

EXPLANATORY
NOTES



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Explanatory Notes for the OOLDEA 1:250 000 Geological Map

**Martin C Fairclough, Mark C Benbow^{*}
and Paul A Rogers[#]**

**Mineral Resources Group
Geological Survey Branch**

**^{*}now with Longlat Enterprises Pty Ltd
[#]retired**

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Government of South Australia
Primary Industries and Resources SA

Division of Minerals and Energy Resources

Primary Industries and Resources South Australia

7th floor, 101 Grenfell Street, Adelaide

GPO Box 1671, Adelaide SA 5001

Phone National (08) 8463 3204

 International +61 8 8463 3204

Fax National (08) 8463 3229

 International +61 8 8463 3229

Email pirs.minerals@sa.gov.au

Website www.minerals.pir.sa.gov.au

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Explanatory Notes for the OOLDEA 1:250 000 Geological Map

Martin C Fairclough, Mark C Benbow and Paul A Rogers

ABSTRACT

The OOLDEA 1:250 000 map area, in the far west of SA, includes portions of Maralinga Tjarutja Aboriginal Land, Maralinga Prohibited Area, and Nullarbor Regional Reserve. It is traversed by the Trans-Australia Railway. There is no significant basement outcrop on OOLDEA, and basement interpretation is based on drillhole intersections and aeromagnetic data of varying quality. Basement rocks on eastern OOLDEA belong to the Christie and Nawa Subdomains of the western Gawler Craton. The Christie Subdomain, in the southeastern map area, comprises Archaean felsic metasediments of the Mulgathing Complex which have been intruded by Palaeoproterozoic to Mesoproterozoic intermediate to felsic rocks of the Ifould Complex. The Nawa Subdomain on OOLDEA consists predominantly of Palaeoproterozoic high-grade metasediments of the Moondrah Gneiss which include magnetite-rich zones of high magnetic intensity. Basement of the Christie Subdomain has been extensively reworked by major northeast-trending mylonitic shear zones. The most prominent of these is the Karari Fault Zone which separates the Christie and Nawa Subdomains. Younger mafic intrusions include dykes related to the Gairdner Dyke Swarm and small plugs within the Karari Fault Zone. The age of the mafic rocks is not known but they may be coeval with Neoproterozoic (Willouran) rift basalts of the Adelaide Geosyncline and Officer Basin. The nature of the basement underlying central and western OOLDEA is unknown and can be interpreted only from low-resolution aeromagnetic data. It is presumably related to the Gawler Craton, and includes zones of high magnetic intensity and two groups of mafic dykes. Basement on OOLDEA, in particular shallow Christie Subdomain basement in the southeastern corner of the map area, is prospective for gold and other metals.

Most of the basement on OOLDEA, except in the southeastern corner, is overlain by Neoproterozoic sediments of the Officer Basin (Nullarbor Platform). An attempt has been made to correlate the platform sediments with the better known succession in the Marla-Giles area to the northeast. Probable equivalents of Willouran sediments (Pindyin Sandstone and Alinya Formation) and Marinoan Lake Maurice Group (Tarlina Sandstone, Meramangye Formation and Murnaroo Formation) have been interpreted from drillhole logs. The Officer Basin sediments are prospective for lead-zinc mineralisation (hosted by carbonates) and evaporite minerals (Alinya Formation). Early Cambrian sediments of the Tallaringa Trough (Relief Sandstone, Ouldburra Formation) may extend into northeastern OOLDEA. The Ouldburra Formation is prospective for evaporite minerals. Minor outcrop of interpreted late Palaeozoic sediments of the Arckaringa Basin occurs near Maralinga, and these sediments may also occur in drillholes in the same area. Equivalents of Algebuckina Sandstone (Eromanga Basin), with latest Jurassic to Early Cretaceous palynofloras, have been intersected in Maralinga drillholes. Early Cretaceous sediments of the Bight Basin margin (Loongana and Madura Formations) occur in drillholes to the south and west.

OOLDEA is located in the northeastern part of the Cainozoic Eucla Basin. The Eocene-Miocene succession of the Eucla Basin is divided into the Eucla Group of marine platform bioclastic carbonates (Wilson Bluff and Nullarbor Limestones), and Immarna Group of predominantly terrigenous clastic sediments deposited in shallow marine, coastal and non-marine environments (Pidginga Formation, Hampton Sandstone, Ooldea Sand, Yarle Sandstone and Garford Formation). OOLDEA contains portions of some of Australia's most remarkable landforms. The Nullarbor Plain is the world's largest semi-arid-arid karst region which has developed on the Nullarbor Limestone. Surficial karst features include depressions (dongas) with associated drainage, surrounded by mobile sand and network

dunes of the Great Victoria Desert and low rocky rises. In addition, the Nullarbor Plain is interrupted by prominent north to northeast-trending fault scarps, including the Karari Fault scarp, which indicate recent movement of ancient basement structures. The Ooldea and Paling Ranges mark the latest Eocene shoreline of the Eucla Basin. They are interpreted as coastal dunes and appear to be the oldest preserved features of this type in the world. The Ooldea Range extends for ~650 km from WA to the Ceduna area in SA. Coastal sand of the ranges and adjacent areas (Ooldea Sand, Hampton Sandstone) are prospective for heavy mineral sand deposits. Underlying palaeochannel sediments (Pidinga Formation) have potential for placer gold deposits and other commodities. Quaternary aeolian sand dunes of the Great Victoria Desert cover northern OOLDEA. Their distribution corresponds closely to the distribution of Tertiary coastal sand units from which they have been sourced (Hampton Sandstone, Ooldea Sand, Yarle Sandstone). Tietkens Plain, formed of playa lake carbonates of the Garford Formation, lies in this area.

INTRODUCTION

The OOLDEA 1:250 000 mapsheet area, in the far west of SA, includes portions of Maralinga Tjarutja Aboriginal Land, Maralinga Prohibited Area, and Nullarbor Regional Reserve. It is traversed by the Trans Australia Railway and by various unsealed station and mineral exploration tracks. There are several railway sidings, including Ooldea, but no significant permanent population in the area; the nearest towns are Tarcoola (now abandoned) ca. 350 km to the east and Ceduna ca. 350 km to the southeast. It lies between latitudes 30°00' and 31°00'S, and longitudes 130°30' and 132°00'E (Fig. 1). The land has remained generally unused for agriculture, but does host some pastoral activity.

OOLDEA lies in the northeastern part of the Cainozoic Eucla Basin which overlies thin marginal sediments of the late Palaeozoic Arckaringa Basin and Mesozoic Bight and Eromanga Basins. These younger sediments rest on widespread Neoproterozoic sediments of the Officer Basin, except for southeastern OOLDEA where Eucla Basin units directly overlie basement rocks of the Gawler Craton. The mapsheet area straddles the margin of the Nullarbor Plain and Great Victoria Desert.

Geological investigations within the OOLDEA map sheet area were conducted over several field seasons largely during the late 1980s–early 1990s by M. C. Benbow, W. Mitchell, A. J. Hayball, P. A. Rogers, A. F. Crookes, and during PhD studies by J. Teasdale (Adelaide University). Geological mapping and photo-interpretation of OOLDEA was carried out by Mark Benbow (formerly of the South Australian Department of Mines, now with Longlat Enterprises Pty Ltd). The published map sheet was compiled by M. Benbow and P. Rogers and publicly released as a full colour plot in 2000. Unpublished notes by the first author were compiled in the same period, and form the basis of this document. It should be noted that significant later work has been completed by several authors (e.g. Hou, PIRSA 2000–2007), which build upon some of the concepts outlined here. The reader is referred to later publications not discussed here for more recent, and on occasion, contradictory views. Nevertheless, for the sake of consistency and historical completeness, this document reflects the ideas represented in the original published map in terms of stratigraphy and geological evolution.

HISTORICAL NOTES

The earliest known inhabitants of BARTON were the Kokata and Wirangu tribes (Tindale, 1940). The Kokata lands extended over a large area that included BARTON, TALLARINGA, COOPER PEDY and OOLDEA; the Wirangu lands extended along the coast from Head of Bight to Streaky Bay, and inland to Ooldea. The Wirangu originally occupied land further north, but migrated southwards during southward expansion of the Kokata prior to 1850 (Tindale, 1940).

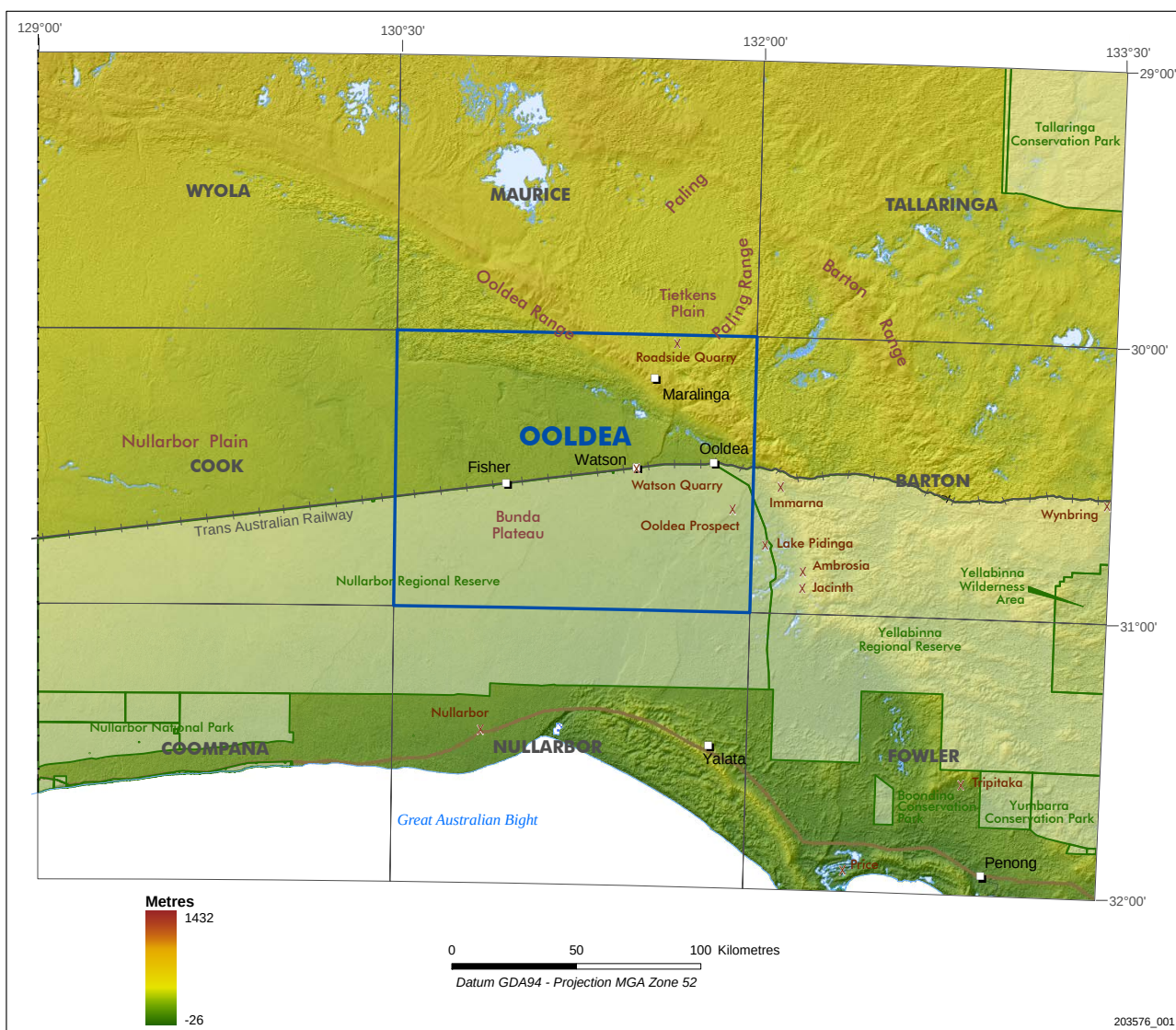


Figure 1. Regional locality and physiographic map of OOLDEA showing major landforms and mineral prospects

The first Europeans to visit the map area are not known. However in 1875 Ernest Giles (Giles, 1889) travelled from Fowlers Bay to Ooldea (which he referred to as Youldah) with six companions using horse and camel. At the time, the Ooldea area was known only to one or two European settlers. Giles passed Ifould Lake and Pidinga Rockhole enroute to Ooldea, and commented on the appearance of a line of higher ground formed of sandhills fringing the Nullarbor Plain (now known as the Ooldea Range; Benbow, 1989). In a separate expedition in the same year, Giles traversed OOLDEA on his way to Perth (Giles, 1889). He again traversed the area in 1880.

In 1880, J.W. Jones travelled northeast from Eucla to Tietkens Wells (on MAURICE), exploring for suitable localities for trial water bores (Jones, 1880). He visited Ooldea and noting the limestone strata and salty water within a well dug at Ooldea.

Daisy Bates lived in the Ooldea area in the early 1900s and worked with the Aboriginal communities. Bates (1920) commented that by 1919 the last of the traditional owners of the 'Ooldea Water' had died, and that the area was being frequented by Aborigines of the Ngallia tribe.

The Trans Australian Railway, opened in 1917, crosses OOLDEA close to the original traverse of Giles from Wynbring to Ooldea. Rail sidings built on the OOLDEA sheet include Fisher, O'Malley and Watson. Testing of atomic weapons and associated experiments occurred in the Maralinga

and Emu areas straddling OOLDEA and MAURICE during the 1950s and part of this area remains closed to public access in northeast OOLDEA. In 1984, the Maralinga-Tjarutja Lands Act was passed by State Parliament and ownership of a large area of OOLDEA north of the railway was handed over to the traditional owners. The area south of the railway line is wholly within the Nullarbor Regional Reserve.

PHYSIOGRAPHY

CLIMATE (AFTER LAUT ET AL., 1977; EARL, 1989)

OOLDEA has a desert climate, with short, cool winters and long, hot summers. Temperatures during summer have a mean maximum of around 35°C. Both diurnal and seasonal temperature variations are high. Rainfall is extremely low and variable, with a mean annual of 150–200 mm. There is no distinct seasonal pattern, with summer rainfall often due to thunderstorm activity.

LANDFORM

OOLDEA is located in the northeastern part of the Cainozoic Eucla Basin (Fig. 2). The Eocene–Miocene succession of the Eucla Basin is divided into the Eucla Group of marine platform bioclastic carbonates (Wilson Bluff and Nullarbor Limestones), and Immarna Group of predominantly terrigenous clastic sediments deposited in shallow marine, coastal and non-marine environments (Pidinga Formation, Hampton Sandstone, Ooldea Sand, Yarle Sandstone and Garford Formation). OOLDEA contains portions of some of Australia's most remarkable landforms. The Nullarbor Plain is usually described as vast, flat and featureless. It is in fact the world's largest semi-arid–arid karst region which has developed on the Nullarbor Limestone. Surficial karst features shown on the map include depressions (dongas) with associated drainage, and low rocky rises. In addition, the Nullarbor Plain is interrupted by prominent north to northeast-trending fault scarps, including the Karari Fault scarp, which indicate recent movement of ancient basement structures. The Ooldea and Paling Ranges mark the latest Eocene shoreline of the Eucla Basin. They are interpreted as coastal dunes and appear to be the oldest preserved features of this type in the world. The Ooldea Range extends for ~650 km from WA to the Ceduna area in SA. Coastal sand of the ranges and adjacent areas (Ooldea Sand, Hampton Sandstone) are prospective for heavy mineral sand deposits. Underlying palaeochannel sediments (Pidinga Formation) have potential for placer gold deposits and other commodities. Quaternary aeolian sand dunes of the Great Victoria Desert cover northern OOLDEA. Their distribution corresponds closely to the distribution of Tertiary coastal sand units from which they have been sourced (Hampton Sandstone, Ooldea Sand, Yarle Sandstone). Tietkens Plain, formed of playa lake carbonates of the Garford Formation, lies in this area.

OOLDEA straddles the eastern margin of the Nullarbor Plain and the encroaching southwestern margin of the dunefield of the Great Victoria Desert, two significant physiographic units in western South Australia (Fig. 2). The Nullarbor Plain is a karst surface, marking most of the terrestrial extent of the Miocene carbonate platform of the Eucla Basin. The Quaternary dunefield mantles and obscures older landforms, including the margin of the Nullarbor Plain, which had their origins much earlier in the Cainozoic (Plate 1; Fig. 3; Benbow and Crooks, 1988; Benbow, 1989, 1990a, 1992; Benbow et al, 1995). Notable are the Ooldea and Paling Ranges, stranded coastal dunes of probable Eocene age. The dissected, duricrust-mantled 'Old Plateau' of Jutson (1934) and the extensive palaeodrainage of the Basin, is most apparent to the east and north (eg on BARTON and MAURICE; Pitt, 1980; Benbow, 1990a). Thus, contrary to much of Europe and North America, there are still preserved in the landscape today, ancient landforms that are testimony to the tectonic stability and relative, prolonged aridity, of much of the continent. On OOLDEA these palaeoforms are related to the evolution and development of the Cainozoic Eucla Basin. Digital satellite topographic data from the Shuttle RADAR Topographic Mission (SRTM) provide the best visual display of regional landform (Fig. 1).

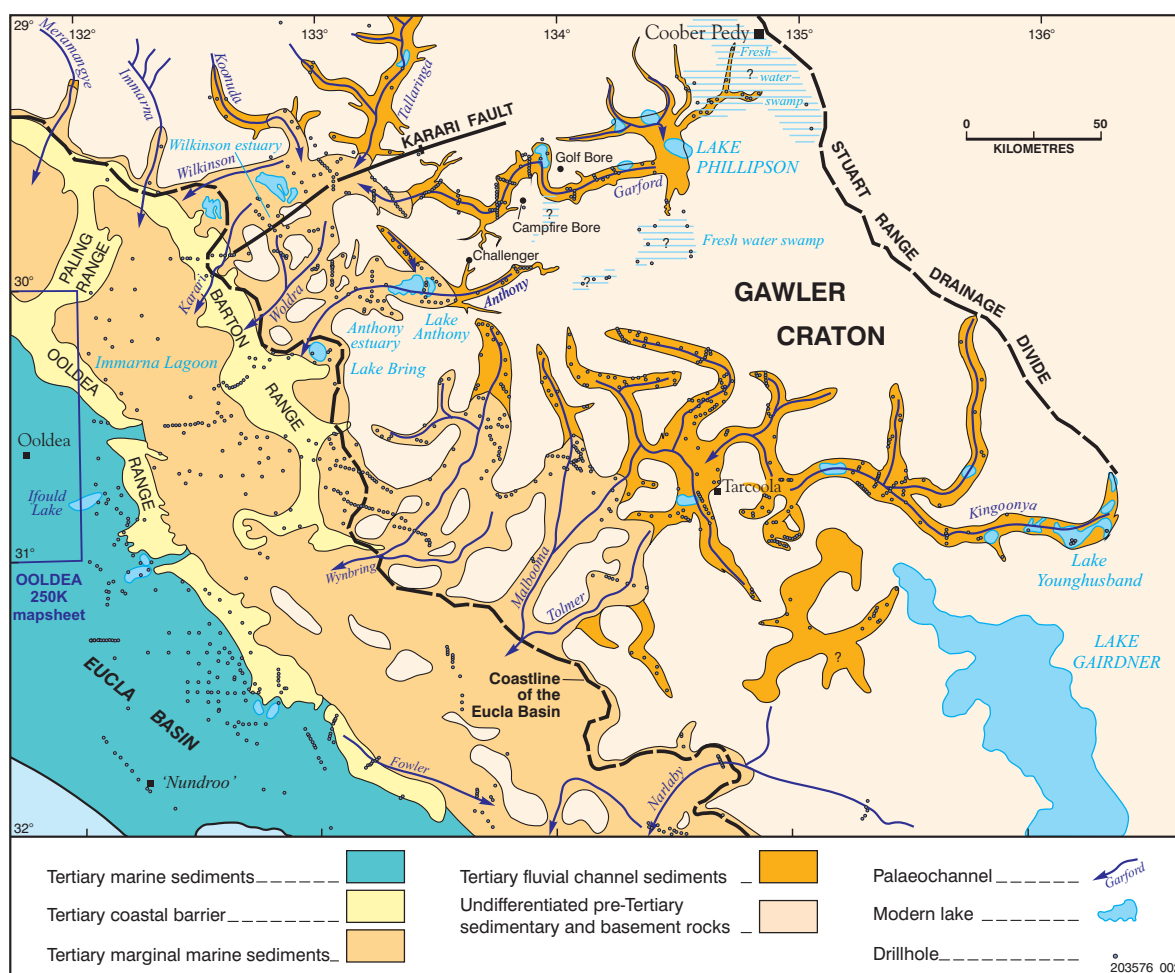


Figure 2. Regional setting east of the eastern portion of the OOLDEA map sheet within the Eucla Basin and circum-basin palaeodrainage (from Hou et al, 2001).



Plate 1. Elongate schlieren of amphibolite in a granite gneiss within an mylonite zone at Lake Tallacootra. Adjacent to OOLDEA, western BARTON (photo 043688)

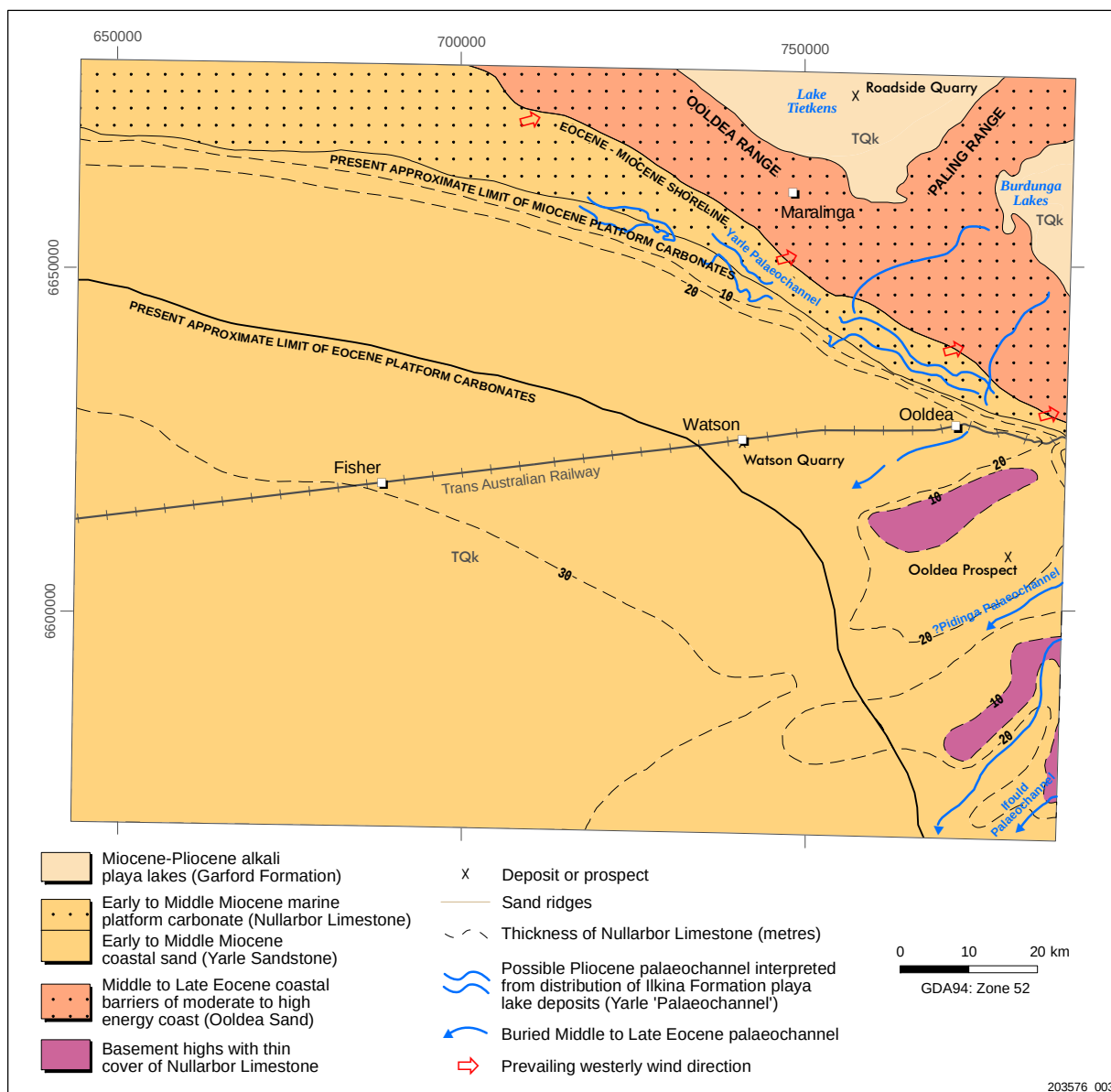


Figure 3. Palaeogeographic model for the OOLDEA map region in the early Tertiary (from the OOLDEA 1:250 000 mapsheet)

The oldest and topographically most pronounced landforms on OOLDEA are the Ooldea and Paling Ranges (Figs 2, 3). Evidence presented elsewhere suggests a latest Eocene age for the construction of these quartz sand ridges (Benbow, 1990a). They appear to be the oldest preserved coastal dunes in the world and the Ooldea Range, which extends into Western Australia to the west and towards Ceduna in the southeast, is at ~ 650 km, the longest such feature on the continent. They were formally believed to be shallow bedrock highs (eg Pitt, 1980; Tapley, 1988).

The Ooldea Range is linear and has a broadly NW-SE orientation. It stands up to 300 m AHD that is, 100–160 m above the Nullarbor Plain and is ~20–25 km wide. On the eastern side of the map the Range rims the Nullarbor Plain, whilst toward the west, it diverges from the Plain to be ~40–50 km further north, where it is situated on adjacent MAURICE. On OOLDEA the Range lacks the curvilinear form that defines palaeo-bays and palaeo-headlands on BARTON, to the southeast. To the northeast there is the parallel Barton Range on BARTON that is linked to the Ooldea Range by the short Paling Range. All three ranges have a similar origin and formed at about the same time.

There are a number of exit points of Eocene to Pliocene palaeodrainage through the Ooldea Range, one of the most notable being that of the Serpentine Lakes Palaeochannel to the west. East of Maralinga, there is a distinct topographic low, now obscured by the dunefield, that is also a likely exit point. This may have some tectonic control because of the aligned scarp on the Nullarbor Plain to the southwest. There is no evidence for incision of the Plain here nor of the construction of large fans as is evident to the west on WYOLA map sheet.

The Nullarbor Plain is one of the world's most remarkable landforms, renowned for its vast (~200 000 km²), flat and featureless extent, as remarked on by the early explorers including Tate (1879; Figs 2, 3). In fact it is the world's largest semi arid/arid karst. It forms part of the Bunda Plateau, a feature that includes fringing, soil and Aeolian sand-mantled surfaces (Lowry, 1970). The Plateau was thought to mark the entire emergent part of the flat lying Tertiary rocks and thus on OOLDEA its inner margin can be defined by the southern limit of the Ooldea Range. On the map sheet the topographic gradient is ~0.4 m/km and the Plain dips from 140 m AHD in the northwest, to around 80 m AHD in the southeast. This general southeasterly decline in elevation is a regional feature of the Plain in South Australia. There are local undulations and some of these are believed to have a structural or tectonic cause. In the vicinity of Watson there are pronounced scarps having a N-S orientation that appear to mark an upfaulted block and to the southeast there are notable scarps, even though they are subdued, parallel to and in the vicinity of, the Karari Fault Zone.

The Plain has subtle karstic features that are best viewed in satellite imagery and aerial photography. They include dongas and intervening shoulders, low ridges and short, shallow creeks. These have been portrayed on the map, which indicates they occur in reasonably well-defined zones. Along the northern margin there are numerous, very small (i.e. <0.5 km) circular, flat-floored, dongas that may be rocky or soil mantled. To the south there are several distinct regions of larger dongas, averaging 0.75–1.5 km in diameter. Some are notably elongate and are associated with short creeks that drain into them, suggesting that they are old, late Cainozoic palaeodrainage features. There are also low ridges that are mostly less than 10 m high and may be distinctly orientated as in the southwest corner of the map. There is an extensive region southwest of Watson, which shows very little surface relief. The caves of the Plain occur to the south and southwest of the map sheet, a region of higher rainfall.

It is unknown whether the Great Victoria Desert mantles an extension of the Nullarbor Plain in the northwest corner of the map sheet as is the case on eastern side of the map. Further west, on WYOLA however, there are beach ridges that may mark a pre-existing coastal plain between the Ooldea Range and Nullarbor Plain (Benbow, 1995).

Wind has deposited low mounds or very subdued dunes alongside some of the flat-floored dongas. These have been subsequently fixed by shrubs and small trees, although wild rabbits have now had some destructive impact. Microrelief structures or gilgai have formed in the wind deposited and sculpted veneer on top of the karst. They have a distinct N-S orientation, are traceable for several 100 m up to ~1 km, are generally no more than 1 m high and are of the order of 100 m apart.

The origins of the Nullarbor Plain are still in some doubt. Some have believed the Plain to be a sediplain, that is, an exposed seafloor surface. Lowry and Jennings (1974) however, believed the surface to be a very gently eroded surface, related to the rainfall gradient, with most erosion having occurred in the south. On OOLDEA the gradient does not appear to coincide with what might be expected of the region's rainfall pattern. Instead, it is believed that there is a tectonic component.

North and northeast of the Ooldea Range there is an elevated region ~50–80 km wide that is largely coincident with the extension of the Eucla Basin (Benbow, 1994). This has been named the Arndinga Plateau and has its origins back in the Middle Eocene at least. Various landforms exist on this surface that lies 50–75 m above the Bunda Plateau. In the southeastern part of the Plateau there is an old landform that has survived since the Miocene or Pliocene. Tietkins Plain is a playa lake carbonate karst north of Maralinga. It was on this surface that the nuclear experiments took place in the early 1960s. Its full extent is unknown, being mantled in part by the dunefield. The Plain stands at ~180 m AHD, and is thus distinctly higher than the Nullarbor Plain. There are

undulations on the surface, with a relief of up to 10 or so meters and associated with some of the depressions are short radial creeks. Karstic dissolution is apparent as it is on the Nullarbor Plain. Similar, dissected karst east of the Paling Range, is largely obscured by the dunefield. Both surfaces are regarded as being immature, arid to semi/arid karsts.

Along the northern margin of the Plain, particularly in the eastern half of the map, there is a topographically low area now marked by a string of playa lakes (see below). There has been up to 10–20 m of erosion and incision of the Plain prior to formation of the Quaternary dunefield. This feature may have arisen in the Pliocene or Pleistocene as there is some evidence for playa lake sediment infill of this age (see below).

The Great Victoria Desert lies in the central southern part of the continental anticlockwise whorl of dunefields (King, 1960; Brookfield, 1970; Wasson et al, 1988). The part of the dunefield on OOLDEA has been referred to as the Yellabinna Association by Laut et al (1977) and is described by Copley and Kemper (1992).

Overall dune orientation is easterly to southeasterly, but local variation can be seen, which is attributable to the pre-existing topography. For example the dunes superimposed on the Ooldea Range have orientations of NW-SE and NE-SW on its southwest and northeast sides respectively, indicating the Ranges orogenic effect. The dunes are mostly the narrow crested, linear, longitudinal type of Wasson et al (1988). Dune spacing is typically 0.3 km but varies from <0.2 km to be in excess of 3 km. Dunes are in fact absent over much of the crest of the Ooldea Range, where undulating sand plains have developed instead. Dune length varies from less than 1 km to be in excess of 15 km. Y-shaped or tuning fork junctions are common and point downwind, that is, toward the southwest and northeast. Dune height varies from around 5 m to in excess of 30 m.

In the topographic depression along the northern margin of the Nullarbor Plain, there is a significant development of network and parabolic dunes in the region where playa lakes have developed. They have a variable orientation, are generally less than 1 km in length and are more subdued in elevation. These dunes can be seen to encroach over the longitudinal dunes to the east and on nearby BARTON suggesting that they are younger in age (Rankin et al, 1996).

There is little well-defined drainage in the dunefield. Along the southwestern flank of the Ooldea Range, in the region where there are no dunes, there are creeks that peter out over very short distances. Some of the playa lakes to the south, have lunettes that have formed on their eastern side.

The Great Victoria Desert had its origins well back in the Quaternary. This contrasts with the view, of Wopfner and Twidale (1988) for example, that the dunefields of the Simpson and Tirari Deserts are Holocene in age. The first indication of some antiquity is the fact that there are substantial calcretes within the core of the longitudinal dunes, as can be observed in the cuttings along the railway line to the east. This evidence, together with the fact of there being superimposed aeolian phases, indicate the dunes have remained fixed in their current position for some time. Recent Thermoluminescence (TL) dates of around 200Ka from near Immarna on the Ooldea Range, provide supportive evidence (Huntley et al, 1999).

VEGETATION

The Nullarbor Plain is dominated by low chenopod shrubland (blue bush, salt bush) with a ground cover that includes tussock grasses (Laut et al., 1977). It is described as being degraded because of introduced faunal species such as the rabbit. Scattered stands of mulga, mallee and myall occur around the margins of the plain on OOLDEA.

The contrasting Great Victoria Desert is dominated by mallee or mulga and includes desert oak, false sandalwood and tea tree (around playa lakes). The understorey is comprised of chenopod species (blue bush, saltbush) and includes button grass. Details of the flora and fauna of the desert are contained in a biological study compiled by Copley and Kemper (1992).

PREVIOUS INVESTIGATIONS

GEOLOGICAL

The first recorded geological investigations near OOLDEA were immediately adjacent to the eastern mapsheet boundary on BARTON and were observations by Tate (1878) on the physiography and rock types near Ifould Lake. J.W. Jones (1880) also noted metamorphic rocks at Ifould Lake. Investigations sparked by the discovery and mining of gold to the east at Tarcoola were conducted by H.Y.L. Brown (1885) during reconnaissance of the west of the State from Port Augusta to Eucla. Further investigations of the west of the State, including OOLDEA were conducted in the early 1900s by Brown (1902, 1905). F.R. George (1905) prospected lands north of the Nullarbor Plain.

Potential for economic commodities within the Maralinga Lands, which incorporates part of OOLDEA, was summarised by Flint et al. (1989). Hydrogeological surveys are outlined by Anderson (1949) and Read (1987). Exploration by companies and PIRSA (including precursor equivalents) for economic commodities are summarised in 'Economic geology' below.

Preliminary maps for OOLDEA, MAURICE and BARTON were compiled by S.J. Daly (1969, 1970, 1974). MAURICE was further updated by G.W. Krieg (1970), who also compiled a preliminary map for adjacent TALLARINGA (Krieg, 1974). Forbes (1970) compiled a brief preliminary overview of the understanding of the geology of the OOLDEA area. The following maps surrounding OOLDEA have been published: FOWLER (Firman, 1975), TALLARINGA (Benbow, 1986) and BARTON (Rankin et al. 1995). Explanatory notes have been published for FOWLER (Firman; 1978), TALLARINGA (Benbow, 1993) and BARTON (Rankin et al, 1996).

A report on the geology and geomorphology of the Yellabinna Environmental Association of Laut et al, (1970) was compiled for inclusion in a biological survey of the area (Benbow, 1990). This covered much of the Tertiary geology of OOLDEA in detail. Unpublished work towards a PhD by Benbow (in prep.) also provided a significant amount of data for the area.

GEOPHYSICAL

Until recently, geophysical data for the OOLDEA mapsheet has been fragmental and sparse. Gravity coverage reflects the nominal state-wide broad regional station spacing in the order of ca. 7 km. Similarly regional aeromagnetic data flown in the 1970s by SADME/BMR (the "Eucla Basin Survey") covered most of the mapsheet at 1600 m line spacing, flown eastwest at 150 m flightline spacing. Shortly after, a minor portion of southern OOLDEA was flown as part of the Southern Eucla Survey 1972 with the same specifications. Gerdes (1977) produced broad interpretations of the western Gawler Craton, including OOLDEA, based upon contoured data.

More recently during the early 1990s Geoscience Australia (formerly BMR then AGSO) undertook airborne magnetic and radiometric surveys flown eastwest with 3000 m line spacing at a 150 m flying height on the northwestern limit of the mapsheet as part of Officer Basin survey. Following this, in 1993 as part of the South Australian Exploration Initiative, eastern OOLDEA was flown at 400 m line spacing and 80 m flying height over areas of shallow basement up to the Karari Fault Zone (Fig. 6a). Radiometric data was acquired concurrently. In 2006 geophysical data was acquired as part of the PIRSA PACE Initiative over northeastern OOLDEA (the One Tree Survey). Data collected were Total Magnetic Intensity (TMI), 4 and 256 Channel Radiometrics and Digital Elevation Model (DEM). The survey was flown at 400 m line spacing with an 80 m sensor height. This data acquisition postdated publication of the OOLDEA mapsheet.

STRATIGRAPHY

The OOLDEA mapsheet area hosts a long and complex geological record, ranging from ?Archean to the Holocene, with particularly good preservation of Tertiary stratigraphy (Fig. 4).

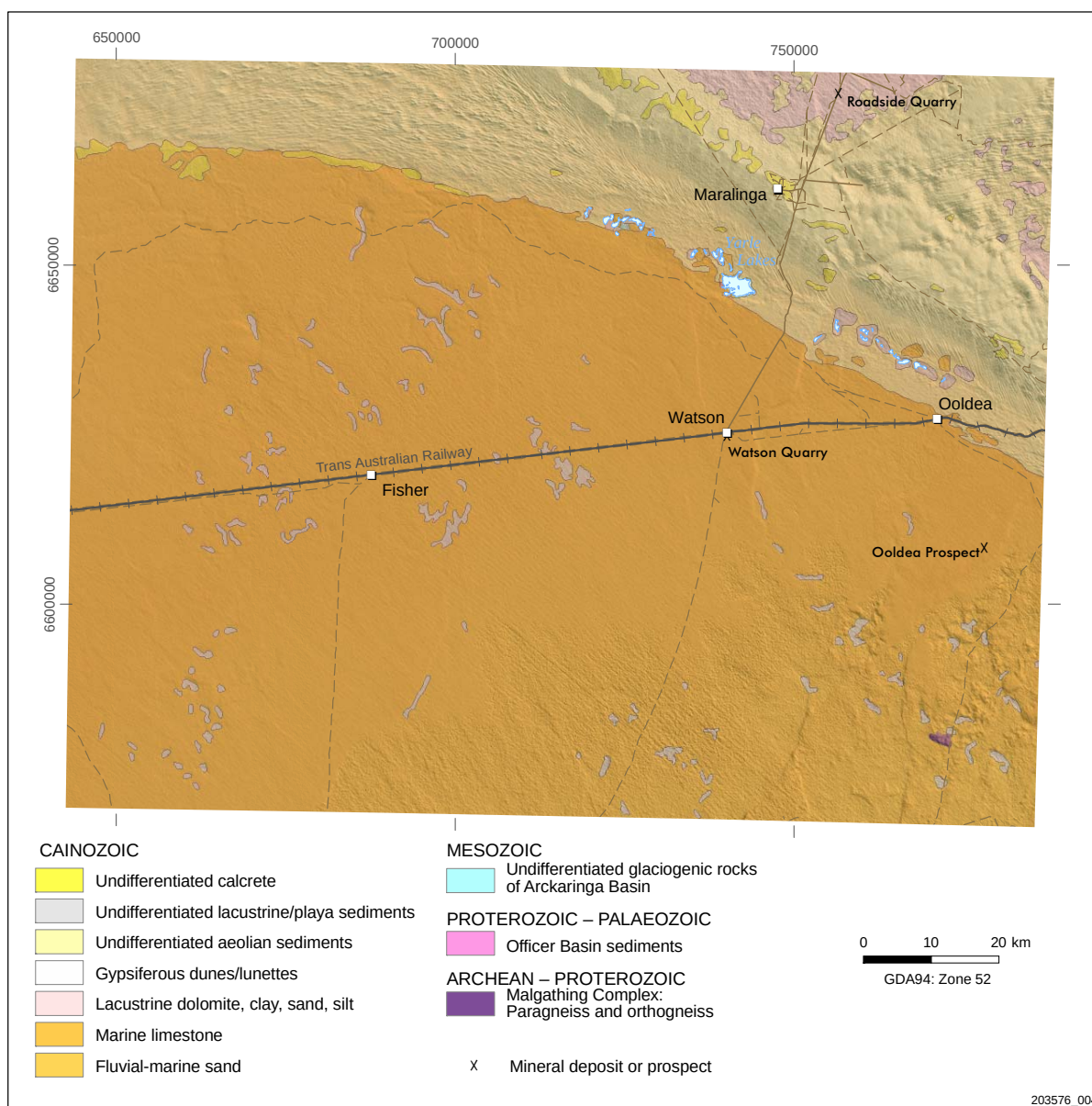


Figure 4. Simplified geology of OOLDEA draped onto a digital elevation model

UNDIFFERENTIATED BASEMENT UNDERLYING OFFICER BASIN

Proterozoic

Due to very sparse basement outcrop, the geology of the Gawler Craton is poorly constrained, compared to other cratonic areas within Australia. From east to west on OOLDEA, the western Gawler Craton has been subdivided into the Fowler, Christie and Nawa Domains based upon variations in tectonostratigraphic history (Fig. 6b). The boundaries of the Gawler Craton are entirely subsurface and have been interpreted from total magnetic intensity and gravity data, combined with regional geological information and drill hole data. A semi-coincident, linear, northeast trending magnetic and gravity anomaly is interpreted to mark the western limit of the known extent of the Gawler Craton extending across OOLDEA. Beyond this feature, the nature of the basement on OOLDEA is unknown. However, based upon geophysical data alone, Teasdale et al. (2001), Rankin (2003) and Cowley (2007) produced basement geology interpretations indicating that the Gawler Craton extended further west than traditionally thought, extending the northeast striking Nawa Domain beyond the western limits of OOLDEA. Further west, Teasdale delineated the Ammaroodinna Subomain, broadly coincident with Rankin's (2003) and Cowley's (2007) Hughes Subdomain.

West of OOLDEA, an isolated geophysical feature, discordant with other defined tectonic domains, the Coompana Block is entirely covered by Neoproterozoic and Phanerozoic sediment of the Officer and Eucla Basins. It comprises a rhombic to irregular area of mafic volcanics and sediments, and hosts a distinct circular reversely magnetised anomaly, which is similar to another smaller feature located south of OOLDEA on NULLARBOR. These probable mafic-ultramafic intrusives, likely coeval with the volcanics, were emplaced within the felsic basement and the volcanic pile. Granitic gneisses were intersected in drilling Mallabie 1, around 1400 m below surface. K–Ar geochronology on biotite and hornblende from DDH Mallabie 1 gave ages of 1159 and 1185 Ma respectively (Webb et al., 1982). These ages are significantly younger than K–Ar ages acquired from the western Gawler Craton, which are generally around 1450 Ma. From this data, Rankin (2001) suggested that the Coompana Block represented a southern zone of Musgravian Orogeny (equivalent) overprint along the far-western Gawler Craton, with a major episode of mafic magmatism during the latter stages of the Orogeny. The mafics might therefore be compared to the Giles Complex & Tollu Volcanics in the western Musgrave Block Fanning (1997) and Fanning et al., (2007) conducted SHRIMP U–Pb dating of a sample from basement in Mallabie 1 in order to determine the crystallisation age of the foliated granites. A weighted mean age of 1455 ± 16 Ma constrained the time of zoned igneous crystallisation within the gneissic granite. In the scheme of Cowley (2007), the Coompana Block rocks may intrude and overlie previously unknown basement now assigned to the Gawler Craton. The crystallisation age calculated by Fanning (1997) marginally falls within the currently accepted age of Gawler cratonisation. Nevertheless, the convention of the published OOLDEA mapsheet is followed here.

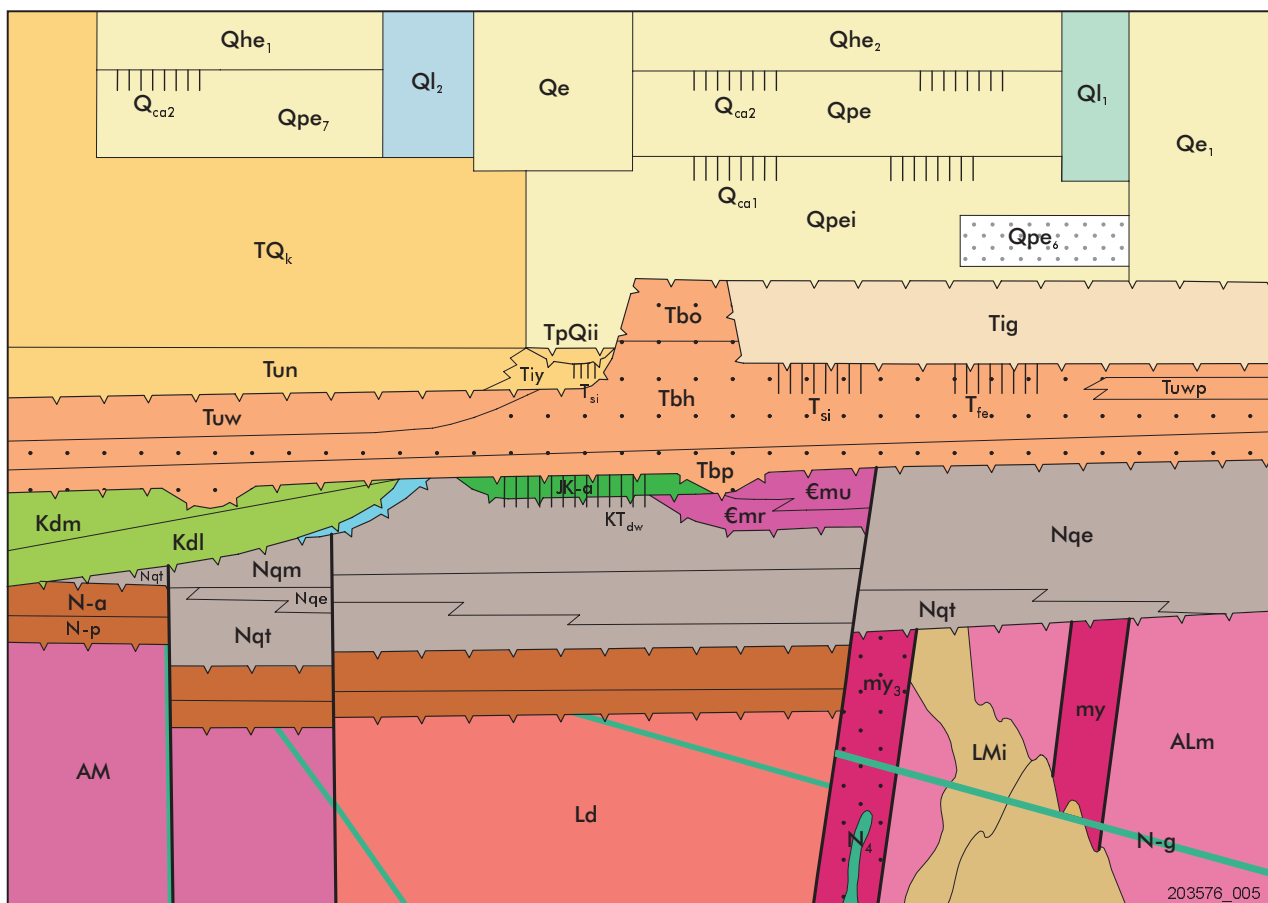


Figure 5. Stratigraphic relationships for the OOLDEA mapsheet area

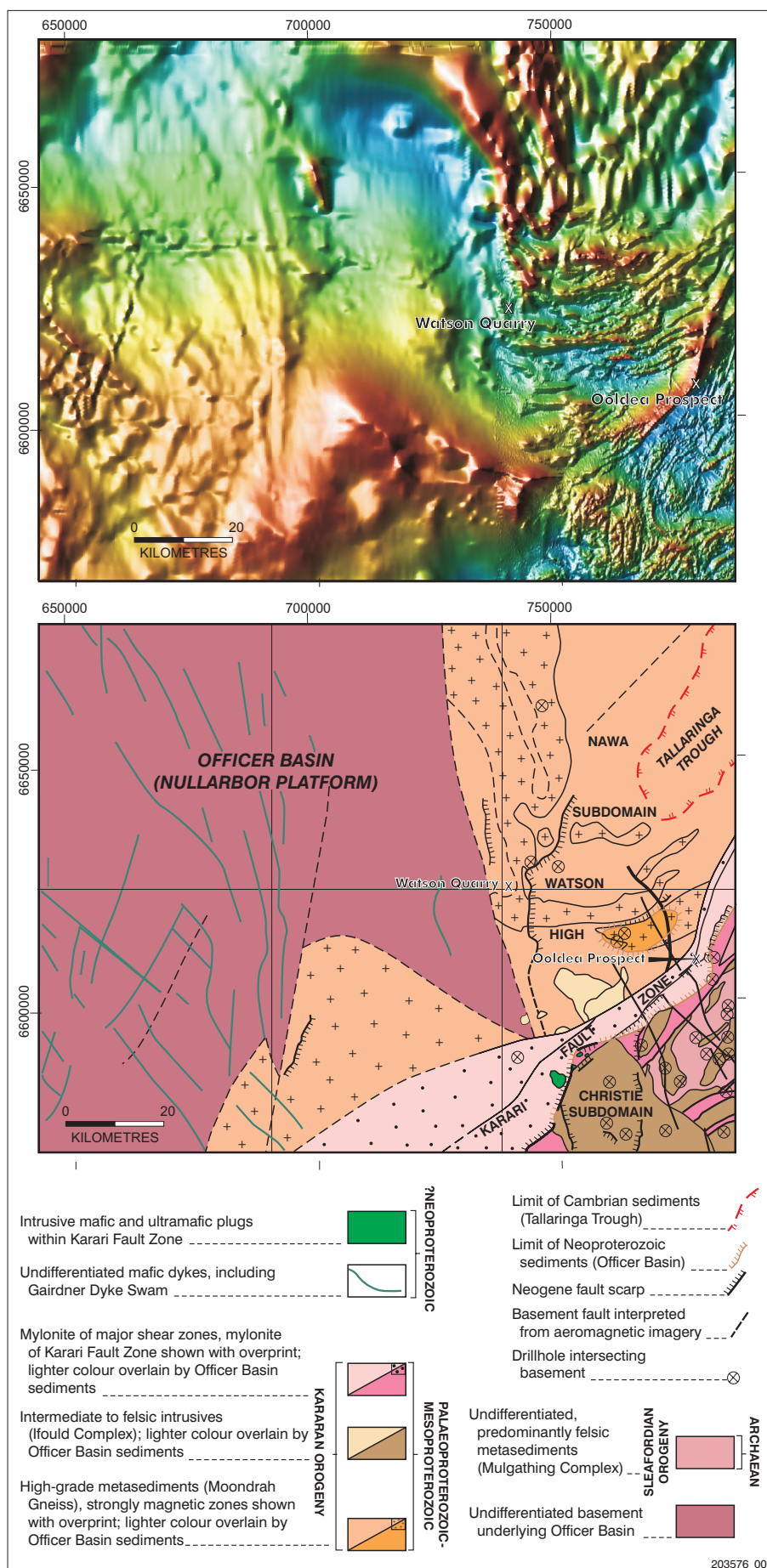


Figure 6. (a) Total magnetic intensity image of OOLDEA, (b) solid geology interpretation (scale 1:1 000 000)

GAWLER CRATON

Archaean – earliest Proterozoic

The Gawler Craton is a large crystalline basement province consisting of late Archaean to Mesoproterozoic rocks (Thomson, 1970; Parker et al., 1988; Fanning et al., 1988, Daly et al. 1998). Development of the Gawler Craton occurred in three megacycles of orogenesis, described by Fanning et al. (see 'Tectonic and structural development'). The craton records crust formation and tectonothermal events in the late Archaean to early Palaeoproterozoic (Sleafordian Orogeny), Palaeoproterozoic (Kimban Orogeny), and Palaeoproterozoic to Mesoproterozoic (Kararan Orogeny). OOLDEA lies largely within the Christie and Nawa Subdomain of the northwestern Gawler Craton; the subdomains were originally defined by Thomson (1980) on the basis of the regional aeromagnetic character of the area, and refined by Daly et al, 1998 and Ferris et al, 2002. The Christie Subdomain, in the southeastern map area, comprises Archaean felsic metasediments of the Mulgathing Complex which have been intruded by Palaeoproterozoic to Mesoproterozoic intermediate to felsic rocks of the Ifould Complex.

There is no significant basement outcrop on OOLDEA, and basement interpretation portrayed in the pre-Permian structural sketch is based on drillhole intersections and aeromagnetic data of varying quality. Drillholes which have intersected crystalline basement on OOLDEA include Ooldea 1, Ooldea 2, Ooldea 3, Maralinga 7, ORP 1 and 2, PIN-R 9, 10, 11, 14, 15, 16, 17, 19, 20, 33 and 93. All of these drillholes are portrayed on the Tectonic Sketch on the OOLDEA map sheet and on Figure 6b. Basement rocks on eastern OOLDEA belong to the Christie and Nawa Subdomains of the western Gawler Craton.

Mulgathing Complex Alm

The Mulgathing Complex (Daly et al., 1979; Daly, 1986; Daly and Fanning, 1993) consists of high-grade metamorphic, multiply deformed meta-igneous and metasedimentary rocks in the northwestern Gawler Craton. Exposures on OOLDEA are restricted to a small area of scattered subcrop in the southeast of the mapsheet area, although several further instances of Mulgathing Complex are interpreted from some of the drillholes known to intersect basement. More extensive occurrences of this complex exist on southwestern TALLARINGA, BARTON and are scattered over southern COOBER PEDY and adjacent TARCOOLA where they have been subdivided into several formation and members, including paragneisses of the Christie Gneiss. On OOLDEA they are undifferentiated, predominantly felsic metasediments of the Christie Domain, including leucocratic gneiss and granulite.

Palaeoproterozoic – earliest Neoproterozoic

The Nawa Domain on OOLDEA contains magnetite-rich metasediments of the Moondrah Gneiss, which Daly et al., 1998 considered to represent aluminous, magnesium-rich metapelites. The domain comprises an intensely faulted, rigid crustal block, which appears relatively unaffected by the ductile, arcuate, roughly northeast–southwest to east–west shear zones which separate domains to the south. It is bounded by the Cambrian to Neoproterozoic Murnaroo Platform to the northwest, the Karari Fault Zone to the south, and the Torrens Hinge Zone to the northeast. The Karari Fault Zone separates the Nawa Domain from the Christie Domain. On the northwestern margin of the Nawa Domain, a U–Pb emplacement age of 1740 Ma is recorded for a foliated granite from the Yoolperlunna Inlier (M. Fanning, PRISE, pers. comm., 1997).

Younger mafic intrusions include dykes related to the Gairdner Dyke Swarm and small plugs within the Karari Fault Zone. The age of the mafic rocks is not known but they may be coeval with Neoproterozoic (Willouran) rift basalts of the Adelaide Geosyncline and Officer Basin. Like the Archean, The nature of the Proterozoic basement underlying central and western OOLDEA is unknown and have been interpreted only from low-resolution aeromagnetic data. It is presumably related to the Gawler Craton, and includes zones of high magnetic intensity and two groups of mafic dykes.

Moondrah Gneiss Ld

In 1981 rotary drilling by Amoco Minerals Australia Co. intersected gneisses within hole AMA ORP 1 that showed granulite facies mineralogies, including hypersthene + sillimanite + quartz along with a probable occurrence of the ultra-high temperature assemblage sapphirine + quartz (Purvis in Miller et al., 1982). High-grade, magnetite-rich, aluminous metasediments of the Nawa Subdomain have also been encountered in several subsequent drillholes on OOLDEA including AMA ORP 2, CES PDH 3, SADME Ooldea 1, SADME Ooldea 2, LRWE Maralinga 7, as well as Elf Aquitaine-MESA Lake Maurice East-1 SMD 5002 on MAURICE. In the Lake Maurice East 1 drillhole very high-grade gneisses with garnet–hematite-magnetite symplectites similar to Ooldea 2 occur ~690 m below Officer Basin sediments (Daly et al., 1998). Rb–Sr isotope data indicate that samples from drillhole Ooldea 2 have a minimum metamorphic age of ~1700 Ma (Parker, 1993).

The term 'Moondrah Gneiss' was proposed by Daly et al. (1998) to encompass these rocks of the southwestern Nawa Domain. Mineral assemblages observed in these drillholes include hypersthene-sillimanite and sapphirine-quartz (Daly, 1987) that indicate conditions of high-grade metamorphism, with temperatures in excess of 800°C (Teasdale, 1997). It should be noted, however, that the high oxygen fugacity (on or above the magnetite-hematite buffer) conditions provided by the iron-bearing minerals may have stabilised the sapphirine-quartz assemblage at lower temperatures than would be required otherwise (Daly, 1987). Garnet–hematite-magnetite intergrowths and symplectites are interpreted to indicate initial reduction under peak pressure-temperature conditions. Aeromagnetic data shows that the iron-rich metasediments trend east-west and are truncated to the southeast by the Karari Shear Zone.

The Ooldea 2 diamond drillhole (Daly, 1987, Taylor, M., 1987) was drilled in 1985 with the aim of recovering a cored interval of the sapphirine + quartz and other granulite-facies gneisses intersected by the previous drilling. Ooldea 2 was thus sited as near as possible to ORP 1 and was successful in obtaining around 164 m of granulite-facies gneiss. Daly (1987) has described the gneisses within DDH Ooldea 2 as being medium to coarse grained, broadly to finely banded, with mineral textures varying from granoblastic to elongate, and with a strong preferred orientation that indicates significant strain partitioning between lithologies within the drillhole. In some zones, feldspars are porphyroblastic and the quartz is completely recrystallized to finer-grained aggregates. In general, the rock consists predominantly of bands of pinkish, quartz–feldspar–garnet–gneiss interlayered with moderately abundant magnetite and pyroxene. Daly (1987) interpreted the broad scale compositional layering to reflect original sedimentary layering, modified during deformation and metamorphism. A handful of dolerite dykes also intrude the quartz feldspar gneiss.

The dated sample is a quartzo-feldspathic gneiss from the interval 153.75–154 m and was sampled for the purposes of constraining the timing of metamorphism within the metasedimentary rocks of the Moondrah Gneiss within DDH Ooldea 2. It is a medium to coarse-grained, banded, locally well-layered quartz–feldspar–magnetite–garnet gneiss. Daly et al. (1998) reported an interpreted metamorphic age of 1653 ± 8 Ma for this sample with inherited components at ~1690–1700 Ma. The age has been recalculated for Fanning et al (2007). A weighted mean $^{207}\text{Pb}/^{206}\text{Pb}$ date of 1659 ± 6 Ma places constraints on the timing of high-grade metamorphic zircon development within the granulites of the Moondrah Gneiss from Ooldea DDH 2.

Pb–Pb analysis using the Kober zircon evaporation technique yielded two ages, 1690 ± 9 and 2426 ± 6 Ma (Teasdale, 1997). Teasdale (1997) interpreted the data to indicate two events, one zircon-forming event at 1690 Ma followed by a high-temperature event at 1653 Ma. The difference of opinion remains problematic, however the onset of the Kararan Orogeny (see below) buried these sediments. At the east-northeast end of the magnetic Nawa Ridge in the Paragon Bore area, upper amphibolite to lower granulite-facies BIF, garnet quartzite, porphyroblastic garnet gneiss and peridotitic ultramafic rock occur at ~175 m below Permian sediments. A quartz–plagioclase–garnet–biotite–sillimanite paragneiss from drillhole Paragon Bore PB 2 has a U–Pb SHRIMP age of ~1540 Ma, which is interpreted as recording the timing of later high-grade metamorphism (Fanning, 1997).

Recent LA ICP MS U–Pb dating of detrital zircons from metasedimentary rocks from drillholes within and adjacent to OOLDEA mapsheet area including Mt Furner 1, Many 4, AM/PB 3, OBD 6, OBD 12 and Ooldea 2 within the Nawa Domain, has suggested a maximum depositional age of around 1740 Ma, with a predominance of ages between 1740–1840 Ma (Payne et al., 2006). In this study only a few Archaean zircons were recorded. Payne et al. (2006) also report evolved ϵ_{Nd} (1.6Ga) values for the metasedimentary rocks, ranging from –4.3 to –7.0, indicating an evolved source region for the sediments.

Ifould Complex Lmi

The recognition of younger deformed granitoids on the western Gawler Craton (Daly et al, 1998) postdating the strict definition of the Lincoln Complex on the eastern Gawler Craton required a revision of stratigraphic nomenclature. Daly et al (1998) defined these intrusive rocks as the Ifould Complex from the “Fowler Suture Zone” (now the Fowler Domain) in the vicinity of BARTON and OOLDEA. The structures effecting these rocks were assigned to the newly defined Kararan Orogeny. Subsequently Ferris and Schwarz (2004) recognised the broadly contemporaneous Tunkillia Suite in the central Gawler Craton and considered the Ifould Complex as correlatives of part of the Tunkillia Suite. The original nomenclature of Ifould Complex as used on the OOLDEA sheet is adopted here for clarity.

Intermediate to felsic intrusives of the Fowler Domain are recognised in outcrop exposed in the Ifould Lake area immediately to the west of OOLDEA on BARTON where co-magmatic granite-diorite complexes occur. These include granodiorite gneiss (Rb-Sr age 1667 $\pm$ 115 Ma), migmatitic quartz-feldspar-biotite gneiss (Rb-Sr 1703 $\pm$ 1106 Ma), gneissic granite, aplite and pegmatite. Similar rocks are interpreted to extend into the subsurface of eastern OOLDEA. They are encountered in drillholes (e.g. TNN 625 1) and possibly form part of poor subcropping and weathered lithologies in southeast OOLDEA.

The Fowler Domain lies within the western Gawler Craton (including eastern OOLDEA) and comprises a northeast trending belt of predominantly mafic and ultramafic intrusives with intercalated metasedimentary rocks (Fairclough et al, 2004). The Fowler Domain is deformed by a series of anastomosing shear zones (Plate 2) that generally lie subparallel to the Karari Fault Zone and separate subdomains of differing metamorphic grade and lithological character (Teasdale, 1997). Primitive gabbros and chromite-bearing olivine-rich ultramafic rocks have been intersected in drill core within the Fowler Domain on BARTON (Rankin et al, 1996) and there has been exploration interest in the region for nickel sulphides related to these mafic intrusions (Constable et al., 2005).

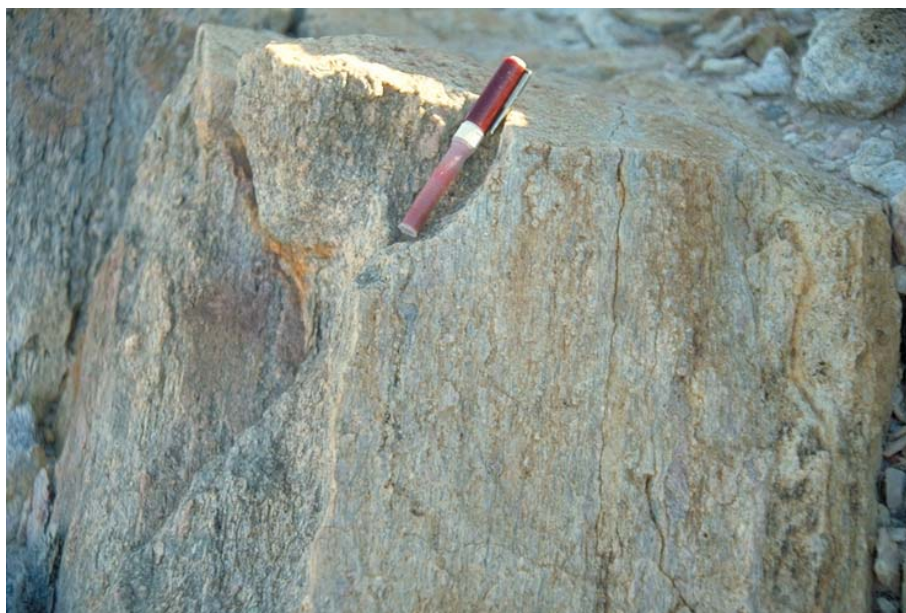


Plate 2. Ultramylonitic gneiss at Lake Tallacootra, adjacent to OOLDEA on western BARTON. Highly elongate quartz ribbons define an intense foliation hosting asymmetric feldspar megacrysts (photo 043690)

In addition to containing the mafic meta-igneous rocks and Tunkillia Suite (Ifould Complex) intrusives, the Fowler Domain is also composed of significant proportions of Palaeoproterozoic metasediments in the form of amphibolite facies metapelites and banded iron formations associated with the Moondrah Gneiss (Teasdale, 1997; Daly et al., 1998). It is possible that instances of these lithologies occur in subsurface areas of OOLDEA interpreted as Ifould Complex.

Mylonite of major, northeast-trending shear zones, my, including mylonite of the Karari Fault Zone my3

Rankin et al, (1989) recognized a 300 km long linear aeromagnetic anomaly coincident with the Karari Fault Zone defining a subvertical “Early Proterozoic”, intracratonic shear zone within the western Gawler Craton. This structure was interpreted to mark the western boundary of the Christie Domain. In early 1985, a drilling program was proposed for two fully-cored diamond drillholes in the Ooldea region. The first, SADME Ooldea 2 is discussed above. Ooldea 3, was sited on the eastern flank of the Karari Fault magnetic anomaly (Parker, 1987) Ooldea 3 intersected 280 m of variably mylonitised gneisses including homogeneous quartz-feldspar-biotite gneiss, Quartz-magnetite gneiss, layered quartz-feldspar-biotite-magnetite-garnet (+/-sillimanite) gneiss, amphibolite and microcline-quartz-tourmaline pegmatite. Mylonites within this sequence are mainly fine to medium grained but are typically inequigranular, with common medium to coarse grained feldspar megacrysts and garnet poikiloblasts within a fine to medium grained matrix. Quartz commonly has undulose extinction under thin section, with deformation bands and lobate grain boundaries. Quartz ribbons are common. Kinematic indicators, including asymmetrical megacryst tails, elongation lineations, vergence relationships of S-C foliations, and mica fish indicate downthrow of the northeastern block with sinistral strike-slip component according to Rankin et al. (1989). However, Teasdale (1997) and Parker (1998) interpreted a west block up sense of movement from the same rocks. Similar non-cored rock types have been intersected in the Karari Fault Zone proper in drillholes PAE PIN-R 33, ERL WS 1A, WS2, WS-WB.

Undifferentiated mafic dykes, including Gairdner Dyke Swarm N-g

Basement domains around and within OOLDEA are intersected by several different orientations of mafic dyke swarms. The most obvious and extensive dyke swarms are NNW-trending negatively magnetic mafic dykes now thought to be associated with the “Coompana Suite” of Rankin (2003). Rankin (2003) discuss two phases of late-tectonic magmatism on the western Gawler Craton viz. “Coompana Suite” (or Coompana Intrusives of Teasdale et al, 2001) and associated mafic dykes, and younger dykes of the Gairdner Dyke Swarm (now the Gairdner Dolerite). Rankin considers that the Coompana Suite is not restricted to the Coompana Block, but is also emplaced within the western Gawler Craton, and continues beneath the Officer Basin. These intrusives are considered older than the Gairdner Dyke Swarm. The northern margin of the Coompana Block is poorly defined, being concealed by increasing sediment cover. It may be coincident with a major NW positively magnetic dyke swarm extending from the Head of Bight coastal area (South Australian) NW across into Western Australian. The NNW dykes are parallel to a series of NNW-trending basement / basin structures within the Officer Basin area and are evident in the Bouger gravity data.

The Gairdner Dyke Swarm (ca. 800 Ma; Wingate et al, 1998), now termed the Gairdner Dolerite (Cowley, 2007) is a major swarm of dykes of variable magnetic character (dominated by positively magnetic dykes). The swarm generally trends NW-SE, and intersects all of the basement domains to the Eastern Officer Basin. They have not been recorded in any drilling on OOLDEA. The dyke swarm represents initial incipient rifting of the crust prior to development of the Officer Basin and Adelaide Geosyncline.

Intrusive mafic and ultramafic plugs N4

Positively and reversely magnetised circular anomalies evident on regional aeromagnetic images have been interpreted to be Palaeo-Mesoproterozoic mafic (or ultramafic) stocks or plugs by Fairclough et al, (2002).

Rocks thought to be equivalent have also been intersected by drilling on OOLDEA in EQR OSAC 1, EQR OSAC 2 and 3, but have been interpreted as Neoproterozoic on the OOLDEA mapsheet. Several diatrema-like circular targets up to 1 km in diameter were identified by Equinox Resources during the 1990s from an interpretation of regional and infill aeromagnetic data over an area 45 km south of Ooldea Siding on the Trans-Australian Railway. Three of these magnetic targets were further investigated with ground magnetic surveys and three aircore drillholes (total 260 m), which bottomed in altered Archaean to Mesoproterozoic intrusive igneous rocks of mafic to ultramafic composition.

EQR OSAC 1 intersected weathered saprolitic basement at 88–95 m above altered dolerite or basalt to 96 m. The massive dark grey non-magnetic dolerite with subophitic texture and strong hematite alteration along grain boundaries hosted disseminated pyrite and a network of thin, black chloritic veinlets. Petrology of basement rock described them as altered olivine basalt comprising fine grained ophitic plagioclase and clinopyroxene and abundant 1 mm-size patches of greenish-brown clay interpreted to represent former olivine. Hematite and trace low-temperature pyrite are the main accessories

EQR OSAC 2 terminated in massive medium-grained pyritic and magnetic gabbro or peridotite (73–78 m). Petrology revealed a highly magnetic altered hornblende peridotite with cumulus olivine and pyroxene and post-cumulus poikilitic hornblende and phlogopite. The olivine was represented by serpentine-magnetite pseudomorphs and there was rare sulphide.

EQR OSAC 3 finished in massive unfoliated nonmagnetic greenish-white plagioclase-rich diorite (85–86 m) composed mainly of white plagioclase, opaque minerals and with up to 5% disseminated pyrite and apple green amphibole. Petrological examination indicated a carbonate-flooded plagioclase-rich mafic intrusive. The rock is now predominantly calcite with fragments of plagioclase, hornblende, biotite and opaque oxide suggesting a mafic precursor. Carbonate flooding represents pervasive replacement which appears not to be supergene.

Whole rock silicate analyses showed that none of the basement lithologies contained anomalous Titanium or REEs to support a kimberlitic origin.

OFFICER BASIN

Neoproterozoic

Most of the basement on OOLDEA, except in the southeastern corner, is overlain by Neoproterozoic sediments of the Officer Basin (Nullarbor Platform). An attempt has been made to correlate the platform sediments with the better known succession in the Marla–Giles area to the northeast. Probable equivalents of Willouran sediments (Pindyin Sandstone and Alinya Formation) and Marinoan Lake Maurice Group (Tarlina Sandstone, Meramangye Formation and Murnaroo Formation) have been interpreted from drillhole logs, and are shown in Sections A–A' and B–B' on the map sheet.

Pindyin Sandstone N-p

The Pindyin Sandstone (formerly Pindyin Beds of Major, 1973) does not outcrop on OOLDEA, but is well known from outcrops further north towards the Musgrave Block. In the central Officer Basin, The basal Pindyin Sandstone contains a bed of lowstand conglomerate thinning to the south. This is followed by a 190 m thick sandstone which contains herringbone cross-bedding, probably indicating a marine transgression. On OOLDEA the Sandstone is encountered in several drillholes including SADME Ooldea 1, possibly OOC Cook 1, LWRE Maralinga 7, GOD/SAN YL1, GOD/SAN YL2, GOD/SAN YL3 and ERL WS 1A, WS 1, WS-WB. It occurs as a white to dark red, very fine to coarse-grained quartz sandstone. It is also observed to be locally pyritic or hematitic with interbeds of dolomitic mudstone and calcareous siltstone. At the base of the sequence basement clasts are observed. A maximum observed thickness within OOLDEA is 58 m in GOD/SAN YL1.

Alinya Formation N-a

The Pindyin Sandstone is conformably overlain by the highstand shale/siltstone of the Alinya Formation that contains dolomitic chert in the lower part and limestone at the top (Zang, 1995). The shale/siltstone in the lower part of the formation is laminated to thin-bedded and mainly thin-bedded in the upper part and containing veneers of ferruginised sandstone and silcrete, probably indicating an upward shallowing sedimentary environment, from subtidal to intertidal or upper subtidal. The Pindyin Sandstone and Alinya Formation were probably deposited in response to the initial Neoproterozoic sag in the Adelaide Geosyncline during the Willouran.

Within drillholes LWRE Maralinga 7, GOD/SAN YL1, GOD/SAN YL2, GOD/SAN YL3 and ERL WS 1A, WS 1, WS-WB (and possibly OOC Cook 1) on OOLDEA the Formation occurs as red-brown shale and calcareous shale interbedded with grey and red-brown micritic limestone which is locally cherty and oolitic. Other variations include red-brown and grey-green dolomitic mudstone to micritic dolostone which is locally stromatolitic, and dark, pyritic, carbonaceous, dolomitic mudstone. Red-brown, very fine to coarse-grained sandstone and anhydrite horizons are also common. Thicknesses generally decrease to the south, but reach a maximum of 116 m in GOD/SAN YL2.

Lake Maurice Group Nq

The lower part of the Marinoan succession of the Officer Basin was originally named Maurice Group (Zang, 1995), and was renamed Lake Maurice Group by Morton (1997). The group comprises three formations: Tarlina Sandstone, Meramangye Formation and Murnaroo Formation, forming a complete transgressive–regressive cycle. The basal Tarlina Sandstone contains a bed of lowstand fluvial conglomerate and grades upwards into transgressive to highstand siltstone and silty mudstone of the Meramangye Formation. A regression is indicated by continuously shallowing-upwards into shoreface and estuarine–fluvial sediments of the Murnaroo Formation. The Officer Basin was subject to relatively rapid subsidence during deposition of the Lake Maurice Group; this is particularly evident on the Murnaroo Platform to the north of OOLDEA (Morton, 1997).

Tarlina Formation Nqt

Sediments encountered within drillholes SADME Ooldea 1, GOD/SAN YL1, GOD/SAN YL2, GOD/SAN YL3 and ERL WS 1A, WS 1, WS-WB are correlated with the Tarlina Formation. The Tarlina Sandstone unconformably overlies the Alinya Formation, or metamorphic basement, and is conformably overlain by the Meramangye Formation or Murnaroo Formation. In the subsurface of OOLDEA it occurs as white, grey and pink, generally poorly sorted, very fine to very coarse-grained quartz sandstone. It is locally pyritic, dolomitic, and with lithic granules to pebbles. Minor interbedded red-brown and green siltstone also occurs. The maximum thickness of unequivocal Tarlina Formation on OOLDEA is 248.5 m recorded in drillhole ERL WS 1A.

Meramangye Formation Nqe

Regionally within the Officer Basin the Meramangye Formation consists of red-brown and minor green-grey silty mudstone interbedded with thin siltstone or fine-grained sandstone, with minor silty limestone. Sedimentary structures include thin-bedded to laminated mudstone, siltstone with planar cross-beds, ripple cross-lamination and graded beds. Slump structures are common. Upward-shallowing parasequences from silty mudstone to siltstone indicate a passage from prodelta to delta front settings.

The Formation has been intersected in drillholes PAE PIN-R 18, SADME Reid 1, 1A, SADME Ooldea 1, GOD/SAN YL1, GOD/SAN YL3 and possibly CEC PDH 3. Lithologies originally interpreted as Cambrian Observatory Hill Formation in SADME Ooldea 3 have been tentatively correlated with Meramangye Formation on the OOLDEA map sheet.

Locally lithologies range from brown, red-brown and grey, partly calcareous claystone, siltstone, shale to very fine to coarse-grained sandstone. Pebbly mudstone and sandstone as well as green limestone and dolostone are also present. Contacts with the underlying Tarlina Sandstone and

overlying Murnaroo Formation are conformable. If the stratigraphic correlation is correct, the maximum recorded thickness of 85.7 m is found within SADME Ooldea 3.

Murnaroo Formation Nqm

The Murnaroo Formation conformably to unconformably overlies Meramangye Formation, Tarlina Sandstone or Alinya Formation. Within the Officer Basin the lithology consists predominantly of sandstone, pale grey-green to pale green when fresh, altered to dark brown and dark red-brown by iron oxide in groundwater. The sandstone is generally poorly sorted with occasional very well rounded, in part bimodal, fine to coarse-grained and minor granule quartz sand with rare conglomerate; lithic grains and clay clasts are variably rare to common. Feldspar and heavy minerals are present, the latter often as concentrations on bedding planes; biotite and muscovite are similarly concentrated. Shale interbeds are more common near the top but are scattered randomly throughout the section. Cement most commonly is silica, with carbonate to a lesser extent. Accessory minerals include feldspar, rare gypsum, and possibly glauconite (Morton, 1987).

Within drillholes SADME Reid 1, 1A, SADME Ooldea 1, LWRE Maralinga 16, GOD/SAN YL1, GOD/SAN YL2, GOD/SAN and YL3, ERL WS 1A, WS 1, WS-WB white, grey and red, very fine to coarse-grained feldspathic quartz sandstone are correlated with the Murnaroo Formation. It is locally pyritic and can also range from calcareous or dolomitic to micaceous or glauconitic. Interbedded red, purple and green shale and siltstone with minor interbedded dolostone and fine-grained quartz sandstone are also observed. Other minor lithologies include conglomerate, green-grey micritic dolostone to dolomitic shale with interbedded red-brown shale and calcareous fine-grained sandstone and micritic limestone.

Cambrian

Early Cambrian sediments of the Tallaringa Trough (Relief Sandstone, Ouldburra Formation) may extend into northeastern OOLDEA.

Marla Group Em

Relief Sandstone Emr

The Relief Sandstone occurs in drillholes on adjacent map sheets BARTON and TALLARINGA and is interpreted to extend into the subsurface of northeastern OOLDEA. In drillholes, the lithology consists of red-brown to white, fine to medium-grained sandstone; minor coarse-grained sandstone and red-brown mudstone. Mudcracks and small-scale cross-beds are locally evident, and intraformational breccia is minor. The Relief Sandstone on BARTON may have been deposited in various environments ranging from fluvial, aeolian to shallow marine. It is calcareous towards the top and passes transitionally up into the Ouldburra Formation on BARTON (Rankin et al, 1996).

Ouldburra Formation Emu

The Ouldburra Formation (Brewer et al., 1987) is a sequence of 'mixed carbonate/siliciclastics, marine carbonates and evaporites' locally occurring mainly in drillholes on BARTON and TALLARINGA. It consists of red-brown, calcareous mudstone with gypsum and anhydrite, minor interbeds of very fine and coarse-grained sandstone, and laminated carbonaceous mudstone. A 594 m thick section in Wilkinson I on adjacent TALLARINGA was originally referred to as Observatory Hill Beds, but Brewer et al. (1987) correlated these sediments with Ouldburra Formation. Conversely, in SADME Ooldea 3 several metres of red-brown mudstone, minor sandstone and occasional limestone. originally correlated with the Observatory Hill Formation (Parker, 1987; Rankin et al., 1989) is now correlated with Neoproterozoic Meramangye Formation.

ARCKARINGA BASIN

Carboniferous-Permian

Minor outcrop of interpreted late Paleozoic sediments of the Arckaringa Basin occurs near Maralinga, and these sediments may also occur in drillholes in the same area.

White and mottled, clay, sandy clay and sand CP

In a small outcrop in the Yarle Lakes area, where exposure is limited, intermixed lithologies occur, ranging from white to mottled white clay and sandy clay to sand are tentatively correlated with other exposures on northeast BARTON (Plate 3). The latter occur along the western margin of a small lake a few kilometres south of Lake Anthony. The silcrete-capped sediments comprise syndepositionally slumped clay, silt and sand, which are in part diamictic and cobble to pebble bearing.



Plate 3. Dissected Nullarbor Plain at Yarle Lakes, where thin, flat-lying Nullarbor Limestone overlies weathered Permo-Carboniferous sediments (photo 039270).

EROMANGA BASIN

Jurassic - Cretaceous

Equivalents of Algebuckina Sandstone (Eromanga Basin), with latest Jurassic to Early Cretaceous palynofloras, have been intersected in Maralinga drillholes, interpreted during mapping of OOLDEA.

Algebuckina Sandstone equivalent JK-a

Interpreted equivalents to the Algebuckina Sandstone are present within the subsurface of OOLDEA, near Maralinga, mainly encountered within drillholes LWRE Maralinga 7 and LWRE Maralinga 3B. They consist of off-white, kaolinitic clay, in part sandy to gritty, and sandstone. Within these lithologies coarser, blue-grey, quartz grains are mostly subangular but some are rounded. Faceted pebbles occur at the base and muscovite and pyrite are locally present. In Maralinga 6 the Sandstone passes up into carbonaceous clay, silt and sand (Alley, 1993).

BIGHT BASIN

Cretaceous

Early Cretaceous sediments of the Bight Basin margin (Loongana and Madura Formations) occur in drillholes in the south and west of the OOLDEA mapsheet area.

Loongana Formation Kdl

Fine to coarse-grained sand intersected in drillholes CRA 80 EP 2 and ERL WS 1A, WS 1, WS-WB are correlated with the Loongana Formation of the Bight Basin in Western Australia (Endeavour Resources Ltd, 1982). In the latter drillhole, this essentially sandstone member, disconformably underlies the Madura Formation. It has a thickness of about 18.3 m, consisting of fluvial continental deposition indicated by light grey to dark red ferruginous gradational, cyclically deposited conglomerates and sandstones through to fine clayey silts. The conglomeratic parts predominantly contain angular shale clasts. The coarser portions are feldspathic and crossbedded.

In CRA 80 EP 2, the Loongana Formation includes mud and conglomerate and may be carbonaceous in part.

Madura Formation Kdm

The Madura Formation in ERL WS 1A, WS 1, WS-WB comprises a 6 m thickness of inter-tidal grey sandy silts which are carbonaceous in the top 0.5 m with some shale interclasts, greenish grey shale bands lower in the section gradually becoming sandier and ferruginous towards the base. Other grey to black, in part carbonaceous, mudstone and shale equivalents occur in SADME Reid 1, 1A, CRA 80 EP 2 and possibly in OOC Cook 1. A maximum local thickness of 43 metres occurs in CRA 80 EP 2.

EUCLA BASIN

Cainozoic

Nullarbor Plain (Bunda Plateau) and Great Victoria Desert

The OOLDEA map sheet is located in the northeastern part of the Cainozoic Eucla Basin (Fig. 2). It formed on the southern margin of the continent, along with a number of other basins, following continental breakup that commenced in the Mesozoic. The Basin is ~ 1000 km wide across the position of the current coast and it is genetically related to the palaeodrainage that has its headwaters in the Yilgarn and Musgrave Blocks, and the Gawler Craton. The Basin is dominated by marine, temperate-water, platform, carbonates of the Eucla Group which outcrop over the Nullarbor Plain today (Singleton, 1954; Lowry, 1970). They thicken offshore to be up to 0.6 km thick in the vicinity of the shelf break as indicated by drilling and seismic work (e.g. Fraser and Tilbury, 1979; Stagg et al, 1990). As recent work has shown, the inner platform margin is dominated by terrestrial clastic sediments that have been named the Immarna Group (Benbow, 1990; Benbow, 1994; Benbow et al, 1995a; Benbow et al, 1995b). They were deposited in river and coastal environments. These sediments occur at the base of the succession and are also dominant north of the Nullarbor Plain. The Pidinga Formation, Hampton Sandstone and Ooldea Sand are placed together as the Burdunga Subgroup (Benbow et al, 1995a). The base of the Cainozoic is an unconformity with the Proterozoic-Paleozoic Officer Basin and Mesozoic Bight Basin rocks.

Pidinga Formation Tbp

This formation was defined by Harris (1966) for the Middle to Late Eocene carbonaceous sediments that are widespread around the Basin margin and that occur beneath the platform carbonates (King, 1950, 1951; Ludbrook, 1958, 1961, 1969). The formation has equivalents on the western side of the Basin (e.g. Clarke, 1994). It is also one of the major units of the Basin's palaeodrainage indicating major reactivation of the palaeorivers in the Middle Eocene. Harris (1966; see lithological log of Anderson, 1950) defined the formation on the basis of the SADME P5 drill hole at Ifould Lake on adjacent BARTON. Samples of this hole are missing and other sections should be referred to, such as the cable tool holes sunk in the exploration for coal to the southeast of Ifould Lake. King (1950, 1951) described these sediments in the Ifould Lake region, referring to them as the 'lignitic series', which occur in the floor of some of the playa lakes, and the overlying and outcropping 'lacustrine' clays and sands.

Little is known about the distribution of the formation on OOLDEA because of the lack of drillhole coverage. It appears to be more confined on OOLDEA than on adjacent BARTON, possibly because of erosion during the Middle Eocene transgressions. Thin occurrences exist at the base of the Ooldea Range at Maralinga and to the north beneath Tietkins Plain, as intersected in the LWRE Maralinga drillholes and in the deeper Tietkins Well (respectively). Evidence from the southeast corner of the map indicates that the formation infills palaeochannels that are now buried beneath the Nullarbor Limestone. Thickness is variable, from a few meters, to in excess of 50 m as in the Burdunga Lakes region of the northeast corner of the map (see Benbow et al, 1995b). On OOLDEA the Pidinga Formation and Hampton Sandstone remain undifferentiated for the most part, on the cross sections.

The Pidinga Formation marks the base of the Tertiary along most of the length of the palaeochannels to the northeast, and also within part of the Basin. On OOLDEA it unconformably overlies the Cretaceous sediments of the Bight Basin and where both sequences are carboniferous, as in some of the LRWE Maralinga drillholes, can make their differentiation difficult; mudstones of the former tend to be more indurated. Toward the Basin's margin, it also overlies the more indurated sediments of the Officer Basin and crystalline basement of the Gawler Craton in the southeast corner of the mapsheet.

Within the Basin it is commonly overlain by the Hampton Sandstone, which has a more sheet-like geometry, with a conformable relationship. The deeper Tietkins Well, northwest of Roadside Quarry, indicates that it can also be conformably overlain by the Wilson Bluff Limestone in marginal settings.

Lithologies include mud, sand and minor conglomerate. The sediments are in part carbonaceous and there are lignites, which have been investigated for their economic potential. There are plant remains, including pollen, in part of the formation, and it may contain siliceous sponge spicules as has been documented to the northeast on BARTON (Benbow et al, 1995b).

The Pidinga Formation was deposited in a range of environments that included river, flood plain, swamp, estuary and possibly coastal. Wet climates during the time of deposition are indicated by the regional palynological record (Benbow et al, 1995a; and references therein). Temperatures are likely to have been cooler than currently prevail.

Hampton Sandstone Tbh

The term Hampton Sandstone is applied to widespread Middle to Late Eocene, siliciclastic sands of marine and coastal origin that form a blanket around the eastern part of the Basin. The formation occurs beneath the western and central, southern part, of the Nullarbor Plain, where it was originally defined, and where it is conformably overlain by the Wilson Bluff Limestone (Fairbridge, 1953; Lowry, 1970). The Formation appears to have scattered occurrences around the margin of the Nullarbor Plain on OOLDEA and this is attributed to erosion during the later Miocene transgression(s). However, beneath and landward of the Ooldea Range, it is very extensive, which has resulted in the redefinition of the Eucla Basin, such that its margin lies some 75–100 km further inland, that is, to about the position of the Barton Range on BARTON (Benbow, 1990a; Benbow et al, 1995b). The entire map area of OOLDEA is now regarded as being within the Basin. The nearest outcrops in the region occur on BARTON, to the southeast, along the southern flank of the Ooldea Range and in some of the playa lakes such as those in the Lake Bring area.

Thickness of the Hampton Sandstone beneath the Ooldea Range is ~25–45 m, as can be seen in the Maralinga area. Here, average grain size varies from very fine to very coarse sand and grits. Colour is varied, being largely iron-stained and is also off-white to pale grey. The finer grained sands are well sorted to very well sorted but they are also in part bimodal, there being a minor population of medium to very coarse grains. Rounding of the coarser grains is good to excellent. The quartz grits are notably both well rounded and polished. Corrosion of grains is common, which is due in part to ferruginisation.

The sands are mostly friable, but are also more indurated where iron-cemented or clayey (as at the base). There are also rare or minor clay horizons. Quartz grains are dominant in the sands and there are rare to trace amounts of other grains including, heavy minerals, microcrystalline quartz and quartz grains with abraded quartz overgrowths.

Upward coarsening in the lower half to two thirds of the formation apparent at Maralinga from very fine sand to grits, followed by upward fining, indicates a transgressive and regressive cycle. Depositional environments range from shallow marine, high energy-beach to river. The polished grits at Maralinga are possibly beach deposits deposited during regression as the Ooldea Range was constructed. The siliceous, sponge spicule-bearing sands to the north and east, are in part estuarine (Benbow, 1986; Benbow et al, 1995b).

A direct age determination of the Hampton Sandstone on OOLDEA is not possible, as there are no diagnostic fossils. In Tietkins Well, a few kilometers northwest of the Roadside Quarry, there is an excellent section in which thin Hampton Sandstone overlies the Paling Member of the Wilson Bluff Limestone (see Fig. 7 of Benbow, 1990a). On BARTON, drillhole Ooldea Range-7 has several meters of Wilson Bluff Limestone interbedded within Hampton Sandstone, and in CRAE- RCH 2 drillhole, east of the Paling Range, extensive Hampton Sandstone overlies the Wilson Bluff Limestone (Benbow et al, 1995b; Rankin et al, 1996). These bryozoan limestones thus indicate maximum transgression in the north eastern Eucla Basin, in the Middle and / or Late Eocene (e.g. Benbow et al, 1982; Alley and Beecroft, 1993). There is no evidence for Nullarbor Limestone intertonguing these sediments.

Ooldea Sand Tho

The Ooldea and Paling Ranges are constructed of aeolian, siliciclastic sands, deposited during regression, immediately after the time of maximum transgression in the Eucla Basin. The formation occurs in the subsurface, covered by ~10–30 m of sands of the Great Victoria Desert. The only known outcrop occurs to the southeast at Immarna, on BARTON.

Lithology is predominantly a medium grained, quartz sand; grain size varies from very fine (minor) to coarse sand. Grain roundness is good to very good and frosting of coarser grains has been observed under the SEM. Colour is off-white, pale grey, to vari-coloured, and toward the top, becomes reddened due to Quaternary weathering. The sands vary in being clean and possibly poorly consolidated, to slightly clayey and moderately consolidated. The clay content is likely to be the result of the weathering of detrital feldspar and other minerals, and may also be related to the luxuriant vegetation that formerly covered the ranges. There are trace to minor amounts of heavy minerals, including zircon, leucoxene, rutile, ilmenite and tourmaline, which has led to significant exploration in the region by BHP Mineral Ltd and National Mineral Sands (see Ferris, 1994). Rare, thin bands of silicified sandstone have been noted.

The Ooldea Sand is up to at least 112 m thick as can be interpreted from the old cable tool holes in the vicinity of Maralinga (e.g. LRWE Maralinga 7: see cross section on map) and the hypsometry (Fig. 1). The boundary with the overlying Quaternary dunefield sands can be difficult to interpret because of reworking and superimposed reddening. The base with the conformably underlying Hampton Sandstone can also be problematical, but in the Maralinga area, very coarse-grained sands that mark the top of this formation make interpretation relatively easy. No direct dates are possible because of the lack of fossils, but an argument for a Middle or Late Eocene age has been based on the age of the immediately underlying, youngest sediments that are believed to be genetically related (see above; Benbow, 1990a; Alley and Beecroft, 1993). It is also possible that during the subsequent transgressions of the Early to Middle Miocene, some reactivation of the Ooldea Range gave rise to localised reworking of the Ooldea Sand.

Wilson Bluff Limestone Tuw

As transgression proceeded during the Middle to Late Eocene, terrigenous clastic sedimentation gave way to limestone deposition and thus the formation of a carbonate platform throughout most of the Basin. Temperate water, bryozoan limestones of the Wilson Bluff Limestone form the foundation of the platform and belong to the Eucla Group (Singleton, 1954; McWhae et al, 1958). The Limestone was first recognised by Tate (1879), who referred to it as the 'white polyzoal limestone'. The formation forms the lower white band of the cliffs that front the Great Australian Bight.

Wilson Bluff Limestone was probably deposited over most of the map sheet. However, today there is a ~40–50 km wide strip around the margin of the Nullarbor Plain where it appears to be largely, if not entirely, absent. This is probably the result of marine and fluvial erosion during the Oligocene and Early Miocene. There are relict domains of limestone however, beneath and landward of the Ooldea Range, as described above. The occurrence north of Maralinga is herein referred to as the Paling Member because of its distinctive, grainy nature (see below).

The formation conformably overlies, and intertongues with, the Pidinga Formation (e.g. at Tietkins Well) and the Hampton Sandstone. Thickness is >50 m in the southwest part of the map as in OOC Cook 1 and increases toward the platform margin to ~300 m in Exoil's Eyre 1.

The dominant lithology of these Eocene limestones is white to off-white, grey, to green, muddy or micritic, bryozoan limestone. Textures include skeletal mudstone, wackestone (dominant), packstone and grainstone, and rudstone where larger bioclasts may be present. Bioclasts are variable in size (i.e. 0.01- >2.0 cm) and the proportion of matrix to framework varies, as does the relative proportions of abraded and non-abraded clasts: sorting is usually poor. Part of the rock could be described as being a siltite in which much coarser grained bioclasts are supported. Whilst bryozoan-derived clasts are dominant, echinoids and molluscs can also contribute; foraminifera are generally rare to very minor. Skeletal remains may be markedly oriented parallel to the bedding and where larger and thus more prominent, may enable the rock to be readily parted. Terrigenous clastic grains, principally silt to very fine sand-sized, quartz grains, generally occur in trace to minor amounts.

The base can be distinctly glauconitic (e.g. up to 25–30%), as for example the bottom ~2 m of the Endeavour Resources drillhole. Here the base is a soft, in part laminated, glauconitic marl with very little fossil content and quartz (silt to very fine sand) is very minor. Ludbrook (1960) and Lowry (1970) have also noted that the basal or lower part of the formation can be very glauconitic (e.g. in Exoil Eyre 1 and Gambanga 1), which may be grounds for 'lower member' status. The glauconite occurs as rounded, very fine sand to granule-sized detrital grains. It also occurs infilling skeletal cavities and may replace skeletal fragments. Bed thickness, as is evident in the core of the Endeavour Resources well, in the southeast part of the map, can vary significantly.

The limestones are in part chalky where weakly to moderately indurated and the top, beneath the overlying formations, may be quite indurated. Where coarser grained and less muddy, the rocks may be more friable. In contrast to the Early to Middle Miocene Nullarbor Limestone, there is no widespread, pervasive, recrystallisation or development of vuggy porosity.

Paling Member Tuwp

This high energy limestone was deposited near the margin of the Basin, north of the Ooldea Range. It is only known from the excellent section in the deeper Tietkins Well near Roadside Quarry and possibly occurs in LRWE Maralinga 5, also on MAURICE. It is likely to occur beneath the Tietkins Plain on OOLDEA. The Paling Member type section occurs between 16.7–28.4 m in Tietkins Well (~12 m thick) where lower and upper boundaries are clearly visible.

Lindsay and Harris (1975) regarded the occurrences north of Maralinga as likely correlatives of the Toolinna Limestone. However, the stratigraphy of grainy limestones of Eocene age in the Basin is not well understood and for the present, the Paling Member is included within the Wilson Bluff Limestone. On the west side of the Eucla Basin, in a tributary of the Lefroy Palaeoriver, there are also proximal occurrences of Eocene limestone, namely the Norseman Limestone (Gregory, 1916; Clarke, 1994).

The Paling Member is predominantly a yellow brown, very fine to fine grained calcarenite, or a bryozoan, echinoidal, grainstone. Foraminifera are a relatively minor (i.e. 1–2%) but important constituent. Non-biogenic clasts include subangular quartz (mostly 1–5% but locally up to 30%, as at the base) and detrital, rounded, glauconite (1–7%). There are trace amounts of opaques, feldspar and muscovite throughout. Sorting is generally moderately good. Approximately half way up the section the limestone is distinctly clayey and coarse to very coarse (quartz) sandy above an erosional surface. There is a marked fabric in part of these grainstones defined by the alignment of rod-shaped or elongate echinoid clasts.

The Member is friable to moderately indurated and has an overall massive aspect with a hint of bedding, dipping ~12 degrees toward 330° in places. At the base, where sharply overlying black carbonaceous muds of the Pidinga Formation in Tietkins Well, it is in part interlaminated with relatively carbonaceous-rich silt and clay. The top of the Member is overlain by clayey, very fine to

fine-grained sands that can be assigned to the Hampton Sandstone. A conformable relationship is interpreted because of the increase in quartz sand in the upper part of the limestone and the fine-grained nature of the overlying sands. Some recrystallisation has occurred and the primary porosity of 10–30% has been partly occluded by rhombs of diagenetic dolomite (average size of the rhombs is 0.01–0.03mm) and has also been diminished where epitaxial calcite has grown over echinoid clasts.

The Wilson Bluff Limestone was deposited on a very broad (i.e. ~1000 km wide) and gently inclined platform, or a ramp where the higher energy facies predominate near the shore. The generally muddy nature of the sediments indicates deposition mostly below fairweather wavebase. However, the occurrence of coarser grained and less muddy rocks, as are exposed along the cliffs to the south, indicates deposition above storm-wave base. The grainy sediments of the Paling Member indicate above wavebase, higher energy, nearshore environments. Construction of the ramp occurred through the vertical accumulation of sediment and there is evidence for upward shoaling from the southern and central parts of the Nullarbor Plain. The vertical passage from limestone, to the terrigenous clastic sediments of the Hampton Sandstone, suggest regression prior to formation of the coastal dunes.

The fossil remains indicate cool temperate water conditions (Lees and Buller, 1972) when the continent was at higher, southern latitudes. The absence of corals, calcareous algae and larger foraminifera supports this contention.

Four transgressive episodes are believed to have occurred during the Middle to Late Eocene in southern Australia, commencing in the Middle Eocene (P 12 foraminiferal zone) and finishing at the end of the Late Eocene (P 17 foraminiferal zone; see McGowran, 1986, 1989). The proximal occurrences of the Wilson Bluff Limestone on OOLDEA and adjacent BARTON had been dated as latest Eocene but this has been modified or reinterpreted as being early Late Eocene by Alley and Beecroft (1993; also see McGowran et al, 1992).

Yarle Sandstone Tiy

There is no record of deposition during the Oligocene around the inner margin of the Basin. This contrasts with the central and southern parts where the Abrakurrie Limestone was deposited in cool to temperate waters on a platform that was drowned for part of the time (Lowry, 1970; James and Bone, 1991).

Around the inner margin of the Nullarbor Plain there are quartz sands and sandstones that form a narrow belt (<10 km wide), and that can be traced, albeit discontinuously, from the Yarle Lake region to the Chundie Swamps area to the southeast. Named the Yarle Sandstone, these sediments have been interpreted as being deposited in coastal environments during the Early to Middle Miocene, presaging the last major phase of platform carbonate deposition, that is, of the Nullarbor Limestone, before Basin emergence in the Late Miocene (Fig. 3; Benbow, 1990b). The type area is in the vicinity of Yarle and Choolalie Lakes. The Colville Sandstone of Lowry (1968, 1970), a conceptually equivalent sediment in the northwestern part of the Basin, is believed to be pre-Tertiary in age (Benbow, 1990b).

The Yarle Sandstone is a siliciclastic sediment that is exposed in some of the playa lakes and adjacent interdune corridors, around the margin of the Nullarbor Plain, where it is generally silicified and/or ferruginised. It is known to be at least 6 m thick and the sands in the LRWE Maralinga 14–17 drillholes to the north up to ~20 m thick, may be Yarle Sandstone. The sands are very fine to medium grained and are commonly bimodal having a small proportion of well rounded, coarse to very coarse quartz grains. Sorting of both modes is usually good. There are rare, deformed, yellow-brown, pebble-sized limestone clasts. The sands may also contain abraded skeletal remains of foraminifera, echinoids, algae and molluscs. Northeasterly dipping crossbedding, has been observed in the Yarle Lakes area.

The formation is sharply overlain by the Nullarbor Limestone, as at Choolalie Lake for example, where the basal transgressive lag that often marks the base of the latter, is absent (see below). The occurrence of *Marginopora vertebralis* in the deformed clasts and of *Austrotrillina howchini* in the sands, indicates a likely Miocene age, in fact an age no older than earliest Miocene (Adams, 1984).

It is conceivable that part of the sandstone represents a short lived transgression that predates the Nullarbor Limestone. To the southeast, in the Seven Miles Swamp area on FOWLER, a Longfordian age (i.e. pre-dating Nullarbor Limestone) has been obtained for thin limestone that is overlain by ~10 m of Yarle Sandstone (Benbow, 1990b; Benbow and Lindsay, 1988).

Nullarbor Limestone Tun

The Nullarbor Limestone forms the top, and most extensive marine carbonate unit, of the platform, over the emergent part of the Basin, and was deposited in the early Middle Miocene, some 15 million years ago (Tate, 1879; Singleton, 1954; Ludbrook, 1958; Lowry, 1970; Lindsay and Harris, 1975; Benbow and Lindsay, 1988). This indurated and recrystallised formation is best exposed along the cliffs fronting the Great Australian Bight and in the quarries, such as that at Watson (~12 m is exposed here), along the Trans Australia Railway (Plate 4). This unit is remarkable for its overall uniformity of thickness, being typically 20–35 m thick across much of the platform. It extends beneath the margins of the dunefield as testified by outcrop within the swales and the intersections in SADME OR-4 and -9 drillholes on the very east margin of the map sheet.

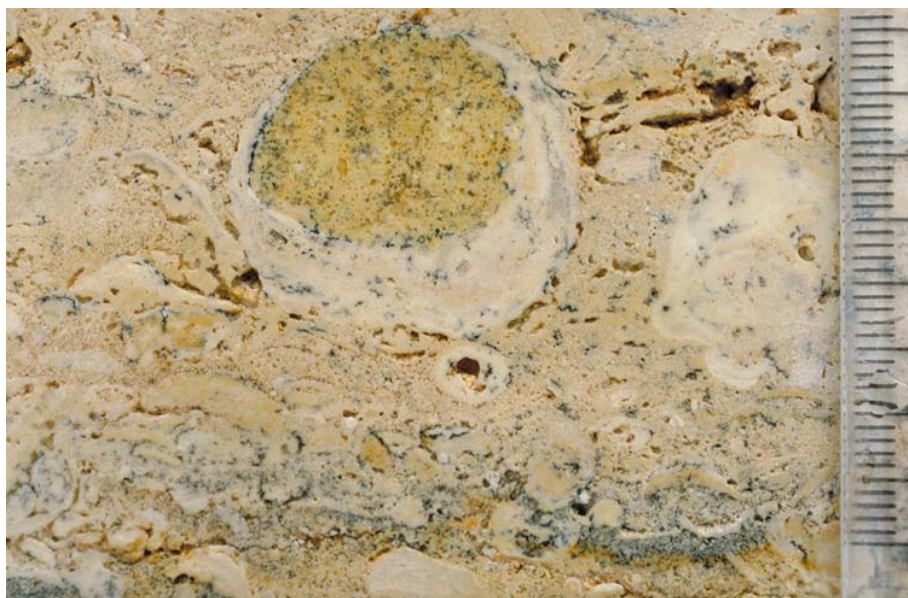


Plate 4. Oolitic carbonate with algal structures deposited in shallow, extensive lakes on the margin of the Nullarbor Plain, east of Maralinga (photo 040045).

Locally at the base of the formation, there is a transgressive lag, of very poorly sorted, non-calcareous, greenish clay, sand and grit. This is very thin, that is, generally no thicker than 20–30 cm, and it is exposed northwest of Yarle Lake. It has been intersected in some drillholes on OOLDEA.

The basal 1–2 m of the limestones commonly contain rare to trace amounts of rounded, coarse sand to granule-sized quartz grains. Most of the overlying part of the formation contains no terrigenous clastic component. However toward the limits of the formation, as in the Yarle Lakes area, it is slightly sandy to very sandy in part (i.e. very fine to fine grained quartz). Other non-bioclasts rarely include glauconite.

The formation is predominantly an indurated, recrystallised, micritic, bioclastic limestone that is white, off white to grey in colour. The skeletal remains of foraminifera, particularly miliolids, are a major constituent of the formation in contrast to the Wilson Bluff Limestone. Other bioclasts include those derived from echinoids, molluscs, coralline algae, bryozoa, surpulids and corals. These occur in predominantly framework supported rocks, that is in packstones and to a lesser extent

grainstones. Trends in bioclast composition have been observed. In the lower part, echinoids, algae and bryozoa are more common, whilst in the upper part, foraminifera are dominant (Benbow, 1994). These trends are apparent in the 41.5 m thick section at Watson Quarry, which includes the ~12 m of exposure and the ~29.5 m of drillhole intersection of SADME Watson 1 in the base of the quarry.

Much of the formation over the plain is very fine to fine grained, foraminifera-rich packstone. Larger, benthonic foraminifera, including *Marginopora vertebralis* and *Austrotrillina howchini* may be present; the former can attain a size of up to 5 cm diameter and has been observed at Watson. A number of microfacies can be recognised. For example the branching coral *Seriatopora ornata* (Felix) is prominent.

The Nullarbor Limestone was deposited in somewhat warmer waters than the Eocene carbonates, possibly warm temperate to subtropical. This interpretation is based on the greater occurrence of corals (although these have not been observed to be reef-building, red coralline algae) and by the miliolid-dominated upper and marginal parts. The limestones were deposited on a shallow platform or distally steep, low to moderate energy ramp, in subtidal to tidally influenced environments, as can be observed in the Cook Quarry to the west. These sediments are mostly muddy or micritic, including those in a coastal position adjacent to the Ooldea Range, which indicates moderate current and wave action. It is possible that water depths were shallow and sea grasses entrapped sediment fines thus diminishing energy on the sea floor (e.g. Benbow and Lindsay, 1988). Resedimentation is likely and some sediment textures indicate mixed energy environments. The trend in the bioclast composition apparent at Watson suggests subtidal, open circulation giving way to upward shallowing and thus more restricted circulation.

The minor terrigenous component of these limestones is likely to have been derived from the reworking of Eocene and older sediments in the vicinity to the coast, namely along the front of the Ooldea Range. The coarser detritus at the base of the limestone and the local clayey basal sediments are a transgressive lag derived by the reworking of sediments on the Oligocene or Early Miocene land surface.

Garford Formation Tig

This Miocene/Pliocene sequence is comprised of lacustrine, argillaceous muds and carbonate mudstones. Originally defined from the Garford Palaeochannel on COOBER PEDY, it is widespread in the palaeodrainage, and has equivalents on the western side of the Basin (Benbow and Pitt, 1978; Benbow, 1994; Benbow et al, 1995a). The Garford Formation is also widespread along the north and northeast margin of the Ooldea Range where extensive lake systems once existed. This includes the Tietkins Plain area, where it outcrops extensively. The best exposures occur at Roadside Quarry and in the two Tietkins wells nearby. Diamond drilling to average depths of ~10 m, at Roadside Quarry, has yielded excellent sections through part of the formation. Maximum thickness of the formation here is likely to be no more than 15 m.

The formation unconformably overlies the Eocene Hampton Sandstone and Pidinga Formation, as it does to the east (Benbow et al, 1995b; Rankin et al, 1996). The lithologies of the formation on OOLDEA, are dominated by calcareous and dolomitic mudstones and dolomite, which are typically white, off-white and grey coloured. The green, palygorskite-rich argillaceous muds that occur elsewhere, do not appear to be prominent, but can occur at, or near, the base. In the Roadside Quarry about 5 m of massive dolomite, partly brecciated is exposed. Circumgranular cracking is locally prominent. In the lower part of the formation, as intersected in drillholes, locally ooid-rich mudstones, packstones and grainstone occur. These tend to be friable in part and may be distinctly bedded or laminated. Also near the bottom in Maralinga DDH 1, there are numerous small gastropod and ostracod? remains. Rocks of this type outcrop east of the Paling Range on BARTON where there are associated stromatolitic carbonates (e.g. Benbow et al, 1995b). There is very little terrigenous clastic component in these rocks.

The Garford Formation was deposited in shallow, alkali playa lakes. The lakes formed as a result of ponding, being bounded by the Ooldea and Paling Ranges. Ancestral Lake Tietkins extended north onto MAURICE and may have been up to 60 km in diameter (Fig. 2). The oolitic carbonates indicate water depths of <5 m and maximum depths are not likely to have been more than 10 m. The lack of wholesale dissolution in this karst indicates marked aridity after the lakes dried out.

The exact age of the formation is arguable because of the lack of diagnostic fossils. Arguments and evidence have been presented elsewhere, for Miocene and Pliocene ages (Benbow, 1994; Rankin et al, 1996). It could be argued that lakes were present during the Middle Miocene when the Nullarbor Limestone was being deposited on the carbonate platform on the other side of the Ooldea Range (Benbow, 1986b). The similarities of the karst, on both the Nullarbor Limestone and Garford Formation, suggest a similar period of time has elapsed since emergence of the former. The fan at the mouth of the Serpentine Lakes Palaeochannel to the northwest, indicates probable Early Pliocene reactivation of palaeochannels there at least (Benbow, 1995).

Weathering Kta_{dw} , silcrete T_{si} and ferricrete T_{fe}

The exposures and record of duricrusts on OOLDEA is limited since the region is dominated by the marine and lacustrine carbonates of the Basin. Deeply weathered rocks (Kta_{dw}) like those exposed in the Ifould Lake area, predate and postdate the Eocene Pidinga Formation, indicating its polycyclic nature (Benbow, et al, 1995; Rankin et al, 1996). Deeply weathered Permian sediments underlying the Nullarbor Limestone west of Yarle Lakes are associated with iron mottles and a ferruginous cap (T_{fe}). Drillholes over the Nullarbor Plain suggest that any deep weathering that may have taken place in the Late Cretaceous to Early Tertiary was largely removed during subsequent Tertiary transgression. North of the Ooldea Range the Alge buckina Sandstone equivalent has been deeply weathered, in contrast to the Cretaceous and Eocene carbonaceous sediments beneath the Range itself.

In the playa lakes and adjacent swales of the dunefield, there are both silcretes (T_{si}) and ferricretes (T_{fe}). They are believed to have formed in the Early to Middle Miocene Yarle Sandstone. The silcretes formed in groundwater environments, indicated by their massive and botryoidal habit and by quartz overgrowth textures. They are varicoloured, dependent on the amount of interstitial iron and iron staining, and to 1 m thick. Thin silcrete bands have also been noted in the Ooldea Sand. There is little local evidence as to the timing of their development but similar silcretes developed in the Early Pliocene Garford Formation of the Narlaby Palaeochannel, on northern Eyre Peninsula. The silicified pods and irregular shaped masses within the Nullarbor Limestone and Garford Formation could be of the same age.

The silcretes have in part been ferruginised possibly during the Pliocene. Clasts or relict domains of silcrete can be locally observed in ferruginised Yarle Sandstone. The Eocene Hampton Sandstone has also been partly ferruginised beneath the Ooldea Range, particularly in the lower part of the sequence where thin ironstone seams are observed. The ferricretes are friable to indurated and microscopic textures indicate corrosion of detrital grains and the formation of quartz shards which may be framework or matrix supported.

The Permian sediments northwest of Yarle Lakes could be of older age. Iron mottles near the top of the 6 m profile pass upwards into a degraded ferricrete cap, 1 m thick, beneath the Nullarbor Limestone, which includes the basal, transgressive lag. Part of the cap includes a rubble of polished ironstone fragments, reminiscent of the buckshot lags over the Carnadinna Surface to the northeast, as on TALLARINGA. However the presence of iron skins and masses adhering to Nullarbor Limestone indicates either remobilisation of the iron, or presents evidence for several events.

Ilkina Formation $TpQii$

This formation is a thin, lacustrine and fluvial sequence, of muds, sands, and interlaminated gypsum horizons, that occurs in some of the playa lakes along the southwestern margin of the Ooldea Range. Outcrops are generally poor and may form low benches up to 0.5 m high above the lake floor. Thickness is typically less than 2.5 m. The formation is lithologically distinctive because

of its common, laminated character and occurrence of blue and grey clays. Sorting is generally good. In the upper part there are laminae and a laminated cap of gypsum.

The best exposures are along the margins of Ifould Lake on BARTON that locally include a distinctive, chara oogonia-rich, cross bedded, calcareous, sandstone facies and very thin beds of carbonate mudstone, which are locally reworked (Benbow et al, 1995b; Rankin et al, 1996). Here there are also thin outwash deposits that include clasts of silcrete and ferricrete.

The Formation is older than the aeolian sands of the Great Victoria Desert and relationships elsewhere, as in the lakes of the Narlaby Palaeochannel, south of the Gawler Ranges, indicate that it is younger than the Garford Formation which it commonly overlies. It is similar to the Milyera Formation of the Lake Eyre Basin. Its deposition indicates a short-lived wetter climate in the Pliocene or Pleistocene, leading to reactivation of the Basins palaeochannels sometime after the erosion of the northern margin of the Plain. The gypseous horizon indicates lake dessication in the waning stages of deposition.

Wintrena Formation Qpei

This aeolian sand unit is widespread throughout the Great Victoria Desert (Benbow, 1986,1993; Benbow et al, 1995b) and is believed to form the base of the dunefield and the core of the dunes on OOLDEA (Plate 5). Best exposures occur to the east and northeast, around the dissected playa lakes of the palaeochannels, including the Garford Paleochannel on COOBER PEDY. There are also excellent exposures along the railway line to the east, provided by sections through both the dunes and the swales.



Plate 5. View across the dunefield, northern OOLDEA (photo 039263)

The dominant lithology is red-brown to orange-brown sand that is in part clayey, particularly in the swales. Sorting is moderately good and grain size ranges from very fine to medium sand. There is also a coarse to very coarse grained, rounded, quartz sand component in part and this may be apparent on the surface where such grains form a lag. Thickness is at least 10 m. Distinctive carbonate palaeosols have developed within the formation. These are traceable from the dune cores down into the swales and for the most part is calcareous (see below). Sand induration above the calcretes is generally weak, but below it is greater, due in part to lime cementation.

The age of the Wintrena Formation is inferred to be Pleistocene. The source of the formation on OOLDEA includes the Eocene Hampton Sandstone and the Ooldea Sand. These sources were not mentioned in the recent work of Pell et al. (1999) who believed the Arckaringa Basin to be major source for the eastern part of the Desert. They also provided evidence suggesting there has been little downwind transport of sand for some ~15 000 years. Fluvial reworking is likely to have occurred on the flanks of the Ooldea Range.

Unnamed lunette sediments Qpe₆

Gypsum and quartz aeolian sediments have accumulated to form lunettes on the eastern, that is, downwind side of the playa lakes. Deposition of these sediments is comparatively minor in contrast to the region of playa lakes on adjacent BARTON. Reworking has occurred giving rise to indurated horizons and soft, floury to weakly consolidated cappings. Lunette height is at least 10 m above the adjacent lake floor. Little is known about the internal structure and makeup of the lunettes because of poor exposures. At Ifould Lake there is evidence for more than one episode of leeside dune construction, and includes formation of leeside dunes built of calcareous quartz sand.

Bowler (1976) considered the last glacial maximum some 18000 years ago to be the time of lunette formation in Australia. It is likely that their formation post-dates the deposition of the Wintrena Formation and growth of the longitudinal dunes.

Calcrete Qca, Qca₁, Qca₂

Calcretes are extensive throughout the region, testimony to semi-arid to arid climates (Esteban and Klappa, 1983) during their formation. They vary in character, reflecting different environments of formation and numerous development episodes as far back as the Early Pleistocene and possibly Pliocene. Only the calcretes of the Great Victoria Desert have been mapped (Qca) - those of the Nullarbor karst are included within TQk.

The Wintrena Formation has a pervasive and extensive calcrete developed on and within it and this is regarded as being a morphostratigraphic marker horizon(Qca₁). The position of the calcrete in the formation has been described above and its character varies considerably. The best local exposures of these calcretes occur along the railway line between Ooldea and Immarna to the east (Plate 6).



Plate 6. Calcrete (calcium carbonate soil) developed in the core of the Great Victoria Desert dunes, evidence for aridity during the Quaternary (photo 040050)

On the east side of the swales, along the railway line, there are outcrops capping the Wintrena Formation, of indurated, massive and nodular calcrete up to 1 m or so thick. Individual nodules are typically 0.5–10 cm in diameter, are concentrically laminated and indurated, and where present, are framework supporting. Where present, the nodules may be loose or cemented by indurated lime. Nodular calcretes can pass down into soft and powdery lime impregnated sand or massive and indurated calcrete and can pass eastwards to the other side of the dune, into calcareous sand. The carbonate rhizomorphs that occur below the dune may be related to Qca₁ or be younger.

Westwards, nodular calcretes can pass into mottled carbonate profiles up to 4–5 m thick in the swales. The mottles are soft to hard, lime cemented or encrusted sand of variable shape from irregular and elongate to spherical. Where dissected the mottles can weather out to form a lag, as typically occurs around some of the playa lakes of palaeochannels. The dissected calcretes mapped along the crest of the Ooldea Range are likely to be of this generation.

There are younger, less substantial, calcretes that have formed within the dune sands (Qca₂). They typically comprise soft and moderately indurated lime accumulations, crusts and rhizomorphs. Time of formation is probably Late Pleistocene after reactivation of the dunes leading to deposition of Qpe.

On the Nullarbor and Garford karsts there have been many phases of calcrete formation. Included are indurated, nodular, laminated and massive forms that are probably equivalent to Qca₁.

Unnamed sediments Qpe

Sometime in the latter part of the Late Pleistocene, perhaps during the last glacial maximum, there was reactivation of the longitudinal dunes, giving rise to remobilisation of the sediments (Plate 7). The sands are similar to the Wintrena Formation, but perhaps overall less indurated, paler coloured and more calcareous.



Plate 7. Longitudinal dunefield with well defined superimposed field of network dunes near Ooldea (photo 039265).

Clear cut boundaries with the Wintrena Formation are rarely observed but reworked calcretes Qca₁, may mark the base. It is believed that the network dunes to the east of Choolalie Lake may be constructed of these sands. Equivalent calcareous sands occur on COOBER PEDY (Qpo) which there clearly post-date deposition of gypseus lunette sediments.

Unnamed sediments Qpe7

Calcareous sands that blanket the Nullarbor Plain are believed to be equivalent to Qpe of the dunefield. They are orange to red-brown in colour, clayey to silty and very fine grained. Reworked, rounded, calcareous, clay or mud pellets are also present. These sediments are both aeolian and fluvial. Sheet wash processes have been particularly important. Reworking of indurated calcrete is locally apparent at the base as can be seen in gutters leading into the dongas.

These sediments pass laterally into the donga sediments Ql₂. They have weak to moderate carbonate cementation in part believed to equate to Qca₂. Lichen crusts have developed on, and in, these sediments, as in the younger sands Qhe₁, and been important in fixing these sediments in a windswept and inhospitable environment.

Unnamed sediments Qhe₁

During the Holocene the Pleistocene sands have been reworked in part. Over the Nullarbor Plain there is a thin blanket of fine-grained, aeolian sediment (Qhe₁), derived and reworked from the underlying and older desert mantle (e.g. Qca and Qpe₇). These sediments are comprised of quartz grains and calcareous grains derived from calcrete and possibly limestone. Where orange-brown coloured, they are part calcareous, silt and fine grained sand. North-south oriented gilgai, or microrelief structures have formed in these sediments, reflecting a prevailing westerly wind regime

for the Holocene (see above). The deflation zone along their western side exposes older sediment, and may include lags derived from the Nullarbor Limestone. The low mounds or dunes around the dongas are comprised of red brown, unconsolidated sand and were probably derived from the Great Victoria Desert sands.

Within the Great Victoria Desert itself, the mobile sands of the crests of the dunes have been reworked from the dune sediments Qpe and Qpei (Qhe₂). The sands are red brown to orange brown and are paler coloured where adjacent to the playa lakes. They are in part calcareous and are largely unconsolidated and mobile, to weakly consolidated.

Karst development in the Nullarbor Limestone and Garford Formation TQk

The Middle Miocene limestones of the Nullarbor Plain and the Miocene-Pliocene carbonates of Tietkins Plain have had a prolonged karst history which has included dissolution, sedimentation, and soil development (Jennings, 1967; Lowry and Jennings, 1974; Benbow and Hayall, 1992). Both Watson and Roadside Quarries provide excellent, 5–10 m sections through both karsts. The Nullarbor Limestone is an immature karst, that is, the degree of dissolution has been limited, indicated by the relatively few caves and the flat nature of the Nullarbor Plain. This implies a considerable degree of aridity since its emergence in the Late Miocene, some 10–15 million years ago (e.g. Lowry and Jennings, 1974) (Plate 8). On this inland part of the karst, the formation of caves is extremely limited. There is a blowhole to the north on the margin of the Plain although variable amounts of dissolution has given rise to channels, small cavities and a vuggy porosity. Drillholes and the vivid exposures at Watson indicate that the formation has been recrystallised, indicated by the degree of induration and the development of microcrystalline textures. Subsequently a succession of diagenetic products have formed, being most apparent in the uppermost part of the formation. Grey carbonate breccias have been succeeded by the formation of pisolitic carbonates, silicification, and red-brown karst breccias. The latter being associated with the deposition of fine grained sediment and the formation of speleothem calcite. Calcretes (see above) and gypcretes have also formed, particularly in the uppermost ~5 m. As noted in the Ifould Lake area by Benbow et al (1995b) there are occurrences of prominent pisolites in which the spherical vadoids are deep blue to black. Lowry (1970) described similar rocks northwest of the Nullarbor Plain in Western Australia. There are trace to minor amounts of quartz sand-sized grains in part of the red brown breccias indicating intensified weather and climatic variation by this time. The detailed sequence of events in this unique karst stratigraphy warrants further study and would provide useful evidence about changes in climate.

Observations made at Roadside Quarry on northermost OOLDEA suggest that the Tietkins Plain karst is remarkably similar to that of the Nullarbor Plain. Circumgranular cracking, which may be void or infilled with sparry calcite, is a common feature of these rocks. There are also rounded, clast-like bodies in places, as can be seen in diamond drillhole from here, which may either be primary or secondary in origin.



Plate 8. Speleothem and interbedded sediment partially infilling a solution cavity in the Nullarbor karst (scale 20 mm) (photo 040047)

Unnamed donga and playa lake sediments Ql1, Ql2

Quaternary sediments have accumulated in the playa lakes within the dunefield and in the dongas on the Nullarbor Plain (Ql1 and Ql2, respectively). They pass laterally into, and are derived from, the adjacent sediments, through the action of both wind and water. Runoff during flash floods has carried orange-brown mud and sand down into the subdued depressions where the dongas are located. Very fine grained sediment, namely calcareous mud has also been deposited by wind when rain has left a veneer of water in the floor of the dongas. These sediments are calcareous and are up to at least 1 m thick and pass laterally into the adjacent sands and muddy sands of Qhe1 and Qpe7

The undifferentiated playa lake sediments are predominantly unconsolidated, red-brown to brown, clay, silt and sand (Ql2). They are largely derived from the adjacent sands of the dunefield and through reworking of the Algebuckina Sandstone. Sorting is moderately good to very good and thickness is not likely to exceed several meters. Gypsum salts have impregnated these sediments in places and is likely to be in part derived from the adjacent gypseous lunettes, through reworking. Surface lags of silcrete, ferricrete and limestone, are derived from outcrops that can occur in the lake floor and margin.

Undifferentiated aeolian sediments Qe, Qe1

There is a narrow, linear, region of undifferentiated aeolian sands, bordering the adjacent Nullarbor Plain and Great Victoria Desert (Qe) (Plate 9). Dunes are absent and it is likely that the sands overly the Nullarbor Limestone and have been derived from both regions.

The aeolian sediments of the Great Victoria Desert are shown on the map as being undifferentiated and comprise the units Qhe2, Qpe and Qpei. Sediments equivalent to the older Delisser Formation on adjacent BARTON may also be present.



Plate 9. Dunefield of the Great Victoria Desert encroaching over, and partly burying, the Nullarbor karst (photo 040049)

TECTONIC AND STRUCTURAL DEVELOPMENT

ARCHEAN-MESOPROTEROZOIC

The Gawler Craton is an ancient crystalline shield comprising Achaean to Mesoproterozoic metasediments, volcanics and igneous intrusives, which has been tectonically stable, with the exception of minor epeirogenic movements, since ~1450 Ma (Thomson, 1975; Parker, 1990, 1993). Three major tectonic periods have fundamentally affected the formation of the Gawler Craton and specifically the OOLDEA region.

1. ~2700–2300 Ma — late Achaean sedimentation and volcanism followed by early Palaeoproterozoic plutonism and metamorphism (Sleafordian Orogeny).

2. 2000–1700 Ma — initial basin–platform sedimentation followed by widespread plutonism, metamorphism and deformation (Kimban Orogeny) with local volcanism and continental sedimentation.
3. 1690–1450 Ma — development of spatially separated granulite and amphibolite-facies rocks during the Kararan Orogeny (1690–1540 Ma) in the northern and western portion of the Craton. Continue faulting resulted in juxtaposition of crustal blocks of different metamorphic grades. This was accompanied by syntectonic intrusion of acid, ultramafic and mafic plutons. Emplacement of extensive Hiltaba Suite plutonism and felsic volcanism (Gawler Range Volcanics), accompanying the formation of the FeO–Cu–Au (“IOCG”) systems on the eastern Gawler Craton.

On OOLDEA, the Christie Subdomain consists of megacycle 1 metasediments, orthogneisses, granitoids, mafic granulites and amphibolites of the Mulgathing Complex. Megacycle 2 sediments are represented by the Moondrah Gneiss, although Kimban structural development has yet to be defined. Megacycle 3 Ifould Complex deformed granitoids, and mafic to ultramafic cumulus bodies occur, transected by the Karari Fault Zone. On adjacent BARTON this cycle is represented by one occurrence of GRV and the presence of Hiltaba Suite inferred from aeromagnetic data

NEOPROTEROZOIC - MESOZOIC

Originally, the Officer Basin was part of the Centralian Superbasin, a very large intracratonic sag basin in central and western Australia. The initial phase of sedimentation in the Centralian Superbasin is represented in the eastern Officer Basin by Neoproterozoic (Willouran) Pindyin Sandstone and Alinya Formation. Crustal extension related to formation of the superbasin resulted in emplacement of mafic dykes, and extrusion of coeval basaltic volcanics, although none are evident in the OOLDEA region. Salt within the Alinya Formation commenced to move soon after this time. This was followed by a major hiatus spanning ~130 million years, between the Alinya Formation and overlying Lake Maurice Group. Elsewhere in the Officer Basin glaciogenic sediments were deposited during part of this time interval, suggesting that glacioeustatic lowering of sea level may have been responsible in part for the gap in the sedimentary record. Up to 500 m of sediments is estimated to have been eroded at the Alinya–Tarlina unconformity, possibly a result in part of post-glacial isostatic rebound. However, Alinya Formation is structurally conformable with overlying sediments, indicating a lack of major tectonism.

Late Neoproterozoic (Marinoan) sediments of the Lake Maurice Group were deposited during north–south compressional tectonics that led eventually to separation of the Centralian Superbasin into its present basin components — including the Officer Basin - and also resulted in differentiation of the basin into its various depositional elements such as the Murnaroo Platform in northern OOLDEA. Alinya Formation salt continued to move during this period, with diapiric structures forming. A significant event during this stage was the incision and infilling of submarine canyons further north, and draining northwards. A eustatic fall in sea level alone would be insufficient to account for the depth of canyon incision (up to ~600 m). A tectonic influence is inferred, and the canyon formation has been related to diapiric uplift.

Sedimentation in the Officer Basin was terminated by the latest Neoproterozoic Petermann Ranges Orogeny (~590–560 Ma). Officer Basin sediments were extensively disrupted by large-scale, predominantly northward-dipping thrust faulting, and rotated normal fault blocks with low-angle, southward-dipping seismic reflectors. The Petermann Ranges Orogeny formed a prominent low angle unconformity between Neoproterozoic and Early Cambrian sediments. Up to 3000 m of strata are estimated to have been eroded at this time.

Sediments of the Marla Group were deposited during the Early to Middle Cambrian, with the thinnest sections deposited on the Murnaroo Platform area and OOLDEA. This period was generally a time of tectonic stability and steady subsidence. The Relief Sandstone is interpreted as transgressive and diachronous over Precambrian strata, including a lower predominantly aeolian sandstone section overlain by a sandstone suggested to be fluvial in origin. Above the Relief Sandstone and relatively unique to South Australia, the lower Ouldburra Formation is a suite of

halite-siliciclastic and halite-carbonate-siliciclastic rocks, indicative of a mosaic of isolated salinas on a shallow marine to exposed sandy mudflat bordered by aeolian dunes. Renewed transgression in the middle of the Ouldburra Formation is manifested by subtidal wackestones and limestones in the northeastern Officer Basin. Deposition of the Marla Group was terminated by the Middle Cambrian Delamerian Orogeny (~507 Ma). This event caused uplift and erosion exceeding 2000 m, reflected in the low-angle unconformity between the Marla Group and overlying sediments in the northeastern Officer Basin. Reactivation of thrust faults and diapiric structures also took place in the Officer Basin during this time.

During the Late Devonian – Early Carboniferous Alice Springs Orogeny (~360 Ma) thrust faults were generated or reactivated and further diapiric movement and anticlinal folding also occurred during this time. Erosion of 1000 m of sediment in the GILES mapsheet area was interpreted to have occurred during the Alice Springs Orogeny. Apatite fission track data have indicated widespread heat flow associated with the orogeny.

Late Carboniferous to Permian sedimentation is preserved in several South Australian intracratonic basins including the Arckaringa Basin. Sediments, are largely of continental origin but with a characteristic shallow-marine to fluvial glaciogenic unit at the base. Each of the principal Permo-Carboniferous basins contain fault-bounded troughs, largely trending northeast and northwest, in which sedimentary units thicken locally. Structurally, the Arckaringa Basin is an intracratonic feature comprising a central platform of gently undulating shallow basement surrounded by depressions. At this time, Australia was still part of Gondwana and lay near the South Pole and ice moved north-northwest across the State. The depositional phase in the Arckaringa Basin commenced with widespread glaciation.

Following deglaciation, marine transgressive conditions prevailed with eustatic rise in sea level and flooding of glacio-isostatically depressed lowlands. Termination of marine sedimentation was brought about by crustal isostatic recovery or eustatic sea-level fall, and return to freshwater conditions with development of coal swamps.

During the Jurassic in South Australia crustal instability increased. Epeirogenic downwarp was accompanied by deposition of widespread fluvial and lacustrine sediments in the Eromanga Basin. These crustal movements were a precursor to final separation between the Australian and Antarctic plates. Epicratonic sediments were laid down over much of inland South Australia in the Eromanga Basin. A similar, slightly younger, phase of sediments underlie the Nullarbor Plain region (onshore Bight Basin). Deposition occurred in two distinct tectonic settings. The South Australian portion of the basin can be divided into a thin, (generally <200 m), marginal shelf or platform area in the southwest (including OOLDEA), and a deeper basinal area to the northeast. No continuity with the adjacent Eromanga Basin has yet been demonstrated.

Sediments within the Eromanga Basin can be divided into three packages -lower non-marine, marine and upper non-marine. In the Early Jurassic to Early Cretaceous lower non-marine succession, large sand-dominated, braided fluvial systems drained centripetally into lowland lakes and swamps. The Early Cretaceous marine succession is dominated by thick highstand mudstones, with thin transgressive shoreface sandstone units. In the Late Cretaceous upper non-marine succession, meandering fluvial systems traversed a flood basin dominated by coal swamps and lakes.

By the mid- to late Cretaceous the retreating sea and resumption of terrestrial conditions marked the end of widespread deposition in the current area of the continent.

ECONOMIC GEOLOGY

Up until recently, mineral exploration within the area of the OOLDEA mapsheet has been limited and consequently no commercial mining activity has been recorded. This was due to a combination of access difficulties related to the remoteness of the area, land access restrictions, lack of outcrop and perceived lack of prospectivity. In recent years, the area has attracted interest

for hydrocarbon exploration and, while it is beyond the scope of this minerals-related document, reviews have been undertaken by Morton & Drexel (1997), Alexander & Hibburt (1996) and O'Brien & Hibburt (in prep). In more recent years, mineral exploration has increased due to a range of government initiatives providing precompetitive geological and geophysical data resulting in renewed interest in metaliferous commodities and discovery of mineral sands deposits north and east of OOLDEA.

Basement on OOLDEA, in particular shallow proterozoic components of Christie Subdomain basement in the southeastern corner of the map area, is prospective for gold and other metals. The Officer Basin sediments are prospective for lead–zinc mineralisation (hosted by carbonates) and evaporite minerals (Alinya Formation). The Ouldburra Formation is prospective for evaporate minerals. Tertiary coastal sands of the ranges and adjacent areas (Ooldea Sand, Hampton Sandstone) are prospective for heavy mineral sand deposits. Underlying palaeochannel sediments (Pidinga Formation) have potential for placer gold deposits and other commodities. The exploration history for OOLDEA (and adjacent BARTON) up until 1993 was reviewed by Youles (1993), and the emphasis in the following summary is upon drilling programs. For more detail the reader is referred to the original company reports submitted as part of statutory requirements and stored as Open File Envelopes (ENV) upon relinquishment of the tenement.

URANIUM

The OOLDEA mapsheet area has been subject to a significant amount of uranium exploration during the 1970s with focus on sediments of the Eucla Basin. In 1970 Australian Mining Corporation explored for Tertiary sediment-hosted uranium in the Pidinga Formation around the Lake Ifould region straddling the boundary of the adjacent BARTON mapsheet area SMS 367, Envelope 1317). An airborne scintillometer survey was flown and 25 rotary holes were drilled, however no holes were drilled on OOLDEA. As part of an Australia-wide study, in 1972 ASARCO (Aust) Pty Ltd analysed material from three existing SADM water bores (SADM holes reported in Ludbrook, 1954)) drilled around Maralinga for Uranium. No significant results were returned and no site visits were undertaken (ENV 1880).

A significant phase of uranium exploration was conducted by Pechiney (Aust) Exploration Pty Ltd from 1972–74 (EL 10, ENV 2170, 2435 and 2504), again targeting Pidinga Formation in the Eucla Basin for sandstone hosted mineralisation. Ground and airborne spectrometer surveys, surface geochemical sampling and auger and rotary drilling were undertaken. All holes were radiometrically logged, with selected resistivity measurements taken. 14 rotary holes (with the prefix PIN-R) were drilled on OOLDEA, totalling ~650 m. Again, no significant results were obtained, and Pechiney concluded that surface radiometric anomalies could be attributed to radium in ground waters or uranium daughter products in modern lake evaporites.

During 1972–74 Chevron Exploration Corporation also undertook exploration for the same style of targets as Pechiney (EL 23, ENV. 2183). Only six rotary (prefix PDH and ODH) holes were drilled on OOLDEA totalling 387 m. Downhole gamma logging and geochemical analysis indicated only minor mineralisation. Chevron concluded that limonite staining, absence of pyrite and weathered and corroded feldspars indicated that the Pidinga Formation was locally weathered and no further exploration was warranted.

BASE METALS

Dampier Mining Co. Ltd examined existing aeromagnetic imagery for potential Iron oxide-copper-gold (IOCG) targets. Three anomalies had further ground magnetic profiles completed, followed by gravity readings. No gravity targets were delineated (EL 595, ENV 3796). Amoco Minerals Australia Company also explored for IOCG deposits (1980-82; EL616, ENV 3855). Ground based magnetic and gravity surveys were completed and soil surveys undertaken. Two holes were drilled (ORP1 and 2) for 592 m during 1981, but no anomalous geochemical assays were returned. Getty Oil Development Co Ltd drilled three deep percussion holes (prefix YL) during combined IOCG and oil shale exploration in 1981 on EL 643 and EL 716 (ENV 3874) totalling 1521 m. Slightly

anomalous Cu, Pb and Zn results were reported for younger sediments overlying basement, although no further work was done. Endeavour Resources Limited also explored for IOCG deposits during 1982 (EL 946, ENV4589). Ground geophysics delineated two targets that were subsequently drilled with drillhole WS WB as a water bore adjacent to WS 1 cored to 597 m (including a re-entry WS 1A after the drill rods were lost). No basement rocks were analysed. Lapp Resources only undertook aeromagnetic interpretation for IOCG evaluation (EL 1431, ENV 6974).

IRON

Dampier Mining Co Ltd explored for iron (and coal) during 1975-76, particularly searching Precambrian iron formations by regional helicopter surveys. None were located on OOLDEA (EL 216, ENV 2691) and no drilling was undertaken.

DIAMONDS

Bamboo Creek Gold Mines NL considered the OOLDEA and NULLARBOR regions prospective for diamonds due to the presence of circular topographic depressions (EL 545, ENV 3794) during 1979-80. Aeromagnetic and radiometric surveys allowed target prioritisation. Surface geochemistry revealed no diamond indicator minerals and the tenement was relinquished.

Following regional interpretation of SAEI aeromagnetic data covering the Karari Fault Zone, Equinox Resources NL delineated several circular diatreme-like targets up to 1 km in diameter in 1998 (EL 2021, ENV8974 and EL 2029, ENV 9004). Orientation ground magnetic surveys were conducted over specific targets. Five holes were drilled (OSAC 1, 2 and 3 and IF-1 and 2), one on each target. Drilling did not intersect any kimberlitic or such material with potential for diamond exploration. It appears that all the magnetic anomalies are due to variably magnetised basaltic to ultramafic intrusions.

HEAVY MINERALS

In 1990 the Ooldea Range was identified by BHP Minerals as an exploration target for heavy minerals following recognition of the range as a palaeo-beach ridge system of unusually large dimensions (EL 1653, ENV 8302 and EL1355, ENV6818). At 650 km long by 15 to 20 km wide and 100 m high, it was considered that the Ooldea Range had the potential to be a major new heavy mineral province. In excess of 6400 m were drilled regionally on 13 traverses (prefix OL and M).

Twelve holes were gamma logged. Magnetic traverses were run along 3 lines - anomalies identified were associated with ferruginous sand and lateritic material. Each drillhole was sampled and logged over 2 m intervals. Samples were composited to 10 m intervals for initial heavy mineral content testing; individual 2 m samples were examined as follow-up. 679 samples were tested. Composites were made of the >2.96SG products from the determinations and examined for grainsize and mineralogy.

Results revealed that low level mineralisation was present in the Hampton Sand, generally below 30 m depth; the best value was 8.37% heavy minerals in M169 28-30 m (EL 1654), with next best values around 3.5% in M37 34-36 m (EL 1653) and M143 36-38 m (EL 1654). In total, 14 anomalous areas were identified. Ilmenite was dominant with lesser zircon and rutile accounts for about 1% of heavies. About 49% of heavy minerals were in 125-63microns grain size range. BHP also identified areas between Ooldea Range and Nullarbor Plain as prospective and untested, but access was considered too difficult due to sand dunes. It was felt that Hampton Sand could have been exposed there with decreasing surface elevations and the possibility of mineral concentrations in later Miocene shore deposits from reworking.

However, the excessive overburden and lack of evidence for a sizeable deposit needed to mitigate the remoteness of the area (chiefly the low rutile content in the heavy mineral assemblage, which was less the 1-2%) led to the conclusion that further work was not warranted.

Recent work by PIRSA geologists (e.g. Hou et al., 2001, 2003) has enhanced the prospectivity of the region for mineral sands and renewed interest has led to the granting of a number of current EL's at the time of writing, but postdating publication of the OOLDEA mapsheet. Recent discoveries to the east of OOLDEA have highlighted this and currently OOLDEA is being explored by Iluka Resources, Bemax resources NL and Lost Sands Pty Ltd amongst others.

LIGNITE, COAL AND OIL SHALE

CRA Exploration Pty Ltd conducted exploration for coal in the period 1975–76 (EL 213, ENV2666) in the Tallaringa Trough and within Tertiary lignites in palaeochannels. Exploration consisted of photogeological interpretation. No drilling was conducted on OOLDEA but drilling in adjacent areas intersected lignite of Eocene age in Pidinga Formation. The Burdunga Tertiary lignite deposit discovered in Pidinga Formation sediments is located just outside the northeast limits of OOLDEA and occurs in flat seams 0.5–5 m thick at depths of 20–50 m. The deposit is open to the southwest on OOLDEA (Kwitko, 1983). Further south on BARTON the South Australian Department of Mines discovered the Chundie Swamps and Pidinga Deposits, the latter of which may also extend onto OOLDEA (EL 281, ENV 3105). Two holes were drilled on OOLDEA (P3 and P3A). Core samples tested for chlorine, sulphur, total carbon, hydrogen, nitrogen, carbonates, with forms of ash analysed for Si, Al, Fe, Ca, Mg, Ti, Na, K, P, Mn, and S showed an ash content >40%.

Kumunga Pty Ltd also explored for coal, during the period 1980-82 (EL 616, ENV 3855). Three holes were drilled on OOLDEA and seams of up to 4 m of coal were intersected. Hole 601/1 recorded 1m with ash content of 25% and the remainder >40% Sulphur content was relatively low at 1.9% for Pidinga Formation lignites.

Between 1980–81, Tannadice Pty Ltd drilled 4 rotary holes within the northern part of mapsheet area (EL 625, ENV 3884) targeting Pidinga Formation west of Maralinga. One rotary/core hole drilled to 92.4 m intersected the interval 44–56 m of mostly lignite. Proximate coal analysis were carried out. In core, the lignite had a dry ash content 41 and total sulphur content of 3.4%.

CRA Exploration Pty Ltd, in joint venture with Swan Resources Ltd and Eagle Corporation Ltd undertook a large exploration program for oil shale (with MVT-style lead and zinc as secondary targets) on BARTON, with minor exploration extending onto western OOLDEA during 1980–81 (EL 739, ENV 4112). Exploration was focussed on Cretaceous Madura Formation and Cambrian sediments. Helicopter rock chip sampling was conducted along the edge of Eucla and Officer Basins in which 92 samples were collected and analysed for Cu, Pb, Zn, Ba, As and U. Cambrian sediments were also analysed for F and Mn. 3 percussion holes were drilled for a total of 488 m, although only one was on OOLDEA, and holes logged for gamma and density. Percussion hole 80EP 2 reached a depth of 128 m but analysis revealed no significant anomalism.

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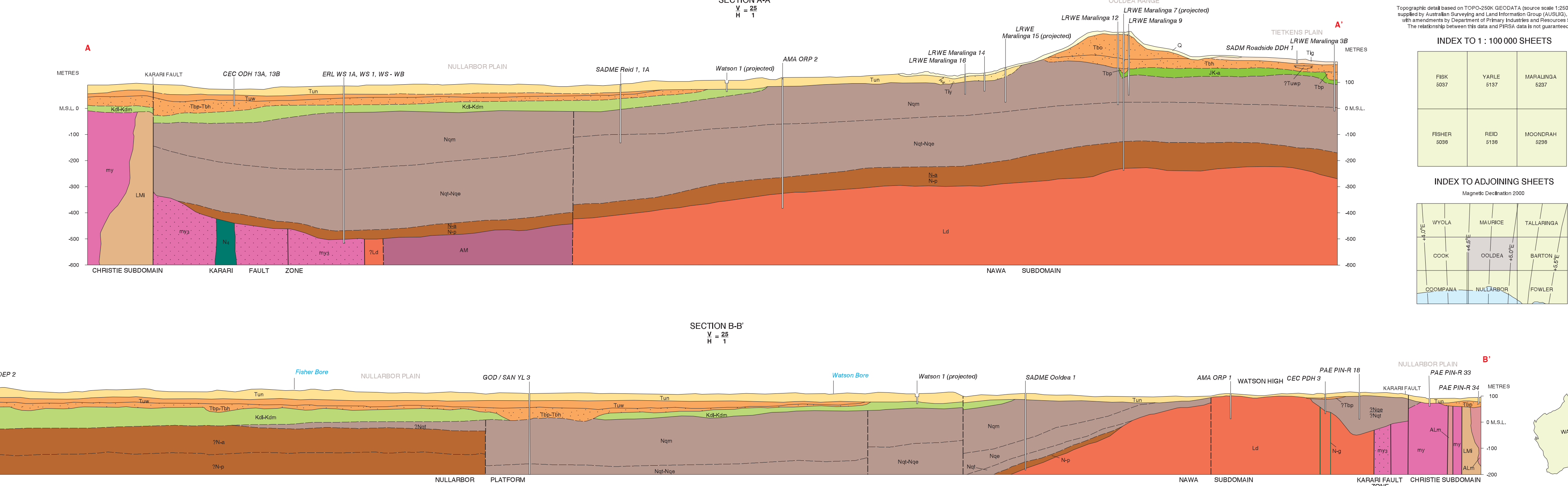
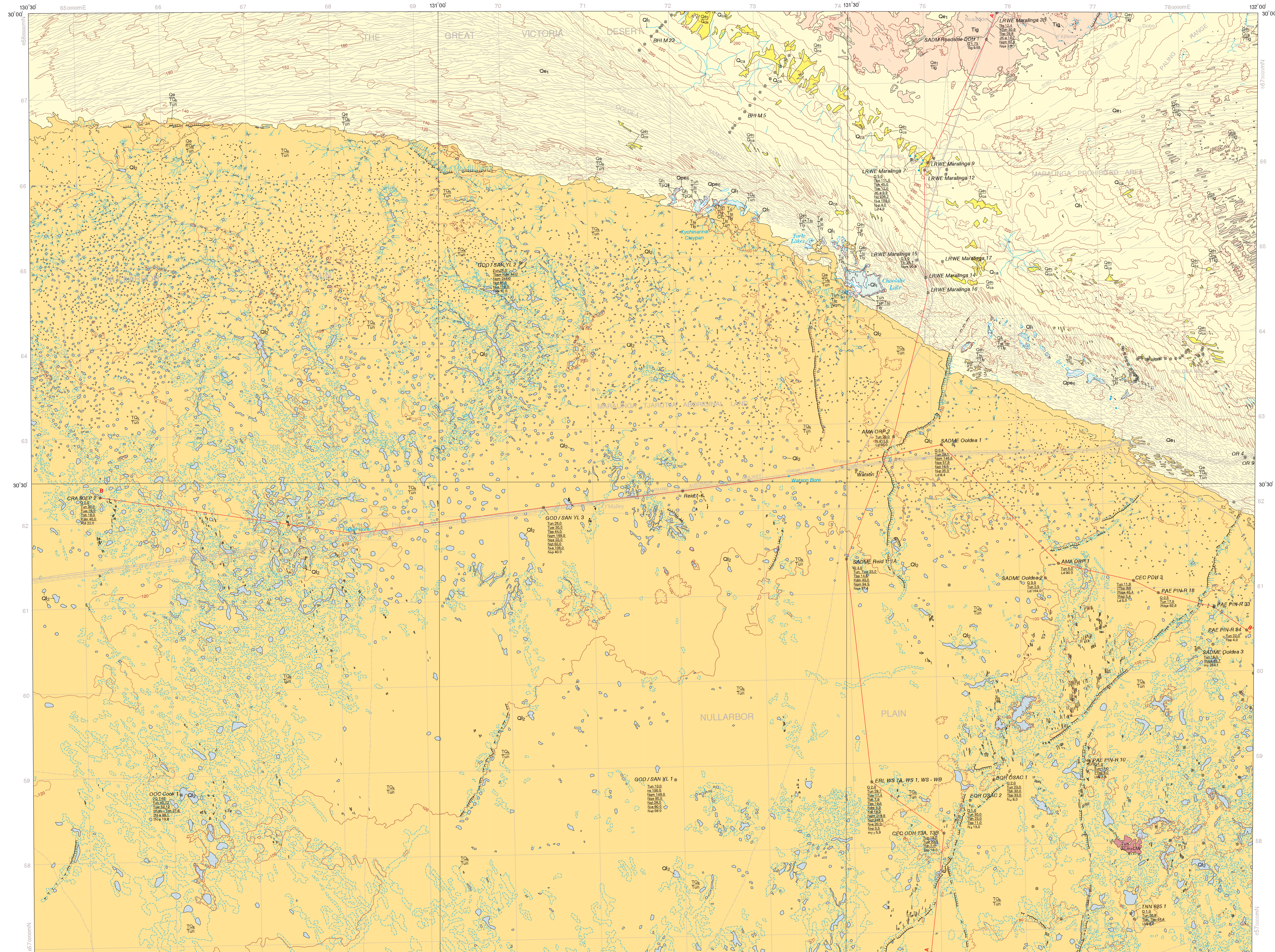
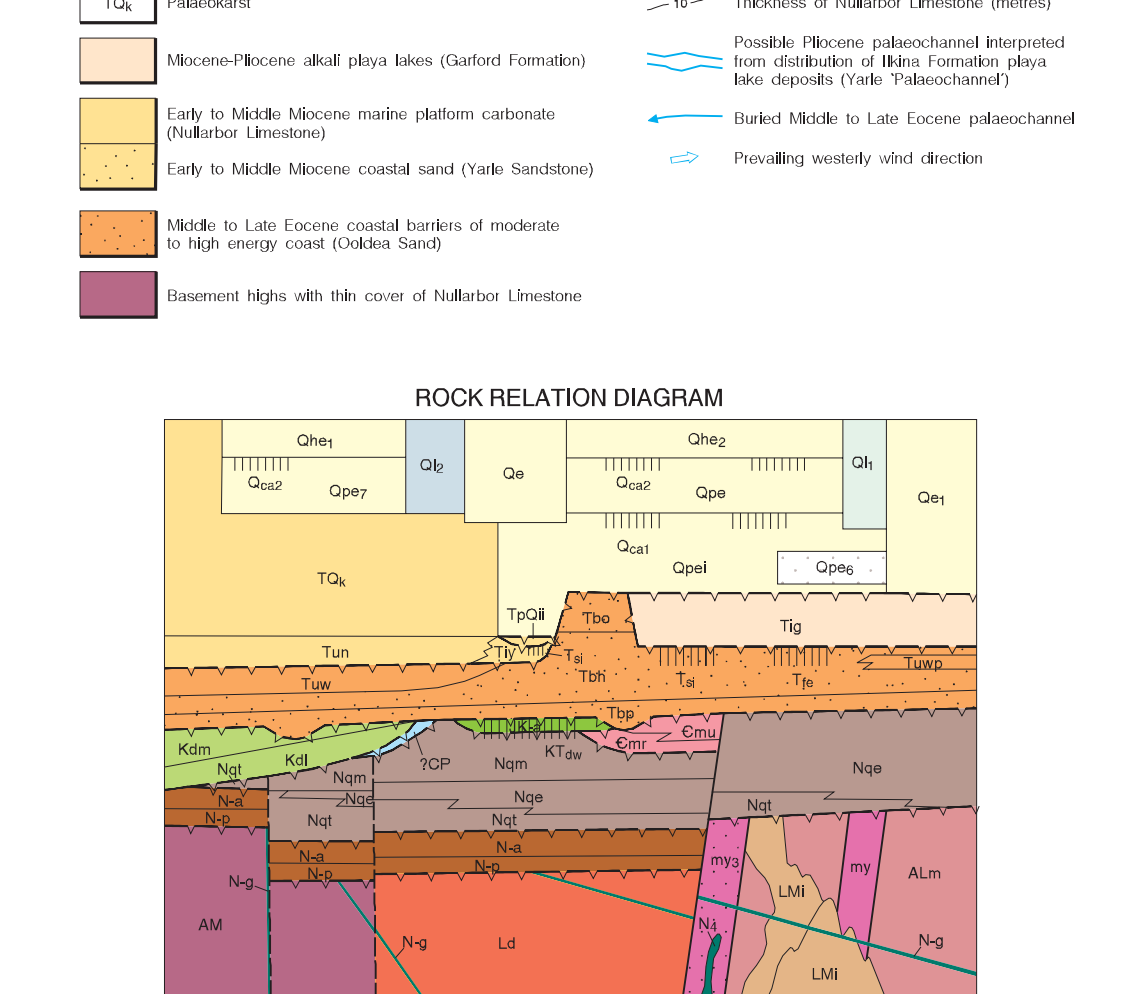
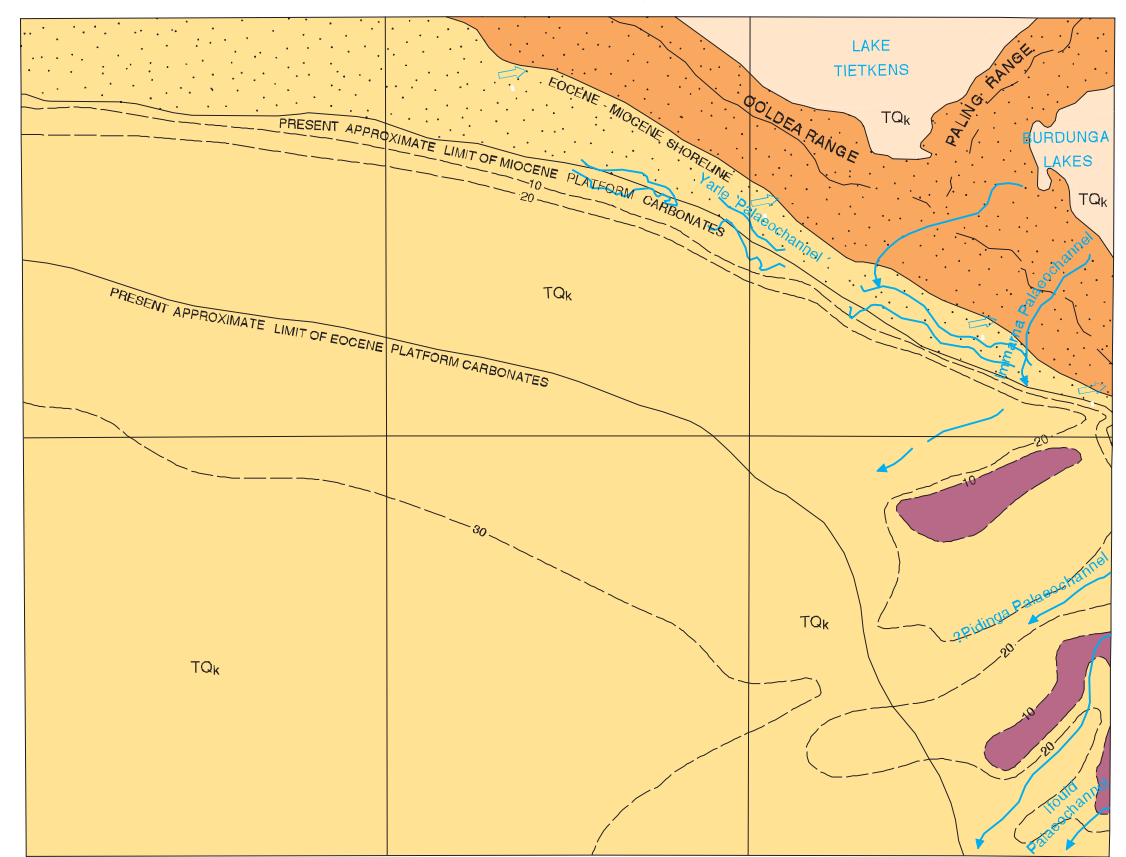
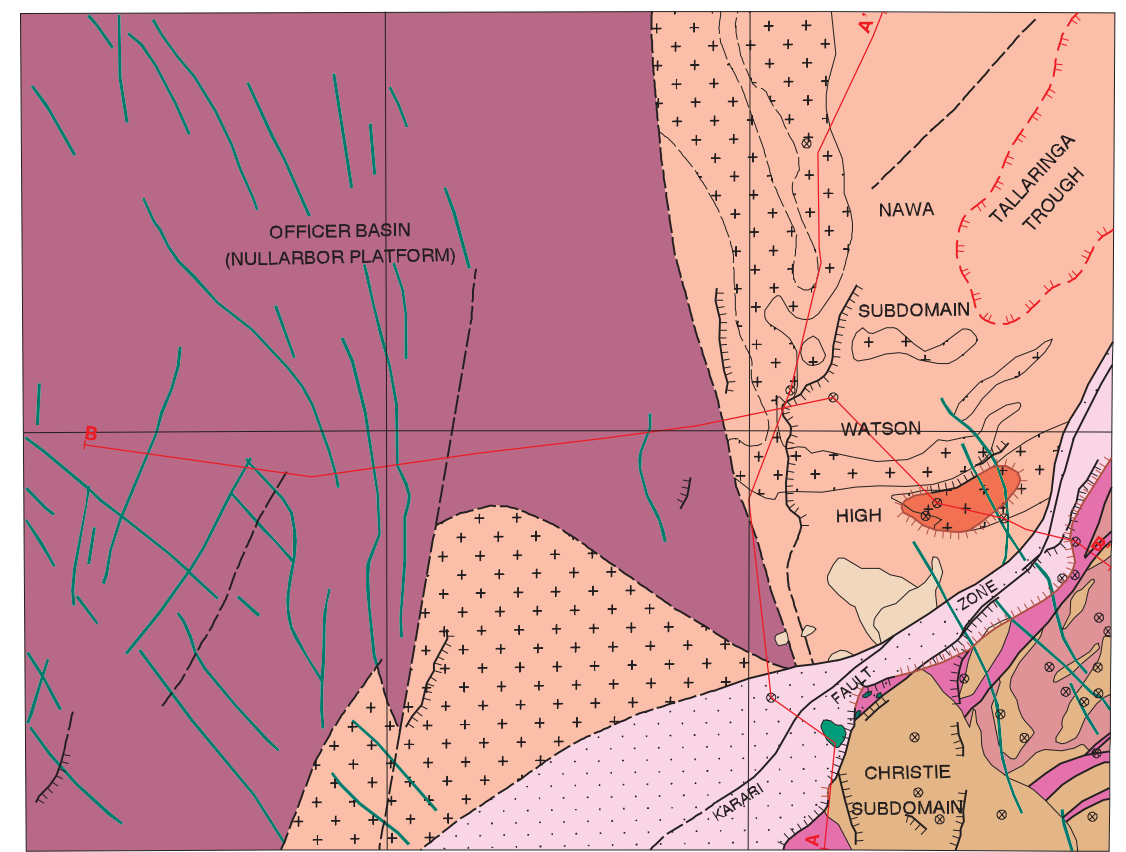
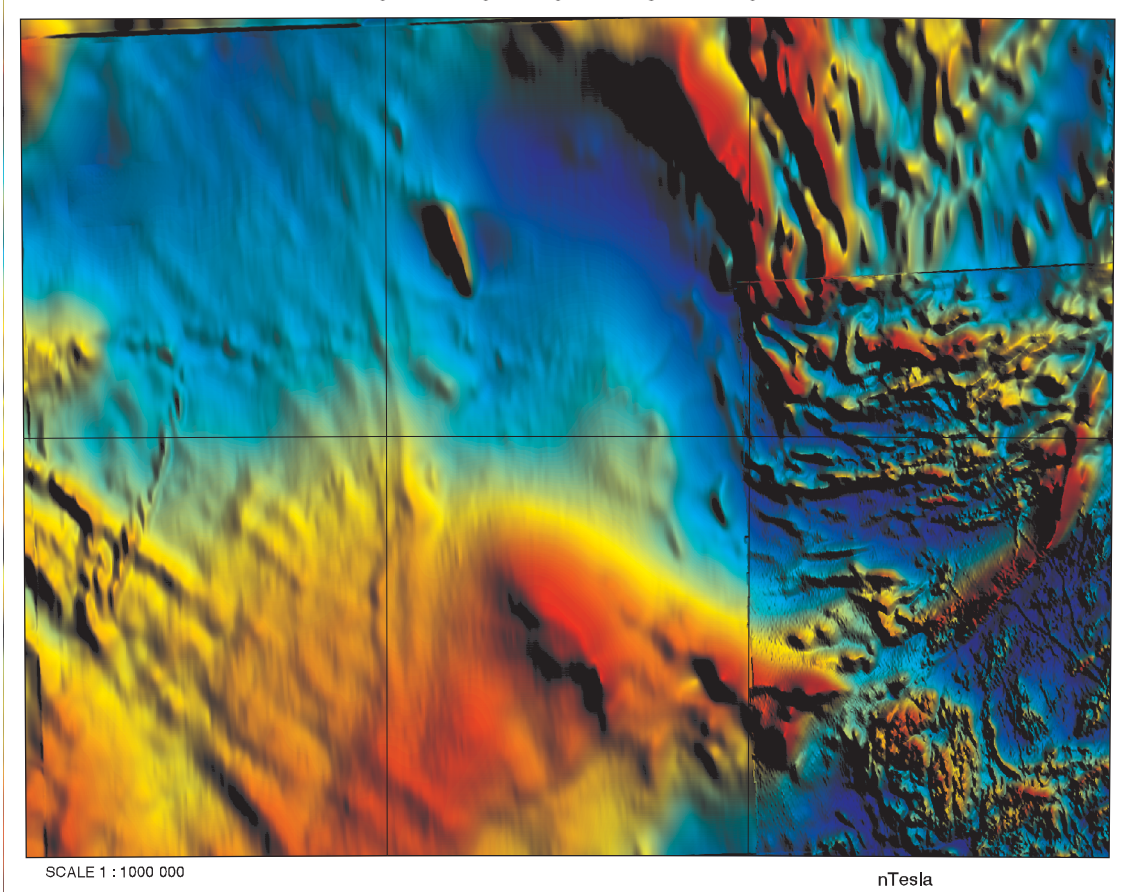
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