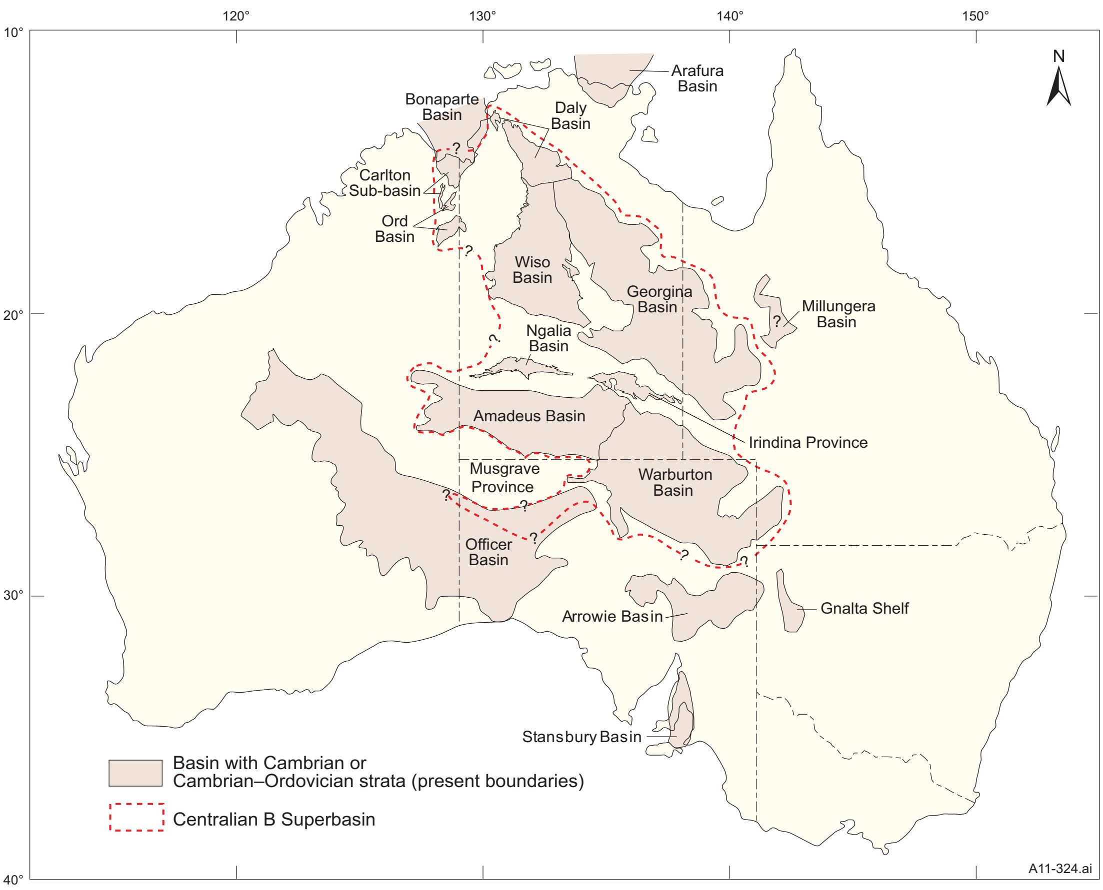

Figure 22.5. Distribution of Australian cratonic Cambrian and Cambrian–Ordovician basins comprising Centralian B Superbasin.

Basin) and western New South Wales (Gnalta Shelf), although the presence of common faunal elements (Kruse *et al* 2009) indicates that these basins were probably interconnected with the Warburton Basin to the north and Stansbury Basin to the south. Central and South Australian archaeocyath and radiocyath species, denoting a single faunal province, are also found throughout Antarctica (Kruse and Shi in Brock *et al* 2000), indicating that shelves/basins in this region were also at least indirectly connected to Australian Cambrian basins while the two continents were joined as part of the Gondwana supercontinent. The eastern limits of the Centralian B Superbasin are unclear and were presumably to the west of deep oceanic regions to the east of Gondwana that are not preserved. However, to the east of the Mount Isa Inlier in Queensland, the extensive subsurface Millungera Basin (Korsch *et al* 2009) has a thick undated succession that is possibly equivalent to that of the Georgina Basin.

The Centralian B Superbasin developed over central Australia during the mid–late early Cambrian and reached its maximum extent to include larger areas of northern Australia during the middle Cambrian following the emplacement of the late early Cambrian Kalkarindji Large Igneous Province. The superbasin became more restricted to areas of central Australia in the late Cambrian and Ordovician (**Figure 22.2**).

EARLY CAMBRIAN

The earliest Cambrian appears to have been characterised by a widespread hiatus over much of Australia (Walter and Veevers 2000), although poorly dated basal portions of early Cambrian successions in the Amadeus, Ngalia and Georgina basins in central Australia may be as old as this (**Figure 22.6**), and deposition may have been continuous from the Neoproterozoic into the early Cambrian in some areas (eg Arumbera Sandstone in northern Amadeus Basin). Walter and Veevers (2000) attributed this short period of relative non-deposition to a eustatic fall in relative sea level, possibly related to the Petermann Orogeny.

Later in the early Cambrian, fluviatile and shallow marine deposition became much more widespread within the eastern Officer, Amadeus, Ngalia, southern Georgina and Warburton basins (**Figures 22.2a**, **22.5**). This is also interpreted to have been the time of significant rift-related deposition in a deep depocentre in the Irindina Province (Buick *et al* 2005, Maidment 2005), in what is now the eastern Arunta Region. In the NT, sedimentary units representative of this earliest stage of development of the Centralian B Superbasin include the Shadow Group of the Georgina Basin, the upper Arumbera Sandstone, Winnall beds and equivalents in the Amadeus Basin, the upper Yuendumu Sandstone of the Ngalia Basin, an unnamed dolostone intersected in drillhole McDills-1 (Amerada Petroleum 1965) in the subsurface Warburton Basin (**Figure 22.6**), and possibly parts of the Harts Range Metamorphic Complex in the Irindina Province.

Late early Cambrian volcanism

In the late early Cambrian, a large part of northern Australia, central Western Australia and western South Australia, including parts of the former Centralian A Superbasin, was covered by variably thick and extensive basalts of the Kalkarindji Large Igneous Province (**Figure 22.2a**; Glass 2002, Glass and Phillips 2006). This significant volcanic event was marked by an eruptive outpouring of vast amounts of subaerial basaltic lava, related to either a large-scale mantle plume, or possibly to catastrophic lithospheric delamination, accompanied by substantial asthenospheric melt segregation (Glass 2002). The basalts have an average radiometric age of 507 ± 4 Ma (Glass and Phillips 2006), of which the oldest age (within error) is compatible with the position of the volcanics below the securely dated Cambrian sequence 1 (Ordian) interval of Shergold *et al* (1988), Southgate and Shergold (1991) and Laurie (2006b).

MIDDLE CAMBRIAN

Following the emplacement of the Kalkarindji Large Igneous Province, widespread regional subsidence resulted in transgression across much of the northern part of Australia (**Figure 22.2b**). Large areas of the northern NT, including the interlinked central and northern Georgina, Wiso, Daly, Ord and Bonaparte basins, were inundated by a shallow marine sea for the first time. The Ord Basin and Carlton Sub-basin (southern Bonaparte Basin) in the northwest of the Northern Territory were probably connected to the Wiso and Georgina basins via the Daly Basin (**Figure 22.2b**).

Sequence stratigraphic studies of middle Cambrian strata in the Georgina Basin (Shergold *et al* 1988, Southgate and Shergold 1991, Laurie 2006b) have identified two successive depositional successions: sequence 1 (Ordian) and sequence 2 (latest Ordian–early Mindyallan). These are characterised by distinctive trilobite, bradoriide, brachiopod, hyolith, mollusc and sponge faunas, documented by Kruse (1990, 1991, 1998, 2002), Kruse *et al* (2004, 2009), Laurie (2004, 2006a, b), Jones and Laurie (2006) and Jones and Kruse (2009) from the Daly, Ord, Wiso, Arafura and Georgina basins. The relatively well described invertebrate faunas can be readily correlated from depocentre to depocentre throughout the superbasin (**Figure 22.6**). Relative sea levels were at their maximum during deposition of these sequences (**Figure 22.2b**).

Sequence 1

Sequence 1 is represented by carbonate and lesser siliciclastic rocks that were deposited mainly in shallow marine, restricted marine and peritidal conditions, with shallower conditions being more prevalent in the north and northwest and adjacent to basement highs. In the southern Georgina Basin, the sequence is represented by limestone, dolostone, marl, phosphorite and some siliciclastic rocks of the peritidal to marine Thorntonia Limestone (**Figure 22.6**). Correlative marine strata in the Undilla Sub-basin in the central and eastern Georgina Basin are assigned to the Thorntonia Limestone and Border Waterhole Formation. In the Barkly Sub-basin, sequence 1 is represented by restricted marine and peritidal limestone and minor siliciclastic mudstone of the Gum Ridge Formation, and equivalent strata on the northern margin of the Georgina Basin are assigned to the shallow marine to peritidal Top Springs Limestone. In the

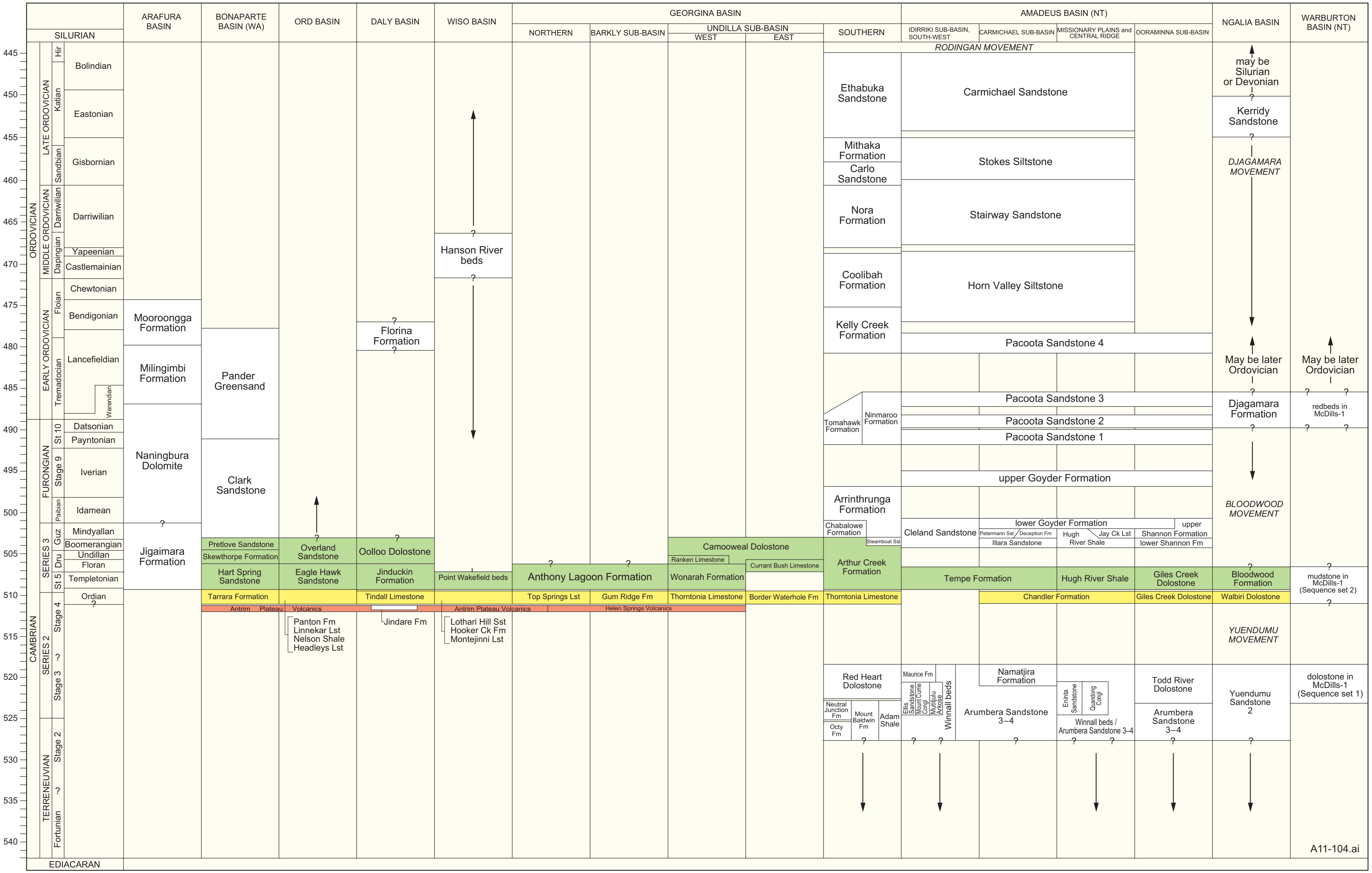

Figure 22.6. Northern Territory Cambrian–Ordovician correlation chart. Units of Kalkarindji LIP are depicted in red; units assigned to or equivalent to middle Cambrian sequence 1 are in yellow; and those assigned to or equivalent to sequence 2 are in green. Abbreviations: Ck = Creek; Congl = Conglomerate; Dru = Drumian; Fm = Formation; Guz = Guzhangian; Hir = Hirnantian; Lst = Limestone; Slst = Siltstone; Sst = Sandstone; St = Stage.

Wiso Basin, sequence 1 is represented by shallow marine and lesser peritidal limestone, dolostone and minor siliciclastic rocks of the basal Montejinni Limestone and overlying fine-grained siliciclastic rocks and lesser dolomitic limestone of the peritidal to restricted shallow marine Hooker Creek Formation, in turn overlain by the sandstone-dominated, peritidal Lothari Hill Sandstone. In the Daly Basin to the north, the correlative succession is referred to the shallow marine to peritidal Tindall Limestone and in the Ord Basin, to the dominantly peritidal fine-grained siliciclastic rocks and lesser shallow marine limestone of the Negri Subgroup, comprising Headleys Limestone, Nelson Shale, Linnekar Limestone and Panton Formation. Equivalent strata in the Carlton Sub-basin of Western Australia are referred to the peritidal to shallow marine Tarrara Formation. In the Amadeus Basin, the interval equivalent to sequence 1 consists of evaporites, carbonate mudstone, shale and siltstone assigned to the Chandler Formation, and carbonate and siliciclastic rocks of the shallow marine to peritidal lower Giles Creek Dolostone. These rocks are correlated with carbonate and siliciclastic rocks of the Walbiri Dolostone in the Ngalia Basin.

Sequence 2

Sequence 2 contains a greater proportion of siliciclastic rocks to carbonate rocks than does sequence 1 and was accumulated in fluviatile, peritidal, shallow marine and basinal environments. In the southern Georgina Basin, the sequence is represented by pyritic-carbonaceous black shale, dolostone, and minor siliciclastic rocks overlain by carbonate rocks and siliciclastic mudstone of the Arthur Creek Formation (**Figure 22.6**), deposited in relatively deep marine and restricted shallow marine conditions respectively. In the Undilla Sub-basin, sequence 2 comprises low- to moderate-energy marine silty dolostone, calci/dolomudstone and siliciclastic mudstone of the Wonarah Formation, overlain by the bioclastic Ranken Limestone and in turn by high-energy barrier and protected back-barrier carbonate rocks of the Camooweal Dolostone. In the Barkly Sub-basin, the unfossiliferous Anthony Lagoon Formation is a lateral equivalent of the Wonarah Formation and consists of dolomitic–siliciclastic siltstone interbedded with dolostone. This formation is also lithologically very similar to and is correlated with the Jinduckin Formation of the Daly Basin to the northwest. The Jinduckin Formation is overlain by the Oolloo Dolostone and these units comprise sequence 2 in that basin. In the Wiso Basin, strata equivalent to the lower Wonarah Formation are referred to the Point Wakefield beds, which consist of fine-grained siliciclastic rocks deposited mainly under shallow marine conditions. Sequence 2 is represented in the Ord Basin by the peritidal Eagle Hawk Sandstone and possibly also the overlying fluviatile Overland Sandstone, and in the Carlton Sub-basin by the peritidal to shallow marine Hart Spring Sandstone and overlying Skewthorpe Formation or possibly younger units of the Carlton Group. In the Amadeus Basin, strata equivalent to sequence 2 include the nearshore to shallow marine Tempe Formation and Hugh River Shale, both dominated by shale and siltstone with lesser dolostone and sandstone, and carbonate rocks and mudstone/siltstone of the upper Giles Creek Dolostone, a shallow marine to peritidal interval. The correlative Bloodwood Formation in the Ngalia Basin contains mudstone and minor sandstone assigned to shallow marine, peritidal and subaerial depositional environments.

LATE CAMBRIAN–ORDOVICIAN

By the late Cambrian and continuing through the middle Palaeozoic, depositional areas had become more restricted in extent to areas of central Australia (mainly Amadeus, Warburton and southern Georgina basins) and the north of the NT (Carlton Sub-basin, **Figure 22.2c–f**). Deposits of late Cambrian age might also be present in the Irindina Province, if sedimentary protoliths of highly metamorphosed rocks are of this age (Buick *et al* 2005, Maidment 2005), and temporally isolated Ordovician units occur in some other areas, including the Ngalia, Wiso and Daly basins (**Figure 22.6**). A marine link between the Amadeus Basin and the Canning Basin in Western Australia may have been present during the Ordovician (Larapintine Seaway; Webby 1978), but the evidence for such a connection is not compelling and if it existed, it is likely to have been either brief or very restricted (Haines and Wingate 2007). Palaeozoic deposition was disrupted and eventually terminated in central Australian areas during the several tectonic events of the 450–300 Ma Alice Springs Orogeny.

SUPERBASIN DEVELOPMENT

The Centralian A Superbasin developed on relatively thick (40–50 km) crust (Lambeck and Penny 1984, Korsch *et al* 1998) that evolved through the Palaeoproterozoic, probably on earlier Archaean continental crust. This basement experienced crustal shortening, voluminous igneous activity and metamorphism, and was blanketed by Palaeo- to Mesoproterozoic sedimentary basins, particularly in the northern areas of Australia. At about 1 Ga, these Australian crustal elements were amalgamated with other crustal components to form the supercontinent Rodinia, which subsequently broke up and was dispersed later in the Neoproterozoic (Lindsay *et al* 1987).

Relationship to large igneous provinces

The initiation and subsequent early development of the Centralian A Superbasin preceded the breakup of Rodinia in the late Neoproterozoic and may have been related to one or both of two widespread mafic-ultramafic magmatic events that are recognised as Large Igneous Provinces (LIPs): the ca 1070 Ma Warakurna LIP and the ca 825 Ma Gairdner LIP (Claoué-Long and Hoatson 2010, **Figure 22.7**). The Warakurna LIP forms a broad west-trending zone extending from central Australia to the Western Australia coastline (Wingate *et al* 2004). In central Australia, igneous rocks of this event are preserved as layered mafic and ultramafic intrusions (Giles Complex) emplaced within the granulite-facies terrane of the central-western Musgrave Province, together with the Stuart Pass Dolerite (southern Arunta Region) and

Alcurra Dolerite (Musgrave Province). An associated thick package of rocks (Tjauwata Group) was deposited in the interval 1090–1040 Ma in the Musgrave Province and has been interpreted as a rift-related succession (Edgoose *et al* 2004) unconformably underlying the southwestern Amadeus Basin. Some authors (eg Korsch and Lindsay 1989, Lindsay and Korsch 1991) have interpreted the Tjauwata Group rift succession as evidence for the thermal peak of an extensional phase, which initiated the opening of the Centralian A Superbasin in a typical rift-sag model. Other workers (eg Shaw 1991) have considered this rift succession to be much too old to be directly related to the development of the superbasin, given the age of the Tjauwata Group and an interpreted age of about 845 Ma for the basal Amadeus Basin sedimentary rocks. This 150–200 million year interval is much longer than would be expected in a typical rift-sag basin (Shaw 1991).

The Gairdner LIP extends northwestward from the South Australia coastline to the northwestern Western Australia coastline **Figure 22.7**). It was interpreted by Wingate *et al* (1998) as being the result of a mantle plume that directly preceded the breakup of Rodinia. The Gairdner dyke swarm is correlated with dykes of the Amata Dolerite, which intrudes the Musgrave Province, and with cogenetic spilitic extrusive rocks in the Bitter Springs Formation of the Amadeus Basin; these mafic rocks are also considered to be a part of the Gairdner LIP (Wingate *et al* 1998, Edgoose *et al* 2004). The Gairdner LIP is too young to have initiated the Centralian Superbasin via thermal deflation, but the northeast-directed extension that accompanied the LIP may have been a factor in the instigation of the superbasin (de Vries *et al* 2008).

In the late early Cambrian, extensive and voluminous outpourings of basalt of the Kalkarindji LIP across large parts of northern and western Australia constitute a third major igneous event that immediately preceded broad regional subsidence and a marine transgression in the middle Cambrian that deposited sediments over much of this province in the northern NT and eastern Western Australia. There is a consecutive temporal association between the LIP and overlying basins that is not evident in the Neoproterozoic, suggesting that regional uplift followed by subsidence may have been a major influence over the development of the superbasin in these areas. If the Kalkarindji LIP flood basalts represent the volcanic expression of a rising mantle plume (see Glass 2002), then crustal uplift prior to emplacement of the LIP may have been a consequence of increased buoyancy of the upper mantle as the plume rose (see Campbell and Griffiths 1990). According to Campbell and Griffiths (1990), the principal causes of the subsidence that follows uplift during the emplacement of an LIP are dispersal of mantle buoyancy over a larger area by lateral spreading of the mantle plume; deflation of the head of the plume as magma is removed; loading of the volcanic material on the earth's surface; and decay of the mantle thermal anomaly over time. A mechanism similar to this could account for the extension of the Centralian B Superbasin over large parts of northern Australia at this time.

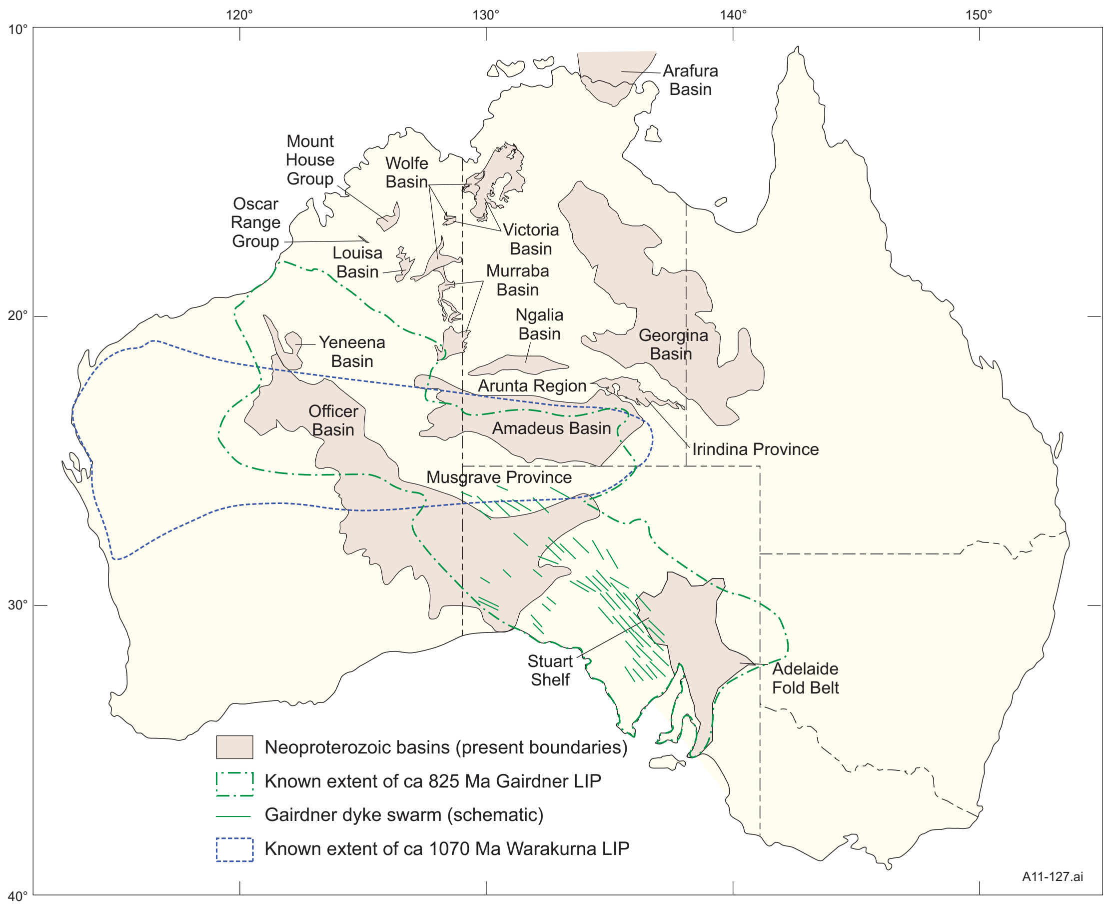

Figure 22.7. Known extent of Warakurna and Gairdner Large Igneous Provinces (LIPs) (after Claoué-Long and Hoatson 2010) with respect to Neoproterozoic basins.

Relationship to Petermann and Alice Springs orogenies

The principal component basins of the Centralian Superbasin are generally asymmetric in cross-section. They typically have deep sub-basins (and/or 'troughs') along one margin and a broad shallow platform along the opposite margin (**Figure 22.8**). This asymmetric basin geometry is typical of the foreland basin architecture (Lindsay 2002) that characterised these basins at various stages during their tectonic evolution. The deeper basin margins are parallel to major thrust zones that mostly developed during the Petermann or Alice Springs orogenies, and adjacent uplifted terranes were a major source of synorogenic sedimentary fill for basin depocentres. Many of these major thrust faults are reactivated older structures, some of which may date back to the Palaeoproterozoic (eg Warren 1981). Thrust faults along the southern margin of the Georgina Basin are interpreted as reactivated normal faults (and associated transfer faults) that were marginal to a series of en echelon Neoproterozoic rift basins that developed along the southern margins of the basin during the breakup of Rodinia (Greene 2003, 2010; see **Georgina Basin**).

Uplift and erosion of the Musgrave Province during the late Neoproterozoic Petermann Orogeny accompanied the development of deep depocentres along the northern margin of the Officer Basin in South Australia and Western Australia (**Figure 22.8**), and along the southwestern margin of the Amadeus Basin (Mount Currie Sub-basin). These depocentres received voluminous synorogenic sedimentary deposits that were included in Supersequence 4 by Walter *et al* (1995).

Haines *et al* (2001) attributed Palaeozoic synorogenic sedimentation to derivation of voluminous detritus from adjacent, thrust-uplifted source regions as a result of north–south shortening during the convergent deformations of the Alice Springs Orogeny. They noted that the effects of the earliest deformation of this orogeny, the Late Ordovician Rodingan Event, were localised to the eastern Arunta Region and adjacent Amadeus Basin, but that the Devonian Pertnjara-Brewer events were more synchronously widespread. Thrusting related to the Alice Springs Orogeny resulted in synorogenic sedimentary deposition in deep sub-basins and troughs (**Figure 22.8**) along the northern margin of the Amadeus Basin (Ooraminna, Carmichael and Idirriki sub-basins, Missionary Plain Trough), the northern margin of the Ngalia Basin, the southern margin of the Georgina Basin (Toko and Dulcie troughs) and the southern margin of the Wiso Basin (Lander Trough).

Sedimentary deposition ended in most basins by the end of the Devonian, except in the Ngalia Basin where Carboniferous foreland sediments, related to the Mount Eclipse Event, were derived from thrust-generated

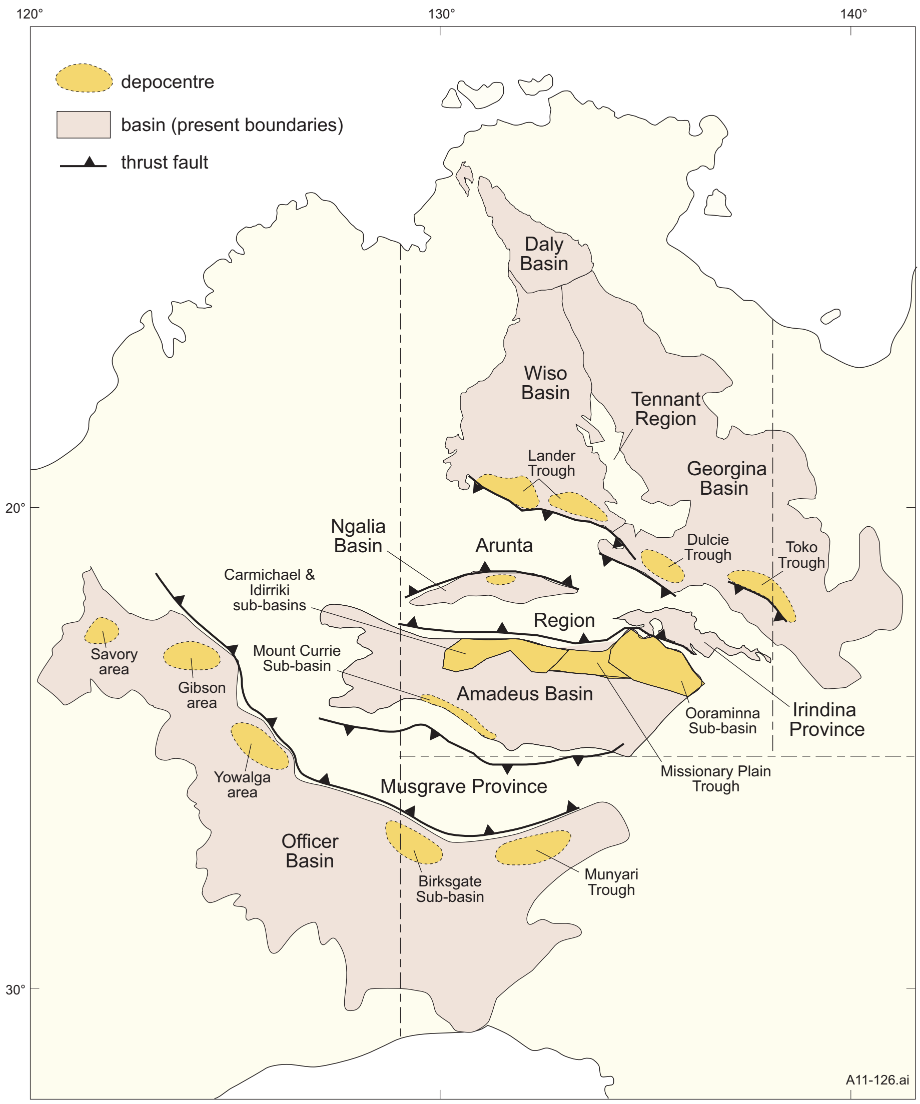

Figure 22.8. Generalised present architecture of major components of Centralian Superbasin, modified from Lindsay (2002), showing relationship between schematic thrust faults related to Petermann and Alice Springs orogenies and marginal foreland troughs and depocentres. Not all basin components and faults are shown.

topography to the northwest (Haines *et al* (2001). The Petermann and Alice Springs orogenies therefore had a dual effect on deposition in central Australian basins: they dismembered formerly contiguous depositional areas, and at the same time generated a foreland basin architecture that resulted in widespread synorogenic deposition within component basins. The Alice Springs Orogeny ultimately led to the termination of sedimentation in the region.

MINERAL RESOURCES

The Neoproterozoic and Palaeozoic basins of the NT host a variety of mineral occurrences and deposits, including base metals, phosphate, diamonds, gold, uranium, manganese, barite, fluorite, limestone, gypsum, potash, salt and dimension stone. Some basins also have significant potential for conventional and unconventional petroleum and helium. These resources are located and discussed in more detail in the respective chapters on these basins, but a brief overview of the more significant commodities with widespread distributions is presented below. In general, most of the basins are very underexplored by global standards and there is potential for significant economic discoveries. The distribution of mineral resources with respect to the Neoproterozoic Supersequences 1–4 of the Centralian Superbasin is shown in **Figure 22.4**. Note that there is an apparent spatial association of many of these mineral occurrences with major faults along the margins of the component basins.

Base metals

The Amadeus Basin contains a number of small occurrences of sediment-hosted copper in several stratigraphic units, including the Bitter Springs Formation, Arumbera Sandstone and younger units. None of these is known to be economic, although some have small-scale historical workings, and the potential for copper in the basin remains largely untested.

The Palaeozoic successions of the Georgina and equivalent basins in both Queensland and the NT contain base metals mines, prospects, occurrences and anomalies that can be assigned to several styles of Cu and Pb-Zn mineralisation, including Mississippi Valley type (MVT), stratiform sediment-hosted and sandstone-hosted types. Lead isotope data indicate that all deposits have been sourced from a single event, probably corresponding to the Alice Springs Orogeny, and that the Pb may be Proterozoic in age (Dunster *et al* 2007). Significant prospects/mines in the NT portion of the Georgina Basin include *Box Hole* mine, *Boat Hill* prospect (Marqua area), *Trackrider* prospect (Ooratippra area) and *Mount Skinner* prospect. These are discussed in detail by Dunster *et al* (2007).

Widespread but economically insignificant copper mineralisation occurs in the uppermost units of the Antrim Plateau Volcanics, near and along the contact with the basal carbonate strata of the overlying Palaeozoic basins. Some copper has also been noted in carbonate rocks close to the contact zone. The mineralisation is structurally controlled in fault and shear zones, disseminated in basalt or overlying carbonate rocks, or is associated with agglomerate, vesicle infills and black manganiferous limestone mounds of possible fumarolic origin (hot seeps).

Phosphate

The Georgina and Wiso basins constitute a world-class phosphate province, with the Georgina Basin in particular hosting numerous deposits in both the NT and Queensland, including the substantial *Wonarah* deposit. Most economic phosphorite deposits formed at 580–500 Ma (Ediacaran–Cambrian), and middle Cambrian sedimentary rocks of both sequence 1 and 2 contain traces of phosphate over wide areas of these basins (Khan *et al* 2007, Dunster *et al* 2007). Exploration models target organic-rich carbonate rocks on depositional basin margins and areas of onlap onto basement highs, where upwelling and favourable palaeogeography would have brought cold phosphate-rich waters onto shallower areas. The formation of phosphate minerals takes place close to the sediment–water interface during times of low overall sedimentation and is intimately connected with the dynamics of diagenetic redox fronts (Shields 2002).

Diamonds

Diamond-bearing kimberlite pipes and dykes have been discovered in several basins across the northern portion of the NT. These include Devonian (367 Ma) pipes in the *Merlin* diamond field that intrude sedimentary rocks of the southern McArthur Basin and northern Georgina Basin, and Jurassic (179 Ma) diamond-bearing kimberlite pipes and dykes that intrude Victoria Basin sedimentary rocks near *Timber Creek*.

Diamond-bearing kimberlites worldwide are commonly associated with Archaean lithospheric mantle, which is believed to underlie much of the NT's orogenic belts and sedimentary basins (Hutchison 2011). The NAC deep lithosphere is demonstrably fertile for diamonds and Palaeozoic cover rocks offer protection and preservation for kimberlite intrusions. Prospectivity for diamonds in the NT's basins should therefore be considered to be high. Diamond exploration surveys over the past few decades have identified a broad swathe of microdiamond and diamond indicator mineral occurrences that extends across the heart of the cratonic NT, embracing known kimberlite occurrences and extending well beyond them. However, despite the significance of this microdiamond swathe to prospectivity, there has been only limited success in locating the sources of the microdiamonds, possibly because of recycling during the Cretaceous that has resulted in widespread redistribution by fluviatile and aeolian processes.

Gold

Although there has been widespread exploration for gold in the NT's Neoproterozoic and Palaeozoic basins, the only significant known deposits occur in basal strata of the Amadeus Basin. In the *Arltunga* and *Winnecke* goldfields, Au is mostly hosted by basement rocks of the Arunta Region, but auriferous quartz is also found within tension gashes, fractures and breccia zones in deformed rocks of the Heavitree Quartzite and Bitter Springs Formation of the Amadeus Basin (Ahmad *et al* 2009). The mineralisation was possibly hydrothermally leached from basement volcanic assemblages by fluids associated with a greenschist-facies retrograde metamorphic event during the Alice Springs Orogeny, then deposited in structurally favourable sites associated with regional thrusts and nappes (Burlinson and Mackie 1986).

Uranium

Palaeozoic basins in the NT include significant sandstone-hosted uranium deposits. These deposits occur within Devonian–Carboniferous sedimentary rocks in the upper parts of the Amadeus (eg *Angela*) and Ngalia (eg *Bigrlyi*) basin successions. Uranium mineralisation occurs at a redox boundary interpreted to have formed either by flushing oxidising groundwater through reduced sandstone beds (Amadeus Basin deposits), or by interaction with detrital organic matter (Ngalia Basin deposits). Uranium deposits of this type might also be present in the Georgina, Wiso and Daly basins. In these basins, possible sources of leachable uranium are provided by radiogenic basement rocks, particularly the Aileron Province in the south and granites of the Pine Creek Orogen in the north. Reductants that could facilitate the deposition of uranium oxides are present as organic-rich intervals and as hydrocarbons at various levels within the successions. Permeable sandstone intervals that could enable fluid flow are present in all the basins, and the lateral and vertical variations in permeability that are needed to focus fluid flow and enable fluid mixing are provided by heterogeneous rock units, unconformities and other structures. There is also potential for unconformity-style mineralisation, particularly at the base of the Neoproterozoic to Palaeozoic succession, as well as for uranium in association with sedimentary phosphorite.

Manganese

A number of manganese occurrences and prospects have been documented in the Amadeus and Georgina basins, all of which are currently regarded as being uneconomic. In the Amadeus Basin, the *Fenn Gap* prospect is in dolostone of the Loves Creek Member of the Cryogenian Bitter Springs Formation, whereas the *Wangatinya* prospect is hosted by the Cambro–Ordovician Pacoota Sandstone (Ferenczi 2001). Both are likely to be distal, low-temperature hydrothermal deposits, where Mn has been remobilised from sedimentary and volcanic rocks elsewhere in the succession, and subsequently enriched by supergene processes. The southern and central Georgina Basin contains numerous widespread, apparently surficial manganese occurrences. Surficial manganocrete and pisolitic manganiferous lag are known from outcrop and subcrop of the Ninmaroo, Tomahawk and Kelly Creek formations, which are similar in age to the Pacoota Sandstone. Two apparently stratabound occurrences, *Lucy Creek 2* (Tomahawk Formation) and *Halfway Dam* (Kelly Creek Formation) have elevated levels of trace metals, replacement ore textures and are in close proximity to basement, suggesting a low-temperature hydrothermal origin (Leadbeatter and Tompkins 2004, Leadbeatter 2005).

Petroleum and helium

Two petroleum systems are recognised within the sedimentary successions of the Centralian A and B superbasins: the Neoproterozoic Centralian Supersystem of Bradshaw *et al* (2004) and early Palaeozoic Larapintine System of Bradshaw (1993) and Draper (2000). Elements of these supersystems are present in the Amadeus, Georgina, Wiso and Ngalia basins in the NT, but although these basins have significant oil and gas potential, they remain very underexplored. In the Amadeus Basin, up to five conventional petroleum systems are present (Marshall 2003, Ambrose 2006), including the Ordovician system that hosts the *Mereenie* oil and gas field, the *Palm Valley* gas field and the *West Walker* gas prospect. Three of the other four petroleum systems are Neoproterozoic in age and the fourth is Neoproterozoic to Cambrian. Sub-economic gas discoveries, including the *Dingo* gas field, have been made within these systems, which are generally regarded as being gas-prone, although there is also some potential for oil (Marshall *et al* 2007). The oldest system, which includes a reservoir in the Heavitree Quartzite sealed by an extensive salt layer in the overlying Gillen Member of the Bitter Springs Formation, is prospective for both gas and helium (eg *Mount Kitty* prospect). A variety of structural and stratigraphic traps is present within the basin. The Amadeus Basin also has considerable unconventional petroleum potential, including shale gas and oil in the Horn Valley Siltstone, and tight gas in the Pacoota and Stairway sandstones (DSWPET 2011, Tiem *et al* 2011).

In the southern Georgina Basin, the middle Cambrian succession contains potentially prolific marine source rocks with expulsion signified, in part, by the abundance of oil and gas shows. The most important potential source rocks occur in the Thorntonia Limestone and lower Arthur Creek Formation, particularly the basal black shale of the latter unit (Ambrose and Putnam 2006). Viable source rocks may also be present in the younger Arrinthrunga Formation and Hagen Member of the Chabalowe Formation. Potential conventional reservoirs may be present in the Thorntonia Limestone, Steamboat Sandstone, upper Arthur Creek Formation and Hagen Member. Numerous conventional stratigraphic and structural traps are present within the basin, which also has considerable unconventional shale gas and oil potential in the lower Arthur Creek Formation, and shale gas potential in the upper Arthur Creek Formation (Central Petroleum Ltd, ASX Announcement, 18 May 2011, Tiem *et al* 2011, PetroFrontier Corp, press release, 3 August 2011).

The Wiso Basin is virtually unexplored for petroleum and the most prospective area, the Lander Trough, has not been drill tested. Potential source rock intervals include the Montejinni Limestone and unit 3 of the Hanson River beds (Questa 1989, Gorter *et al* 1998), but there may be other source rock intervals in the subsurface in the Lander Trough. A number of Cambrian and Ordovician sandstone and carbonate intervals within the succession, including the Montejinni Limestone and overlying Hooker

Creek Formation, have good reservoir potential and either underlie effective sealing strata or contain intraformational seals. Analogues of the middle Cambrian Arthur Creek/Thorntonia petroleum system of the Georgina Basin or the prolific Ordovician Horn Valley Siltstone petroleum systems of the Amadeus Basin might be present within the Lander Trough. There is also potential for unconventional basin-centred gas and oil plays over large areas of the basin (Central Petroleum Ltd, ASX announcement, 26 May 2011).

Only limited petroleum exploration has been conducted in the Ngalia Basin and the petroleum potential is largely unknown. The basin is likely to be gas-prone, and siliciclastic, carbonate and evaporitic rocks of Proterozoic and early Cambrian to Carboniferous age constitute the most prospective sedimentary successions for hydrocarbons. The Albinia Formation, Rinkabeena Shale and Mount Eclipse Sandstone may have source rock potential, whereas the Mount Eclipse Sandstone, Yuendumu Sandstone, Kerridy Sandstone and Vaughan Springs Quartzite all have potential as reservoirs, the latter two due to fractures (Wells and Moss 1983, Deckelman and Davidson 1993). Possible traps include anticlines and structural highs (Deckelman and Davidson 1993).

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