Precambrian and Palaeozoic Geology of the Peake and Denison Ranges

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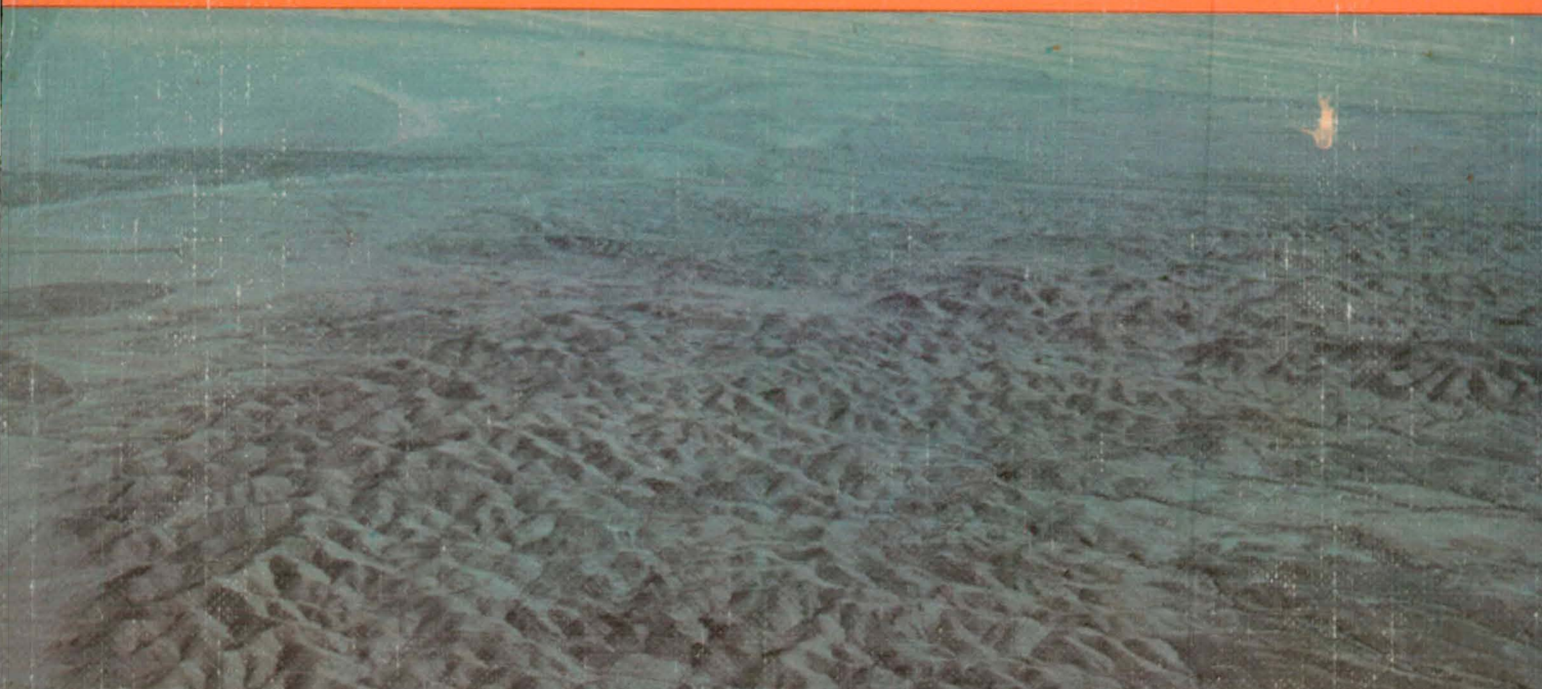

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17th November 1980

To the Honourable the Minister of Mines and Energy

I submit for publication a report by G. J. Ambrose, R. B. Flint and A. W. Webb on the 'Precambrian and Palaeozoic Geology of the Peake and Denison Ranges'.

The Bulletin provides a descriptive account of the accompanying geological map of the ranges presented at a scale of 1:150 000. The Precambrian sequence exposed is remarkably thick and well displayed, and the relationships of mineralisation to major volcanic and sedimentary units, structures and intrusive bodies has been demonstrated.

The region has been of interest since the discovery of gold near Algebuckina in 1870 and the finding of a one-carat diamond by H. Y. L. Brown near Peake Creek in 1894. Copper prospecting and mining in the area in the late 1890's and early 1900's has prompted repeated search without significant success.

The Peake and Denison Ranges represent an inlier of older basement rocks on the southwestern margin of the Great Artesian Basin and exposures of these sediments along the flanks of the ranges have been important in the search for oil, gas, coal and uranium.

Approval is sought to publish this report as Bulletin 50 of the Geological Survey.

B. P. WEBB, Director-General
Department of Mines and Energy

Approved, E. R. GOLDSWORTHY,
Minister of Mines and Energy

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ABSTRACT

The Peake and Denison Ranges comprise four northerly trending Precambrian inliers in the southwestern portion of the Great Artesian Basin. The Peake Metamorphics (?Early Proterozoic), the oldest rocks exposed, are composed of interlayered metabasalts and quartzites, in sequences over 10 000 m thick. These rocks were subjected to greenschist to amphibolite facies metamorphism and syntectonic granite intrusion about 1650 Ma, and further deformation and probable greenschist facies metamorphism at 1050 Ma.

Unconformably overlying the Peake Metamorphics there are at least 29 000 m of Adelaidean paralic sediments deposited in a steadily subsiding, fault-bounded trough which was a northern extension of the Adelaide Geosyncline. The thickness (27 000 m) of Willouran and Torrensian sediments preserved here is greater than elsewhere in the geosyncline. Adelaidean sedimentation is first recorded by the Willouran Callanna Beds: a basal clastic sequence (Younghusband Conglomerate) is overlain by the stromatolitic Coominaree Dolomite and the predominantly basaltic Cadlareena Volcanics. Faulting and diapirism have caused extensive disruption of the sequence above the Cadlareena Volcanics. From this dismembered succession the following stratigraphic units of Willouran or Torrensian age have been recognised: Rockwater Beds, War Loan Beds, Nilpinna Beds, Duff Creek Beds, and Murrana Beds.

The overlying Torrensian sequence (Burra Group) exceeds 10 000 m and comprises: unnamed siltstones, Fountain Spring Beds, Mount Margaret Quartzite, Skillogalee Dolomite, unnamed transition unit, and Kalachalpa Formation.

A period of mild erosion preceded deposition of the Sturtian-Marinoan Umberatana Group. The onset of glacial conditions resulted in deposition of the glaciomarine Calthorinna Tillite and interfingering sandstones. Subsequent marine silty shales and silty dolomites of the Tapley Hill Formation are overlain by the regressive Thora Dolomite and Willochra Subgroup.

Folding, diapirism, and metamorphism (to low greenschist facies) of the Adelaidean succession during the Cambro-Ordovician Delamerian Orogeny was accompanied by late-tectonic intrusion of porphyritic monzonites, syenites, diorites and albitites (Bungadillina Monzonite).

INTRODUCTION

The Peake and Denison Ranges are approximately 1000 km north of Adelaide. They trend northerly for 130 km parallel to the Central Australia Railway (narrow gauge) and Marree-Oodnadatta road, and cover an area of 2 600 km^2 between latitudes 27°45′ and 28°55′S, and longitudes 135°30′ and 136°25′E (Figs 1 and 2).

The first comprehensive map of the area was compiled by Reyner (1955). In 1972, R. P. Coats and W. V. Preiss (S. Aust. Dept. Mines and Energy) mapped a portion of the ranges as part of the program to compile the WARRINA 1:250 000 sheet on which the ranges are mainly situated. Subsequent detailed mapping by the authors during 1975-76 completed this mapping program. Field observations were plotted on 1:20 000 scale aerial photographs (Department of Lands, Surveys 88, 89, 90). Geological data were transferred onto 1:77 000 aerial photographs (Department of Lands, Surveys 588, 591) and subsequently onto photoscale base maps. From these bases a 1:150 000 geological map was prepared (in pocket).

GEOGRAPHY

The Peake and Dension Ranges consist of a northerly trending series of low-lying ranges with a maximum relief of 300 m above undulating plains. Four Precambrian inliers constitute the Peake and Denison Ranges—the Dutton, Algebuckina, Denison, and Margaret Inliers. The Dutton and Algebuckina Inliers lie to the north of, and are subordinate to, the Denison and Margaret Inliers which form the bulk of the ranges (Fig. 1).

The southernmost range (Margaret Inlier) extends northward from Anna Creek H. S. (Homestead) for 70 km and averages 16 km in width. This inlier is named after Mount Margaret (410 m above MSL) the highest peak in the region. Topography is particularly rugged along the eastern margin of the inlier. The Mount Margaret Plateau, a conspicuous, gently dipping peneplain, comprises the northern core of the Margaret Inlier. This imposing plateau rises about 250 m above the surrounding plains and from its maximum elevation, just north of Mount Margaret, it slopes gently westwards and northwards.

The Denison Inlier, with an average width of 7 km, rises abruptly from the plains about 10 km north of the Margaret Inlier and extends northwards for about 25 km. Mounts Denison and Kingston are two high points on the inlier. Approximately 7 km northwest of the Denison Inlier, on the banks of the Neales River, are a series of small low hills comprising the Algebuckina Inlier. The Dutton Inlier is named after Mount Dutton, the highest point in a small prominent range of hills about 15 km northwest of the Algebuckina Inlier.

Rock exposures are good except on the western margin of the ranges where Mesozoic and Tertiary weathering, leaching, kaolinisation and peneplanation of Precambrian rocks has resulted in a subdued topography. Mesozoic and Permian sediments lap onto the western margin of the ranges and the weathered Precambrian rocks are often masked by a veneer of younger sediments and associated lag deposits.

Drainage from the ranges is dominantly easterly, with creeks draining via the Peake Creek and Neales River into Lake Eyre 80 km to the east. There are two permanent waterholes in the region, one near Algebuckina R.S. (Railway Siding) on the Neales River, and the other at Warrawaroona W. H. (Waterhole) on the Peake Creek. Along the faulted eastern margin of the ranges are several springs including Freeling, Edith, and Tarlton Springs. On the plains to the east of the ranges are numerous artesian springs (e.g. Hawker, Outside, and Fanny Springs) and artesian bores (e.g. Hope Creek, Birthday, and Umbum Bores—see geological map in pocket.

Climate of the region is arid with a mean annual rainfall of 125 mm; average annual evaporation is 3 800 mm. The low rainfall results mainly from thunderstorms between October and May. The region experiences hot summers with an average summer maximum temperature of 36·5°C; minimum winter temperatures often fall below 0°C.

Although vegetation in the region is sparse, a considerable variety of species is present (Laut *et al.*, 1977). The ranges themselves are hosts to *Acacia aneura* (mulga), *A. brachystachya* (umbrella mulga), *Eremophila freelingii*, *Digitaria browaii* (cotton grass), *Bassia* spp. (bindyi), and *Eremophilia maculata* (native fuchsia). Areas marginal to the ranges contain varying proportions of the following species: *Atriplex rhagodioides* (silver saltbush), *A. vesicaria* (bladder saltbush), *Maireana astrotricha*, *Cucumis myriocarpies* (paddy melon), *Kennedia astrotricha* (pearl bush), *Salicornia* spp. (samphire) and bindyi. The following species are found in dune country on the plains: *Acacia ligulata* (sandhill wattle), *Zygochloa paradoxa* (sandhill cane grass), *Cassia* spp. (Kangaroo bush), *Eremophila* spp., *Dodonaea attenuata* (hop bush), native fuchsia and mulga. Large trees are restricted to creeks draining from the ranges and species include *Eucalyptus microtheca* (coolibah), *E. camaldulensis* (river red gum), and *Acacia cambagei* (gidgee).

Because of the harsh climate the region is sparsely settled, and since the area lies north of (outside) the dingo-proof 'Dog-Fence', land use is restricted to cattle grazing. The four cattle stations are Anna Creek, Peake, Nilpinna and Allandale. A very small township is located at William Creek.

The graded Marree-Oodnadatta road provides reasonable access to the region. Through the ranges a system of rough tracks allow access, the adequacy of which varies according to weather conditions.

PREVIOUS INVESTIGATIONS

John McDouall Stuart, who explored much of Central Australia in the late 1850s and early 1860s, made the first recorded geological observations in the Peake and Denison Ranges (Stuart, 1860, 1862). Scoular (1887) described the topography from Anna Creek to Mount Margaret, analysed water samples from several bores and wells, and described quartzites and sandstones in the area. Basement metamorphics

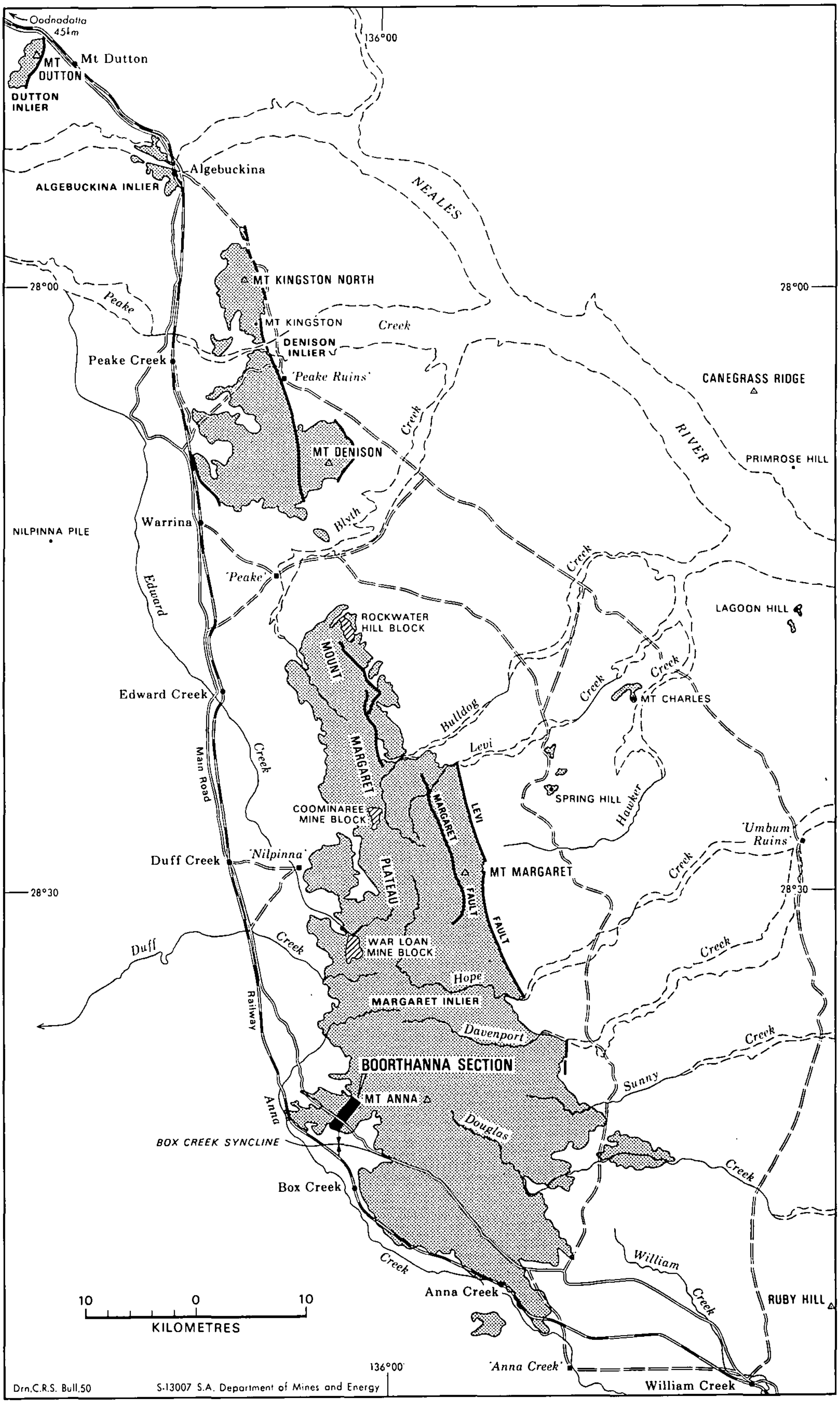


Fig. 1. Locality plan, Peake and Denison Ranges

near Mount Denison, granites and gneisses near Mount Kingston, and a quartz syenite at Spring Hill were described by East (1889). Shortly after, Brown (1894) found traces of gold and a one-carat diamond while panning on the western side of the ranges near Peake Creek.

Copper prospecting was active in the late 1890s after the establishment of a permanent settlement at 'Peake,' a station on the original overland telegraph line from Adelaide to Darwin. A smelting plant was built near the telegraph station to treat ore from the Peake and Copper Top Mines. In the period 1915-1920 copper was mined from the War Loan, Coominaree, and Last Chance Mines; early mining activities at these localities were reported by Winton (1919).

Preliminary observations on the geology and hydrology of the area were made by Jack (1930). The first detailed hydrological report was written by Chugg (1957). Regional geological mapping of the Peake and Denison Ranges during 1953 resulted in the publication of seven 1:63 360 geological maps, namely *Algebuckina, Nilpinna, Conway, Umbum, Boorthanna, Cadlareena,* and *Anna* (Dickinson *et al.,* 1954a, 1954b, 1955a, 1955b, 1955c, 1955d, 1955e). The first comprehensive study of the geology of the region was published by Reyner in 1955. He divided the Adelaidean sequence into the following units:

Sturtian	—The Sturtian Tillite (1 300 m)
Torrensian	—the 'Magnesite Series' (3 600 m)
	—the Mount Margaret Quartzites (3 200 m)
Willouran	—the Duff Creek Formation (3 200 m)

In 1964, Thomson and Coats proposed the name Duff Creek beds to replace Duff Creek Formation which they correlated with the type section of the Callanna Beds in the Willouran Ranges, 240 km southeast of the Peake and Denison Ranges. The Mount Margaret Formation (a modification of Reyner's term) was considered equivalent to the Witchelina and Copley Quartzites, then believed to be at the base of the Burra Group.

In 1966, Thomson described a basal Adelaidean (Willouran) sequence unconformably overlying crystalline basement and in faulted contact with younger Duff Creek beds. From these oldest Adelaidean rocks, Preiss (1973a) has reported columnar stromatolites. Schopf and Fairchild (1973) and Fairchild (1975) have studied late Precambrian stromatolites and microbiota and their stratigraphic significance.

Detailed stratigraphic sections through Adelaidean sequences within the ranges, and Mesozoic rocks flanking the ranges, were first measured in 1963 by French Petroleum Company geologists (Cooper *et al.,* 1963).

Since 1920 no mines have been worked, however, in the past decade, mineral exploration has been carried out for U, Cu, Pb, Zn, Ni, Co, Cr, Mn, Ag, As, and Au in the Precambrian rocks and U, Au, S, K, clay, coal, and liquid hydrocarbons in the younger sedimentary basins flanking the ranges. In the period 1966-1968, North Broken Hill Ltd carried out extensive soil and stream sediment sampling and drilled three diamond-drillholes: Peake 1, and War Loan 1 and 2 (Forwood, 1968). In 1970, Australasian Mining Corporation took out a special mining lease and conducted radiometric and aeromagnetic surveys; three percussion and four diamond-drillholes (Algebuckina 1, 2, 3, and 4) were drilled (Sargeant, 1970). Geochemical and geophysical investigations for copper-uranium mineralisation at the Last Chance Mine indicated no economic mineralisation (Leeson, 1972). Uranerz (Australia) Pty Ltd explored for uranium and drilled two diamond-drillholes, one in the Cadlareena Volcanics (2BAA/DDHI) and the other (DDH2/MG2) in migmatites of the Peake Metamorphics (Iliff *et al.,* 1974; Iliff, 1975). Western Mining Corporation Ltd carried out extensive stream sediment surveys and soil and rock chip sampling for base metals (Western Mining Corporation Ltd, 1975).

GEOLOGICAL SETTING OF THE PRECAMBRIAN ROCKS

The Peake and Denison Ranges are a series of northerly trending Precambrian inliers situated in the southwestern portion of the Great Artesian Basin, approximately midway between the Musgrave Block and Willouran Ranges (Fig. 2). They are linked to the Willouran Ranges and Mount Painter Province by the Muloorina Gravity High, and consist of ?Early Proterozoic Peake Metamorphics unconformably overlain by Adelaidean sediments. The Peake Metamorphics have no apparent correlatives in South Australia and are tentatively correlated with the Eastern Creek Volcanics of the Mount Isa Trough. Adelaidean sedimentation represents deposition in the northern extension of the Adelaide Geosyncline which was intermittently connected to other basins to the north and east (i.e. Amadeus Basin and Broken Hill area).

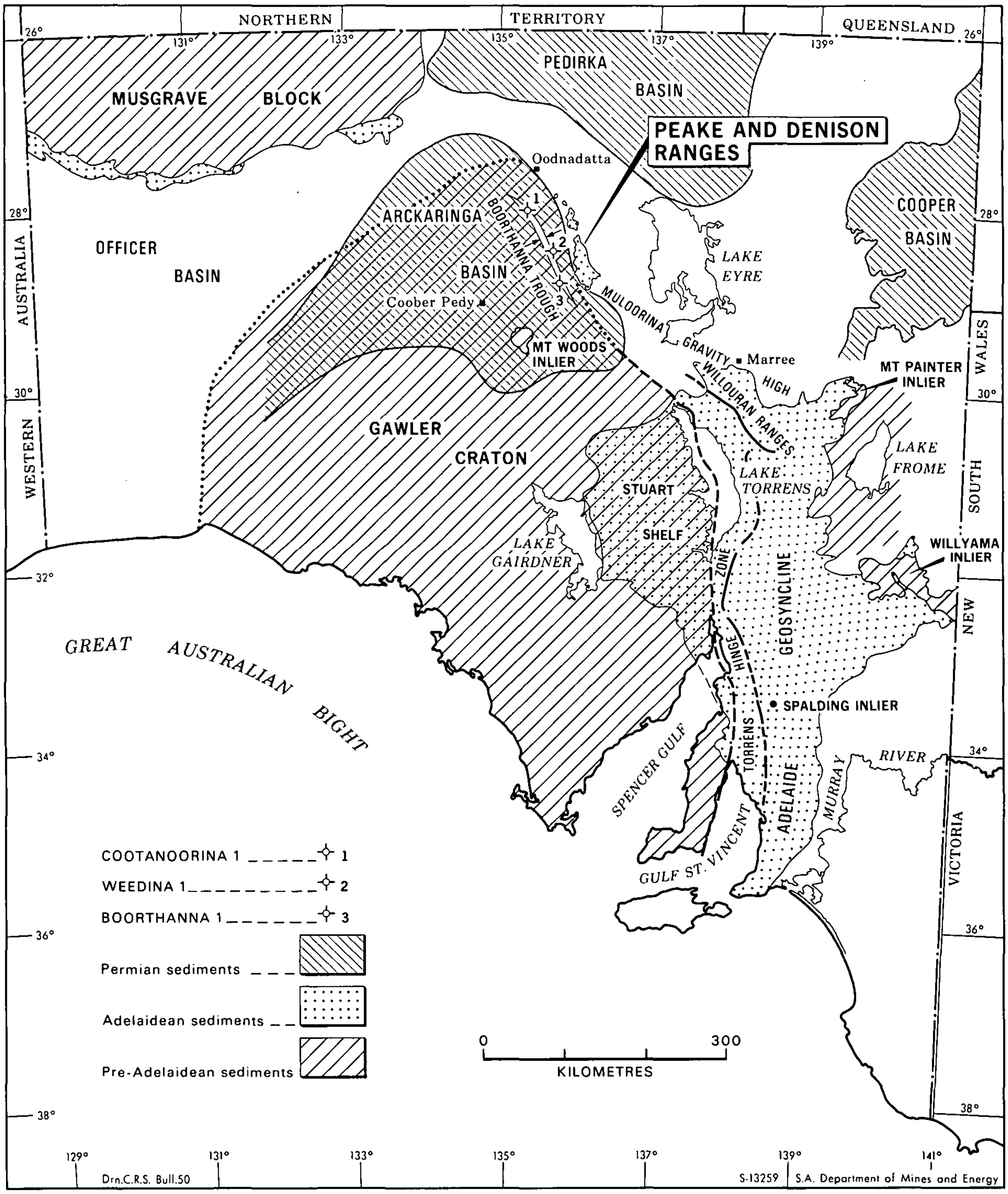


Fig. 2. Peake and Denison Ranges, regional geological setting

The Peake and Denison Ranges are flanked by two Permian basins—the Arckaringa Basin to the west and Pedirka Basin to the northeast. Beneath the Boorthanna Trough (a sub-basin of the Arckaringa Basin) early Palaeozoic sediments intersected in drillholes include ?Ordovician quartzites in Weedina No. 1 (Papalia, 1970) and ?Devonian dolomites, arenites, and anhydrite of the Cootanoorina Formation in Cootanoorina No. 1 and Weedina No. 1 (Papalia, 1970; Allchurch *et al.*, 1973). Below the Pedirka Basin, a more complete early Palaeozoic sequence is represented comprising Cambrian carbonates and shales, Ordovician sands and Devonian terrestrial sands, shales, and conglomerates. (Youngs, 1975a).

The Permian sediments of the Arckaringa and Pedirka Basins have been extensively studied in recent years (Ludbrook, 1961; Holmes, 1970; Wopfner, 1970; Holmes and Rayment, 1970; Papalia, 1970; Allchurch *et al.*, 1973; Townsend, 1973; Barclay, 1974; Townsend and Ludbrook, 1975; Youngs, 1975a, 1975b). In the Boorthanna Trough, the base of the Permian is marked by glacial diamictites, conglomerates, pebbly sandstones and grey clays of the Boorthanna Formation. Diamictites and conglomerates of this basal unit outcrop along the western margin of the ranges. The Boorthanna Formation is overlain by marine shales of the Stuart Range Formation, which is in turn overlain by the Mount Toondina Formation, a terrestrial sequence of coals, carbonaceous shales and siltstones, and arenaceous sediments (Townsend and Ludbrook, 1975).

In the Pedirka Basin, glacial diamictites, pebbly sandstones and clays of the Crown Point Formation are overlain by the Purni Formation, a terrestrial sequence of sandstones, siltstones, shales, conglomerates and thin coal bands (Youngs, 1975a, 1975b).

Great Artesian Basin sediments flanking the ranges consist of ?Jurassic basal conglomeratic, kaolinitic sandstones (Algebuckina Sandstone) and overlying micaceous and arenaceous sediments of the Cretaceous Cadna-owie Formation (Wopfner and Heath, 1963; Wopfner *et al.*, 1970). Other Cretaceous sediments include carbonaceous shales and concretionary, fossiliferous limestones of the Bulldog Shale (Freytag, 1966; Teluk, 1974) and argillaceous siltstones and shales, and olive glauconitic sandstones of the Oodnadatta Formation (Freytag *et al.*, 1967).

Tertiary sediments comprise silicified claystones and sandstones, and silcrete conglomerates (Freytag *et al.*, 1967). These have been extensively eroded with pebbles, cobbles, and boulders of silicified sediments occurring as a Quaternary gibber lag over Mesozoic units. Rare outcrops of Tertiary sediments have been preserved at Mount Harvey and along the eastern margin of the ranges.

During the late Miocene and Pleistocene, faulting resulted in uplift of huge blocks tilted gently to the west, forming the Peake and Denison Ranges (Wopfner, 1968, 1972).

Quaternary sediments surrounding the ranges include sand dunes, gibber plains, calcareous silts and clays, gypsiferous gravels, and alluvial sands, silts and clays.

STRATIGRAPHY

Geological mapping by Reyner (1955) and Dickinson *et al.* (1954a, 1954b, 1955a, 1955b, 1955c, 1955d, 1955e) established the outcrop boundaries and general stratigraphy for the ranges. However the stratigraphic succession and facing for the Peake Metamorphics were not known; the existence and extent of volcanics were not fully realised and the Adelaidean succession was only partly assembled. The structures now recognised as diapirs were interpreted as complex crush zones resulting from interaction of thrusting, rifting, and polyphase folding. During the present mapping program these zones were remapped in detail and are shown on the geological map. Details of the revised stratigraphic succession are highlighted in Table 1.

Peake Metamorphics (?Early Proterozoic)

Pre-Adelaidean basement rocks chiefly outcrop in the northern portion of the Peake and Denison Ranges. Reyner (1955) originally named the basement rocks the Peake Series, which was subsequently amended to Peake Metamorphics (Thomson, 1966). However an intrusive granite (Wirriecurrie Granite) has been recognised and it is proposed that the term Peake Metamorphics exclude the Wirriecurrie Granite and be restricted to the remainder of the pre-Adelaidean rocks.

The metamorphics can be subdivided into five mappable units (Table 1).

Unnamed metamorphics (Ᵽd1) This unit consists of a wide variety of rock types including quartzites, quartz+biotite and muscovite schists, quartz+biotite+feldspar gneisses, migmatites, pegmatites, and diorites.

Tidnamurkuna Volcanics (Ᵽdt) Volcanics within this unit include flow-banded porphyritic rhyolites and amygdaloidal basalts with a 600 m section exposed.

Unnamed schists (Ᵽd2) Rock types are dominantly quartz+muscovite schists and quartz+chlorite phyllites, with minor sandstones.

Baltucoodna Quartzite (Ᵽdb) The unit is characterised by interlayered greyish white quartzites, basalts and amphibolites, and minor sillimanite gneisses, pyroxene granulites, calcite marbles, and hornblende+epidote calc-silicates.

Unnamed metamorphics (Ᵽd3) A wide variety of rock types present include grey quartzites, magnetite-rich epidosites and arenaceous schists, and minor clinopyroxene granulites and amphibolites.

Table 1 *Stratigraphic table—Peake and Denison Ranges*

Age	Stratigraphic unit: symbol and primary references	Thickness (metres)	Lithology	Remarks
			Post-Adelaidean Stratigraphy	
ORDOVICIAN	Bungadillina Monzonite-Odb (Reyner, 1955)	—	Coarse-grained porphyritic monzonites and syenites, porphyritic diorites, porphyritic white albitites.	Intrusives are plagioclase rich and quartz poor.
			Adelaidean Stratigraphy	
			UMBERATANA GROUP	
MARINOAN	Unnamed siltstone—Ᵽh1 (Thomson, *In* Parkin, 1969)	950 (minimum)	Red-brown silty shales, grey-green shales, silty dolomites, fine sandstones and thin grey-yellow dolomites.	Records the first appearance of reddish siltstones in the Umberatana Group—hence allocated to the Willochra Subgroup.
STURTIAN	*Thora Dolomite—Ᵽfl (Mawson and Sprigg, 1950)	30-40	Buff-weathering, grey-green and brown dolomites, minor siltstones; large festoon surfaces and algal bedding.	Characterised by a light-coloured weathering pattern which distinguishes it from adjacent units.
	Tapley Hill Formation—Ᵽft (Coats, 1964; Coats and Blissett, 1971)	150	Laminated grey-green silty shales and silty dolomites; basal thin sandy dolomite.	Exhibits characteristic fine lamination; records a marine transgression following the pre-existing glacial conditions.
	Unnamed sandstone—Ᵽu1	530	Quartzitic sandstones, arkoses, argillaceous sandstones; red porphyry granules and large-scale cross-bedding.	Fluvio-glacial; intertongues with the Calthorinna Tillite and marks the end of the glacial period.
	*Calthorinna Tillite—Ᵽub (Coats, 1964; Coats and Blissett, 1971; Coats and Forbes, 1977; Reyner, 1955)	650 (minimum)	Diamictites, conglomeratic dolomites, pale green shales, gritty sandstones, arkoses and quartzites.	Represents the upper phase of lower Sturtian glacial activity. Interbedded diamictites (glacial) and marine sediments indicate a glacial marine environment.
			Disconformity	
			BURRA GROUP	
TORRENSIAN	*Kalachalpa Formation—Ᵽbh (Fairchild, 1975; Coats, 1973)	900	Grey-green and brown siltstones and shales, gritty sandstones and quartzites, conglomeratic dolomites, stromatolitic dolomites, oolitic sediments, black cherts; quartzites and shales at the top.	Stramatolitic microflora described by Fairchild, 1975; considered to be equivalent to the Myrtle Springs Formation; gradational contact with the underlying unnamed unit.
	Unnamed unit—Ᵽb2 (Fairchild, 1975)	2 000 (minimum)	Gritty quartzitic sandstone, stromatolitic dolomites, conglomeratic dolomites, magnesite conglomerates, black and minor red cherts, grey shales and siltstones; mud cracks, ripple marks and cross-bedding.	Many lithological affinities with the Skillogalee Dolomite e.g. dolomite pebble conglomerates, magnesites and black cherts; this unit is probably transitional between the Kalachalpa Formation and Skillogalee Dolomite.
			Gap in the sedimentary record (gradational contact suspected)	
	Skillogalee Dolomite—Ᵽbk (Mirams and Forbes, 1964; Reyner, 1955)	3 600 (minimum)	Basal member composed of quartzites, sandstones, shales and minor dolomites. The middle member consists of sandstones, dark and pale grey conglomeratic dolomites, magnesite conglomerates and blue-black cherts. The upper member is mainly dark grey conglomeratic dolomite.	Outcrops in a series of basinal synclines forming the core of Margaret Inlier; stromatolite form *Baicalia burra* is common in the upper two members; lower contact with the Mount Margaret Quartzite is comformable although often disrupted by diapirism.

Table 1 *Stratigraphic table—Peake and Denison Ranges (continued)*

Age	Stratigraphic unit: symbol and primary references	Thickness (metres)	Lithology	Remarks
	*Mount Margaret Quartzite—Ᵽbo (Reyner, 1955; Thomson and Coats, 1964)	2 500	White orthoquartzites, slaty quartzitic sandstones, dark grey sandy siltstones, green-grey silty shales, minor dolomitic siltstones near the base; thick orthoquartzites at the top; clay galls, ripple marks and cross-bedding.	Comprises Mount Margaret and also constitutes the Mount Margaret Plateau. The lower contact with the Fountain Spring Beds is gradational, the passage downwards being marked by an increased siltstone content.
	*Fountain Spring Beds—Ᵽbl (Forbes, 1964)	1 100 (minimum)	Characteristic laminated grey dolomitic siltstones, interbedded grey quartzites with clay-gall laminations, grey-green silty shales containing salt casts, minor grey silty dolomites.	The upper contact with the Mount Margaret Quartzite is marked by an increase in the frequency of orthoquartzites; laminated dolomitic siltstones and silty dolomites are similar to lithologies in the underlying unnamed siltstone; considered to be River Wakefield Subgroup equivalent.
	Sedimentary contact not observed—gradational contact suspected on the basis of lithological overlaps			
	Unnamed siltstone—Ᵽb1	1 200 (minimum)	Laminated grey pyritic dolomitic siltstones, green shales, pyritic silty dolomites, fine sandstones and minor quartzites; ripple marks, cross-beds, salt casts.	Dark grey laminated siltstones are typical of the Fountain Spring Beds, some of the dolomites and sandstones (salt casts) are reminiscent of the Duff Creek Beds.
	Gap in the sedimentary record			
	SEQUENCES OF UNCERTAIN AGE			
	Undifferentiated blocks in diapirs and faulted sequences—Ᵽa	5 000 (minimum)	Lithologies from 8 blocks are described in the text. Sediments observed in diapirs often contain an abundance of salt casts.	Most of the sediments in these blocks are derived from early Adelaidean sequences, above the Cadlareena Volcanics, which have been dismembered by diapirism and faulting.
	Gap in the sedimentary record			
	*Murrana Beds—Ᵽaa	2 900 (minimum)	Laminated gritty quartzitic sandstones, grey-green silty shale interbeds; arkoses, pebbly dolomites, purple and grey silty shales near the top; ripple marks, mud cracks, cross-beds, flute casts and salt casts.	This unit has lithological affinities with the Duff Creek Beds e.g. minor pale dolomites in the lower part of the unit and fine sandstones and green shales both containing salt casts.
	Sedimentary contact not observed—gradational contact suspected on the basis of lithological overlaps			
WILLOURAN OR TORRENSIAN	*Duff Creek Beds—Ᵽaf (Reyner, 1955; Thomson and Coats, 1964)	5 500 (minimum)	Laminated olive-green silty shales and thin arkose interbeds, flaggy grey and yellow dolomites, dolomitic siltstones, pyritic fine sandstones, minor quartzites; mud cracks, ripple marks, clay galls, cross-bedding; horizons with abundant salt and gypsum casts.	Pale buff, flaggy dolomites characterise the unit; deposited in lagoonal, supratidal and intertidal environments; fine platy sandstones (salt casts) in the lower part of the sequence are similar to the Nilpinna Beds.
	Sedimentary contact not observed—gradational contact suspected on the basis of lithological overlaps			
	*Nilpinna Beds—Ᵽan	2 100 (minimum)	Fine sandstones, grey-green silty shales, quartzites and minor grey silty dolomites and green arkoses; mud cracks, cross-bedding and salt casts.	Blue-grey shales and fine-medium sandstones (festoon cross-beds, salt casts) near the base of the unit are similar to the War Loan Beds.
	Sedimentary contact not observed—gradational contact suspected on the basis of lithological overlaps			
	*War Loan Beds—Ᵽaw	600 (minimum)	Blue-grey shales and siltstones, dark grey silty dolomites and greenish feldspathic sandstones and arkoses.	Blue-grey colour of the sediments is characteristic.

			Gap in the sedimentary record	
	*Rockwater Beds—Ᵽad	200 (minimum)	Blue-grey and black cherts (weather to a cream colour), grey-black pebbly dolomites, black shales and siltstones and quartzitic sandstones.	This unit outcrops only in small blocks stratigraphically isolated by faulting and diapirism; the sequence probably lies in close proximity, stratigraphically, to the Cadlareena Volcanics.
			Gap in the sedimentary record—sequence dismembered by diapirism and faulting	
			CALLANNA BEDS	
WILLOURAN	*Cadlareena Volcanics—Ᵽcc (Coats and Blissett, 1971; Thomson, 1966; Preiss, 1973)	750 (minimum)	Vesicular basalts and altered dolerites; minor andesites, dacites, and rhyolites; tuffs and lapilli tuffs; minor lenticular reddish mudstones and quartzites with red shale interbeds near the base and top of the unit.	The volcanics mark the last recognised unit of the Callanna Beds; equivalents are recognised in the Willouran Ranges and Mount Painter Province; the upper contact is always disrupted by diapirism.
	*Coominaree Dolomite—Ᵽck (Thomson, 1966; Coats and Blissett, 1971; Preiss, 1973)	77	Interbedded buff dolomites (stromatolitic) and minor sandstones in the lower part; the upper part consists of non-stromatolitic dolomites, oolitic at the base, and an overlying stromatolitic dolomite.	Contains stromatolite forms *Acaciella c.f. australica* and *Gymnosolen c.f. ramsayi.*
	Younghusband Conglomerate (Ᵽco) (Thomson, 1966; Preiss, 1973)	27	Basal quartzitic breccias, red-brown shales and sandstones at the top.	Basal Adelaidean unit containing clasts reworked from the underlying Peake Metamorphics.
			Angular unconformity	
			Pre-Adelaidean Stratigraphy	
MIDDLE PROTEROZOIC	*Wirriecurrie Granite—Ᵽαw (Reyner, 1955)	—	Coarse-grained, porphyritic granites, augen granites, minor aplite dykes.	Intrusive, syn-orogenic granite, radiometrically dated at approximately 1 650 ma.
			PEAKE METAMORPHICS	
EARLY PROTEROZOIC	Unnamed metamorphics—Ᵽd3	not known	Amphibolites, grey quartzites, magnetite-rich epidosites, arenaceous schists, minor clinopyroxene granulites.	Lithologies (amphibolites and quartzites) are broadly similar to Baltucoodna Quartzite; all rock types are magnetite rich.
			Sedimentary contact not observed	
	*Baltucoodna Quartzite—Ᵽdb (Reyner, 1955)	4 500 (minimum)	Greyish-white quartzites, porphyritic and amygdaloidal basalts, amphibolites, minor quartz + muscovite schists, grey phyllites, sillimanite gneisses and plagioclase + hornblende + epidote calc-silicates.	Unit is characterised by interlayered basalts and quartzites.
	Unnamed schists—Ᵽd2	1 000	Quartz + muscovite schists, grey quartz + chlorite phyllites, minor sandstones.	Thickest development of metamorphosed pelitic sediments.
	*Tidnamurkuna Volcanics—Ᵽdt	600 (minimum)	Flow-banded porphyritic rhyolites, amygdaloidal basalts, rare epidosites and phyllites.	Rhyolites record the only phase of acidic vulcanism in the Peake Metamorphics.
			Sedimentary contact not observed	
	Unnamed metamorphics—Ᵽd1	5 500 (minimum)	Grey quartzites, quartz + biotite + muscovite schists and gneisses, garnetiferous schists, migmatites, pegmatites and diorites.	Metamorphosed to amphibolite facies, sedimentary structures have been obliterated. Stratigraphic relationship with other units is not known.

*New names: for formal definition see Appendix.

The Baltucoodna Quartzite conformably overlies the unnamed schists, which in turn conformably overlie the Tidnamurkuna Volcanics. However, the stratigraphic relationships of the unnamed metamorphics (Ᵽd1 and Ᵽd3) with themselves and the other units are not known.

Unnamed metamorphics (Ᵽd1)

Metamorphic rocks outcrop in the Algebuckina Inlier and at the northern end of the Denison Inlier. In the Algebuckina Inlier, garnetiferous quartz+biotite schists and quartz+feldspar+biotite gneisses are common. The garnets are red, euhedral, and up to 10 mm in size. Quartz+biotite metasandstones and quartzites are rare, while diorite and pegmatites (with Ooarse, graphic quartz+feldspar intergrowths) are common.

In the Denison Inlier, outcropping metamorphics are quartz+biotite and quartz+muscovite schists, quartz+feldspar+biotite and plagioclase+hornblende gneisses, and greyish white quartzites. Ellipsoidal pods of epidote occur sporadically within the quartzites. Dioritic and pegmatitic sills and dykes are common. Metamorphosed basalts could be widespread, as rocks containing amygdales with quartz centres and radiating, actinolite-rich margins were observed in several localities. However, metamorphism and a strong cleavage renders distinction between diorites and basic volcanics difficult. Migmatites are locally developed just north of Peake Creek and indicate middle to upper amphibolite facies metamorphism.

K-Ar dating on hornblende from two diorite sills yielded ages of 1518 Ma and 1464 Ma.

Tidnamurkuna Volcanics

The Tidnamurkuna Volcanics consist of greater than 600 m of amygdaloidal basalts, porphyritic rhyolites, epidosites, and minor phyllites, which outcrop southwest of Peake ruins and north of Mount Denison. The sequence is dominantly basaltic with two major periods of acidic eruptions.

The common minerals within the basalts are actinolite, hornblende, plagioclase, epidote, chlorite, and magnetite. Plagioclase laths (up to 0·5 mm and very rarely to 10 mm in length) show only poorly developed polysynthetic twinning and exhibit a decussate texture. Amygdales are common and have been filled by quartz and radiating aggregates of fibrous epidote crystals (Plate 1).

A lower, single rhyolite flow, up to 5 m thick, has plagioclase, potash feldspar and quartz phenocrysts. Phenocryst abundance varies from 10 to 30 per cent with subhedral to ovoid feldspar (up to 20 mm) and spherical bluish grey quartz phenocrysts averaging 2 mm in size (Plates 2 and 3). Quartz phenocrysts are common near (but not restricted to) the margins, while very coarse feldspar phenocrysts occur in the centre of the flow.

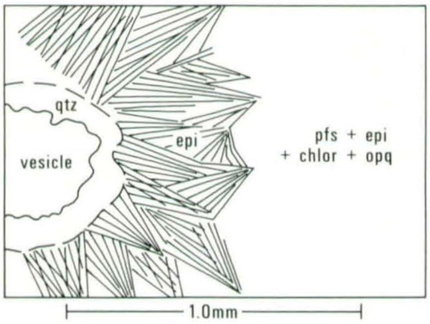
An upper rhyolitic unit contains about 250 m of interlayered rhyolites, epidosites, and basalts. These rhyolites are also strongly porphyritic, with phenocrysts of potash feldspar, plagioclase, and quartz. The phenocrysts often show undulose extinction or have been completely recrystallised forming elongate aggregates of smaller grains. The aphanitic (0·4 mm) groundmass is comprised of quartz and subordinate feldspar, biotite, muscovite, and pyrite. Relict flow layering is indicated by biotite and muscovite trains which wrap around the phenocrysts (Plate 3).

Near the top of the volcanics there are several thin bands of tremolitic marble consisting of acicular tremolite crystals (up to 10 mm) in a calcite matrix.

Silicate analyses of two rhyolites and one basalt are shown in Table 2. The two rhyolites differ from the world average (column 4) in an enrichment of K_2O and a deficiency of Na_2O, Al_2O_3, and CaO. Similarly, the basalt is enriched in K_2O and Na_2O and deficient in CaO and MgO compared with the world average. The silica percentage of basalt in column 5 is anomalously high owing to numerous quartz-filled amygdales.

Unnamed schists

Schists outcrop southwest of Peake ruins and north of Mount Denison. They are poorly exposed and outcrop only in creeks. Rock types are pale grey quartz+chlorite+muscovite and quartz+chlorite+epidote schists and phyllites derived by the metamorphism of silty clays. Thin metasiltstone and metasandstone lenses, often with graded bedding and cross-bedding are common. The beds in the unit have gradational, conformable contacts with the underlying Tidnamurkuna Volcanics and overlying Baltucoodna Quartzite.



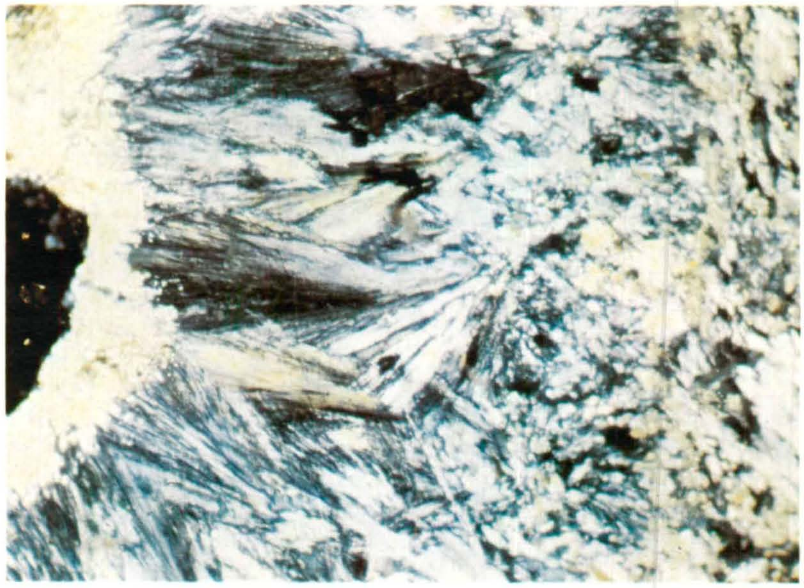
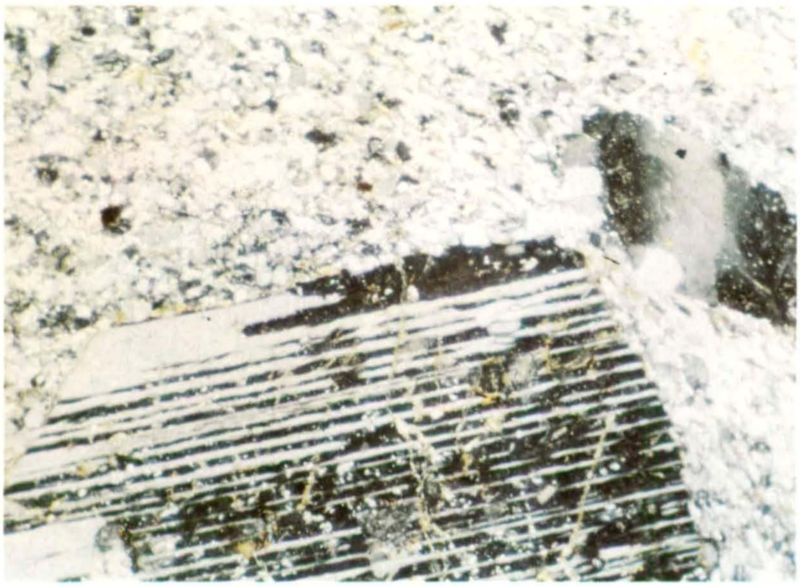


Plate 1. Vesicle and infilling quartz and fibrous epidote in amygdaloidal basalt, Tidnamurkuna Volcanics.

Transparency 14459



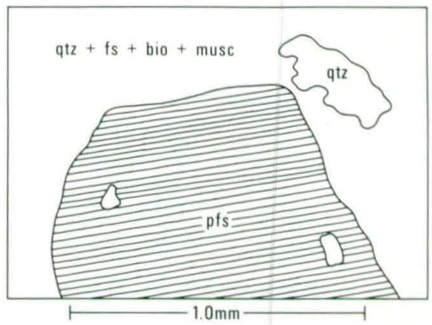


Plate 2. Plagioclase and quartz phenocrysts within porphyritic rhyolite, Tidnamurkuna Volcanics.

Transparency 14460

Plate 3. Phenocrysts of feldspars and quartz within porphyritic rhyolite, Tidnamurkuna Volcanics.

Transparency 14461

Baltucoodna Quartzite

South of Peake ruins and near Mount Denison there is a thick sequence of greyish white quartzites, metabasalts, amphibolites, schists and phyllites. These rocks, with quartzites, schists, gneisses and calc-silicates occurring in various basement blocks in the Margaret Inlier, comprise the Baltucoodna Quartzite (see geological map). It has a gradational boundary with the underlying unnamed schist unit and the top is not exposed.

The stratigraphic sequence near Mount Denison has a minimum thickness of 4 500 m. The quartzites are greyish white and are composed dominantly (90 per cent) of quartz. Bedding is defined by numerous metamorphosed clay laminations, which range in thickness from 1-10 mm. Interbedded pelitic sediments (quartz+muscovite+ chlorite schists) rarely exceed 20 m thick.

Interlayered with the quartzites are several basaltic flows and associated sediments, and possibly metamorphosed basic sills. The basalts are strongly cleaved, fine to medium grained, and consist of plagioclase, hornblende, epidote, biotite and magnetite. Plagioclase phenocrysts are abundant, and vary in size from 2 to 25 mm (Plate 4). Elongate vesicles and quartz+epidote amygdales are common. The one basalt sample analysed (Table 2, column 6) is similar to the average basalt quoted by Le Maitre (1976). Interlayered with the basalts are dark grey, chloritic phyllites, epidote+actinolite quartzites, and rare, thin, cream to pale grey limestones.

Quartzites, schists, gneisses and calc-silicates exposed in areas of basement rocks in the Margaret Inlier have tentatively been included within the Baltucoodna Quartzite. In the Coominaree Mine Block quartz+feldspar+ biotite and sillimanite gneisses, quartz+biotite schists, plagioclase+hornblende+microcline calc-silicates, and a tremolite-talc marble are exposed. A granulite, containing 30 per cent clinopyroxene, outcrops in the War Loan Mine Block.

Table 2 *Chemical analyses of rhyolites and basalts— Peake Metamorphics*

	1	2	3	4	5	6	7
SiO_2	74·28	73·48	74·80	72·82	57·19	49·14	49·20
TiO_2	0·32	0·31	0·46	0·28	1·19	1·86	1·84
Al_2O_3	12·61	12·29	13·05	13·27	15·41	15·53	15·74
Fe_2O_3	1·32	3·00	0·99	1·48	5·45	3·91	3·79
FeO	0·90	0·60	1·56	1·11	4·50	7·20	7·13
MnO	0·01	0·02	0·01	0·06	0·04	0·08	0·20
MgO	0·46	0·28	1·45	0·39	3·58	5·85	6·73
CaO	0·38	0·34	0·22	1·14	3·58	8·98	9·47
Na_2O	1·64	2·58	4·77	3·55	3·65	3·20	2·91
K_2O	7·24	6·61	1·89	4·30	2·72	1·60	1·10
P_2O_5	0·08	0·03	0·05	0·07	0·13	0·42	0·35
H_2O^+	0·57	0·27	0·99	1·10	1·55	1·63	0·95
H_2O^-	0·13	0·13	0·60	0·31	0·17	0·21	0·43
Total	99·94	99·94	100·84	99·88	99·16	99·61	99·84

1. Rhyolite (Tidnamurkuna Volcanics) near Peake ruins. Specimen 6041 RS 145.
2. Rhyolite (Tidnamurkuna Volcanics) near Peake ruins. Specimen 6041 RS 144.
3. Average of 2 rhyolite analyses. Pepegoona Porphyry (Mount Painter Province) A 3830/62 and A 668/65 (Coats and Blissett, 1971).
4. Average of 554 rhyolites (Le Maitre, 1976).
5. Amygdaloidal basalt (Tidnamurkuna Volcanics) near Mount Denison. Specimen 6041 RS 146.
6. Basalt (Baltucoodna Quartzite) near Mount Denison. Specimen 6041 RS 143.
7. Average of 3156 basalts (Le Maitre, 1976).

Unnamed metamorphics (Ꞓd3)

To the east of the Margaret Inlier there are four, small, isolated basement inliers (see geological map). Rock types in each inlier differ and include a variety of magnetite-rich psammites, calc-silicates and amphibolites.

Epidote-rich quartzites have the epidote concentrated in thin layers and ellipsoids. The quartzites are whitish grey, frequently cross-bedded and heavy-mineral laminated (Plate 5). They are also often fractured and brecciated with a plagioclase, amphibole, epidote, magnetite matrix. A quartz + plagioclase + clinopyroxene granulite outcrops at Lagoon Hill. Quartz, quartz and muscovite, and biotite-rich metasandstones and metasiltstones are exposed at Mount Charles and Spring Hill.

Amphibolites present may represent both metavolcanics and metamorphosed calcic sediments. Quartz, and quartz+epidote amygdales, in various units near Spring Hill, suggest a high proportion of metabasalts.

Correlation

The Peake Metamorphics have one possible correlative in South Australia. The Radium Creek Metamorphics, in the Mount Painter Province 350 km to the southeast of the ranges, are a sequence of dominantly arenaceous sediments, but also include a possible extrusive acid porphyry (Pepegoona Porphyry, Coats and Blissett, 1971). Silicate analyses of the Pepegoona Porphyry are shown in Table 2 and indicate dissimilar oxide contents to the rhyolites of the Tidnamurkuna Volcanics. No basalts have been observed in the Radium Creek Metamorphics. The correlation between metamorphics of the two terrains must be considered very tenuous.

However, the interfingering of volcanics and quartzites, so characteristic of all units in the Peake Metamorphics, is very similar to the Eastern Creek Volcanics of the Haslingden Group, 800 km to the northeast in the Mount Isa Trough. The Eastern Creek Volcanics, dominantly of metabasalts (often amygdaloidal) and quartzites, are described in detail by Derrick *et al.*, (1976) and Derrick *et al.*, (1977), and are considered to be possibly equivalent to the Peake Metamorphics.

Wirriecurrie Granite (Middle Proterozoic)

The Wirriecurrie Granite outcrops in the vicinity of Peake Creek. The name 'Wirriecurrie' is derived from the Aboriginal word for Peake Creek. The southern and eastern boundaries of the granite are sheared, while the northwestern margin is gradational into a zone of migmatites, pegmatites, gneisses and diorites.

The Wirriecurrie Granite consists of gneissic augen granites, porphyritic granites, adamellites, granodiorites and minor aplites. Phenocrysts are ovoid to lenticular bluish quartz (3 mm), and rounded to ovoid red potash feldspar and minor plagioclase (30 mm) (Plate 6). Plagioclase crystals are heavily altered to epidote and sericite, while the potash feldspar crystals (which are dominantly perthitic orthoclase and microcline) are only slightly altered (Steveson, 1973; Webb and Lowder, 1971). Within strongly foliated granites mobilisation of silica has resulted in monomineralic aggregates of quartz exhibiting a granoblastic texture. The foliation is defined by a preferred orientation of biotite. Biotite, epidote and chlorite are only present in minor amounts.

Silicate analyses of two specimens reveal that the Wirriecurrie Granite is slightly deficient in Na_2O and Al_2O_3, and enriched with respect to K_2O relative to world averages for granites and adamellites (Table 3).

Diorite dykes form a semicircular pattern in the centre of the granite and have also intruded along faults and the foliation. They vary in thickness from two metres to several hundred metres. Plagioclase and hornblende are the dominant mineral constituents, with lesser amounts of quartz, chlorite, epidote and iron oxides. Plagioclase phenocrysts occasionally exhibit a subvariolitic texture.

Table 3 *Chemical analyses of Wirriecurrie Granite*

	1	2	3	4
SiO_2	70·80	68·65	69·31	71·30
TiO_2	0·46	0·54	0·60	0·31
Al_2O_3	13·50	14·55	13·55	14·32
Fe_2O_3	0·99	1·23	1·15	1·21
FeO	2·90	2·70	3·65	1·64
MnO	0·03	0·08	0·04	0·05
MgO	0·66	1·14	0·78	0·71
CaO	1·57	2·68	1·95	1·84
Na_2O	2·45	3·47	2·58	3·68
K_2O	5·54	4·00	5·26	4·07
P_2O_5	0·14	0·19	0·15	0·12
H_2O^+	0·77	0·59	0·95	0·64
H_2O^-	0·15	0·14	0·12	0·13
Total	99·96	99·96	100·09	100·02

1. Adamellite (Wirriecurrie Granite) north of Mount Denison. Specimen 6041 RS 12.
2. Average of 27 adamellites (Le Maitre, 1976).
3. Porphyritic granite (Wirriecurrie Granite) near Peake Creek. (Specimen 6041 RS 62.
4. Average of 197 granites (Le Maitre, 1976).

Geochronology of the Wirriecurrie Granite incorporates nine K-Ar age determinations on biotite and twelve Rb-Sr determinations on total rock samples (see Geochronology, pp. 57-59). The ages can be interpreted as granite intrusion around 1650 Ma overprinted by tectonism during the Musgravian Orogeny (circa 1050 Ma) and Delamerian Orogeny (circa 500 Ma).

A probable correlative of the Wirriecurrie Granite is the Engenina Adamellite in the Mount Woods Inlier 150 km to the southwest. The Engenina Adamellite is also foliated and porphyritic (Benbow and Flint, 1979) and has been dated by Rb-Sr (total rock) at 1641 ∓ 38 Ma (Webb, 1977a).

Callanna Beds (Willouran)

Mawson (1927) originally assigned the name Willouran Series to a sequence very generally described as quartzites, slates and calcareous rocks in the Willouran Ranges. Sprigg (1949) adopted the same name to describe the sequence below the Witchelina Quartzite and later proposed that the Willouran Series be included in the Adelaidean System (Sprigg, 1952).

Plate 4. Plagioclase phenocrysts in an amphibolite within the Baltucoodna Quartzite.

Transparency 14462

Plate 5. Heavy-mineral banding in quartzites near Spring Hill.

Transparency 14463

Plate 6. Plagioclase and potash feldspar augen in the Wirriecurrie Granite.

Transparency 14464

The Callanna Beds, as defined by Thomson and Coats (1964), is the name applied to the type Willouran sequence including the underlying sedimentary-volcanic succession now occurring as dismembered blocks in diapiric context. The Callanna Beds are considered to represent the earliest depositional cycle of the Adelaidean System, and in the Peake and Denison Ranges are defined by a basal sequence overlying the Peake Metamorphics with angular unconformity. Formations ascribed to the Callanna Beds are Younghusband Conglomerate (new name), Coominaree Dolomite (new name) and Cadlareena Volcanics (new name)—see Table 4. The maximum total thickness is at least 800 m.

Table 4 *Stratigraphy—Callanna Beds*

Formation	Map Symbol
——?——?——?——	
Cadlareena Volcanics	Ᵽcc
Coominaree Dolomite	Ᵽck
Younghusband Conglomerate	Ᵽco
Peake Metamorphics	

———— conformable contact
—⌄—⌄— angular unconformity
—?—?—?— contact uncertain—unknown sequences suspected to intervene.

It is important to note that in the Peake and Denison Ranges disruption always occurs above the Cadlareena Volcanics. As a consequence, the position of the upper boundary of the Callanna Beds with the Burra Group is unresolved. Work by Preiss (1974) in the vicinity of the Spalding Inlier near Adelaide (Fig. 2) established that the base of the Burra Group is marked by a heavy mineral laminated sandstone (Rhynie Sandstone), which is in turn overlain by the River Wakefield Subgroup and Bungaree Quartzite (Forbes, 1977). The Mount Margaret Quartzite is tentatively correlated with the Bungaree Quartzite and the Witchelina Quartzite of the Willouran Ranges, but as the equivalent of the Rhynie Sandstone has not been recognised definitely in the Peake and Denison Ranges, the position of the base of the Burra Group (and upper boundary of the Callanna Beds) remains uncertain.

As discussed by Thomson (1966) and Preiss (1973a), the lower Willouran sequence in the Peake and Denison Ranges closely resembles that of three other regions in which basement rocks are exposed. These are:

—the Mount Painter Province (Coats and Blissett, 1971)
—the Willouran Ranges (Murrell, 1977)
—Broken Hill area—the Barrier Ranges (Cooper and Tuckwell, 1971).

Table 5 depicts equivalent Adèlaidean sequences from the Mount Painter and Broken Hill regions, where the basal Willouran sequences correlate closely with those in the Peake and Denison Ranges. A sequence composed of a basal quartzite conglomerate, overlain by a dolomite-chert unit, in turn overlain by altered amygdaloidal basalts, is common to the three regions.

Younghusband Conglomerate

Thomson (1966) first recognised a basal Adelaidean (Willouran) succession unconformably overlying older basement rocks of the Peake Metamorphics about 3 km south of War Loan Mine (War Loan Mine Block). Subsequent mapping by Coats and Preiss in 1972 confirmed the presence of this unconformity, and the same Willouran sequence was observed intact, unconformably overlying a small basement inlier 1·2 km north of Coominaree Mine (Coominaree Mine Block). Descriptions of these successions are in Preiss (1973a). The lowermost unit in the Willouran succession is herein named the Younghusband Conglomerate (Appendix, Unit 4). The thickest development and best exposure occurs in the type section on the eastern margin of the Coominaree Mine Block, where 27 m of basal clastics are recorded. A detailed description of this section is shown on Figure 3.

The Younghusband Conglomerate is composed of two unnamed members. The lower member (12 m thick) consists of a basal sedimentary breccia (2 m thick) overlain by gritty and pebbly sandstones, minor siltstone, coarse dolomitic sandstones, and minor red-maroon shales towards the top of the unit. The upper member consists of 15 m of red-brown shales with fine sandstone intercalations. To the south, on the eastern flank of the War Loan Mine Block, a sequence of purple and green-weathering siltstones overlies a basal quartzitic conglomerate-breccia. Clasts in the basal sedimentary breccia are predominantly vein quartz with minor granites and quartzite pebbles set in a brown feldspathic quartzite matrix. The lithology and high angularity of the clasts suggest a local basement source. Cross-bedding in both members of the Younghusband Conglomerate suggests a shallow water environment of deposition.

Table 5 *Stratigraphic correlation of Adelaidean sediments*

STRATIGRAPHIC CORRELATION TABLE — ADELAIDEAN

	WARRINA (Peake and Denison Ranges)	COPLEY (Mount Painter Province) (Coats and Blissett, 1971)	BURRA (Spalding Inlier) (Mirams, 1964 and Preiss, 1974)	BARRIER RANGES– BROKEN HILL AREA (Cooper and Tuckwell, 1971)
MARINOAN	Unnamed siltstone – WILLOCHRA SUBGROUP (UMBERATANA GROUP)	ELATINA FORMATION – WILLOCHRA SUBGROUP BALPARANA SANDSTONE, MOUNT CURTIS TILLITE, FORTRESS HILL FORMATION – YERILENA SUBGROUP TREZONA FORMATION, ENORAMA SHALE, AMBEROONA FORMATION – FARINA SUBGROUP ANGEPENA FORMATION – WILLOCHRA SUBGROUP (UMBERATANA GROUP)	TARCOWIE SILTSTONE	NUNDURO CONGLOMERATE DERING SILTSTONE GAIRDNERS CREEK QUARTZITE ALBERTA CONGLOMERATE (TEAMSTERS CREEK SUBGROUP) FLOODS CREEK FORMATION / YOWAHRO FORMATION (EURIOWIE SUBGROUP) (TORROWANGEE GROUP)
STURTIAN	THORA DOLOMITE TAPLEY HILL FORMATION Unnamed sandstone CALTHORINNA TILLITE (UMBERATANA GROUP)	BALCANOONA FORMATION TAPLEY HILL FORMATION MERINJINA TILLITE LYNDHURST FORMATION BOLLA BOLLANA TILLITE FITTON FORMATION (UMBERATANA GROUP)	BRIGHTON LIMESTONE TAPLEY HILL FORMATION APPILA TILLITE	MITCHIE WELL FORMATION / CORONA DOLOMITE / TANYARTO FORMATION, WAMMERRA FORMATION (EURIOWIE SUBGROUP) YANGALLA FORMATION, MULCATCHA FORMATION / McDOUGALLS WELL CONGLOMERATE (YANCOWINNA SUBGROUP) (TORROWANGEE GROUP)
TORRENSIAN	KALACHALPA FORMATION Unnamed transition unit SKILLOGALEE DOLOMITE MOUNT MARGARET QUARTZITE FOUNTAIN SPRING BEDS Unnamed siltstone	Unnamed siltstones, shales and dolomites MYRTLE SPRINGS FORMATION SKILLOGALEE DOLOMITE WORTUPA QUARTZITE COPLEY QUARTZITE OPAMINDA FORMATION BLUE MINE CONGLOMERATE WOODNAMOKA PHYLLITE–HUMANITY SEAT FM. (BURRA GROUP)	BELAIR SUBGROUP SADDLEWORTH FORMATION AUBURN DOLOMITE UNDALYA QUARTZITE SKILLOGALEE DOLOMITE BUNGAREE QUARTZITE RIVER WAKEFIELD SUBGROUP RHYNIE SANDSTONE (BURRA GROUP)	
WILLOURAN or TORRENSIAN	Undifferentiated sequences MURRANA BEDS DUFF CREEK BEDS NILPINNA BEDS WAR LOAN BEDS ROCKWATER BEDS	?	RIVER BROUGHTON BEDS Basement not exposed	
WILLOURAN	CADLAREENA VOLCANICS COOMINAREE DOLOMITE YOUNGHUSBAND CONGLOMERATE (CALLANNA BEDS)	WOOLTANA VOLCANICS WYWYANA FORMATION PARALANA QUARTZITE (CALLANNA BEDS)		WILLANGEE VOLCANICS (WENDALPA SUBGROUP) BOCO FORMATION CHRISTINE JUDITH CONGLOMERATE LADY DON QUARTZITE (PINTAPAH SUBGROUP) (POOLAMACCA GROUP)
	PEAKE METAMORPHICS	RADIUM CREEK METAMORPHICS		WILLYAMA COMPLEX

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To the north on *WARRINA**, about 3·5 km southwest of 'Peake' ruins, the southern margin of the Peake Metamorphics is bounded in part by the Younghusband Conglomerate. Only the lower member is present and it outcrops sporadically along a total strike length of 7 km. Graded bedding and cross-bedding are common. Clast lithologies correspond to local basement rocks, i.e. quartzites, schists, vein quartz, granites and pegmatites, with quartzites predominating. A laminated, pebbly, red-brown shale is occasionally interbedded with the conglomerate. Outcrop is often in the form of isolated residual cappings, separated from, and lying topographically above the Cadlareena Volcanics (Plate 7). These cappings, resting unconformably on Peake Metamorphics, represent erosional remnants and provide evidence of a minor pause in sedimentation between the Younghusband Conglomerate and the Cadlareena Volcanics. The absence of the Coominaree Dolomite, at least to the northwest, confirms the presence of a hiatus above the basal conglomerate in this northern part of the ranges. Drilling by Uranerz (Iliff, 1975), intersected 7 m of basal clastics on the northwestern margin of the conglomerate outcrop, which is the maximum thickness recorded on *WARRINA*.

Coominaree Dolomite

The Younghusband Conglomerate is conformably overlain by a sequence of mainly stromatolitic dolomites herein named the Coominaree Dolomite (Appendix, Unit 5). The most complete succession (thickness of 77 m) occurs 1·1 km north-northeast of Coominaree Mine, where a detailed section was described by Preiss (1973a). This type section is described on Figure 3.

The lower part of the Coominaree Dolomite is predominantly buff and pale brown dolomites

*To avoid constant repetition of map scales with sheet names the following code of type styles has been adopted to signify scale:

WARRINA—1:250 000
BOORTHANNA—1:100 000
Nilpinna—1:63 360

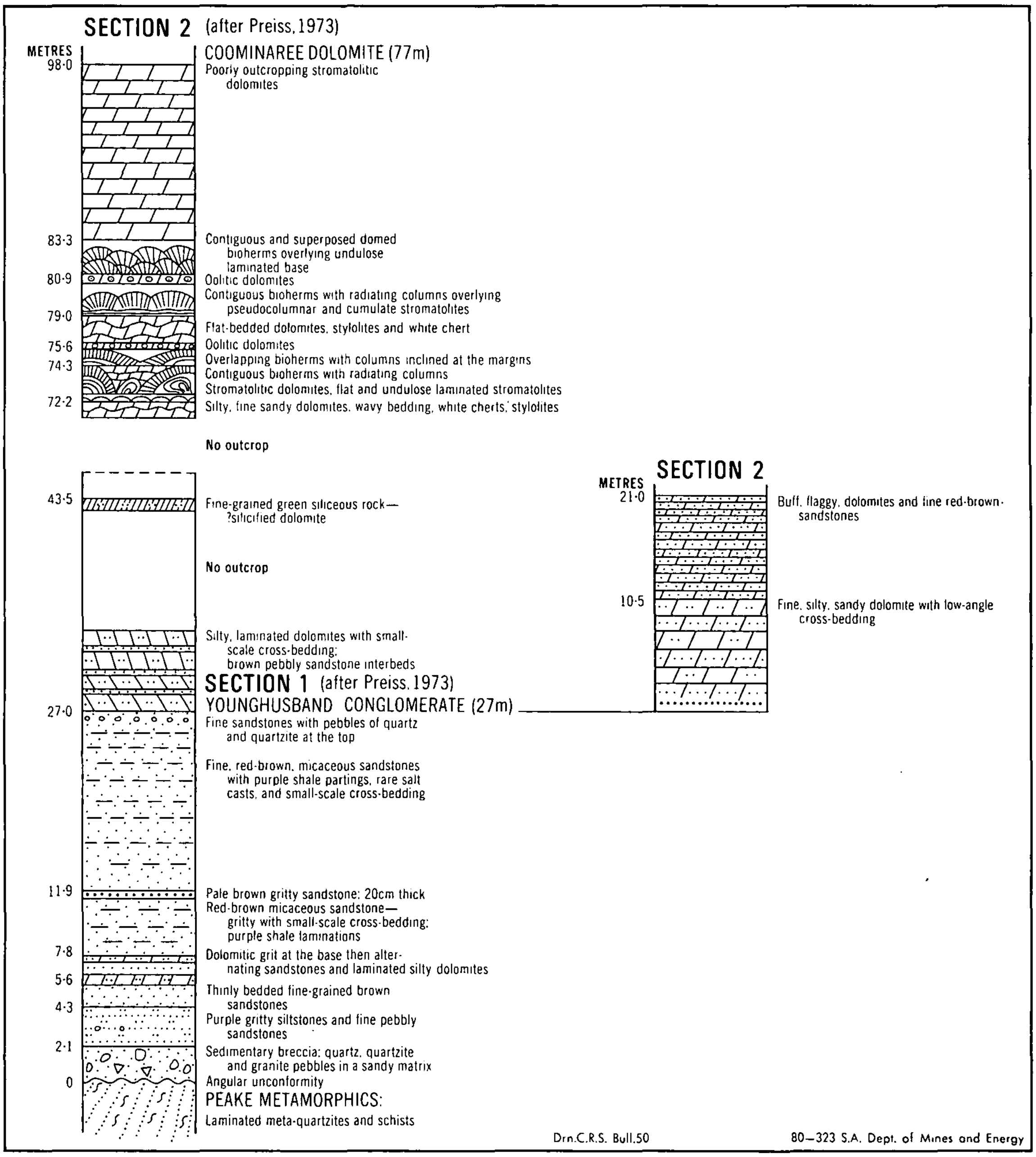

Fig. 3. Stratigraphic type sections, Younghusband Conglomerate and Coominaree Dolomite

with gritty and pebbly layers displaying low-angle cross-bedding. Overlying this there is a series of flaggy, buff dolomites and fine sandstones which pass upwards into stromatolitic dolomites, then non-stromatolitic dolomites (oolitic at the base), and finally, an upper stromatolitic dolomite. The upper part of the formation is poorly exposed, although stromatolitic float is observed. The stromatolites *Acaciella cf. australica* and *Gymnosolen cf. ramsayi* occur in this formation and are described by Preiss (1973a).

On the eastern flank of the War Loan Mine Block, the Coominaree Dolomite conformably overlies the Younghusband Conglomerate and passes upwards into the Cadlareena Volcanics. This sequence was first studied by Thomson (1966) and later by Preiss (1973a). To the north on *WARRINA*, the Coominaree Dolomite is largely absent, being present only on the southeastern margin of the Younghusband Conglomerate outcrop. Here a thin bed (2 m thick) of pebbly, silty dolomite outcrops along a strike length of 100-150 m before lensing out to the northwest. Stromatolitic dolomites, typical of the Coominaree Dolomite, also occur in a small rafted block in a diapir about 1 km to the west of this outcrop.

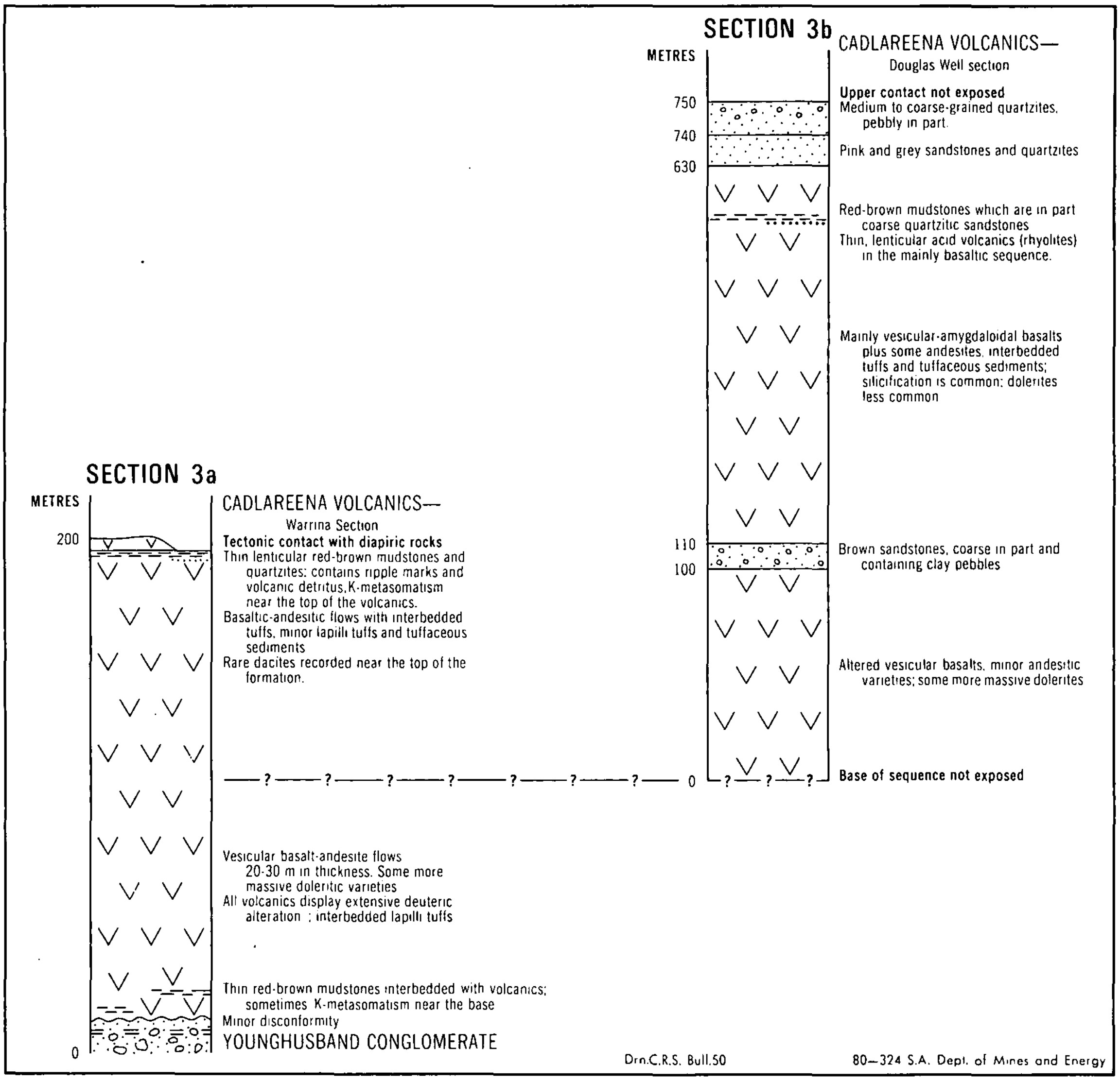

Fig. 4. Stratigraphic type section, Cadlareena Volcanics

The Coominaree Dolomite was probably deposited in a shallow water/shelf environment, but the thin pebbly dolomite, in places underlying volcanics, may represent a tidal channel facies deposited on the margin of a shallow basin. Along strike to the northwest, Cadlareena Volcanics disconformably overlie Younghusband Conglomerate and the Coominaree Dolomite is absent.

Cadlareena Volcanics

Amygdaloidal lavas of Willouran age were first recognised in the Peake and Denison Ranges on *ANNA CREEK*, near Douglas Well, in 1962 (Wopfner and Heath, S. Aust. Dept. Mines and Energy, pers. comm.). Similar rocks were described by Thomson (1966) in a basal Adelaidean sequence outcropping northeast and southeast of Nilpinna H.S. and also about 45 km to the north on *WARRINA*. This volcanic sequence is herein named the Cadlareena Volcanics (Appendix, Unit 6). The lower part of the type section is on *WARRINA*, where a basal contact with the Younghusband Conglomerate is preserved. The upper part of the type section is best recorded on *ANNA CREEK* near Douglas Well. Detailed descriptions of both these sections are on Figure 4.

Plate 7. Younghusband Conglomerate capping Peake Metamorphics 11.5 km north-northeast of Warrina R.S.

Plate 8. Angular unconformity between steeply dipping metasiltstones of the Peake Metamorphics and overlying, gently dipping Cadlareena Volcanics, 11 km northeast of Warrina R.S.

Plate 9. Interbedded vesicular basalt and lenticular mudstone in the Cadlareena Volcanics.

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Transparency 14466

Transparency 14467

In addition to the outcrops in stratigraphic context, a number of rafted blocks of volcanics (varying in size from a few to several hundred metres across) occur in diapirs, most commonly in the northern part of the ranges. A typical example is along the eastern margin of the Rockwater Hill Block, where a number of rafted volcanic blocks (too small to be shown on the geological map) occur within a diapir, but are aligned parallel to the basement-diapir contact. As a result of diapirism associated with decollement at the base of the Adelaidean, these scattered volcanic remnants provide the sole evidence of an original basal Adelaidean sequence at this particular locality.

The volcanics thin northwards, from a maximum thickness of 730 m at Douglas Well to approximately 200 m on *WARRINA*. It should be emphasised, that throughout the ranges, diapirism occurs above the volcanics, and hence these thicknesses are minimum estimates considering the uncertainty of the upper contact. The volcanics extend northwards at least as far as Mount Dutton, where a small block of volcanics outcrops in a fault zone.

Altered basaltic to andesitic volcanics tentatively correlated with the Cadlareena Volcanics were intersected in Boorthanna No. 1 Well, 30 km southwest of the ranges (Fig. 2) (Holmes, 1970; Holmes and Rayment, 1970).

On *WARRINA*, the volcanics generally disconformably overlie the Younghusband Conglomerate (Plate 7), more rarely, basalts lie directly on rocks of the Peake Metamorphics (Plate 8). On the southern part of *WARRINA* and on *BOORTHANNA* the volcanics conformably overlie the Coominaree Dolomite.

The Cadlareena Volcanics are a complex series of mainly basaltic lava flows, with individual flows 20-30 m thick, and thin interbedded sediments and pyroclastics (Plate 9). Associated with the basalts are dolerites and andesites, plus rare thin rhyolites and dacites. Several volcanic rocks of trachytic composition have been identified and are thought to be products of potash metasomatism (Radke, 1976, 1977). Whitehead (1972b) recognised secondary microcline in basalts from Douglas Well. The presence of tourmaline in several samples indicates boron metasomatism.

The lavas are predominantly amygdaloidal. The abundance and size of the amygdales are variable within individual flows and are generally at a maximum at the tops of flows. Plagioclase (often albite), orthoclase, chlorite, zeolites, tremolite-actinolite, epidote, calcite, quartz and fine-grained basalt infill the amygdales. Whitehead (1972b) showed that these amygdales contain varying proportions of these minerals with the order of crystallisation as follows: albite–epidote–calcite–chlorite–quartz. The groundmass of the basalts generally consists of randomly orientated plagioclase laths together with abundant amphibole and chlorite (Radke, 1976).

All of the volcanics have suffered extensive alteration (mostly deuteric), although the original igneous textures are generally well preserved. Alteration processes include:

—alteration of calcic plagioclase to albite-andesine
—muscovite-sericite replacing plagioclase
—fibrous tremolite-actinolite replacing pyroxene
—chlorite and opaque minerals replacing amphibole, pyroxene and ?olivine
—secondary microcline replacing plagioclase.

Interstitial granular and microcrystalline silica has been introduced during weathering.

The volcanics on *WARRINA* have not been previously studied in detail. They disconformably overlie the Younghusband Conglomerate and outcrop about 4 km southwest of 'Peake' ruins along a northwesterly trending strike length of 9 km. Thickness is about 200 m in the southwest, decreasing to less than 50 m along strike to the northwest. Thin, lenticular mudstones are interbedded with basalts at or near the base of the unit (Plate 9). The mudstones are usually red-maroon and are occasionally sandy and more rarely pebbly. The volcanics are mainly dark green-grey amygdaloidal basalts, dolerites, and andesites, with interbedded lapilli, and maroon tuffs and tuffaceous sediments. The proportion of pyroclastics and tuffaceous sediments generally increases towards the top of the unit, as indicated by the drilling results of Uranerz (Iliff, 1975), which recorded a thin volcanic breccia near the top of the sequence.

Several basaltic flows were identified, each displaying the following sequence of rock types (C.D. Branch, S.Aust. Dept. Mines and Energy, pers. comm.):

(Top)—coarsely vesicular basalt
—coarse-grained non-vesicular dolerite
—lapilli tuffs and intertonguing tuffaceous sediments.

Estimated thickness of the flows is 20-30 m, but their exact thickness and number were not measured due to rapid horizontal and vertical variability.

The upper part of the volcanics is often marked by a thin, lenticular, rippled, red-brown mudstone or quartzite. Volcanic clasts in the mudstones indicate reworking of the basalts in a shallow water environment.

The volcanic sequence at Douglas Well on *ANNA CREEK* (Fig. 4) is similar to that on *WARRINA*, but important differences and characteristics of the Cadlareena Volcanics at Douglas Well are:

- —the sequence is at least 730 m thick, with the base and top not exposed
- —a 5-10 m thick medium-coarse sandstone with numerous clay pebbles occurs low in the sequence
- —up to 100 m of quartzite and sandstone (some coarse grained) marks the upper part of the formation
- —several thin, lenticular rhyolites outcrop near the top of the sequence
- —secondary silicification is extensive.

On *BOORTHANNA*, in the vicinity of War Loan Mine, at least 300 m of volcanics outcrop in a synclinal structure. Thin rhyolites have been recognised in the mainly basaltic sequence.

Immediately northeast of Coominaree Mine, on *BOORTHANNA*, the basal Adelaidean sequence lies with high angular unconformity on Peake Metamorphics (Coominaree Mine Block), and includes several hundred metres of volcanics conformably overlying the Coominaree Dolomite.

The volcanics near Douglas Well were first correlated with the Wooltana Volcanics of the Mount Painter Province by H. Wopfner (Wopfner *in* Thomson, 1966). In both areas, the basal Adelaidean stratigraphy can be generalised into a basal conglomerate and an overlying dolomite unit which passes upwards into volcanics. The similarity of stratigraphic position and mineralogy of the volcanics in the two regions is the basis for the correlation. Other aspects common to both formations are:

- —the volcanics consist of a complex series of flows with minor interbedded sediments
- —interbedded sediments include lapilli tuffs, tuffs, volcanic breccia (minor), plus shallow water sandstones and mudstones
- —amygdaloidal lavas with associated basaltic textures (randomly orientated plagioclase laths)
- —original mineralogy of pyroxene, hornblende, and olivine has been extensively altered to tremolite-actinolite, epidote, chlorite, calcite, and opaque minerals
- —potash metasomatism and albitisation are evident to varying degrees
- —the volcanics are iron rich and show secondary enrichment of iron oxides plus late stage silicification
- —similarity of silicate and trace element analyses (Tables 6 and 7)
- —minor acid volcanics (rhyolite) occur in the mainly basaltic sequences.

Crawford (1963) considered the Wooltana Volcanics to be sub-aerially extruded from fissures, with explosive activity from central vents supplying the pyroclastic material. A similar environment is envisaged for the Cadlareena Volcanics, but with material derived from explosive activity and shallow water sedimentation increasing towards the top of the unit.

On *WARRINA*, minor copper and uranium mineralisation has been identified in the Cadlareena Volcanics. Aerial surveys by Uranerz revealed radiometric anomalies and these were examined in detail by extensive carborne and footborne scintillometer surveys along the unconformity between the volcanics and Peake Metamorphics (Iliff, 1975). At the base of the volcanics several radiometric anomalies were identified. Samples taken from trenches, on the western margin of the volcanics, assayed up to 100 ppm uranium, and minor malachite and azurite staining were observed in one of the trenches. Drilling, however, yielded no significant mineralisation. Copper carbonates were observed in one locality in the basal mudstone and faulting nearby suggests a hydrothermal origin for the mineralisation. Trace element contents of volcanics from *WARRINA* and *ANNA CREEK* (Douglas Well) are listed in Table 7. Uranium contents are uniformly low, as are the mean base-metal contents, which are generally less than those quoted for an average basaltic rock by Turekian and Wedepohl (1961).

A summary of the major element chemistry of the Cadlareena Volcanics and the Wooltana Volcanics (from the Mount Painter Province and Depot Creek) is presented in Table 6. The average composition of continental basalts (column 6) applies to basalts erupted through continental crust at continental rifts (Pearce, 1976).

Table 6 *Chemical analyses of Cadlareena Volcanics and Wooltana Volcanics*

	1.	2.	3.	4.	5.	6.	7.
SiO_2	48·48	47·71	48·43	48·22	48·54	48·81	66·00
Al_2O_3	13·05	12·97	13·08	13·85	13·79	14·41	14·22
Fe_2O_3	10·64	9·63	9·08	12·33	13·29	12·00	3·53
FeO	3·84	1·88	3·74	2·91	—		0·35
MnO	0·12	0·09	0·10	0·25	0·04	5·96	0·01
MgO	5·86	8·25	6·92	7·26	9·21	10·05	0·29
CaO	6·94	8·24	8·86	4·71	0·36	2·90	0·87
Na_2O	3·38	3·35	3·04	1·80	0·21	—	0·23
K_2O	1·97	1·65	1·66	3·66	5·61	0·95	12·29
P_2O_5	0·16	0·13	0·15	0·13	0·14		0·18
TiO_2	1·99	1·46	1·63	1·55	1·76	2·47	0·70
H_2O+	2·37	2·59	2·57	3·03	—	—	0·44
H_2O-	0·34	0·28	0·24	0·25			0·16
CO_2	0·85	—	0·05	0·67			
S	0·04						
Total	100·03	98·23	99·55	100·62	92·95	97·55	99·27

1. Cadlareena Volcanics from *ANNA CREEK* (Douglas Well). Average of 7 analyses 6140 RS 4-8, 23 and 25. Range SiO_2 45.1-49.4, Al_2O_3 11.96-13.8, total Fe 12.25-17.1, MgO 2.7-7.63, CaO, 5.2-9.44, Na_2O 2.94-4.7, K_2O 0.33-4.7
2. Cadlareena Volcanics from *WARRINA*. Average of 4 analyses; 6041 RS 161-164. Range SiO_2 46.57-49.84, Al_2O_3 11.93-14.67, total Fe 10.3-12.8, MgO 5.24-11.53, CaO 5.1-11.99, Na_2O 1.7-4.45, K_2O 1.13-2.41.
3. Average of Cadlareena Volcanics from *WARRINA* and *ANNA CREEK* (as above, plus 6040 RS 14 and 15 from *BOORTHANNA*. Average of 13 analyses. Range SiO_2 45.1-49.84, Al_2O_3 11.93-14.67, total Fe 10.3-17.1, MgO 2.7-11.53, CaO 5.1-15.4, Na_2O 0.48-4.7, K_2O 0.33-4.7.
4. Wooltana Volcanics from the Mount Painter Province—average of 15 analyses. Range SiO_2 37.8-59.2, Al_2O_3 10.8-18.76, total Fe 8.25-37.0, MgO 0.22-12.68, CaO 0.04-15.8, Na_2O 0.13-4.6, K_2O 0.15-10.2.
5. Wooltana Volcanics from Depot Creek. Average of 8 analyses, 6433 RS 2, 3, 5, 6, 7, 8, 9 and 10. Range SiO_2 40.5-55.1, Al_2O_3 10.4-20.2, total Fe 2.6-20.3, MgO 3.2-11.2, CaO 0.16-0.57, Na_2O 0.05-0.72, K_2O 2.5-11.0.
6. Average distribution of elements in a continental basalt (Pearce, 1977).
7. Rhyolite from Cadlareena Volcanics on *ANNA CREEK:* 6140 RS 24.

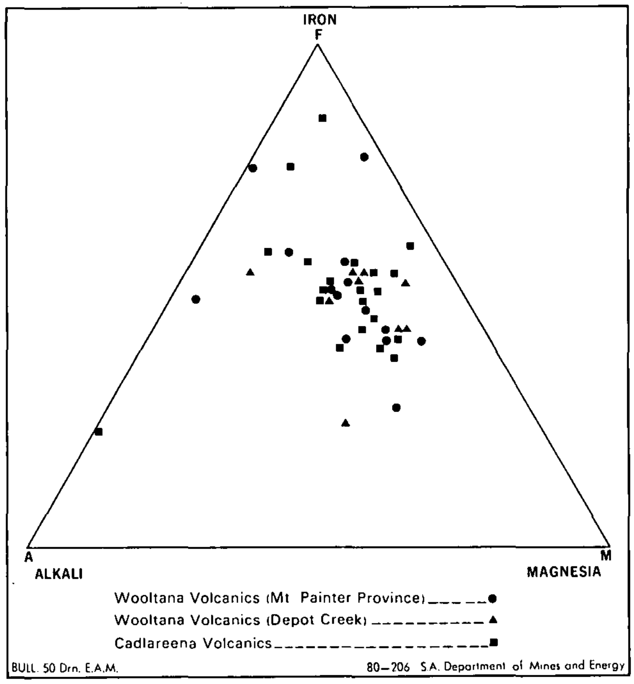

Fig. 5. AFM ternary diagram, Cadlareena and Wooltana Volcanics

Average analyses of Cadlareena Volcanics from *WARRINA* and *ANNA CREEK* (Table 6, columns 1 and 2) are similar. The average compositions of the Cadlareena and Wooltana Volcanics are similar (Table 6, columns 3, 4 and 5), although there are variations in the alkali contents. The Cadlareena Volcanics are less potassic and more calcic than the Wooltana Volcanics, and the samples from Depot Creek are particularly low in Ca and Na and correspondingly high in K. As noted by Thomson (1966), the Cadlareena Volcanics are characterised by a MgO/CaO ratio of less than one, while MgO/CaO ratios for the Wooltana Volcanics exceed one.

Fander (1963) noted the highly variable alkali content of the Wooltana Volcanics and generally described the lavas as sodic trachytes with subordinate andesites and rhyolites. Turner (1969) summarised the Wooltana Volcanics as belonging to the trachyte family with a late-stage, predominantly potash-rich mineral assemblage. This contradiction in itself testifies to the highly variable alkali content of these volcanics, which is largely due to deuteric alteration (e.g. albitisation) and potash metasomatism.

Whitehead (1972b) described the Cadlareena Volcanics as spilites (Na enriched), while Radke (1976) used the term 'altered basalts'. Both writers recognised minor potassium-rich varieties and considered them to be products of potash metasomatism, and this, together with the type of deuteric alteration, are features common to both the Cadlareena and Wooltana Volcanics.

Plotting analyses of Cadlareena and Wooltana Volcanics on an AFM diagram (Fig. 5) does not reveal any differentiation trends. Most of the analyses plot in a restricted zone, but are scattered in an irregular manner. This scatter may reflect alteration of the volcanics and effectively masks any pre-existing differentiation trends. One can generally conclude that the major element compositions of the Cadlareena and Wooltana Volcanics are broadly analogous and notable variations in Na, K, and Ca abundances occur within both units.

Table 7 *Geochemical analyses of Cadlareena Volcanics and Wooltana Volcanics*

	Zn	Cr	Mo	Cu	Ni	Co	Li	Pb	Ag	Rb	Sr	V	Ba	Zr	U	Th
1.	27	199	8	18	197	39	40	81		55	162	251	202	87	6	<4
2.	51	375	8	21	93	37	25	27	0·2	116	114	600	1 448	113	<4	4
3.	43	335	6	20	125	40	29	19	0·2	92	142	407	416	99	<4	<4
4.	183			31	155	57		8	0·2			128	156			
5.	105	170	1·5	87	130	48	17	6	0·1	30	465	250	330	140	1	4

1. Cadlareena Volcanics (6041 RS 93, 95-101, 161-164). Mean of 12 samples from *WARRINA*.
2. Cadlareena Volcanics (6140 RS 4-8 and 23-28). Mean of 8 samples from *ANNA CREEK* (Douglas Well).
3. Cadlareena Volcanics. Mean of all analyses from *WARRINA, ANNA CREEK* and *BOORTHANNA* (6040 RS 14-15).
4. Wooltana Volcanics. Mean of 8 analyses (Coats and Blissett, 1971).
5. Distribution of elements in basaltic rocks (Turekian and Wedepohl, 1961).

A summary of the trace element geochemistry of the Cadlareena and Wooltana Volcanics is presented in Table 7. Analyses of volcanics from *WARRINA* and *ANNA CREEK* (Douglas Well) are broadly analogous, although the rocks from Douglas Well appear enriched in Ba. The Cadlareena Volcanics as a whole are depleted in Cu and Zn relative to 'average' basaltic rocks (Turekian and Wedepohl, 1961) but Ni, Pb, Co, Li, Ba, Zn, U and Th values are generally similar (Table 7, lines 3 and 5). The highest Cu (80 ppm) and Pb (800 ppm) contents occurred in a dacite from *WARRINA* (6041 RS 93). Uranium contents are uniformly low, although several andesites on *WARRINA* recorded uranium contents up to 30 ppm (6041 RS 100).

The Wooltana Volcanics have higher average Cu, Pb and Zn contents than the Cadlareena Volcanics while Rb and Sr contents are similar.

Sequences of Uncertain Age (Willouran or Torrensian)

Block faulting and diapirism have caused dislocation and disruption of most of the Adelaidean sequences above the Cadlareena Volcanics. No complete succession is observed from the Callanna Beds upwards into the Burra Group. At least 16 000 m of sediments intervene between the youngest recognised unit in the Callanna Beds (Cadlareena Volcanics) and the oldest recognised unit in the Burra Group (unnamed siltstone). Reconstruction of the stratigraphy of this considerable thickness of sediments is a difficult proposition owing to the structural contexts in which most of the rocks occur, i.e. in rafted blocks in diapirs and in faulted blocks. Since none of these rocks can be ascribed with certainty to either the Callanna Beds or the Burra Group they are described under the heading 'Sequences of Uncertain Age'. The units involved are the Rockwater Beds, War Loan Beds, Nilpinna Beds, Duff Creek Beds and Murrana Beds (Table 8).

Table 8 *Stratigraphy—sequences of uncertain age*

Formation	Map Symbol
Undifferentiated blocks	Ᵽa
———? ——— ?———	
Murrana Beds	Ᵽaa
---? -----?---	
Duff Creek Beds	Ᵽaf
---? -----?---	
Nilpinna Beds	Ᵽan
---? -----?---	
War Loan Beds	Ᵽaw
---? -----?---	
Rockwater Beds	Ᵽad
———? ——— ?———	
Callanna Beds Cadlareena Volcanics	

——? — ?—— contact uncertain: unknown sequences suspected to intervene

---? ----?--- transition suspected on basis of lithological overlap

The stratigraphic succession is far from complete. Lithological overlaps between spatially separated sequences are the main criteria used in assembling the stratigraphic sequence. Some of the gaps in the succession portrayed in Table 8 may be filled, at least in part, by miscellaneous sequences described under the subheading 'Undifferentiated blocks'. These rock units are not formally named, and occur as thin sequences in blocks in diapirs, and in small faulted blocks.

Equivalents of the Rockwater Beds and Duff Creek Beds occur in the Willouran Ranges (R.P. Coats, S. Aust. Dept. Mines and Energy, pers. comm.). It is probable other units described in this section also have equivalents in the Willouran Ranges.

Rockwater Beds

The Rockwater Beds (Appendix, Unit 7) outcrop in four small blocks, all tectonically isolated in disrupted diapiric zones. Distinctive black cherts (which weather white) and black dolomites characterise the unit. The Rockwater Beds are believed to be equivalent to the Dunn's Mine Formation found in the Willouran Ranges (Murrell, 1977).

Two small blocks outcrop on *WARRINA*in a broad disrupted zone, above the Cadlareena Volcanics, about 11 km northeast of Warrina R. S. A third block outcrops immediately south of Comminaree Mine.

These blocks are composed of sequences of blue-grey to black cherts, grey-black pebbly dolomites, black shales, siltstones and quartzitic sandstones. The largest block contains about 100 m of sediments. Similar distinctive lithologies occur in several small blocks outcropping in a disrupted diapiric zone on the western margin of the Rockwater Hill Block. Small outcrops of brecciated Cadlareena Volcanics also occur in this zone, which probably represents remnants of a lower Adelaidean sequence disrupted by diapirism.

It is noteworthy that all blocks containing Rockwater Beds sequences, although tectonically isolated, outcrop very close to the Cadlareena Volcanics. This association, which in itself suggests the Rockwater Beds lie in close proximity stratigraphically to the top of the volcanic sequence, is supported by the fact that the Dunn's Mine Formation in the Willouran Ranges occur in a sequence closely overlying the volcanics (Murrell, 1977).

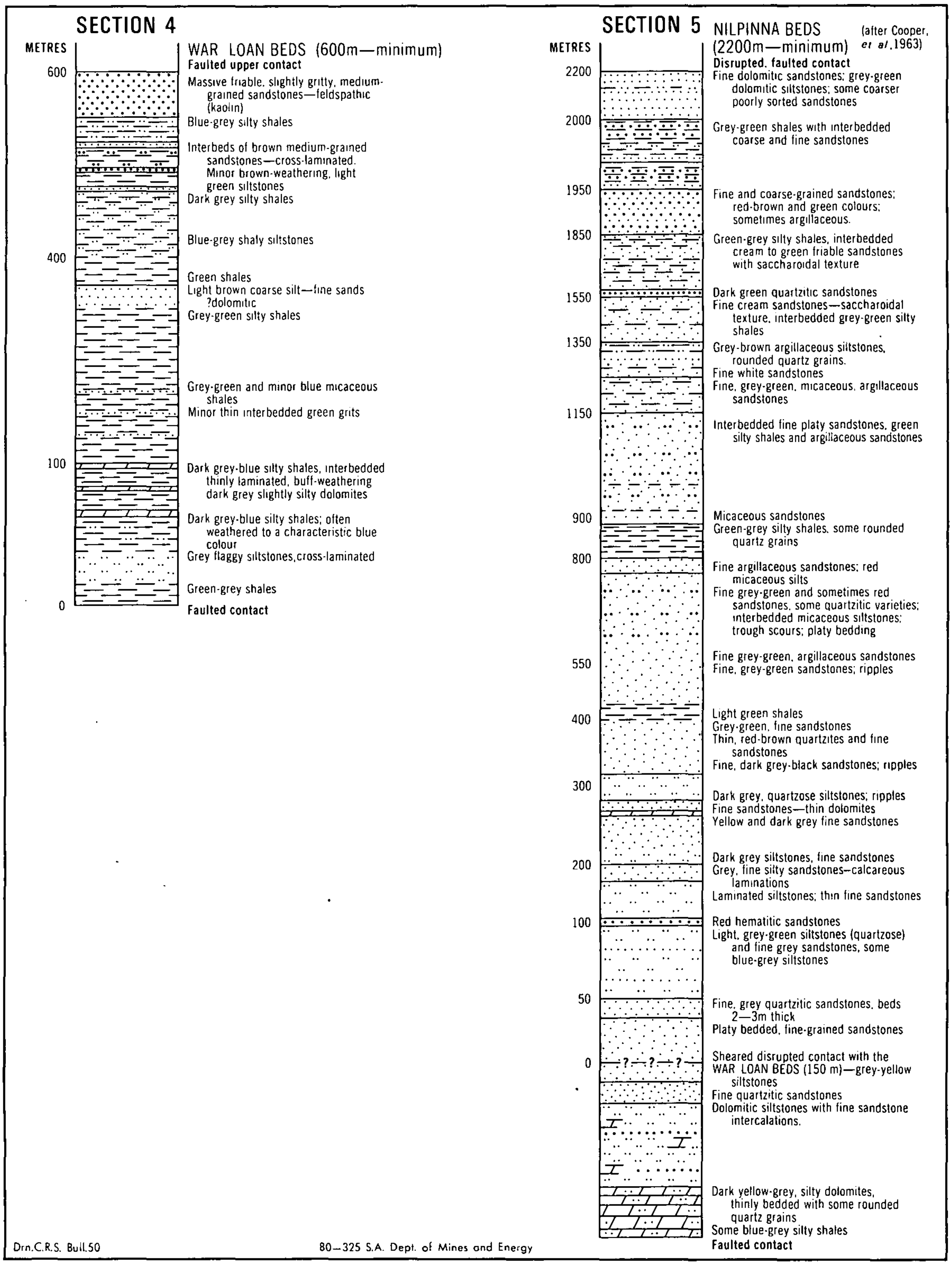

Fig. 6. Stratigraphic type sections, War Loan Beds and Nilpinna Beds

War Loan Beds

A sequence of 600 m of shales, sandstones and minor dolomites outcropping in a synclinal structure adjacent to the War Loan Mine, 8 km southeast of Nilpinna H.S., is herein named the War Loan Beds (Appendix, Unit 8). A detailed description of the type section is shown on Figure 6.

The War Loan Beds exhibit tectonic contacts with the Cadlareena Volcanics in the type section immediately south of War Loan Mine and consequently the lower boundary of the sequence is unresolved. The section headed 'Undifferentiated blocks' describes a total of 5 000 m of sediments which occur in faulted blocks and as rafted blocks in diapirs. It is probable that at least some of these rocks belong to sequences intervening between the Rockwater Beds and the War Loan Beds.

The lower part of the War Loan Beds consists of laminated bluish grey shales, buff-weathering dark grey dolomites, and minor cross-laminated flaggy siltstones. Green-grey and blue-grey shales, brown friable sandstones, and greenish gritty feldspathic sandstones characterise the upper part of the section. These lithologies have many affinities with the lower part of the Nilpinna Beds, although the only contact observed between the two units (1km north of War Loan Mine) is sheared. Despite the tectonic nature of this contact, overlap of lithologies suggests a passage from the War Loan Beds into the Nilpinna Beds (Table 8).

Nilpinna Beds

A thick sequence of laminated sandstones and silty shales, outcropping in a fault-bounded sequence 1 km north of War Loan Mine, is herein named the Nilpinna Beds (Appendix, Unit 9). This unit probably intervenes between the War Loan Beds and Duff Creek Beds.

The type section, 6 km southeast of Nilpinna H.S., exhibits sheared contacts at the base and top with the War Loan Beds and Duff Creek Beds respectively. The Nilpinna Beds are approximately 2 100 m thick and a description of the type section is on Figure 6. Main lithologies are thinly bedded sandstones (festoon cross-bedding, salt casts—Plate 10), green arkoses, grey-green silty shales (ripples, mud cracks and salt casts), and minor grey silty dolomites towards the top of the unit.

Platy friable sandstones (salt casts, cross-beds) near the top of the sequence strongly resemble sandstones in the basal Duff Creek Beds. Blue-grey shales and fine-medium sandstones (festoon cross-bedding, salt casts) near the base of the Nilpinna Beds have many affinites with units in the upper War Loan Beds. These lithological criteria are considered to indicate that the Nilpinna Beds record an interval of sedimentation between the War Loan Beds and Duff Creek Beds. The transition upwards into the Duff Creek Beds is marked by a gradual increase in the frequency of dolomites.

Duff Creek Beds

Reyner (1955) defined the Duff Creek Formation to include all Willouran rocks of the Peake and Denison Ranges. The term Duff Creek Formation has since been abandoned and the name Callanna Beds is used to describe the earliest Adelaidean sediments.

The term Duff Creek beds was introduced by Thomson and Coats (1964) to apply to a unit composed of green and carbonaceous shales and thin distinctive yellow dolomites. Approximately 3 700 m of shallow water sediments outcrop in the type section on *WARRINA*, east of Nilpinna Homestead. Subsequent mapping revealed that an additional 1 800 m of similar sediments conformably underlie this sequence about 9-10 km to the south on *BOORTHANNA*. It is proposed that the type section of Thomson and Coats (1964) be extended to include these sediments, resulting in a total thickness of 5 500 m (Fig. 7).

This is a minimum thickness, since both the upper and lower limits of the type section are bounded by faults.

Lithologies characteristic of the unit include:

- —fine sandstones with platy bedding, ripples, cross-bedding and rare salt casts. Pyritic sandstones occur in the lower half of the section.
- —olive-green siltstone-shales with ripples, mud cracks and rare salt-cast horizons. Thin arkosic grits with characteristic blue quartz are often interbedded with these siltstones and shales.
- —flaggy, pale orange-buff weathering, pale grey-yellow dolomites, often gypsiferous, pyritic and occasionally stromatolitic (Plate 11). Most of the stromatolites are a flat laminated type. The dolomites are occasionally sandy and more rarely conglomeratic and contain intraformational dolomite clasts.
- —medium-coarse gritty sandstone (sometimes feldspathic) and quartzites;
- —black pyritic shales plus occasional brown to buff-weathering black dolomites.

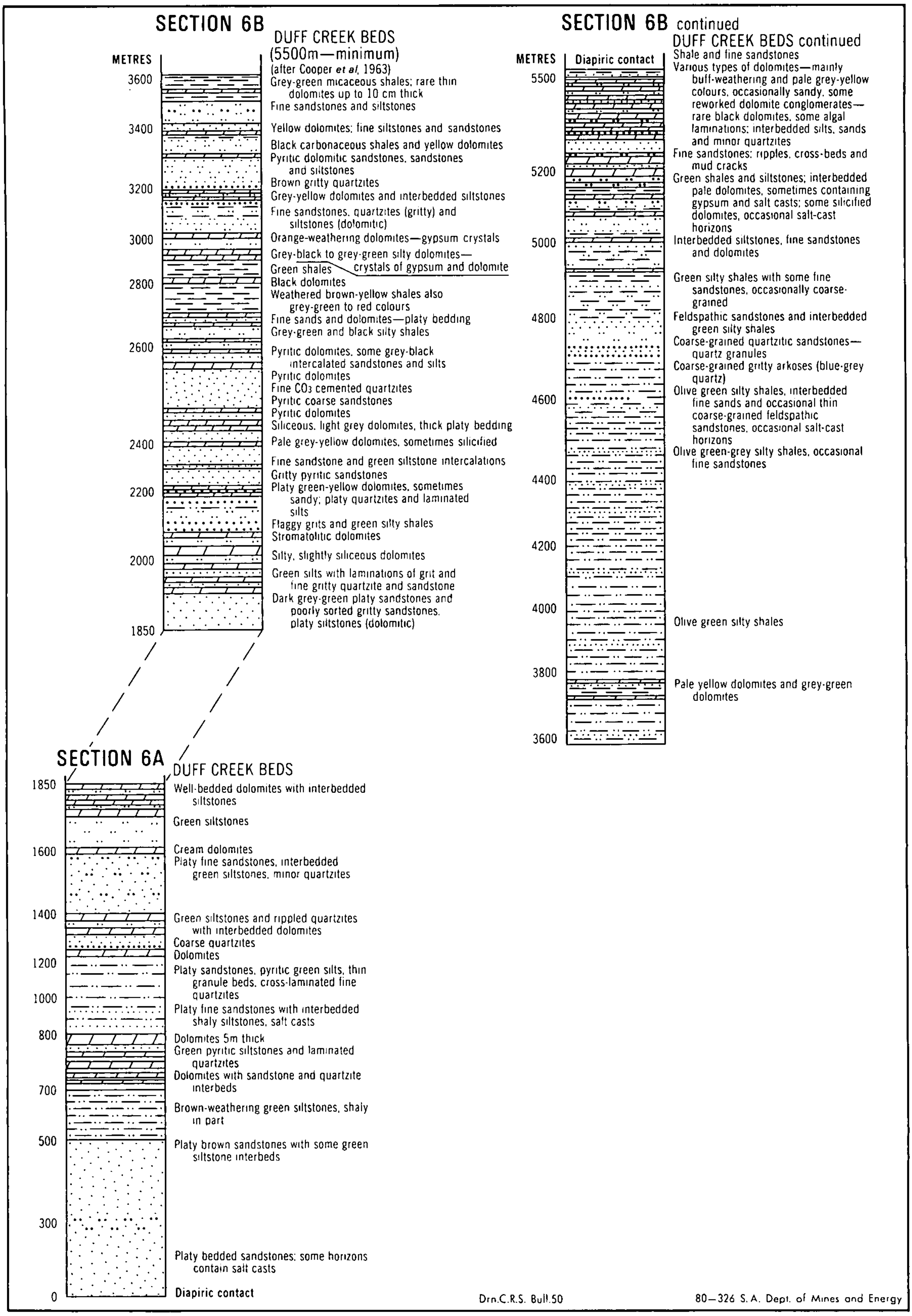

Fig. 7. Stratigraphic type section, Duff Creek Beds

Plate 10. Well developed cross-laminations in the lower part of the Nilpinna Beds, 1.5 km northwest of War Loan Mine.

Transparency 14468

Plate 11. Typical laminated, buff-weathering dolomite in the Duff Creek Beds, 6 km northwest of Douglas Well; note the thin siliceous interbeds.

Transparency 14469

Plate 12. Mud cracks in a silty dolomite of the Duff Creek Beds, west of Tarlton Springs.

Transparency 14470

Shallow water conditions in lagoonal, supratidal, and inter-tidal environments are indicated by numerous sedimentary structures including mud cracks (Plate 12), cross-bedding, ripple marks, graded bedding, flute casts and salt casts. Black, pyritic shales, and dolomites were deposited in a reducing lagoonal environment. Pale, gypsiferous dolomites, and fine-grained siltstone-sandstone units containing salt and gypsum casts are indicative of a supratidal environment, while quartzites and cross-bedded sandstones suggest intertidal shoreline conditions.

The large thickness of shallow water sediments (5 500 m) attests to considerable basinal subsidence during deposition. Terrigenous clastic-carbonate couplets indicate cyclic sedimentation in response to sea-level fluctuations. Regressive, upward-shoaling cycles (Wilson, 1975) account for at least part of the large thickness of shallow water sediments preserved.

The dolomites are most likely the result of early diagenetic (syngenetic) dolomitisation by seawater. Brines in tidal flats, lagoons, and supratidal zones (sabkhas) often gain high Mg/Ca ratios due to loss of Ca through evaporative precipitation of gypsum and anhydrite. These Mg-enriched brines migrate down through unconsolidated lime mud dolomitising the sediment. Extensive dolomitisation through thick sections may be aided by the tendency towards prograding sedimentation (Wilson, 1975).

A number of blocks containing rocks belonging to the Duff Creek Beds occur in faulted and diapiric contexts. The largest of these are described below.

—Approximately 1 100 m of Duff Creek Beds occur in a faulted block immediately west of Tarlton Springs on *ANNA CREEK*. Pyritic green-grey shales, pale yellow-brown gypsiferous dolomites, fine sandstones, quartzites, thin arkoses, and minor dark grey dolomites represent the main rock types. Flat laminated stromatolites, ripple marks, cross-bedding, mud cracks and minor salt casts are characteristic.

—Approximately 1 800 m of sediments belonging to the Duff Creek Beds outcrop in a faulted block about 5·5 km northwest of Douglas Well. Main lithologies include pale stromatolitic dolomites, quartzites, fine sandstones, olive-green shales, and arkoses. A pebbly quartzite containing fragments of Peake Metamorphics (quartz, quartzite, granite and pegmatite) occurs in the lower part of the section. The lowermost 800 m of the section consists of arenaceous-argillaceous sediments with quartzites, sandstones and shales predominating. Mud cracks, ripple marks, salt casts and cross-bedding are common.

—Approximately 5 km west of Mount Denison, on *WARRINA*, a number of disconnected blocks occur in a diapiric zone. The sediments are strongly folded, with quartz+biotite schists and slaty argillaceous quartzites predominating. Minor carbonates are present.

—Immediately southeast of Mount Kingston, approximately 800 m of green slaty pyritic siltstone, fine sandstone, quartzite, and minor pyritic dolomite and arkosic grit occur in an anticline faulted against basement rocks to the west. Similar but smaller blocks are infaulted against basement rocks to the south of 'Peake' ruins along the eastern faulted margin of the Denison Inlier.

—The southern part of the Dutton Inlier consists of 250 m of Duff Creek Beds. Coarse cross-bedded arkoses, olive-green siltstones, fine sandstones, and pale stromatolitic dolomites predominate. A laminated, gritty, quartzitic sandstone at the top of the sequence has many affinities with units in the Murrana Beds.

Murrana Beds

A thick sequence of arenaceous sediments, which probably grade downwards into the Duff Creek Beds, is herein named the Murrana Beds (Appendix, Unit 11). The type section, about 4 km northwest of Warrina R.S., comprises the eastern limb of a faulted, basinal syncline. The total thickness of the type section is 2 900 m (Fig. 8).

The lower 700 m of the type section consists of laminated gritty quartzites, fine sandstones, and feldspathic sandstones with grey-green silty shale intercalations. This lower part of the section has been party disrupted; crumpled and dislocated bedding, faulting and minor intrusion of carbonate breccia are characteristic. However, in this lower disrupted zone, the general maintenance of bedding orientations and lithological types, consistent with the undisturbed overlying sequence, indicates stratigraphic continuity.

The lower disrupted zone grades upwards into an undisturbed sequence of mainly arenaceous and silty sediments approximately 1 800 m in thickness. Gritty quartzitic sandstones and interbedded grey-green silty shales are characteristic . Cross-bedding (small and medium scale), ripples, flute casts, mud cracks, and graded bedding are ubiquitous. Salt casts are less common.

The uppermost 400 m consists of green nodular siltstones (rarely blue-grey), massive pebbly dolomites, fine to coarse gritty feldspathic sandstones, laminated quartzites, purple and maroon shales, and a lenticular, pebbly ?stromatolitic dolomite near the top. The sedimentary structures and lithologies observed in the type section are consistent with deposition in a shallow marine environment.

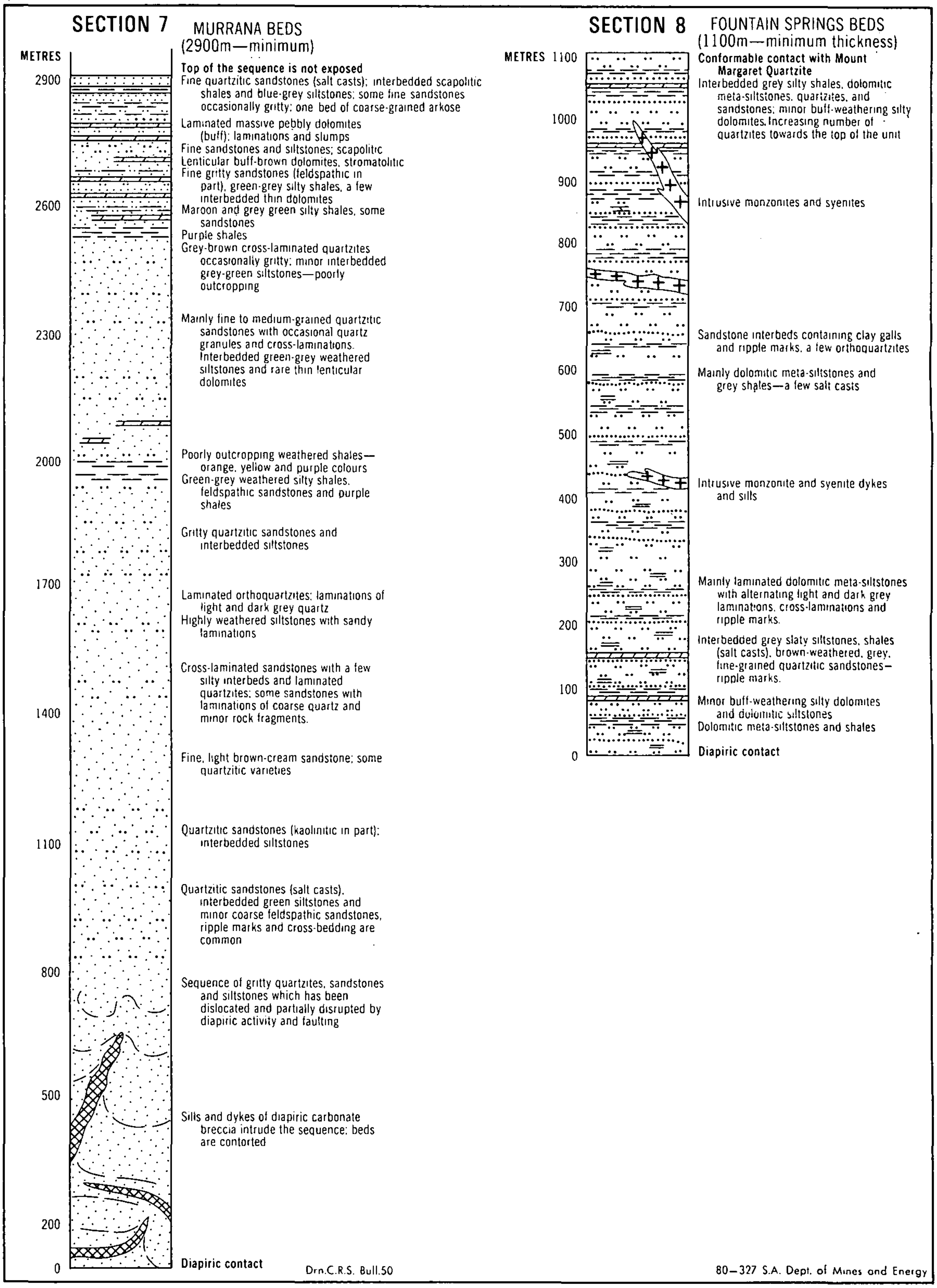

Fig. 8. Stratigraphic type sections, Murrana Beds and Fountain Spring Beds

In the Dutton Inlier, a thick sequence of Murrana Beds is separated from the Duff Creek Beds by a thin wedge of diapir. A gritty quartzitic sandstone, at the top of Duff Creek Beds sequence, strongly resembles quartzites characteristic of the Murrana Beds. Similarly, near the base of the Murrana Beds there are a few thin beds which are reminiscent of the Duff Creek Beds. Thus, although no sedimentary contact is observed between the two units, these lithological criteria suggest a passage from the Duff Creek Beds into the Murrana Beds marked by an increased sand-silt to carbonate ratio.

On *WARRINA*, both 9·1 km north of Warrina R.S. and 1·2 km east of Nilpinna H.S., the Murrana Beds are observed in tectonic contact with sequences of Duff Creek Beds. Both units have the same facing and orientation and are separated by a thin zone of brecciation.

Undifferentiated blocks

Rocks from sequences of unknown age, described below, occur in two general contexts:

—in fault-bounded blocks of various sizes
—in rafted blocks bounded by carbonate breccia in disrupted 'diapiric' zones. One such zone occurs above the Cadlareena Volcanics on *WARRINA*. Sediments from the larger blocks in this zone are described below (see geological map for block localities).

—*Block* 1 consists of approximately 200 m of maroon shales (salt casts), interbedded fine silty sandstones (ripples, cross-beds), and occasional feldspathic sandstones.

—*Block* 2 comprises sandstones and quartzites interbedded with minor stromatolitic dolomites, purple shales and siltstones.

—*Block* 3 contains a sequence of pale dolomites and dolomitic siltstones, laminated grey quartzites, green siltstones, and rippled sandstones.

—*Block* 4 consists mainly of cross-laminated quartzites and sandstones with interbedded orange-weathering dolomites, grey-green flaggy siltstones, and minor maroon shales.

—*Block* 5 consists of black shales, olive-green silty shales, and buff dolomites.

—*Block* 6, at the head of Levi Creek, consists of interbedded coarse feldspathic sandstones, quartzites and grey-green slaty siltstones (salt casts, ripples and cross-bedding).

—*Block* 7, immediately northeast of Rockwater Hill, consists of quartzites, sandstones, siltstones and minor sandy stromatolitic dolomites.

—*Block* 8 is faulted against basement rocks north of Mount Kingston. The sequence is 700 m thick; the lower 500 m consisting of coarse pebbly arkoses and sandstones overlain by black shales and dolomites (pyritic) with some pale brown dolomites and blue-grey siltstones. The upper 200 m consists of green-grey siltstones (gritty), fine-coarse sandstones, and minor cross-laminated quartzites.

The exact stratigraphic positions of the sediments described in Blocks 1-8 are unresolved. These rocks only occur in faulted or diapirically rafted blocks and are not observed in thick sequences anywhere in the Peake and Denison Ranges. The total thickness of sediments in these blocks is approximately 5 000 m. Obviously a significant lower part of the Adelaidean stratigraphy has been dismembered by diapirism and block faulting. The sediments, in the blocks described, probably represent remnants of sequences which occur somewhere above the top of the Cadlareena Volcanics (Callanna Beds) and below the recognisable base of the Burra Group (unnamed siltstone). This was concluded after considering:

—the close spatial relationship between Willouran rocks (e.g. Cadlareena Volcanics) and many of the blocks described
—the fact that diapirism has disrupted early Adelaidean sequences in other parts of the Adelaide Geosyncline
—the blocks described above contain no sediments which correspond with late Torrensian or Sturtian sequences observed in the Peake and Denison Ranges.

Burra Group (Torrensian)

The following units (see Table 9) comprise the Burra Group in the Peake and Denison Ranges: unnamed siltstone, Fountain Spring Beds (new name), Mount Margaret Quartzite, Skillogalee Dolomite, unnamed transition unit, and Kalachalpa Formation (new name). The sediments are almost entirely of shallow marine deposition and total at least 10 000 m in thickness.

As previously discussed, the Rhynie Sandstone, with its characteristic heavy-mineral laminations provides a useful marker for the base of the Burra Group in the southern part of the Adelaide Geosyncline (Preiss, 1974). This heavy-mineral laminated unit has not been recognised in the Peake and Denison Ranges and the lowermost unit attributed to the Burra Group (unnamed siltstone) outcrops in tectonically isolated blocks. Consequently, the base of the Burra Group cannot be defined. Units observed in the 'unnamed siltstone' have

Table 9 *Stratigraphy—Burra Group*

Formation	Map symbol
Kalachalpa Formation	Ᵽbh
——— disconformity ———	
Unnamed transition unit	Ᵽb2
———?——— ?———	
Skillogalee Dolomite	Ᵽbk
Mount Margaret Quartzite	Ᵽbo
Fountain Spring Beds	Ᵽbl
---?--- ?---	
Unnamed siltstone	Ᵽb1
———?——— ?———	
Sequences of uncertain age	

———	conformable contact
---? --- ?---	transitional contact suspected on basis of lithological overlap
——? —— ?——	contact uncertain—unknown sequences suspected to intervene
——⌄ ⌄——	disconformity

lithological affinities with sequences previously described under the heading 'Sequences of Uncertain Age' and at least some of these sequences may belong in the lower Burra Group.

Burra Group sediments are restricted in outcrop to the Margaret Inlier, where they crop out in a series of basinal synclines forming the central core of the inlier. The synclines have axial plane traces generally aligned north-northwest, which form an *en echelon* pattern, stepped over to the east as the axes are traced from south to north. Upper Burra Group sediments are restricted in outcrop to folded sequences exposed on the southwest margin of the Margaret Inlier.

Unnamed siltstone

A sequence of siltstones, fine sandstones and silty dolomites, totalling at least 1 200 m in thickness, comprise the lowermost part of the Burra Group recognised on *WARRINA*. The sequence has been dismembered by faulting and occurs in several blocks outcropping on the eastern side of the Margaret Inlier, about 4·5 km north of Mount Margaret. The stratigraphy is obscured by a combination of faulting, folding, and diapirism. The sequence is believed to grade upwards into the Fountain Spring Beds, but the base of the unit is not defined.

Laminated, grey, pyritic dolomitic siltstones comprising interlayered light grey quartz+dolomite and dark grey biotite+muscovite laminations characterise the unit. The laminations have sharply defined bases with graded tops and commonly display small-scale slumping. Quartzites and flaggy, buff-weathering, silty pyritic dolomites occur towards the base of the section. Buff-weathering, grey, pyritic dolomites, grey quartzites, green shales (ripples and salt casts) and fine sandstones (ripple marks, cross-laminations, salt casts) increase in frequency towards the top of the unit.

The laminated, light grey-dark grey dolomitic siltstones and silty buff-weathering dolomites are also typical of overlying sediments in the lower Fountain Spring Beds, suggesting a gradational boundary, but this is uncertain because contacts are faulted.

This unit contains several lithologies typical of those occurring in some of the 'Sequences of Uncertain Age', e.g. fine sandstones, pyritic dolomites and green shales all with ripple marks and salt casts.

Fountain Spring Beds

Siltstones, shales, and quartzites outcropping on the northwestern and eastern margins of the Margaret Inlier are herein defined as the Fountain Spring Beds (Appendix, Unit 12). Approximately 1 100 m of sediments occur in the type section 3 km north of Mount Margaret. The sequence grades upwards into the Mount Margaret Quartzite, the transition being marked by an increase in orthoquartzites. The base of the Fountain Spring Beds is not exposed, but in several localities, the unit is observed in tectonic contact with the unnamed siltstone unit. Both sequences are correlated with the River Wakefield Subgroup defined by Forbes (1964).

Predominant lithologies include laminated dolomitic metasiltstones, pale grey quartzites with clay galls, rippled fine sandstones, green slaty siltstones containing salt casts, and minor flaggy buff-weathering grey dolomites near the base. Quartzite increases at the expense of silt-carbonate upwards through the sequence. A description of the type section is shown on Figure 8.

Porphyritic monzonite and syenite sills commonly intrude the Fountain Spring Beds and lower Mount Margaret Quartzite, particularly the siltstone and shale units. Apparently the intrusives were largely unable to penetrate the thick massive quartzites of the upper Mount Margaret Quartzite.

The presence in the Fountain Spring Beds of dolomitic sediments, ripple marks and salt casts suggest marine influence, although the upper part of the sequence may have been deposited in a fluvial environment.

Mount Margaret Quartzite

Reyner (1955), in the text of his report, applied the name Mount Margaret Quartzites to a sequence of quartzites he considered to conformably overlie the Duff Creek Beds, but he used the name Mount Margaret Formation for the same unit on the published 1-mile geological sheets; Formation was also used by Thomson and Coats (1964). It was Thomson (1969, p. 59) who first used the term Mount Margaret Quartzite. It is proposed in this report, that the name Mount Margaret Quartzite apply to a thick sequence of mainly arenaceous sediments conformably overlying the Fountain Spring Beds (Appendix, Unit 13). The type section, about 5·5 km north-northwest of Mount Fox, includes the complete sequence. The lower contact with the Fountain Spring Beds is gradational and occurs in a section 3 km north of Mount Margaret. The upper contact of the Mount Margaret Quartzite is comformable with the Skillogalee Dolomite. Near the type section, there is local brecciation along this upper contact with minor intrusions of carbonate breccia. The large difference in competency between the thick quartzites of the Mount Margaret Quartzite and the thinly bedded shales and dolomites of the Skillogalee Dolomite probably caused this minor brecciation during folding.

The formation is restricted to the southern part of the Margaret Inlier: it occurs at Mount Margaret itself and also constitutes the Mount Margaret Plateau (Plates 13 and 14). The resistant quartzites forming this imposing landform rise up to 300 m above the surrounding plains.

In the type section, the Mount Margaret Quartzite has a thickness of approximately 2 500 m. It is described on Figure 9. The sediments are 80 per cent arenaceous and 20 per cent silty-argillaceous. The lower part of the unit consists of interbedded fine slaty quartzitic sandstones (sometimes feldspathic) and green-grey laminated silty shales alternating with massive light grey orthoquartzites. Argillaceous sandstones and thinly bedded cream-grey orthoquartzites with minor interbedded sandy shales (occasionally dark grey) comprise the remainder of the formation. Massive orthoquartzites increase in frequency towards the top of the sequence.

Clay galls, cross-bedding and interference and current ripple marks are common. Mud cracks are rare. It is possible this sequence of mainly arenaceous sediments was deposited in a deltaic environment. Some marine influence is indicated by minor dolomitic siltstones near the base.

Skillogalee Dolomite

Conformably overlying the Mount Margaret Quartzite is a sequence containing 3 600 m of dolomites, siltstones, quartzites and sandstones, together with minor cherts and magnesites. This sequence in the Peake and Denison Ranges is far more varied lithologically than the Skillogalee Dolomite in the Clare-Riverton region, with which it is correlated (Mirams and Forbes, 1964).

The formation is confined to the eastern and central parts of the Margaret Inlier and crops out in a series of basinal synclines (and a complimentary anticline to the southwest) trending north-northwest through the ranges. The formation erodes to a moderately rugged topography, but is more subdued than the adjacent quartzites comprising the Mount Margaret Plateau. A preponderance of small trees and shrubs growing on the dolomitic members is a useful criterion in identifying carbonate-rich parts of the sequence (Plate 15). The unit consists of three unnamed members. The basal member conformably overlies the Mount Margaret Quartzite in the vicinity of Mount Fox; the contact being marked by a sudden change in relief from the orthoquartzites to the sandstones and siltstones of the lower Skillogalee Dolomite. This lower sandy member comprises 75 per cent arenaceous, 20-25 per cent argillaceous-silty and 5 per cent dolomitic sediments, and has a thickness of 1 100 m 3 km northwest of Douglas Well, although the lower contact with the Mount Margaret Quartzite is not preserved here. Main lithologies are platy sometimes gritty sandstones, quartzitic sandstones, and green-grey silty shales with rare pale brown, sometimes sandy, dolomites. These mainly arenaceous sediments are characteristic of winnowed sands deposited in beach, shoal, and tidal environments. No stromatolites are observed in this member, which indicates that the environment was not hospitable to algal-colonisation because of the shifting substrate. Precipitation of carbonate was limited to a few, thin, pale dolomites near the top of the member. Clay galls, cross-bedding, graded bedding and ripple marks are common throughout.

This arenaceous member grades into a sequence of dolomites and sandy sediments, the transition being marked by an increased carbonate content (sediments average 55 per cent arenaceous, 15 per cent argillaceous-silty and 30 per cent dolomitic). This middle member reaches a maximum thickness of 1 500 m 17 km north-northwest of Douglas Well. It should be noted that folding has distorted true thickness: both thickening and thinning of the Skillogalee Dolomite are common, especially on the hinges of folds. Most of the dolomites are

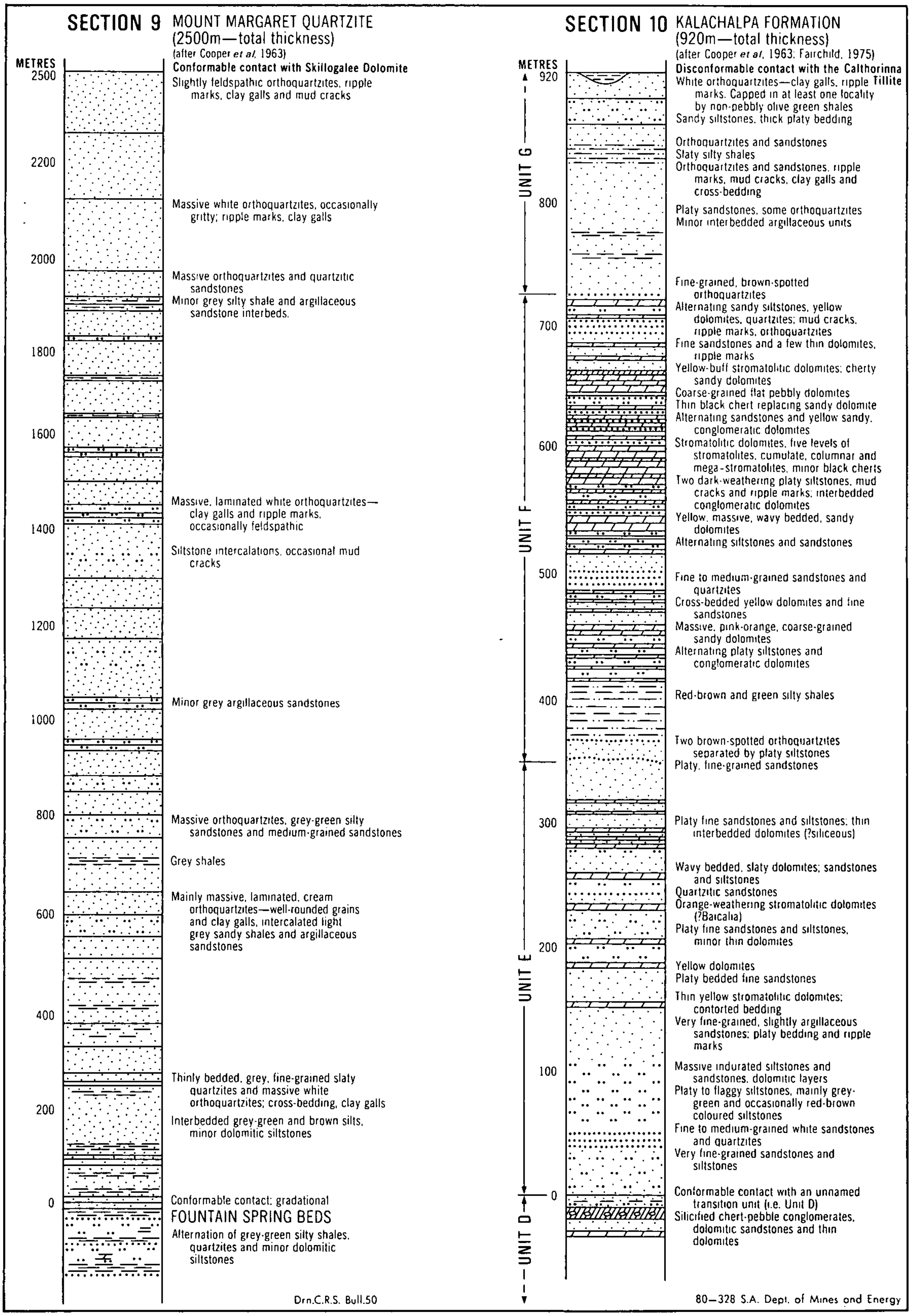

Fig. 9. Stratigraphic type sections, Mount Margaret Quartzite and Kalachalpa Formation

Plate 13. Rugged, faulted, eastern margin of Margaret Inlier, north of Tarlton Springs. Quartzites of the Mount Margaret Quartzite are faulted against Mesozoic and younger sediments. Mount Margaret is situated right of centre on the skyline.

Transparency 14471

Plate 14. Looking south on the western margin of Margaret Inlier. Quartzites of the Mount Margaret Quartzite are faulted on the right against (topographically lower) siltstones of the Fountain Spring Beds. The peneplain surface forming the Mount Margaret Plateau dips gently to the west.

Transparency 14472

Plate 15. Looking north-westward across gently dipping dolomites and sandstones of the Skillogalee Dolomite in the Margaret Inlier. The Mount Margaret Plateau is visible on the skyline.

Transparency 14473

conglomeratic, cross-bedded, and contain reworked dolomite fragments and quartz grit. Colours vary from pale grey-brown to dark grey-black, the latter variety becoming more frequent towards the top of the member. A few stromatolitic dolomite horizons, containing characteristic stromatolites of the group *Baicalia,* occur in the middle and upper parts of the member. Silicifiction of the dolomites is common. Associated sediments include green-grey and black pyritic shales, gritty friable sandstones (sometimes feldspathic), thin grey vitreous quartzites, minor blue-black cherts, and magnesite pebble conglomerates. This member probably records deposition in open lagoons and bays, which received considerable amounts of terrigenous sediment. Terrigenous clastic-carbonate couplets imply cyclic sedimentation of unknown complexity, but it is probable that upward shoaling, facilitated by seaward outbuilding of carbonate facies, has been followed by rapid transgressions. The vast amounts of reworked dolomite in many of the sediments supports this view. The regressive-rapid transgressive cyclic effects envisaged (due largely to sea level fluctuations), together with the relatively high clastic content of the sediments, explains the paucity of stromatolites. Minor magnesite may have been precipitated by alkaline waters of continental origin reacting with seawater (Forbes, 1961). The magnesite has been reworked into thin, lenticular conglomerates usually less than 0·5 m thick.

The carbonate content shows a marked increase in the upper member and the terrigenous clastic influence is minimal (sediments average 5 per cent arenaceous, 10 per cent argillaceous-silt, 85 per cent dolomitic). Dark grey-black, laminated-thinly bedded dolomites predominate. Reworking of the dolomite into conglomerates is evident and stromatolitic horizons are common. Minor black shales, grey quartzites, feldspathic sandstones, magnesite conglomerates and blue-black cherts are interbedded with the dolomites. Deposition probably occurred in shallow cut-off ponds and lagoons with restricted circulation, where reducing conditions favoured the accumulation of organic material. Contributions of terrigenous sediments were minimal. The upper boundary of this member is unknown, and the estimated maximum thickness is about 1 000 m.

The accumulation of such a large thickness of shallow water sediments (3 600 m) attests to steady basinal subsidence during deposition. In addition, the rapid sedimentation of shallow water carbonates under optimum conditions has resulted in the prevalence of regressive sedimentary cycles. The dolomite component of the Skillogalee Dolomite accumulated by either direct precipitation of dolomite, or formation of syngenetic dolomite by early replacement of calcium carbonate. The second alternative is described by Badiozamani (1973) in a model which requires continuous mixing of groundwaters (low in Mg) with seawater (supplying Mg) during fluctuations of sea level to form a fluid saturated with respect to dolomite and undersaturated with respect to calcite. During emergence, the interface, where this mixing occurs, becomes a dolomitising zone, and fluctuating sea levels cause this zone to migrate through the sequence.

Preiss, 1973b, proposed various environments of deposition for the Skillogalee Dolomite in different parts of the Adelaide Geosyncline. At Adelaide and near Spalding (Bundaleer), the section is 200 m thick and contains between 10 and 30 per cent sandstone, which was considered to be deposited in a lagoonal or barred embayment environment. A higher energy environment of deposition occurred in the Willouran Ranges, where sandstone forms more than 30 per cent of the section which is 1 000-4 000 m thick. The northerly trends of increasing sandstone content, and increasing thickness, are continued in the Peake and Denison Ranges where the section has a minimum thickness of 3 600 m and contains 40-50 per cent sandstone, mostly concentrated in the lower two members. The increased thickness and terrigenous clastic component reflects active tectonism in the northern portion of the Adelaide Geosyncline with continental sources existing to the west and southwest.

Unnamed transition unit

In an anticlinal structure on the southwest margin of the Margaret Inlier, 6 km north of Box Creek R.S., 3 000 m of upper Burra Group sediments disconformably underlie the Sturtian tillite, in a section referred to as the Boorthanna section (Fig. 10). Sediments are predominantly thinly bedded, fine-grained clastics, with minor, locally abundant, carbonates (sediments average 60 per cent arenaceous, 25 per cent argillaceous-silty, and 15 per cent dolomitic). The upper part of the section was originally described by Cooper *et al.,* (1963). Interest was rekindled in the Boorthanna section following discovery of a well-preserved late Precambrian microflora in stromatolitic black cherts, collected by H. Wopfner (Schopf and Fairchild, 1973). Later Fairchild (1975) subdivided the sequence into seven units (Units A-G, Fig. 10). Units A-D comprise the lower 2 000 m of the Boorthanna section and represent the unnamed unit, which is transitional between the underlying Skillogalee Dolomite and overlying Kalachalpa Formation—Units E-G of Fairchild (1975).

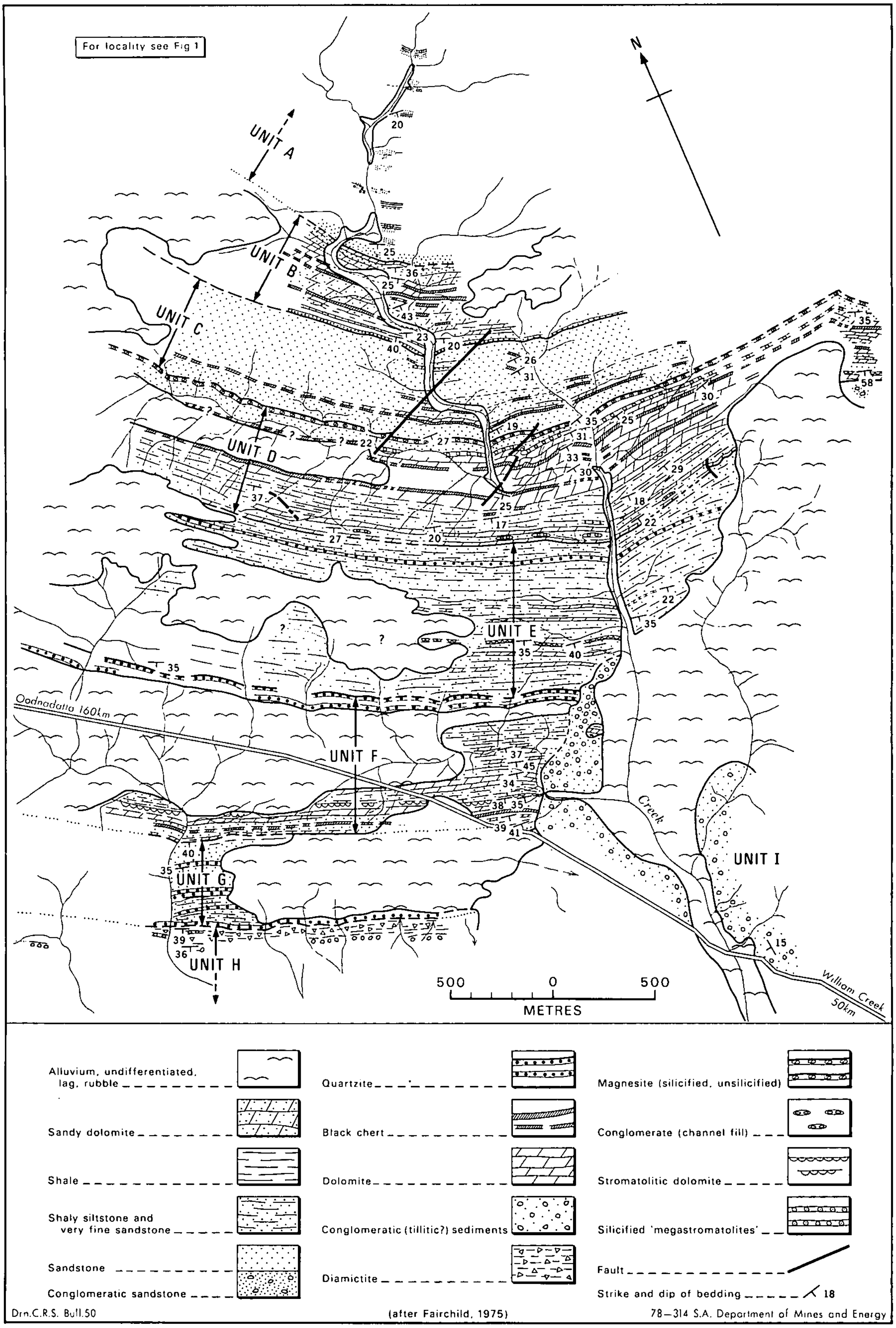

Fig. 10. Boorthanna section, Margaret Inlier

Unit A consists of 1 500 m of mainly laminated, gritty, quartzitic sandstones (often feldspathic), interbedded grey-green shales, with minor laminated grey-brown dolomites (sediments average 75-80 per cent arenaceous, 20 per cent argillaceous-silty, and 0-5 per cent dolomitic).

Unit B is more dolomitic (sediments average 25 per cent arenaceous, 35 per cent argillaceous-silty, and 40 per cent dolomitic) and consists of 190 m of alternating dolomites and fine clastics, with black chert interbeds, and minor magnesite pebble conglomerates. Dolomites are conglomeratic and often silicified and several stromatolitic horizons are present (including *Baicalia).*

The clastic content increases in *Unit C* (sediments average 90 per cent arenaceous, and 10 per cent dolomitic), which is predominantly platy friable sandstones with minor magnesite pebble conglomerates, orange dolomites, and silicified carbonate pebble conglomerates.

Unit D contains characteristic coarse chert-pebble conglomerates (Plate 16), magnesite pebble conglomerates, black cherts, and stromatolitic dolomites (sediments average 45 per cent arenaceous, 15 per cent argillaceous-silty, and 40 per cent dolomitic).

Mud cracks, ripple marks, cross-bedding, graded bedding, and convolute bedding are common throughout, and suggest a shallow marine environment of deposition, which was intermittently exposed and desiccated. There is extensive evidence of penecontemporaneous reworking (e.g. intraformational conglomerates and erosional micro-unconformities—Plate 17). Cyclic sedimentation appears to be similar to that operating during the deposition of the Skillogalee Dolomite and the mode of dolomitisation is also probably similar. Fairchild (1975) suggests silicification may be related to regressive cycles during which evaporative pumping of silica-enriched groundwaters facilitated silicification.

Units A-D have a number of affinities with the Skillogalee Dolomite. These include the presence of:

—magnesite pebble conglomerates

—stromatolites of the group *Baicalia*. Fairchild (1975) discovered stromatolitic microfloras in eighteen beds in the Boorthanna section.

—chert, conglomeratic dolomite, together with other lithologies and sedimentary structures, indicating a similar environment of deposition to that of the Skillogalee Dolomite.

However, the unnamed sequence is not as dolomite-rich as the Skillogalee Dolomite (Skillogalee Dolomite sediments average 35-40 per cent dolomitic, 45-50 per cent arenaceous, 15 per cent argillaceous-silty: unnamed unit averages 10-15 per cent dolomitic, 70 per cent arenaceous, 15-20 per cent argillaceous-silty). The Skillogalee Dolomite is less extensively silicified and contains only minor chert. No stratigraphic contact between the two units has been observed, and there is no definite lithological overlap recognised between the upper Skillogalee Dolomite and the lower part of the unnamed unit. Thus, barring rapid facies changes, it is apparent that part of the upper Torrensian sedimentary record is missing; the magnitude of the gap being uncertain. The fact that the unnamed unit has many lithological affinities with the overlying Kalachalpa Formation, as well as the underlying Skillogalee Dolomite, indicates that it is transitional between these two formations.

An equivalent sequence, faulted against the Kalachalpa Formation, crops out 1 km east of the Box Creek R.S. It is doubtful if the lithological subdivision of Fairchild (1975), i.e. Units A-D, applies here, as the upper part of the sequence is considerably less sandy than its counterpart to the north.

Kalachalpa Formation

The upper 900 m of sediments outcropping in the Boorthanna Section, 6 km north of Box Creek R.S., are herein named the Kalachalpa Formation (Appendix, Unit 14), which is composed mainly of fine-grained clastics and associated dolomite horizons (Fig. 9). The sequence corresponds to Units E-G of Fairchild, 1975 (Fig. 10), and conformably overlies the unnamed transitional unit. The upper contact with the Sturtian glacials is marked by a disconformity. The Kalachalpa Formation correlates with the Myrtle Springs Formation (Coats, 1973, Table 1).

Although the Kalachalpa Formation has lithological affinities with the conformably underlying unnamed transitional unit (Units A-D of Fairchild, 1975) it differs in a number of respects. The Kalachalpa Formation

—is more argillaceous, containing 45-50 per cent arenaceous, 35 per cent argillaceous, and 15-20 per cent dolomitic sediments.

—contains a higher proportion of oolitic sediments.

—contains only a minor percentage of chert.

—does not contain any magnesite conglomerates.

—records a wide variety of stromatolites (Plate 18; Fairchild, 1975).

—does not contain silicified dolomite pebble conglomerates or chert-pebble conglomerates. Fairchild (1975) suggests silicification may have occurred late in the diagenetic history.

Plate 16. Intraformational chert pebble-cobble conglomerate in the upper part of the unnamed transition unit, Boorthanna Section.

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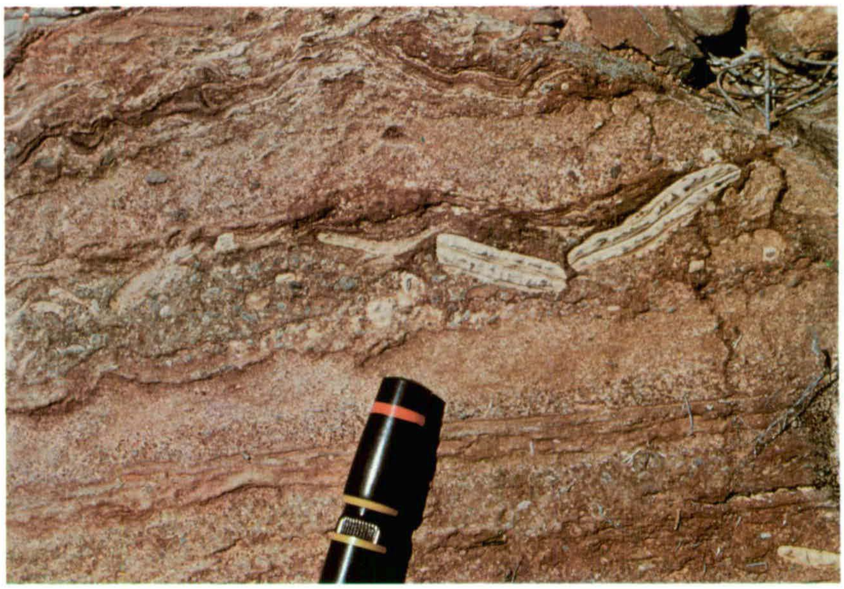

Plate 17. Conglomeratic dolomite typical of much of the upper Burra Group, showing convolute bedding and graded bedding. Most of the clasts are intraformational.

Transparency 14475

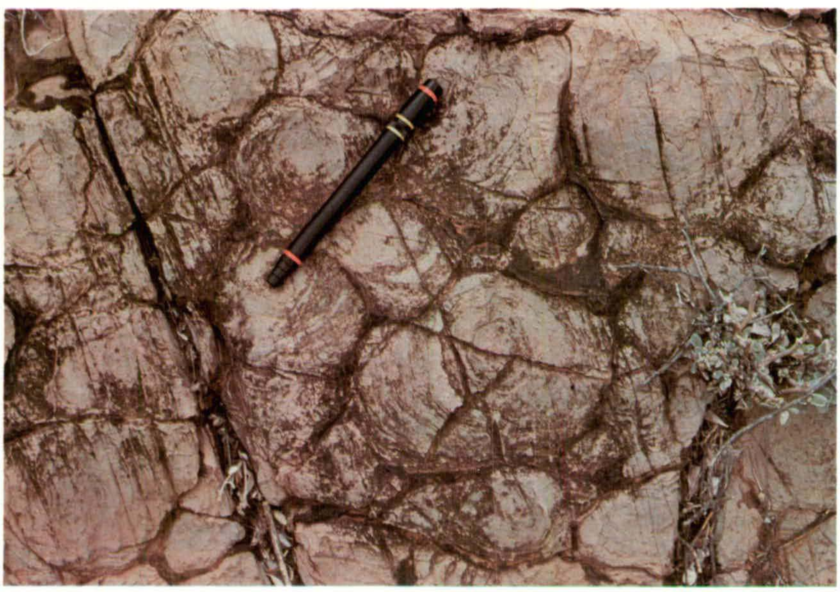

Plate 18. Columnar stromatolites in the Kalachalpa Formation on the southern limb of the Box Creek Syncline.

Transparency 14476

The most useful criteria for identifying the contact between the unnamed transitional unit and the Kalachalpa Formation in the field are:

- —the last occurrence of chert-pebble conglomerates
- —an increase in frequency of green-grey, olive-green and occasionally dark red-brown argillaceous units
- —a decrease in the amount of dolomite from Unit D to Unit E.

The basal part of the Kalachalpa Formation, *Unit E,* consists of 365 m of platy siltstones and fine sandstones, with minor dolomites (sediments average 55 per cent arenaceous, 45 per cent argillaceous, and 5 per cent dolomitic). There is one distinctive biohermal stromatolite horizon.

Dolomite content increases in *Unit F* (sediments average 35 per cent arenaceous, 30 per cent argillaceous, and 35 per cent dolomitic) and slaty red and green siltstones and a few orthoquartzites separated by platy sandstones predominate. Dolomites are often sandy and become increasingly stromatolitic towards the top of the unit. Black chert and oolitic sediments are locally abundant. Total thickness is 380 m.

Unit G is made up of 175 m of mainly arenaceous sediments (sediments average 75 per cent arenaceous and 25 per cent argillaceous). Main lithologies are orthoquartzites and sandstones, with minor slaty and sandy siltstones.

Mud cracks, clay galls, ripple marks, cross-bedding, intraformational conglomerates etc., indicate deposition in a shallow water environment similar to that existing during deposition of Units A-D.

A study of palaeocurrent indicators by Fairchild (1975) indicates sediment transport was generally from west to east and southeast, with the Gawler Craton constituting the principal source area. The predominance of clastic sediments in the Boorthanna section is consistent with proximity of the Boorthanna area (and the Peake and Denison Ranges generally) to active continental sources probably situated to the west and southwest.

Umberatana Group (Sturtian-Marinoan)

In the Peake and Denison Ranges there was a period of mild erosion, prior to the onset of Umberatana Group sedimentation, with early Sturtian glacials deposited disconformably over late Burra Group sediments on the northern limb of the Box Creek Syncline. There is no evidence of significant Sturtian tectonism. The following units comprise the Umberatana Group in the Peake and Denison Ranges—Calthorinna Tillite of significant Sturtian tectonism. The following units comprise the Umberatana Group in the Peake and Denison Ranges—Calthorinna Tillite (new name), unnamed sandstone, Tapley Hill Formation, Thora Dolomite (new name), and an unnamed siltstone belonging to the Willochra Subgroup (Table 10).

Table 10 *Stratigraphy—Umberatana Group*

Formation	Map Symbol
Unnamed siltstone (Willochra Subgroup)	Ꝑh1
Thora Dolomite (Farina Subgroup)	Ꝑfl
Tapley Hill Formation	Ꝑft
Unnamed sandstone	Ꝑu1
Calthorinna Tillite	Ꝑub
Burra Group—Kalachalpa F.	

——— conformable contact
- - - - interfingering contact
—⌄ ⌄— disconformity

The Umberatana Group as defined by Coats (1964b) consists of an early (Sturtian) and a late (Marinoan) glacial phase separated by an interglacial period. However, the early glacial phase is now considered by Coats (1973) to consist of two glacial episodes separated by an unconformity. The Sturtian glacials (Calthorinna Tillite and unnamed sandstone) are thought to be representative of the second episode of the lower glacial phase on the basis of gritty quartzite clasts with fossil red weathering, assumed to have been reworked from the Pandurra Formation. This criterion has been used elsewhere in the Adelaide Geosyncline to distinguish between the first and second episodes of the lower (Sturtian) glaciation (Coats and Forbes, 1977). An unnamed sandstone unit overlies and interfingers with the Calthorinna Tillite and marks the end of the glacial period. There followed a marine transgression with the deposition of marine sequences comprising the Tapley Hill Formation, Thora Dolomite, and an unnamed siltstone.

Umberatana Group sediments are restricted in outcrop to a syncline 1 km northeast of Box Creek R.S. (Box Creek Syncline) and a rafted block in a diapir 6 km south of Mount Anna. Approximately 2 200 m of Sturtian sediments crop out on the southern limb of the Box Creek Syncline.

Calthorinna Tillite

Disconformably overlying the Kalachalpa Formation there is a sequence of glaciomarine and marine sediments herein named the Calthorinna Tillite (Appendix, Unit 15). The type section, 5·5 km northwest of Box Creek R.S., consists of approximately 650 m of diamictites, conglomerates, and interbedded marine sediments (Fig. 11).

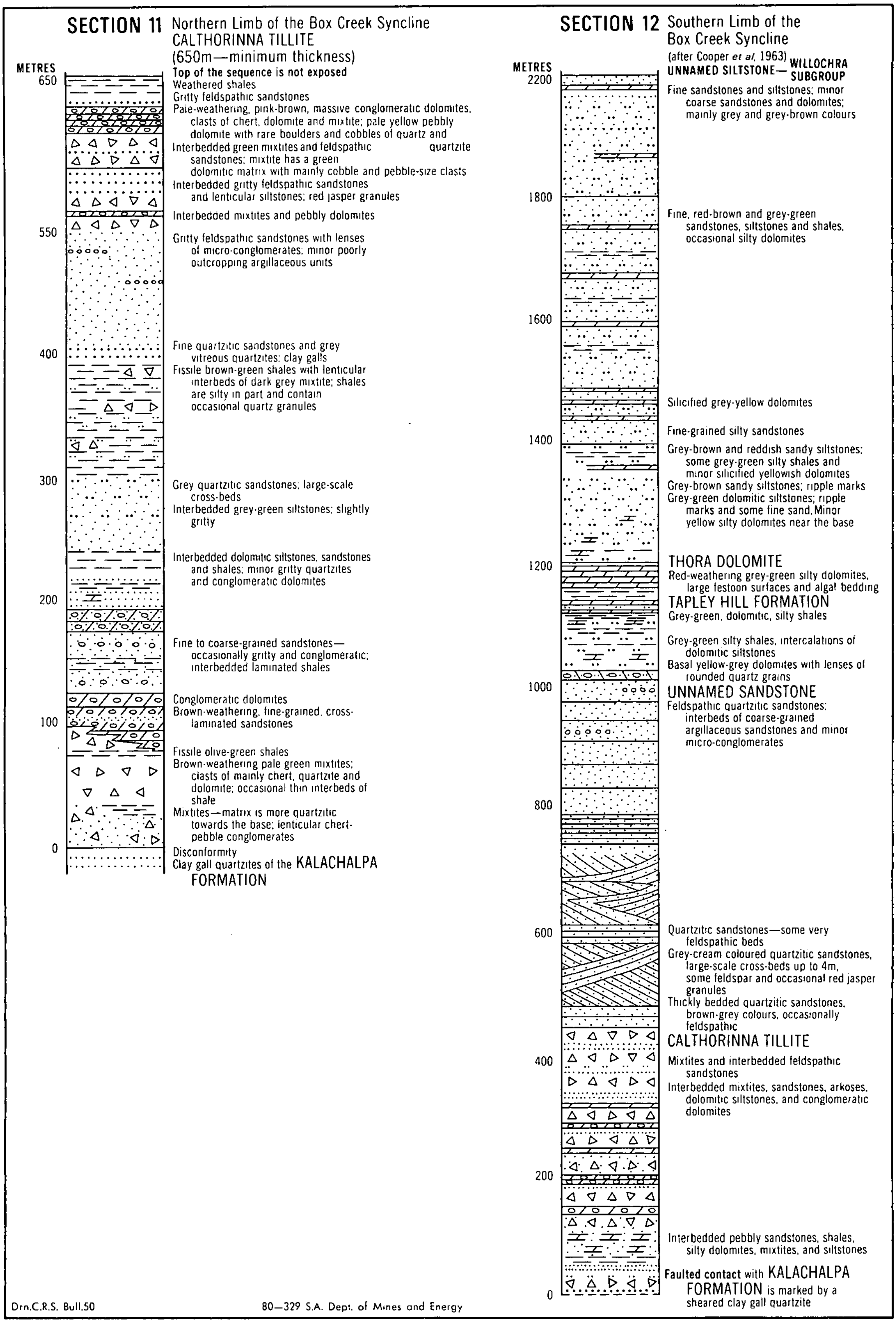

Fig. 11. Stratigraphic type sections, Calthorinna Tillite and Thora Dolomite. Stratigraphic sections unnamed sandstone, Tapley Hill Formation and unnamed siltstone

Dominant lithologies comprising the Calthorinna Tillite are gritty quartzitic sandstones, medium-coarse feldspathic sandstones, thinly bedded pale yellow-grey pebbly dolomites and dolomitic siltstones, finely laminated pale grey-green shales, plus interbedded diamictite and conglomeratic dolomites (Plates 19, 20 and 21). The formation is characterised by rapid lateral and vertical facies changes. The conglomerate and diamictite units are variable in composition, texture and thickness. The conglomerates are massive, buff-coloured dolomites containing pebbles and cobbles of mainly chert and dolomite and minor quartz grit. A few exotic clasts occur in these conglomerates, which are usually less than 10 m thick.

The diamictite units are variable in thickness up to 100 m. The matrix contains varying proportions of quartz, dolomite and clay, with the silt-size fraction predominating. Bedding is occasionally observed. Pebble and granule size clasts predominate, with cobbles less common, and boulders rare.

Clast lithologies have a dominant local component, but there is considerable evidence for more distal southwesterly sources including the Mount Woods Inlier on BILLA KALINA and the Gawler Ranges. Main clast lithologies and suspected sources are as follows:

- —oolitic chert, pale and dark grey laminated chert, silicified chert and quartz-pebble conglomerate, dark grey and pale yellow dolomite, siltstone and stromatolitic dolomite (Burra Group sediments—local source)
- —red porphyritic granite and hornblende granite (Balta Granite-Mount Woods Inlier)
- —red porphyritic rhyolite (Gawler Range Volcanics)
- —rare clasts of vesicular basalt (Cadlareena Volcanics—local source)
- —numerous types of quartzite and quartzitic sandstone with one boulder of gritty quartzite showing fossil red weathering (?Pandurra Formation—R. P. Coats, S.Aust. Dept. Mines and Energy, pers. comm.)
- —dolomitic sandstone and laminated pale yellow dolomite (Duff Creek Beds—local source)
- —microgranodiorite, dark grey schist and phyllite (source unknown).

In addition to the sources listed above, it is probable that a small percentage of dolomite and chert clasts in the diamictites are intraformational. Conglomeratic dolomites contain a high proportion of intraformational clasts (etched pale green and grey dolomite, and cream to dark grey chert) presumably reworked during rapid transgressive-regressive cycles as sea level responded to temperature fluctuations (Plate 19).

On the northern limb of the Box Creek Syncline, a basal green-brown diamictite, about 100 m thick, disconformably overlies the upper part of the Kalachalpa Formation, which consists mainly of quartzites with clay-gall laminations.

The matrix of the diamictite is usually silty, although it becomes more quartzitic towards the base of the unit. A silicified channel-fill conglomerate containing mainly chert pebbles and a cross-bedded sandstone occur near the base in a railway cutting 4·5 km northwest of Anna Creek R.S. A fissile, olive-green shale interfingers with the diamictite.

Overlying this basal unit there are 500 m of gritty and pebbly sandstones, conglomeratic dolomites, dolomitic silty shales, quartzites, and chocolate-green shales with diamictite interbeds. The uppermost unit observed in this northern section is a pink-brown, massive conglomeratic dolomite containing mainly chert and pale dolomite fragments, and clasts of green matrix diamictite presumably reworked from lower in the section (Plate 21). In the upper part of the section, gritty feldspathic sandstones, typical of the overlying unnamed sandstone, interfinger with diamictites and conglomerates of the Calthorinna Tillite.

On the southern limb of the Box Creek Syncline, the Calthorinna Tillite exhibits faulted contacts with Burra Group sediments. A comprehensive section is located 1·5 km northeast of Box Creek R.S. where 450 m of diamictites, conglomerates, and interbedded marine sediments outcrop (Fig. 11). The base of this section is marked by a cross-bedded quartzite containing flat, shale-pebble conglomerate laminations. This unit is sheared and silicified, indicating a tectonic contact with underlying stromatolitic dolomites of the Kalachalpa Formation. An unnamed sandstone normally overlies the Calthorinna Tillite on this southern limb of the syncline. There is no apparent interfingering between these two units as observed on the northern limb of the Box Creek Syncline and in a rafted block in a diapir 6 km south of Mount Anna.

Sediments of the Calthorinna Tillite were deposited under glacial marine and marine conditions. It is unlikely that the diamictites were deposited from a grounded continental ice sheet considering their lenticular nature, and in many cases, carbonate-rich matrix. The presence of intimately associated marine sediments supports this view. Quartz and clay-rich diamictites may have been deposited from a wet-based glacier grounded offshore (Carey and Ahmad, 1960). Other diamictite interbeds, including the more carbonate-rich varieties, may represent reworked till deposited by mudflows and debris flows (turbidity currents) on a foreset slope where the glacier became buoyant. There may be minor contributions of ice-rafted material.

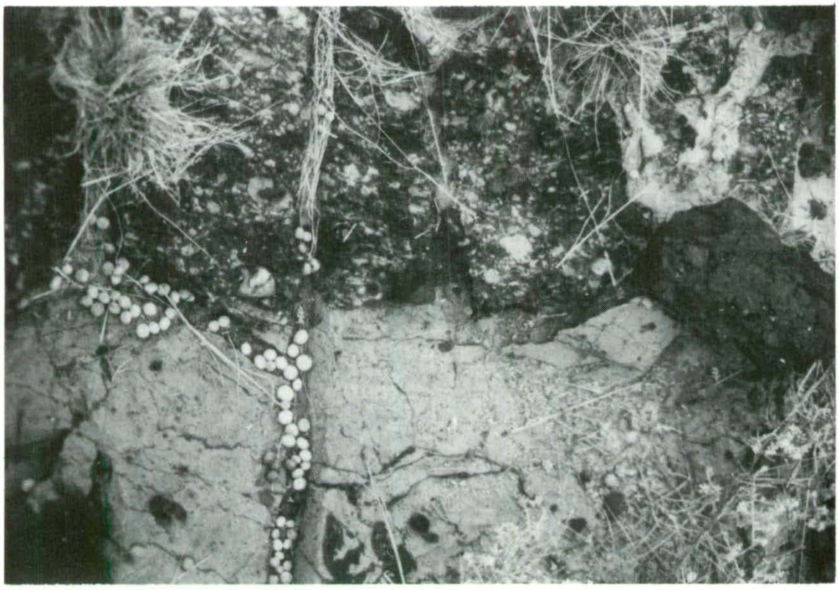

Plate 19. Conglomeratic dolomite overlying a more massive dolomite in the Calthorinna Tillite on the southern limb of the Box Creek Syncline. The conglomerate contains dolomite clasts re-worked from the underlying dolomite.

Negative 30314

Plate 20. Sharp contact between a conglomeratic dolomite (left) and diamictite (right) in the Calthorinna Tillite on the southern limb of the Box Creek Syncline. The diamictite has a quartz-rich matrix.

Transparency 14477

Plate 21. Reworked dark-coloured diamictite clasts set in a pale dolomite, in the upper part of the Calthorinna Tillite type section on the northern limb of the Box Creek Syncline. Chert and dolomite clasts are also common in this unit.

Transparency 14478

Interbedded with the mixtites there are dolomites, shales and arenaceous sediments displaying ripple marks, cross-laminations, and graded bedding. These were deposited under marine conditions as sea level responded to temperature fluctuations. Some of the laminated shales resemble varves, and rare clusters of boulders and cobbles suggest ice rafting during periods of high-sea level. Conglomeratic dolomites (containing almost solely chert and dolomite fragments and in one case clasts of silty green-matrix diamictite) represent intraformational conglomerates formed by cannibalisation of earlier sediments during periodic sea level fluctuations (Plate 19). Evidence of cyclic sedimentation is most convincing on the southern limb of the Box Creek Syncline where conglomeratic dolomite-mixtite-sandstone triplets are repeated through the sequence.

As discussed by other workers (eg. Spencer, 1971; Young, 1976) the intimate association of glacial rocks with dolomitic sediments, which normally are considered indicative of warm climate and low latitude, is incompatible. This anomalous association occurs in many parts of the world and Young (1976) has summarised explanations provided by various writers. Two of the more attractive theories are:

—Williams (1975) suggested that secular variation in obliquity of the earth's ecliptic gives rise to periodic low latitude glaciation and extreme seasonal variation in climate

—differences in the earth's atmosphere in the Precambrian (high partial pressure CO_2), as suggested by Young (1976), permitted sedimentation of rock types normally ascribed to a warm climate regime in relatively high latitudes subject to periodic glaciation.

Unnamed sandstone

Conformably overlying and interfingering with the Calthorinna Tillite there is a sequence of feldspathic sandstones and quartzitic sandstones. The type section, 2 km east-northeast of Box Creek R.S., consists of 530 m of medium to coarse-grained, well-rounded, feldspathic sandstones displaying large-scale cross-bedding up to 4 m in height. Subordinate lithologies include thickly bedded quartzitic sandstones (sometimes feldspathic), with minor micro-conglomerates, and argillaceous sandstones. A detailed description of this section is shown on Figure 11.

On the southern limb of the Box Creek Syncline, this sandstone unit maintains a constant thickness along strike for about 6 km. On the northern limb, a number of gritty feldspathic sandstones are interbedded with diamictites, conglomerates and shales illustrating interfingering between the sandstone unit and the Calthorinna Tillite.

Deposition of this unit marks the end of the glacial period. As temperatures rose, so did sea levels, and meltwater streams probably transported a large amount of sorted glacial material into a deltaic-marine environment, where the thick sandstone unit was deposited. Large-scale cross-beds indicate a high-energy environment of deposition and the abundance of fresh feldspar suggests that cold conditions still prevailed. Interfingering of the sandstone and Calthorinna Tillite, on the northern limb of the Box Creek Syncline, supports this view and indicates flagging glacial activity prior to the major marine transgression associated with the deposition of the Tapley Hill Formation. Approximately 2·5 km northeast of Box Creek R.S., some of the sandstone beds appear to be truncated at a shallow angle by shales of the overlying Tapley Hill Formation. These mesoscopic trends may represent large foreset beds of glacial outwash material, deposited in a deltaic-marine environment, which have been truncated by the overlying transgressive marine sequences. Red granules of porphyry are common throughout the sandstone. They may have been reworked locally from clasts in the tillite, although a more southwesterly origin from the Gawler Range Volcanics is a possibility.

Tapley Hill Formation

The Tapley Hill Formation, which comprises a consistent facies throughout the Adelaide Geosyncline (Coats and Blissett, 1971), is slightly more calcareous and much reduced in thickness in the Peake and Denison Ranges compared with the type sequence in the Mount Painter Province (Coats, 1964b). The formation outcrops only on the southern limb of the Box Creek Syncline, where a total thickness of 150 m is recorded. A description of this section is shown on Figure 11.

The deposition of this formation marks the onset of marine conditions following termination of glacial activity. The base of this transgressive sequence occasionally truncates bedding planes in the underlying sandstone unit. At the base, there is a 10 m-thick, pale yellow dolomite, which thins to the east, containing rounded quartz grains. The overlying 140 m consists of finely laminated, dark grey to black silty shales, and silty dolomites, which weather grey-green. The sequence becomes more dolomitic towards the top.

Thora Dolomite

Conformably overlying the Tapley Hill Formation there is a distinctive dolomite, 30-40 m in thickness, herein named the Thora Dolomite (Appendix, Unit 16). The type section is on the southern limb of the Box Creek Syncline and a description is included on Figure 11.

The unit consists of red-brown to orange-weathering, grey-green to brown dolomite, with minor interbedded siltstones. Bedding is irregular and ranges up to 20 cm in thickness. Algal bedding and large festoon surfaces are common. A few intraformational dolomite fragments suggest minor reworking of the dolomite in a shallow marine environment. The Thora Dolomite is correlated with the Brighton Limestone of Mawson and Sprigg (1950).

Unnamed siltstone

Conformably overlying the Thora Dolomite there are 950 m of mainly green-grey and reddish silty shales and fine sandstones. The thickest section is on the southern limb of the Box Creek Syncline, 5 km east-northeast of Box Creek R.S. (Fig. 11).

The Willochra Subgroup, as defined by Thomson (1969), is characterised by reddish, medium-coarse grained clastics with minor tongues of granule limestone. This unnamed siltstone records the first appearance of red beds in the Umberatana Group in the Peake and Denison Ranges, and hence the unit is assigned to the Willochra Subgroup.

The base of the unit consists of grey-green siltstones, dolomitic siltstones, and fine argillaceous sandstones. The major part of the sequence consists of interbedded, finely laminated, grey-green and red-brown silty shales with ripple marks, fine sandstones, thin (50 cm) grey-yellow dolomites, and silty dolomites. The dolomites are frequently silicified and occasionally gritty, and the sand content generally increases in the upper part of the sequence, with several thin, reddish coarse sandstones occurring towards the top. The red-brown colour and gradual coarsening upwards of the sediments indicates a regressive sequence. The upper boundary of the unit is not exposed.

Bungadillina Monzonite

An igneous suite of monzonites, syenites, diorites, albitites, and minor granites outcropping 12 km northeast of Nilpinna Homestead are collectively defined as the Bungadillina Monzonite. The cluster of intrusive bodies is coincident with a major lineament (interpreted from E.R.T.S. Landsat imagery), which is an extension of the Karari Fault and which trends northeast-southwest, intersecting the ranges where the monzonitic suite outcrops. K-Ar geochronology yields a Delamerian age for intrusion of the Bungadillina Monzonite.

In the two largest intrusive bodies, northeast of Nilpinna Homestead, porphyritic monzonites and syenites are the dominant rock types (Plate 22), while porphyritic diorites are less frequent. Feldspar phenocrysts are ubiquitous and often define a mineral elongation trending 155° to 185° (Plate 23). The feldspars are euhedral and many are 30 mm in length. Potash feldspar phenocrysts are dominantly perthitic orthoclase and microcline, while plagioclase phenocrysts are strongly zoned with sericitic cores and clear rims (Plate 24). Water-clear plagioclase rims mantling potash feldspar crystals have also been recorded (Turner, 1969b). Plagioclase compositions (Turner, 1969b) fall in the range An_{30-40}. Free quartz is often absent, but if present, forms less than 10 per cent of the rock. Augite, hornblende and biotite are locally abundant, and may rarely constitute 25 per cent of the rock. Accessory minerals are magnetite, garnet, sphene, epidote and calcite.

In the diapiric zone, in the headwaters of Edwards and Bulldog Creeks, there are numerous, small, irregularly-shaped intrusives. Albitites are common within this zone and consist of greater than 95 per cent plagioclase. In the accompanying diorites, hornblende and plagioclase are dominant constituents, with many euhedral hornblende crystals, up to 10 mm across, mantled by plagioclase. Microgranites, granodiorites and leucoadamellites are rare, and when present, form small circular stocks.

Porphyritic monzonites and syenites intruding the Fountain Spring Beds and Mount Margaret Quartzite have formed a series of sills up to 6 km long and 20 m thick. Numerous xenoliths of quartz+chlorite schist, metasiltstone, and rounded quartz grains indicate considerable contamination by nearby Adelaidean sediments. Phenocrysts within the sills are hornblende, and zoned potash and plagioclase feldspars, within a fine-grained felsic groundmass. Large plagioclase phenocrysts are mantled by potash feldspar (Steveson, 1976b, 1976c).

Silicate analyses of two specimens, a hornblende syenite and a hornblende monzonite, are tabulated in Table 11. The analyses reveal a significant difference from the average for monzonites and syenites quoted by LeMaitre (1976). These include an enrichment in SiO_2 at the expense of TiO_2, FeO, MnO, CaO, and P_2O_5.

Seven monzonites and syenites, and one dolerite, dated by the K-Ar method on hornblende, biotite, potash feldspar, and total rock yielded ages ranging from 469 to 679 Ma. The Bungadillina Monzonite is interpreted as being a late-stage orogenic intrusive of the Delamerian Orogeny (circa 500 Ma) and is analogous to similar granitic intrusives over a wide area in the southeastern part of the State (Webb, 1976).

Table 11 *Chemical analyses of Bungadillina Monzonite*

	1	2	3	4
SiO_2	65·25	58·58	65·36	62·60
TiO_2	0·24	0·84	0·28	0·78
Al_2O_3	16·26	16·64	17·41	15·65
Fe_2O_3	1·30	3·04	1·52	1·92
FeO	1·00	3·13	1·20	3·08
MnO	0·02	0·13	0·03	0·10
MgO	0·59	1·87	0·60	2·02
CaO	1·85	3·53	2·66	4·17
Na_2O	4·65	5·24	5·22	3·73
K_2O	6·76	4·95	4·55	4·06
P_2O_5	0·09	0·29	0·09	0·25
H_2O+	0·24	0·99	0·39	0·90
H_2O-	0·19	0·23	0·17	0·19
Total	98·44	99·46	99·48	99·45

1. Hornblende syenite (Bungadillina Monzonite) northeast of Nilpinna Homestead. Specimen 6141 RS 18.
2. Average of 102 syenites (Le Maitre, 1976).
3. Hornblende monzonite (Bungadillina Monzonite) north-northeast of Nilpinna Homestead. Specimen 6041 RS 58.
4. Average of 102 monzonites (Le Maitre, 1976).

Fission track dating on apatite in one specimen (hornblende syenite—6141 RS 18) yielded a Permian age of 266 ± 23 Ma (average of six apatite grains—Radke, 1973) and may be interpreted as indicating tectonism during the Permian.

Dykes

In the southern part of the ranges several dolerite and uralitised dolerite dykes intrude dolomites, sandstones and siltstones of the Skillogalee Dolomite and Duff Creek Beds. The dykes have long, linear outcrops, which suggest a late-stage orogenic time of intrusion. The dolerite dykes have undergone varying degrees of alteration. Turner (1969b) reported olivine, augite and plagioclase in a dolerite to the northeast of Nilpinna H.S., while Cooper (1976) recorded abundant quartz, chlorite, dolomite and muscovite in altered dolerites near Davenport Creek.

Near a crocidolite-malachite mine, 2 km west of Tarlton Springs, there are rare and unusual spherulitic dykes up to 0·3 m wide. The spherulites, which are up to 5 mm in diameter, are composed of radiating potassium feldspar crystals in a secondary dolomite and quartz matrix (Steveson, 1976b). Spherulites have been interpreted to be the product of devitrification of glassy lavas with the spherulites being enriched in potassium as the degree of spherulite development increases (Ewart, 1971). The spherulitic potassium feldspar dyke near Tarlton Springs is believed to be a late-stage acidic intrusive related to the Bungadillina Monzonite.

Boorthanna Formation

Scattered outcrops of Permian sediments along the western margins of the Peake and Denison Ranges and Dutton Inlier were first recognised by Reyner (1955). Townsend and Ludbrook (1975) named these sediments the Boorthanna Formation and considered the abundance of striated, faceted, and soled pebbles to indicate a glacial origin.

A number of small outcrops of Permian sediments occur several kilometres northeast of Box Creek R.S. Some of these consist of shallow dipping, gritty dolomites, with occasional boulders. Several areas of closely scattered boulders (many of which are striated and faceted) represent lag deposits (Plate 25). Similar rocks are observed 5 km northwest of Duff Creek R.S. A small pocket of consolidated Permian diamictite outcrops 6·5 km north of Warrina R.S. Striated and faceted clasts indicate a glacial origin: local Adelaidean rocks comprise the dominant clast lithologies and clasts derived from Burra Group and Umberatana Group sediments predominate.

Permian sediments outcropping on the western and southwestern margins of the Dutton Inlier are described in detail by Heath (1965). According to Heath, the Permian section is at least 35 m thick, with the base transgressive onto Adelaidean rocks. The lower part of the sequence consists of gritty dolomites (1 m thick) which grade into diamictites (30 m thick) and bluish laminated shales. The Permian sediments outcrop poorly; erosion has resulted in extensive coarse lag deposits of faceted and striated boulders of a wide variety of rock types. Some of the pebbles and boulders, particularly the red porphyries, may have originated by erosion of the overlying conglomerates and boulder beds in the Algebuckina Sandstone and Cadna-owie Formation (Heath, 1965).

Ludbrook (1961) presented lithological and palaeontological data of available cores and sludges from Boorthanna and Anna Creek Bores drilled in 1911 and 1887 respectively. Boorthanna Bore, 14 km southeast of Nilpinna H.S., penetrated nearly 590 m of Permian sediments without disclosing the base. Anna Creek Bore, 18·5 km south of Nilpinna H.S., records approximately 300 m of Permian sediments lying on Precambrian basement. Grey carbonaceous siltstones, mudstones, and occasional sandstones are the most prominent lithologies. Smith (1973), following a study of gravity data on the southwestern flank of the Margaret Inlier, discussed a prominent negative gravity anomaly in the vicinity of Boorthanna and Anna Creek Bores. Smith noted that this negative gravity anomaly circles the southern margin of the ranges, passing between Jurassic and Precambrian outcrops, and suggested that the feature may record a locally preserved Permian sequence at least 60 m thick.

Plate 22. Feldspar phenocrysts in porphyritic monzonite of the Bungadillina Monzonite.

Transparency 14479

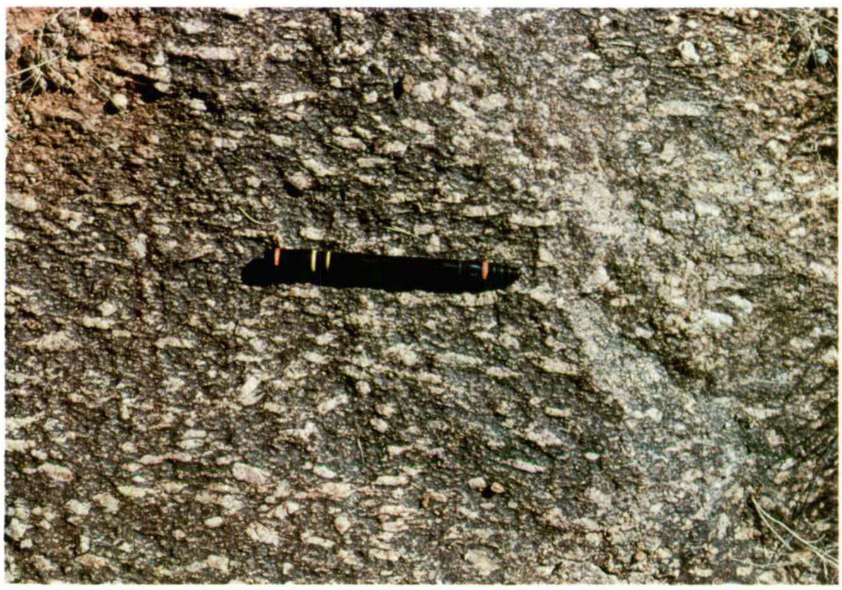

Plate 23. Aligned feldspar phenocrysts in a monzonite of the Bungadillina Monzonite.

Transparency 14480

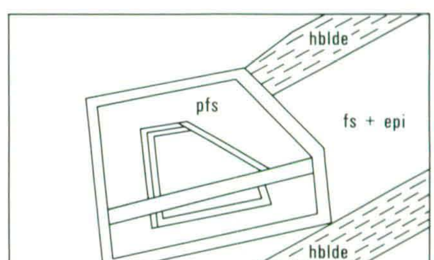

Plate 24. Zoned plagioclase phenocryst in a syenite of the Bungadillina Monzonite.

Transparency 14481

Plate 25. Angular unconformity between dipping dolomites of the Kalachalpa Formation and overlying, flat-lying Permian boulder lag, 6 km north of Box Creek R.S. The boulder lag (Boorthanna Formation) contains boulders of mainly local Adelaidean sediments.

Transparency 14482

Plate 26. Typical view of brecciated and highly contorted lower Adelaidean sediments in a broad diapiric zone above the Cadlareena Volcanics, 9 km northwest of Warrina R.S. The carbonate matrix breccia crops out poorly between the blocks.

Transparency 14483

Plate 27. Diapiric carbonate matrix breccia; deformed blocks of Adelaidean sediments in a carbonate matrix.

Transparency 14484

DIAPIRISM

Diapirism is common throughout the Peake and Denison Ranges and plays an important role in the present geological framework of the region. Diapiric activity is recorded in two general contexts.

- —broad zones of disruption containing disorientated, rafted blocks of varying size and lithology incorporated in a carbonate-matrix breccia
- —narrow zones of carbonate breccia intruded as sills, plugs, and more rarely as dykes. Diapiric breccia is often intruded along faults and anticlinal fold hinges.

A broad diapiric zone, several kilometres wide, occurs above the Cadlareena Volcanics on *WARRINA*. Incorporated within the diapiric breccia are rafted blocks of quartzite, siltstone, dolomite, chert, and occasional volcanics mostly derived from early Adelaidean sequences. Several blocks contain quartzites identified as Baltucoodna Quartzite, and one contains basement quartzites unconformably overlain by Younghusband Conglomerate and Cadlareena Volcanics.

The blocks are up to several kilometres across and bedding is often highly contorted; incompetent shale and dolomite units display extremely plastic deformation. Descriptions of some of the larger blocks are on page 38. The carbonate-matrix breccia, in which these blocks are incorporated, weathers easily and forms a subdued topography. The diapiric zones are often characterised by a conglomeration of resistant, disorientated blocks, possessing characteristic contorted bedding, set in lower lying and poorly outcropping carbonate breccia (Plates 26 and 27).

In the diapiric zone, above the Cadlareena Volcanics on *WARRINA*, the degree of disruption decreases to the southwest.

A transition is seen from:

- —a zone of complete disruption; diapiric breccia is common and blocks of contrasting lithologies are observed in confused orientations
- —to a zone of less intense disruption; minor diapiric breccia and dislocation of thick sequences (Murrana Beds) but with retention of original bedding orientations
- —to a generally undisturbed stratigraphic sequence (Murrana Beds) with only minor tongues and plugs of diapiric breccia.

A second diapiric zone occurs in the headwaters of Levi Creek about 16 km east of Duff Creek R.S. This disrupted zone, 2-3 km wide, coincides with the intersection of two major anticlinal fold hinges. Faulting, intrusion of carbonate breccia, brecciation, and plastic deformation are characteristic. Intrusive albitites, diorites, syenites and monzonites are concentrated in this zone, and photo-interpretation of LANDSAT 1 imagery reveals that the zone lies along a lineament which is an extension of the Karari Fault. This disrupted anticlinal zone reflects movements triggered deep in the crust during the Delamerian Orogeny.

Disruption always occurs immediately above the Cadlareena Volcanics and as seen elsewhere in the Adelaide Geosyncline, the early Adelaidean sequences were the most severely affected (see Thomson and Coats, 1964; Coats, 1973).

Diapiric carbonate is intruded along many faults (e.g. along the fault marking the eastern margin of the ranges near Peake ruins). Breccia is also often intruded parallel to bedding in relatively undisturbed sequences, as is the case in the lower Murrana Beds 4 km east of Warrina R.S. Tongues, dykes, sills and plugs of diapiric breccia commonly intrude deformed and block-faulted sequences, as seen on the eastern side of Margaret Inlier, south of Levi Creek.

Several small pockets of brecciated Adelaidean sediments, set in carbonate breccia, are entirely surrounded by basement rocks to the south of Mount Kingston and also on the southern margin of the Denison Inlier. These small outliers may represent remnants of Adelaidean rocks thrust over basement rocks. The southern margin of the Denison Inlier is bound by brecciated Adelaidean rocks and carbonate breccia, which intrudes basement rocks along faults, indicating high mobility for the diapiric material.

The source of the carbonate breccia is uncertain. In the Mount Painter Province, the Wywyana Formation (actinolitic marble unit) can be traced from normal stratigraphic sequence into diapiric context, and it has been suggested that this formation is the source material for diapirs in the Adelaide Geosyncline (Coats, 1973; Coats and Blissett, 1971). The equivalent of this formation in the Peake and Denison Ranges is the Coominaree Dolomite, which may be the source of the diapiric breccia, but there is no conclusive evidence to support this view. On the contrary, the Coominaree Dolomite has behaved in a competent manner during deformation where it is seen in undisturbed sequence on the margins of the Coominaree Mine Block and War Loan Mine Block. Nowhere was this unit traced from stratigraphic sequence into diapiric context. It is significant that disruption occurs immediately above the Cadlareena Volcanics in a number of localities, suggesting the source of diapiric breccia may have been higher in the sequence. It should be noted however, that disruption has occurred below the volcanics, notably 0.5 km northeast of War Loan Mine and on the western margin of the Rockwater Hill Block, where decollement with basement rocks was associated with intrusion of diapiric carbonate breccia.

Salt casts are locally abundant in early Adelaidean rocks and many blocks in the diapirs are enriched in salt casts relative to adjacent sequences. However, there is no evidence of evaporite minerals in the carbonate breccia, and there are no evaporite beds recorded in early Adelaidean sequences. Consequently, the role that salt has played in diapirism is uncertain. It is possible that sequences closely overlying the volcanics and containing evaporites provided a source for the diapirs. All evidence of such source beds would be obliterated by diapiric processes. The apparent absence of evaporite strata led Dalgarno and Johnson (1968) to the assumption 'that extreme incompetence of the Callanna Beds under stress caused first the decollement with the basement and then piercement folding.'

On COPLEY, evidence from the Burr Diapir suggests that the earliest diapirism occurred prior to deposition of the Umberatana Group (Coats, 1973). Subsequent to a study of the Blinman Diapir Coats (1964a) suggested diapirism may have been initiated by a mild orogeny prior to the Sturtian glaciation and continued through to Cambrian times. There is no evidence of significant Sturtian tectonism in the Peake and Denison Ranges, and there is no indication of diapiric detritus in Adelaidean sediments which makes dating of diapiric activity difficult. The youngest outcropping Adelaidean rocks (Umberatana Group) are intruded by diapiric breccia and it appears that the major phase of diapirism was synchronous with the Delamerian Orogeny (late Cambrian to early Ordovician).

The main evidence supporting this view is:

- —The presence of blocks of Ordovician syenite in a diapir
- —the presence of strongly folded and cleaved blocks in diapirs
- —the proliferation of carbonate breccia intruded along many faults
- —the presence of disrupted anticlinal hinge zones.

It is noteworthy that leucogranite stocks of Ordovician age intrude diapirs in several localities e.g. in the diapiric zone at the head of Levi Creek.

GEOCHRONOLOGY

Introduction

Isotopic age determinations on crystalline rocks (collected by R. P. Coats and B. P. Thomson, S. Aust. Dept. Mines and Energy) from the Peake and Denison Ranges were carried out by Amdel, between 1970 and 1973, as part of Project 11.07.0357—The geochronology of the eastern basement rocks. During this period, 18 K-Ar and 12 Rb-Sr analyses were made and these data are presented in Tables 12 and 13. The analytical methods used were described in Webb (1976) and the results calculated using the revised ^{40}K and ^{87}Rb decay constants recommended by Steiger and Jager (1977). The sample localities are shown on the geological map.

The present work represents the first isotopic investigations in the Peake and Denison Ranges. However, field work and comparison with other basement inliers in the Adelaide geosynclinal zone has indicated that crystalline rocks of pre-Adelaidean and also post-Adelaidean (probably Delamerian) age occur. Also, since post-Adelaidean folding and tectonism had involved the basement rocks, it appeared likely that the isotopic ages of some of these older rocks would have been reset. The basement rocks include the Peake Metamorphics and the Wirriecurrie Granite; the metamorphics being correlated with the Radium Creek Metamorphics of the Mount Painter Inlier. The younger, post-Adelaidean intrusive suite includes syenites and monzonites (Bungadillina Monzonite) and basic dykes.

Middle Proterozoic Intrusives

A suite of gneissic granites from the Wirriecurrie Granite in the Denison Inlier, was investigated using both the K-Ar and Rb-Sr methods. The sampling sites for these rocks are shown on the geological map, from which it can be seen that the granite has apparently been fragmented and two sections displaced about 5 km by a dextral fault. Samples were collected from both the northwestern and southeastern portions of the granite.

Hornblende from two basic sills that intrude the Peake Metamorphics in the northwest of the Denison Inlier were dated by the K-Ar method. These sills appear to be an integral part of the original sequence, and their metamorphism and the emplacement of the Wirriecurrie Granite are considered to have occurred during the first deformation and amphibolite facies metamorphism of the basement rocks.

The two hornblende and nine biotite K-Ar dates are listed in Table 12. The hornblende dates of 1464 and 1518 are significantly older than any of the granite biotite dates and give a minimum age for the first metamorphism. The biotite dates indicate resetting of the K-Ar systems during one or two later metamorphic events and fall into three distinct groups: 960 Ma in the northwestern area, and 1080 Ma and 500-600 Ma in the southeastern area. In the latter region, the older dates are from the granites closest to the fault, while the sample with the younger (500-600 Ma) dates lie less than 1 km to the east.

Rubidium-strontium analyses of 12 total rock samples of the Wirriecurrie Granite (4 from the northwest and 8 from the southeast section) are given in Table 13 and plotted in Figure 12. This correlation diagram shows that there is a broad scatter of the data, which do not define a single straight line. However, several groups of analyses can be selected to produce different straight lines, which in turn lead to a variety of geological interpretations.

Group 1

The samples with $^{87}Rb/^{86}Sr$ ratios greater than 3, with the exception of 6041 RS 60 and 62 define a line with a slope equivalent to an age of 1041±116 Ma and which intersects the $^{87}Sr/^{86}Sr$ axis at 0·7508±0·0089. The samples forming this group come from both the northwestern and southeastern areas and in addition, they are the samples which gave biotite K-Ar dates of approximately 960 and 1070 Ma. Thus, there is a general correlation between the K-Ar mineral dates and the Rb-Sr total rock isochron age for these samples. The initial $^{87}Sr/^{86}Sr$ ratio of >0·75 for this group of samples is abnormally high and could be the result of a rehomogenisation of a much older granite body about 1000 Ma ago.

Table 12 *K-Ar analytical data*

Sample number	Mineral	Ave % K	$^{40}Ar^*/^{40}K$	$\frac{^{40}Ar^*}{^{40}Ar\ total} \times 100$	Age (Ma)
Palaeozoic igneous rocks—Margaret Inlier					
6041 RS 43	Total rock	1·025	0·03634	96·9	537
6041 RS 46	Biotite	6·98	0·04793	98·6	679
6141 RS 15	Hornblende	0·761	0·03315	91·3	496
6141 RS 18	Hornblende	0·638	0·03366	93·2	502
6041 RS 50	Hornblende	0·455	0·03115	90·3	469
6041 RS 58	Hornblende	1·011	0·03291	95·4	493
6041 RS 59	Hornblende	0·954	0·03285	93·4	492
Proterozoic rocks—Denison Inlier					
6041 RS 63	Biotite	7·55	0·07369	99·6	960
6041 RS 64	Biotite	6·97	0·07360	99·6	959
6041 RS 6	Biotite	7·63	0·03493	99·0	519
6041 RS 7	Biotite	7·69	0·03526	99·3	523
6041 RS 9	Biotite	7·27	0·03888	99·5	569
6041 RS 10	Biotite	8·03	0·04231	99·2	612
6041 RS 12	Biotite	7·08	0·08665	99·8	1087
6041 RS 13	Biotite	7·13	0·08445	99·8	1066
6041 RS 14	Biotite	6·77	0·08597	99·8	1080
6041 RS 77	Hornblende	0·510	0·13838	98·4	1518
6041 RS 82	Hornblende	0·235	0·13118	94·3	1464

* Denotes radiogenic ^{40}Ar

Constants used; ^{40}K = 0·01167% atomic

$\lambda_\beta = 4{\cdot}963 \times 10^{-10} y^{-1}$

λ_ϵ total $= 0{\cdot}5811 \times 10^{-10} y^{-1}$

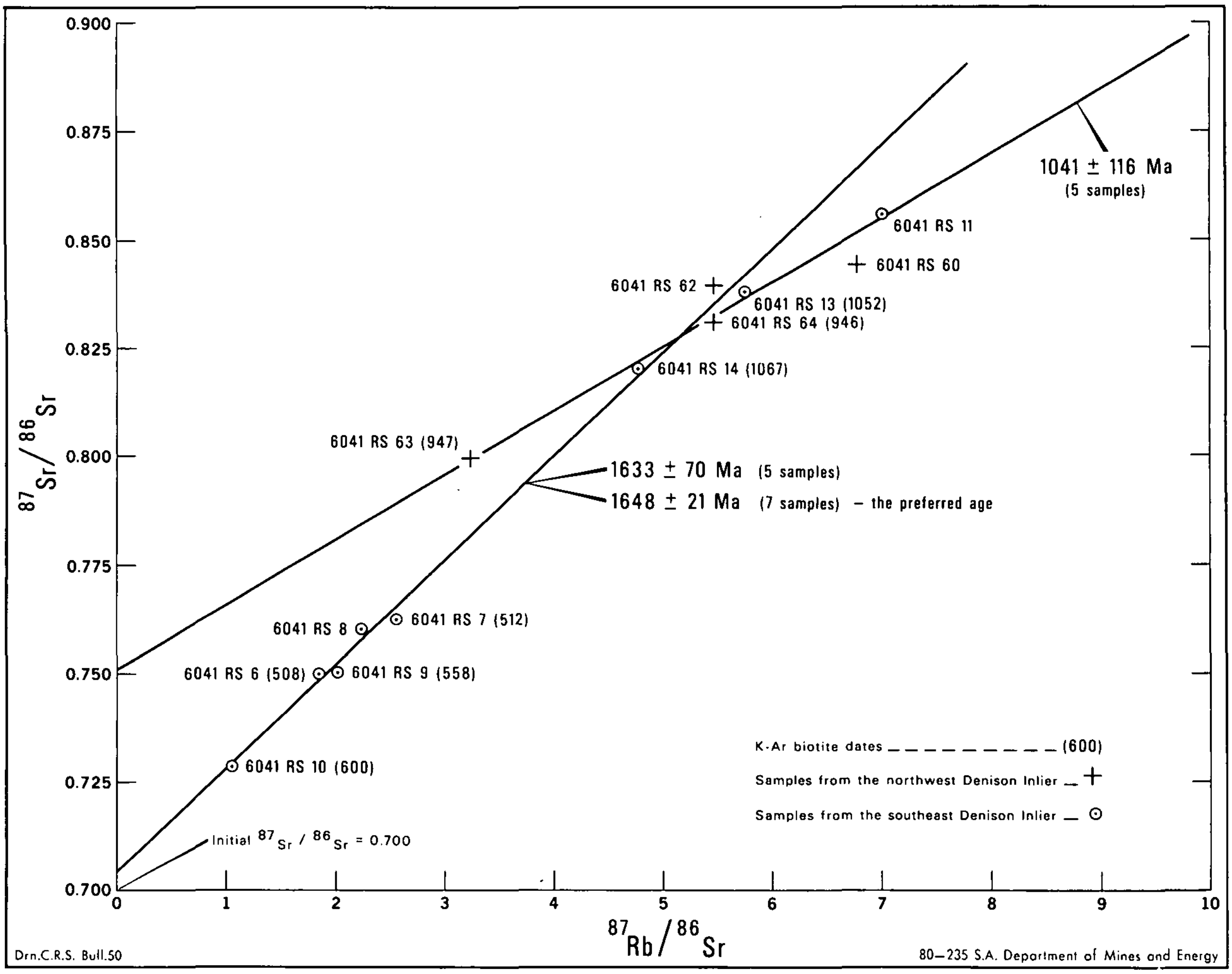

Fig. 12. Rb-Sr isochrons for the Wirriecurrie Granite

Group 2

The more easterly samples in the southeastern area, which produced K-Ar biotite dates between 500 and 600 Ma, also define a straight line when their total rock analyses are plotted on an $^{87}Rb/^{86}Sr$-$^{87}Sr/^{86}Sr$ variation diagram. Although linear regression of the analyses indicates that there is a significant residual variance in excess of experimental error, the isochron is equal to an age of 1633± 70 Ma and indicates an initial ratio of 0·7045±0·0020. The low initial ratio is characteristic of a granite that has formed from a young crustal source, in marked contrast to the 'initial ratio' of the samples in Group 1 above, 1040 Ma ago. The 1633 Ma age is similar to that of other basement complexes exposed within the Adelaide geosynclinal zone, and within the error limits of the isochron, probably indicates the age of the amphibolite grade metamorphism of the Peake Metamorphics.

Group 3

Two samples from the southeastern area which plot on the 1040 Ma isochron (Group 1) lie close to the intersection with the 1633 Ma (Group 2) isochron. If these two analyses are included with the 5 from Group 2, an isochron of 1648±21 Ma is produced and the degree of linear correlation is slightly better than that for Group 2 above. However, if this grouping of the 7 analyses is accepted, the justification for the 1040 Ma isochron of Group 1 is greatly reduced. It should be noted that two samples from the northwestern section 6041 RS 62 and 64 also lie within the error limits of the 1648 Ma isochron.

Table 13 *Rb-Sr analytical data for total rock samples*

Sample number	Rb/Sr	$^{87}Rb/^{86}Sr$	$^{\#87}Sr/^{86}Sr$
N.W. Denison Inlier			
6041 RS 60	2·32	6·788	0·8438
			0·8436
6041 RS 62	1·87	5·469	0·8392
			0·8382
6041 RS 63	1·11	3·234	0·7999
6041 RS 64	1·87	5·465	0·8311
S.E. Denison Inlier			
6041 RS 6	0·642	1·8615	0·7500
6041 RS 7	0·890	2·5837	0·7625
6041 RS 8	0·775	2·2494	0·7604
6041 RS 9	0·695	2·0298	0·7504
6041 RS 10	0·365	1·0561	0·7287
6041 RS 11	2·39	7·001	0·8555
6041 RS 13	1·97	5·761	0·8377
6041 RS 14	1·63	4·759	0·8200

#Ratios normalised to $^{88}Sr/^{86}Sr$ = 8·3752
Constants used: $^{85}Rb/^{87}Rb$ = 2·600
$\lambda^{87}Rb = 1{\cdot}42 \times 10^{-11}y^{-1}$

This third interpretation is considered to be the most plausible explanation of the Rb-Sr data. In spite of the apparent agreement between the Group 1 Rb-Sr analyses and the 960-1080 Ma K-Ar dates, the alignment of the few Rb-Sr analyses on a 1040 Ma line is probably fortuitous. The major metamorphic event in the region occurred about 1600-1650 Ma ago and the subsequent greenschist facies metamorphisms would be unlikely to cause homogenisation of the Sr isotopes in the total rock samples.

Early Palaeozoic Intrusions

Potassium-argon dates were determined on minerals from the Bungadillina Monzonite, which comprises several small intrusions cutting Adelaidean sediments in the Margaret Inlier. Five hornblende dates fall between 500 and 470 Ma, four of the analyses grouping closely between 500 and 490 Ma. These dates indicate a minimum age of early Ordovician for the Bungadillina Monzonite, equivalent to those determined on granitic intrusives in the Encounter Bay-Murray Bridge-Kingston area (Webb, 1976; Milnes *et al*, 1977) and in other basement inliers within the Adelaide Geosyncline. Granitic emplacement associated with the Delamerian Orogeny therefore occurred synchronously in widely separated parts of the Adelaide geosynclinal zone.

One syenite sample gave a biotite age of 680 Ma, significantly older than the hornblende dates from the same and adjacent intrusions. The meaning of this result is not clear, and the analysis should be regarded with caution until further work is done to verify this date.

A slightly earlier phase of basic igneous activity is indicated by a total rock K-Ar age on a dolerite from the Margaret Inlier, 4 km east of 'Nilpinna'. The result of 537 Ma for sample 6041 RS 43 is Middle Cambrian.

Conclusions

The conclusions that can be drawn, with a reasonable degree of confidence, from the Rb-Sr and K-Ar data are as follows:

The Wirriecurrie Granite was emplaced in the Peake Metamorphics during a period of amphibolite grade metamorphism, ~1650 Ma ago. This metamorphic and magmatic activity is analogous with that found in other basement blocks within the Adelaide Geosyncline. The isotopic evidence on the origin of the Wirriecurrie Granite is equivocal and the low initial $^{87}Sr/^{86}Sr$ ratio of 0·7045 is consistent with either a primary magmatic origin or anatexis of young sedimentary and volcanogenic material low in radiogenic ^{87}Sr.

The K-Ar hornblende dates from the diorite sills in the Peake Metamorphics give a minimum age of 1520 Ma for the end of the early metamorphic period; the 50 Ma difference between the two dates suggesting that some subsequent argon loss has occurred on a minor scale in one or both samples.

Potassium-argon biotite dates from both the northwestern and southeastern parts of the Wirriecurrie Granite indicate an episode of argon loss about 1000 Ma ago. The evidence from the Rb-Sr analyses for an event at this time is inconclusive, and the hornblendes from the diorite sills to the northwest of the granite do not show evidence of updating at this time. Thus the event which produced the five dates between 1080 and 960 Ma must have been quite localised, perhaps being related to movements on the fault that displaces the two parts of the Wirriecurrie Granite.

The next recognisable event occurred in the early Palaeozoic with the folding of the Adelaidean sediments and the emplacement of basic dykes and the Bungadillina Monzonite in the Margaret Inlier. The single date on a basic dyke (537 Ma) suggests that this body was intruded significantly earlier (~40 Ma) than the monzonites.

Potassium-argon dates from the southeastern part of the Wirriecurrie Granite fall between 600 and 500 Ma. This scatter indicates variable argon loss from these older rocks during the Delamerian folding, and since other parts of the granite show no response to the 500 Ma event, the cause of the updating must have been very localised. It has been suggested that the intrusions of the Bungadillina Monzonite in the Margaret Inlier were structurally controlled by the intersection of the Karari Fault lineament with the predominantly north-south Adelaidean fold axes. Thus, thermal effects may have been much weaker elsewhere in the region, accounting for the variable degee of argon loss in the Denison Inlier.

TECTONISM

Rocks within the Peake and Denison Ranges display a complex deformational history. At least six periods of tectonism have been recognised ranging in age from Middle Proterozoic to Quaternary.

The first deformation is evidenced by a layer-parallel foliation in units of the Peake Metamorphics. This is expressed by a muscovite, biotite, or chlorite schistosity and gneissosity in the metasediments, and a hornblende-chlorite schistosity in metamorphosed diorites and basalts. The Wirriecurrie Granite has a biotite schistosity, which is parallel to the layer-parallel schistosity of adjacent metamorphics, implying granite intrusion synchronous with the first deformation episode. Rb-Sr geochronology on the granite and K-Ar dating on diorite sills indicate a Middle Proterozoic age (1650 Ma) for the tectonism.

The second tectonic phase is indicated by the updating of geochronological dates on the Wirriecurrie Granite. K-Ar data suggests an orogenic event about 1050 Ma, which probably equates with the Musgravian Orogeny. No faults or folds have been recognised as being of this generation.

Tectonism during the Delamerian Orogeny has resulted in folding, faulting and disruption of Adelaidean sediments and refolding of basement metamorphics. The widespread diapirism was probably coincident with this orogenic phase. Cross-folding with approximately north-south and east-west striking axial planes have formed open basins and tight, disrupted domes in Adelaidean sediments. These are exemplified by the broad elongate basin of Skillogalee Dolomite south of Mount Margaret, and a disrupted, elongate dome just north of Anna Creek R.S. Axial plane crenulations with axial planes striking both 100° and 180° were observed within schists of the Peake Metamorphics and probably equate with the deformations producing the cross-folds in the cover sediments.

Wopfner (1972) concluded that during the Permian there was faulting synchronous with sedimentation, which is also indicated by fission track dating on a syenite sample from the Bungadillina Monzonite which yielded an average age of 266 ± 23 Ma (Radke, 1973).

Tertiary tectonism has caused uplift of huge fault blocks to form the Peake and Denison Ranges. Jurassic and Cretaceous sediments, and Tertiary silcretes are strongly upturned (dips to 60°) adjacent to the ranges. Tectonism on the Mount Margaret Fault has been postulated as being late Miocene (Wopfner, 1972).

The sixth and final phase of tectonism is represented by the renewal of faulting during the Pleistocene along the Mount Margaret Fault, an event indicated by a 150 m vertical displacement of the gypsite surface (Wopfner, 1968). Post-Cretaceous faulting and uplift along the Mount Margaret and Levi Faults has a combined throw in excess of 300 m (Wopfner, 1968).

METAMORPHISM

From this present study three metamorphic episodes are evident:

—amphibolite facies metamorphism of the Peake Metamorphics during the Middle Proterozoic (approx. 1650 Ma)
—?greenschist facies metamorphism during the Musgravian Orogeny (approx. 1050 Ma)
—low greenschist facies metamorphism of Peake Metamorphics and Adelaidean sediments during the Cambro-Ordovician Delamerian Orogeny (approx. 500 Ma).

Within the Peake Metamorphics two zones of different metamorphic grade have been recognised for the Middle Proterozoic metamorphic event. Upper amphibolite facies metamorphism is evident from locally abundant migmatites northwest of the Wirriecurrie Granite. This is further supported by metamorphosed calcareous and pelitic sediments in particular:

—sillimanite gneisses and microcline+hornblende calc-silicates in the Coominaree Mine Block
—plagioclase+clinopyroxene granulites in the War Loan Mine Block
—plagioclase+microcline+epidote+hornblende calc-silicates in the Rockwater Hill Block
—clinopyroxene granulites at Lagoon Hill.

However, the good preservation of volcanic textures, and the mineralogy of rock types to the southwest and southeast of Peake ruins suggest only upper greenschist facies metamorphism in this area. Rock types are metavolcanics, quartz+muscovite schists, quartz+chlorite phyllites, and micaceous metasandstones and quartzites.

Probable tectonism and low greenschist facies metamorphism during the Musgravian Orogeny are recorded by ?Rb-Sr and K-Ar geochronology on the Wirriecurrie Granite. The K-Ar and ?Rb-Sr systems have been updated indicating a thermal event around 1050 Ma.

Metamorphism of basement rocks and Adelaidean sediments during the Delamerian Orogeny reached only low greenschist facies conditions. In general, the Adelaidean sediments exhibit little evidence of being metamorphosed. However, greenschist facies conditions are evident from rock types in the southern portions of the Denison Inlier and near Mount Fox. Sandy dolomites occasionally exhibit porphyroblasts of potash feldspar, muscovite, chlorite and dolomite in a dolomite+quartz+biotite matrix, while metamorphosed shales exhibit lenticular quartz-rich aggregates in a lepidoblastic biotite+chlorite texture (Radke, 1976, 1977). A contact metamorphic aureole surrounds the largest Bungadillina Monzonite intrusive. Rock types in this aureole include spotted, muscovite metasiltstones, biotite+chlorite and biotite+muscovite metasiltstones, biotite metasandstones, and quartz+biotite schists (Cooper, 1976; Steveson, 1976b; Radke, 1977). Veins of quartz, feldspar, muscovite, chlorite and magnetite also occur within the contact aureole. Metamorphism during the Delamerian Orogeny was the last metamorphic episode; the rocks in the Peake and Denison Ranges have existed as a shallow or exposed basement block since the early Palaeozoic.

ECONOMIC GEOLOGY

Historical Mining Activities

Alluvial gold was first discovered near Algebuckina in 1870 and near Peake Creek by the government geologist H. Y. L. Brown (1894). However, only a small amount of alluvial gold was found from numerous shallow pits on the north bank of the Neales River at Algebuckina.

During the late 1890's and early 1900's copper prospecting and mining flourished in the area. At that time, there was a large community at the Peake overland telegraph station with 30 men employed in the mines. A smelter was built to treat copper ore from numerous mines and shafts, and a water bore drilled near the telegraph station to a depth of 32·6 m, supplied 455 000 litres per day to maintain the operation. Copper mining continued until 1920, but since then no mines have been worked. A description of the individual mines is presented below; their locations are shown on the geological map.

Copper Top Mines

Numerous shafts, pits and prospects occur in the vicinity of Peake ruins and near Copper Top Hill. These include Joes Prospect, Enrico Mine, Warrina Copper Mine, Coorunctite Mine, Central Mine, Warden Mine, and Denison Mine, all of which are grouped under the Copper Top Mines because of the paucity of information.

In 1897, the Warrina Copper Mining Syndicate was formed, followed shortly afterwards in 1899 by the Amalgamated Copper Top Proprietary Company. The latter company erected a smelter, drilled a water bore, and employed 30 men. Operations continued until 1904. By April 1903, 242·8 tonnes of ore, averaging 4 per cent copper, were treated (Reyner, 1955). The deepest shaft was 35 m. The copper occurs as malachite, azurite and chalcocite in quartz+hematite veins (Reyner, 1955). The copper-bearing veins are located within basalts of the Tidnamurkuna Volcanics and in the Baltucoodna Quartzite and either strike parallel to the foliation, or are cross-cutting, striking north-northwesterly parallel to the major faults.

Algebuckina Mine

The mine is located 1 km west of Algebuckina railway bridge in a sheared, gossanous zone within amphibolites, pegmatites and biotite-rich schists and gneisses. Two shafts were sunk, each 9 m deep. Little else is known of the early history of this mine. In 1970, Australasian Mining Corporation Limited drilled four diamond-drillholes to test for uranium mineralisation. The best intersection was 290 ppm U_3O_8 between 24·00 and 26·21 m in DDH 1 (Sargeant, 1970).

Mount Kingston prospect

The prospect lies 1·5 km north of Mount Kingston North within high-grade metamorphics of the Peak Metamorphics, and is adjacent to a major north-south striking fault. The copper occurs as malachite and minor chalcocite in quartz veins.

Printa Mine

The Printa Mine is located 2 km north-northwest of Mount Kingston. It was first worked by the Pig Hill Copper Company in 1900. Surface shows were promising, and 2 000 to 3 000 men were to be employed, however only a series of small open cuts, two shafts (9·75 and 3·0 m deep) and an adit were dug. The copper mineralisation occurs within a small gossanous zone adjacent to pegmatites (Peake Metamorphics).

Asbestos mine

A malachite crocidolite mine 2 km west of Tarlton Springs comprises several shallow pits within silty shales, dolomites and sandstones of the Duff Creek Beds. Malachite, and blue, fibrous crocidolite are associated with quartz, biotite and ? goethite in hydrothermal aggregates. One specimen of dump material (6140 RS 15) contained greater than 1 per cent Cu and 1 per cent Mn (Table 14). A spherulitic potassium feldspar dyke outcrops at the mine, and both the dyke and mineralisation are believed to be late-stage hydrothermal products from intrusion of the Bungadillina Monzonite. No early records of mining can be found.

Last Chance Mine

The Last Chance Copper Mine, located 11·5 km south-southeast of Nilpinna Homestead, is on the margin of a large diapiric zone. It was worked from 1915 to 1919 under the name of W. J. and T. M. Briscoe. The main workings consisted of an open cut measuring 18·3 x 6·1 x 8·2 m, with an inclined shaft 11·6 m deep on one side of the open cut (Winton, 1919). The 0·5-0·6 m thick ore band, consisting of malachite, cuprite, chalcocite and chalcopyrite in a quartz+hematite lode, thinned with depth. Total ore shipments, to 1918, were 162 tonnes containing 20-25 per cent copper (Reyner, 1955).

Investigations by Leeson (1972) revealed a small copper anomaly and a low radiometric anomaly in the vicinity of the mine, however there was no evidence of significant mineralisation.

War Loan Mine

In 1916, two mineral claims were taken out by D. Clifford and J. Hillman who established a copper mine 8·5 km southeast of Nilpinna Homestead. An open cut measuring 36·6 x 4·3 m and 4·6 m deep was excavated. About 6·1 m from the northern end of the cut an inclined shaft was sunk to a depth of 23·8 m, with several drives at the 12·2 m level (Winton, 1919). The claim was worked until 1920, and produced a total of 149·5 tonnes of ore. Copper contents ranged between 19 and 37 per cent . Ore minerals were malachite and chalcocite, with traces of pyrite and gold in a ferruginous quartz lode (Reyner, 1955).

The mine is situated within blue-grey shales and siltstones of the War Loan Beds, which tectonically overlie basalts of the Cadlareena Volcanics. Two diamond-drillholes sited by North Broken Hill Limited (War Loan DDH 1 and 2) intersected several thin bands with anomalous copper contents (Forwood, 1968; Western Mining Corporation, 1975).

Coominaree Mine

The Coominaree Mine is located 6·5 km northeast of Nilpinna Homestead within diapiric, Adelaidean sediments. The mine is on the site of a mineral claim taken out by W. Briscoe in 1916. However only one shaft, 10·7 m deep, and several shallow trenches and pits were sunk. Only two tonnes of copper ore are recorded to have been treated. The copper occurs as malachite in a quartz+calcite+hematite vein within disrupted dolomites and shales. The veins are associated with anomalous radioactivity and one specimen assayed 130 ppm U_3O_8 (Iliff *et al.*, 1974).

Geochemistry

As part of the stratigraphic mapping program, some of the main rock units were sampled and analysed to establish regional geochemical background values. A total of 83 specimens were analysed for up to 24 elements (Table 14). The values have been summarised in Table 15, which presents the average elemental abundances for the Bungadillina Monzonite, Cadlareena Volcanics, Wirriecurrie Granite, and all units within the Peake Metamorphics. However a comparison of the results obtained with the average elemental abundances of the respective rock types listed in Turekian and Wedepohl (1961) and Hawkes and Webb (1962), revealed no significantly anomalous values in this regional rock sampling program.

Table 14 *Geochemical analyses of rock samples*

Rock specimen Number	Analyses number	Rock name	Lithological unit	Ag	As	Au	Ba	Bi	Co	Cr	Cu	Li	Mn	Mo	Ni	P	Pb	Rb	Sb	Sn	Sr	Th	U	V	W	Zn	Zr
				Elements																							
6040 RS 14	A3378/63	Dolerite	Cadlareena Volcanics	0·3					50	700	40		400		120		12							600		120	
6040 RS 15	A3379/63	Dolerite	Cadlareena Volcanics	0·2						1 000	10		600		120		15							500		180	
6040 RS 19	A4860/76	Gneiss	Baltucoodna Quartzite	X	X	X	1 500	X	100	250	150		500	10	200	500	3		X	X				300	X	50	
6040 RS 20	A4861/76	Granulite	Baltucoodna Quartzite	X	X	X	X	X	20	80	10		70	X	70	1 000	15		X	1				50	X	X	
6040 RS 21	A4862/76	Gneiss	Baltucoodna Quartzite	X	X	X	1 000	X	80	150	30		1 000	10	100	500	3		X	5				300	X	X	
6041 RS 12	A4879/76	Granitic gneiss	Wirriecurrie Granite			+	*1 200*		**45**	**20**	**30**	**30**		+	**10**		*75*	*250*			*140*	*22*	*12*	**30**		**45**	*340*
6041 RS 43	A52/72	Dolerite	Bungadillina Monzonite (dyke)						80	100	40																
6041 RS 44	A53/72	Monzonite	Bungadillina Monzonite						50		20			X						1					X		
6041 RS 45	A54/72	Monzonite	Bungadillina Monzonite						30		10			X						1					X		
6041 RS 46	A55/72	Monzonite	Bungadillina Monzonite						30		10			X						1					X		
6041 RS 58	A4878/76	Syenite	Bungadillina Monzonite			+	*945*		**45**	20	**10**	**10**		+	**10**		*20*	*120*			*1 050*	*6*	n.d.	**80**		**15**	*135*
6041 RS 62	A4880/76	Granite porphyry	Wirriecurrie Granite			+	*1 250*		**55**	**15**	**95**	**35**		**10**	**10**		*28*	*250*			*250*	*36*	*8*	**35**		**60**	*450*
6041 RS 93	A30/76	Dacite	Cadlareena Volcanics	0·5				X	X	30	80				5		800					n.d.	n.d.	100		X	
6041 RS 95	A31/76	Dolerite	Cadlareena Volcanics	X				X	100	300	10				150		20					n.d.	n.d.	500		30	
6041 RS 96	A32/76	Dolerite	Cadlareena Volcanics	X				X	50	200	20				80		10					n.d.	n.d.	500		X	
6041 RS 97	A33/76	Basaltic pyroclastic	Cadlareena Volcanics	X				X	10	100	5				30		10					n.d.	*8*	300		X	
6041 RS 98	A34/76	Andesite	Cadlareena Volcanics	X				5	X	80	10				30		10					n.d.	*22*	200		X	
6041 RS 99	A35/76	Dolerite	Cadlareena Volcanics	X				X	X	20	1				X		10					n.d.	n.d.	10		50	
6041 RS 100	A36/76	Andesite	Cadlareena Volcanics	X				X	30	100	5				20		10					*4*	*30*	200		X	
6041 RS 101	A37/76	Basalt	Cadlareena Volcanics	X				X	50	80	5				20		10					n.d.	n.d.	200		20	
6041 RS 114	A785/76	Monzonite	Bungadillina Monzonite	X		+			5	20	50			X	10		3			X		*12*	*4*	150		X	
6041 RS 115	A786/76	Syenite	Bungadillina Monzonite	X		+			5	30	150			X	10		5			X		*16*	n.d.	100		X	
6041 RS 116	A787/76	Monzonite	Bungadillina Monzonite	X		+			5	20	10			X	10		3			X		*16*	n.d.	80		X	
6041 RS 124	A4845/76	Calc-silicate	Baltucoodna Quartzite	X	X	X	800	X	80	100	50		500	X	150	500	10		X	1				150	X	50	
6041 RS 125	A4847/76	Gneiss	Unnamed metamorphics Ɛd_1	X	X	X	700	X	30	70	30		300	X	10	1 000	3		X	X				150	X	X	
6041 RS 126	A4848/76	Schist	Unnamed metamorphics Ɛd_1	X	X	X	500	X	100	100	150		800	X	200	300	1		X	X				200	X	50	
6041 RS 127	A788/76	Microgranite	Bungadillina Monzonite	X		+			5	20	5			X	5		5			X		*16*	*6*	80		X	
6041 RS 128	A794/76	Diorite	Bungadillina Monzonite	X		+			X	20	10			X	X		5			X		*14*	n.d.	10		X	
6041 RS 129	A4849/76	Calc-silicate	Baltucoodna Quartzite	X	X	X	X	X	80	100	30		1 000	10	80	300	10		X	X				200	X	150	
6041 RS 130	A4850/76	Schist	Baltucoodna Quartzite	X	X	X	1 000	1	80	150	30		300	X	150	500	3		X	2				200	X	50	
6041 RS 135	A4851/76	Metabasalt	Tidnamurkuna Volcanics	X	X	X	300	X	200	300	100		1 000	X	300	500	3		X	X				500	X	X	
6041 RS 136	A4852/76	Metabasalt	Tidnamurkuna Volcanics	X	X	X	1 000	X	150	300	100		800	X	250	1 000	10		X	X				300	X	100	
6041 RS 137	A4853/76	Amphibolite	Baltucoodna Quartzite	X	X	X	X	X	30	100	200		1 000	X	80	200	10		X	X				100	X	150	
6041 RS 138	A4854/76	Metabasalt	Tidnamurkuna Volcanics	X	X	X	700	X	200	200	300		1 000	X	300	500	3		X	X				300	X	70	
6041 RS 139	A4855/76	Metabasalt	Baltucoodna Quartzite	X	X	X	500	X	150	200	500		1 000	X	300	1 000	5		X	X				500	X	X	
6041 RS 140	A4856/76	Amphibolite	Wirriecurrie Granite (dyke)	X	X	X	500	X	80	150	70		1 000	X	100	1 000	10		X	X				200	X	80	
6041 RS 141	A4857/76	Amphibolite	Baltucoodna Quartzite	X	X	X	700	X	200	150	100		800	X	200	500	5		X	X				500	X	50	
6041 RS 142	A4859/76	Diorite	Wirriecurrie Granite (dyke)	X	X	X	1 500	X	200	300	80		500	X	250	X	3		X	X				300	X	50	
6041 RS 143	A4876/76	Metadolerite	Baltucoodna Quartzite			+	*300*		**55**	**120**	**170**	**15**		+	**100**		*10*	*50*			*95*	n.d.	*14*	**170**		**90**	*165*
6041 RS 144	A4873/76	Rhyolite	Tidnamurkuna Volcanics			+	*960*		**70**	**10**	**45**	**15**		+	**15**		*32*	*210*			*44*	*34*	*8*	+		**25**	*570*
6041 RS 145	A4874/76	Rhyolite	Tidnamurkuna Volcanics			+	*1 000*		**80**	**15**	**15**	**10**		+	**10**		*26*	*260*			*65*	*30*	*12*	**20**		**20**	*240*
6041 RS 146	A4875/76	Dacite	Tidnamurkuna Volcanics			+	*800*		**55**	**90**	**240**	**25**		+	**100**		*10*	*95*			*100*	*8*	n.d.	**210**		**45**	*165*
6041 RS 147	A4863/76	Amphibolite	Unnamed metamorphics Ɛd_1	X	X	X	500	X	30	100	30		100	X	100	5 000	1		X	1					X	X	
6041 RS 148	A4864/76	Amphibolite	Unnamed metamorphics Ɛd_1	X	X	X	300	X	150	800	200		1 000	X	300	1 000	10		X	1					X	80	
6041 RS 149	A4865/76	Amphibolite	Unnamed metamorphics Ɛd_1	X	X	X	700	X	200	100	200		1 000	X	200	500	5		X	1					X	100	
6041 RS 150	A4866/76	Schist	Unnamed schists Ɛd_2	X	X	X	800	X	150	300	100		500	20	300	500	3		X	X				200	X	X	
6041 RS 151	A4867/76	Schist	Unnamed schists Ɛd_2	X	X	X	200	X	100	100	50		500	X	100	1 000	1		X	X				200	X	50	
6041 RS 152	A4868/76	Marble	Tidnamurkuna Volcanics	X	X	X	500	X	300	100	30		500	X	300	1 000	10		X	X					X	50	
6041 RS 153	A4869/76	Amphibolite	Baltucoodna Quartzite	X	X	X	X	2	20	80	80		3 000	10	100	500	5		X	X				300	X	100	
6041 RS 154	A4870/76	Rhyolite	Tidnamurkuna Volcanics	X	X	X	300	X	80	70	200		100	X	80	1 000	10		X	X					X	100	
6041 RS 155	A4871/76	Rhyolite	Tidnamurkuna Volcanics	X	X	X	700	X	5	80	100		100	10	100	X	20		X	2					X	X	
6041 RS 156	A4872/76	Epidosite	Tidnamurkuna Volcanics	X	X	X	1 500	X	5	50	10		500	10	70	500	20		X	1					X	X	
6041 RS 157	A4858/76	Diorite	Wirriecurrie Granite (dyke)	X	X	X	300	X	200	300	200		800	X	300	500	3		X	X				500	X	70	
6041 RS 161	A4881/76	Basalt	Cadlareena Volcanics			+	*390*		**70**	**280**	**25**	**40**		+	**320**		*30*	*110*			*140*	n.d.	n.d.	**300**		**55**	*80*
6041 RS 162	A4882/76	Basalt	Cadlareena Volcanics			+	*90*		**50**	**520**	**20**	**45**		**10**	**160**		*12*	*36*			*150*	n.d.	n.d.	**320**		**45**	*75*
6041 RS 163	A4883/76	Basalt	Cadlareena Volcanics			+	*260*		**55**	**400**	**10**	**55**		+	**120**		*14*	*46*			*100*	n.d.	n.d.	**330**		**40**	*110*
6041 RS 164	A4884/76	Basalt	Cadlareena Volcanics			**0·05**	*70*		**50**	**280**	**30**	**20**		**10**	**190**		*12*	*28*			*260*	n.d.	n.d.	**280**		**35**	*85*
6042 RS 1	A4846/76	Epidosite	Unnamed metamorphics Ɛd_1	X	X	X	500	X	150	100	100		1 000	X	300	500	10		X	X				300	X	50	
6140 RS 4	A555/62	Syenite	Cadlareena Volcanics	0·2		X			30	1 000	15				120		100							700		80	
6140 RS 5	A556/62	Synite	Cadlareena Volcanics	0·2		X			30	400	3				70		30							600		40	
6140 RS 6	A557/62	Syenite	Cadlareena Volcanics	0·1		X			25	500	20				80		20							600		25	
6140 RS 7	A558/62	Syenite	Cadlareena Volcanics	0·2		X			25	300	3				100		15							500		30	
6140 RS 8	A559/62	Syenite	Cadlareena Volcanics	0·2		X			70	400	15				120		20							600		70	
6140 RS 15	A4838/76	Quartz-crossite rock	Duff Creek Beds	X	X	X	X	X	30	50	>10 000		10 000	10	80	200	3		X	2				80	X	300	
6140 RS 16	A4839/76	Biotite-crossite rock	Duff Creek Beds	X	X	X	X	X	10	80	300		2 000	X	70	1 000	1		X	1				80	X	200	
6140 RS 17	A4840/76	Spherulites	Bungadillina Monzonite	X	X	X	1 500	X	30	100	300		300	X	80	>10 000	10		X	1				200	X	X	
6140 RS 23	A4885/76	Basalt	Cadlareena Volcanics			**0·15**	*1 450*		**75**	**190**	**20**	**35**		+	**150**		*10*	*60*			*150*	n.d.	n.d.	**340**		**55**	*110*
6140 RS 24	A4886/76	Tuff	Cadlareena Volcanics			**0·05**	*3 950*		**25**	**80**	**80**	**10**		**15**	**10**		*10*	*280*			*34*	*10*	n.d.	**120**		+	*125*
6140 RS 25	A4887/76	Basalt	Cadlareena Volcanics			**0·05**	*250*		**45**	**130**	**15**	**30**		+	**80**		*12*	*9*			*160*	n.d.	n.d.	**340**		**70**	*105*
6141 RS 10	A56/72	Syenite	Bungadillina Monzonite						5		15			X						1					X		
6141 RS 12	A57/72	Monzonite	Bungadillinia Monzonite						5		10			X						1					X		
6141 RS 18	A4877/76	Syenite	Bungadillina Monzonite			+	*1 400*		**35**	**15**	**10**	+		**15**	**10**		*20*	*200*			*1 200*	*30*	*12*	95		+	*95*
6141 RS 22	A4841/76	Amphibolite	Unnamed metamorphics Ɛd_3	X	X	X	200	X	200	300	100		800	10	300	500	3		X	X				200	X	80	
6141 RS 23	A4842/76	Calc-silicate	Unnamed metamorphics Ɛd_3	X	X	X	700	X	100	100	50		500	X	80	1 000	3		X	1				100	X	X	
6141 RS 24	A4843/76	Hornfels	Unnamed metamorphics Ɛd_3	X	X	X	X	X	30	100	30		200	X	100	1 000	1		X	1				200	X	X	
6141 RS 25	A4844/76	Granulite	Unnamed metamorphics Ɛd_3	X	X	X	200	X	30	150	70		300	X	70	200	3		X	2				150	X	X	
6141 RS 26	A789/76	Diorite	Bundadillina Monzonite	X		+			80	20	50			X	30		3			X		*12*	*4*	300		X	
6141 RS 27	A790/76	Syenite	Bungadillina Monzonite	X		+			5	50	5			X	X		3			X		*30*	*6*	80		X	
6141 RS 28	A791/76	Diorite	Bungadillina Monzonite	X		+			20	20	5			X	20		X			X		*8*	*4*	80		X	
6141 RS 29	A792/76	Albitite	Bungadillina Monzonite	X		+			X	20	50			X	5		X			X		*16*	n.d.	80		X	
6141 RS 30	A793/76	Monzonite	Bungadillina Monzonite	X		+			10	20	20			X	X		5			X		*26*	*6*	80		X	
6141 RS 33	A4836/76	Metasiltstone	Mount Margaret Quartzite	X	X	X	500	X	20	100	100		500	X	100	2 000	3		X	1				100	X	X	
6141 RS 35	A4837/76	Hornfels	Fountain Springs Beds	X	X	X	X	X	30	100	70		300	5	150	3 000	3		X	1				50	X	100	

Emission Spectroscopy		
	X	Not detected
	770	Values in ppm

Atomic Absorption Spectroscopy		
	+	Not detected
	770	Values in ppm

X-Ray Fluorescence		
	n.d.	Not detected
	140	Values in ppm

Table 15 *Mean element abundances*

Rock unit	Elements																								
	Ag	As	Au	Ba	Bi	Co	Cr	Cu	Li	Mn	Mo	Ni	P	Pb	Rb	Sb	Sn	Sr	Th	U	V	W	Zn	Zr	La	Y
Bungadillina Monzonite	x_{10}	-	x_{12}	1170_2	-	23_8	35_{13}	27_{18}	x_2	-	x_{17}	20_{13}	-	6_{12}	160_2	-	x_{15}	1125_2	17_{12}	x_{12}	101_{12}	x_5	x_{12}	115_2	-	-
Cadlareena Volcanics	$0{\cdot}1_{15}$	-	x_{12}	922_7	x_8	40_{21}	322_{22}	29_{22}	33_7	500_2	x_7	95_{22}	-	54_{22}	81_7	-	-	142_7	x_{15}	4_{15}	370_{22}	-	43_{22}	98_7	-	-
Wirriecurrie Granite	-	-	x_2	1225_2	-	50_2	17_2	62_2	33_2	-	x_2	10_2	-	52_2	250_2	-	-	145_2	29_2	10_2	33_2	-	-	395_2	-	-
associated dykes	x_3	x_3	x_3	767_3	x_3	160_3	250_3	117_3	-	767_3	x_3	217_3	400_3	5_3	-	x_3	x_3	-	-	-	333_3	x_3	67_3	-	x_3	50_3
Unnamed metamorphics Ꝑd_3	x_4	x_4	x_4	367_4	x_4	90_4	162_4	62_4	-	450_4	x_4	137_4	675_4	2_4	-	x_4	l_4	-	-	-	162_4	x_4	20_4	-	x_4	115_4
Baltucoodna Quartzite																										
basalts	x_4	x_4	x_5	300_5	x_4	91_5	130_5	210_5	15_1	1450_4	x_5	156_5	550_4	7_5	50_1	x_4	x_4	95_1	x_1	14_1	314_5	x_4	78_5	165_1	x_4	92_4
metasediments	x_6	x_6	x_6	717_6	x_6	73_6	138_6	50_6	-	562_6	x_6	125_6	550_6	7_6	-	x_6	l_6	-	-	-	200_6	x_6	50_6	-	92_6	70_6
Unnamed schists Ꝑd_2	x_2	x_2	x_2	500_2	x_2	125_2	200_2	75_2	-	500_2	10_2	200_2	750_2	2_2	-	x_2	x_2	-	-	-	200_2	x_2	25_2	-	x_2	45_2
Tidnamurkuna Volcanics																										
rhyolites	x_2	x_2	x_4	740_4	x_2	58_4	44_4	90_4	12_2	550_2	x_4	51_4	500_2	22_4	235_2	x_2	l_2	55_2	32_2	10_2	72_4	x_2	36_4	405_2	75_2	50_2
basalts	x_3	x_1	x_4	700_4	x_3	151_4	222_4	185_4	25_1	933_3	x_4	237_4	666_3	6_4	95_1	x_3	x_3	100_1	8_1	x_1	72_4	x_3	54_4	165_1	x_3	73_3
Unnamed metamorphics Ꝑd_1	x_6	x_6	x_6	533_6	x_6	110_6	212_6	118_6	-	700_6	x_6	185_6	1380_6	5_6	-	x_6	x_6	-	-	-	208_6	x_6	46_6	-	50_6	93_6

115_{22} Values in ppm, number of analyses shown as subscripts.
x_6 Analysed but not detected, or average falls below detection limit.
\- Not analysed.

(The averages are derived from values quoted in Table 14)

Analyses of basalts within the Peake Metamorphics generally show higher elemental abundances than other rock types, but the values are typical for basaltic rocks (Hawkes and Webb, 1962). Hydrothermal quartz+hematite+malachite veins are common within the basalts, particularly near the upper contact between the basalts and overlying metasediments. Many of the old mines are located in this environment, e.g. the shafts near Peake ruins and Mount Denison. The basalt-metasediment association thus provides a good target for future base-metal exploration in the Peake and Denison Ranges.

SUMMARY

Detailed mapping of the pre-Mesozoic rocks of the Peake and Denison Ranges has enabled a revised stratigraphic succession to be established. The ? Early Proterozoic Peake Metamorphics have been subdivided into six units while the unconformably overlying Adelaidean sediments have been subdivided into twenty-one units.

The Peake Metamorphics comprise a minimum of 11 500 m of dominantly volcanic rocks and coarse-grained arenaceous sediments. The volcanics are chiefly porphyritic and amygdaloidal basalts with minor flow-banded, porphyritic rhyolites.

Greenschist to amphibolite facies metamorphism and deformation of the Peake Metamorphics, and syntectonic granite intrusion (Wirriecurrie Granite) have been dated at about 1 650 Ma.

The updating of ? Rb-Sr and K-Ar systems, revealed by the geochronological studies, indicate probable mild tectonism and greenschist facies metamorphism about 1050 Ma (Musgravian Orogeny).

Overlying the Peake Metamorphics there are at least 29 000 m of Adelaidean sediments. Deposition occurred in a steadily subsiding, fault-bounded trough, with shallow-water sediments predominating. Clastic sediments were chiefly derived from the Gawler Craton to the west and southwest.

Adelaidean sedimentation is first recorded by the Willouran Callanna Beds. The basal unit of conglomerates and quartzites (Younghusband Conglomerate) is overlain by stromatolitic dolomites (Coominaree Dolomite) and vesicular basalts and altered dolerites of the Cadlareena Volcanics. These three units correlate with a similar basal Adelaidean succession in the Mount Painter Province, and this correlation is further supported by the major and trace element chemistry of the volcanics in the two areas.

Diapirism has caused extensive disruption of the sequence immediately above the Cadlareena Volcanics. From the dismembered succession the following stratigraphic units (of Willouran or Torrensian age) have been established: Rockwater Beds, War Loan Beds, Nilpinna Beds, Duff Creek Beds, and Murrana Beds. Lithologies, and the abundance of mud cracks, ripple marks, clay galls, salt and gypsum casts indicate a paralic environment of deposition.

Sequences of Torrensian age, which can be definitely assigned to the Burra Group, include: unnamed siltstone unit, Fountain Spring Beds, Mount Margaret Quartzite, Skillogalee Dolomite, unnamed transition unit and Kalachalpa Formation. Deposition during the Torrensian occurred in a paralic environment, as indicated by the presence of intraformational dolomitic and magnesitic conglomerates, stromatolitic dolomites and oolitic sediments. Over 10 000 m of Burra Group sediments outcrop in the Peake and Denison Ranges; a thicker and more arenaceous sequence than elsewhere in the Adelaide Geosyncline. For example in the Mount Painter Province (Coats and Blissett, 1971), Willouran and Torrensian sediments total 6 500 m compared with 27 000 m in the Peake and Denison Ranges, thus indicating a prolonged period of more rapid basinal subsidence and sedimentation in the Ranges.

A period of mild erosion preceded deposition of the Sturtian-Marinoan Umberatana Group. The onset of glacial conditions resulted in deposition of the glacio-marine Calthorinna Tillite and interfingering sandstones. The overlying marine siltstones and shales of the Tapley Hill Formation are, in turn, overlain by a regressive sequence of dolomites (Thora Dolomite), and fine sandstones and reddish silty shales (unnamed siltstone of the Willochra Subgroup).

Folding, faulting and diapirism of the Adelaidean succession during the Cambro-Ordovician Delamerian Orogeny was accompanied by low greenschist facies metamorphism and intrusion of quartz-poor porphyritic monzonites, syenites, diorites and albitites (Bungadillina Monzonite).

Outcropping gritty limestones and diamictites of Permian age have been assigned to the Boorthanna Formation. Clast lithologies within the diamictites are dominantly of local Adelaidean rock types, and striated, faceted and soled clasts indicate a glacial origin.

Analyses of 83 specimens (for up to 24 elements) revealed no significant anomalous values in a regional rock sampling program. However the basalt-metasediment association within the Peake Metamorphics provides a good target for future base-metal exploration in the Peake and Denison Ranges.

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APPENDIX

New Stratigraphic Units

Unit 1

Name of Unit Tidnamurkuna Volcanics *State* SA

Proposer R. B. Flint

Definition

Derivation of Name Tidnamurkuna is an Aboriginal name for a waterhole on the Peake Creek just west of the Peake and Denison Ranges, 9·5 km northwest of the ruins of the Peake overland telegraph station. *WARRINA* 1:100 000 sheet area, WARRINA 1:250 000 sheet area, metric reference 6898050, 580000.

Distribution The unit outcrops along a strike length of 10 km to the west of "Peake" ruins and 3 km north of Mount Denison on the WARRINA 1:250 000 sheet area.

Type Section 500 metres of amygdaloidal basalts and porphyritic rhyolites exposed in the creek banks from 6888940, 590850 (bottom) to 6888300, 590750 (top of section). The base is not exposed and the top is identified by a cream-weathering porphyritic rhyolite.

Lithology Flow-banded porphyritic rhyolites, amygdaloidal basalts, minor epidosites and phyllites.

Thickness Minimum thickness of 600 m.

Relationships and Boundary Criteria The base is not exposed. Conformably overlain by unnamed schist unit of the Peake Metamorphics.

Age and Evidence ? Early Proterozoic: the intrusive Wirriecurrie Granite has been radiometrically dated at 1 648±21 Ma providing a minimum age.

Unit 2

Name of Unit Baltucoodna Quartzite *State* SA

Proposer R. B. Flint

Definition

Derivation of Name Baltucoodna is an Aboriginal name for a waterhole on the Peake Creek east of the Peake and Denison Ranges, 4·3 km north of the ruins of the Peake overland telegraph station. *WARRINA* 1:100 000 sheet area, WARRINA 1:250 000 sheet area, metric reference 6898300, 589350.

Distribution Peake and Denison Ranges: the unit is exposed over 25 km^2 south and southeast of "Peake" ruins and within ? Early Proterozoic basement rocks in the southern portion of the ranges.

Type Section 4 500 metres of white quartzites and basalts from 6888100, 592200 (base) through Mount Denison 6886100, 594100 to 6883600, 592150 (top of section).

Lithology In the type section, greyish white quartzites, porphyritic and amygdaloidal basalts, minor quartz+muscovite schists, and grey phyllites. Elsewhere, also sillimanite gneisses, quartz+feldspar+biotite gneisses and schists, plagioclase+hornblende+epidote calc-silicates, calcite marbles.

Thickness Minimum of 4 500 metres.

Relationships and Boundary Criteria In the type section, the base is sheared, elsewhere the unit conformably overlies unnamed schists of the Peake Metamorphics. Top of the unit is not exposed.

Age and Evidence ?Early Proterozoic: the intrusive Wirricurrie Granite has been radiometrically dated at 1648 ± 21 Ma providing a minimum age.

Unit 3

Name of Unit Bungadillina Monzonite *State* SA

Proposer R. B. Flint

Definition

Derivation of Name Bungadillina is an Aboriginal name for a waterhole and creek near Warrina railway siding. *WARRINA* 1:100 000 sheet area, WARRINA 1:250 000 sheet area, metric reference 6874650, 580950.

Distribution Occurs as sills, dykes, stocks, and irregularly shaped intrusives around the headwaters of Bulldog, Levi and Bungadillina Creeks. *BOORTHANNA* and *ANNA CREEK* 1:100 000 sheet areas.

Type Section Porphyritic monzonites, syenites and diorites from 6853100, 602250 to 6852700, 600000. Reference section of porphyritic monzonitic and syenitic sills from 6861400, 597050 to 6858500, 593400.

Lithology Porphyritic monzonites and syenites, porphyritic diorites, porphyritic albitites, minor granites, adamellites and granodiorities.

Age and Evidence Ordovician: radiometrically dated by K-Ar method. Youngest unit intruded is the Torrensian Skillogalee Dolomite.

Unit 4

Name of Unit Younghusband Conglomerate *State* SA

Proposers G. J. Ambrose, R. P. Coats and W. V. Preiss

Definition

Derivation of Name Mount Younghusband occurs within the Denison Inlier in the northern Peake and Denison Ranges, 1·5 km east of Mount Denison, *WARRINA* 1:100 000 sheet area, WARRINA 1:250 000 sheet area, metric reference 6886500, 594500.

Distribution The unit outcrops along a strike length of 7 km, 3·5 km southwest of "Peake" ruins on *WARRINA*. Other small outcrops occur 3 km south of War Loan Mine and 1·2 km north of Coominaree Mine.

Type Section 27 metres of clastic sediments outcropping on the northeastern margin of the Coominaree Mine Block (?Early Proterozoic basement), 1·2 km north of Coominaree Mine. The lower part (12 m thick) contains coarse clastic sediments. The upper 15 m is mainly argillaceous. Metric reference is 6853275, 596475. The unit was first described by Thomson (1966).

Lithology Basal quartzitic breccia, red-brown shales and sandstones at the top.

Thickness Variable up to 27 m (Preiss, 1973a).

Relationships and Boundary Criteria Overlies ?Early Proterozoic basement rocks (Peake (Metamorphics) with angular unconformity. Reworked basement clasts recognised in the basal breccia. The unit is lenticular. In the type section it is conformably overlain by the Coominaree Dolomite while 3·5 km southwest of "Peake" ruins the Younghusband Conglomerate is disconformably overlain by the Cadlareena Volcanics.

Age and Evidence Basal Adelaidean—Callanna Beds (Willouran): an angular unconformity with ?Early Proterozoic basement rocks is observed 3·5 km southwest of "Peake" ruins.

Unit 5

Name of Unit Coominaree Dolomite *State* SA

Proposers G. J. Ambrose, R. P. Coats and W. V. Preiss

Definition

Derivation of Name Coominaree Mine situated 7 km northwest of Nilpinna H.S. in the Peake and Denison Ranges. *WARRINA* 1:100 000 sheet area, WARRINA 1:250 000 sheet area, metric reference is 6852300, 596080.

Distribution Small outcrops occur 3 km south of War Loan Mine and 1·2 km north of Coominaree Mine on the eastern margin of Margaret Inlier in the Peake and Denison Ranges.

Type Section Occurs in an early Adelaidean succession on the northeastern margin of the Coominaree Mine Block (? Early Proterozoic); totals 77 metres in thickness. Metric reference is 6853300, 596600. The unit was first described by Thomson (1966).

Lithology The lower part of the unit consists of interbedded buff and pale brown dolomites with minor sandstones and pebbly layers; low-angle cross-bedding is common. The upper part of the unit consists of non-stromatolitic dolomites, oolitic at the base, and an overlying stromatolitic unit.

Thickness Variable up to 77 m.

Relationships and Boundary Criteria A lenticular unit conformably overlying the Younghusband Conglomerate and in turn, conformably overlain by the Cadlareena Volcanics.

Age and Evidence Early Adelaidean—Callanna Beds (Willouran): contains stromatolite types *Acaciella c.f. australica* and *Gymnosolen c.f. ramsayi* (Preiss, 1973a). In the Mount Painter Province the Wywyana Formation (Lower Callanna Beds—Coats, 1971) is a carbonate-rich unit considered equivalent to the Coominaree Dolomite.

Unit 6

Name of Unit Cadlareena Volcanics *State* SA

Proposers G. J. Ambrose, R. B. Flint, R. P. Coats

Definition

Derivation of Name *Cadlareena* 1:63 360 sheet area, WARRINA 1:250 000 sheet area.

Distribution Peake and Denison Ranges; the unit is exposed over about 6 km^2, 1-2 km east of Douglas Well, metric reference 6822020, 616750. A number of small outcrops occur on the western side of the Ranges about 5-10 km southeast of Nilpinna H.S. and 1·5 km northeast of Coominaree Mine. On *WARRINA,* about 3·5 km southwest of "Peake" ruins, the volcanics outcrop along a total strike length of 7 km.

Type Section The basal part of the type section is on *WARRINA,* where a basal contact with the Younghusband Conglomerate is preserved, metric reference base: 6890725, 587562—top: 6890725, 687625. The upper part of the section occurs about 5 km east of Douglas Well on *ANNA CREEK,* metric reference base: 6823210, 622333 top: 6823210, 622333.

Thickness Maximum true thickness is uncertain. Maximum observed thicknesses are variable up to 750 m measured near Douglas Well.

Lithology Vesicular basalts and altered dolerites; minor andesites, dacites and rhyolites; tuffs, lapilli tuffs; minor lenticular reddish mudstones and quartzites with red shale interbeds near base and top.

Relationships and Boundary Criteria Disconformably overlies the Younghusband Conglomerate in the type section. Conformably overlies Coominaree Dolomite on the western side of the Peake and Denison Ranges. Throughout the ranges diapirism occurs above the volcanics and consequently the upper limit of the unit is unknown.

Age and Evidence Early Adelaidean—Callanna Beds (Willouran): the Cadlareena Volcanics are the uppermost member of the Callanna Beds recognised in the Peake and Denison Ranges. In the Mount Painter Province the Wooltana Volcanics (Coats, 1971) are considered equivalent.

Unit 7

Name of Unit Rockwater Beds *State* SA

Proposer G. J. Ambrose

Definition

Derivation of Name Rockwater Hill situated 18 km southwest of Warrina R.S. on the Central Australia Railway. *UMBUM* 1:100 000 sheet area, WARRINA 1:250 000 sheet area, metric reference 6869200, 595510.

Distribution Several small outcrops occur as blocks in a diapir on the western margin of the Rockwater Hill Block. Two small blocks outcrop on *WARRINA* about 11 km northeast of Warrina R.S. A third block outcrops immediately south of Coominaree Mine on *WARRINA*.

Type Section The unit only outcrops in blocks stratigraphically isolated by faulting and diapirism and hence a type section has not been defined. The best reference section is a block immediately south of Coominaree Mine on *WARRINA*, metric reference 6852050, 595900.

Thickness True maximum thickness is uncertain. The thickest section (200 m) is in the reference section south of Coominaree Mine, metric reference 6852050, 595900.

Lithology Blue-grey and black cherts, black dolomitic limestones, black silty shales, and grey quartzites.

Relationships and Boundary Criteria The unit is stratigraphically isolated by faulting and diapirism; thought to occur stratigraphically above the Cadlareena Volcanics and below the War Loan Beds, although no contacts are observed.

Age and Evidence Early Adelaidean: it is not certain whether the unit is Willouran or Torrensian; the unit probably closely overlies the Willouran Cadlareena Volcanics although no contact is exposed; it correlates with the Dunn's Mine Formation of the Willouran Ranges (Murrell, 1977) which closely overlies Willouran volcanics in that region.

Unit 8

Name of Unit War Loan Beds *State* SA

Proposers G. J. Ambrose and R. P. Coats

Definition

Derivation of Name War Loan Mine situated on the western margin of the Peake and Denison Ranges, 8·5 km southeast of Nilpinna H.S. *BOORTHANNA* 1:100 000 sheet area, WARRINA 1:250 000 sheet area, metric reference 6844733, 597225.

Distribution Outcrops in a synclinal structure adjacent to War Loan Mine.

Type Section 600 m of sediments outcropping in a synclinal structure adjacent to War Loan Mine, metric reference base: 6844675, 597225—top: 6844210, 597233.

Lithology Blue-grey shales and siltstones, dark grey silty dolomites, greenish feldspathic sandstones and arkoses.

Relationships and Boundary Criteria Faulted against the Cadlareena Volcanics in its type section. Probably grades upwards into the Nilpinna Beds, although all contacts are tectonic.

Thickness Maximum true thickness uncertain; the thickest development of sediments, 600 metres, is in the type section.

Age and Evidence Early Adelaidean (Willouran or Torrensian): the unit is believed to grade upwards into the Nilpinna Beds; lithological affinities and spatial relationships between outcrops of these units support this view. The lower contact is uncertain, but probably occurs somewhere above the Rockwater Beds.

Unit 9

Name of Unit Nilpinna Beds *State* SA

Proposers G. J. Ambrose and R. P. Coats

Definition

Derivation of Name Nilpinna H.S. situated on the eastern margin of the Peake and Denison Ranges, 6·5 km east of Duff Creek R.S. on the Central Australia Railway. *WARRINA* 1:100 000 sheet area, WARRINA 1:250 000 sheet area, metric reference 6849133, 5900075.

Distribution Outcrops in a west-facing, fault-bound sequence 1 km north of War Loan Mine, metric reference 6844733, 597225.

Type Section 2 100 metres of sediments in a fault-bound sequence outcropping 6 km southeast of Nilpinna H.S. The base of the section, metric reference 6846125, 596650, is faulted against War Loan Beds and the top of the section, metric reference 6846175, 594650, is faulted against Duff Creek Beds.

Lithology Fine cross-laminated, rippled sandstones, rippled quartzites (salt casts), green-grey silty shales, minor grey silty dolomites and greenish arkoses; mud cracks, ripple marks and salt casts are common.

Thickness Maximum true thickness is uncertain. The thickest development of sediments (2 100 m) is in the type section.

Relationships and Boundary Criteria Believed to grade downwards into the War Loan Beds and upwards into the Duff Creek Beds, although all contacts with these units are sheared. Lithological affinities and spatial distribution of outcrops support this view.

Age and Evidence Early Adelaidean (Willouran or Torrensian): probably intervenes between the War Loan Beds and Duff Creek Beds.

Unit 10

Name of Unit Duff Creek Beds *State* SA

Proposer G. J. Ambrose (after Thomson and Coats, 1964)

Definition

Derivation of Name Duff Creek R.S. on the Central Australia Railway. *WARRINA* 1:100 000 sheet area, WARRINA 1:250 000 sheet area, metric reference 68498500, 583730.

Distribution Outcrops in several thick sequences on the eastern margin of the Peake and Denison Ranges, east and south of Nilpinna H.S., and in faulted sequences 7 km southeast of "Peake" ruins, and immediately east of Mount Kingston. Other faulted blocks containing Duff Creek Beds occur west of Tarlton Springs, 5·5 km northwest of Douglas Well, 4 km west of Mount Denison, and one kilometre south of Mount Dutton.

Type Section The type section is defined by two separate sections totalling 5 500 m in thickness. The upper part of the type section (3 700 m) occurs east of Nilpinna H.S. and is defined by metric reference base: 6847600, 595050—top: 6849025, 5911660. The lower 1 800 m of the type sequence outcrops 9 km to the south and is defined by metric reference base: 6838350, 593700—top: 6841090, 592960.

Lithology Laminated olive-green silty shales and thin arkose interbeds, flaggy buff-weathering pale grey and yellow dolomites, minor dark grey dolomites and carbonaceous shales, flaggy dolomitic siltstones, laminated pyritic fine sandstones, minor quartzitic sandstones; mud cracks, ripple marks, clay galls and cross-bedding are common; horizons with abundant salt casts and gypsum casts; algal laminations.

Thickness Maximum true thickness is uncertain. Thickest development of sediments (5 500 m) is in the type section.

Relationships and Boundary Criteria Exhibits faulted contacts with underlying and overlying sequences. Believed to grade downwards into the Nilpinna Beds and upwards into the Murrana Beds, although all contacts with these units are sheared. Lithological affinities and spatial distribution of outcrops support this view.

Age and Evidence Early Adelaidean (Willouran or Torrensian): probably intervenes between the Nilpinna Beds and Murrana Beds. N. B. Reyner (1955) defined the Duff Creek Formation to include all Willouran rocks in the Peake and Denison Ranges.

Unit 11

Name of Unit Murrana Beds *State* SA

Proposer G. J. Ambrose

Definition

Derivation of Name Murra Murrana bore situated on the southern margin of the Denison Inlier in the Peake and Denison Ranges, 5 km northeast of Peake H.S. *WARRINA* 1:100 000 sheet area, WARRINA 1:250 000 sheet area, metric reference 6878480, 593250.

Distribution Outcrops in a basinal syncline 4 km northwest of Warrina R.S.; constitutes most of Mount Dutton Inlier; outcrops in a faulted sequence 1 km east of Nilpinna H.S.

Type Section Comprises 2 900 m of sediments outcropping on the eastern limb of a basinal syncline 4 km northwest of Warrina R.S. Metric reference of the base of the section is 6885100, 587650, of the top 6885680, 581290. Contacts at the base and top of the section are faulted.

Lithology Laminated gritty quartzitic sandstones, grey-green silty shale interbeds; arkoses, pebbly dolomites, purple and grey silty shales near the top; ripple marks, mud cracks, cross-laminations, flute casts, and salt casts.

Thickness Maximum true thickness is uncertain. Thickest development of sediments (2 900 m) is in the type section.

Relationships and Boundary Criteria Nature of overlying sequences is uncertain. The unit is often faulted at the base against Duff Creek Beds. Lithological affinities with the Duff Creek Beds suggest a gradational contact between the two units although this has not been observed intact in the field.

Age and Evidence Early Adelaidean (Willouran or Torrensian): the unit probably grades down into the Duff Creek Beds.

Unit 12

Name of Unit Fountain Spring Beds *State* SA

Proposer G. J. Ambrose

Definition

Derivation of Name Fountain Spring on the plains abutting the eastern margin of the Peake and Denison Ranges, 43 km east of Edwards Creek R.S. on the Central Australia Railway. *UMBUM* 1:100 000 sheet area, WARRINA 1:250 000 sheet area, metric reference 6863290, 625690.

Distribution Outcrops solely on the middle-eastern and northwestern margins of the Margaret Inlier in the Peake and Denison Ranges.

Type Section 1 100 metres of sediments occur in the type section 3 km north of Mount Margaret, metric reference base: 6853033, 603590—top: 6852020, 603590.

Lithology Laminated grey dolomitic siltstones and interbedded thick grey quartzites with clay gall laminations, grey-green silty shales (salt casts), minor grey silty dolomites, and a few quartzites near the base.

Thickness Maximum true thickness is uncertain. Thickest development of sediments (1 100 m) is in the type section.

Relationships and Boundary Criteria Grades upwards into the Mount Margaret Quartzite, the contact being marked by an increase in orthoquartzites. The lower contact is tectonic, although the unit probably grades downwards into an unnamed siltstone with which it has many lithological affinities.

Age and Evidence Adelaidean—Burra Group (Torrensian); considered equivalent to the River Wakefield Subgroup.

Unit 13

Name of Unit Mount Margaret Quartzite *State* SA

Proposer G. J. Ambrose (after Reyner, 1955; Thomson and Coats, 1964).

Definition

Derivation of Name Mount Margaret, on the eastern margin of the Margaret Inlier in the Peake and Denison Ranges, 15·5 km east of Nilpinna H.S. *UMBUM* 1:100 000 sheet area, WARRINA 1:250 000 sheet area, metric reference 6848490, 605010.

Distribution The formation is restricted to the southern part of the Peake and Denison Ranges (i.e. the Margaret Inlier) and outcrops at Mount Margaret and also constitutes the Mount Margaret Plateau.

Type Section Outcrops 5·5 km north-northwest of Mount Fox. From the base of the section (metric reference 6853810, 598120) to the top (metric reference 6850175, 600675) measures 2 500 m.

Lithology White orthoquartzites, slaty quartzitic sandstones, dark grey sandy siltstones, green-grey silty shales, minor dolomitic siltstones near the base; thick orthoquartzites at the top; clay galls, ripple marks and cross-bedding.

Thickness Maximum total thickness of the formation is 2 500 m in the type section.

Relationships and Boundary Criteria The lower contact with the Fountain Spring Beds is gradational. A high silt-shale: quartzite ratio marks the transition down into the Fountain Spring Beds. The Mount Margaret Quartzite is conformably ovelain by a sandy facies of the Skillogalee Dolomite.

Age and Evidence Adelaidean—Burra Group (Torrensian).

Synonyms Mount Margaret Quartzites (Reyner, 1955); Mount Margaret Formation (Thomson and Coats, 1964); Mount Margaret Quartzite (Thomson *in* Parkin, 1969).

Unit 14

Name of Unit Kalachalpa Formation *State* SA

Proposer G. Ambrose

Definition

Derivation of Name Kalachalpa is the aboriginal synonym for Anna Creek, which is a creek on the southern margin of the Peake and Denison Ranges. Anna Creek also gives its name to a cattle station encompassing most of the Ranges and a railway siding on the Central Australia Railway. *BOORTHANNA* 1:100 000 sheet area, WARRINA 1:250 000 sheet area.

Distribution Crops out in a southwesterly facing sequence, 6 km north of Box Creek R.S. on the Central Australia Railway. A faulted sequence of the formation outcrops 1 km northeast of Box Creek R.S. Smaller outcrops occur 8 km northwest and 11 km north of Anna Creek H.S.

Type Section The type section occurs in an area first described in detail by Fairchild (1975). The type section outcrops 6 km north of Box Creek R.S., metric reference base: 6826575, 595450—top: 6824900, 594275; thickness is 900 metres.

Lithology Grey-green and brown siltstones and shales, gritty sandstones and quartzites, conglomeratic dolomites, stromatolitic dolomites, oolitic sediments, black cherts; quartzites and shales at the top; abundant sedimentary features throughout the sequence include ripple marks, cross-bedding, graded bedding, clay galls, and mud cracks.

Thickness Maximum total thickness of the formation is 900 m in the type section.

Relationships and Boundary Criteria Grades downwards into an unnamed transitional unit which in turn overlies the Skillogalee Dolomite. The formation is disconformably overlain by Calthorinna Tillite.

Age and Evidence Adelaidean—uppermost Burra Group (Torrensian); probably correlates with the Myrtle Springs Formation (Coats, 1973).

Unit 15

Name of Unit Calthorinna Tillite *State* SA

Proposers G. Ambrose and R. P. Coats

Definition

Derivation of Name Calthorinna Creek, which is a tributary of Anna Creek and joins the main stream 1 km south of Anna Creek R.S. on the Central Australia Railway. *BOORTHANNA* 1:100 000 sheet area, WARRINA 1:250 000 sheet area, metric reference 6812550, 607475.

Distribution The unit is restricted in outcrop to a syncline 1 km northeast of Box Creek R.S. (Box Creek Syncline) in the southern part of the Peake and Denison Ranges (Margaret Inlier). A smaller outcrop occurs as a rafted block in a diapir 6 km south of Mount Anna.

Type Section 650 m of sediments outcropping on the northern limb of the Box Creek Syncline, 5·5 km northwest of Box Creek R.S. The top of the unit is not exposed. Metric reference base: 6825850, 591950—top: 6824710, 591550.

Lithology Diamictites, conglomeratic dolomites, laminated green shales, gritty sandstones, arkoses and quartzites; cross-bedding, ripple marks and graded bedding are common. The unit was first described by Reyner (1955).

Thickness Maximum thickness of the unit observed (650 m) is in the type section. True maximum thickness of the unit is uncertain since the top of the unit is not exposed in the type section.

Relationships and Boundary Criteria The unit is underlain disconformably by upper Burra Group sediments (Kalachalpa Formation). It is overlain by and interfingers with an unnamed sandstone.

Age and Evidence Adelaidean—Umberatana Group (Sturtian). Believed to represent the second of the two Sturtian glaciations; main evidence is the presence of gritty quartzite clasts assumed to have been reworked from the Pandurra Formation (Coats and Forbes, 1977).

Unit 16

Name of Unit Thora Dolomite *State* SA

Proposers G. Ambrose and R. P. Coats

Definition

Derivation of Name Thora Soakage, 2 km northeast of Peake H.S. in the Peake and Denison Ranges. *WARRINA* 1:100 000 sheet area, WARRINA 1:250 000 sheet area, metric reference 6877620, 589800.

Distribution Sole outcrop is on the southern limb of a syncline (Box Creek Syncline) 5 km northeast of Box Creek R.S. on the Central Australia Railway, *BOORTHANNA* 1:100 000 sheet area.

Type Section 30-40 m of sediments in the southern limb of the Box Creek Syncline 5 km northeast of Box Creek R.S., metric reference 6820525, 601350; section occurs where a tributary of Wilyalallina Creek cuts through the units.

Lithology Grey-green and brown dolomites, minor siltstones; weathers a light brown buff colour; large festoon surfaces and algal bedding.

Thickness Range 30-40 m.

Relationships and Boundary Criteria Conformably overlies the Tapley Hill Formation (Coats, 1971); gradational upper contact with an unnamed siltstone of the Willochra Subgroup.

Age and Evidence Adelaidean Umberatana Group (Sturtian).

Unit 17

Name of Unit Wirriecurrie Granite *State* SA

Proposer R. B. Flint

Definition

Derivation of Name Wirriecurrie is the aboriginal word for Peake Creek, which cuts the ranges north of the ruins of the Peake overland telegraph station. *WARRINA* 1:100 000 sheet area, WARRINA 1:250 000 sheet area.

Distribution The granite outcrops in an area of 15 km^2 to the west and northwest of Peake ruins and 4 kms north of Mount Denison on the WARRINA 1:250 000 sheet area.

Type Area 3 km northwest of "Peake" ruins, area bounded by metric references 6896600, 6894700 and 585800, 587800.

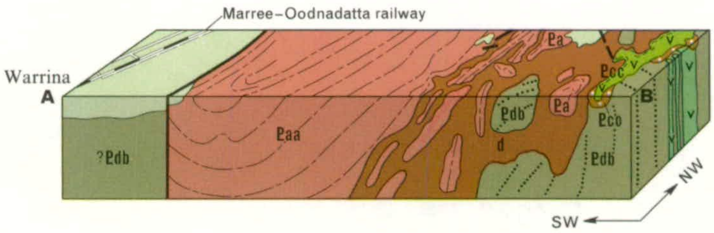
Lithology Coarse-grained porphyritic granites, augen granites, adamellites, granodiorites, minor aplitic dykes.

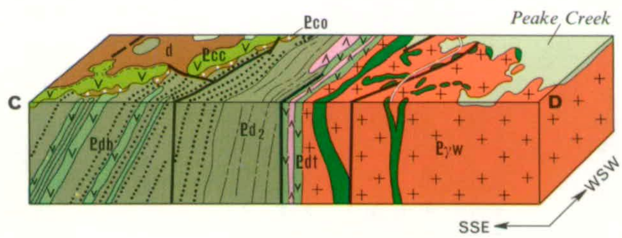
Age and Evidence Middle Proterozoic, radiometrically dated by K-Ar method on biotite yielding an age of 1050 Ma and by Rb-Sr method on total rock giving an age of 1648 ± 21 Ma. Intrudes the Tidnamurkuna Volcanics and unnamed metamorphics north of Peake Creek.

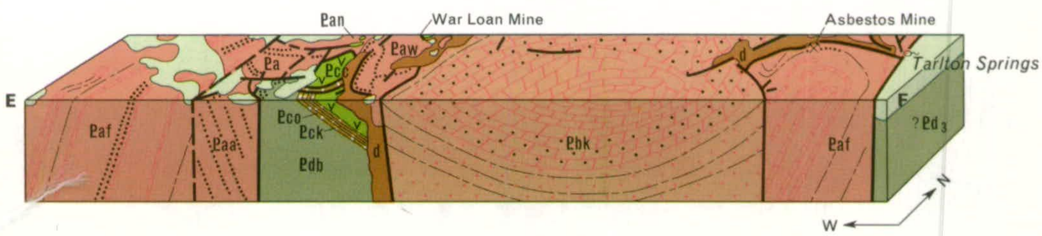
PEAKE AND DENISON RANGES

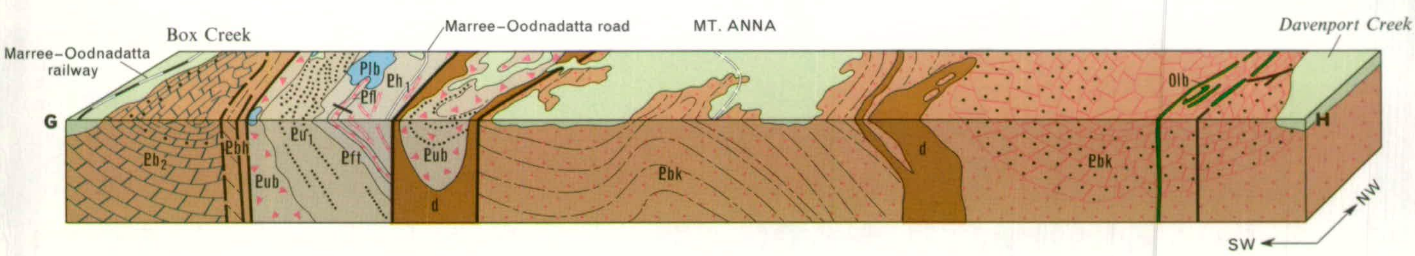
GEOLOGICAL BLOCK DIAGRAMS

GEOLOGICAL SURVEY OF SOUTH AUSTRALIA
DEPARTMENT OF MINES AND ENERGY









For section locations and reference, consult the Geological Map.

NATURAL SCALE 1:150 000

KILOMETRES 5 0 5 10 15 KILOMETRES

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D. J. WOOLMAN, GOVERNMENT PRINTER
SOUTH AUSTRALIA

GEOLOGICAL MAP

PEAKE AND DENISON RANGES

SCALE 1:150 000

KILOMETRES 5 0 5 10 15 20 KILOMETRES

PRINTED IN AUSTRALIA
D. J. WOOLMAN, GOVERNMENT PRINTER
SOUTH AUSTRALIA

Grey numbered lines indicate the 10,000 metre Australian Map Grid.

Geological mapping and compilation by
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with contributions by R. P. Coats, B.Sc. and W. V. Preiss, Ph.D.

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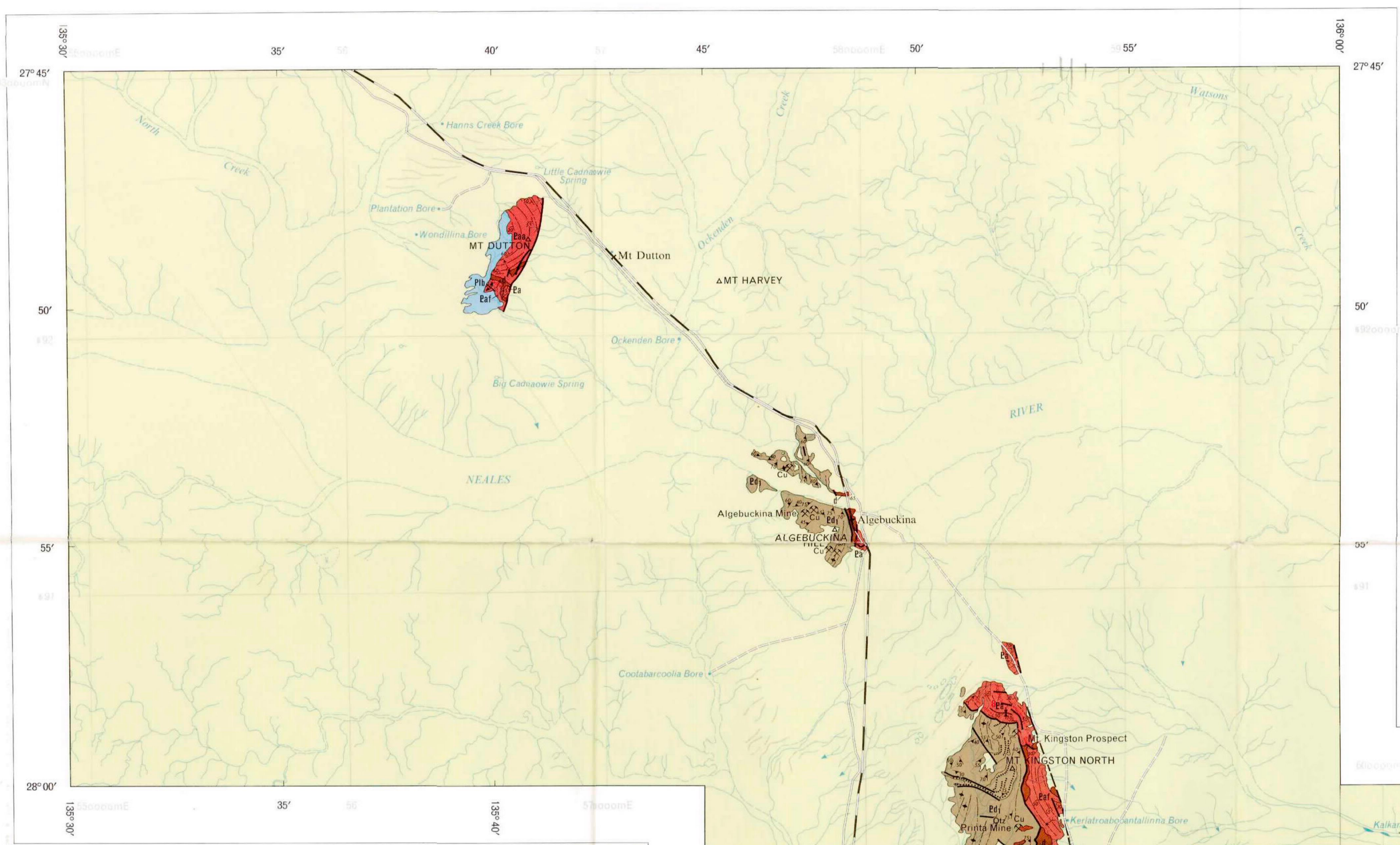
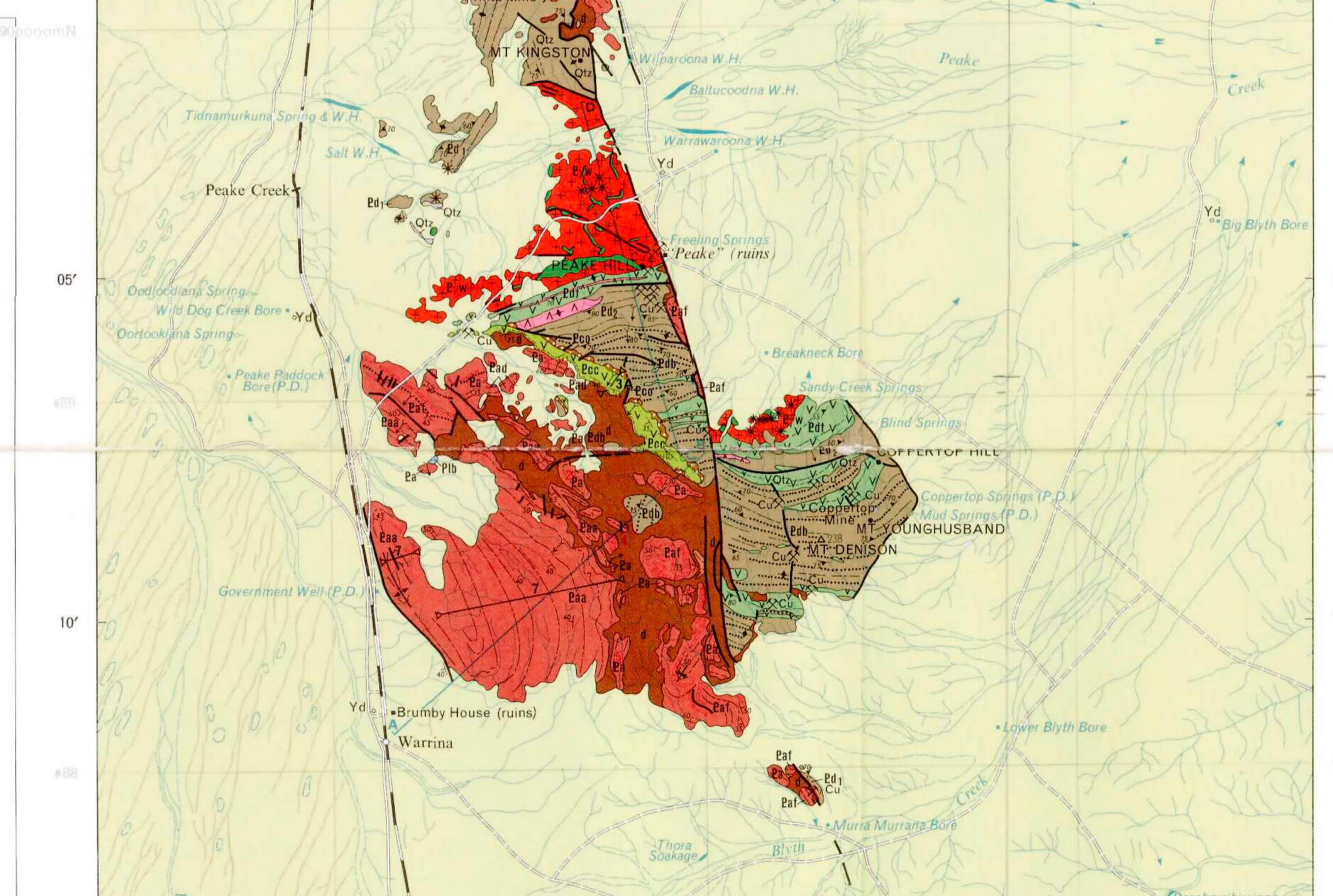
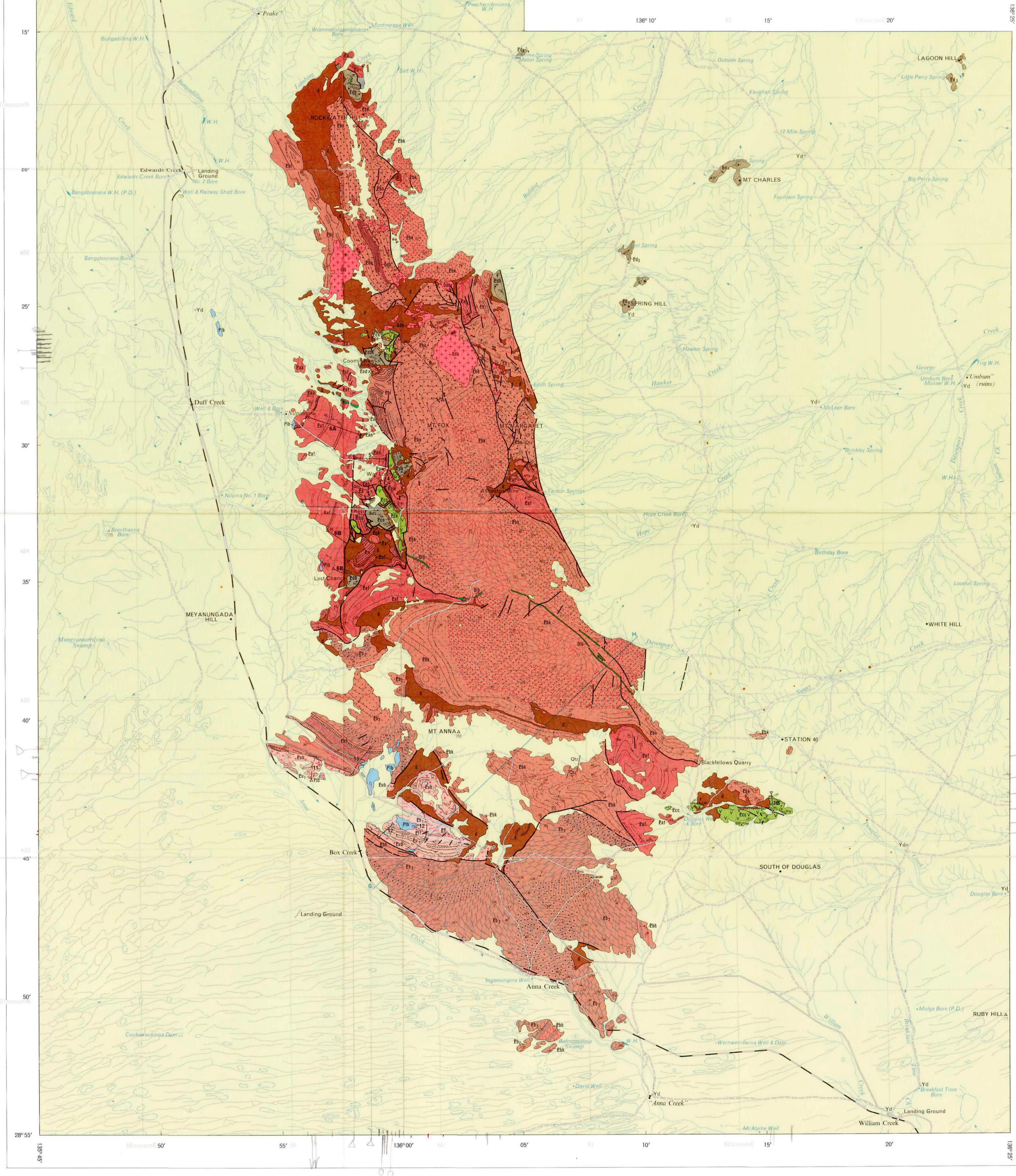
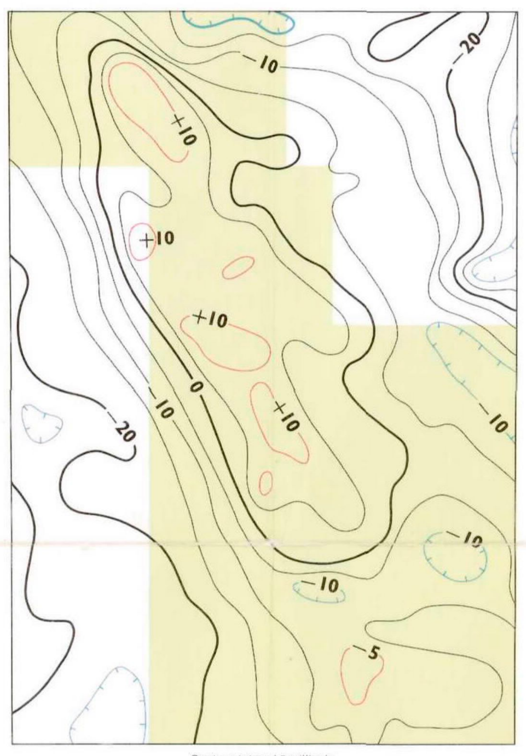




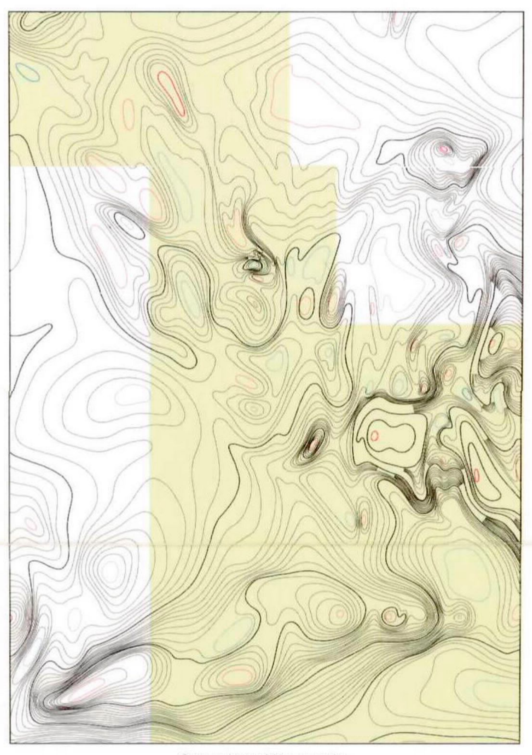


BOUGUER GRAVITY ANOMALY MAP



Contour interval 5 milligals.

TOTAL MAGNETIC INTENSITY CONTOUR MAP



Contour interval 50 nano teslas.

SCALE

KILOMETRES 10 0 10 20 30 40 50 KILOMETRES

GEOLOGICAL SURVEY OF SOUTH AUSTRALIA
DEPARTMENT OF MINES AND ENERGY

REFERENCE

MESOZOIC and CAINOZOIC sediments.

PALAEOZOIC

PERMIAN

- Plb — BOORTHANNA FORMATION: Brown, gritty dolomites and mixtites with striated and faceted boulders.

ORDOVICIAN

- Olb — Dolerite dykes. Radiometric age 537 Ma (K/Ar–T.R.).
- Odb — BUNGADILLINA MONZONITE: Coarse-grained, porphyritic monzonites and syenites, minor diorites. Albitites. Radiometric age c. 470–500 Ma (K/Ar–hblde & bio).
- d — Diapiric breccia with carbonate matrix.

PROTEROZOIC

ADELAIDEAN

MARINOAN / STURTIAN — UMBERATANA GROUP (WILLOCHRA SUB-GROUP; FARINA SUB-GROUP)

- Ɛh₁ — Unnamed siltstone: Red-brown silty shales, grey-green shales, silty dolomites, fine-grained sandstones and thin grey-yellow dolomites.
- Ɛfl — THORA DOLOMITE: Grey-green and brown dolomites, minor siltstones; large festoon surfaces and algal bedding.
- Ɛft — TAPLEY HILL FORMATION: Laminated grey-green silty shales and silty dolomites; basal, thin sandy dolomites.
- Ɛu₁ — Unnamed sandstone: Quartzitic sandstones, arkoses, argillaceous sandstones; red porphyry granules and large scale cross-bedding; minor microconglomerates.
- Ɛub — CALTHORINNA TILLITE: Mixtites; conglomeratic dolomites, laminated pale green shales, gritty sandstones, arkoses and quartzites.

Disconformity

TORRENSIAN — BURRA GROUP

- Ɛbh — KALACHALPA FORMATION: Grey-green and brown siltstones and shales, gritty sandstones and quartzites, conglomeratic dolomites, stromatolitic dolomites, oolitic sediments, black cherts; quartzites and shales at the top.
- Ɛb₂ — Unnamed unit: Gritty quartzitic sandstones, stromatolitic dolomites, conglomeratic dolomites, magnesite conglomerates, black and minor red cherts, grey shales and siltstones; mudcracks; ripplemarks, cross-bedding.
- Ɛbk — SKILLOGALEE DOLOMITE: Basal member comprises quartzites, sandstones, silty shales and minor pale brown dolomites; middle member comprises sandstones and pale grey to black conglomeratic dolomites, minor magnesite conglomerates and blue-black cherts; upper member is predominantly dark grey-black flaggy conglomeratic dolomites; stromatolites occur in upper two members.
- Ɛbo — MOUNT MARGARET QUARTZITE: White orthoquartzites, slaty quartzitic sandstones, dark grey sandy siltstones, green-grey silty shales, minor dolomitic siltstones near base; thick orthoquartzites at top; clay galls, ripplemarks, cross-bedding.
- Ɛbl — FOUNTAIN SPRING BEDS: Laminated grey dolomitic siltstones and interbedded thick grey quartzites with clay gall laminations, green-grey silty shales (salt casts); minor grey silty dolomites and a few quartzites near base.
- Ɛb₁ — Unnamed siltstone: Laminated grey pyritic dolomitic siltstones, green shales, pyritic silty dolomites, fine-grained sandstones, minor grey quartzites; ripplemarks, cross-laminations, salt casts.

WILLOURAN OR TORRENSIAN

- Ɛa — Undifferentiated blocks (in diapirs and faulted sequences): Sequences observed in these blocks include purple shales, maroon shales, sandstones, quartzites and dolomites. Blocks numbered 1–8 described in text.
- Ɛaa — MURRANA BEDS: Laminated gritty quartzitic sandstones, grey-green silty shale interbeds; arkoses, pebbly dolomites, purple and grey silty shales near top; ripplemarks, mudcracks, cross-laminations, flute casts and salt casts.
- Ɛaf — DUFF CREEK BEDS: Laminated olive green silty shales and thin arkose interbeds; flaggy buff weathering pale grey and yellow dolomites, minor dark grey dolomites, flaggy dolomitic siltstones; laminated pyritic fine-grained sandstones; minor quartzitic sandstones; mudcracks, ripplemarks, clay galls and cross-bedding are common; horizons with abundant salt casts and gypsum casts; algal laminations.
- Ɛan — NILPINNA BEDS: Fine-grained cross-laminated sandstones, ripplemarked quartzites (salt casts), grey-green silty shales, minor grey silty dolomites and greenish arkoses; mudcracks, ripplemarks and salt casts are common.
- Ɛaw — WAR LOAN BEDS: Blue-grey shales and siltstones; dark grey silty dolomites, greenish feldspathic sandstones and arkoses.
- Ɛad — ROCKWATER BEDS: Blue-grey and black cherts, black dolomitic limestones with black silty shales and grey quartzites.

WILLOURAN — CALLANNA BEDS

- Ɛcc — CADLAREENA VOLCANICS: Vesicular basalts and altered dolerites; minor andesites, dacites and rhyolites; tuffs, lapilli tuffs; minor lenticular reddish mudstones and quartzites with red shale interbeds near base and top.
- Ɛck — COOMINAREE DOLOMITE: Pale brown and pink stromatolitic dolomites; gritty dolomites.
- Ɛco — YOUNGHUSBAND CONGLOMERATE: Basal quartzitic breccias; red-purple shales and sandstones at top.

MIDDLE PROTEROZOIC

- Diorite and dolerite dykes.
- Ɛyw — WIRRIECURRIE GRANITE: Coarse-grained, porphyritic granites. Radiometric age 1648±21 Ma (Rb/Sr–T.R.); 519–1087 Ma (K/Ar–bio).

EARLY PROTEROZOIC — PEAKE METAMORPHICS

- Ɛd₃ — Unnamed metamorphics: Grey quartzites, epidote quartzites, arenaceous schists, rare clinopyroxene granulites; minor amphibolites and pegmatites.
- Ɛdb — BALTUCOODNA QUARTZITE: Greyish-white quartzites and basalts, amphibolites, minor quartz + muscovite schists, bluish-grey phyllites, sillimanite gneisses, plagioclase + hornblende + epidote calc-silicates and calcite marble.
- Ɛd₂ — Unnamed schists: Quartz + muscovite schists, quartz + chlorite phyllites, rare sandstone lenses; minor graded bedding and cross-bedding.
- Ɛdt — TIDNAMURKUNA VOLCANICS: Flow-banded porphyritic rhyolites, amygdaloidal basalts, rare epidosites and marbles.
- Ɛd₁ — Unnamed metamorphics: Quartz + biotite schists, often garnetiferous; muscovite schists, quartz + biotite + feldspar gneisses, white quartzites, rare epidote quartzites; pegmatites and diorite sills common; local migmatites. Radiometric age 1460–1520 Ma (K/Ar–hblde).

MAIN ROAD	GEOLOGICAL BOUNDARY
SECONDARY ROAD	OBSERVED
TRACK	INFERRED
RAILWAY	FAULT
WITH STATION	OBSERVED
WITH SIDING	INFERRED
TRIANGULATION STATION	FOLD
IDENTIFIED POINT	ANTICLINAL
HOMESTEAD, BUILDING	SYNCLINAL
YARD (Yd)	BEDDING
EPHEMERAL STREAM	INCLINED
FLOOD PLAIN BOUNDARY	VERTICAL
SWAMP	TREND OF BEDDING
CLAYPAN	FACING
SPRING	FOLIATION
WATERHOLE (W.H.)	INCLINED
DAM	VERTICAL
BORE, WELL (W)	GEOLOGICAL BLOCK DIAGRAM (A B)
SAND DUNES	TYPE SECTION
MINE	GEOCHRONOLOGY SAMPLE SITE
COPPER (Cu)	TECTONIC BRECCIA

LOCALITY