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EXPLANATORY NOTES (PHANEROZOIC) FOR THE CURDIMURKA 1:250 000 GEOLOGICAL MAP

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EXPLANATORY NOTES (PHANEROZOIC) FOR THE CURDIMURKA 1:250 000 GEOLOGICAL MAP

INTRODUCTION

The CURDIMURKA map area lies about 600 km NNW of Adelaide in the arid central region of South Australia (**Fig. 1**). The Willouran Ranges in the southeast, and Lake Eyre South (usually a dry salt lake) in the north are the two main physiographic features. Higher points include Willouran Hill (330 m AHD), Tarlton Knob (235 m), Cadnia Hill (211 m), Mount Norwest (311 m), High Hill (232 m) and Hermit Hill (about 120 m). Most watercourses drain in a northerly direction into the Lake Eyre depression. High plateaus and mesas occur in the south west of the sheet area and broad gibber plains, dune fields and sand spreads comprise the remainder of the landscape. The region is underlain by an artesian aquifer (The Great Artesian Basin), leakage from which has formed a series of mound springs.

Access to the area is by the Oodnadatta Track, an unsealed road that connects Marree and Oodnadatta, and by station tracks of varying quality. There are no settlements on CURDIMURKA, although Marree is only 6 km past the eastern margin and William Creek is about 20 km beyond the northwest corner. Permanent habitation is restricted to the station homesteads, "Callanna", "Muloorina", "Stuart Creek", and sometimes "Finniss Springs", of the large sheep and cattle pastoral leases.

January is the hottest month, with a mean maximum temperature of 36°C; July, the coolest month, has a mean minimum temperature of 5°C (mean maximum 17°C). Mean annual evaporation may exceed 3000 mm, while average annual rainfall is only about 150 mm.

Prior to white settlement, the Willouran Ranges were part of the territory of the Kujani Aboriginal People (Tindale, 1940). One of the earliest white explorers was E.J. Eyre who travelled through the region in 1840 to reach Lake Eyre South. After Stuart's discovery of Chambers Creek (now Stuart Creek) in 1858, pastoralists began to settle in the area. Other explorers to visit the area were Babbage

(1858) and Warburton (1866). The Overland Telegraph Line was completed in 1872, and by 1889 the railway had been extended from Marree to William Creek (Litchfield, 1983). Mining of copper deposits began in the 1880's, the two main producers being Clara St Dora (worked 1880-1915) and Warra Warra (worked 1888-1920) (Wells, 1976).

PREVIOUS GEOLOGICAL INVESTIGATIONS

ADELAIDEAN

The earliest recorded geological observations are those of Scoular (1887) who travelled between Marree and Anna Creek noting geological features including Adelaidean rocks at Davenport Springs and Humphreys Springs. Brown (1908) described visits to various copper mines in the 1890s and Brown (1892) reported on the country south of Lake Eyre.

Howchin (1926) paid a brief visit to the Willouran Range near Marree in 1906 and noted glacial erratics in a "Sturtian Tillite", probably the upper or lower diamictite of the Umberatana Group. Mawson (1927) visited the Willouran Range in 1920, describing his "Willouran Series" north of Willouran Hill: this would have included lower Burra Group rocks. He also noted breccias, faulting, dolerite and copper deposits. The first relatively detailed map of the Willouran Ranges was produced by Sprigg (1949) who made a structural and photogeological study. Miles (1952) made a mineral reconnaissance but did not find the region promising for large mineral deposits. Geological mapping by the S.A. Geological Survey in 1960 resulted in publication of the Callanna 1:63 360 geological map (Webb, et. al.,1963). This covers the northern fringe of the Willouran Ranges and shows a basic lithological outline of the Precambrian sequence.

Investigations by mineral exploration companies are summarised in **Fig. 2**. Australian Selection (Sampey and Driessen, 1966a, b) searched for copper in the Willouran Range and near Tarlton Knob, and appear to be the first to note a dacite layer in the Callanna Group near the old Rook workings. Anaconda (Dalgarno, 1966; Ruker, 1966) in their exploration for base metals produced excellent photogeological maps of a wide region. Some other companies making valuable geological contributions were Noranda (Thomas and Dunlop, 1968), Mount Isa Mines (Fairburn, 1969), Finance Facilities (Dewar, 1974; Gillespie, 1974 a,b), Dampier Mining (Bischoff, 1975; Carthew, 1975) and Utah Development Company (Rowlands et al., 1978, 1980; 1983). Fairburn (1969) concluded that although some copper anomalies appeared to be stratigraphically controlled, copper deposits were related to fracturing and were essentially epigenetic.

He regarded complex breccia zones to be diapiric in nature, with features similar to diapirs elsewhere in the Adelaide Geosyncline. Carthew (1975) regarded gabbroic rocks as basement to the Adelaidean and did not consider megabreccias to be of diapiric origin. Later exploration sought Middle Proterozoic, Olympic Dam-type, copper-uranium-gold mineralisation in western CURDIMURKA (eastern Stuart Shelf). Late Proterozoic overburden was found to be unfavourably thick, but the drillholes Newmont SR 17/2 and WMC FHD1 provided useful stratigraphic data.

Further geological traversing and stratigraphic studies were carried out by R.P. Coats as a contribution to a preliminary CURDIMURKA 1:250 000 geological map (Daly, 1970). Preiss (1971) also reported on the area and Murrell (1977) made a regional study, establishing the stratigraphy of the Callanna Group: this was later published in summarised and slightly modified form (Forbes et al., 1981). Mapping and correlation by Murrell and Utah Development Company geologists has been most useful in the current project, although their interpretations of crystalline basement inliers, a largely olistostrome origin of Callanna Group megabreccias, and basal Burra Group unconformities have not been adopted here. Rowlands et al. (1980) interpreted the Callanna Group, as a sabkha association and recognised a suite of evaporitic minerals and structures. Rayner and Rowlands (1980) described stratiform copper in deltaic sediments of the Umberatana Group and this received comment from Dalgarno et al. (1981). Parker (1983) described overprinting of folds and thrusts within the Rischbieth structural complex and suggested significant tectonism prior to or during sedimentation of the lower Burra Group. Coats and Dalgarno (1986) illustrated large-scale slumping in the Umberatana Group and Belperio (1986) described the stratigraphy and sedimentology of the Skillogalee Dolomite.

B ackground information on the Adelaide Geosyncline is provided by Preiss (1987).

PHANEROZOIC

The earliest geological records illustrating Phanerozoic strata on CURDIMURKA are the geological maps of South Australia prepared by H.Y.L. Brown and published in 1883 and 1899. Subsequent reports, prior to the beginning of petroleum exploration in the late 1950s, were regional in nature and dealt with various aspects of the Great Artesian Basin and the overlying silcreted sandstones. The discovery and identification of marine Cretaceous fossils[1] were perhaps the first studies to be made, a Mesozoic rock nomenclature developed[2], and the Cretaceous `glaciation[3]' and silcrete[4] controversies began.

After World War II, petroleum exploration gathered momentum, especially following the publication of a paper by Sprigg (1958) on the petroleum prospects of the Great Artesian Basin. Regional studies continued on both Mesozoic and Cainozoic strata, including the major biostratigraphic account by Ludbrook (1966), mapping and stratigraphic nomenclature of Freytag (1966), Forbes (1966) and Stewart (1968), and the regional syntheses of Wopfner and others[5]. The Callanna 1:63 360 geological map (Webb et al., 1963) provided useful detail of Phanerozoic geology, reflecting the growing interest in petroleum exploration. Studies of Lake Eyre by King (1956) and Johns and Ludbrook (1963) were among the notable early contributions to the geomorphology, stratigraphy and geochemistry of this area.

GEOPHYSICS

An aeromagnetic map of total field intensity was compiled from BMR surveys flown at 1500 ft above ground level with E-W flight lines spaced at 2 miles (Exploration Geophysics Section, SADM, 1968). The CURDIMURKA Bouguer anomaly map was compiled using readings from SADME helicopter and ground gravity stations (Anderson et al., 1980).

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[1]Brown, 1905; Etheridge, 1905; Ward, 1925.

[2]Jack and Etheridge, 1892; Dunstan, 1916; Whitehouse, 1925; 1928.

[3]Brown, 1894, 1905; Jack, 1915, 1931; Woolnough and David, 1926; David and Howchin; 1923, David, 1950; Ward, 1925; Parkin, 1956.

[4]Brown, 1894; Daintree, 1872; Ward, 1925; Woolnough, 1927.

[5]Wopfner et al., 1970; Wopfner et al., 1974; Wopfner, 1969, 1972, 1974, 1978; Stephens, 1971.

CURDIMURKA MAPPING PROJECT (1:250 000 ATLAS SERIES)

The latest phase of investigations leading to publication of the CURDIMURKA geological map began essentially in 1983. Mapping and compilation was carried out by G.W. Krieg (Phanerozoic of Wangianna), P.A. Rogers (Strangways, Bopeechee and Curdimurka), B.G. Forbes (Adelaidean) and R.A. Callen (Trecompana, Muloorina, and northern Wangianna), with contributions from A.P. Belperio (Adelaidean) and R.G. Aldam (northern Wangianna). Geology was plotted onto S.A. Department of Lands colour air photos, scale 1:40 000, Surveys 2091, 2092, 2094 and 2095, flown in 1977 and, for selected detailed investigation, on 1:10 000 enlargements. Completed photogeology was plotted on 1:100 000 base maps by the Map Compilation Section, prior to reduction to final publication scale.

To assist map compilation, two shallow stratigraphic drilling programmes were carried out in 1985, one concentrating on Mesozoic units (Rogers et al., 1989) and the other on Cainozoic stratigraphy (Callen & Plane, 1985; SADME Poole Creek 4-6). These resulted in 16 fully or partly cored and geophysically logged holes; the cores are stored at the Glenside Core Library. SADME Muloorina-1 bore also intersected Cainozoic and Mesozoic sediments (Forbes, 1984). Shallow stratigraphic drilling of the mound spring deposits was carried out by the Bureau of Mineral Resources (M.A. Habermehl) to assist their hydrogeological studies.

Detailed geophysical surveys (mainly seismic) of the Bopeechee - Curdimurka area began in 1981 when Australian Groundwater Consultants (1987) began evaluation of the artesian aquifer as a water supply for the large Olympic Dam Project to the southwest. Subsequent seismic profiling and shallow drilling (GAB holes 1-18) by AGC, and seismic and other geophysical surveys by SADME (Cockshell, 1988) have provided detailed structural and hydrogeological data for Wellfield A in the Bopeechee area. Additional seismic profiling to the north and east of Lake Eyre South by Adelaide Petroleum Pty Ltd (Gatti, 1986) has extended the knowledge of pre-Mesozoic basement structure.

STRATIGRAPHY

The geology of CURDIMURKA consists of several, overlapping sedimentary basins of various ages and structural settings (**Figs. 3,15**). Rocks of Adelaidean age (Late Proterozoic) occur as the strongly folded Adelaide Geosyncline sediments of the Willouran Ranges, as moderately folded Torrens Hinge Zone strata sporadically exposed to the west, or as flat-lying, thinner and largely concealed Stuart Shelf deposits along the southwestern margin of the sheet area. Middle Proterozoic Pandurra Formation, Cambrian rocks of the Arrowie Basin, and Permian rocks of the Arckaringa Basin may be present at depth in the western part of CURDIMURKA.

The Mesozoic Eromanga Basin, composed of terrestrial and marine sandstone and shale, largely covers the older rocks.

Thin Cainozoic deposits of the Lake Eyre Basin and Billa Kalina Basin overlie Mesozoic sediments in the northern half and southwestern part of CURDIMURKA respectively. They comprise a complex assemblage of fluvial, lacustrine, evaporitic, aeolian and mound spring deposits with marked geomorphological and morphostratigraphic character. Cainozoic basin terminology for this report broadens the former definition of Lake Eyre Basin to include the Early Tertiary units (c.f. Krieg, 1985; Callen et al., 1986) and replaces the ill-defined Birdsville Basin (Veevers and Rundle, 1979).

MIDDLE PROTEROZOIC

It is possible that the latest Middle Proterozoic Pandurra Formation underlies the far southwest corner of CURDIMURKA, as it has been intersected at a depth of 438 m in Playford-1 and is believed to extend into the southern part of BILLA KALINA (Ambrose and Flint, 1981a).

LATE PROTEROZOIC (ADELAIDEAN)

The Adelaidean stratigraphy of CURDIMURKA has been dealt with in detail by Forbes (1988) and is not discussed further in this report.

PALAEOZOIC

Cambrian

Andamooka Limestone (Cha) has been penetrated in a drillhole within 15 km of CURDIMURKA on the diagonally adjoining KINGOONYA sheet (Cowley & Martin, in prep.). It is a massive, grey, brown or off-white, fine to medium grained, recrystallised limestone and dolomitic limestone which may be locally well-bedded, oolitic, or may have intraformational breccia interbeds. Occasional red to blue-grey (haematitic) or fetid phases, scattered grey-black chalcedony concretions, rare small stromatolites and algal laminations, and archaeocyaths may be present.

Permian

The subsurface occurrence of Boorthanna Formation (Pb) is inferred from the presence of this unit in Margaret Creek Bore (Ludbrook, 1961) on BILLA KALINA, only 1 km from the western boundary of CURDIMURKA. The Boorthanna Formation on BILLA KALINA consists of glacial marine calcareous diamictite with striated clasts, well-sorted cross-bedded sandstone, poorly sorted calcareous and pebbly sandstone, and green and brown shale (Ambrose and Flint, 1981a).

LATE PALAEOZOIC TO EARLY MESOZOIC WEATHERING AND REGOLITH DEVELOPMENT - THE BOPEECHEE REGOLITH

A widespread regolith of chemically altered rocks (palaeosol) or mechanically-derived debris (waste mantle) occurs immediately beneath the Mesozoic succession in outcrop and drillcore. It was formed by soil processes during long periods of tectonic stability when erosion and deposition were minimal, sometime between the Early Palaeozoic Delamerian Orogeny and the beginning of Jurassic sedimentation. On CURDIMURKA, this feature is referred to as the Bopeechee Regolith. The zone of chemical alteration is restricted to the subsurface and the clastic mantle has been seen only in outcrop.

Lithology

The palaeosol facies of the Bopeechee Regolith occurs as a zone of chemically altered Adelaidean shale up to 25 m thick extending discontinuously for some 70 km between Muloorina-1 and GAB-2 drillholes. In core from GAB-2, it consists of greyish-white clay passing down to mottled reddish-brown and blue clay, which grades through slightly weathered to fresh shale of probable Tapley Hill Formation.

The clastic facies of the Bopeechee Regolith has been observed on CURDIMURKA only at Davenport Springs where it is an irregular layer of rock debris up to 30 cm thick resting on steeply dipping Burra Group sediments of unweathered, grey, thin-bedded siltstone. It consist of angular fragments, broken off the underlying bedrock with only partial disruption of bedding, enclosed in a sand/carbonate matrix similar to the overlying Mesozoic sediments (**Plate 1**). In places, the regolith is strongly ferruginised.

Age and Correlation

The age and duration of the Bopeechee Regolith cannot be precisely determined. During the long interval between Delamerian folding and Mesozoic deposition, nearly 300 Ma, there could have been several major episodes of regolith formation. The oldest of these may be of pre-Permian age making the Bopeechee Regolith a correlative of the Playfair Weathering Zone (Firman, 1981). However, it seems likely that a pre-Permian regolith would have been largely stripped by the Permian glaciation, and so a preserved widespread regolith is more likely to be post-Permian. In support of this, a zone of chemical alteration has been observed in the top of Permian sediments underlying Late Jurassic sediments in CRA 83KD1A hole to the southwest of CURDIMURKA (R.B. Flint, pers. comm.). It may be inferred that this post-Permian weathering event is the one represented on CURDIMURKA. The age of Bopeechee Regolith on CURDIMURKA is thus thought to lie between Late Permian and Early Jurassic. Another possibility, however, is that this regolith is a polygenetic profile representing superimposed palaeosols of various pre-and post-Permian ages.

The clastic mantle at Davenport Springs is assumed to be the remnant, fragmental base of an eroded Bopeechee Regolith profile, but as it underlies Cretaceous deposits, it could alternatively be of Late Jurassic to earliest Cretaceous age.

Interpretation

The post-Permian landscape prior to Mesozoic deposition is interpreted as a "low relief, tectonically stable" environment (Wopfner, et al., 1970) of such long duration that weathering processes could develop the deep and widespread profile of complete chemical alteration. The climate, at least in part, must have been sufficiently wet to maintain local fresh water lakes and swamps with abundant fringing vegetation, as indicated by the Late Triassic-Jurassic Leigh Creek Coal Measures 70 km southeast of CURDIMURKA. Such a wet environment would have assisted near-surface oxidation and development of the Bopeechee Regolith through fluctuation of a high water table and/or lateral groundwater movement.

The palaeosol facies was probably eroded from localities such as Davenport Springs and Finniss-2 borehole , as suggested by the appreciable local relief of the unconformity surface and by the presence of completely kaolinised Adelaidean clasts in the overlying fluvial Algebuckina Sandstone. Elsewhere, the absence of the palaeosol may relate to the predominance of chemically resistant rocks, such as quartzite, in the landscape.

MESOZOIC

The Mesozoic sedimentary record on CURDIMURKA is represented by deposits of the Eromanga Basin, for which a summary of stratigraphic and palynological terminology is shown in **Fig. 4**. These deposits are mainly sandstone and shale of Late Jurassic to Cretaceous age which form a sequence influenced both by eustatic changes in sea level and by local tectonism. The sequence consists of non-marine Algebuckina Sandstone, non-marine to marginal marine Cadna-owie Formation, marine Marree Subgroup (Bulldog Shale, Coorikiana Sandstone, Oodnadatta Formation), marginal-marine Mackunda Formation, and non-marine Winton Formation and Mt Howie Sandstone equivalents. The succession dips gently and thickens basinwards from the edge of the Willouran Ranges. Exposures are often good near the ranges but over most of the northern half of the sheet area, Mesozoic sediments are concealed beneath Cainozoic deposits.

The Mesozoic succession on most of CURDIMURKA rests unconformably on Adelaidean strata, but in the extreme west of the sheet area it may rest on Cambrian and Permian deposits.

Algebuckina Sandstone (Ja)

Algebuckina Sandstone (Wopfner, et al., 1970) is a fluvial, quartzose and kaolinitic sandstone exposed extensively around the northern and western margins of the Willouran Ranges, at Hermit Hill and near Beatrice Bore. Minor outcrops occur at Smith and McLachlans Springs, adjacent to a northwesterly trending fault. The unit rests unconformably on steeply dipping Adelaidean strata and is overlain gradationally to disconformably by Cadna-owie Formation. Away from the ranges the unit has been penetrated in numerous water bores and stratigraphic holes. However, it may be locally absent over buried basement highs (e.g. Finniss-2 drillhole) and is also absent over much of southwestern CURDIMURKA. Maximum observed thickness is 66 m in Muloorina-1 drillhole.

Lithology

Algebuckina Sandstone on CURDIMURKA may be divided into a lower, kaolinitic part and an upper, clean and well sorted part, as in the type section and the Mount Anna reference section (Wopfner, et al., 1970).

The lower part is exposed only in a small area about 13 km southeast of "Finniss Springs" H.S. where it is best displayed in a small, narrow gorge with up to 5 m of section. Here, the unit is a white to very pale brown, yellow or mauve, fine to coarse, kaolinitic, cross-bedded, pebbly sandstone. The gravel component consists of well rounded pebbles and cobbles usually 2 to 10 cm in size, occasional small boulders, and rare large boulders. These clasts comprise resistant quartz and quartzite, and completely kaolinised, white or pale coloured claystone. Several large blocks of weathered pebbly claystone are interpreted as kaolinised Adelaidean glacial diamictite. The sand component is predominantly quartz, and a kaolinitic matrix is common to abundant. Some roughly circular ferruginous zones enclosing small irregular pits are probably oxidized pyrite.

Large and small scale sedimentary structures are well displayed in the lower part of Algebuckina Sandstone, with northerly-directed, tabular cross-bedding up to 1.5 m thick predominating (**Plate 2**). Large scale, low angle, trough cross-bed sets with pebble lags along scour bases are also common (**Plate 3**). Smaller sets between 0.5 and 1.0 m thick are more usual and may be bounded top and bottom by horizontal pebble layers containing weathered shale clasts. These smaller sets appear almost tabular-planar or very gently concave upwards, passing asymptotically into bottom sets, and cut off sharply at about 30^{o} by an upper bounding surface. Minor planar bedding is also present. Small scale sedimentary structures include climbing ripple laminae, reverse graded bedding within very regular, thin cross-beds, and small liquefaction features including gravelly pipes and possible dish structures (Lowe, 1975) (**Plates 4,5,6**).

The upper part of the unit forms most of the outcropping Algebuckina Sandstone on CURDIMURKA. It is commonly a light brown weathering, medium to very coarse, porous and semi-friable, quartzose sandstone with predominant large scale trough cross-bedding. Sets 3 m thick, or more, have been observed near Cockatoo Bore.

The large scale cross bedding and porous quartzose nature are the main field criteria for recognising the upper part of Algebuckina Sandstone and distinguishing it from overlying Cadna-owie Formation. The boundary between the lower and upper parts is not clearly exposed but appears to be sharp.

Texturally, the upper part ranges from fine sand to pebbles with fining upward sequences common. It is moderately well sorted, and grains are typically sub-rounded but range from angular and elongate in the fine fraction to well rounded and near spherical in the coarse fraction. Monocrystalline quartz is the predominant mineral, but minor siliceous lithic grains and trace amounts of tourmaline are consistently present. Zircon and muscovite in trace amounts occur in some samples, and a kaolinitic or goethitic matrix is usually present in very minor amounts.

At a locality 1 km west-northwest of Cockatoo Bore, the top of Algebuckina Sandstone is marked by an unusual assemblage of carbonate and ferruginous cements. The sandstone exhibits solution features and a spheroidal structure, apparently related to the presence of carbonate cement. Ferruginisation occurs as discontinuous irregular layers, as diffuse patches, or as discrete bulbous pods and spheroidal accumulations. Sporadically within this ferruginous zone, clusters of hemispherical structures a few centimetres in diameter extend down from a bedding plane and cubic crystals of goethite (after pyrite) extend upwards (**Plate 7**). Ferruginous fossil wood occurs as large logs to 4 m in length, or as fragments with growth rings and horizontal ribbing preserved. At one locality fossil wood fragments and ex-pyrite crystals are intimately associated.

Equivalent to Algebuckina Sandstone is a grey siltstone/ mudstone exposed over a few metres at Davenport Springs. This unit rests unconformably on steeply dipping Adelaidean sediments, and is overlain by Cadna-owie Formation. It appears to be a small lens preserved in a shallow basement depression. The unit consists of at least 1.0 m of carbonaceous black mud overlain by 0.5 m of grey, plant- bearing silt and sand containing abraded wood fragments. It is grouped with Algebuckina Sandstone as palynological evidence indicates Late Jurassic terrestrial deposition. (Alley, 1987).

Age and correlation

The age of Algebuckina Sandstone on CURDIMURKA probably ranges from Late Jurassic to earliest Cretaceous. The carbonaceous siltstone and mudstone at Davenport Springs contains a palynoflora of Late Jurassic age, reported (Alley, 1987) as follows:

> *"The presence of Retitriletes watherooensis Backhouse 1978 in the absence of Crybelosporites stylosus Dettman 1963 and Cicatricosisporites australiensis (Cookson) Potonie 1956 indicates a correlation of the assemblage with the Retitriletes watherooensis Zone of Backhouse (1978) and Helby et al. (1987). This Zone is also equivalent to the lower Microcachryidites antarcticus Assemblage-zone (Filatoff, 1975), the lower J6 of Evans (1966a, b), and to PJ 6 spore/pollen zone (Price et al., 1985). The palynological zonation for the assemblages can be further refined on the basis of index forms employed by Price et al., (1985). Thus, the presence of Ceratosporites equalis Cookson and Dettmann 1958 and Foraminisporis dailyi (Cookson and Dettmann) Dettmann 1963 places the assemblages in PJ6.2.2.*
>
> *The age of the assemblages and the mud at Davenport Springs is thus Late Jurassic. This designation*

implies that the mud would be approximately equivalent to the middle Algebuckina Sandstone."

Lithological correlation can be made with parts of the type and reference sections of Algebuckina Sandstone which are located some 280 km and 190 km respectively to the northwest of the areas discussed, in a similar geological setting. The lower, kaolinitic part of the unit on CURDIMURKA has very similar lithology and sedimentary structures to units 6-8 of the type section and units 1-9 (especially unit 9) of the Mount Anna reference section. The upper part of the unit on CURDIMURKA compares closely with the uppermost unit (unit 9) of the type section and with the upper part (units 10-12) of the reference section. Thus, Algebuckina Sandstone exposed on CURDIMURKA (**Fig. 5**) correlates well with the upper part of the type and reference sections. On this basis, a latest Jurassic to early Neocomian age is suggested for the unit on CURDIMURKA, a designation which agrees with the palynological dating at Davenport Springs and the age of the upper part of the formation in SADME Toodla-1 stratigraphic well (Alley, 1985a).

Interpretation

As stream gradients diminished during the Middle and Late Jurassic, following the beginning of basinal development, deposition gradually replaced erosion as the dominant fluvial process on CURDIMURKA. Current bedding directions show that the rivers flowed generally in northerly and northeasterly directions towards the basin depocentre. On CURDIMURKA, deposition in the slightly elevated regions may have been largely channel-confined or restricted to shallow basement hollows, and more widespread in areas of lower elevation and relief.

During the first phase of Algebuckina Sandstone deposition, rivers were eroding a weathered source region that yielded an abundant sediment supply of weathered, kaolinitic material as well as resistant, siliceous lithologies. A generally moderate flow velocity for this first phase is suggested by the common sets of tabular-planar cross-beds that may have been formed by sand waves migrating along stream beds (Harms et al., 1975). However, evidence for sporadically stronger flow, perhaps with brief episodes of high velocity, is provided by large scour and fill trough cross-bedding with conglomeratic layers and rare cross-bed sets with reverse graded bedding. These features indicate current velocities that varied between the weaker and stronger energy levels of the lower flow regime (Harms et al., 1975). Deposition probably occurred in an environment of large, gravelly, low-sinuosity meandering rivers, or sandy, braided rivers, flowing in a landscape of low to moderate relief. Fluctuating discharge may have been due to marked seasonal variation in precipitation, occasional torrential rain possibly in a semi-arid environment (Wopfner, et al., 1970), or a pronounced snow-melt season. Palaeoenvironmental interpretations below suggest that the latter may apply.

The upper part of Algebuckina Sandstone was deposited by rivers of stronger, more uniform flow than those which deposited the lower part. This is indicated by the abundance of large-scale, trough cross-bedding, the paucity of fine interstitial material, and the absence of conglomeratic beds. Sustained higher flows indicate a wetter climate with more uniform precipitation.

Towards the end of Algebuckina Sandstone deposition, stream gradients had so diminished that swamps and freshwater lakes may have been widespread. The top of Algebuckina Sandstone near Cockatoo Bore, for example, has indications of waterlogging and preservation of woody material in a reducing environment, with formation of pyrite in the more anaerobic areas.

Palynofloral data allow only generalizations to be made on the palaeoenvironment because of uncertainties about modern affinities and ecological tolerances. Apart from palynofloras from the Algebuckina Sandstone equivalent at Davenport Springs, there is little information available for the unit on CURDIMURKA. The following generalizations include information from Toodla-1 drillhole, southeast of Oodnadatta.

The Algebuckina Sandstone produces diverse palynofloras, with a total of 113 species of pollen and spores being recognised. This implies that a varied assemblage of plants grew in and around the basin of sedimentation. Pollen of the conifers forms the greatest part of the palynofloras, being as high as 88% in one sample from Davenport Springs. Ferns, particularly tree ferns, are well represented, as are the herbaceous plants, such as club-mosses, and the bryophytes that include plants similar to modern sphagnum mosses. The vegetation was probably an association dominated by evergreen conifers, deciduous ginkgos (maidenhair tree) and an understorey of tree ferns (along moister, shaded valley floors) and ferns. Mosses occupied a variety of habitats, with club-mosses more common in the shaded forest and sphagnum-like mosses dominating open peat bogs and other wet areas.

These vegetation associations suggest high precipitation (or low evapo-transpiration) and cool temperate to temperate conditions. It is possible that high parts of uplands supported vegetation that was adapted to cool to cold conditions, as suggested by the significant presence of pollen from Microcachrys, a shrubby conifer currently growing in the sub-alpine areas of Tasmania. Pollen from this plant dominates the palynofloras from Davenport Springs, perhaps suggesting the proximity of uplands.

Cadna-owie Formation (Kc)

Cadna-owie Formation is a thin transgressive sequence of sandstone, siltstone and shale that was deposited during a period of rising eustatic sea level (Wopfner et al., 1970; Morgan, 1980; Moore and Pitt, 1984, 1985). The unit lies transitionally between Algebuckina Sandstone and Bulldog Shale, and is usually identified in outcrop by the distinctive uppermost bed of khaki-brown, calcitic sandstone. It has a similar distribution on CURDIMURKA to Algebuckina Sandstone, and it also may be absent over buried basement highs as in Finniss 2 drillhole. At some locations, e.g. Davenport Springs, Cadna-owie Formation onlaps Algebuckina Sandstone and rests directly on Adelaidean strata.

The lower boundary of Cadna-owie Formation may occur in outcrop as a thin, ferruginous layer that separates the broadly uniform, cross-bedded, upward fining Algebuckina Sandstone from the more heterogeneous, finer-grained Cadna-owie Formation. This boundary can also be observed in some geophysical borehole logs, e.g. the neutron log of Muloorina-1 well. The upper boundary of Cadna-owie Formation is marked by an abrupt lithological change from hard calcitic sandstone to the overlying dark grey mudstone of Bulldog Shale. This boundary is readily mappable at the surface and is clearly seen in gamma, neutron, sonic and other borehole logs. It also forms the pronounced seismic `C' reflector.

Maximum thickness of Cadna-owie Formation on CURDIMURKA is about 50 m in the subsurface, e.g. in Jackboot Bore and Muloorina-1 Well. Outcrop thicknesses are less than 10 m.

Lithology

Apart from its upper beds, Cadna-owie Formation on CURDIMURKA is generally a siltstone - very fine sandstone - minor claystone unit with occasional fine sandstone intervals and minor medium to coarse sandstone lenses. The finer-grained sandstone beds are commonly silty and the coarser-grained lenses contain clean, well-sorted intervals. In outcrop, the unit has thick planar beds with internal lamination and rare cross-lamination. Near the base of the formation at Davenport Springs, hummocky cross-stratification is well developed in fine, well sorted sandstone (**Plate, 8**).

The sand fractions consist predominantly of detrital quartz with common randomly oriented mica (mainly muscovite) and accessory amounts of fresh plagioclase and microcline (Farrand, 1983). Pyrite is also common and occurs either in finely disseminated form or, less frequently, as partly altered cores surrounded by sub-spherical masses of iron oxide.

Towards the top, Cadna-owie Formation coarsens and becomes increasingly calcareous; the uppermost bed is a khaki brown, fine to medium and sometimes gritty, pebbly or cobbly, well cemented, blocky sandstone (**Plate 9**). The cement consists of large, optically continuous, calcite crystals ("mega-sparite" of Wopfner et al., 1970) which completely enclose the detrital grains and produce a lustre mottling on broken surfaces (Farrand, 1983). A local variant of this uppermost bed occurs in several small outcrops at Davenport Springs, and consists of a calcareous, sandy breccia with angular quartzite clasts, 5 to 20 cm across, derived from the surrounding Adelaidean basement. The breccia intertongues with sandstone, as illustrated in **Fig. 6**.

Ferruginisation of Cadna-owie Formation is widespread, occurring as lenses with vertical pipe-like structures, flat concretionary lenses, and well-defined to diffuse layers parallel to bedding. The ferruginisation may result from oxidation of finely disseminated pyrite.

Two other local features, mentioned because of possible palaeoenvironmental significance, are (1) the occurrence in one section (**Fig. 5**) of a boulder layer with well-rounded, Adelaidean quartzite clasts up to 40 cm in diameter, in a very fine, silty sandstone; and (2) the presence at Davenport Springs of parallel, irregular, pipelike structures (**Plate 10**) 2-5 cm in diameter and extending subvertically up to 40 cm.

Age and Correlation

Palaeontological control for Cadna-owie Formation on CURDIMURKA comes from Muloorina-1 water well (Forbes, 1984) and Davenport Springs (Ludbrook, 1966). In the Muloorina-1 interval, the palynofloras were tentatively assigned to the *Crybelosporites stylosus* spore-pollen Zone of Dettmann and Playford (1969) which indicates a Neocomian to Barremian age (Alley, 1984a). This zone is now superseded by the *Cicatricosisporites australiensis* and *Foraminisporis wonthaggiensis* zones of Helby *et al*., (1987) (**Fig. 4**). At Davenport Springs, rare foraminifera *Reophax geniculatus*, *Trochammina minuta* and *Haplophragmoides sp* have been recovered from Cadna-owie Formation (Ludbrook, 1966; p. 61) indicating an Aptian or Neocomian age. On the basis of lithological similarity and stratigraphic position, outcropping Cadna-owie Formation on CURDIMURKA can be correlated with the upper part of the type section which is considered to be earliest Aptian in age (Alley, 1988).

Interpretation

The Cadna-owie Formation is broadly regarded as "shallow water, marginal marine" (Wopfner *et al*., 1970) and is the depositional record of numerous local environments that formed along the margin of an advancing sea. At various localities around the southwestern margin of the Eromanga Basin, the formation contains non-marine facies (Alley, 1985a, 1988).

As the unit spans a large part of the Neocomian, the Barremian and the earliest Aptian (about 15 million years) and yet is only some 50 m thick, it is likely to contain major disconformities representing non-deposition and/or erosion. These could indicate marine regressions within the overall transgressive event, and fluvial erosion in the non-marine facies.

The common occurrence of mica and presence of fresh feldspar suggest fairly rapid deposition of sediment eroded from a tectonically unstable crystalline source area. Such tectonism could have influenced local coastline position, superimposing local regression or enhancing transgression on the generally advancing shoreline.

Various local environments of deposition within the broadly marginal marine setting are evident from outcrops on CURDIMURKA. Sections show a general upward coarsening from laminated claystone through laminated to massive, moderately bioturbated siltstone and very fine sandstone to a medium grained sandstone with scattered pebbles and cobbles and rare pieces of fossil wood (**Fig. 5**). This sequence is interpreted as an upward gradation from near offshore through shoreface to foreshore deposition, representing minor marine regression. The pebbles and cobbles of the upper unit could be interpreted as lag deposits of a high energy foreshore swash zone, marking the depositional edge of the unit. Discontinuous and intermittent deposition of talus from adjacent uplands onto the shoreline, perhaps in response to tectonic activity, is suggested by the occurrence of intertonguing breccia and sandstone at Davenport Springs. In this shoreline setting, the convoluted pipe-like structures in fine well sorted sand are thought to be water-escape tubes formed by numerous small springs along a beach. They are almost identical to the "concretionary sand tubes" of Cloud and Lajoie (1980).

Another palaeoenvironmental setting can be inferred from boulder layers with lenses of coarse, well-sorted sandstone, which occur in a very fine, silty sandstone unit (**Fig. 5**). It is possible that the boulders were eroded by the sea from Permian diamictite, or transported to the coast by seasonal ice in high energy rivers (Frakes and Francis, 1988) and reworked into the shoreface. From there, they may have been moved seawards by intermittent tectonism, marine currents or by ice-rafting. Major storm events, indicated by sand lenses in the siltstone unit and by hummocky cross-stratification may also have helped move the boulders from the foreshore into the shoreface or near off-shore environments. The possibility of seasonally cold conditions during deposition of Cadna-owie Formation may also be consistent with a frost-shattering origin for angular clasts in the upper part of the unit.

As well as beach and shoreface depositional environments there is also evidence for more restricted, reducing environments. The very fine, well sorted sand with pyrite nodules is suggestive of a back barrier lagoonal sand, and the dark brown or grey claystones, and silty shale and sandstone in Muloorina-1 drillhole were possibly deposited in a central or inner lagoonal environment or a coastal marsh. A similar environment is inferred from palynological evidence derived from a carbonaceous clay-siltstone unit at the type section of Cadna-owie Formation (Alley, 1988).

The sparite cement at the top of Cadna-owie Formation is a regional characteristic of the unit extending for hundreds of kilometres around the southwestern margin of the Eromanga Basin (Wopfner, et al., 1970). Such an unusual, yet widespread fabric suggests a rather singular set of conditions controlled by some regional influence. One possible interpretation is that of a tectonically quiet episode during which the shoreline slowly retreated over a broad sandy sea bed in response to a eustatic fall in sea level. Shallowing of the sea may have allowed increased evaporation, resulting in carbonate saturation in the sediment of the coastal marginal zone. This would have caused a broad precipitation front to advance across the slowly emerging coastal plain. The process may have been aided by terrestrial water, perhaps carbonate-enriched itself, invading the coastal plain and mixing with the hypersaline seawater occluded in the near surface sediments. The resulting decrease in carbonate solubility by "freshing", with the possible introduction of further carbonate, may have assisted the formation of large calcite crystals within the sediments. However, this hypothesis is not supported by palynological evidence which indicates a marked transgression at the top of the Cadna-owie Formation.

Other aspects of the palaeoenvironment in Cadna-owie time are derived from palynological studies. Plant species diversity as inferred from the palynofloras in Toodla-1 drillhole and the type section of the Cadna-owie Formation (Alley, 1988) show a continuation of the diversity seen in the Algebuckina Sandstone. However, not all of the formation is represented at these localities (Alley, 1985a, 1988), and so the palaeoenvironmental interpretation below may apply only to the earliest Aptian part of the section. Conifers were again common, but not to the extent they were in Algebuckina time. This decrease is balanced by a relative increase in the nonarboreal (understorey) taxa: tree ferns, ferns, club mosses, bryophytes and other herbaceous plants. Changes also occurred in the structure of the evergreen forest vegetation. There was a decrease in the more temperate species such as the *Araucaria* group and the podocarps. On the other hand, the more cold-tolerant plant *Microcachrys* increased significantly.

These changes in vegetation structure may imply a shift towards colder temperatures and an increase in precipitation or a decrease in evapo-transpiration. The inferred deterioration in temperature also supports some of the interpretations made above about environments of deposition and broadly agrees with the proposal by Frakes and Francis (1988) for winter freezing of streams and possibly nearshore sea water.

Evidence of one other significant palaeoenvironmental change is provided by the palynofloras. During the earliest Aptian, the Cadna-owie Formation was at first terrestrial to paralic, but in the uppermost part of the unit there is a great influx of microplankton (dinoflagellates and acritarchs), signifying marine transgressive conditions. This also implies that the shoreline was some distance from the sites discussed above. What influence this had on the distribution and deposition of various kinds of pollen and spores is unknown.

Bulldog Shale (Kmb) and Wilpoorinna Breccia Member (Kmw)

Bulldog Shale (Freytag, 1966) is a grey marine mudstone that ranges in thickness from 80 m (top eroded) in the west of CURDIMURKA, to more than 200 m in the deeper parts of the basin to the northeast, e.g. Muloorina-1 drillhole. Its lower boundary is either a conformable, sharp contact with Cadna-owie Formation, or an unconformable contact with Adelaidean rocks. The upper boundary of the unit is conformable with Coorikiana Sandstone and is usually gradational. Bulldog Shale locally includes the Wilpoorinna Breccia Member at its base.

Lithology

Bulldog Shale consists of dark grey, bioturbated, shaley mudstone with silty and very fine sandy layers. Intervals of pale to medium grey, micaceous, fine clayey sandstone also occur, and irregular wispy interlamination of the shaley and sandy lithologies is common. Bedding is very thin and generally parallel, producing the broadly horizontal shaley parting seen in outcrop. In the sandier layers, disturbed bedding, wavy to irregular lamination and cross-lamination may also be present. The Bulldog Shale contains shell fragments, plant fragments (including small pieces of carbonized wood), and pyrite occurring as disseminated patches, partly oxidised blebs or as rare small crystalline aggregates.

Various sandy lithologies (6338 RS 71-77) have been described petrographically as sandy claystone with argillaceous matrix (smectite, quartz, feldspar, mica/illite, calcite, chlorite, pyrite) and detrital quartz, glauconite (?green smectite), feldspar, accompanied by chlorite, ?clinoptilolite, muscovite, calcite and opaque minerals (Radke and Brown, in Rogers et al., 1989).

The basal portion of Bulldog Shale contains numerous, very large, well rounded boulders. Boulders up to a metre across are not uncommon and one clast at Davenport Springs is 3 m in its longest dimension (**Plate 11**). The boulders are mainly of Adelaidean quartzite but other lithologies, notably acid igneous types, are also present. Some boulders are associated with lenses and stringers of pebbly sand. The basal part of the unit also contains large pieces of fossil wood and occasional lenses of khaki-brown, cone-in-cone limestone. An abundance of large boulders and fossil wood is restricted to the basal ~10 m of Bulldog Shale, thus forming a broad stratigraphic marker.

Higher in the unit, dark grey ellipsoidal limestone concretions up to a metre thick and 2 or 3 m across, often fossiliferous and enveloped by cone-in-cone limestone, occur in discrete horizons over a few hundred metres (**Plate 12,13**). Field and drillhole observations (e.g. Finniss-2; **Fig. 7**) indicate that the concretions occur at several stratigraphic levels but are generally more common in the middle part of the unit.

Wilpoorinna Breccia Member (Kmw)

Wilpoorinna Breccia Member was first applied by Forbes (1966) to a pebbly unit occurring locally at the base of Marree Formation on MARREE. When Marree Formation became Marree Subgroup (Thomson, 1980), Wilpoorinna Breccia Member was elevated to formation status. Mapping on CURDIMURKA, however, has confirmed that the unit is only very locally developed and thus should be returned to member status.

Wilpoorinna Breccia Member has been seen at only two localities on CURDIMURKA; one in outcrop near "Callana" H.S. and the other in drill-core from Finniss-2; (**Fig. 7**). Near "Callana" H.S., it rests on a thin bed of Cadna-owie Formation and consists of a layer of Adelaidean siltstone pebbles about 0.5 m thick extending discontinuously for a few tens of metres. In Finniss-2, the unit occurs at the base of Bulldog Shale and rests directly on Burra Group. It consists of sandy and pebbly mudstone with basal sandstone and conglomerate composed of sub-rounded Adelaidean clasts up to 6 cm in length. Core specimens (Radke and Brown in Rogers, et al., 1989) were petrographically described as sandy claystone containing lithic fragments of siltstone and fine-grained quartzite. The argillaceous matrix is composed of smectite and quartz with accessory clinoptilolite, kaolinite, mica/illite, plagioclase, K feldspar and pyrite. Other detrital components are quartz grains up to 0.5 mm diameter, feldspar and pale green "glauconite" or smectite pellets.

Palaeontology and Age

Bulldog Shale contains numerous shellbeds usually associated with calcareous concretions, sandy layers and reworked conglomeratic deposits. The shellbeds are dominated by large gregarious bivalves, notably Maccoyella barklyi and Fissilunula clarkei, with Eyrena linguloides, Pseudavicula anomala, Cyrenopsis meeki and C. australiensis. Other macrofossils include the gastropod Euspira reflecta and belemnites (Ludbrook, 1966). A sparse echinoderm fauna has been found in calcareous concretions from Gregory Creek and consists of starfish and a crinoid calyx.

Long (1985) has described a toothplate from a chimaerid fish (Edaphodon eyrensis), discovered at Lake Phibbs. Remains of marine reptiles (ichthyosaurs and plesiosaurs) are recorded but not described.

Foraminifera consist mostly of agglutinated forms such as Haplophragmoides chapmani, H. dickinsoni, Textularia wilgunyaensis, Bigenerina loeblichae and Pseudobolivina engeninensis (? = P. manitobensis)(N.H. Ludbrook, pers. comm., 1989).

Preliminary work on samples of Bulldog Shale and Wilpoorinna Breccia Member from the Finniss-2 stratigraphic drillhole (Alley, 1986a) indicates the presence of the upper part of the Cyclosporites hughesii spore/pollen zone of Helby et al., (1987). The dinoflagellate assemblages from the well are correlated with the Odontochitina operculata Zone, Subzone c and the upper part of Subzone a. Subzone b appears to be absent, suggesting a local hiatus within the Bulldog Shale, which corresponds to a minor regression of

Morgan (1980).

Samples of Bulldog Shale from Davenport Springs can be assigned to the *Odontochitina operculata* Subzone b (Alley, 1987). Therefore, the sequence here includes sediments which are represented by a period of non-deposition (or erosion) in Finniss-2.

Alley and Rogers (1985) have shown that calcareous concretions from the Cretaceous marine units often preserve microfloras which have been lost from the surrounding weathered sediments. One such concretion from Margaret Creek yielded a dinoflagellate assemblage belonging to the *Odontochitina operculata* Subzone c.

The samples from Finniss-2, Davenport Springs and Margaret Creek are all interpreted to be from the lower part of Bulldog Shale. The upper part of the unit is represented by silty clay in Poole Creek-2 well which contains palynofloras assignable to the *Crybelosporites striatus* spore/ pollen Zone and the *Pseudoceratium turneri* dinoflagellate Subzone b (Alley, 1985c).

Palynofloras from Bulldog Shale in Alford-1 are correlative with the *Coptospora paradoxa* spore/pollen Zone and the *Pseudoceratium turneri* microplankton Zone. There were insufficient zonal microplankton to determine which dinoflagellate subzone they should be assigned to. Thus, the palynofloral evidence indicates an early to middle Albian age for the younger part of Bulldog Shale that was intersected in the well (Rogers *et al*., 1989).

These results indicate an early Aptian to early Albian age for Bulldog Shale, which is in accord with age determinations from elsewhere in the Eromanga Basin.

Interpretation

Bulldog Shale was deposited during an early Aptian - early Albian transgressive period following deposition of Cadna-owie Formation. A basal transgressive conglomerate may be represented by Wilpoorinna Breccia Member but the bulk of the unit is a bioturbated mud deposited in an offshore epicontinental marine environment. Most of the sediment was deposited from suspension below normal wave base. Storm wave influence may be indicated by the wavy and cross-laminated fine sandy intervals, and less frequent and more intense storms by the shell beds. The latter may be swell lags which formed in deeper water further from the shore.

Although the Aptian sea covered a vast area and must have been subjected to major storms, there seems to have been only limited aeration by marine currents. Pyrite and carbonised wood fragments are common in Bulldog Shale, particularly in the basal part of the unit, indicating the reducing conditions of restricted or anaerobic parts of the sea floor. A restricted environment is also indicated by the low diversity of microplankton assemblages which may comprise only a few species of acritarchs, notably Micrhystridium. However, abundant bioturbation suggests good aeration of other parts of the sea floor.

The common occurrence of large boulders in the basal part of Bulldog Shale is the most striking feature of the unit on CURDIMURKA. These boulders represent a continuation of processes which emplaced those in Cadna-owie Formation but their much larger size and greater abundance require either a different source or a more powerful transport agent. A greater development of seasonal river and shore ice (Frakes and Francis, 1988) may have captured and carried the large boulders of high gradient streams, fan deltas, or eroding diamictites. The regional distribution of the larger clasts around the southern margin of the Eromanga Basin and the more southerly position of the area during the Early Cretaceous (Frakes and Francis, 1988) point to ice-rafting as the most likely mechanism of emplacement. However, the abundance of fossil wood in the lower Bulldog Shale suggests that some clasts may have been rafted into the basin in the roots of floating trees.

Plant species diversity remained high in the interval of time occupied by deposition of Bulldog Shale. Coniferous taxa were still important, although the Araucaria group was greatly diminished. The podocarps increase in relative frequency, especially in the lower to middle part of Bulldog Shale, whereas Microcachrys maintains its importance (to the extent it has in the Cadna-owie Formation) in the lower part of the unit, then decreases significantly in younger horizons.

Ferns are well represented and exceed the frequency of the conifers in some middle and upper beds. Herbaceous plants, such as the club mosses and sphagnaceous mosses, remained an important part of the flora.

Palaeoclimate during deposition of the early part of Bulldog Shale appears to be similar to that prevailing during deposition of the earliest Aptian interval of Cadna-owie Formation. However, the mixed plant assemblages and the abundance of ferns in the latter part of the Aptian and the early Albian is difficult to interpret. Perhaps the forest was dominated by podocarps with abundant ferns in the understorey, suggesting an amelioration in climate.

Microplankton are present throughout Bulldog Shale, although in greatly varying frequencies and diversities, suggesting marine conditions ranging from shallow to more open and deeper water. In Toodla-1 drillhole (on OODNADATTA), greatest water depths are inferred in the lower part of the unit, whereas in Finniss-2 drillhole, transgressive conditions are recognizable in the middle part of the unit, and in Alford-1, in the upper part. These three events may be correlative with transgressive conditions during the early Aptian, late Aptian and early Albian recorded elsewhere in the Eromanga Basin (Morgan, 1980).

Again the shoreline must have been distant from the sites being discussed and thus mixing by currents and by bioturbation may have significantly altered the distribution of pollen and spores in the sediment.

Coorikiana Sandstone (Kmk)

The Coorikiana Sandstone was originally defined as a basal member (Coorikiana Member) of the Oodnadatta Formation, with a type area at Coorikiana Creek, southwest of Oodnadatta (Freytag, 1966). It was later renamed the Coorikiana Sandstone Member (Pitt and Barnes, 1973), then elevated to formation status (Thomson, 1980; Moore and Pitt, 1982). The unit is equivalent to the Attraction Hill Sandstone Member of the Marree Formation (now Marree Subgroup), which Forbes (1966) defined in the area east of CURDIMURKA. Coorikiana Sandstone is restricted to the southwestern part of the Eromanga Basin; in the central basin, marine shales of the upper Wallumbilla Formation are equivalent (**Fig. 4**).

On CURDIMURKA, Coorikiana Sandstone outcrops around the northern end of the Alberrie Creek plateau, and extends eastwards through Wangianna where it has been described by Aldam (1986). It also occurs at the outlets of Warriner and Wergowerangerilinna Creeks on the southern shore of Lake Eyre South, and in the bed of Warriner Creek near Anchor Rise. Between here and Lake Callara, outcrops are limited to the margins of salt lakes.

Thicknesses interpreted from water well logs range from 8.2 m

(Prices Bore) to 15 m (Muloorina-1; Forbes, 1984). In the southwestern Eromanga Basin, geophysical logs of oil and gas wells indicate thicknesses of up to 18 m (Moore et al., 1986). In the Alford-1 stratigraphic drillhole, lithological and geophysical logs indicate a thickness of 9.85 m (**Fig. 7**).

In most areas, both upper and lower boundaries of Coorikiana Sandstone are conformable. The Alford-1 lithological log shows a relatively sharp, though conformable, contact with Oodnadatta Formation; the lower boundary with Bulldog Shale is of a more transitional nature.

Lithology

Coorikiana Sandstone in Alford-1 consists of pale to medium grey, thin-bedded, very fine to very coarse sandstone with interbeds of very fine to fine sandy siltstone and claystone, and clayey sandstone. The sandstone is micaceous and slightly carbonaceous, and the coarser layers are generally well sorted, with subangular to subrounded grains. A pebbly layer includes a quartz pebble and a probable siltstone cobble.

Petrographic examination of a clayey, very fine sandstone (6438 RS 468) from Alford-1 reveals "glauconite" and clay pellets, and angular quartz and feldspar grains in a clay matrix (Radke and Brown in Rogers et al., 1989). The "glauconite" pellets are probably composed of smectite (see Radke in Kwitko, 1986).

Most outcrops of Coorikiana Sandstone consist of very fine to medium sandstone similar to that encountered in Alford-1. The sandstone is feldspathic, "glauconitic", micaceous and carbonaceous, with minor interlayered dark grey carbonaceous clay and grit. Tabular calcareous concretionary zones are common. Sedimentary structures include medium-scale cross-bedding (tabular, low-angle and festoon), ripple marks and ripple cross-lamination, cut and fill structures, parallel lamination, clay intraclasts, burrows and trails.

At the northern end of the Alberrie Creek Plateau, and further eastwards, the Coorikiana Sandstone contains thin layers of pebble conglomerate. These coarser lithologies are best developed on both sides of the mouth of Wergowerangerilinna Creek, where several conglomerate layers up to 0.5 m thick interfinger with fine to medium sandstone. The conglomerates consist largely of flat, rounded, concretionary ferruginous mudstone pebbles with imbricate structure, in a coarse sandy matrix (**Plate 14**). Angular Adelaidean quartzite and quartz pebbles, and fossil wood fragments with "Teredo" - style borings are common (**Plate 15**).

Some conglomerate layers have sharp eroded lower surfaces, which slope gently at 5^{o} to 10^{o}. On the west bank of the mouth of Wergowerangerilinna Creek, a basal pebbly layer of Coorikiana Sandstone disconformably overlies Bulldog Shale, and, at one location, vertical cracks in the upper surface of Bulldog Shale are infilled with coarse sand from the overlying unit.

The coarse conglomeratic facies seen on CURDIMURKA is similar to the type section of Attraction Hill Sandstone Member. At Attraction Hill, however, the pebbly facies is thicker and highly ferruginised, and fossil wood is absent.

Palaeontology and Age

Although Coorikiana Sandstone contains evidence of animal activity in the form of burrows and trails, it is sparsely fossiliferous and small bivalves are only occasionally seen. Maccoyella sp. occurs at the mouth of Wergowerangerilinna Creek, but these could be reworked from Bulldog Shale. Scarce vertebrate remains, including shark teeth (**Plate 16**) and a reptilian tooth, are associated with conglomeratic layers.

Calcareous siltstone and very fine sandstone from Blue Bush Dam (S5793) yielded a palynoflora which could be assigned to either the Crybelosporites striatus or lower Coptospora paradoxa Zones (Alley, 1984b; Alley and Rogers, 1985). This indicated an early to middle Albian age for the sample, which was interpreted to have come from either Coorikiana Sandstone or the immediately overlying beds of the Oodnadatta Formation. Further material from the sample has been examined, and this palynoflora produced rare angiosperm pollen and a marker spore Pilosisporites grandis. This assemblage is assigned to the upper Coptospora paradoxa Zone, confirming that the sample probably came from the upper Coorikiana Sandstone or lower Oodnadatta Formation.

Samples of Coorikiana Sandstone from Alford-1 contain Coptospora paradoxa and Pilosisporites grandis in the absence of Phimopollenites pannosus, and are assigned to the upper C. paradoxa spore-pollen Zone. The presence of Canninginopsis intermedia in a sample from

35.5 m indicates that the formation here can be assigned to the Muderongia tetracantha dinoflagellate Zone (Rogers et al., 1989). These results indicate a middle Albian age for the Coorikiana Sandstone.

Interpretation

The Coorikiana Sandstone is a sand sheet with a coarsening-upward profile that can be traced for over 1000 km around the southwestern margin of the Eromanga Basin. The formation is interpreted as a regressive, nearshore to shoreface deposit (Moore and Pitt, 1985) which was laid down in a shallow epicontinental sea, in response to a eustatic fall in sea level (Morgan, 1980). The restricted marine conditions caused by the falling sea level are reflected in the reduced molluscan fauna and the low frequencies and diversity of microplankton.

There is little quantitative palynofloral evidence available from which the palaeoclimate prevailing during deposition of Coorikiana Sandstone can be inferred. In general, assemblages are similar to those in Bulldog Shale suggesting that similar conditions prevailed. Angiosperms became established during the interval of time represented by Bulldog Shale, and they continued to diversify during deposition of Coorikiana Sandstone. Perhaps this implies that climate also continued to ameliorate.

Lithology and sedimentary structures point to a moderate to high energy, intertidal environment of deposition for most of the unit. The conglomerate layers probably represent gravel bars and beaches, and tidal channel deposits which may have formed close to river mouths.

A drop in sea level would have caused stream rejuvenation, resulting in an influx of terrigenous clastics into the Eromanga Basin. The sea level fall would also have exposed older Cretaceous units, notably Bulldog Shale, to the effects of subaerial and submarine erosion in marginal basin areas. In fact, much of the coarse clastics, including the ferruginous pebbles, is likely to have been reworked from the Bulldog Shale.

Oodnadatta Formation (Kmo)

The Oodnadatta Formation was defined by Freytag (1966) from a type section at Mount Arthur, east of Oodnadatta. Originally, the formation included lower and upper sandy members, and a calcareous member. The lower sandy member is now the Coorikiana Sandstone, and the upper sandy unit (Mount Alexander Sandstone Member) is now considered to be equivalent to Mackunda Formation (Moore and Pitt, 1985). Sandy beds overlying Oodnadatta Formation on CURDIMURKA are mapped as Mackunda Formation. Therefore, the top of Oodnadatta Formation as mapped on CURDIMURKA would fall at the base, rather than at the top, of the Mount Alexander Sandstone Member.

The calcareous unit in the Oodnadatta area is the Wooldridge Limestone Member, which may be equivalent to the Toolebuc Formation. These units are restricted to the more central part of the Eromanga Basin, and are not recognised on CURDIMURKA.

The Oodnadatta Formation is poorly exposed in the map area, except at the northern end of the Alberrie Creek Plateau, where a sequence about 5 m thick overlies Coorikiana Sandstone.

There are very few drillholes on CURDIMURKA that fully penetrate Oodnadatta Formation. The unit is estimated to be 229 m thick in Jackboot Bore, but this interval probably includes some Mackunda Formation. Forbes (1984) records a thickness of 77 m in Muloorina-1, and in Clayton-2, on the adjoining MARREE sheet, estimated thickness is 114 m (Smith et al., 1985). During stratigraphic drilling on CURDIMURKA, the lower part of the unit was cored in Alford-1, and the upper part in Crowsnest-2 (**Fig. 7**). The Oodnadatta Formation is generally conformable with both overlying and underlying units.

Lithology

In Alford-1 and Crowsnest-2 drillholes, Oodnadatta Formation consists of pale to medium grey claystone with laminae of silt and very fine sand, and minor fine sandstone. Bedding is generally thin, lenticular, and often disturbed by bioturbation. The sediments are slightly carbonaceous and finely micaceous, and contain mollusc shells and shell fragments.

X-ray diffraction of a claystone sample (6438 RS 467) from basal Oodnadatta Formation in Alford-1 shows a composition of dominant smectite with minor mica/illite, kaolinite, quartz and chlorite (Radke and Brown in Rogers et al., 1989).

In outcrop, the formation consists of laminated and thin-bedded pale to medium grey and green-grey claystone, siltstone and minor fine sandstone. Sedimentary structures include parallel and lenticular bedding, ripple cross lamination and possible cut and fill structures (Aldam, 1986). Other features seen in outcrop include calcareous and ferruginous concretions, cone-in-cone limestone and celestite-barite veins.

Palaeontology and Age

Very few macrofossils (rare belemnites) were seen in the Oodnadatta Formation during field mapping. This may reflect poor exposure and weathering of the unit, which elsewhere has a diverse molluscan fauna. The basal part of Oodnadatta Formation cored in Alford-1 is also sparsely fossiliferous. The upper part of the unit in Crowsnest-2, however, contains a rich fauna, including an ammonite, belemnites, a scaphopod, a possible echinoid, gastropods, and abundant bivalves dominated by the genus Inoceramus.

Ludbrook (1966) records a foraminiferal microfauna of Haplophragmoides chapmani, H. dickinsoni and Verneuilinoides crespinae from lower Oodnadatta Formation near Mt Alford. However, these three species are widely distributed in the Aptian and Albian, and do not give direct evidence of an Albian age.

A calcareous concretion from the Oodnadatta Formation north of Lake Callara (S 5792) yielded a diverse palynoflora assigned to the Phimopollenites pannosus and lower Appendicisporites distocarinatus Zones, indicating a late Albian or younger age. Other elements present in the microplankton assemblage suggest a correlation with the Pseudoceratium ludbrookiae Zone, which is consistent with the above conclusion (Alley and Rogers, 1985).

Another concretion collected 7.5 km south-southeast of Eyre Lookout (S6267) contained a spore/pollen assemblage and a restricted dinoflagellate assemblage belonging to the upper part of the Coptospora paradoxa Zone (Alley, 1986c).

Cuttings from the interval in Muloorina-1 assigned to the Oodnadatta Formation (S5871-5873) yielded dinoflagellates which may belong to the Canninginopsis denticulata and Pseudoceratium ludbrookiae Zones (Alley, 1984a).

Samples of core from the formation between 26.7 m and 30.7 m in Alford 1 contain Coptospora paradoxa and Pilosisporites grandis but lack Phimopollenites pannosus, indicating a correlation of the assemblages with the upper C. paradoxa Zone. The microplankton can be placed in the interval spanning the Muderongia tetracantha, Canninginopsis denticulata and Pseudoceratium ludbrookiae Zones (Rogers et al., 1989).

A sample from 69.7 m in Crowsnest 2 contains Coptospora paradoxa in the absence of Phimopollenites pannosus, thus this assemblage is correlative with the C. paradoxa Zone. The Oodnadatta Formation above this level contains P. pannosus, and the assemblages are assigned to that zone. The presence of Pseudoceratium ludbrookiae in the absence of Xenascus asperatus indicates that the microplankton assemblages are correlative with the P. ludbrookiae dinoflagellate Zone (Rogers et al, 1989).

The palynofloras and the zonations indicate an age range for the Oodnadatta Formation of middle to late Albian, which is in accord with age determinations from other parts of the basin.

Interpretation

The lithology, sedimentary structures and fossil content of the Oodnadatta Formation indicate that it was deposited in a quiet, shallow water marine environment.

Plant species diversity remains much the same as found in older formations, although a number of different species of pollen of unknown affinity appear and often become a significant part of the assemblages.

The importance of the gymnosperms continued to decline, this trend being made up for by increasing ferns. Araucaria and Classopollis are present only in very low frequencies, although the ginkgos are better represented. The podocarps and Microcachrys decline, relative to what is found in older formations. A few species of angiosperms are consistently present, although their modern affinities are unknown.

Ferns achieved greater dominance than during the Late Jurassic and earlier Cretaceous intervals. Herbaceous plants were also common, in particular the bryophytes in Toodla 1, and this may be due to localised peat bogs in that area, although Sphagnum produces abundant, resistant spores and thus may be over-represented in the palynofloras.

Microplankton are moderately to very common in the lowest part of the formation in both Toodla 1 and Alford 1, but their frequency declines rapidly higher in the sequence in Toodla 1. This implies that regressive conditions followed a higher stand of the sea during which deposition of the oldest part of the formation had occurred.

Again, what influence sea level changes had on the distribution of pollen and spores in the basin of sedimentation (and thus on palaeoclimatic interpretations) is unknown.

Mackunda Formation (Ka)

Vine and Day (1965) defined the Mackunda Formation as a transitional marine to paralic unit between the marine Allaru Member (now Allaru Mudstone) and freshwater Winton Formation in the northern Eromanga Basin.

Mackunda Formation is now recognised in the southwestern Eromanga Basin, and has been mapped on CURDIMURKA. The formation is regarded as an equivalent of the Mount Alexander Sandstone Member of Freytag (1966), and the lower fossiliferous part of Blanchewater Formation in the Marree area (Forbes, 1966).

Mackunda Formation is exposed in the Belt Bay area, at Lake Bowman and in small saltpans south of Jackboot Bore. It also outcrops in the Eyre Lookout area and further east on Muloorina.

The lower part of the formation has been intersected in Jackboot Bore and Crowsnest-2 (**Fig. 7**) and a total thickness of 86 m was interpreted in Muloorina-1 (Kwitko, 1986). A complete sequence of Mackunda Formation cored in Clayton-3 on the adjoining MARREE sheet is 57 m thick (Kwitko, 1986).

Lithology

The Mackunda Formation in Crowsnest-2 consists of two sandy units separated by an interval of fossiliferous claystone and siltstone. Several thin calcareous mudstone and limestone horizons up to 0.5 m thick are also present.

The sandy units comprise medium to dark grey very fine sandstone, and interlayered very fine sandstone and claystone. The sandstone is thinly to very thinly bedded and cross-bedded, with intraclasts and minor thin layers of claystone. Lenticular bedding and bioturbation are features of the interlayered very fine sandstone and claystone. The sandy sediments are generally micaceous and carbonaceous.

Petrographic examination of sandstone samples (6439 RS 101,103) shows a composition of oxidised "glauconite" (probably smectite) and clay pellets, with angular grains of quartz and minor fresh feldspar, in a clayey matrix (Radke and Brown in Rogers et al, 1989).

The intervening fine-grained unit consist of medium grey claystone and pale grey siltstone. These sediments are bioturbated and finely micaceous. X-ray diffraction of a clay sample (6439 RS 102) from this interval indicates the presence of dominant smectite, with lesser quantities of kaolinite, quartz, chlorite and mica/illite (Radke and Brown in Rogers et al, 1989).

The Mackunda Formation exposed at Belt Bay consists of thinly-bedded and laminated claystone, siltstone and very fine to fine sandstone overlying a prominent sandstone unit. The sandstone is yellow-grey, silty, and very fine to fine grained, with medium-scale, low-angle cross-bedding and zones of large, irregular, tabular calcareous concretions (**Plate 17**). Clay intraclasts and wood fragments are also present. The top of the sandstone unit in some places is marked by a thin carbonate horizon.

The sediments in Crowsnest-2 and at Belt Bay represent the lower part of the Mackunda Formation. The upper part of the unit is less well-exposed on CURDIMURKA. However, sections near the mouth of Morris Creek, east of Eyre Lookout, are close to outcropping Winton Formation and are presumably high in the Mackunda Formation. These sections consist of grey and yellow-grey, irregularly layered and bioturbated siltstone, claystone and very fine sandstone with plant fragments.

Palaeontology and Age

Mackunda Formation contains only rare macrofossils, mainly bivalves. A small shellbed in calcareous siltstone and very fine sandstone outcropping near Crows Nest Bore contains belemnites, bivalves and gastropods. An ophiuroid (brittlestar) was found in core from Crowsnest-2.

At Belt Bay, a shellbed in calcareous very fine to fine sandstone contains the bivalve Inoceramus sutherlandi (J. Morton, SADME, pers. comm.). Ludbrook (1966) assigns an Albian age to this species. Inoceramus is also common in the fine-grained interval in Crowsnest-2.

Mackunda Formation from Lake Bowman (S5992) yielded a palynoflora which is assignable to either the uppermost *Coptospora paradoxa* Zone, or the two succeeding zones (Alley, 1985b).

A sample (S5870) from Muloorina-1, which Forbes (1984) places in the Mackunda-Winton interval, yielded a dinoflagellate assemblage that may lie within the *Pseudoceratium ludbrookiae* and *Xenascus asperatus* Zones (Alley, 1984a).

Samples of Mackunda Formation from the Crows Nest Bore area and Morris Creek (S6266, 6268, 6277-8) contain palynofloras that can be assigned to the *Phimopollenites pannosus* and lower *Appendicisporites distocarinatus* Zones. Here also, the marine microplankton component is restricted, with the assemblage suggesting correlation with the *Pseudoceratium ludbrookiae*, *Xenascus asperatus* and lower *Diconodinium multispinum* Zones. These results indicate a late Albian to earliest Cenomanian age (Alley, 1986c).

In Crowsnest 2, the Mackunda Formation contains *Phimopollenites pannosus*, and is assigned to that Zone. Although microplankton frequencies are generally low to very low, the presence of *Pseudoceratium ludbrookiae* in the absence of *Xenascus asperatus* indicates that the assemblages are correlative with the *P. ludbrookiae* Zone. These zonations indicate a late Albian age for the Mackunda Formation in Crowsnest 2 (Rogers *et al*., 1989).

Elsewhere in the Eromanga Basin, a latest Albian age has been assigned to the Mackunda Formation (Moore and Pitt, 1985).

Interpretation

The sandy units of the Mackunda Formation show a marked lithological resemblance to Coorikiana Sandstone, and are similarly interpreted as regressive shoreface units. The Mackunda Formation in Crowsnest 2 consists of shoreface sand bodies alternating with bioturbated and irregularly layered subtidal sand and mud. The sequence is interrupted by a thin fossiliferous marine mudstone which probably marks a minor transgression. A similar transgressive interval may occur in the top 3m of core in Crowsnest-2. The sequence in Crowsnest-2 is broadly similar to the lower part of Mackunda Formation cored in Clayton-3 (Unit No. 6539-10) (Kwitko, 1986).

The lithology and sedimentary structures of the Mackunda Formation generally indicate a low to moderate energy environment of deposition. Small to medium-scale cross-bedding, clay intraclasts and detrital wood fragments in the sandstone units indicate moderate current flow.

The Mackunda Formation was laid down during a predominantly regressive period at the end of the Albian, interrupted by two minor transgressions. Although insufficient palynological information is available to recognise these minor transgressions, the low frequency and species diversity of the microplankton supports the sedimentological evidence for restricted to shallow water conditions.

Only scant quantitative palynological information is available from Mackunda Formation in the southern Eromanga Basin. These data, however, suggest that the more temperate conditions inferred during deposition of Oodnadatta Formation continued to prevail. Palynofloral assemblages are dominated by pollen of the gymnosperms and spores from ferns, particularly tree ferns. Of the conifers, pollen of the podocarps is the most common while Microcachrys is greatly diminished and Classopollis is rare. Overall, the vegetation association appears dominated by forest types and herbaceous taxa are only poorly represented.

Winton Formation (Kw)

The Winton Formation was named by Whitehouse (1955) for freshwater sediments with coal seams encountered in bores near Winton in central Queensland. It is equivalent to the upper part of the Blanchewater Formation (Forbes, 1966).

Outcrops of Winton Formation are restricted on CURDIMURKA to the lower reaches of Morris Creek, near Three Mile Well on Frome River, and near the mouth of Nelly Creek, where a 5 m section is overlain by Eyre Formation.

Kwitko (1986) has interpreted a thickness of 88 m for the Winton Formation in Muloorina-1 water well. The unit has also been cored in Lake Eyre Bore 8A (Johns and Ludbrook, 1963) and in the bottom of Muloorina-2 drillhole (**Fig. 7**). A section of Winton Formation, 29 m thick, was cored in Clayton-3 on MARREE (Kwitko, 1986). The formation attains a maximum thickness of about 1200 m in the southeastern Eromanga Basin (Moore and Pitt, 1985).

Winton Formation is transitional and conformable with the underlying Mackunda Formation, and is generally unconformably overlain by Cainozoic deposits.

Lithology

Outcrops of Winton Formation consist of laminated dark grey claystone and pale grey siltstone to very fine feldspathic sandstone. The sediments are carbonaceous, with abundant plant fragments. Lamination is irregular and wavy, and is disturbed by slumping, microfaulting and bioturbation (**Plate 18**).

The formation in Lake Eyre Bore 8A comprises carbonaceous greenish silty claystone, laminated very fine to fine sandstone and grey to dark grey claystone (Callen, 1983). The sequence includes several dolomitic layers, 0.6 - 0.9 m thick (Johns and Ludbrook, 1963).

The Winton Formation in Clayton-3 is a laminated to medium bedded sequence of claystone, siltstone and very fine to fine sandstone. Clay intraclasts are present, and the sandstone layers show small-scale (ripple) cross-bedding. There are occasional thin (0.02-0.05 m) horizons or concretions of off-white silty dolomite (Kwitko, 1986).

Kwitko (1986) records a thin (less than 1 m) coal seam in Muloorina-1. Drilling of Winton Formation in the "Clayton" H.S. area (MARREE) has revealed the presence of several thin discontinuous coal seams, 0.02 - 1 m thick, of lignitic to sub - bituminous rank. The coal seams are interbedded with highly carbonaceous clay.

Palaeontology and Age

Palynofloras from the Winton Formation elsewhere in the Eromanga Basin are correlated with the upper Phimopollenites pannosus and Appendicisporites distocarinatus spore/pollen zones of Helby et al. (1987), indicating an age range for the unit from late Albian to Cenomanian (Moore and Pitt, 1985; Dettmann and Williams, 1985). A preliminary assessment of palynofloras from the formation in Nelly Creek indicates that they correlate with the Phimopollenites pannosus zone. This implies that the sediments are late Albian and that only the older part of the formation is present in the exposure.

Although plant fossils, including wood, are common in Winton Formation, no other macrofossils have been recorded on CURDIMURKA. However, the formation elsewhere contains freshwater bivalves, lungfish and dinosaur remains (Moore and Pitt, 1985; Ludbrook, 1985).

Interpretation

The Winton Formation was deposited in a low-energy fluvial to lacustrine environment consisting of sluggish streams meandering through broad floodplains dominated by lakes and marshes. Coal seams and associated highly carbonaceous clays resulted from the accumulation of plant material in swamps and lakes. Rivers carried an influx of terrigenous clastics into the basin.

The origin of the dolomitic layers recorded in Lake Eyre Bore 8A and Clayton-3 is uncertain. They may have originally been limestone deposited in response to lacustrine plant growth, and later dolomitised by magnesium-rich groundwater. The dolomitic layers may be comparable with the "Betoota limestone horizon" which Wopfner (1960) records at a higher level in Winton Formation in the far northeast of the State.

The only palynofloral evidence for palaeoenvironment of Winton Formation on CURDIMURKA is restricted to one sample from the lower part of the unit in Nelly Creek. Here, pollen from the conifers forms almost 60% of the assemblage, of which *Microcachrys*-type pollen is the most abundant. The podocarps are well represented, but ginkgo and araucarian pollen are present only in very low numbers. Fern spores are common, but the spores of tree ferns are reduced in frequency compared with older Mesozoic units. Herbaceous plants appear diverse but form only a small part of the vegetation assemblage. Rare pollen from two species of angiosperms and well preserved megaspores from freshwater ferns are present.

In view of the fluvial origin of a large part of Winton Formation, flowing streams are likely to have played a significant role in the transportation of palynomorphs. Therefore, the assemblage in Nelly Creek probably contains pollen derived from the whole drainage basin, not just from the local vegetation. Hence, the preponderance of *Microcachrys* may be related to longer distance transport of pollen from adjacent forested uplands. The abundance of this pollen, however, implies that cool, temperate conditions may have prevailed and that the uplands, at least, may have supported a subalpine vegetation assemblage. Freshwater lakes and extensive swampland vegetation are suggested by the common occurrence of megaspores from freshwater ferns. The presence of spore tetrads and layers of wood (branches and small trunks) indicates that vegetation grew very close to the site of deposition at Nelly Creek.

Palynofloras from Winton Formation in Clayton-3 have also been studied (Alley, 1986b). Here, spores of the pteridophytes dominate, especially tree fern spores (almost 50% in one sample). Conifer pollen is again very common with Microcachrys being the most important genus, although not to the same extent as at Nelly Creek. Angiosperm pollen is more diverse and megaspores of aquatic ferns occur consistently in all samples. These factors, along with the greater diversity of spores from schizaeaceous ferns in the younger parts of the formation, suggest that temperatures may have warmed into the Cenomanian.

An increase in the rate of subsidence in the depocentre overlying the Cooper Basin resulted in the accumulation of up to 1200m of Winton Formation. This represents a fivefold increase in the rate of sedimentation, compared with the Bulldog Shale-Mackunda Formation interval. Deformation structures (slumping and microfaulting) may reflect this more rapid rate of sedimentation. Much thinner sequences of Winton Formation were deposited on the more stable marginal areas of the basin, including CURDIMURKA.

Mount Howie Sandstone Equivalents (Kh)

Wopfner (1963) defined the Mount Howie Sandstone as a sequence of fluvial channel sediments, up to 45 m thick, which locally overlies Winton Formation in the far northeast of South Australia (CORDILLO). The formation consists of large-scale cross-bedded, medium to coarse quartz sandstone with interbeds of shale and shale conglomerate composed of clasts reworked from the Winton Formation. The contact with Winton Formation is a sharp and irregular erosional disconformity. The unit contains plant fossils of possible Mesozoic affinities, and Wopfner (1963) regarded the Mount Howie Sandstone as Turonian or younger in age. Outcrops of the formation also occur in the Innamincka and Gason Domes.

Forbes (1972) records possible equivalents of Mount Howie Sandstone in the "Clayton" H.S. area and elsewhere on MARREE. These equivalents are lithologically similar to the type section on CORDILLO, and also occupy a similar stratigraphic position between Winton and Eyre Formations.

Lake Eyre Bore 20 (LAKE EYRE) passed through a 12.5 m sequence of clay, silt and fine to medium sand which was assigned a Turonian or possible Senonian age. Johns and Ludbrook (1963) regarded these sediments as conformable with the underlying Winton Formation.

Forbes (1984) records a sequence, approximately 20 m thick, of fine to very coarse sand at the top of the Cretaceous section in Muloorina - 1. A sample from the upper part of this unit (S5897) yielded an assemblage of spores and pollen that is tentatively assigned to the Phyllocladidites mawsonii Zone of Turonian to Coniacian age (Alley, 1984a).

Interpretation

Uplift at the end of the Cenomanian caused a change in depositional regime from a widespread, low-energy fluvial-lacustrine environment (Winton Formation) to localised, high-energy fluvial channels (Mount Howie Sandstone and equivalents). The increase in gradient of the drainage caused an increase in flow rates, allowing the streams to erode into the Winton Formation, and deposit layers of clasts reworked from the underlying fine-grained sediments. Uplift appears to have extended to source areas as well, which supplied coarse quartz-rich clastics to the fluvial channels.

It is possible that there was continuous sedimentation between Winton Formation and younger Cretaceous deposits at a few locations, e.g. Lake Eyre Bore 20.

PRE-TERTIARY WEATHERING

A pallid zone, associated with termite burrows is developed on Cretaceous sediments but is poorly represented on CURDIMURKA. The burrows show characteristic features associated with exploitation by termites of moisture from a fluctuating watertable. They consist of vertical tubes descending several metres, back-filled with termite pellets, and with horizontal galleries at former water table levels. Gypsum veins developed, and are sometimes replaced by alunite. Ferruginous mottles developed in the southwest.

Grey, massive silcrete developed on Cretaceous sandstone, and white porcellanite on claystone. These duricrusts were almost completely eroded during the early Tertiary, and some of the detritus occurs as silcrete pebbles at the base of the Eyre Formation.

TERTIARY

The extensive Lake Eyre Basin occupies the northeastern part of South Australia, corresponding approximately to the Simpson - Tirari Desert and Strzelecki Desert areas (**Fig. 3**) and is roughly the Cainozoic counterpart of the Mesozoic Eromanga Basin. It is divided into two subbasins by the Birdsville Track Ridge, which is surficially expressed as the Cooryanna and Gason Domes. The two subbasins are the Tirari Subbasin to the northeast and the Callabonna Subbasin to the east and southeast. The southernmost part of the Tirari Subbasin lies on CURDIMURKA.

The Tirari Subbasin contains up to 200 m of Tertiary sediments, comprising the arenaceous Eyre Formation and the clay-carbonate Etadunna Formation, largely buried beneath up to 20m of Quaternary aeolian, fluviatile and playa deposits (**Fig. 8**). Subsidence of the Lake Eyre - Simpson Desert region continued from the Cretaceous, becoming rapid during the Eocene, and slowing to a minimal rate during the Quaternary.

Between the Davenport-Willouran Divide and the Stuart Range is the Billa Kalina Basin, a smaller basin which contrasts with the Tirari Subbasin in containing a much thinner sequence which has been considerably eroded (**Fig 8**).

The Billa Kalina Basin contains the Willalinchina and Watchie Sandstones, both comprising arenaceous fluvial/lacustrine sediments, and the Mirikata Formation, which resembles the Etadunna Formation. The top of the Tertiary sequence throughout these basins is silicified and cemented with carbonate, and is often ferruginised.

The Poole Creek `Palaeochannel' is a complex set of channel fill deposits of Middle Eocene to late Pleistocene age (**Figs. 9, 10**), occupying a topographic low which trends north-northwest from the Willouran Ranges.

Nothing is known of the Paleocene landscape, but during the Early and Middle Eocene (**Fig. 11**) the Willouran ranges had low relief, with a few basement highs projecting above a veneer of mainly Mesozoic sediments. Sediment was transported south from the Davenport-Willouran Divide across the Billa Kalina Basin and possibly through the Lake Labyrinth area on KINGOONYA, and also north into the Lake Eyre Basin. While the Lake Eyre Basin continued to sink, the Billa Kalina Basin remained high in the landscape. Old northwesterly trending faults continued to control sedimentation, and northerly trending structures appeared.

During the Eocene, swamps and streams were surrounded by abundant and locally diverse vegetation comprising Myrtaceae (including *Eucalyptus*), grevilleas, banksias, ferns, *Podocarpus*, *Nothofagus* and *Brachychiton*, in addition to broad-leaved species typical of rainforest and woodland in tropical regions of Australia (Callen *et al*., 1986; Lange, 1980, 1982).

Eyre Formation (Tee)

The Eyre Formation (Wopfner *et al*., 1974) is a widespread and distinctive unit of carbonaceous, loose, cross-bedded sand identified in many bores in the northern part of the sheet and exposed in the lakes between Jackboot Bore and Goyder Channel. It is also found near the surface of Lake Eyre South, and occurs as sporadic outcrop, often silicified, north of the Willouran Ranges. It can be distinguished from other sandstone units in the region by its maturity, and presence of polished siliceous pebbles at the base. It is about 100 m thick in the major depocentre beneath the Tirari Desert, northeast of the sheet area, and thins out across central CURDIMURKA. The Eyre Formation lies unconformably on Mesozoic sediments and is overlain unconformably by the Miocene Etadunna Formation.

Lithology

Arenites are dominant, ranging from fine to very coarse sand, with basal scour surfaces covered with granule to small cobble-sized clasts. In the subsurface, the arenites are pyritic and carbonaceous, and beds of lignite or lignitic montmorillonite clay may be present. Typically, grains have high sphericity but relatively low roundness (subrounded to subangular), and the sands are mineralogically mature. A characteristic feature are the layers of polished siliceous clasts, including quartz, agate, fossil wood, black 'chert' and silcrete. The largest and most abundant clasts of this type are located to the east of Mt. Alford.

Ferruginisation of the lower Eyre Formation is widespread, but nodular and boxwork structures like those developed in the Mesozoic sequence are absent. This ferruginisation, together with the high degree of rounding of clasts and the frequent presence of silcrete clasts, enables the Eyre Formation to be distinguished from the ferruginous pebbly facies of the Early Cretaceous Coorikiana Sandstone.

Local lithological variations occur in the channels. Greenish-brown, fine-grained floodplain facies or channel fills without a basal lag are rare. These may contain opalized leaves, and are cemented by brittle cherty silica.

Strongly ferruginised basal gravels, containing pebbles and cobbles of Adelaidean lithologies, silcrete and ferruginous Coorikiana Sandstone, occur at Cooranna Bore and elsewhere.

Secondary alteration and cementation is common, with development of massive or cavernous grey to brown silcrete, white kaolin, gypsum and alunite, iron oxides and carbonate. The silcrete and ferruginous horizons probably formed shortly after deposition, and were continually modified by later processes. The iron oxide, present as colloform hematite in secondary cement (Brown et al., 1989), is likely to have formed as a groundwater outcrop precipitate under evaporative conditions (cf boinkas of Macumber, 1980).

Along the margin of the Willouran Ranges are a number of high-level, silicified sandstone mesas (T) such as Flat Hill and Glen Hill. The sandstone is cemented by the "ant nest" silcrete Because of their high topographic level, the mesas are interpreted as remnants of Eyre Formation.

Palaeontology and age

Plant fossils (figs 30-32 of Callen et al., 1986; pp. 129-133 and 139 of Greenwood et al., 1989) are characteristic and locally abundant, including microfossils (spores, pollen, fungi, algae and dinoflagellates), and leaves, fruits and stems. There are two different styles of preservation of macrofossils: (1) impressions in silcrete or replacement by silica, sometimes with preservation of cellular detail, and (2) impressions or mummified remains of leaf cuticle, seeds and wood in carbonaceous sediment at or below the water table. Carbonate casts of plant stems and leaves occur in some areas, particularly Poole Creek palaeochannel, and rare iron-stained impressions are present at Stuart Creek. Silicified leaves occur in flaggy fine grained sandstones or rarely in pebbly scour hollows.

Carbonaceous horizons within the Eyre Formation contain abundant pollen, spores and freshwater dinoflagellates of Late Paleocene to Middle Eocene age.

Previous studies (Wopfner et al., 1974) recognized three palynostratigraphic subdivisions in the Eyre Formation: Gambierina edwardsii Zone (Middle to Late Paleocene), Proteacidites confragosus Zone (early Middle Eocene) and Proteacidites pachypolus Zone (Middle Eocene). Revisions of the palynostratigraphic zonation in southern Australia have modified the ages of these zones to Late Paleocene, late Early Eocene to early Middle Eocene, and Middle Eocene respectively. Subsequently, Sluiter and Alley (in prep.) have proposed a zonation comprising the Proteacidites fromensis Zone (Late Paleocene to Early Eocene) and Nothofagidites falcatus Zone (Middle Eocene).

Most palynofloras have been obtained from drill core, but relatively unaltered Eyre Formation exposed in the lower reaches of Nelly Creek has been assigned to the Nothofagidites falcatus Zone of Middle Eocene age (Alley, 1989). This age can be applied to other areas of Eyre Formation on CURDIMURKA which contain macrofloras comparable with the fossil plants at Nelly Creek.

Late Paleocene palynofloras have so far been recognised only in BMR Muloorina 2 bore (**Fig. 7**), but are expected to be more widespread.

Palynological data indicate that deposition of Eyre Formation was generally continuous, although a local hiatus is recognised between Early and Middle Eocene sediments in BMR Peachawarinna 2 (KOPPERAMANNA) and Minad LC-1A (FROME). However, there is little evidence for the widespread disconformity within the Eyre Formation postulated by Wopfner et al. (1974).

Palaeoenvironments (**Fig. 11**)

The Eyre Formation, particularly the widespread Middle Eocene sequence, was deposited as fluvial sheet sands in large, meandering and braided streams. Near the ranges, the streams cut through the Mesozoic sequence into Adelaidean rocks, forming valley-confined watercourses. These were sand-bed streams, carrying large amounts of sediment in a terrain of relatively low relief, like that of today. Abundant plant fossils include a mixture of rainforest and xeromorphic types (Greenwood et al., 1989), and an analysis of leaf types and taxa suggests monsoonal vegetation. This is in keeping with evidence for abundant sand transport, which is not compatible with a continuous forest cover in a uniform tropical/sub-tropical climate. Rainfall was high and temperatures probably more equable than at present.

Cross-bedding is common, with small to medium-scale crossbeds having straight or curved asymptotic foresets and scoured tops; the foreset strata may be curved in plan in the medium-scale structures. These features represent crescentic and linguoid bars with large ripples or sandwaves, and complex scour hollows (**Plates 19, 20**).

Cross-bedding measurements from ferruginised and silicified channel deposits at Mt Alford, Poole Creek, east of Morris Bore, and at Nelly Creek, indicate westerly to northeasterly current directions. The variation in current directions is attributed to the meandering nature of the braid channels coupled with the slightly sinuous nature of the large bedforms.

Willalinchina Sandstone (Tew)

The Willalinchina Sandstone (Callen et al., 1986) of the Billa Kalina Basin consists of channel-fill arenites with basal silcrete and Adelaidean clasts, and is a probable correlative of the Eyre Formation at Nelly Creek. The unit is up to 10 m thick and is restricted to the Stuart Creek and its headwaters. It rests on rocks ranging from Cretaceous to Adelaidean in age and appears to lens out beneath the Watchie Sandstone (**Fig. 12**).

The Willalinchina Sandstone was previously included in the Watchie Sandstone (Ambrose & Flint, 1981b; Ambrose et al., 1979). It has been separated from that unit on the basis of distinctive lithological features, presence of characteristic plant fossils, and a disconformable relationship with the overlying Watchie Sandstone. The Willalinchina Sandstone has been identified in the same stratigraphic position at Screechowl Creek on Bopeechee (Nicol, 1979).

The areas on Trecompana are geological monuments and have been nominated for National Estate listing. Collecting of fossils and rocks is not permitted.

Lithology

The unit is a cross-bedded, medium to fine-grained sandstone with basal pebbly lags in channels. A finer grained, brown, flaggy sandstone with ripple marks contains plant macrofossils.

Conglomerate, dominated by rough clasts and reworked nodules of silcrete and Adelaidean clasts, forms a prominent horizon near the base of the formation on the north side of the Stuart Creek valley on Trecompana. The top of the unit is characterised by reed-like fossils and is cemented to a massive grey silcrete, known as "reed mould" silcrete (**Plate 21**).

Palaeontology and age

Plant macrofossils (**Plate 22**) are locally abundant and include possible Eucalyptus and other fruits (Lange, 1978; Ambrose et al., 1979). Leaves, stem impressions and seeds are restricted mainly to the silcrete conglomerate.

A characteristic silicified horizon with strap-like impressions and vertical polygonal hollow tubules occurs at the top of the unit. These are monocotyledonous reed-like forms, but some of the tubules do not appear to be organic as they are perfectly parallel and unbranched.

The presence of the strap-like impressions has led to the use of the name "reed mould" silcrete for the silicified cap on these rocks.

The same reed-like fossils occur east of Mt. Alford on Wangianna where they are jointed and up to 10 cm across, and are associated with common branching forms interpreted as roots. Tubers have also been identified.

All the lithofacies found in the Tertiary sandstones of the Stuart Creek valley are duplicated in the Poole Creek palaeochannel (**Fig. 9**), with the same spatial relationships. In particular, the "reed-mould" horizon has been found in low-level sandstone outcrop at the head of Nyaroo Creek on Wangianna, with the same relationship to the "ant nest" silcrete of the Watchie Sandstone (see below) as at Stuart Creek. Both lithology and plant macrofossils are similar, and can be correlated with the Nelly Creek outcrop, indicating a Middle Eocene age.

Palaeoenvironments (**Fig. 11**)

The Willalinchina Sandstone was deposited in a fluvial channel environment, cutting through Mesozoic sediments into Adelaidean rocks at Stuart Creek. Current directions are variable, although some channels in the Wirragilpina Dam area (southwestern Trecompana) have consistent palaeocurrent directions to the south west, towards the centre of the Billa Kalina Basin. The overall pattern of outcrop in Stuart Creek suggests that streams drained towards the Lake Eyre Basin, although they may have reversed with uplift of the Davenport-Willouran Divide.

Vegetation is similar to that preserved in the Eyre Formation, and hence a similar high-rainfall monsoonal climate is envisaged.

Watchie Sandstone (Tw)

The Watchie Sandstone is a sheet of sandstone and siltstone, generally less than 10m thick, which maintains a remarkably persistent lithofacies assemblage in the Billa Kalina Basin.

The type section is located 2km SW of White Cliff on the south side of Stuart Creek valley (Lat. 29°52'21", Long. 136°31'53"), and a supplementary section is located at Ferguson Hill (Ambrose and Flint, 1981b). A detailed description of the type section is given in Callen et al., 1986 (p. 137-8, Figs. 17 & 37, Site 9).

The unit caps the extensive plateau reaching north from Olympic Dam on ANDAMOOKA to the Turret Range on Trecompana, and east to the Willouran Ranges on Bopeechee. This plateau is between 110-130m AHD, and exhibits a pattern of concentric ridges 2-10 m high on its surface. Preferential erosion of the concentric ridges has left the intervening strips of massively silcreted sediment as arcuate mesas (**Plate 23**).

The unit rests on Bulldog Shale with slight angular unconformity (**Plate 24**, **25**), and is overlain disconformably by gypseous gravels (Czg).

The Watchie Sandstone was named by Ambrose and Flint (1981b) as a member of the Mirikata Formation. Although the spatial distribution of Watchie Sandstone in relation to the Mirikata Formation on BILLA KALINA and KINGOONYA suggests the concentric facies distribution of a single lake, there is no firm evidence for correlating the two units. This led Callen et al., (1986) to elevate the Watchie Sandstone to formation status and restrict Mirikata Formation to BILLA KALINA and KINGOONYA.

The reasons for these changes are as follows:

1) The Danae Conglomerate, Millers Creek Dolomite and Billa Kalina Clay Members of the Mirikata Formation are restricted to an area west of the Watchie Sandstone and separated from it by a broad

eroded zone. Hence stratigraphic relations have not been seen.

2) The Danae Conglomerate has been equated with the conglomerate at the base of the Watchie Sandstone, but the clast lithology and overall sediment character differs.

3) The Mirikata Formation and Watchie Sandstone each consists of a unique and distinct lithofacies assemblage which hardly varies over the whole extent of its distribution.

Lithology

The Watchie Sandstone on Trecompana consists of two units, each with a basal grit lag (**Fig. 12**). The lower grit rests on Bulldog Shale, and consists of multicolored quartz granule to pebble beds with rough silcrete clasts and boulders of Adelaidean quartzite reworked from the Bulldog Shale. Rare polished pebbles of silcrete, silicified wood and agate may be present, but clear, milky and yellow quartz, and red and black chert are more common. Rare, thin crossbedded sand layers may be present.

The basal grit is overlain by 1-3m of festoon cross-laminated, and rarely horizontally laminated, siltstone. This grades laterally into, or is cut into, by cross-bedded to horizontally laminated or thin bedded fine sand in the Turret Range. The siltstone is infused with patchy iron oxide, and silicification of this has produced a red porcellanite.

Overlying the siltstone is the upper unit, of coarsening-upwards medium sandstone with some polished silcrete and milky quartz pebbles at the top. A coarser grained sand layer often marks the sharp boundary with the underlying siltstone.

Cementing the sequence are several silcrete layers of varying structure and degree of silicification. The upper layer is the most persistent and is a vughy brown silcrete containing numerous burrows and rhizomorphs ("ant-nest" silcrete)(**Plates 26, 27**).

Age and Correlation

The Watchie Sandstone can be readily distinguished from the Willalinchina Sandstone by the "ant nest" silcrete cap, and the lower siltstone unit with a basal polished pebble lag.

The Watchie Sandstone can be correlated with a very similar sequence at the head of the Poole Creek Paleochannel (**Fig. 9**). At a slightly higher topographic level nearby is a sequence identical to the Mirikata Formation. The relationship between this and the Watchie Sandstone is difficult to interpret because of possible faulting, but it is suggested that the Watchie Sandstone predates the Mirikata Formation, which can be correlated with the Miocene Etadunna Formation further down the palaeochannel. This suggests an Oligocene age for the Watchie Sandstone.

The relationship with Willalinchina Formation is uncertain. The massive grey silcrete (Tsi_1) developed at the top of this unit, but without reed moulds, underlies Watchie Sandstone at two locations (**Fig. 12**, **Plate 28**). This suggests that the Watchie Sandstone is younger than Willalinchina Formation, and was deposited probably between Middle Eocene and Miocene time.

Palaeontology

The commonest fossils are burrows, possibly of insects such as ants, termites and beetles. These are abundant in the "ant nest" silcrete, and in the lower siltstone beds. The burrows vary in width from a centimetre to a few millimetres, and are mostly of irregular shape. Some appear to be feeding traces, others are vertical burrows associated with horizontal galleries and are infilled in the manner of grass termite nests. However, no characteristic termite pellets or insect remains have been found.

Occasional leaf impressions and strap-like "reed" impressions are found.

Palaeoenvironments (**Fig. 11**)

The Watchie Sandstone is a lacustrine sequence comprising, in upwards succession, a local channel-sand facies and widespread lag deposits, a transgressive fine-grained lacustrine facies, and regressive strandline deposits with a wave-base lag. Transgression occurred over a very low-gradient surface. Strandlines are still to be seen on the upper surface, where they incorporate pedogenic silcrete clasts. These were presumably formed by reworking of silicified material near the fluctuating shoreline. The palaeocurrent evidence is consistent with longshore processes and bar accretion onto the foreshore, and storms probably produced larger bedforms. Abundant burrowing animals reworked the sediment.

Silicification and ferruginisation alternated during lake regression. Insects (probably including ants and termites) lived in developing soil profiles, and rhizonodules indicate that plants grew in these soils. The exposed or near- surface silcrete (vadose type) developed pedogenic features, whereas phreatic silcretes remained essentially unchanged.

The arenaceous nature of the unit suggests that it may have been deposited in similar conditions to the Eyre Formation, but the scarcity of plant fossils suggests a more arid environment. It could have formed by reworking of older units such as Willalinchina Sandstone.

The strandline ridges are higher near the outer margins of the area. They would have formed when the lake was larger and deeper, with more energetic shore processes operating (Callen, et al., 1986; Krieg et al., in press). Ridges formed only on the eastern side of the lake, thus winds at this time were essentially westerly, with storms from the southwest, indicating that a strong westerly airstream prevailed in central South Australia (see also Benbow, 1990) at a much earlier time than that proposed by Bowler (1982).

Possible equivalents of Watchie Sandstone

In the Stuart Creek valley and Screechowl Creek on Trecompana and Bopeechee, there are finely laminated siltstone and sandstone units which sometimes contain plant macrofossils. These sediments are overlain sharply by the basal pebbly unit of the Watchie Sandstone, and disconformably overlie Bulldog Shale. They have a thin basal gritty bed containing Bulldog Shale clasts, but no silcrete clasts. At present these sediments are included in the Watchie Sandstone, but may be equivalent to Willalinchina Sandstone, and are best developed in the Stuart Creek area of the Billa Kalina Basin. The unit contains ferruginised plant impressions of a type not found elsewhere on CURDIMURKA, including a bilobate leaf resembling *Ginkgo*.

Etadunna Formation (Tmd)

The Etadunna Formation (Stirton et al., 1961) is a sequence dominated by white dolomitic carbonate with minor claystone, which occurs in the Tirari Subbasin. These sediments are present throughout the northeastern quarter of CURDIMURKA, averaging about 30 m thick in the north, and thinning out along the southern basin margin, where they have been eroded. The unit was deposited between Late Oligocene and Late Miocene time.

Sandy channel facies in the Poole Creek palaeochannel (**Fig 10**) have a silica-carbonate cement which causes them to crop out as prominent ledges near the valley floors. They can be distinguished from the Eyre Formation by the presence of intraformational dolomite clasts, a distinctive macroflora (Greenwood et al., 1989), style of cross-bedding, and absence of polished siliceous pebbles.

Lithology

The most complete sections of Etadunna Formation are in the Lake Eyre Bores (Johns & Ludbrook, 1963), where the unit is mainly dolomite with minor limestone and thin beds of green-grey to bright blue-green dolomitic palygorskite clay. Beds of pure montmorillonite, interstratified montmorillonite-illite and pure illite clay are also present.

At the base is a persistent unit, here named the Muloorina Member, of green calcareous laminated clay and silt with thin beds of fine sand. The type section is in Lake Eyre Bore 4, between 40.23 and 44.5m. Sand and silcrete grains reworked from Eyre Formation occur at the base of the unit. Ferruginisation is probably a result of pyrite oxidation, prior to the deposition of overlying dolomitic beds. The sands may be carbonaceous, with plant microfossils.

Intraformational breccias are typical of the Etadunna Formation, with angular clasts of dolomite, limestone or clay in a matrix of calcareous clay, clayey dolomite or clay. Bioturbation is common and ferruginous mottled horizons, interpreted as palaeosols, are present in the upper part of the unit.

In the headwaters of the Poole Creek Palaeochannel (**Fig. 9**), the Etadunna Formation is represented by thin calcreted limestone and dolomite with siliceous nodules (**Plates 29**, **30**), which overlie channels infilled with silicified sand containing clasts of Adelaidean rocks, Mesozoic sandstone and silcrete, some of which contain fossil plants and are presumably derived from the Eyre Formation or Watchie Sandstone.

The middle part of the Poole Creek Palaeochannel (**Fig. 10**) contains a sequence of nodular dolomite with gypsum casts, thinly interbedded with bright blue-green clay and coarse to fine sand lenses. The basal channel sand lenses fine upwards from a basal lag of milky quartz pebbles, large fossil wood fragments (?reworked from the Coorikiana Sandstone) and intraformational dolomite clasts (**Plate 31**) to fine sand. They contain plant macrofossils near the base.

On top of the clay-dolomite sequence is a thin, horizontally laminated, fine sandstone which grades into a channel facies with well rounded milky quartz pebbles and cobbles in places. Very rare plant fragments are present. The extent of this unit is uncertain but it may include the isolated mesas of sandstone to the east of Poole Creek. The sequence has been cemented by carbonate and silica.

Palaeontology and age

The most common fossils are small irregular burrows with internal laminae that often follow particular horizons. They were probably made by polychaete worms or insects. The burrows vary in diameter from 0.2 cm to 2.0 cm, but are mostly 0.3-0.4 cms. Broad rounded domal stromatolites about 1 m across occur in dolomite in the lakes west of Goyder Channel.

Small gastropods include Coxiella and Coxielladda. Foraminifera and ostracods are also present (Lindsay, 1987), suggesting an occasionally saline environment.

Vertebrates of probable Miocene age have been found in green clay at Snake Dam, immediately east of CURDIMURKA (Callen, et al., 1986). The green clay is correlated with Unit 9 of Stirton et al., (1961), a distinctive pale green clay with abundant vertebrate remains.

Plant macrofossils (stems and leaves) are found in the lower channel facies of the Poole Creek Palaeochannel, and include \`Banksieaeformis III' (possibly a dryland fern)(**Plate 32**), gymnosperms, and Casuarina.

Two samples from the base of the unit in Lake Eyre Bore 20 in Madigan Gulf on LAKE EYRE yielded Tertiary pollen and spores (Johns and Ludbrook, 1963).

A specimen of palygorskite clay from outcrop near Muloorina 2 bore yielded a Rb/Sr date of about 25 Ma (Late Oligocene/Early Miocene) (Norrish & Pickering, 1983).

The Etadunna Formation in the CURDIMURKA area has been correlated by Wopfner et al., (1974) and Callen and Tedford (1976) with the type section at Lake Palankarinna on the basis of similar lithology, but there are important differences. The Etadunna Formation east of Lake Eyre has the characteristic Unit 9 of Stirton et al., (1961), which overlies white dolomite, whereas the unit in the Lake Eyre bores contains a higher proportion of dolomite and includes the persistent basal Muloorina Member. The Etadunna Formation is consistently about 35 m thick, whereas the sequence east of Lake Eyre, including the type section, is 20-25m thick. The type section contains only a sparse palynoflora of possible Late Miocene to Pliocene age at the top, but also contains abundant specimens of a rare species of foraminifera in the basal dolomite, similar to species of Late Oligocene age elsewhere (Lindsay, 1987). Vertebrates are of probable Middle Miocene age (Tedford et al., in Callen et al., 1986). The formation may range in age from Late Oligocene to Pliocene, but is most probably largely Early Miocene.

Palaeoenvironment (**Fig. 11**)

The Etadunna Formation is an essentially lacustrine and fluvial unit, deposited under conditions of low relief and a drier climate than the Eyre Formation. Streams had extensive floodplains and probable deltaic facies (see Callen & Plane 1985), with a more local source than those of the Eyre Formation. Pre-existing valleys were infilled with fine grained sediment, much of it evaporative flood plain-lacustrine in character. Streams drained northwards into the Lake Eyre Basin, and deposited a sandy dark clay facies in floodplains and deltas. Silicification and ferruginisation took place in swampy soils at this time.

Beach deposits associated with the extensive lakes are apparently absent, because of erosion or non-recognition (the beach sands would be difficult to distinguish from the Eyre Formation). However, some silicified shoreline deposits have been recognised at the mouth of the Clayton River (MARREE), north of Bullysandhill Tank on Muloorina, and at Lake "Hydra" (KOPPERAMANNA). They probably formed on regressive shorelines as the lakes dried.

Current directions in the lower Etadunna Formation channel facies of the Poole Creek Palaeochannel indicate deposition within highly sinuous channels with an overall north to northeasterly transport direction. Cross-beds are similar to those in the Watchie

Sandstone, but smaller and more irregular than those of the Eyre Formation. The upper sands are low-angle fan and channel deposits, possibly of a nearshore fluvial environment.

Evaporative magnesium - rich sediments are abundant in sequences of similar age throughout Australia, which are part of a series of world wide events linked to aridity (Callen in Singer and Galan 1984).

An abundance of vertebrate life, including birds, reptiles, browsing and grazing marsupials, and riverine porpoises, is indicated by data from elsewhere in the Lake Eyre Basin (Krieg et al., in press; Callen, in press; Callen et al., 1986), and indicate permanent water and vegetated river banks and shorelines.

Millers Creek Dolomite Member (Tmd)

The Millers Creek Dolomite Member of the Mirikata Formation (Jessup & Norris, 1971; Ambrose & Flint, 1981b) consists of white silicified dolomite and limestone with minor sepiolite, and is restricted to the Billa Kalina Basin.

An isolated patch of the unit occurs on the southern margin of Bopeechee. The Millers Creek Dolomite and Danae Conglomerate Members have equivalents in a sequence in the headwaters of Poole Creek near Cockatoo Bore, which is correlated with the upper part of the Etadunna Formation (**Fig. 9**). Environments of deposition are similar to those of the Etadunna Formation, and are discussed by Ambrose & Flint (1981b) and Cowley & Martin (in preparation).

Silcretes and associated secondary cementation (Tsi_1, Tsi_2, Tsi)

Silcretes have already been mentioned under individual rock units, but because of their importance in the landscape, their preservation of sedimentary structures and fossil plants, and their inferred stratigraphic significance, they are discussed further here. They also reveal something of the groundwater conditions and climate during intervals of non-deposition.

Lithology

Silcretes are secondary silicified rocks usually containing nodular and columnar structures with micro-banding caused by the uneven distribution of quartz, cement types and titania. The cement is generally dominated by cryptocrystalline, often isotropic silica, and detrital grains are generally quartz of silt or sand size. Silcretes are surficial deposits usually forming massive duricrusts.

On CURDIMURKA, silcretes invariably cement regolith material or sediments of Late Cretaceous or Tertiary age. Nearly all of the cemented materials are sandstone or siltstone, although some are claystone and carbonate. The more porous rocks, such as Tertiary sandstone and conglomerate, are silicified to massive columnar silcrete or cavernous silcrete in which corroded quartz grains float in a groundmass of cryptocrystalline to microcrystalline quartz. Nodular structures typically have banded geopetal caps and complex growth structures, including cavities with layered fragmental deposits at the base. These structures indicate vertical, frequently downward movement of silica and are thought to be pedogenic.

In less porous siltstone and shale, much of the detrital quartz is replaced by isotropic silica (quartz or opal C-T). Cavities are lined with banded chalcedony and opal, sometimes with clear quartz crystals in the centres. However, dolomite of the Etadunna Formation often contains grey microquartz silcrete nodules (**Plate 30**) which replace the dolomite, or perhaps infill cavities that formed during solution. This suggests a chemical relationship between host rock lithology and silica type, in addition to a porosity effect.

Another form of silicification forms botryoidal masses up to several tens of metres across and usually parallel to bedding, although smaller nodules tend to be vertically oriented. Its distinctive botryoidal form reflects internal growth layering. This type of silcrete grades into orthoquartzite, and is characterised by microquartz cement and quartz overgrowths on detrital grains. Large scale banding of quartzitic silcrete has been observed parallel to palaeochannel edges in the headwaters of Poole Creek. These `groundwater' or phreatic silcretes contrast with those higher in the landscape which formed in the vadose zone, but there are gradations between the two as a result of falling groundwater level.

Stratigraphy

Stratigraphic relationships of silcretes are difficult to interpret because of their probable association with past groundwater tables, and the lack of detailed knowledge of their mode of origin.

Silcrete horizons occur on the top of, and at various levels within, the Eyre Formation and other Tertiary sandstones. These horizons appear to reflect old soil horizons, groundwater tables and porosity barriers. At Stuart Creek and Screechowl Creek, and in the headwaters of Poole Creek palaeochannel, two prominent and distinctive horizons ("reed mould" and "ant-nest" silcretes) are clearly visible (**Figs. 9, 12**), controlling the landscape forms. The widespread occurrence of these horizons, always in the same relationship and cementing the same beds within the Tertiary sequence, suggests that they are genetically associated with the sediments they cement (Ambrose & Flint, 1981b; Callen, 1983).

Alternatively, although the "reed mould" silcrete occurs beneath the "ant-nest" silcrete (which caps the Watchie Sandstone), it could well be younger, having formed when the groundwater table dropped. The reeds were probably restricted to waterlogged valleys, and although they occur at the top of the Willalinchina Sandstone, they do not appear to extend beneath the Watchie Sandstone whereas the silcrete does. Lateral changes in silcrete from pedogenic vadose types to massive phreatic types suggest that the landscape surface and its relation to the watertable were critical in determining silica types and distribution - anything above the watertable developed pedogenic structures (**Fig. 13**).

Silcrete also occurs as a cap on fine shoreline and channel sands of the Etadunna Formation where they are exposed at the surface. These local occurrences show the same variations as seen in the other silcretes: massive grey nodular forms or crusts with banded structures and cherty chalcedonic types, with extensive nodular carbonate patches. Most of these occurrences are in Poole Creek palaeochannel, or just off the edge of the sheet area on MARREE and KOPPERAMANNA; there are also some at Bullysandhill Tank (Muloorina).

Age

Silcretes contain no materials which are dateable by existing methods. The oldest clasts are at the base of the Middle Eocene part of the Eyre Formation, and the youngest silcretes occur on the Etadunna Formation and are overlain by Pliocene-Pleistocene units, thus giving broad age limits of pre-Middle Eocene to late Tertiary.

The relationship of the "ant nest" silcrete to the beach ridges developed on the top of the Watchie Sandstone shows that the distribution and type of silcrete was controlled by the pre-existing topographic forms, and hence the silcrete is younger than the beach ridges. However, the time gap between deposition and silicification was probably quite short. Thus the age of this silcrete could range from Late Eocene to Miocene.

The age of silcrete on the Etadunna Formation is constrained by the youngest age of the formation (?Late Miocene) and the age of the oldest overlying unit with abundant silcrete clasts. The latter is a gypsified and calcreted high level gravel, equated with the Tirari Formation (Stirton et al., 1968) and Willawortina Formation (Callen & Tedford, 1976). These sediments contain Pleistocene vertebrate fossils, and are older than 0.5 Ma (from TL dating; Callen and Nanson, in prep). Radiocarbon and TL dating of overlying dunes suggests an age older than middle Pleistocene (Callen & Nanson, in prep; Callen et al., 1986).

Another criterion that can be used in dating some vadose silcretes is the mode of preservation of fossil leaves. It has been suggested (Lange, 1978; Ambrose et al., 1979) that the preservation of minute structures including epiphytal fungi and open stomata indicates that the leaves were silicified very shortly after they fell, and therefore that some silicification was contemporaneous with deposition.

Associated secondary cements, and geochemical environment

1. Carbonate cements.

The silcretes are associated with two types of carbonate: (i) white to buff, vertically elongate, botryoidal calcite nodules beneath the silcrete layers in Watchie Sandstone and (ii) massive, grey, coarsely crystalline calcite, cementing sand and associated with both types of silcrete.

Type (i) is not very common; type (ii) is of importance because it reveals something about the complexity of groundwater conditions, of which silicification is one result. Calcite of type (ii) occurs in radially oriented crystals of centimetric scale which often produce a knobbly external surface. These calcite masses cross-cut sedimentary features, indicating a post-sedimentary origin. Pure calcareous sandstone layers may form in some areas. Boundaries with silica cement are gradational and alternating, like those between silcrete nodules and dolomite of the Etadunna Formation. It seems more likely that the carbonate preceded the silica, as silica cement is very difficult to dissolve because of lack of porosity and low solubility. It is possible for the two to be deposited simultaneously, since degassing of CO_2 in the surficial environment will cause precipitation of carbonate, and silica will precipitate if saturation is high. Organic matter (humic and amino acids, and chelates) plays a further role, inhibiting carbonate precipitation, and permitting silica deposition (Mitterer & Cunningham, 1985).

2. Gypsum

Gypsum crystal moulds, with crystal shapes typical of gypsum formed under saline groundwater conditions (Warren, 1982), are preserved in the "ant nest" silcrete, and are sometimes infilled with carbonate. These relationships indicate that the gypsum was already present when silica cementation took place.

3. Ferruginisation

Ferruginisation took place in the "ant nest" silcrete profile before silicification, indicating strongly oxidising and acidic conditions similar to the groundwater outcrop environments existing today in the semiarid zone of Victoria (Macumber, 1980). These would also have been suitable conditions for the solution of silica, which was then later precipitated in the profile as the groundwater became more neutral.

Limestone of the Alberrie Creek plateau (Czl)

The limestone forms a thin sheet capping the Alberrie Creek plateau in the northeast corner of Bopeechee, and rests on Cretaceous sediments. The unit consists of vuggy limestone, and overlies a thin sepiolite zone of altered Cretaceous claystone. The limestone is a boxwork boundstone (Warren, 1982) with flowstone laminae in cavities. Deposition probably took place in a lake fed by mound spring discharge.

The Alberrie Creek plateau has been cut by the cliff associated with the old 10m shoreline of Lake Eyre, discussed below, which indicates that the limestone is at least as old as late Pleistocene. The position of the unit in the landscape and its lithological affinities with the Etadunna Formation suggest that it could be as old as Miocene.

QUATERNARY

During the Quaternary, tectonism and climatic variations, together with erosion and deposition, produced a complex pattern of depositional environments between the Willouran Ranges and Lake Eyre.

Coarse, fluvial and colluvial deposits pass laterally into fine-grained equivalents and then into lake deposits with shoreline features; aeolian and playa deposits represent times of aridity and regional deflation, and the mound spring deposits of various ages are a direct response to faulting and erosional thinning of confining beds overlying the artesian aquifer.

Fluvial and colluvial deposits

Three phases of gravel deposition cap the remnant Tertiary strata of the higher level plains, as demonstrated in BMR Poole Creek 1 and 2 coreholes. The youngest of these is essentially a soil horizon developed on the older surfaces, and is shown as a patterned ground overprint (Qa) on the map.

On Muloorina and Wangianna, lower gravel benches also exhibit three phases, the oldest being younger than the two lower phases in Poole Creek 1 bore. The youngest is probably the equivalent of the younger patterned ground on the high level plains. Thus, there is a total of five alluvial phases in the area.

The high-level gravels are restricted to the tops of old Tertiary plateaus and palaeochannels around the margins of the highlands. Here they are clearly separated from younger low-level gravels, such as those at Welcome Springs. As the gravels are followed downstream, these two levels no longer have vertical separation and the younger gravels rest directly on the older gravels.

High level gravels (Czg)

Lithology

Unit Czg consists of large-scale cross-bedded and poorly bedded medium sand with a coarse well-rounded fraction up to boulder size, but mainly pebble to small cobble size. Clasts include Adelaidean rocks and silcrete, with large boulders of Etadunna Formation carbonate locally common along the Poole Creek Palaeochannel on Wangianna. The unit is patchily cemented by gypsum and diffuse to massive buff carbonate. Greenish- coloured clayey patches and reddish to brownish mottling are common.

To the south of Trecompana, towards Olympic Dam (ANDAMOOKA), massive nodular calcrete with altered siliceous dolomite corestones is developed at the surface of, or within, unit Czg.

Stratigraphy and Correlation

Unit Czg may be equivalent to Tirari Formation or Kutjitara Formation from the Tirari Desert sequence described in Callen et al., (1986). This correlation is based on the assumption that unit Czg is older than unit Qpt at Frome River. The latter is a probable equivalent of the Katipiri Formation, which overlies Kutjitara and Tirari Formations. The widespread Tirari Formation is older than 440 000 yrs BP.

Units Opt and Qpg

The gravel units (Qpt, Qpg) form sheets at a relatively low level in the landscape, and are dissected by modern streams. Where cemented by carbonate or gypsum, low cliffs or breakaway slopes may form.

In the vicinity of Welcome Springs is a large gravel spread (Qpt, **Plate 33**) interbedded with spring travertine and containing reworked travertine clasts. This gravel unit is cut into the high level gravel (Czg).

Unit Qpg is part of the continuum of erosion and deposition resulting in formation of gypsified gibber spreads, of various ages, with red-brown sandy soil matrix. Toe-cutting, river capture and degradation of interfluvial remnants have led to the complex gibber terrain with its numerous breakaway slopes and remnant tributary valleys. Breakdown of the silcrete plateau continues at some gully heads, where the duricrust is undercut.

Broadly, unit Qpt is a channel facies, and is frequently cemented by carbonate downslope from springs, whereas unit Qpg is a colluvial and proximal channel facies, largely cemented by gypsum.

Unit Qpt at Frome River is perhaps the distal facies of these deposits, including overbank as well as channel facies. It grades into beach and lake deposits (Qpb and Qpl) and is a probable equivalent of the Katipiri Formation, an extensive fluvial unit in the Tirari Desert (Callen, et al., 1986) which was deposited between about 130 000 and 100 000 yrs BP (from TL dating of Callen & Nanson, in prep.; Nanson et al., 1988).

Diprotodon bones have been found in unit Qpt at Welcome Springs (N. Pledge South Australian, personal communication, 1987) and land snails occur in unit Qpg.

The gravel units are probably Late Pleistocene equivalents of Pooraka Formation.

Undifferentiated alluvium (Qa)

This unit comprises alluvial spreads not placed in units Qpg or Qha, and terraces of older ?Holocene gravel which are dissected by modern streams.

The unit includes surficial alluvium of gravelly brown sand between the 10 m shoreline and the present edge of Lake Eyre South, which is extensively veneered by patchy modern drift sand. Topographic contours suggest that these deposits are low angle fans or fan-deltas which spread into the Pleistocene playa (**Fig. 14**) as the shoreline receded to its present position.

Holocene fluvial deposits (Qha)

Around the Tertiary plateaus, this unit is represented by brown silty sand with abundant bleached Bulldog Shale clasts in present-day watercourses and floodouts. Clay clasts do not survive for more than 1 - 2 km from the source, hence most stream channels have coarse sandy beds, often with silcrete cobbles and Adelaidean pebbles from the Willouran Ranges or reworked from the Bulldog Shale.

In Goyder Channel, algal mats are interbedded with aeolian drift sand and alluvium of playa - channels. Two apparent directions of cross-bedding were found in this alluvium, the upper corresponding to the 1984 flooding which flowed north through Goyder Channel from Lake Eyre South; and the lower probably to the 1973 flooding which flowed south (Bonython and Fraser, 1989).

Lacustrine and beach deposits (Qpl, Qpb).

The lake deposits have been drilled in the Australian National University SLEADS programme (Chivas *et al*., 1986), and in the earlier SADM survey (Johns and Ludbrook, 1963). Both projects were in Madigan Gulf of Lake Eyre North, except for Lake Eyre Bore 8A which was drilled in Lake Eyre South.

The lake deposits are rarely seen in section except in recently cut creek banks and freshly trimmed lake shores. Featureless areas within the limits of beach deposits are underlain by lacustrine sediments, e.g. the region between "Muloorina" H.S. and Goyder Channel.

The beach deposits are also difficult to see in cross-section, but the linear ridges are readily recognised on air photos and in the field. Rabbit burrows frequently reveal the presence of shells and coarse sand or gravel.

Persistent sets of three or more beach ridges close to the 10 m contour border Lake Eyre South (**Fig. 14**). The beaches are flanked by an old cliff line, which at Eyre Lookout surrounds an island linked by beaches to the mainland (**Plate 34**). The cliff line has a series of beaches at its foot, and is sometimes capped by beach deposits. It has been dissected by later erosion.

Lithology

The lacustrine deposits consist of laminated green to grey clay with red horizons and thin silt and gypsum seed crystal partings, and ripple-marked *Chara*-rich beds or gypsum beds at two levels (**Plate 35**).

Dark clay occurs in Madigan Gulf. Two horizons of salt crust in Lake Eyre Bore 4 and in some of the ANU holes indicate two long-term lake levels.

The beach deposits are well-washed clean to pebbly sand and gravel which grade into lake deposits through yellow-orange to yellow-green finely-laminated sand. Nearshore bars have not been distinguished from beaches. The beach ridges have an armoured gibber cap and are sometimes lightly cemented by gypsum and carbonate.

Palaeontology

The clayey lacustrine deposits contain numerous ostracods, charophytes and locally abundant fish impressions. A layer consisting entirely of large Chara oogonia occurs in the southwestern corner of Jackboot Bay.

Vertebrate bones (Dulhunty et al., 1984), gastropods and bivalves are common in the laminated fine sand, together with ostracods and charophytes (tubules and oogonia). The beach deposits contain abundant shells of small spiral-trochoid gastropods (Coxiella, Coxielladda and other genera), and small bivalves. Foraminifera are also present.

Stratigraphy and Age

Along the east side of Madigan Gulf on LAKE EYRE (Callen, et al., 1986) are cliff sections of gypseous dunes and beach deposits on a red clay lunette, which rests on green laminated clay (Qpl).

Elsewhere, the lacustrine clays are always found beneath aeolian sequences. These are not necessarily the oldest aeolian sequences, as the aeolian deposits have transgressed onto the lake surface.

These lacustrine deposits are related to the 10 m beach level. At Eyre Lookout, aeolian gypsum sand deposits are closely associated with this beach, and both are capped by gypsum crusts. The aeolian gypsum sands are correlated with those on the east side of Madigan Gulf. These relationships suggest that aeolian deposits were building up during the last phase of beach formation.

Radiocarbon dates of shells from beach deposits at Morris Creek, near "Muloorina" H.S., and Snake Dam (KOPPERAMANNA) gave ages greater than 35 000 and 40 000 yrs BP (Callen et al., 1986). Thus the 10 m level beachline is likely to have an age of 45-50 000 yrs BP. This is consistent with AAR dates from the shell, but a TL date of 22 800 ± 2 300 yrs BP demonstrates that the overlying sand is much younger than the shell, indicating multiple reworking (Callen & Nanson, in prep) or problems in dating.

Aeolian Deposits (Qps, Qs, Qs', Qhs)

There are four aeolian units on CURDIMURKA:

(1) Qps - large lunettes transverse to the prevailing wind with a high gypsum sand content, and generally grey to light brownish colour. The largest lunette forms most of the northern shore of Lake Eyre South (**Plate 36**).

(2) Qs - long, linear, bifurcated dunes of red quartz-sand, essentially sub-parallel to the present wind direction and joining down-wind.

(3) Qs' - extensive sand sheets grading into unit Qs occur between the linear dunes north and west of Lake Eyre South.

(4) Qhs - small transverse crescentic and longitudinal dunes of light-coloured mobile sand.

Stratigraphy

Qps

Relationships of unit Qps are not clear on CURDIMURKA. Outcrops at Shelly Island (personal communication, D.L.G. Williams 1976), "Shelly Point" on the opposite coast, Sulphur Peninsula, the eastern coast of Madigan Gulf, and in small lakes in the southwest corner of LAKE EYRE, show that the red clay-pellet and gypsum quartz sand of the leeside mounds overlies lacustrine sediments. The mounds were formed during regression of the lake to its present, or smaller, size. It is unlikely that the beach deposits formed later than unit Qps, as there is no evidence for partial submergence of the lunettes to the 10 m level, with consequent cutting of benches and trimming of tops.

At Eyre Lookout and Sulphur Peninsula, gypseous/quartz dunes of unit Qps overlie beach deposits of the 10 m shoreline.

Thus most of the lunettes postdate the lacustrine and shoreline deposits.

Qs and Qs'

Unit Qs forms the older, more indurated cores of the longitudinal dunes.

The longitudinal dunes on the Watchie Sandstone plateaus of the Stuart Creek area spill over the edges of the plateaus, but retain their internal stratigraphy. Hence they postdate erosion of the plateaus and deposition of unit Czg.

The relationship with gravels of unit Qpt and their equivalents is less clear. A long, straight, north-trending dune west of Callanna is developed at the eastern edge of a higher level surface of unit Qpg.

Longitudinal dunes override the gypsum lunette along the northern shore of Lake Eyre South, and are therefore younger than unit Qps.

Qhs

Mobile caps on unit Qs, and smaller longitudinal dunes, are of Holocene age. A dune cap dated at Lake "Medusa" on KOPPERAMANNA was modern (Callen & Nanson, in prep.) and overlies an unconsolidated dune, without any distinctive soil development, of probable Holocene age. A patch of mobile crescentic to parabolic dunes passing north into longitudinal forms occurs west of the 10 m shoreline on <u>Muloorina</u>. This sand spread has formed on an area which was a lake floor when the 10 m shoreline formed. The dunes are paler in colour than the red dunes to the southeast, between the 10 m shoreline and Frome River.

<u>Age</u>

Eggshell from a longitudinal dune sequence on LAKE EYRE just north of Lake Clayton, produced ages at the limit of, or beyond, radiocarbon dating (Williams <u>in</u> Callen <u>et al</u>., 1986). The eggshell was obtained from the upper surface of the consolidated dune, beneath the active sand of the dune crest.

Thus, longitudinal dunes to the east of Lake Eyre were forming at various intervals from well beyond 40 000 yrs BP to modern times.

Dune phases in the Strzelecki Desert of around 243 000, 167 000, 90 000, 40-35 000 18 - 10 000 and 4 000 yrs BP to the modern period have been documented by Callen & Nanson (in prep.), Callen <u>et al</u>. (1983), Wasson (1983), and Gardner <u>et al</u>. (1987). It is likely that all these phases exist in the Tirari Desert, although areas such as the southwestern corner of CURDIMURKA appear to record only two phases.

Fossils

Eggshell of Genyornis, emu and ?duck is common on eroded dune surfaces. Aboriginal artifacts are common on the surface of 11 000 years old dunes (Veth and Hamm, 1990).

Mound Spring Deposits (Czm, Qm)

Mound springs on CURDIMURKA are divided into two groups: extinct high-level springs; and active or recently active low-level springs.

Well-preserved extinct springs form the prominent landmarks of Hamilton Hill and the twin hills near Beresford (**Plate 37**). Shallow, circular, silt-filled depressions on the summits of these features are the remains of the original vents. Eroded remnants of older spring deposits occur near Kewson Hill and Hamilton Hill.

The deposits of the extinct mound springs (Czm) consist of yellow-grey, pinkish-brown and pale grey, massive, very well indurated, very fine grained limestone, sometimes containing small patches of iron oxide and minor manganese oxide. Fossils include reed casts and moulds and gastropods. Petrographic examination of limestone samples from Beresford Hill indicate a higher iron oxide (goethite) content, and a generally greater degree of recrystallization, than carbonates from an adjacent younger spring. Other petrographic features include silcrete granules, brecciated and intraclastic textures, and colloform (algal) layering (Cooper, 1977).

There is no direct evidence for determining the age of the extinct springs. However, the good preservation of mound spring forms at Hamilton Hill and Beresford Hill suggests an age no older than Pleistocene. The considerable elevation of the older mound springs above the surrounding landscape (about 40m at Beresford Hill) is a result of lowering of the landsurface by erosion and deflation (Habermehl, 1986). This has resulted in the exposure of Bulldog Shale beneath resistant cappings of spring limestone.

Younger, active and recently-active mound springs are more widespread and numerous on CURDIMURKA than the older extinct examples. They occur along faults (e.g. the pronounced alignment of springs between Strangways Springs and Quart Pot Dam) and near contacts between the Mesozoic aquifer and Adelaidean outcrop (e.g. Davenport Springs and Hermit Hill).

The deposits of the younger mound springs (Qm) vary from limestone to reworked Mesozoic sediments, with intermediate lithologies such as muddy and sandy limestone.

The limestones are off-white to pale grey, very fine grained, and range from very well indurated and massive, to porous and weakly indurated types. Fossils include reed casts and gastropods. Algal limestones are common; these are composed of algal balls or oncolites which have formed around nuclei such as gastropod shells. These features are seen in terraced deposits at Kewson Hill. Other features include intraclastic and brecciated textures, often associated with travertine. Cooper (1977) provides petrographic descriptions of limestone samples from a mound spring 500m northwest of Beresford Hill.

At several locations, the spring-deposited limestones contain considerable quantities of mud and sand derived from the Mesozoic formations through which the groundwater passed on its way to the surface. Some active springs are not precipitating significant amounts of carbonate, and have formed mounds of unconsolidated mud (e.g. Fred Springs).

Sheets up to 2 m thick of sandy and gravelly limestone, and carbonate-cemented, cross-bedded sand and gravel occur in the vicinity of mound springs. These are Pleistocene gravels of unit Qpt which have been intermixed and interlayered to varying degrees with spring-derived carbonate. The sandy and gravelly limestone is probably equivalent to the Wondillina Limestone as mapped on OODNADATTA (Freytag et al., 1967).
The age of the younger spring deposits is not firmly established, but is considered to range from late Pleistocene to Holocene.

STRUCTURE, GEOPHYSICS AND SUBSURFACE INTERPRETATION

The main structural elements on CURDIMURKA are the Muloorina Gravity Ridge in the northeast, the Stuart Shelf, Torrens Hinge Zone and Adelaide Geosyncline in the south, and a major fault zone, including the Norwest and Bungarider Faults, which diagonally bisects the sheet area (**Fig 15**). An elongate Bouguer gravity low (`Willouran Gravity Trough'), coinciding with the Adelaide Geosyncline, runs parallel to the Muloorina Gravity Ridge on its southwestern side.
The dominant structural trend is northwesterly as seen in the pattern of Bouguer gravity contours, exposed folds and faults and mound spring alignments. An east-west structural zone through the middle

of CURDIMURKA, offsetting the northwesterly-trending structures with left-lateral displacement, may possibly be inferred from aeromagnetic, drillhole and seismic data, and the regional outcrop configuration.

MULOORINA GRAVITY RIDGE

The Muloorina Gravity Ridge has the same northwesterly trend as structurally complex zones of Adelaidean sediments in the Willouran, Davenport and Denison Ranges and the Mt Freeling/Mt Babbage area. It coincides with outcropping rocks of the Torrensian and Willouran Series in the Peake and Denison Inlier to the northwest (**Fig. 3**), and with pre-Adelaidean sequences of the Mt Painter Block to the east.

It is not known which sub-surface geological formations correspond with the Muloorina Gravity Ridge on CURDIMURKA, although moderately folded rocks of the Umberatana and Wilpena Groups outcrop on the eastern margin of the Willouran Ranges and could be expected to extend toward the gravity anomaly. SADME Muloorina-1 waterbore is situated on the centre of the gravity ridge and it intersected probable Adelaidean grey siltstones (Tapley Hill Formation equivalents ?) at a depth of 609 m (Forbes, 1984).

Although it may be tempting to regard the Muloorina Gravity Ridge as an actual culmination of dense, crystalline basement, aeromagnetic and limited drilling data suggest otherwise: crystalline basement, similar to Peake Metamorphics outcropping east of the Davenport Range, may occur at a depth of 4 km or more (Preiss, 1987). There is some stratigraphic evidence to suggest that rocks of similar character to the Gawler Craton were easterly source materials for sedimentation in the Willouran "rift-valley" e.g. of Late Willouran Dome Sandstone and Early Torrensian Top Mount Sandstone. However, these basement rocks ceased to form the northeastern margin of the Adelaide Geosyncline rift from Marinoan time onwards, and became covered with extensive deposits of the Umberatana and Wilpena Groups (Preiss, 1987).

STUART SHELF

The Stuart Shelf underlies the southwestern corner of CURDIMURKA where outcrop consists of flat-lying to gently warped Brachina Formation. A profile derived from the contoured Bouguer anomaly map

(**Fig. 16**), following the line of section AA', indicates a gradual westward decrease in gravity values which appears to correspond to the westward, erosional thinning of ABC Range Quartzite equivalents.

A cluster of broad, elliptical magnetic and gravity anomalies characterises the southwestern corner of the map sheet. Geophysical modelling of an elongate, positive gravity anomaly of ~10 mgal (Ferguson Hill area) indicated a depth to the anomaly source of the order of 1300 m (Paterson and Muir, 1986). Associated with this gravity feature is an intense, positive, total magnetic field intensity anomaly with an amplitude of 1700 nT ("Joe's anomaly" - Catley et al., 1981; "Ferguson Hill anomaly" - Paterson and Muir, 1986), which has been a target for Olympic Dam-style mineralisation in pre-Adelaidean crystalline basement. Modelling of this bullseye anomaly indicated a depth of 1100 m to the magnetic source (Paterson and Muir, 1986). However, a much greater depth to the magnetic source has been calculated (PJF) to be of the order of 3 km.

FHD-1, drilled in 1977 by Western Mining Corporation, was positioned approximately half way between the centres of the gravity and aeromagnetic anomalies. The drillhole penetrated 523 m of Brachina Formation and 200 m of Umberatana Group (including Tapley Hill Formation) without reaching crystalline basement.

Newmont Pty Ltd drilled SR-17/2 (1500 m deep), 10 km to the north of FHD-1, and intersected a relatively thick section of Wilpena Group and Umberatana Group sediments, on the northern flank of the aeromagnetic anomaly. Stratigraphic data from drillholes Playford-1 (46 km SSW of FHD-1) and SR-6 (30 km NW of FHD-1) also indicate that the Adelaidean sequence rapidly thickens to the north and west.

TORRENS HINGE ZONE

The Torrens Hinge Zone is a zone of faulting and mild folding that marks the transition from the Stuart Shelf to the more strongly deformed sequences in the Adelaide Geosyncline (Preiss, 1987). The Hinge Zone on CURDIMURKA extends from the Ferguson Hill area to the Willouran Ranges. Small, scattered inliers of Wilpena Group sediments indicate that the Hinge Zone has open to tight folds that plunge shallowly to the southeast, and numerous, relatively small faults that trend north and northwest.

The cross-sections BB' and CC' illustrate the interpreted easterly thickening and folding of the Adelaidean sequence and the probable onlap of Burra Group sediments onto crystalline basement at an approximate depth of 2 km (Section BB').

The Bouguer gravity anomaly profile across the Torrens Hinge Zone is gently undulating about an average value of -10 mgal. A broad aeromagnetic high extends northwestwards from the western margin of the Willouran Ranges, through the Coward Cliff area and turns northeastwards towards Lake Eyre South. It attains total intensity values of up to 3240 nT immediately south of section AA' and in the vicinity of Roxby Management Services Wellfield A ("Wellfield magnetic rise", **Fig. 16**). This feature may indicate the transition from Hinge Zone to Geosyncline and could reflect tectonic/sedimentary thickening or updrag adjacent to the Norwest fault zone.

A marked thickening of the Adelaidean or Mesozoic sequences in this area is not indicated by the gravity profile, except immediately west of the fault zone.

ADELAIDE GEOSYNCLINE (WILLOURAN RANGES)

General

The Willouran Ranges are a "complex fractured anticlinorium" that exposes one of the early depocentres of sedimentation in the Adelaide Geosyncline (Forbes, 1988). Narrow, fault-bounded, northwesterly trending zones of severely disrupted Callanna Group sediments are enclosed within thick, tightly folded Burra Group sequences (**Fig. 15**). These zones have been previously described as thrust structures (Sprigg, 1949), syn-and post-depositional diapirs (Dalgarno and Johnson, 1968), syn-sedimentary slump breccias (Murrell, 1977) and tectonic décollements (Burns et al., 1977).

The marked contrast in structural style and complexity between the Callanna and Burra Groups has been interpreted by Parker (1983) to indicate an intervening period of folding and thrusting. From detailed mapping of Callanna Group rocks within the Rischbieth Complex, Parker (1983) concluded that this period of deformation produced westerly directed thrusting with deep-seated, shallowly inclined, isoclinal folds, and associated gently eastward dipping thrust surfaces. He envisaged that these steepened at the surface and that thrust movement prior to or during Burra Group sedimentation formed highs separating active and complex depocentres. Consistent with this idea is the interpretation of Belperio (1987a) that the mid-Burra Group Skillogalee Dolomite accumulated in four discrete axial basins with the bounding faults now represented by the zones of structurally complex Callanna Group rocks.

Syn-sedimentary `diapiric' activity is thought to have occurred during Torrensian, and even Sturtian deposition, mainly in regions where the low-density Callanna Group had already been upthrusted and disrupted. Sub-basins of Burra Group would have added to density-related instabilities in these structural `corridors'. The structurally incompetent nature of the partly evaporitic sediments of the Callanna Group would allow a considerable degree of shortening (i.e. buckling and thrusting) without need for major deformation within the crystalline basement. Preiss (1987) observed regionally that where evaporitic sediments of the Callanna Group are exposed, basement-cored anticlines are not, which suggests that the basal Adelaidean `diapiric' structures are detached from the basement. This model also helps explain the strong negative gravity anomaly over the Willouran Ranges (informally named `Willouran Gravity Trough') and the notable lack of magnetic anomalies attributable to basement.

The `Willouran Gravity Trough' is an elongate Bouguer gravity anomaly with a maximum amplitude of -18 mgal. The low coincides with Adelaidean outcrop and contains several lower amplitude positive and negative anomalies of local origin. According to Milton and Morony (1975), the small magnitude peaks define areas of `diapiric' breccias and steeply dipping fault zones. Adjacent, minor strike-parallel lows represent less-deformed, Sturtian and Marinoan sequences. The complexity and width of the `Willouran gravity trough' attains a maximum in the vicinity of Hermit Hill and diminishes northwards, suggesting that the disrupted Lower Adelaidean units become either thinner and less deformed or covered by younger sequences to the north.

Significant magnetic anomalies do not occur in the Willouran Ranges. However, small blocks of gabbro or Noranda Volcanics within tectonic breccias appear to correlate with some low-amplitude, discrete positive anomalies of the order of 100 nT.

A narrow curvilinear magnetic feature, defined by steep gradients and elongate lowS in the total magnetic intensity contours, extends northwestwards from near Hermit Hill, passes under Lake Eyre South, and swings to a westerly direction between Prices Bore and

Strangways Springs (**Fig. 15**). This magnetic feature does not occur in areas of pre-Mesozoic outcrop, but it may be significant that numerous mound springs coincide with it, including Smith, McLachlans, Strangways and some Lake Eyre springs, and possibly the Francis Swamp Springs further westwards on BILLA KALINA. Although the major, outcropping fault zones in the Willouran Ranges do not resolve into linear magnetic features, due to lack of magnetic susceptibility contrast, they do appear to merge with the southeastern end of the curvilinear magnetic zone.

Therefore, it is possible that this area, north of Hermit Hill and beneath Lake Eyre South, marks the northernmost, concealed point of the Adelaide Fold Belt on CURDIMURKA. The fold belt reappears on WARRINA, sinistrally offset from the Willouran Ranges by a presumed tectonic feature. The short break under Lake Eyre South and consequent curvature of the magnetic lineament into an east-west orientation could indicate the deflection of the Torrens Hinge Zone into a transfer fault zone. Supporting evidence for such an interpretation is the groundwater connection by a "high transmissivity channel" which extends westwards from "Muloorina" H.S. beneath Lake Eyre South, and breaches the normally impermeable Norwest Fault (Aust. Groundwater Consultants, 1987). The "channel" is thought to indicate east-west faulting, a process which may have been active during rifting of the Willouran arm of the Adelaide Geosyncline (Preiss, 1987).

Interpreted depths to magnetic basement indicate a very shallow magnetic basement east of the Norwest Fault, and an increase to 4000 m depth west of the fault. From here, the depth is considered to decrease westwards towards outcropping crystalline basement of Mt Woods Inlier and Gawler Craton. In the western areas of CURDIMURKA, the interpreted magnetic basement may be correlated with crystalline pre-Adelaidean rocks. However, east of the Norwest Fault, the shallower magnetic basement is probably produced by Adelaidean units such as Ulupa Siltstone. It is considered likely therefore, that the 4000 m elevation difference in magnetic basement represents much less than 4000 m of stratigraphic displacement across the Norwest Fault (Milton and Morony, 1975).

Particular Features

The *Norwest Fault* occurs alongside the westernmost zone of strongly disrupted Callana Group rocks on CURDIMURKA. In the Black Knob area, this consists of large fault-bounded segments of steeply-dipping, east-facing quartzite of the Dome Sandstone, surrounded by strongly disturbed sandstone and carbonate of the Callanna Group. A nappe-like structure here suggests possible southeasterly movement of an eastern block, which may also have influenced folding northeast of Top Mount Well (Sprigg, 1949; Dalgarno, 1966). The terms Stony Range, Rocky Point, High Hill and Clara St. Dora Diapirs have been applied by Dewar (1974) to the more disturbed zones along the Norwest Fault. The Clara St Dora Diapir comprises an inner core of megabreccia which includes blocks of Black Knob Marble surrounded by strongly disturbed quartzite and siltstone correlated with the Recovery Formation.

The *West Bungarider Diapir*, between the Norwest and Bungarider Faults, sharply intrudes generally east-facing Skillogalee Dolomite. It is probably the simplest diapiric structure in the region and is associated with a minor parallel synclinal fold on its southwestern margin.

The *Bungarider Fault*, with associated *Rischbieth structural complex* and other breccia zones, lies at the western edge of a less-deformed area of moderately folded Burra Group rocks. The Rischbieth complex resembles the complex in the Black Knob area in that it contains large folded segments of Dome Sandstone interspersed with tectonic breccia. The margins are faults, with no evidence of sedimentary unconformities. If the stratigraphic elements within the structure have been correctly identified, there must have been considerable disruption, since the stratigraphically well-separated Dome Sandstone and Boorloo Siltstone have been brought close together.

The eastern edge of the area of relatively less-deformed Burra Group rocks is bounded by a sinuous, complex fracture zone extending southwards from "Callanna" H.S. to the southeastern corner of CURDIMURKA. This zone incorporates a narrow belt of Curdimurka Subgroup sediments separated from adjacent Burra Group sediments by numerous faults and tectonic breccias, including the Mirra and Breaden Hill diapirs. A major fault forming the eastern edge of this disrupted zone and the western limit of Emeroo Subgroup outcrop is named here the *West Willouran Fault*. Outcrop relationships across the West Willouran Fault imply that this structure dips eastwards, and Thomas and Dunlop (1968) infer some dextral strike-slip movement from drag effects in folded Cooranna Formation southeast of Kingston Dam.

Many minor fractures cut the pre-Mesozoic rocks. These fractures are mostly oriented at a high angle to the main faults and may be clustered into fracture zones, as in the Mirra Bore-Mirra Dam area. There is a minor strike-slip component of movement on these fractures. Some similarly oriented fractures are carbonate-filled and may represent a late tensional phase of the Delamerian Orogeny.

MESOZOIC AND CAINOZOIC STRUCTURES

Predominant structures in the Mesozoic reflect the major northwesterly fault trends in the Adelaidean strata. These faults extend up into Bulldog Shale and then appear to pass into low amplitude folds in the stratigraphically higher units. The trace of one such fold in Mackunda Sandstone, exposed east of Lake Eyre South, indicates a wavelength of 2-3 km and limbs dipping at one or two degrees.

Fault style, as interpreted from seismic data, is predominantly high-angle normal, with lesser, high-angle reverse displacement, giving rise to a broad, shallow horst and graben profile in the Adelaidean and overlying lower Eromanga Basin units. Faulting in the Mesozoic is best illustrated at Finniss Swamp where an extension of the Norwest Fault Zone has juxtaposed the upper part of Algebuckina Sandstone, containing faulted slivers of Adelaidean quartzite, with the lower, bouldery part of Bulldog Shale. The fault is exposed as a crush zone and slickensided fault plane (**Plate 38**). The sub-horizontal slickenside striations indicate a major strike-slip component to the last movement on the fault. Other surface evidence of faulting in the Mesozoic units are the alignments of mound springs, e.g. between Hamilton Hill and Strangways Springs, where fractures in the confining Bulldog Shale allow upward movement of groundwater from the underlying aquifer. Further evidence of faulting of Mesozoic units occurs west of Cockatoo Bore, where there is a marked elevation difference, across a fault, between Cadna-owie Formation and topographically much lower Bulldog Shale.

Cainozoic units are essentially flat-lying, with only minor, local structural deformation. North of the Poole Creek - Mt Alford area, very gentle warping in Eyre Formation may be inferred from the outcrop pattern of the unit, while near the Poole Creek - Dog Fence intersection, a syncline in silcreted Tertiary sandstone (Eyre Formation or Willalinchina Sandstone) is indicated from airphoto interpretation and field observations. Within the Ranges near Cockatoo Bore, Tertiary sandstone has been locally faulted and brecciated.

There is about 6 m elevation difference between the Middle Eocene Nelly Creek fossil site and the top of the Eyre Formation in Lake Eyre bore 8A, where the unit is Late Paleocene in age. This suggests either erosion of the intervening Early Eocene sequence, or the presence of a fault with upward displacement to the north between the two sites. Data from drillholes to the east of CURDIMURKA (Callen & Plane, 1985) indicate that at least 100m of sedimentary section may be missing from the Lake Eyre bore 8A sequence, suggesting the presence of a fault.

On a broader scale, mild Cainozoic tectonism is expressed in the geomorphological variation of Cainozoic units across the sheet area. Within and around the ranges where uplift has occurred, units are disposed as a toposequence, an older unit being topographically higher than a younger unit, while in the Lake Eyre Basin where subsidence occurred, units are in normal stratigraphic sequence. Between the ranges and the basin there is a broad pivotal zone where neither uplift nor subsidence prevailed. Here, all units occupy much the same topographic level so that in places they appear to be laterally adjoining.

These relationships are shown on the Cainozoic rock relationship diagram which portrays each unit as representing a particular Cainozoic landsurface with a specific topographic profile; successively younger profiles have successively lower average gradients, and the profiles cross over in the pivotal zone. The total effect of this Cainozoic tectonism, based on elevation differences of early Tertiary sandstones, consists of vertical displacements of some 70 m across the Norwest Fault and at least 200 m between the ranges and the basin.

SUMMARY OF TECTONIC HISTORY

From stratigraphic information, it appears that the Norwest, Bungarider and West Willouran structural corridors have been active since at least Burra Group time. These are the predominant structures affecting Phanerozoic units on CURDIMURKA, and were reactivated in Cainozoic time. The regional folding of the Willouran Ranges, characterised by northwesterly-trending, northeasterly-dipping, steep to vertical axial planes, is ascribed to the Early Palaeozoic Delamerian Orogeny. Structures attributable to tectonic activity between Early Palaeozoic and Cainozoic time are not known on CURDIMURKA, but some uplift of the ranges during the late Triassic or early Jurassic, following a time of stability and deep weathering, may be inferred from the field relationships of Algebuckina Sandstone and Cadna-owie Formation. The horst and graben faulting that affects the older units of the Eromanga Basin is thought to be of Cainozoic age as no evidence for Late Cretaceous movement has been found on CURDIMURKA.

Cainozoic uplift (and downwarp) became prominent after deposition and silicification of the older Tertiary sandstones (eg Eyre Formation) and has continued to the present day. Intermittent, rather than steady movement, may be inferred from the dissected and topographically stepped configuration of the Cainozoic units. Holocene tectonism is demonstrated by the proximity of the lowest land surface on the Australian continent (Lake Eyre, -16 m AHD), modern seismicity, and active, fault-aligned mound springs that have formed at the present day surface. One episode of fault reactivation may have occurred in the Pliocene to early Pleistocene period, producing the oldest, now-extinct mound springs such as Hamilton Hill. Major spring discharge at Hermit Hill, contemporaneous with such reactivation, may have maintained the lake in which the limestone of the Alberrie Creek plateau was deposited. Faulting and tilting of the silcreted Tertiary sandstone south of Cockatoo Bore could also belong to this phase of tectonism.

ECONOMIC GEOLOGY

ADELAIDEAN

Although there has been considerable exploration for minerals, mainly in the Willouran Ranges, only small deposits of copper and gold have so far been discovered and none of these are being currently worked. Exploration has been directed mainly toward copper, including Olympic Dam-type deposits in pre-Adelaidean rocks of the Stuart Shelf, and there have also been unsuccessful searches for diamonds (**Fig. 2**). Scott (1984) provides a comprehensive review of mineral exploration and potential in the Willouran ranges.

Metallic Minerals

Anomalous copper, zinc and lead values have been reported from some formations (e.g up to 0.47 per cent Cu in the Rook Tuff and Dunns Mine Limestone, 0.11 per cent Cu in the Boorloo Siltstone: Rowlands et al., 1983), but economic concentrations of metals are largely related to quartz-carbonate veins which developed mainly during Delamerian folding and faulting. Deposits are described here in geographic order, from west to east, some of the more significant being Clara St. Dora, Warra Warra and Boorloo. A number of mines in post-Willouran rocks lie just east of megabreccia zones. Numerous workings southeast of "Callanna" H.S., including the Rook, Dunns, Dome, Euchre Pack and Callanna Mines, occur in fractured Dunns Mine Limestone adjacent to intrusive breccia. Most of the occurrences noted below are of copper. Minor gold is recorded from the following localities: 2.5 km north of "Dunn's Hill", "Vickery's Claim" west of Warra Warra, Rischbieth Well, Douglas Gully and the southern end of the Rook workings (Bluck, 1988; Wells, 1976).

The Clara St. Dora Mine was worked between the 1890's and 1915 as a series of open cuts and shallow shafts. This produced over 2000 t of high grade ore (Brown, 1908; Wells, 1976). Chalcocite, cuprite, copper carbonates and chalcopyrite fill fractures and vugs in blocks of dolomitic Black Knob Marble and also occur in adjacent, softer calcitic rocks near the edge of the central breccia core of the Clara St. Dora Diapir. This setting is analogous to the Blinman Copper Mine, which occurs within a carbonate block near the edge of the Blinman Diapir (Coats, 1964).

Roses Prospect is probably located east of Black Knob in faulted Dome Sandstone with interbedded carbonate. An inclined shaft here has exposed malachite in a hematitic fracture zone. A small quantity of ore raised from 1906 to 1908 assayed 11 per cent Cu (Wells, 1976).

Gold was discovered near Rischbieth Well in 1888 (Brown, 1908, p. 266) both in alluvium and in a ferruginous vein. Dalgarno (1966) reports nearby copper mineralisation in quartz veins cutting sandstone and dolomitic siltstone at the top of the Skillogalee Dolomite, adjacent to the Rischbieth structural complex.

The Rischbieth Well Mine lies northwest of Booth Hill within the Rischbieth structural complex. Wells (1976) records that this produced a small quantity of ore in 1891.

The Blue Hill Mine to the southwest produced 19 t ore containing 8 per cent Cu in 1907 (Wells, 1976).

The Tarlton Knob workings, south of Booth Hill, occur in upper Witchelina Quartzite and lower Skillogalee Dolomite. Wells (1976) records a production of 60 t of 22 per cent Cu ore in the early 1900's.

The Warra Warra Mine (Brown, 1908; Miles, 1952; Dalgarno, 1966) is the most extensive in the region and consists of shafts up to 68 m deep and open cuts extending along the southern limb of an easterly-plunging anticline in Skillogallee Dolomite. Malachite, native copper, chalcopyrite and cuprite are associated with quartz-goethite veins parallel to bedding in silty calcareous shale and sandstone. Secondary enrichment extends down to 18 m depth. Reported production is less than 180 t ore containing up to 20-24 percent Cu. The deposit was tested geochemically by Australian Selection (Sampey and Driessen, 1966b) and drilled by Utah Development Co. (Rowlands et al., 1983). Wells (1976) notes that it was worked for 32 years until 1920: over 1 300 t ore may have been produced.

The May Flower Mine (Brown, 1908, Wells, 1976) has not been located in the field. Production in 1899-1901 was 159 t, partly assaying 18-24 per cent Cu.

The Kingston copper prospect is noted by Dewar (1974) as in quartz veins cross-cutting in siltstone (possibly Top Mount Sandstone Beds) northeast of Kingston Bore.

The West Willouran workings (with some associated alluvial gold) are in quartz-hematite veins in tightly folded and fractured Top Mount Sandstone Beds just east of the West Willouran Fault. Other copper mines in this locality are the Douglas, Douglas East and Douglas South (1897-1899) from which small quantities of ore were raised, assaying 12-35 per cent Cu (Wells, 1976). Alluvial gold has also been obtained from nearby Douglas Gully, where gold has been detected in rock samples (Bluck, 1988).

The Rook workings lie east of Mirra Bore. Secondary copper minerals are associated with quartz, hematite and carbonate veins in sheared and partly brecciated carbonate, siltstone and sandstone of the Curdimurka Subgroup (including Dunns Mine Limestone) just west of the West Willouran Fault. Dewar (1974) and Bluck (1988) report gold in samples from the workings.

Dunns Mine (or Willouran Mine) is also associated with the Dunns Mine Limestone. Recorded production is 141 t of 2.4-8.5% Cu (1880-

1883). Copper carbonates occur on joint faces and there are ferruginous quartz-carbonate veins sub-parallel to strike (Sampey and Driessen, 1966a). Some open cuts are in fault breccia (Dewar, 1974).

The Dome prospect was excavated in malachite veins in the early 1900's (Wells, 1976). It occurs in a diapiric zone (Sampey and Driessen, 1966a).

The Callanna Mine comprises shallow pits in folded Dunns Mine Limestone with ironstone, quartz and minor copper mineralisation. Utah Development Co. (Rowlands et al., 1983) regarded this area as the most prospective for stratiform copper. In a drillhole (WP122D) north of the mine, they noted 1.2% Cu over small intervals containing pyrite, pyrrhotite and chalcopyrite.

The Boorloo Mine was worked in the early 1900's and was extensively investigated by Australian Selection, Noranda and Utah (Sampey and Driessen, 1966a; Dalgarno, 1966; Rayner and Rowlands, 1980). A geochemical anomaly, 900 m long and 120 m broad, is centred on sandy conglomerate and dolomitic shale of basal Tapley Hill Formation. Mineralisation of chalcopyrite, malachite, azurite, chalcocite and native copper is mostly associated with quartz-carbonate veins and better intersections encountered between 0.4 per cent and 2.5 per cent Cu. There are some stratiform, crystalline malachite layers. At depth chalcopyrite is exclusively present, mainly along joints and fractures. Rayner and Rowlands (1980) note fine dissemination of chalcopyrite and pyrite which they regard to be of sedimentary derivation within a delta fan.

Magnesite

The Skillogalee Dolomite contains numerous intervals of magnesite conglomerate, up to 3.5m thick and containing up to 98% $MgCO_3$ (Belperio, 1987a). Belperio (1987b) lists chemical and XRD analyses of magnesite-bearing samples from the Skillogalee Dolomite.

Groundwater

Groundwater within pre-Mesozoic rocks is mostly saline and in low supply because of the arid climate, with low and unreliable rainfall. Rainfall does provide some recharge to groundwater held in open rock fractures but this is soon counteracted by a high rate of evaporation. Murrell (1984) has commented on these aspects and

Safta and Dennis (1979) have made a survey of wells. Water suitable for stock can be obtained from wells sited on major creeks within fractured rocks. Examples of these are Rischbieth Well, which provides modest supplies of the best-quality water in the region and is in fractured Dome Sandstone or associated rocks of the Rischbieth structural complex; and Utah WP 072 (Max's Bore), providing a good supply of good stock water from fractured Top Mount Sandstone Beds south-southwest of Willouran Hill. Another exploration well providing good stock water (used at "Callanna" H.S.) is Utah WP099 (Utah Bore) within Dunns Mine Limestone southeast of The Dome. Some details, partly from Safta and Dennis (1979) are tabulated below.

Table 1. Water Well Data

Well Name	Depth (m)	Salinity (mg/l)	Supply (Kl/day)
Utah (WP099) Bore	190	4250	140
Max's (WP072) Bore	62	5250	130
Kingston Bore	36	9000	76
Rischbieth	13.7	1700	46
Top Mount	17	5400	36
Netting Bore	32	5250	131

MESOZOIC

Groundwater

Artesian water from the Great Artesian Basin is the most important economic geological resource on CURDIMURKA. It is the cornerstone of the pastoral industry, it was used in the steam era for the Ghan Railway to central Australia, and it now supplies the total water needs of the Olympic Dam Project and associated Roxby Downs Township from the Roxby Management Services Wellfield A near Bopeechee.

The main aquifer sequence comprises Algebuckina Sandstone and Cadna-owie Formation. Water salinities generally range between about 2000 mg/l and 6000 mg/l. The main dissolved constituents are Na-HCO_3-C1 with SO_4 also being a significant though lesser component. Ionic composition shows a marked regional variation. High-sulphate water is derived from the western margin, while high-bicarbonate water originates from the east. The natural flow rate from bores ranges from ~6000 Kl/day from high discharge bores to virtually zero in wells where the potentiometric surface is near ground level. Six pumped wells in Wellfield A supply a total of 9 Ml/day to the Olympic Dam Mine and Roxby Downs township.

A more detailed understanding of the RMS Wellfield region has followed the hydrogeological studies of Australian Groundwater Consultants (1987). Seismic investigations have shown the margin of the aquifer to be thin and discontinuous in the southwestern area of CURDIMURKA. Fault-bounded or erosional ("bald-headed") basement highs bring the aquifer closer to ground surface and water discharge occurs where the confining Bulldog Shale has been substantially thinned by erosion, and along fault zones (Aldam and Kuang, 1988). Wellfield-A can be subdivided into two, northwesterly trending sub-basins which parallel the structural trends of the Willouran Ranges. It is envisaged that fluvial sediments of the Algebuckina Sandstone were deposited in at least two, northwesterly draining river valleys, an interpretation supported by palaeocurrent measurements from outcrop.

The effects of structure and palaeo-topography are reflected in groundwater movement and chemistry. For example, the Norwest Fault is a barrier, at least locally, to groundwater flow as shown by a "head" difference of 15 m between two adjacent bores drilled on either side of the fault. Recharge of Wellfield-A from the main, easterly source region is therefore thought to take place through a breach in the Norwest Fault Zone. The location of the breach could be under the western boundary of Lake Eyre South, where contoured values of the HCO_3: Total anion ratio indicate a high transmissivity pathway, and where the position of the postulated left-lateral transfer fault system in the Adelaidean rocks is also broadly located. Areas of high sulphate and low sulphate groundwater are also thought to be separated by the north-westerly trending zone of basement highs.

In particular, the thinness or absence of the aquifer sequence between Margaret Siding and RMS MB2 borehole has been cited by AGC (1987) as a restriction to water flow across this zone, thus limiting the mixing of bicarbonate-rich water from the east with the sulphate-rich, locally derived water.

Celestite

Numerous small patchy occurrences of celestite (with associated barite) have been observed in Bulldog Shale, mainly in the area adjacent to the southern shore of Lake Eyre South. The celestite occurs as thin cross-cutting veins (mostly 0.5-2 cm thick) and crystalline aggregates in mudstone, nodules in sandstone, and crystalline aggregates in ferruginous concretions. Minor occurrences have also been noted in the Oodnadatta Formation. The celestite deposits have been investigated by Butt (1988), who also reports anomalous Sr values (1320 - 3000 ppm) in the limestone of the Alberrie Creek plateau.

CAINOZOIC

Coal

Lignite with a high pyrite content is present in the Eyre Formation. The thickest known lignite beds are in Peachawarinna stratigraphic corehole, east of Lake Eyre (KOPPERAMANNA). The presence of abundant Botryococcus sp. suggests a potential for oil shale development.

Groundwater and Brines

The Eyre Formation, a useful aquifer in other basins, is largely unconfined in the Lake Eyre Basin. North of "Muloorina" H.S., however, the unit is confined by dolomite of the Etadunna Formation. Recharge is likely to be from brines in Lake Eyre South, rather than from rainfall, and there is a potential for rare earth concentrations in the brines.

Opal

Black and white potch occurs as veins 4-5 cm thick in Bulldog Shale at the Charlie Swamp opal diggings. At Coward Cliff, opal is found in joints and horizontal partings in weathered Bulldog Shale (Barnes and Scott, 1979; Barnes and Townsend, 1982).

Samples of Opal-A ("potch") and Opal-C ("common opal") were noted in the southern part of Trecompana, associated with "ant nest" silcrete (Tsi_2) developed at the top of Watchie Sandstone and porcellanite developed in Bulldog Shale.

Refractory materials

Dolomite of the Etadunna Formation in the Babbage Peninsula area has been evaluated for use in the refractory industry, but was found to contain too much silica and clay (Byerlee, 1970). Massive grey silcrete (Tsi_1) may be a suitable source of refractory material.

Clays

Etadunna Formation has been prospected for attapulgite (palygorskite) used as an absorbant, a catalyst, and in drilling muds. Thin beds of high-grade palygorskite are common, but are seldom exposed. High-grade illite is also present in the Etadunna Formation (Norrish and Pickering, 1983; Brown, 1981).

Sand

Sands of the beach deposits (Qpb) are suitable for mixing with cement, as they are well-washed and relatively free of gypsum beneath the surface. Sorting is variable, and shell could be an undesirable contaminant.

Zeolites

Analcite associated with gypsum is recorded in Etadunna Formation of the Poole Creek Paleochannel (Brown, 1983).

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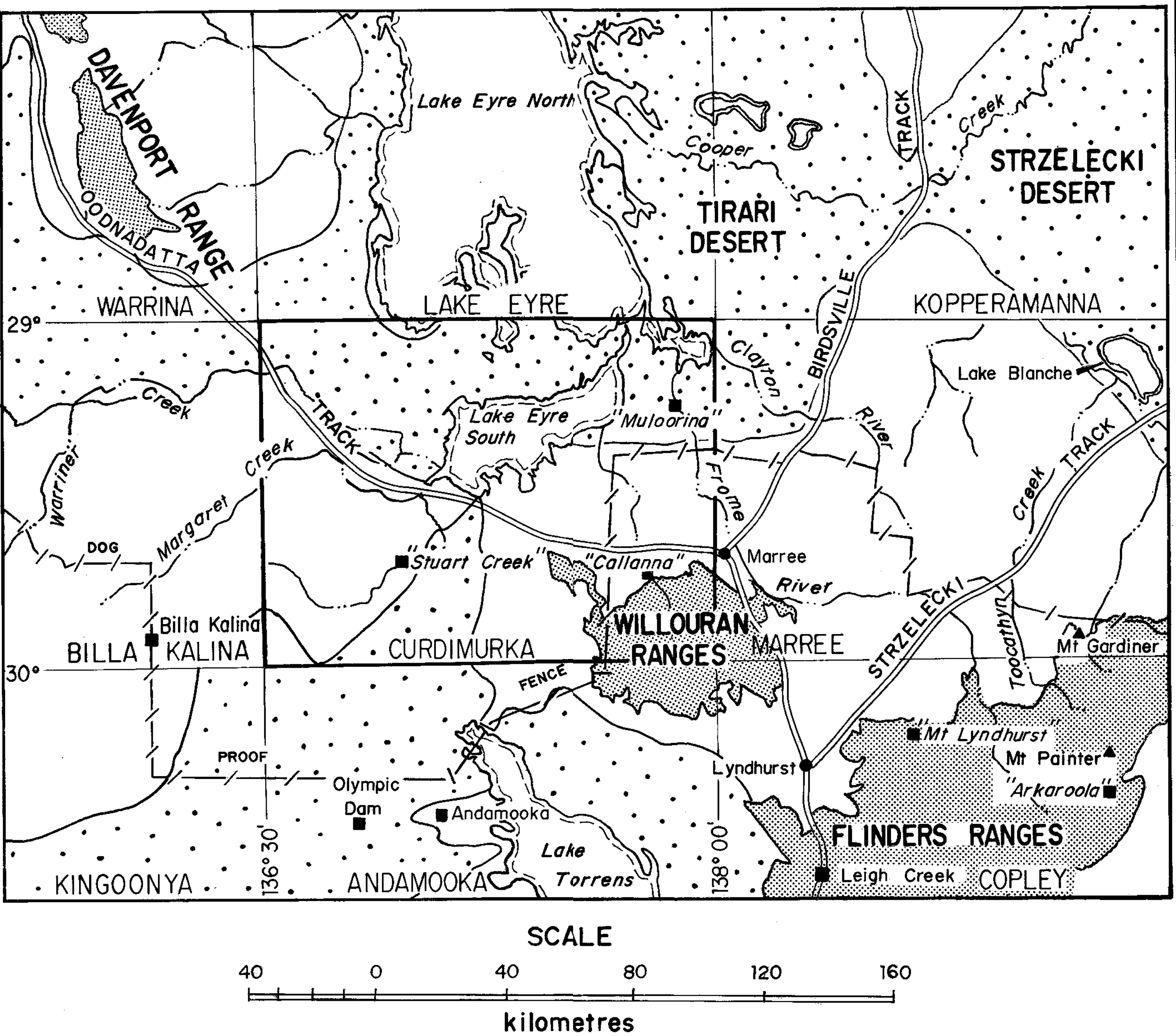


Dunefields and sand spreads

Ranges

Undifferentiated tablelands and gibber plains

Playas

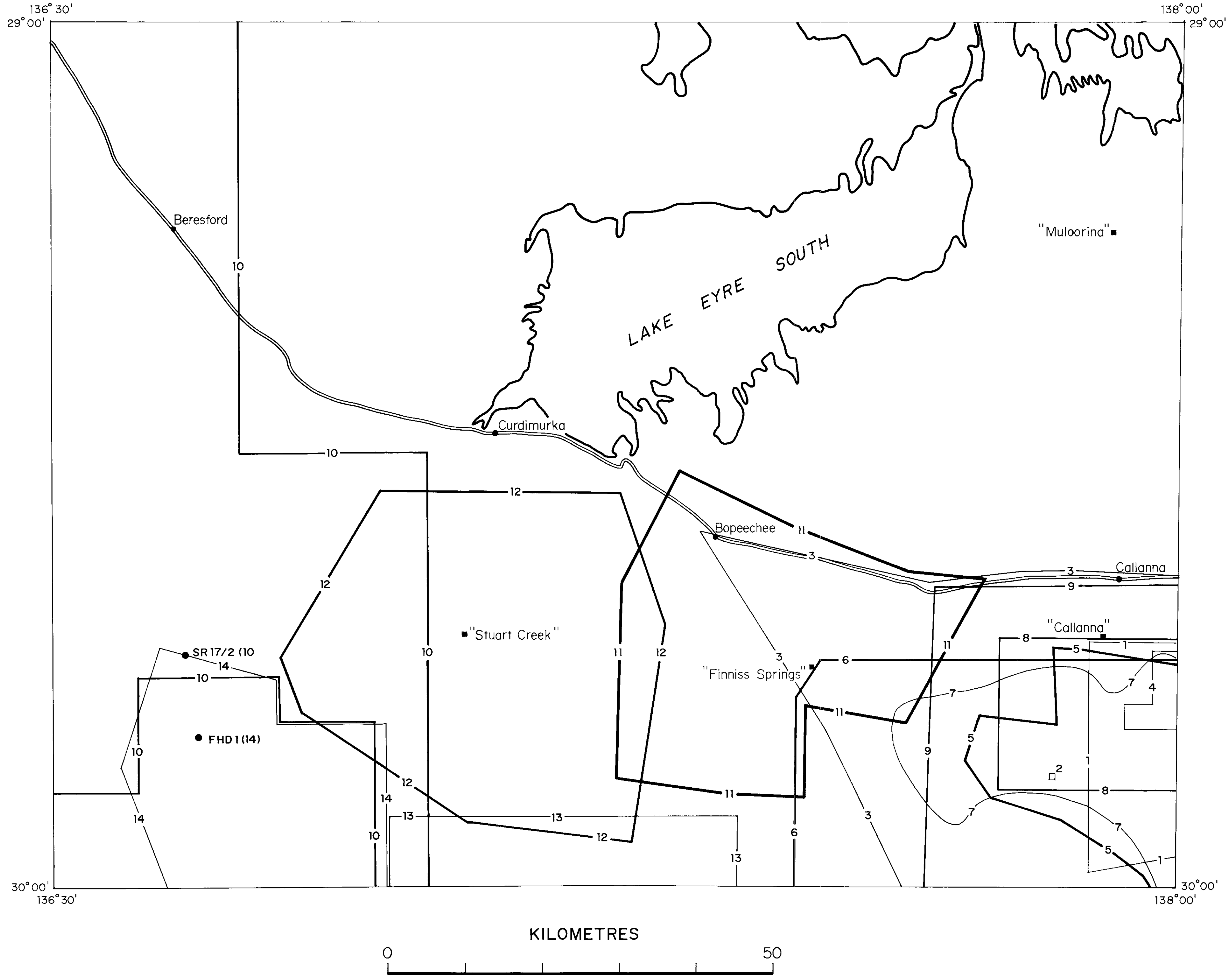
Figure. 1

4927

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

CURDIMURKA 1:250 000 SHEET
REGIONAL LOCALITY AND PHYSIOGRAPHIC MAP

COMPILED G. Krieg	CDO 12.9.90	DATE
DRAWN D.S.L	SCALE	
DATE OCT 89	PLAN NUMBER S 216 40	
CHECKED		



LOCALITY	COMPANY	PERIOD	ENVELOPE	METHOD	ANALYSIS FOR	NOTES
1	Australian Selection Pty Ltd	1964-1966	389	c, e, f, p, q	Cu	Search for copper. A 1965 map is first to record dacite layer in Rook Tuff.
2	Australian Selection Pty Ltd	1964-1966	599	c, d, f	Cu	Search for copper
3	Anaconda Aust. Inc.	1966	637	a, b, c, d, e, f	Cu, Pb, Zn	Search for base metals; good photogeological maps
4	Noranda Aust. Pty Ltd	1968-1969	884	b, c, d, f, g, q	Cu	Search for copper
5	Mount Isa Mines Ltd	1968-1969	1145	b, c, d, f, i	Cu	Search for copper
6	Altarama Search Pty Ltd	1970	1328	b, e	Pb, Zn, Ag, V	Search for base metals
7	Finance Facilities Pty Ltd	1973-1974	2289	b, d	Cu, Pb, Zn, Co, Ni, Mn, Ba, Fe, Cr	Search for base metals
8	Dampier Mining Co Ltd	1974-1975	2436	c, d, g	Cu, Pb, Zn, Co, Au, Ag	Search for base metals
9	Utah Development Co.	1977-1983	2915 3507	c, d, f, g, l, n, p, q, s	Cu, Pb, Zn, Co, Au, As, U	Search for base metals
10	Newmont Pty Ltd, Getty Oil Development Co. Ltd	1979-1981	3803 3804	i, l, p, q	Cu, Pb, Zn, U	Search for Olympic Dam-type deposit. Drillhole SR17/2
11	Central Coast Exploration NL, Shell Co. Aust. Ltd	1980-1983	3914	c, d, e, g, j, l	Cu, Pb, Zn, Co, Ni, Mn, Mo, Au, Ag, Fe, As, Sn, U	Search for base metals
12	Stockdale Prospecting Ltd	1982-1985	4571	e		Search for diamonds
13	CRA Exploration Pty Ltd	1984-1985	5943	e, h, j		Search for diamonds
14	Western Mining Corporation Ltd, B P Aust. Ltd	1976-1986	6562	h, i, j, k, l, p	Cu, Pb, Zn, Co, Mo, Au, Ag, Ba, Fe, Sn, W, Ce, La, U, F	Search for base metals. Drillhole FHD 1

a Photogeology
b Geological traversing
c Geological mapping
d Rock sampling
e Stream sediment sampling
f Soil sampling
g Petrology
h Aeromagnetic survey
i Interpretation of aeromagnetics
j Airborne radiometric survey
k Ground magnetic survey
l Gravity survey
n Ground radiometric survey
p Diamond drilling and sampling
q Rotary percussion drilling and sampling
s Remote sensing application

Fig. 2

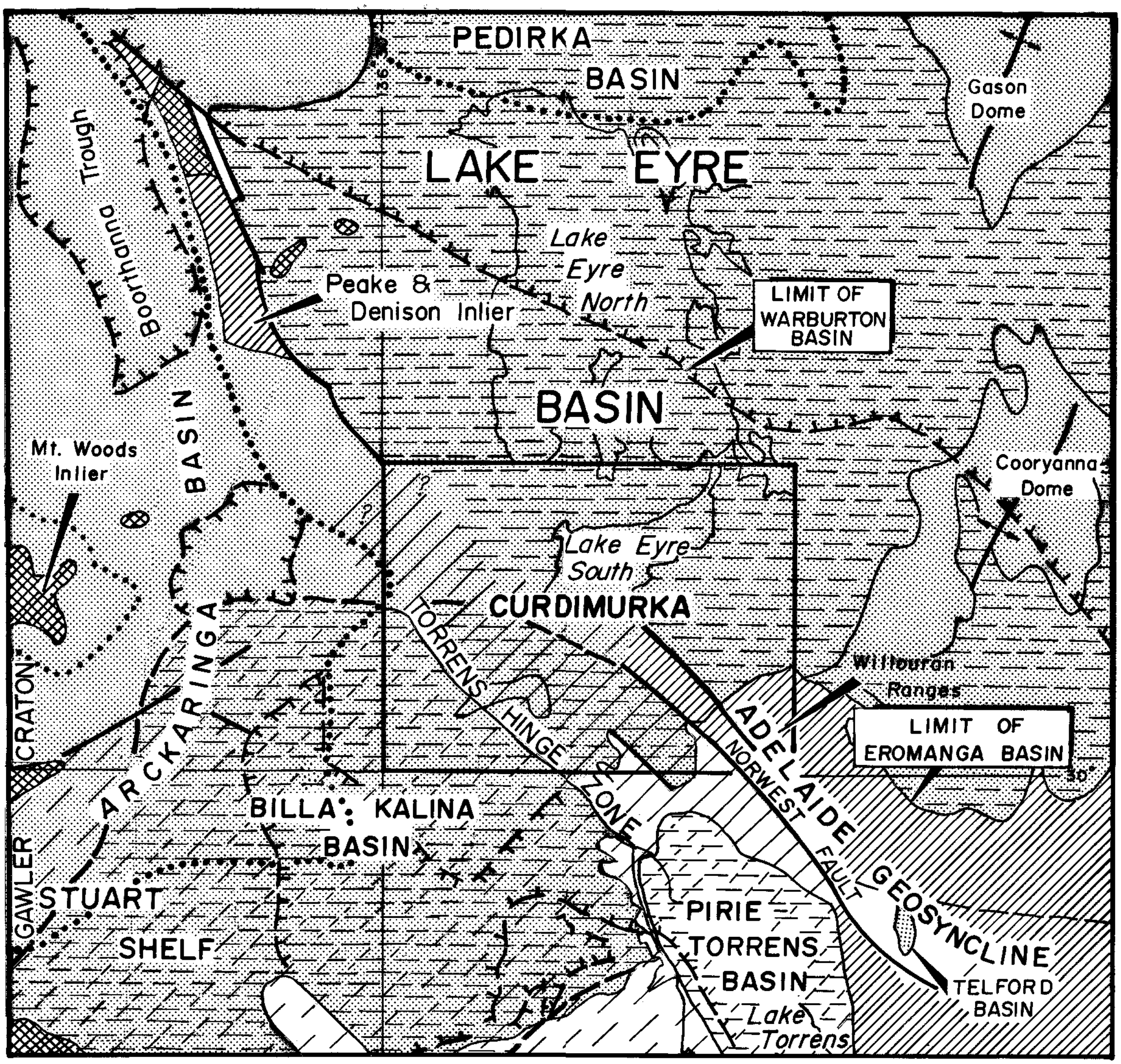
DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA

CURDIMURKA 1:250 000 SHEET

EXPLORATION ACTIVITY

COMPILED B.G.F.	23-11-88 CDO DATE
DRAWN A.F.	SCALE 1:500 000
DATE	PLAN NUMBER
CHECKED	87-774

4408



SCALE

50 0 50 100 150 200

kilometres

Cainozoic
Lake Eyre Basin, Billa Kalina Basin, Pirie - Torrens Basin:
Fluvial and lacustrine sediments.

Mesozoic
Jurassic to Cretaceous Eromanga Basin: Marine to non-marine clastics
Triassic - Jurassic Telford Basin: Non - marine clastics with coal.

Palaeozoic
Carboniferous to Permian Pedirka and Arckaringa Basins:
Glacial marine and non - marine sediments, coal.

Cambrian to Devonian Warburton and Arrowie Basins and
Boorthanna Trough: Marine clastics and carbonates.

Adelaidean (Late Proterozoic)
(1) Strongly folded Adelaide Geosyncline and Peake and Denison
Inlier sediments (2) Moderately folded Torrens Hinge Zone and
(3) flatlying Stuart Shelf sediments.

Early - Middle Proterozoic
Metamorphic and igneous basement

—— Fault

FIG. 3

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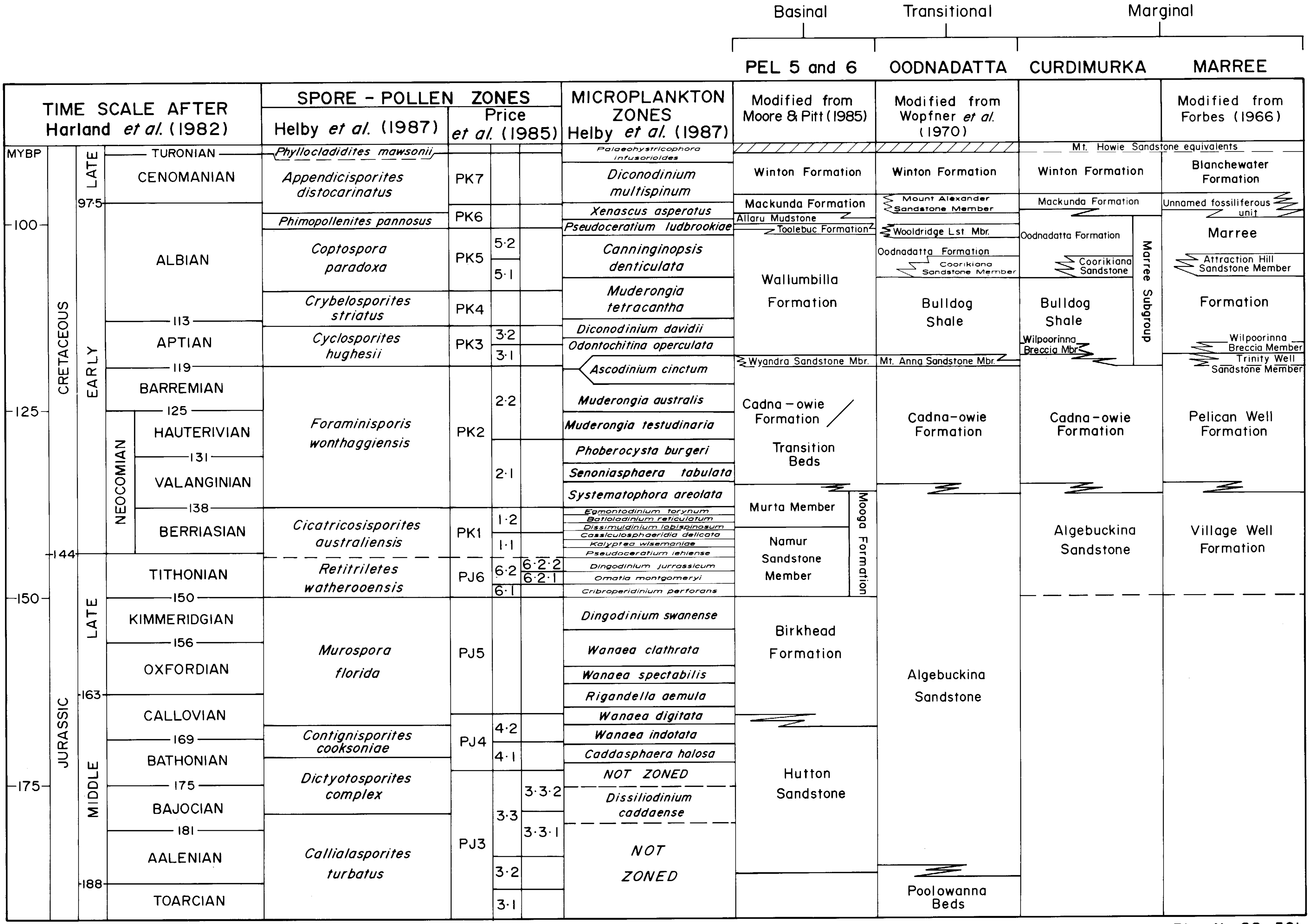
DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

CURDIMURKA 1:250 000 SHEET	COMPILED G. Krieg	12.9.90 CDO DATE
REGIONAL GEOLOGICAL SETTING	DRAWN D.Simpson	SCALE As shown
	DATE Nov 1989	PLAN NUMBER
	CHECKED	S 216 41

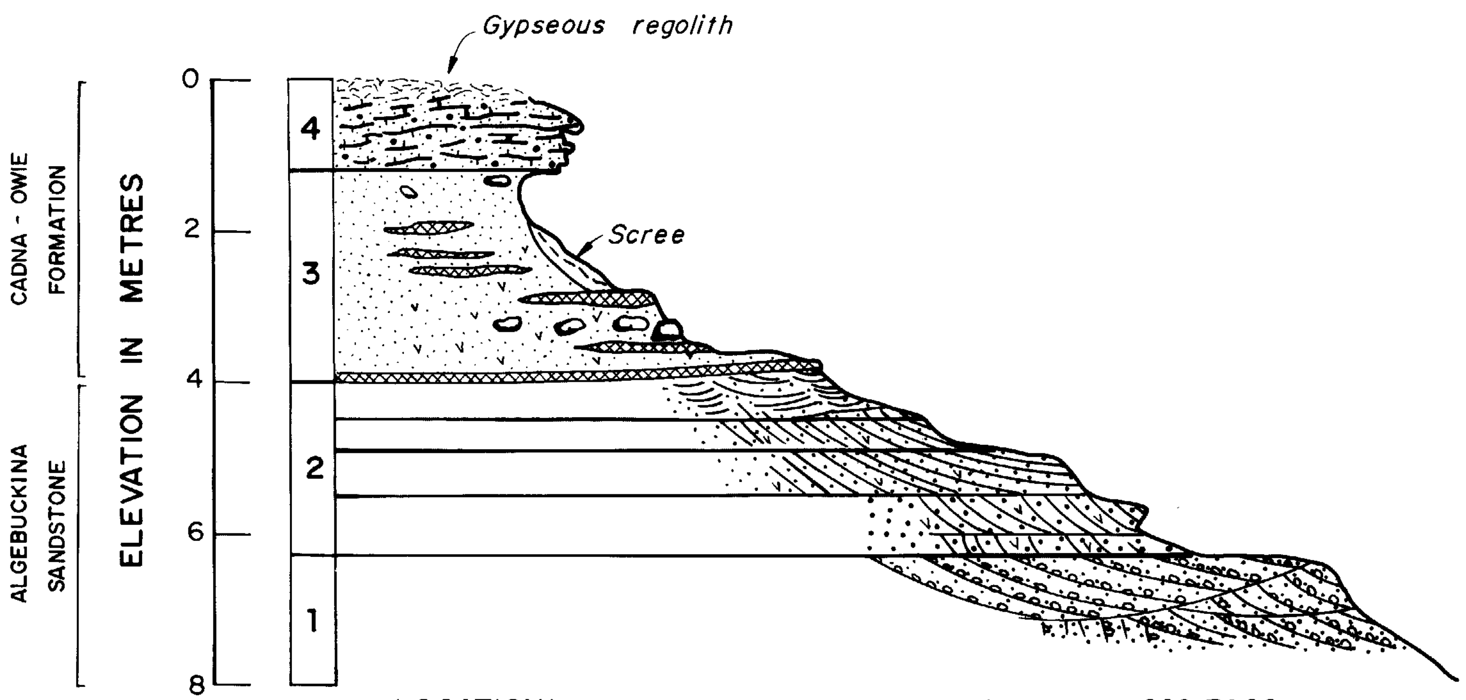
STRATIGRAPHIC AND PALYNOLOGICAL TERMINOLOGY
SOUTHWESTERN EROMANGA BASIN



DEPARTMENT OF MINES AND ENERGY – SOUTH AUSTRALIA

Plan No. 88-501
Figure. 4

4712



LOCATION: GRID REFERENCE AMG 748 225m E, 669 7900 N

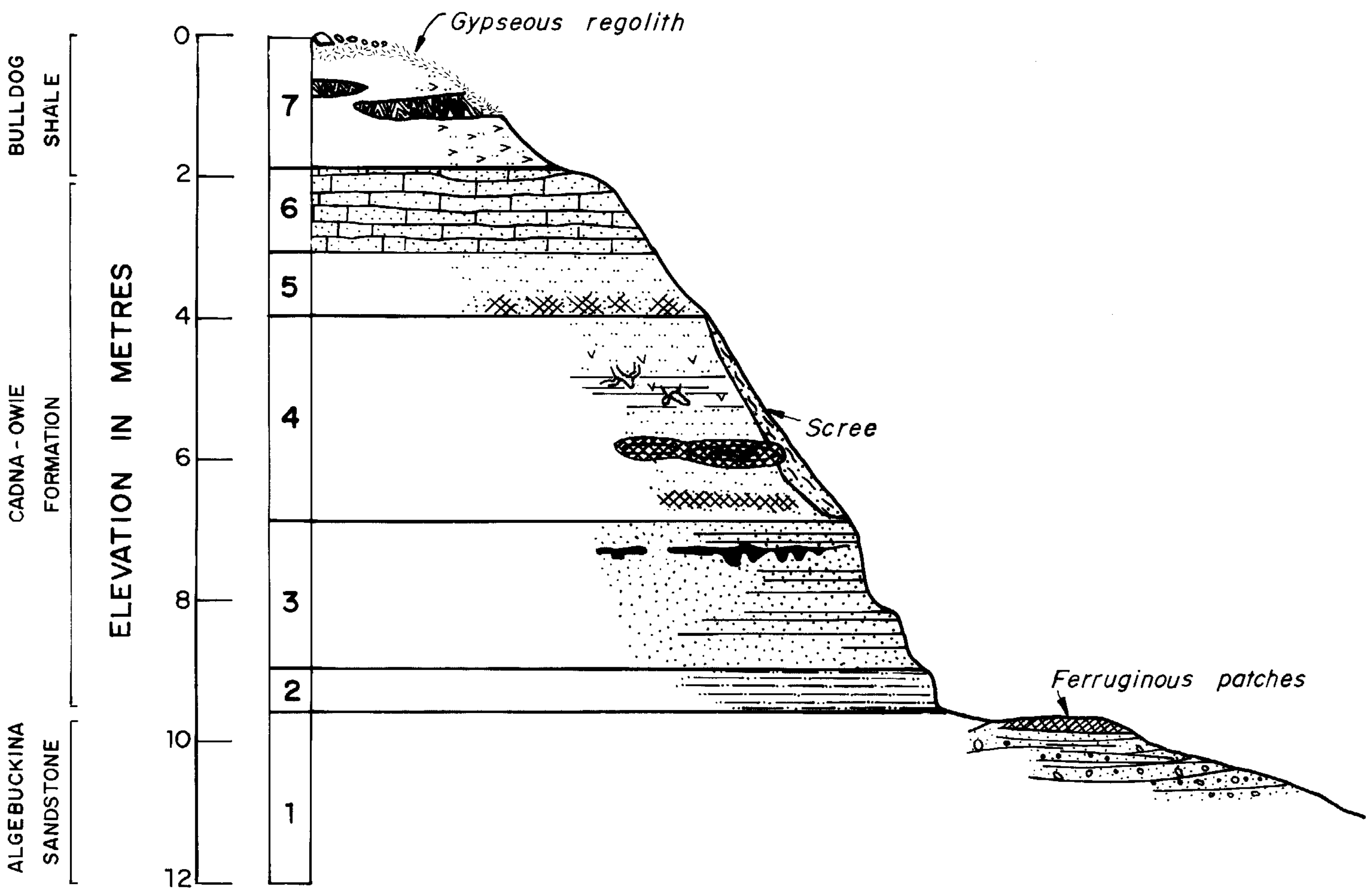
Hard, yellowish, very calcareous, medium grained sandstone with abundant granules and small pebbles. Passes down to fine and very fine, silty sandstone, only moderately to slightly calcareous and with a trace of muscovite.

Pale grey, very fine silty sandstone, non-calcareous, friable. Bench-forming purplish ferruginous lenses, (up to 40cm thick) of fine, micaceous, very porous, well sorted, quartz sandstone. Well rounded cobbles and boulders up to 40 cm in diameter common near base of unit. Rare small wood imprints.

Sandstone as above but with ubiquitous crossbedding at various scales from very small (sets 1cm) to medium (sets 30cm). Current direction west to northwest.

Coarsens downwards becoming coarse grained with granule and small pebble lenses and stringers towards base.

Light yellow-brown weathering, coarse, porous sandstone with white claystone pebbles and granules common along bedding planes. Medium to large northwesterly directed crossbedding.



LOCATION: GRID REFERENCE AMG 740 775m E, 671 4750m N

Top surface of thick gypsum crust and dense gibber mantle with occasional well rounded medium-sized boulders. Pale buff gypseous silt with lenses of yellowish cone-in-cone limestone that form discontinuous bands up to 30cm thick.

Hard, very calcareous, pebbly to gritty, medium- to fine-grained sandstone with khaki - brown weathering and irregular blocky to flaggy habit. Becomes pale grey towards base of unit.

Siltstone to very fine sandstone, slightly ferruginous at base.

Soft pale siltstone with thin harder bands of very fine siltstone, slightly micro-micaceous and with signs of bioturbation.

Flat concretionary ferruginous lenses of pebbly, medium to coarse grained sandstone.

Very fine, friable, pale grey to mauve, slightly micaceous sandstone. Occasional dark ferruginous lenses of fine- to medium-grained sandstone with downwards extending cylindroidal or lobate protrusions. Unit generally massive but shows thin parallel bedding in places.

Rather indurated, very thinly bedded to laminated siltstone. Lamination accentuated by secondary colouration.

Coarse-grained fining up to medium-grained gritty and pebbly sandstone with pinkish mauve colouration. Thin to medium bedding.

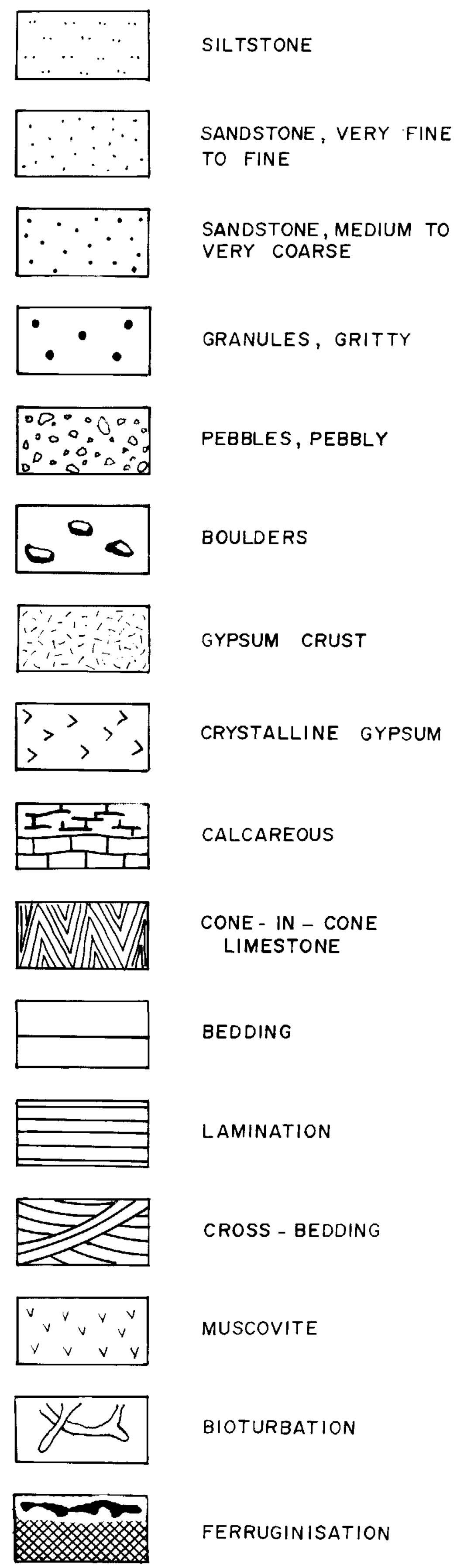
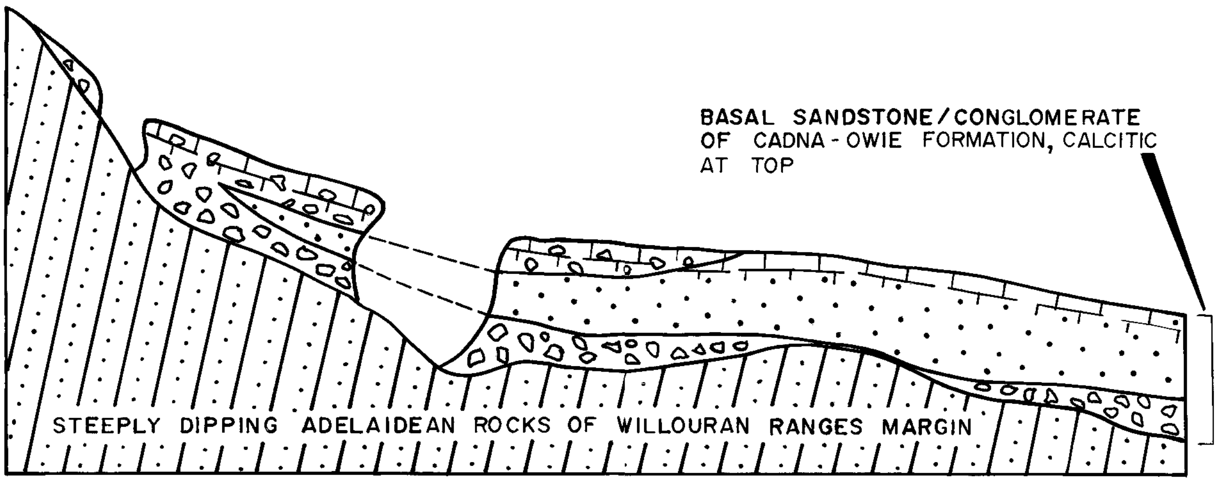


Figure. 5

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED G. KRIEG	CDO 12.9.90 DATE
CURDIMURKA 1:250 000 SHEET STRATIGRAPHIC SECTIONS OF BASAL MESOZOIC UNITS	DRAWN D.S.L.	SCALE as shown
	DATE Nov. '89	PLAN NUMBER
	CHECKED	90-485

4927



4927

Figure. 6

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED G. Krieg	C.D.O. DATE 12.9.90
CURDIMURKA 1:250 000 SHEET CADNA - OWIE FORMATION FACIES AT DAVENPORT SPRINGS	DRAWN D.S.L	SCALE
	DATE Dec. 89	PLAN NUMBER S 216 42
	CHECKED	

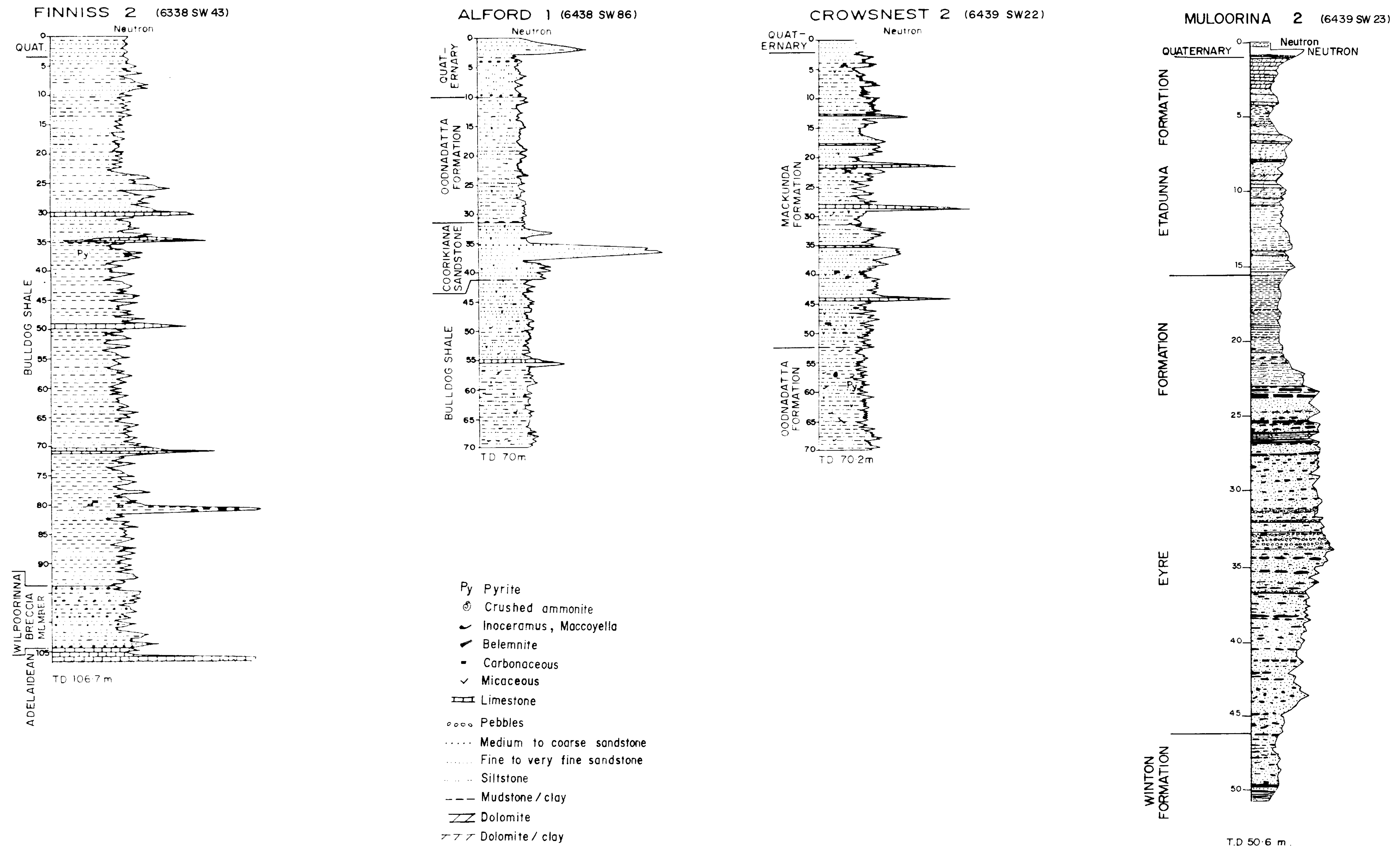


Figure. 7

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED G.W.K, R.C.A	C.D.O. 12.9.90 DATE
CURDIMURKA 1:250 000 SHEET	DRAWN D. Simpson	SCALE
SUMMARY DRILLHOLE LOGS	DATE June 90	PLAN NUMBER
FINNISS 2, ALFORD 1, CROWSNEST 2, MULOORINA 2	CHECKED	90-486

4927

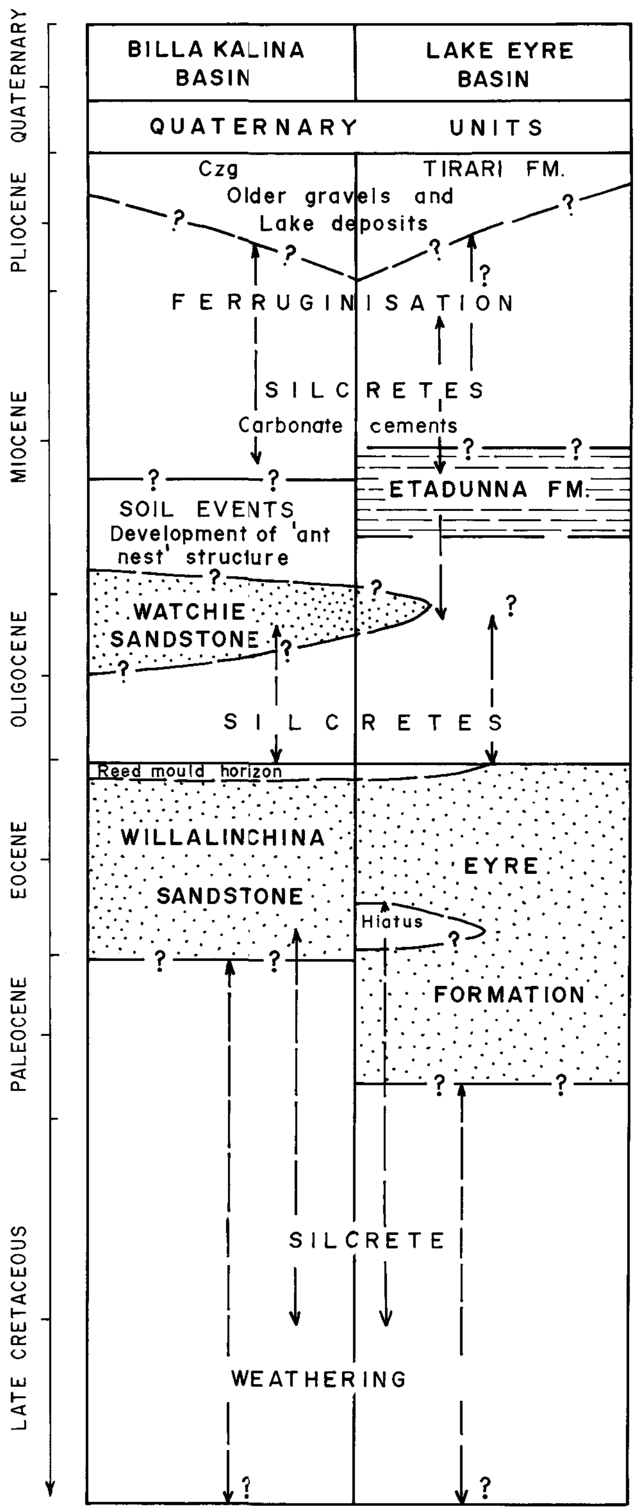
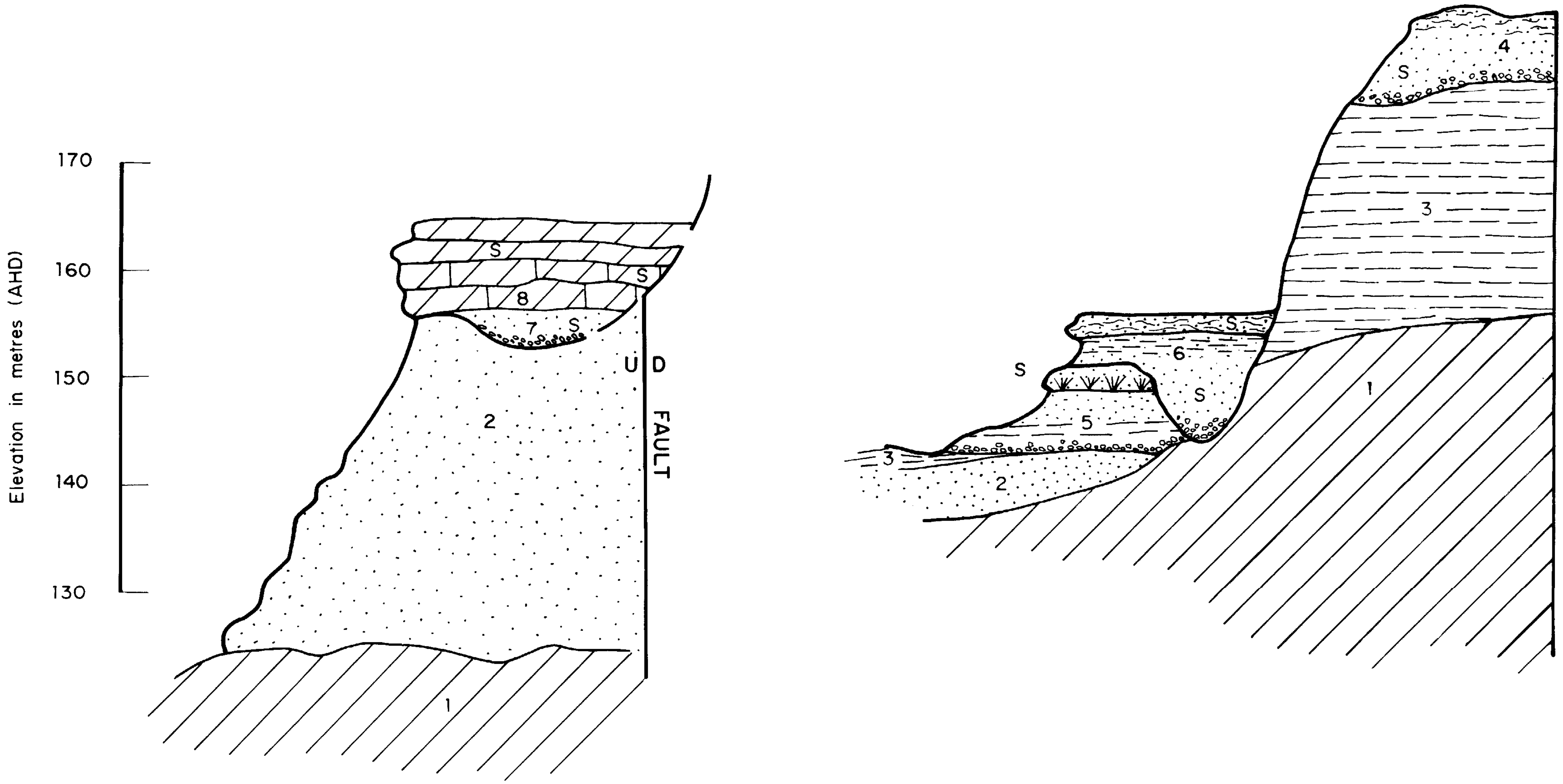


Figure 8

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED R. Callen	C.D.O. 12.9.90 DATE
CURDIMURKA 1:250 000 SHEET	DRAWN M.B.	SCALE
TERTIARY STRATIGRAPHY	DATE Mar '90 CHECKED	PLAN NUMBER S 216 43

4927



Mirikata & Etadunna Formation equivalents

CAINOZOIC

- 8 — Millers Creek Dolomite Member equivalent
- 7 — Danae Conglomerate Member equivalent
- 6 — Watchie Sandstone equivalent
- 5 — Willalinchina Sandstone equivalent
- 4 — Eyre Formation

MESOZOIC

- 3 — Bulldog Shale
- 2 — Cadna-owie Formation; Algebuckina Sandstone
- 1 — Adelaidean

S .... Silicification
.... 'Ant-nest' silcrete
.... 'Reed mould' silcrete

Figure. 9

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED R. Callen	C.D.O. DATE 12.9.90
CURDIMURKA 1:250 000 SHEET	DRAWN D. Simpson	SCALE
CAINOZOIC STRATIGRAPHY OF POOLE CREEK PALAEOCHANNEL UPPER CHANNEL REGION	DATE May 1990	PLAN NUMBER
	CHECKED	90 - 487

4927

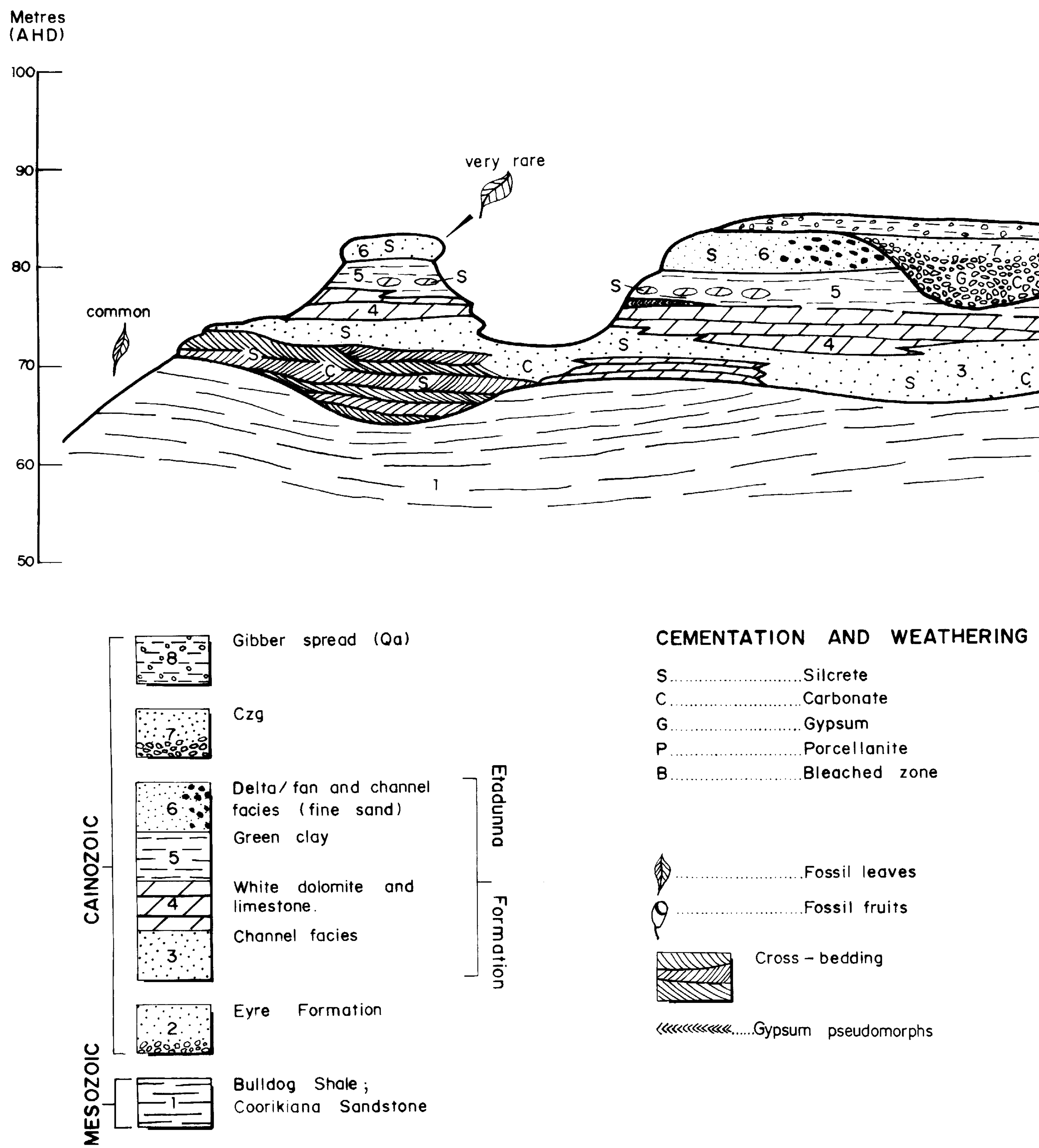


Figure. 10

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

CURDIMURKA 1: 250 000 SHEET
CAINOZOIC STRATIGRAPHY OF
POOLE CREEK PALAEOCHANNEL
MIDDLE CHANNEL REGION

COMPILED R. Callen	C.D.O. 12·9·90	DATE
DRAWN D. Simpson	SCALE	
DATE April 1990	PLAN NUMBER 90-488	
CHECKED		

4927

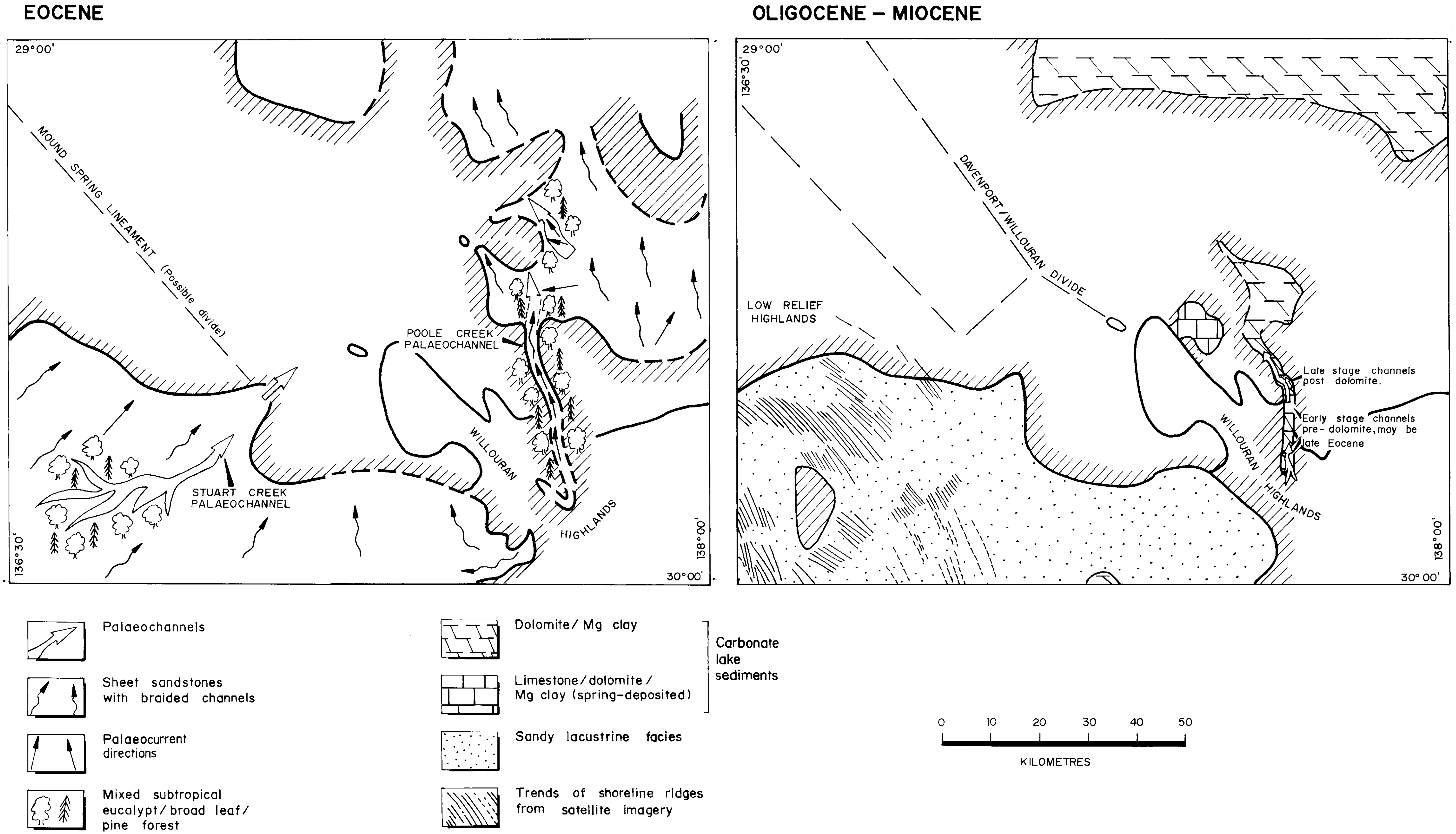


Figure. 11

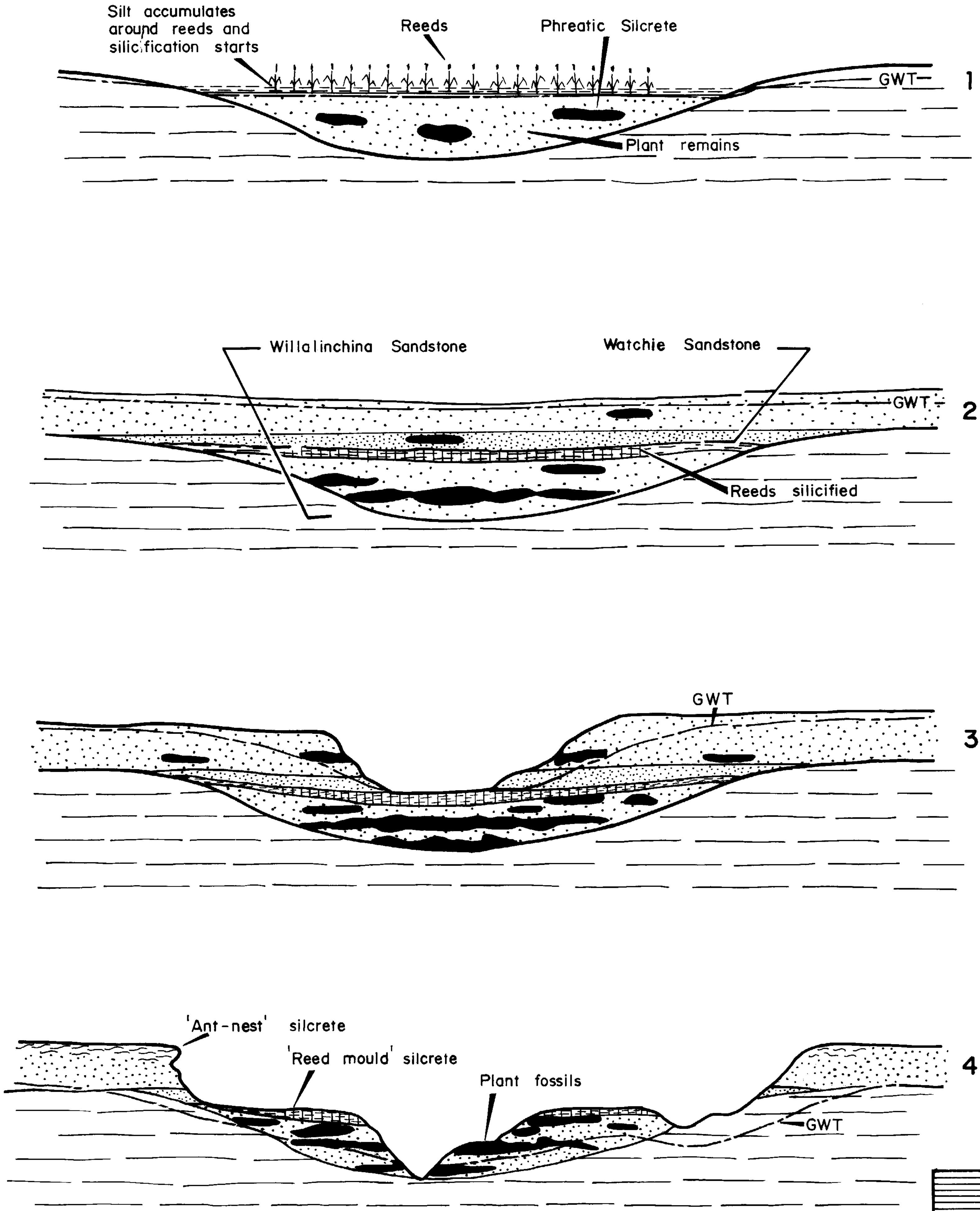
DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED R. Callen	C.D.O. DATE 11·9·90
CURDIMURKA 1:250 000 SHEET	DRAWN D. Simpson	SCALE
EOCENE AND OLIGOCENE – MIOCENE PALAEOGEOGRAPHY	DATE May 1990	PLAN NUMBER 90 – 489
	CHECKED	

4927

Figure. 12

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED R. Callen	C.D.O. 12.9.90 DATE
CURDIMURKA 1 250 000 SHEET	DRAWN D. Simpson	SCALE
SCHEMATIC CROSS SECTION OF STUART CREEK VALLEY	DATE May 1990	PLAN NUMBER
	CHECKED	90-490

4927



1 Willalinchina Formation time - ? Eocene

2 Watchie Sandstone time - Oligocene/Miocene

3 Pliocene and Quaternary valley development (Quaternary units not shown)

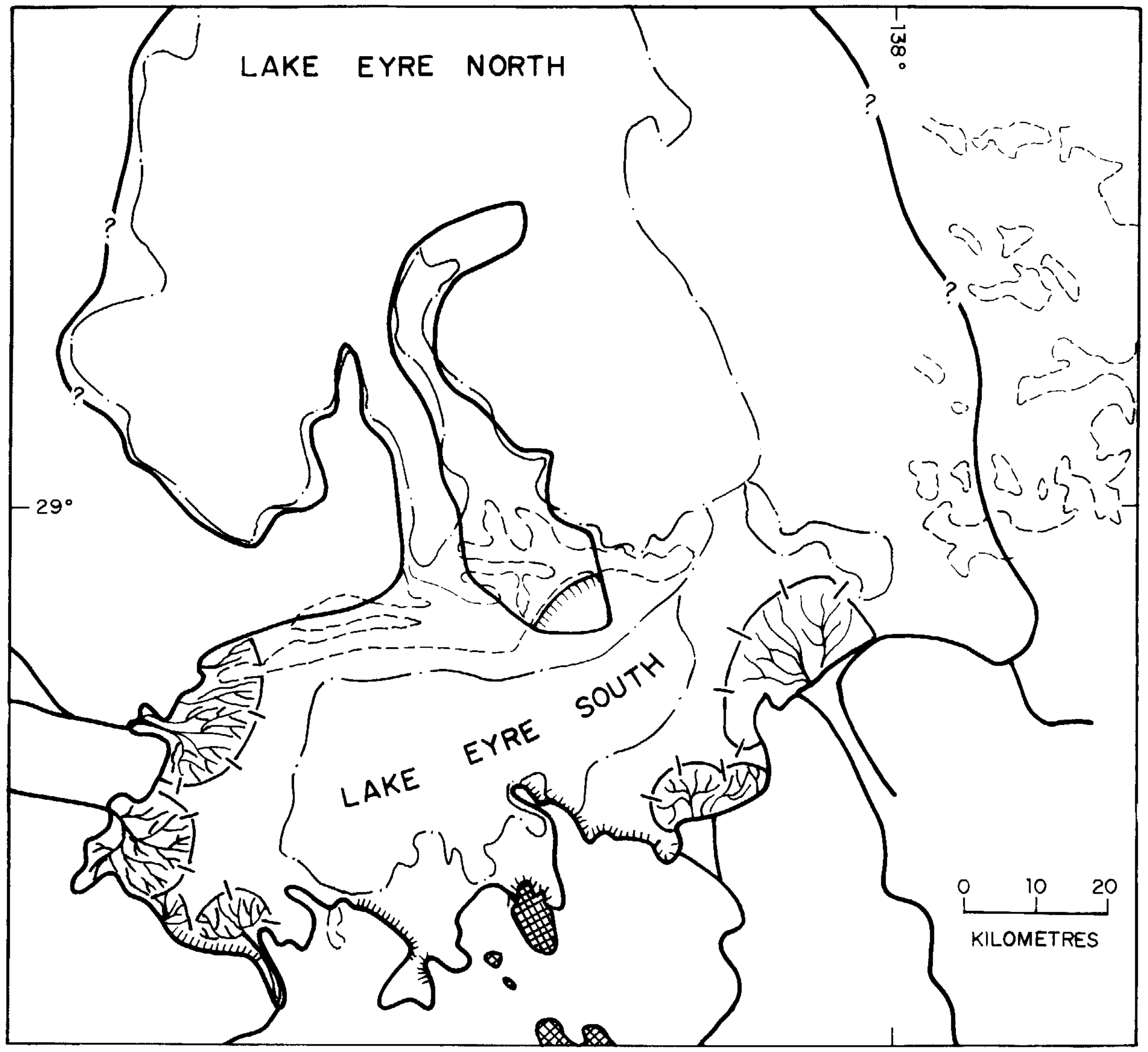
4 Present day (Quaternary units not shown)

Figure. 13

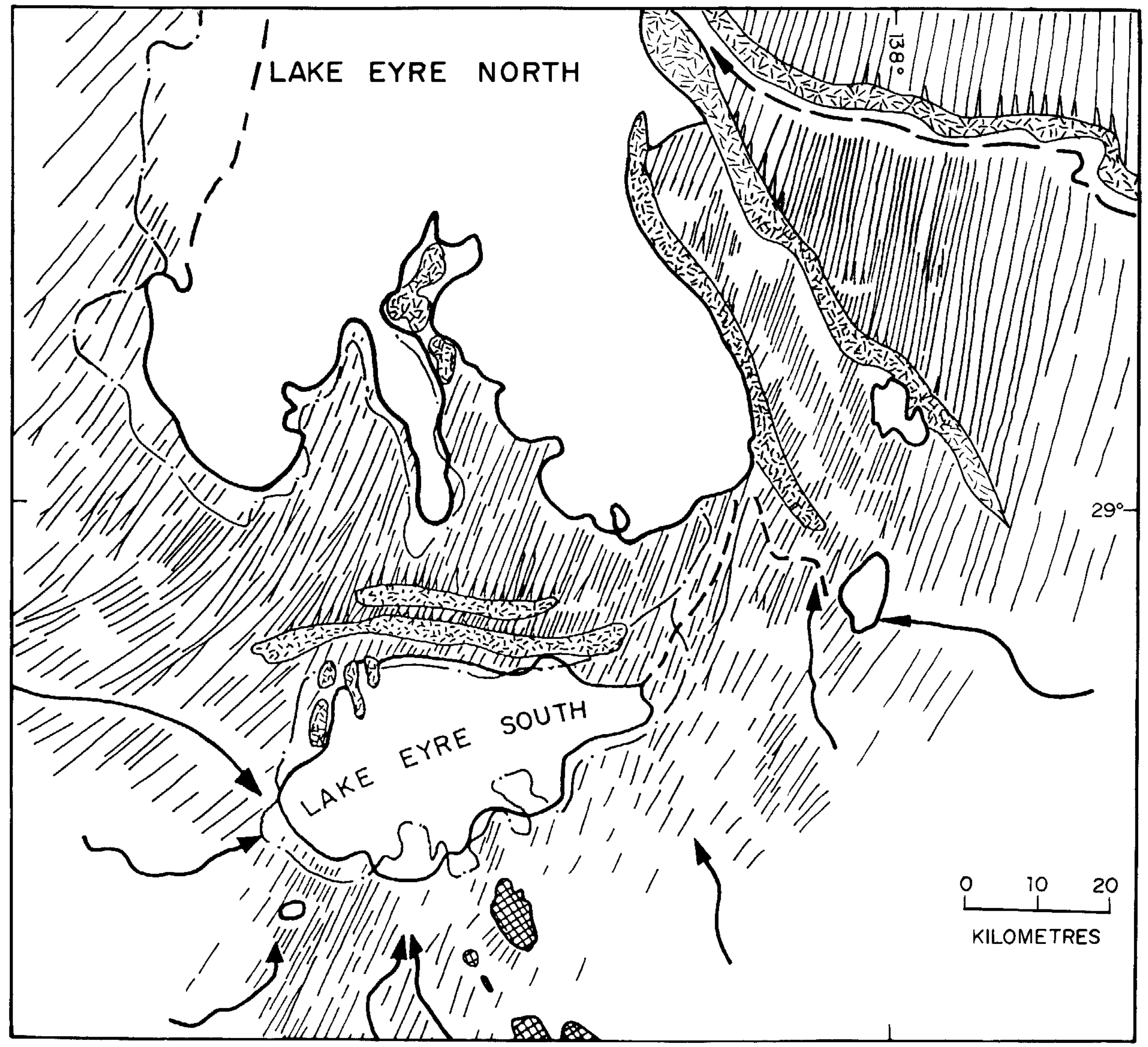
DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED R. Callen	WR 12.9.90 C.D.O. DATE
CURDIMURKA 1 250 000 SHEET **SILCRETE DEVELOPMENT IN STUART CREEK VALLEY**	DRAWN D. Simpson	SCALE
	DATE May 1990	PLAN NUMBER
	CHECKED	90-491

4927

Last interglacial period



Last glacial period



Cliff line

Fan/deltas

Modern Lake Eyre

Older shorelines

10m contour shown where not coincident with last interglacial shoreline

Dunes (diagrammatic)

Major lunettes

Highlands

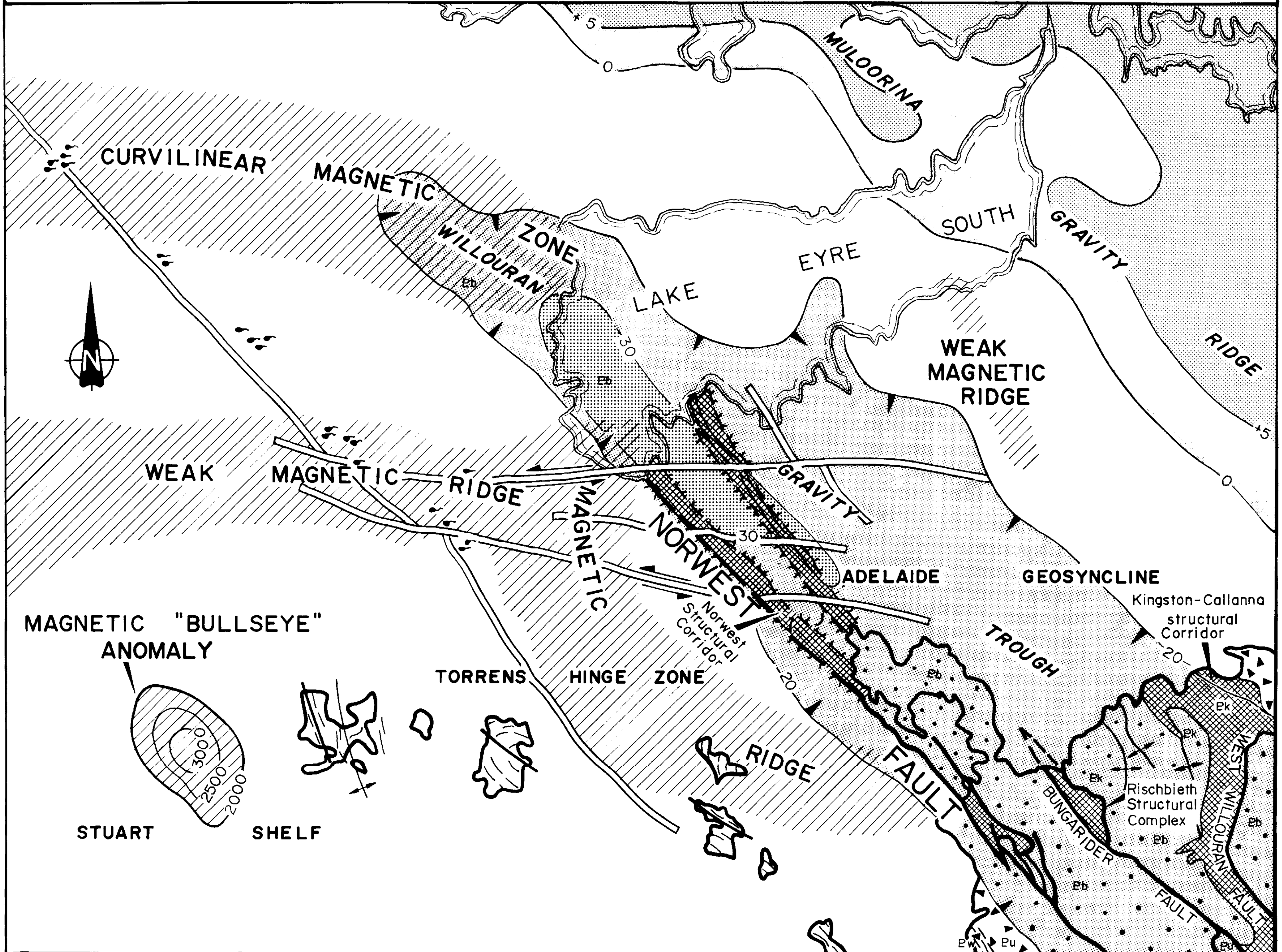
Figure. 14

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

CURDIMURKA 1 250 000 SHEET
PLEISTOCENE PALAEOGEOGRAPHY OF SOUTHERN LAKE EYRE

COMPILED R. Callen	C D O	12·9·90 DATE
DRAWN D. Simpson	SCALE as shown	
DATE May 1990	PLAN NUMBER	
CHECKED	90-492	

4927



Structurally complex corridors

Interpreted faults

Mound springs

Figure. 15

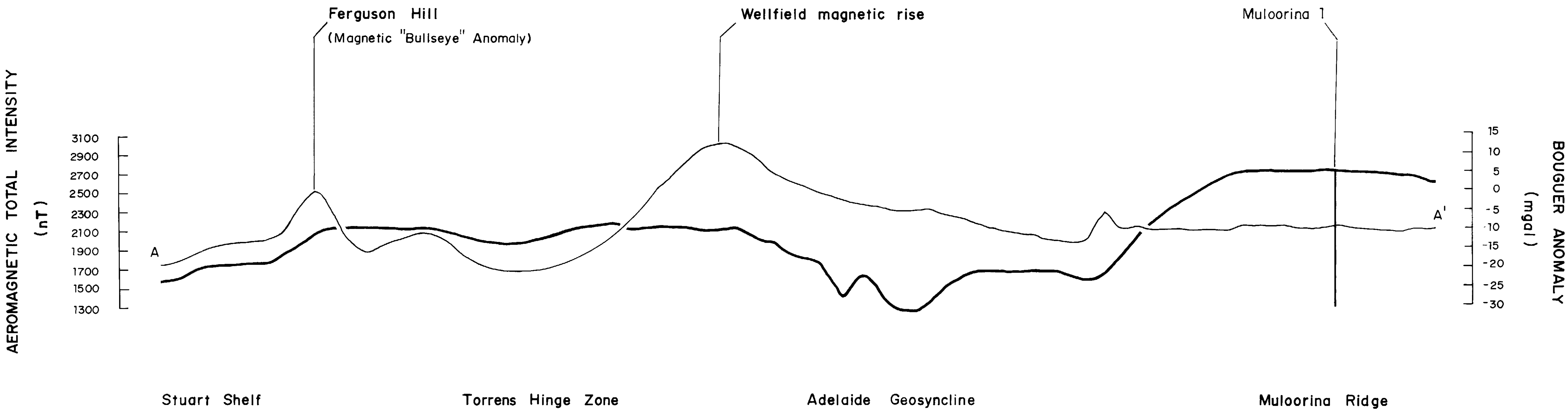
DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

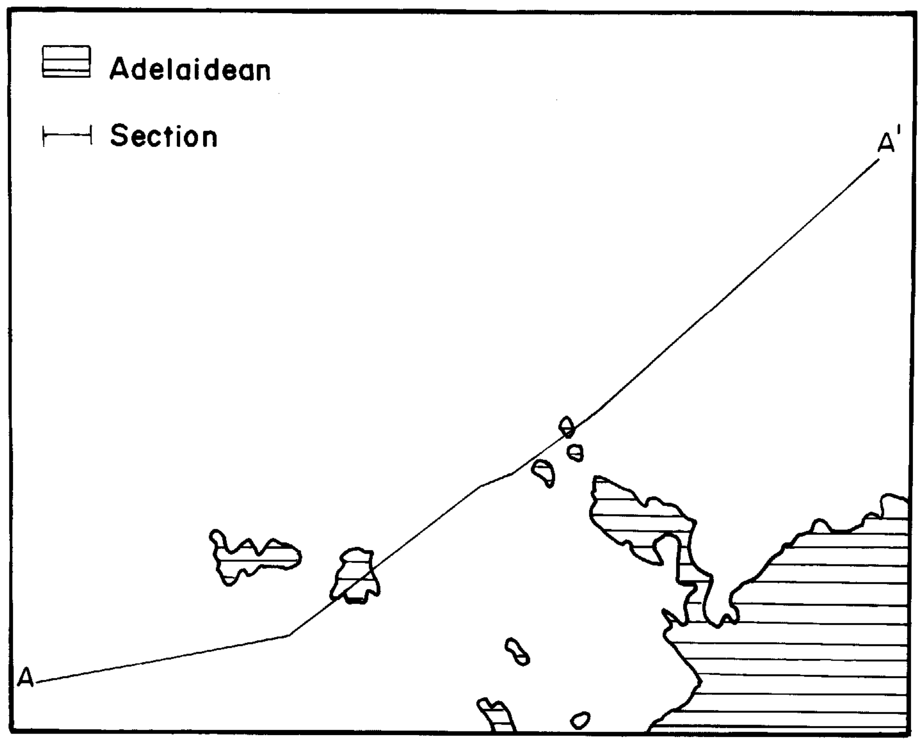
CURDIMURKA 1:250 000 SHEET

MAIN STRUCTURAL ELEMENTS

COMPILED G. Krieg	C.D.C.	DATE 12-9-90
DRAWN D.S.L	SCALE as shown	
DATE Dec. 89	PLAN NUMBER 90-493	
CHECKED		

4927





…………Aeromagnetic Total Intensity

……………Bouguer Anomaly (Bouguer density = 2·4 gm/cm^3)

Profiles plotted from contour intercepts

4927

Figure. 16

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA

CURDIMURKA 1:250 000 SHEET
PROFILES OF BOUGUER GRAVITY ANOMALIES AND AEROMAGNETIC TOTAL INTENSITY ALONG SECTION A - A'

COMPILED P. J. M	C D O 12·9·90 DATE
DRAWN D.S.L	SCALE As shown
DATE Dec 89	PLAN NUMBER
CHECKED	90 - 494