DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

REPT. BK. NO. 91/7

THE PANDURRA FORMATION

GEOLOGICAL SURVEY

BY

W M COWLEY

REGIONAL GEOLOGY

JANUARY 1991 DME 528/81

G01216

CONTENTS | PAGE

TABLES

PLATE CAPTIONS

FIGURES | PLAN NO

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

REPT BK NO. 91/7
DME 528/81
G01216.WP

THE PANDURRA FORMATION

ABSTRACT

Pandurra Formation crops out in a broad belt extending northwesterly from Whyalla for approximately 230 kilometres. It also crops out near Pernatty Lagoon. Extensive drilling has demonstrated that the formation is present in the subsurface between these areas and for a further 200 kilometres to the northwest. Possible equivalents exist on Eyre Peninsula and near Lake Frome.

The Mesoproterozoic Pandurra Formation comprises fluvial redbeds, mainly poorly-sorted, immature, medium to coarse-grained sandstone, but including well-sorted, very fine to medium-grained sandstone, siltstone, shale and pebbly sandstone interbeds. Characteristic features include a distinctive frame-work composition indicative of a Gawler Ranges source area, a mottled, sericite/kaolinite and haematite matrix, large-scale cross-beds and liesegang banding.

Four members are recognised, including a distinctive red-brown siltstone-shale interval in the lower part, and a member characterised by cyclic deposition in the upper part. The persistence of this subdivision irrespective of the depth to underlying basement indicates that the Pandurra Formation was probably not deposited into graben as previously believed. Instead, the present half-graben morphology is a result of later faulting, largely confined to the northeastern and eastern margins near Olympic Dam and Port Augusta.

Limited sedimentological work indicates a braided-stream origin, with indications of alluvial fan, aeolian, deltaic and lacustrine influences, but there is much scope for further study.
Copper mineralisation is prominent in the upper part of the Pandurra Formation near Pernatty Lagoon, and includes the Cattlegrid deposit. Potential for placer

gold and redox uranium deposits has not been fully evaluated.

INTRODUCTION

The Pandurra Formation is a thick, monotonous unit of unmetamorphosed, relatively flat-lying, predominantly arenaceous sediments deposited on the northeastern Gawler Craton (Fig. 1). It was first described by Crawford (1964) and Crawford and Forbes (1969) in the Whyalla area (Fig. 2) but was previously known as the Pernatty Grit (Johns, 1968), whose upper part is now assigned to the Neoproterozoic (Adelaidean) Whyalla Sandstone (Dalgarno *et al.,* 1968).

The age of the Pandurra Formation has long been uncertain, the unit having been ascribed to the ?Cambrian (Johns and Solomon, 1952), to upper Sturtian glacials of the Umberatana Group (Johns, 1963), to the Burra Group (eg. Thomson, *et al.,* 1976 and to the Callanna Group (eg. Mason *et al.,* 1978). Subsequent Rb-Sr geochronology on interbedded shale and siltstone indicates that the unit is pre-Adelaidean (Mesoproterozoic), with a probable depositional age of 1424 ± 51 Ma (Fanning *et al.,* 1983).

The type section of the Pandurra Formation, shown as being located several kilometres southeast of "Pandurra" (Thomson *et al.,* 1976, p.23), has not, to the author's knowledge, been described. In addition, no detailed or formal descriptions of its tectonic setting, lithological variation or internal stratigraphy have previously been undertaken.

This report is a compilation and synthesis of published and unpublished data on the Pandurra Formation available at May 1990. It takes advantage of data from intensive exploration drilling that has taken place on the northeastern Gawler Craton, largely since the discovery of the Olympic Dam deposit in 1975.

TECTONIC SETTING

The intrusion of granitic plutons of the Hiltaba Suite (Fig. 3) at ca 1600-1575 Ma (Fanning *et al.*, 1988; Creaser, 1989) was the final regional-scale event in the cratonisation of the Gawler Craton (Webb *et al.*, 1986). Subsequent Mesoproterozoic activity within the Craton was transitional in character, and was largely confined to the northeastern portion of the craton (Fig. 1). Here, continental sediments and mafic volcanics of the Pandurra Formation, Backy Point Formation and Beda Volcanics (Cowley, in prep.) were deposited in response to northeast-southwest-directed extension and subsidence, accompanied by erosion of the elevated cratonic areas to the southwest. Intrusion of the Gairdner Dyke Swarm (Flint, in prep.) coincided with extrusion of the Beda Volcanics.

To emphasise the transitional tectonic character of the Pandurra Formation, the name **Cariewerloo Basin** has been adopted to differentiate this unit from the older portion of the Gawler Craton and from the overlying Mesoproterozoic Beda Volcanics/Backy Point Formation (tectonic unit not named) and Neoproterozoic (Adelaidean) to Cambrian Stuart Shelf.

The disposition of the Pandurra Formation in an elongated, 120 kilometre-wide, northwest-trending belt (Fig. 2) strongly suggests northwesterly fault control of its present-day margins. This, together with the numerous dykes of the Gairdner Dyke Swarm which intrude the Pandurra Formation in the same direction, has led many authors to interpret deposition of this unit in a northwest-trending graben or a series of down-faulted basement blocks (e.g. Thomson *et al.*, 1976; Mason *et al.*, 1978; Parker, 1980; Lemon and Gostin, 1983; Parker, 1983; Preiss, 1987). Parker (1983) went further, suggesting that the Pandurra Formation was deposited in an aulacogen indirectly related to later rifting which led to formation of the Adelaide Geosyncline.

Tonkin (1986), however, with access to then-confidential exploration drilling data, recognised that the Pandurra Formation has a regional tilt to the northeast from a monoclinal axis on the southwestern margin near Lake Gairdner, and is bounded by major northwest-trending faulting bordering the basement highs around Olympic Dam and Mt Gunson. He also interpreted younger northeast-trending faults which disrupted this upfaulted eastern margin between Olympic Dam and Mt Gunson. Tonkin further noted that the Pandurra Formation showed the same internal stratigraphy and sedimentary facies irrespective of the depth to underlying basement (Fig. 4), and inferred from this that deposition of the Pandurra Formation largely preceded the faulting resulting in its present half-graben morphology. Therefore, the Pandurra Formation was probably deposited in a down-warped portion of the northeastern Gawler Craton without appreciable fault control.

This suggestion is confirmed (see later) by the persistence of internal members from the deepest parts of the half-graben, over basement highs such as that north of Pernatty Lagoon, and onto the southwestern onlapping margins (Fig. 4).

Local syndepositional faulting, however, can be inferred. CSR EC-35, north of Pernatty Lagoon, intersected a thick sequence of sediments dominated by granitic detritus adjacent to a granitic basement high. At the Acropolis prospect the basal member of the Pandurra Formation is much thicker to the southeast of the basement high than it is to the west.

At Water Tank Hill, Whyalla, Pandurra Formation containing pebbles of Moonabie Formation onlaps a curved 8 m escarpment of Moonabie Formation. This was originally interpreted as a fossil wave-cut cliff (Miles, 1954), but because the Pandurra Formation is probably terrestrial, the cliff is more likely to be a steep river bank. Near Red Rock, east of "Roopena", Pandurra Formation thickens appreciably to the east of a fault (Thomson *et al*., 1976, fig. 14). In both these instances, pre- or syndepositional faulting may be involved, but in neither locality is the member subdivision evident to verify this.

The Gairdner Dyke Swarm (Fig. 2) intruded into northwest-trending fractures which may have been initiated during this post-Pandurra faulting. The two events may have been closely spaced in time, at approximately 1070 Ma, the minimum intrusive age of the dykes (Flint, in prep.).

North-south faulting evident near "Roopena" (Fig. 2; Thomson *et al*., 1976, fig. 14) may be unrelated to the northwest-trending faulting affecting the Pandurra Formation further north. It may represent a southern extension of the faulting which bounds the eastern side of the Pernatty Upwarp (Pernatty Culmination of Johns (1974)), and which forms the present-day western margin of the Beda Volcanics and Backy Point Formation (Cowley, in prep.). Knutson *et al*. (1983), however, consider that the north-south-trending Pernatty Upwarp near Mt. Gunson consists in detail of north-northwesterly-trending fault blocks of Pandurra Formation offset by north-northeasterly-trending faults. The silicified upper surface of the Pandurra Formation evident here and to the south suggests that the Pernatty Upwarp may also be in part an erosional remnant of a formerly-widespread silcrete plateau.

DISTRIBUTION AND THICKNESS

Pandurra Formation crops out in a broad belt extending northwesterly from Whyalla to near Lake Hart, and also along the western side of Pernatty Lagoon and east of Lake Windabout. Extensive company drilling has shown that the unit is continuous in the subsurface between these exposures, and also extends below younger sediments to the northwest as far as "Bulgunnia", "Mount Eba" and "Billa Kalina" (Fig. 2; Table 1). It appears to onlap Gawler Range Volcanics to the southwest and may have originally extended a considerable distance in this direction. In contrast, the northwestern, northeastern and southeastern margins are mostly fault-controlled; the Pandurra Formation has been largely removed from uplifted blocks such as those west of the northern end of Lake Torrens (including Olympic Dam), northeast of Lake Windabout, southeast of Pernatty Lagoon, and the Cultana Inlier. Gaps in this upfaulted eastern margin where the Pandurra Formation may be preserved beyond the major depocentre are evident north of "Billa Kalina" and north of Port Augusta. The latter possibility implies that Pandurra Formation may be present in the Torrens Hinge Zone and below the Adelaide Geosyncline.

Preiss (1987), however, notes that Pandurra Formation xenoclasts are absent in diapirs within the Adelaide Geosyncline, so significant deposition of Pandurra Formation in areas now beneath the geosyncline is not substantiated. Previous interpretations of Pandurra Formation in drillholes within the Torrens Hinge Zone near Port Pirie have been refuted; these sediments are now assigned to the Burra Group (Parker *et al*., 1990).

On the S.A. - N.S.W. border east of Lake Frome (Fig. 2), there exists an isolated outcrop of purple, cross-bedded, liesegang-banded coarse-grained and pebbly sandstone, which dips at a moderate angle to the northwest, and which is veined by quartz (Callen, 1976). This outcrop closely resembles Pandurra Formation (Preiss, 1987, p. 38).

Similar, but flat-lying, sediments were intersected in SADME Bumbarlow 1 (Youngs, 1978) 90 kilometres to the west near Lake Frome. In this hole, red-brown, maroon and green mudstone, siltstone, medium to coarse-grained sandstone and granule to pebble conglomerate are interbedded with basic lava flows. The shale and siltstone are flat-laminated or rarely ripple-marked, and one interval is dolomitic. Cross-bedding, graded bedding and scouring are observed in the sandstone, and the conglomerate contains intraformational sandstone, siltstone and mudstone clasts, as well as exotic clasts of quartz, metasediments and volcanics.

Rb-Sr dating of the siltstone in Bumbarlow 1 yielded an age of 1344 $\pm$ 51 Ma (Webb, 1969). The initial ratio of 0.7226 $\pm$ 0.0116 is very high and indicates that the 1344 Ma age is a minimum age only, and that the siltstone is likely to be considerably older than this. Giles and Teale (1981) compared the trace-element geochemistry of these tholeiitic basalts with basalts from the ca 1600 Ma Gawler Range Volcanics near Lake Everard and basalts from the Neoproterozoic Adelaide Geosyncline. They concluded that the basalts and sediments in Bumbarlow 1 are equivalent to the Gawler Range Volcanics and their interpreted correlative, the Corunna Conglomerate, rather than the Pandurra Formation (Preiss, 1987, p. 38), which is not known to include mafic volcanics.

The Blue Range Beds (Fig. 1; Flint and Parker, 1981; Flint and Rankin, 1989) of the Itiledoo Basin on central Eyre Peninsula comprise immature coarse clastics which display distinctive purple-and-white mottling and liesegang banding. These features are also well displayed in the Pandurra Formation, and prompted Thomson (1980) to assign some of the outcrops to the Pandurra Formation. Flint and Rankin (1989), however, point out that the gentle folding and haematite veining observed in the Blue Range Beds suggest that they were deposited prior to the last stages of the Kimban Orogeny (Wartakan Event, ca 1500-1450 Ma; Thomson, 1969; Flint and Parker, 1981) and are therefore more likely to be equivalent to the Corunna Conglomerate. Nevertheless, although the arkosic, micaceous matrix of the Blue Range Beds contrasts with the haematite-kaolinite matrix typical of the Pandurra Formation, equivalence of these two units cannot be ruled out, as the difference in matrix mineralogy may only reflect local tectonics and/or source area geology.

The preserved thickness of the Pandurra Formation is highly variable, being a function of post-depositional faulting and differential erosion prior to deposition of the overlying Backy Point Formation, Beda Volcanics and Adelaidean units (Figs. 2 and 4). The thickest intersection obtained to date is 950 m, in Western Mining Corporation DRD-1. Pandurra Formation thicknesses approaching 2000 m near "Mount Eba", as interpreted from aeromagnetics by Anderson (1978), may include underlying non-magnetic material such as Tarcoola Formation; nevertheless, 1500 m is a likely value for the Pandurra Formation's maximum thickness in this area.

Bedding is normally near-horizontal, although dips up to 15^{o} have been recorded along the southwestern outcropping margin, and steeper dips are observed adjacent to faults near "Roopena".

LITHOLOGY

The Pandurra Formation is a thick and monotonous, yet distinctive unit of largely arenaceous redbed sediments. It is typically a medium to coarse-grained, poorly sorted, subangular quartz and lithic sandstone but the unit also includes moderately well-sorted, very fine to medium-grained sandstone. The red, red-brown or purple matrix of kaolinite (or sericite) and ochrous haematite has generally suffered some reduction of the ferric iron content and displays spotting or mottling in grey or white. Occasionally the iron content has been redistributed into curvilinear liesegang bands by a fossil weathering event (Plate 1); this is a characteristic feature of outcropping and subsurface Pandurra Formation. Interbeds of laminated, red-brown or purple shale and siltstone are present, mainly in the lower part of the formation; yellow or green reduction spots are common in these. In SADME ERD-6, however, it appears that the red colour of the Pandurra Formation has resulted from oxidation of an original grey-green to white colour, patches of which remain in the less porous shale and siltstone interbeds (Cowley and Martin, 1988).

Moderate to large-scale cross-bedding in sets up to 1.5 m thick is ubiquitous in the sandstone, and is accompanied locally by scouring, slumping and pebble-imbrication. More vigorous local reworking is indicated by the presence of large intraclasts of Pandurra Formation in an 11 m interval in Shell RL-1 (Cowley and Martin, in prep.). Graded bedding is usually poorly developed, the grainsize more commonly showing an uneven variation, without sharp grainsize variations to delineate the individual beds. Siltstone-shale interbeds are often intercalated with sandstone in a cyclic pattern.

The framework of the Pandurra Formation is remarkably consistent basin-wide, and comprises sub-rounded to subangular quartz, with minor to common amounts of altered feldspar, chert, ferruginous chert, ironstone, muscovite and acid volcanics, indicating derivation dominantly from the Gawler Range Volcanics to the southwest. Plagioclase has not been reported. Current directions measured by Busbridge (1981) at the Cattlegrid Mine, and by O'Shea (1982) near Lake Gairdner both indicate easterly transport of sediment. Minor constituents of the framework are detrital iron oxides (including local magnetite), sphene and rutile/leucoxene (Curtis, 1977; Busbridge, 1981). The basal parts of the formation occasionally contain locally-derived lithic detritus.

The matrix is normally kaolinite, with a highly variable content of fine haematite. Sericite is often stated to be a major matrix mineral in the Pandurra Formation (e.g. Johns, 1968; Blissett and Thomson, 1978), but it is not clear whether this represents misidentification of kaolinite or detrital muscovite, or replacement of kaolinite, as suggested by CSR Limited and Mount Gunson Mines Pty Ltd (1983). Illite has been identified in thin section near the Cattlegrid Mine (Curtis, 1977), and near "Pandurra" (Tonkin, 1979; Curtis, 1975 a and b).

Chlorite, haematite and carbonate alteration is evident in Pandurra Formation adjacent to Gairdner Dyke Swarm dykes in Shell RL-1, Auitaine SSR-1001 and CSR LY-3.

A period of pre-Adelaidean weathering has affected the undulating upper surface of the Pandurra Formation in the Pernatty Upwarp-Whyalla area. Silicification and liesegang-banding (Plate 1) of the upper portion of the formation can be seen in outcrop west of Pernatty Lagoon, below Whyalla Sandstone at Cattlegrid Mine (Gersteling and Heape, 1975; Busbridge, 1981), and in drillholes further south such as CSR BK-8 (below Tapley Hill Formation; Tonkin, 1978) and 6332J-12 (below Backy Point Formation; Tonkin, 1979). In CSR LY-2 at the Cattlegrid Mine, liesegang banding is observed to a depth of 380 m, while silicification is intense down to 42 m and progressively fades down to 192 m (Curtis, 1977). Replacement of the clay matrix by quartz overgrowths and chert (Gersteling and Heape, 1975) faithfully preserves the liesegang banding, suggesting that the banding predates the silicification. The silicification noted by Crawford and Forbes (1969) within outcropping Pandurra Formation north of Whyalla may also be pre-Adelaidean, as silicified Pandurra Formation is also intersected to the east in drillholes such as BHP CU-3 (Dampier Mining Co Ltd, 1980), where it underlies Tapley Hill Formation. Clasts of silicified Pandurra Formation are locally very common in the Backy Point Formation, implying that the weathering event predates 1076 Ma, the likely minimum age of the interbedded Beda Volcanics and Backy Point Formation (Cowley, in prep.). Minor silicification of the Pandurra Formation southeast of Lake Gairdner is reported by O'Shea (1982); elsewhere, the silicifed carapace appears either to have not formed, or to have been stripped by pre-Adelaidean erosion. Liesegang banding, on the other hand, is widely observed over the whole Pandurra Formation extent. Studies by Busbridge (1981) on packing and compaction of the quartz grains in the formation at the Cattlegrid Mine indicate that a substantial thickness has been removed by erosion, probably prior to the silicification event.

This silicified carapace on the Pandurra Formation was subjected to frost shattering, heaving and thrusting during the Marinoan (late Adelaidean) glaciation at the Cattlegrid Mine (Busbridge, 1981; Williams and Tonkin, 1985). This breccia is the locus for economic copper sulphide mineralisation here (see later).

SUBDIVISION

Despite the overall uniformity of the Pandurra Formation, extensive exploration drilling on the Stuart Shelf has enabled a preliminary subdivision to be erected, based on observations made initially by Mason (1978) near Island Lagoon, and extended by Tonkin (1980) to the Mount Gunson region. Examination by the author of the logs of over 120 drillholes intersecting the Pandurra Formation below the Stuart Shelf has established the applicability of the subdivision wherever sufficient section is revealed. Sparse and/or shallow drilling northwest of "Parakylia" and southeast of "Cariewerloo" prevents confident use of the subdivision in these areas at present.

The Pandurra Formation has been divided by Mason (1978) and Tonkin (1980) into four members (1-4), two of which are locally split into two further sub-units (Fig. 5). Of these, uppermost Member 4 is by far the most widespread in outcrop. The lower units are confined to near the present-day margins of the Pandurra Formation but they have not been mapped in outcrop, and may in fact be unrecognisable due to poor outcrop and surficial weathering, factors noted by O'Shea (1982) between Lake Gairdner and "Cariewerloo".

Member 1

Member 1 is composed of red-brown, purple and greenish-grey, very poorly sorted, fine to medium-grained, gritty, lithic sandstone, with abundant bleached spots and patches. With an increase in the proportion of grit, it grades locally to a granular or pebbly sandstone, particularly near Lake Gairdner, near the Acropolis prospect and in Western Mining Corporation (WMC) WJD-1 and DRD-1. Well-rounded sandstone is prominent in this unit in Samedan BDH-2 near "Bulgunnia" and in several holes near Lake MacFarlane. The unit also contains numerous interbeds of red, brown and grey-green shale and siltstone. The lithic component of the sandstone framework comprises fragments of acid volcanics, ironstone, feldspar, mica and chert, and locally includes shale intraclasts and some locally-derived granite and gneiss detritus. The green-grey colouration of some of the sandstone is a result of detrital chlorite. O'Shea (1982) recognised numerous slump features in outcropping Pandurra Formation (possibly Member 1) near "Cariewerloo".

The thickness of Member 1 is highly variable, ranging from zero (WMC CSD-1, Pacminex EX-24) up to 272.9 m, recovered in WMC ACD-8; thicknesses of 35-90 m are most common.

Tonkin (1980) split Member 1 into a basal conglomerate which he termed Member 1, and the remainder of the interval as above, which he termed Member 1A (Plate 2). Tonkin's basal Member 1 (Plates 3 and 4) comprises purple to red-brown or red-grey, usually poorly-sorted, coarse-grained to granular sandstone and pebble conglomerate, with common, irregularly-distributed interbeds of fine to medium-grained sandstone and siltstone. In addition to the regional clast suite of quartz, acid volcanics and chert, this interval sometimes contains locally derived angular to well-rounded clasts such as banded iron formation (Samedan BDH-2 and BDH-3), sericitised gneiss (WMC HHD-1), granite (CSR EC-48), haematite and haematised acid volcanics (Acropolis prospect) and Corunna Conglomerate and Moonabie Formation quartzite (Water Tank Hill and Mt Laura, near Whyalla, Parker *et al*., 1988). This subunit is thickest (56.3 m) in CSR PY-2.

CSR EC-35, north of Pernatty Lagoon, recovered over 166 m of very poorly-sorted, maroon to red-grey, coarse-grained to conglomeratic sandstone composed almost entirely of quartz, feldspar and chlorite derived from a granitic basement high immediately to the southeast. This thick interval is tentatively assigned to Tonkin's Member 1, although the rapid influx of granitic debris here may have disguised the usual subdivisions.

Member 2

Recognition of the distinctive Member 2 (Plates 5 and 6) is normally the key to establishing the subdivision of the Pandurra Formation in any particular area. This widespread member predominantly comprises red-brown and purple shale, micaceous sandy shale and micaceous siltstone, which are often laminated and fissile and usually display greenish-yellow reduction spots and bands. Interbeds of fine to medium-grained micaceous sandstone with shale intraclasts are common. Wavy and lenticular bedding and desiccation cracks have been recorded from WMC HHD-1 and from holes in the Acropolis prospect, and abundant anhydrite is present in Australian Selection PDH-12. The lower part of this Member in Australian Selection PIL-14 is a strongly-chloritic siltstone. Fanning *et al*. (1983) noted that shale from CSR PY-1 and siltstone from Kennecott/Samedan Peeweena 1 are composed of subangular quartz and feldspar, detrital muscovite and biotite, and a ferruginous clayey matrix.

Member 2 is remarkably persistent for a thin unit, and is usually 10 to 65 m thick, but ranges from 109 m in Afmeco KGB-4 near Lake Gairdner to 3-5 m. The only holes in which the member is apparently absent are WMC ACD-10, AD-2 (faulted out) and AD-20. It has not yet been intersected in drilling northwest of "Parakylia", nor southeast of "Cariewerloo", probably because drilling has not been deep enough. An interval of several metres of silty micaceous sandstone noted in the type section near "Roopena" (Thomson *et al.*, 1976, locality 7), and an outcrop of red-brown micaceous shale with green spots and bands near "Mahanewo" (Blissett, 1985) may belong to Member 2.

Member 3

Member 3 is mostly composed of very fine to medium-grained, red-brown and purple quartz sandstone, interbedded with variable amounts of purple to red-brown laminated shale and micaceous siltstone (Plate 7). The haematite-sericite matrix of the sandstone is typically mottled white, and the same bleaching event has produced green and yellow spots and bands in the intervening siltstone and shale. Moderate to good sorting and sub-rounded to sub-angular quartz sand characterise the sandstone, which is commonly heavy-mineral-banded and cross-bedded. The sandstone beds often grade abruptly upwards into siltstone and shale, forming fining-upward cycles approximately 1-2 m thick, with the siltstone and shale being eroded and incorporated as intraclasts in the succeeding sandstone. The siltstone/shale portions of the cycles are typically only 10-30 cm thick. The sandstone of Member 3 is locally much coarser, particularly northwest of Mt Gunson (WMC ASD-2, CSD-1, DRD-1) and southeast of Pernatty Lagoon (WMC WHD-1). Minor lithic sandstone contains acid volcanics, feldspar, granite, muscovite and ironstone in addition to the regional framework component. Very dark brown-grey to purple sandstone in BHP LH-2 contains a large proportion of mafic lithic detritus. Several intervals of green, chloritic sandstone near the base of Member 3 in SAR-3 were described by Australian Selection Pty Ltd as tuffs, but this identification has not been verified by petrological sampling. Anhydrite (or gypsum) and MnO_2 nodules have been reported from several holes along the southwestern limit of the member.

Near Lake MacFarlane, Mason (1978) identified a local two-fold subdivision of Member 3 (Fig. 5), splitting it into an upper subunit (his Member 3A, which is identical with Member 3 described in the previous paragraph) and a lower subunit (his Member 3), which apparently lenses out elsewhere into usual Member 3. Mason's Member 3 is composed of sandstone interbedded with red shale and siltstone like Member 3A, but the sandstone contains instead a steel-grey (?recrystallised) haematite matrix. The sandstone also contains well-rounded grains of sericite, quartzite and chert and variable amounts of gypsum and/or anhydrite.

Member 3 has a fairly constant thickness of 100-200 m over most of its extent, with a maximum of 351 m in Australian Selection SAP-1, and reduced thicknesses along the southwestern margin near Lake Gairdner and "Pandurra".

Member 4

Poorly sorted, cross-bedded, medium-grained to granular, purple, red-brown and grey sandstone with mottled bleaching characterises the uppermost Member 4 of the Pandurra Formation (Plate 8). This sandstone contains angular to subrounded grains of quartz and locally common feldspar, and granules and small pebbles of quartz, chert, jasper and acid volcanics, in a haematite-sericite/kaolinite matrix. It also contains scattered muscovite, ironstone, banded iron formation, metaquartzite, gneiss and granite granules. Heavy-mineral banding (locally including magnetite grains) is widespread but never abundant. Scattered thin interbeds of pebble conglomerate (Plate 9) and red to green shale, siltstone and fine-grained sandstone are present. Sorting is generally better in the finer-grained sandstone, and the member as a whole is better-sorted in WMC HHD-1 and Australian Selection SAP-1.

Approximately 100-300 m of Member 4 is usually preserved, ranging up to a maximum of 637 m in CSR LY-2 near Pernatty Lagoon, and diminishing to zero at the subcrop limits. The top of the member is not preserved, and a large thickness of Pandurra Formation has probably been removed by erosion

(Busbridge, 1981).

ENVIRONMENT OF DEPOSITION

The Pandurra Formation has generally been interpreted as a terrestrial, dominantly fluvial sequence, because of its ubiquitous haematite content (indicative of oxidising conditions during deposition and diagenesis), the prevalence of moderate-scale cross-beds, and its generally coarse grainsize.

Alluvial fan, aeolian and possible deltaic environments have also been inferred for some portions of the sequence (Lemon and Gostin, 1983; Lemon, 1987). Some authors, however, have favoured a shallow marine environment for parts of the formation (Curtis, 1977; O'Shea, 1982).

Busbridge (1981) carried out grainsize analysis on samples of Member 4 of the Pandurra Formation from the Cattlegrid Mine area, and concluded that it was deposited in a braided-stream environment. The common lack of clear depositional breaks (reactivation surfaces) in the sandstone (particularly Member 4) which comprises the majority of the Pandurra Formation is problematic, however.

Interbedded sandstone-shale sequences, such as those prominent in Member 3, possibly represent stacked meandering fluvial cycles. Common mud-flake clasts and local anhydrite in this member suggest periodic desiccation and breaks in sedimentation.

The paucity of coarse clastics supplied to the Cariewerloo Basin during deposition of the Members 3 and 2 points to tectonic quiescence and subdued elevation of the source area and consequent reduction in palaeoslope, with suspended-load deposition from meandering rivers replacing bed-load deposition in braided streams. Alternatively, the commonly laminated fine-grained sediments of Member 2 may have been deposited from a body of water, either a large lake (Tonkin, 1986) or a shallow sea. Local desiccation cracks and rare anhydrite suggest periods of evaporative conditions, possibly in an intermittent lake or sabkha environment. Herringbone cross-beds recorded by O'Shea (1982) in probable Member 2 near Lake Gairdner may represent local reworking on the shores of a small lake.

A braided stream or alluvial plain environment of deposition is inferred for the poorly-sorted lithic sandstone of Member 1, which also contains a basal conglomerate of probable alluvial fan origin together with interbeds of shale and siltstone possibly representing intervals of lacustrine deposition.

Large metreages of core are available from the listed exploration drillholes (Table 1) and careful study would probably elucidate the depositional environment of the various facies of the Pandurra Formation.

ECONOMIC GEOLOGY

Copper mineralisation, concentrated along the contact of the Pandurra Formation with either the overlying Whyalla Sandstone or Woocalla Dolomite Member of the Tapley Hill Formation, was mined from several small deposits in the Pernatty Lagoon area in the periods 1898-1937, 1941-1943 and (by Mt Gunson Mines Pty Ltd) in 1970-1971 (Johns, 1968; 1974). Mineralisation consisted of chalcocite, bornite, covellite, malachite, atacamite and chrysocolla as a cement to the friable Whyalla Sandstone and as fracture-filling in the Pandurra Formation. Minor accumulations of copper exist in fractured, silicified Pandurra Formation elsewhere, for example in BHP CU-3 near Whyalla (Dampier Mining Co. Ltd, 1980).

Further exploration by CSR Ltd near Pernatty Lagoon led to the discovery, in 1972, of the Cattlegrid copper deposit, which was worked from 1974 until 1984 (CSR Ltd and Mt Gunson Mines Ltd, 1983). At the end of 1982, the sum of ore mined plus recoverable reserves was estimated at 6.37 million tonnes (dry) at 1.9% Cu; substantial extra revenue was obtained from production of silver.

Of similar geology to the previously mined deposits, the Cattegrid orebody much larger due to the greatly-increased fracture porosity provided by brecciation of the Pandurra Formation as a result of freezing and thawing during the Marinoan glaciation (Busbridge, 1981; Williams and Tonkin, 1985). Located some 36 metres below the surface, the mineralisation comprised mainly chalcocite-digenite-djurleite, bornite, chalcopyrite and pyrite in a crescent-shaped tabular zone averaging 4.5 metres thick, and predominantly hosted by the periglacial breccia. Significant amounts of silver, lead, zinc and cobalt were present in the orebody and as a geochemical halo. Enrichment in nickel, mercury and arsenic and depletion in manganese were also observed in the halo. Zoning of copper minerals was evident, from chalcopyrite-rich in the centre and northwest through bornite-rich ore to chalcocite-rich mineralisation on the southwestern, southeastern and northern fringes. Textures indicative of replacement of chalcopyrite by bornite, and of bornite by chalcocite-digenite-djurleite, are common, and define a broad paragenetic sequence (Creelman, 1983). Two alternative theories on the genesis of the Cattlegrid orebody have been proposed, by Creelman (1983) and by Lambert *et al*. (1987).

Results of a detailed mineragraphic, electron probe and lead isotope study led Creelman (1983) to infer the following series of events (as summarised in CSR Limited and Mt Gunson Mines Pty Ltd (1983)):

1) Migration of dense metalliferous brine from the "basin that contained the Tapley Hill Formation" into the brecciated Pandurra Formation (It is not clear whether this occurred close to the time of deposition of Tapley Hill Formation or significantly later).
2) Deposition of, firstly, carrollite ($CuCo_2S_4$) and arsenic-bearing pyrite, and, secondly, marcasite, pyrite, sphalerite, chalcopyrite and further carrollite, by mixing of this brine with less saline connate waters.
3) Protracted dissolution and local redeposition of ore minerals mainly by the process of replacement of chalcopyrite by bornite and of bornite by chalcocite-digenite-djurleite, through changes in groundwater geochemistry at low temperatures. Some evidence of bacterial reduction is apparent in the latter stages of this event. Complex colloform textures are common results of this redistribution of copper.

Creelman and Hladky (1986) attribute the colloform textures and complex mineralogical replacement to rapid deposition of these relatively insoluble ore minerals at many points of nucleation from groundwater near the point of supersaturation. They consider the major control to be Eh, brought about by fluctuating amounts of sulphate-reducing bacteria resulting from cycles of stagnation and freshening of the groundwater.

Creelman (1983) states that microtextural evidence precludes mass replacement of pyrite by copper-bearing minerals, but this is an essential component of ore genesis as proposed by Creelman (1976) and subsequently supported by Knutson *et al*. (1983) and Lambert *et al*. (1987).

Lambert *et al*. (1987), using sulphur isotope work by Knutson *et al*. (1983), proposed the following genetic model for the Cattlegrid and related deposits:

1) Anoxic waters generated during deposition of the organic-rich Tapley Hill Formation percolated through the underlying Pandurra Formation, reducing and mobilising iron.
2) These iron-enriched fluids migrated to the permeability window of the Pernatty Upwarp, where there is no Tapley Hill Formation overlying the Pandurra Formation, and surficial oxidation caused precipitation of iron oxides in the previously-brecciated Pandurra Formation.
3) Sandy sediments (Whyalla Sandstone) subsequently deposited above the Tapley Hill Formation channelled reducing groundwater, containing sulphide, to the culmination, converting some of the iron oxides to iron sulphides. Isotope ratios indicate that this sulphur is not related to the sulphur in syngenetic sulphides in the Tapley Hill Formation, and is best explained by bacterial sulphate reduction rather than by hydrothermal activity.

   Creelman (pers. comm., in CSR Ltd and Mt Gunson Mines Ltd, 1983), on the other hand, suggests that the sulphur isotope data only records the latest redistribution of metal sulphides and gives no indication of the early stage of sulphide deposition which he observes.

4) Metal-enriched fluids ascended through fractures related to earlier formation of the Pernatty Upwarp, and replacement of iron sulphides by metal sulphides took place over a protracted period of time. The copper and other metals were probably leached from the Pandurra Formation and underlying basement by these rising fluids. Either the intrusion of dolerite dykes of the Gairdner Dyke Swarm into the Pandurra Formation, or the subsequent weathering of the overlying basalt flows (Beda Volcanics; now removed by erosion) could be the ultimate source of these metals.

Following closure of the Cattlegrid Mine, Top Australia Ltd, and subsequently Adelaide Chemical Company, treated oxidised ore mined from the Main Open Cut at Mount Gunson; mining ceased in early 1990 when the ore was exhausted. Copper is recovered by heap leaching of silicified Pandurra Formation ore containing atacamite and minor malachite and cuprite (South Australian Department of Mines and Energy, 1987).

During the period 1938 to 1967, 2 188 tonnes of barite were produced from the Mt Whyalla deposit, north of Whyalla (Olliver and Nichol, 1975). A series of open cuts, shafts and pits were opened along a vertical fracture zone within Pandurra Formation, which hosted a series of lenses of coarsely-crystalline barite up to 1.5 metres wide. The barite varies from transparent to white, pale brown, pink and purple; most of the production is of a grade suitable for oil drilling, and about half is of sufficient purity for use as pigments. Olliver and Nichol (1975) proposed that the barium was derived from the Gawler Range Volcanics which occur below and west of the area.

Dalgarno (1986) raised the possibility of redox-style uranium or placer gold deposits within the Pandurra Formation, with the gold (and possibly uranium) sourced from Olympic Dam-style or other deposits within the underlying basement. Primary reduced sediments do not appear to have formed in the Pandurra Formation (except possibly ERD-6) and so redox-style uranium accumulations are considered unlikely.

ACKNOWLEDGEMENTS

Western Mining Corporation and its joint venture partners kindly provided data on the Pandurra Formation from confidential drillholes on their Stuart Shelf exploration licence.

REFERENCES

Anderson, C.G., 1978. Magnetic interpretation in the northwestern Stuart Shelf area, South Australia. South Australia. Geological Survey. Quarterly Geological Notes, 68: 4-7.

Anderson, C.G., 1980. Magnetic and gravity interpretation on the Stuart Shelf. Australian Society of Exploration Geophysicists. Bulletin, 11:115-120.

Blissett, A.H., 1985. GAIRDNER, South Australia. Sheet SH/53-15. South Australia. Geological Survey. 1:250 000 Geological Series - Explanatory Notes.

Blissett, A.H. and Thomson, B.P., 1978. Gawler Range Excursion, October 16th to October 20th, 1978. South Australia. Department of Mines and Energy. Report Book, 78/130.

Busbridge, M., 1981. An analysis of the sedimentary host rocks to mineralisation at the Cattlegrid orebody, Mt. Gunson. University of Adelaide, B.Sc. (Hons.) thesis. South Australia. Department of Mines and Energy. Open file Envelope, 6593 (unpublished).

Callen, R.A., 1976. 1:250 000 Geological Series Explanatory Notes, FROME, South Australia. Sheet SH/54-10 International Index. South Australia. Department of Mines and Energy. Report Book, 76/27.

Cowley, W.M., in prep. Beda Volcanics and Backy Point Formation of the eastern Gawler Craton. South Australia. Department of Mines and Energy. Report Book, 90/16.

Cowley, W.M., and Martin, A.R., 1988. Kingoonya geophysical and stratigraphic drilling project-well completion report. South Australia. Department of Mines and Energy. Report

Book, 88/81.

Crawford, A.R., 1964. *Cultana* map sheet. South Australia. Geological Survey. Geological Atlas 1:63 360 series.

Crawford, A.R. and Forbes, B.G., 1969. The geology of the *Cultana* 1:63 360 map area. South Australia. Geological Survey. Report of Investigations, 34.

Creaser, R.A., 1989. The geology and petrology of Middle Proterozoic felsic magmatism of the Stuart Shelf, South Australia. La Trobe University. Ph.D. Thesis (unpublished).

Creelman, R.A., 1983. A petrological, mineralogical and lead isotope study of copper in sandstones and related sediments. Macquarie University. Ph. D. thesis (unpublished).

Creelman, R.A., 1976. The mineralogy of the Pernatty Lagoon copper deposits, South Australia. Australasian Institute of Mining and Metallurgy. Proceedings, 257: 9-27.

Creelman, R.A. and Hladky, G., 1986. Copper bearing sulphide minerals in colloform textures from the Pernatty Lagoon copper deposits, South Australia. Geological Society of Australia. Abstracts, 15: 50-51.

CSR Limited and Mount Gunson Mines Pty Ltd, 1983. Geology of the Cattlegrid Mine, 1972-1982. South Australia. Department of Mines and Energy. Open file Envelope, 5429 (unpublished).

Curtis, P.J., 1975a. Petrography of Pandurra thin sections, III. Report PMR 29/75, for Pacminex Pty Ltd. South Australia. Department of Mines and Energy. Open file Envelope, 2273: 218-284 (unpublished).

Curtis, P.J., 1975b. A review of stratigraphic petrography, Pandurra area. Report PMR 127/75, for Pacminex Pty Ltd. South Australia. Department of Mines and Energy. Open file Envelope, 2564: 103-158 (unpublished).

Curtis, P.J.., 1977. Mount Gunson Exploration. Petrography of LY2 DDH deep stratigraphic hole in Pandurra Formation. Report PMR 190/77, for Pacminex Pty Ltd. South Australia. Department of Mines and Energy. Open file Envelope, 3026: 345-435 (unpublished).

Dalgarno, C.R., 1986. Tectonic history of the Stuart Shelf. In: Paterson, H.L., Dalgarno, C.R., Esdale, D.J. and Tonkin, D. Basement geology of the Stuart Shelf region, South Australia. 8th Australian Geological Convention, Adelaide, 1986.

Dalgarno, C.R., Johnson, J.E., Forbes, B.G. and Thomson, B.P., 1968. PORT AUGUSTA, South Australia. Sheet SI/53-4. South Australia. Geological Survey. Geological Atlas, 1:250 000 Series.

Dampier Mining Co. Ltd, 1980. Exploration Licence 645, Cultana, South Australia. Report for the quarter ended 17th September, 1980. South Australia. Department of Mines and Energy. Open file Envelope, 3917: 3-37 (unpublished).

Fanning, C.M., Flint, R.B., Parker, A.J., Ludwig, K.R. and Blissett, A.H., 1988. Refined Proterozoic evolution of the Gawler Craton, South Australia, through U-Pb zircon geochronology. Precambrian Research, 40/41: 363-386.

Fanning, C.M., Flint, R.B. and Preiss, W.V., 1983. Geochronology of the Pandurra Formation. South Australia. Geological Survey. Quarterly Geological Notes, 88: 11-16.

Flint, R.B., in prep. Gairdner Dyke Swarm. In: Handbook of South Australian Geology (revised edition). Geological Survey of South Australia.

Flint, R.B. and Parker, A.J., 1981. The Blue Range Beds, central Eyre Peninsula. South Australia. Geological Survey. Quarterly Geological Notes, 80: 12-15.

Flint, R.B. and Rankin, L.R., 1989. Explanatory notes for the KIMBA 1:250 000 geological map. South Australia. Department of Mines and Energy. Report Book, 90/1.

Gersteling, R.W. and Heape, J.M., 1975. The Cattlegrid Orebody, Mt Gunson, South Australia. In: South Australian Conference, 1975. Part A: Adelaide and Port Pirie. Australasian Institute of Mining and Metallurgy. Conference Series, 4: 103-112.

Giles, C.W., and Teale, G.S., 1981. An investigation of altered volcanic rocks in Bumbarlow 1. South Australia. Geological Survey. Quarterly Geological Notes, 78: 4-10.

Johns, R.K., 1963. Stratigraphic correlations in the Lake Torrens region. South Australia. Geological Survey. Quarterly Geological Notes, 6.

Johns, R.K., 1968. Geology and mineral resources of the Andamooka - Torrens area. South Australia. Geological Survey. Bulletin, 41.

Johns, R.K. and Solomon, M., 1952. *Corunna* map sheet. South Australia. Geological Survey. Geological Atlas, 1:63 360 Series.

Knutson, J., Donnelly, T.H. and Tonkin, D.G., 1983. Geochemical constraints on the genesis of copper mineralisation in the Mount Gunson area, South Australia. Economic Geology, 78: 250-274.

Lambert, I.B., Knutson, J., Donnelly, T.H. and Etminan, H., 1987. Stuart Shelf - Adelaide Geosyncline Copper Province, South Australia. Economic Geology, 82: 108-123.

Lemon, N., 1987. Corunna - Depot Creek - Blinman Field Trip. 30th May - 6th June, 1987. University of Adelaide. National Centre for Petroleum Geology and Geophysics.

Lemon, N. and Gostin, V.A., 1983. Fluvial sedimentology field excursion. Whyalla - Corunna - Depot Creek area. 18th - 20th August, 1983. Australasian Sedimentologists Specialist Group, Geological Society of Australia.

Mason, M.G., 1978. Island Lagoon, EL 301. Sixth quarterly report, 23rd June to 22nd September, 1978, for Australian Selection (Pty) Ltd. South Australia. Department of Mines and Energy. Open file Envelope, 2996: 129-204 (unpublished).

Mason, M.G., Thomson, B.P. and Tonkin, D.G., 1978. Regional stratigraphy of the Beda Volcanics, Backy Point Beds and Pandurra Formation on the southern Stuart Shelf, South Australia. South Australia. Geological Survey. Quarterly Geological Notes, 66: 2-9.

Miles, K.R., 1954. The geology and iron ore resources of the Middleback Range area. South Australia. Geological Survey. Bulletin, 33.

Olliver, J.G. and Nichol, D., 1975. Mt Whyalla barite deposit. Out of hundreds, Co. Manchester. South Australia. Department of Mines. Report Book, 75/63.

O'Shea, P.D., 1982. ELs 935, 710, 713, Lake Hart, Kangaroo Bluff, Fiddle Hill. Report on mapping of the Pandurra Formation. Report WY82.7, for Afmeco Pty Ltd. South Australia. Department of Mines and Energy. Open file Envelope, 3992: 20-67 (unpublished).

Parker, A.J., 1983. Tectonic development of the Adelaide fold belt. In: Adelaide Geosyncline sedimentary environments and tectonic settings symposium, Adelaide, 1983. Geological Society of Australia. Abstracts, 10: 23-28.

Parker, A.J., Fanning, C.M., Flint, R.B., Martin, A.R. and Rankin, L.R., 1988. Archaean-Early Proterozoic granitoids, metasediments and mylonites of southern Eyre Peninsula, South Australia. Geological Society of Australia. Specialist Group in Tectonics and Structural Geology. Field Guide Series, 2.

South Australian Department of Mines and Energy, 1987. Company News. Adelaide and Wallaroo Fertilizers Ltd. In: South Australia. Dept. of Mines and Energy. Mineral Industry Quarterly, 46: 22-23.

Thomson, B.P., 1969. Precambrian crystalline basement. In: Parkin, L.W. (Ed.). Handbook of South Australian Geology. Geological Survey of South Australia: 21-48.

Thomson, B.P. (Compiler), 1980. Geological Map of South Australia. South Australia. Geological Survey. Maps of South Australia Series, 1:1 000 000 scale.

Thomson, B.P., Daily, B., Coats, R.P. and Forbes, B.G., 1976. Late Precambrian and Cambrian geology of the Adelaide "geosyncline" and Stuart Shelf, South Australia. 25th International Geological Congress, Sydney, 1976. Excursion Guide, 33A.

Thomson, B.P and Johnson, J.E., 1968. Marinoan stratigraphy, Port Augusta region. South Australia. Geological Survey. Quarterly Geological Notes, 25: 4-7.

Tonkin, D.G., 1978. Charlinga area. Second quarterly report on exploration for EL 338. Period ending 5th February, 1978. Report PMR 18/78, for Pacminex Pty Ltd. South Australia. Department of Mines and Energy. Open file Envelope, 3025: 105-139 (unpublished).

Tonkin, D.G., 1979. Seventh quarterly report on exploration of EL 332 for period ending 7th March 1979. Pandurra area, South Australia. Report PMR 33/79, for Pacminex Pty Ltd. South Australia. Department of Mines and Energy. Open file Envelope, 3024: 280-310 (unpublished).

Tonkin, D.G., 1980. Report on deep stratigraphic drillhole EC 21. Gunson, EL 543. Report EMR 42/80, for CSR Limited - Minerals Division, Exploration Group. South Australia. Department of Mines and Energy. Open file Envelope, 3703: 433-464 (unpublished).

Tonkin, D.G., 1986. Structural outline of the Stuart Shelf. In: Paterson, H.L., Dalgarno, C.R., Esdale, D.J. and Tonkin, D. Basement geology of the Stuart Shelf region, South Australia. 8th Australian Geological Convention, Adelaide, 1986.

Webb, A.W., 1979. The geochronology of the eastern basement rocks. Progress Report No. 22. South Australia. Department of Mines and Energy. Open file Envelope, 2136: 337-341 (unpublished).

Webb, A.W., Thomson, B.P., Blissett, A.H., Daly, S.J., Flint, R.B. and Parker, A.J., 1986. Geochronology of the Gawler Craton, South Australia. Australian Journal of Earth Sciences, 33(2): 119-143.

Williams, G.E. and Tonkin, D.G., 1985. Periglacial structures and palaeoclimatic significance of a late Precambrian block field in the Cattle Grid copper mine, Mount Gunson, South Australia. Australian Journal of Earth Sciences, 32: 287-300.

Youngs, B.C., 1978. Bumbarlow 1 - well completion report. South Australia. Department of Mines and Energy. Report Book, 78/117.

TABLE 1 DRILLHOLE STRATIGRAPHIC SUMMARY

DRILLHOLE	COMPANY	ENVELOPE	DEPTH TO BASE (METRES)							
				PANDURRA FORMATION						
			CAINOZOIC TO BEDA VOLCANICS/ BACKY POINT BEDS	MEMBER 4	MEMBER 3A	MEMBER 3	MEMBER 2	MEMBER 1A	MEMBER 1	MEMBERS UNASSIGNED
BDH-2	Samedan Oil Corporation	3293	210.3	-	-	-	-	253.72	280.9	-
BDH-3	Samedan Oil Corporation	3293	331.5	-	-	-	-	374.5	380	-
Eba 3	Carpentaria Exploration Co. Pty Ltd	3236	140	400+	-	-	-	-	-	-
Eba 2	Carpentaria Exploration Co. Pty Ltd	3236	150	400+	-	-	-	-	-	-
Eba 1	Carpentaria Exploration Co. Pty Ltd	3236	124	400+	-	-	-	-	-	-
BB-1	Carpentaria Exploration Co. Pty Ltd	3509	66	-	-	-	-	-	-	72
ERD-6	SADME	-	44	-	-	-	-	-	-	111+
ERD-7	SADME	-	34	-	-	-	-	-	-	126+
DP-2	Esso Exploration and Production Inc.	3784	204.5	-	-	-	-	-	-	860+
Peeweena 1	Kennecott Explorations (Aust) Pty Ltd/Samedan Oil Corp.	3002,3067	353.44	-	-	655.6+	-	-	-	-
Playford 1	Kennecott Explorations (Aust) Pty Ltd/Samedan Oil Corp.	3002,3067	442.41	545.05	-	586+	-	-	-	-
Prices Bore 1	Kennecott Explorations (Aust) Pty Ltd/Samedan Oil Corp.	3002,3067	364.02	499.5+	-	-	-	-	-	-
RL-1	Shell Co. of Aust. Ltd	4113	238.22	-	-	-	-	-	-	674.6+
LY-1	Dampier Mining Co. Ltd	3030	9	~530	-	675+	-	-	-	-
BDM-1	Carpentaria Exploration Co. Pty Ltd	2980,3444	266	352	-	400+	-	-	-	-
BDM-2	Carpentaria Exploration Co. Pty Ltd	2980,3444	294	400+	-	-	-	-	-	-
SSR-1001	Aquitaine Australia Minerals Pty Ltd	3878	242.39	-	-	-	-	-	-	499.5+
SAP-1	Australian Selection Pty Ltd	3693	464.5	~853	-	1203.5	1254	-	1369+	-
ACD-1	Western Mining Corporation	Confidential	412.9	-	-	696.85	715.2	-	718.95	-
ACD-2	Western Mining Corporation	Confidential	402.55	-	-	-	-	-	-	431.9
ACD-3	Western Mining Corporation	Confidential	433.2	-	-	513.85	550.5	-	640.1	-

TABLE 1 DRILLHOLE STRATIGRAPHIC SUMMARY

			DEPTH TO BASE (METRES)							
				PANDURRA FORMATION						
DRILLHOLE	COMPANY	ENVELOPE	CAINOZOIC TO BEDA VOLCANICS/ BACKY POINT BEDS	MEMBER 4	MEMBER 3A	MEMBER 3	MEMBER 2	MEMBER 1A	MEMBER 1	MEMBERS UNASSIGNED
ACD-4	Western Mining Corporation	Confidential	486.1	-	-	507.25	520.25	569	576.25	-
ACD-6	Western Mining Corporation	Confidential	482.9	-	-	-	-	567	607	-
ACD-7	Western Mining Corporation	Confidential	448.9	-	-	-	-	463.1	464.3	-
ACD-8	Western Mining Corporation	Confidential	442.9	-	-	508.5	554.6	771.4	795	-
ACD-9	Western Mining Corporation	Confidential	410.2	-	-	607.9	642.95	-	-	-
ACD-10	Western Mining Corporation	Confidential	430.5	-	-	549.85	-	-	550.6	-
ACD-12	Western Mining Corporation	Confidential	452.32	-	-	570.6	609.34	806.71	813.53	-
WRD-16	Western Mining Corporation	Confidential	437.35	-	-	-	-	443.1	443.65	-
HHD-1	Western Mining Corporation	6562	361.1	809.5	-	947.5	1012.2	1121.3	1132.8	-
DRD-1	Western Mining Corporation	6562	118	~825	-	~926	~973	~1050	1067.65	-
LH-1	Dampier Mining Co. Ltd	3022	95	-	-	-	-	-	-	443.2+
LH-2	Dampier Mining Co. Ltd	3022	37.5	225	-	459.7	465	-	507.15+	-
Woomera Bore	Clarence River Basin Oil Exploration Co.	-	453	611+	-	-	-	-	-	-
PPR-3	Australian Selection Pty Ltd	2991	145	160+	-	-	-	-	-	-
CSD-1	Western Mining Corporation	6562	399.3	718.7	-	~839	864.95	-	-	-
WJD-1	Western Mining Corporation	6562	755.95	-	-	-	-	-	827.2	-
ASD-2	Western Mining Corporation	6562	802.32	823.61	-	903.6	945.9	1020	1023.87	-
ASD-1	Western Mining Corporation	6562	522.84	~765	-	866.6	910	-	946.56	-
HWD-1	Western Mining Corporation	6562	839.7	-	-	-	853.7	-	861.2	-
AD-20	Western Mining Corporation	Confidential	162	~292	-	~537.5	-	-	568.5	-
AD-2	Western Mining Corporation	6562	341.58	610	-	776.9	-	812.27	812.52	-
AD-8	Western Mining Corporation	6562	362	656	-	775.9	~783	-	825.5	-
PEB-48	Australian Selection Pty Ltd	Confidential	154	-	-	-	-	-	-	352+
SASC-3	Australian Selection Pty Ltd	Confidential	355	-	-	-	-	-	-	694
PEB-47	Australian Selection Pty Ltd	Confidential	121	-	-	-	-	-	-	352+
SASC-1	Australian Selection Pty Ltd	Confidential	319	-	-	-	-	-	-	380+
SASC-2	Australian Selection Pty Ltd	Confidential	298	-	-	-	-	-	-	517

TABLE 1 DRILLHOLE STRATIGRAPHIC SUMMARY

			DEPTH TO BASE (METRES)							
				PANDURRA FORMATION						
DRILLHOLE	COMPANY	ENVELOPE	CAINOZOIC TO BEDA VOLCANICS/ BACKY POINT BEDS	MEMBER 4	MEMBER 3A	MEMBER 3	MEMBER 2	MEMBER 1A	MEMBER 1	MEMBERS UNASSIGNED
PSC-6	Australian Selection Pty Ltd	Confidential	226	-	-	-	-	-	-	234+
SAR-3	Australian Selection Pty Ltd	2703	222.7	271.0*	-	271.0*	277.1	-	286.44+	-
EC-46	CSR Ltd	3703	150	-	-	-	-	-	-	248
EC-35	CSR Ltd	3703	<200	-	-	-	-	-	366	-
EC-49	CSR Ltd	3703	214	-	-	-	-	-	-	224
EC-48	CSR Ltd	3703	198	-	-	246	252	-	256	-
EC-43	CSR Ltd	3703	132	-	-	-	-	-	-	146
EC-22	CSR Ltd	3703	138	-	-	-	-	-	-	152
EC-44	CSR Ltd	3703	136	-	-	-	-	-	-	146
EC-53	CSR Ltd	3703	84	-	-	-	-	-	-	200+
EC-51	CSR Ltd	3703	264	-	-	-	-	-	-	284
EC-40	CSR Ltd	3703	310	-	-	-	-	-	-	-
SAR-4	Australian Selection Pty Ltd	2703	316	-	-	333.4+	-	346	362	-
SAR-10	Australian Selection Pty Ltd	3693	486.6	-	-	-	-	-	-	503.8+
SAR-2	Australian Selection Pty Ltd	2703	405.11	409.7*	-	409.7*	412	-	415.2+	-
PY-1	CSR Ltd	3703	39.8	432.25	-	590	608.4	631.01	679.65	-
PY-4	CSR Ltd	3703	46.5	-	-	-	-	-	-	562.6
PY-2	CSR Ltd	3703	3	357.7	-	461.63	495.2	509.16	565.43	-
PY-3	CSR Ltd	3703	-	~490	-	591.11	616.07	641.86	663.6	-
EC-21	CSR Ltd	3703	-	314	376	415	442	468	521	-
EC-5	CSR Ltd	3703	215	-	-	-	-	-	-	240
LY-3	Mt Gunson Mines	2330	29.5	246.4+	-	-	-	-	-	-
	Pty Ltd								-	-
LY-2	Mt Gunson Mines Pty Ltd	2330,3026	30	667.4+	-	-	-	-	-	-
BM-1	CSR Ltd	3703	256	700+	-	-	-	-	-	-
LW-67	CSR Ltd	3703	136	-	-	-	-	-	-	148+
LH-1	CSR Ltd	3026	698.38	787.8+	-	-	-	-	-	-

TABLE 1 DRILLHOLE STRATIGRAPHIC SUMMARY

			DEPTH TO BASE (METRES)							
				PANDURRA FORMATION						
DRILLHOLE	COMPANY	ENVELOPE	CAINOZOIC TO BEDA VOLCANICS/ BACKY POINT BEDS	MEMBER 4	MEMBER 3A	MEMBER 3	MEMBER 2	MEMBER 1A	MEMBER 1	MEMBERS UNASSIGNED
Van-guard 1	CSR Ltd	3703	374.39	795.1	-	991.18	1001.2	-	1067.47	-
PIL-9	Australian Selection Pty Ltd	2996	150	203+	-	-	-	-	-	-
PIL-10	Australian Selection Pty Ltd	2996	96	230	300+	-	-	-	-	-
PIL-19	Australian Selection Pty Ltd	4116	-	262	324	352	374	-	390+	-
SAI-1	Australian Selection Pty Ltd	2996	114	320.4+	-	-	-	-	-	-
KGB-4	Afmeco Pty Ltd	4040	3	-	-	23	131	-	198	-
KGB-2	Afmeco Pty Ltd	4040	16	-	-	-	-	-	23	-
KGB-1	Afmeco Pty Ltd	4040	1	-	-	40	67	-	81	-
G-3	PNC Exploration (Aust) Pty Ltd	5868	4	-	-	94	122	-	187	-
MH-1	Dampier Mining Co Ltd	3036	-	15	-	53	59	-	133	-
G-2	PNC Exploration (Aust) Pty Ltd	5868	-	-	-	-	-	-	42	-
PIL-2	Australian Selection Pty Ltd	2996	42	194	228+	-	-	-	-	-
PIL-17	Australian Selection Pty Ltd	2996	2	140	190+	-	-	-	-	-
PIL-16	Australian Selection Pty Ltd	2996	2	100	134	182	230	-	314+	-
PIL-18	Australian Selection Pty Ltd	2996	44	117	158+	-	-	-	-	-
PIL-13	Australian Selection Pty Ltd	2996	6	180	220	281	310	-	381	-
PIL-15	Australian Selection Pty Ltd	2996	-	-	6	54	120	-	140	-
MF-2	Mt Gunson Mines Pty Ltd	2330	71	95+	-	-	-	-	-	-
PIL-5	Australian Selection Pty Ltd	2996	20	180+	-	-	-	-	-	-
PIL-11	Australian Selection Pty Ltd	2996	186	306+	-	-	-	-	-	-

TABLE 1 DRILLHOLE STRATIGRAPHIC SUMMARY

DRILLHOLE	COMPANY	ENVELOPE	DEPTH TO BASE (METRES)							
				PANDURRA FORMATION						
			CAINOZOIC TO BEDA VOLCANICS/ BACKY POINT BEDS	MEMBER 4	MEMBER 3A	MEMBER 3	MEMBER 2	MEMBER 1A	MEMBER 1	MEMBERS UNASSIGNED
PIL-6	Australian Selection Pty Ltd	2996	186	293+	-	-	-	-	-	-
PIL-7	Australian Selection Pty Ltd	2996	167	323+	-	-	-	-	-	-
PIL-14	Australian Selection Pty Ltd	2996	32	115	160	191	219	-	246+	-
PIL-8	Australian Selection Pty Ltd	2996	158	305+	-	-	-	-	-	-
WP-72	CSR Ltd	2627	86	96+	-	-	-	-	-	-
SAR-6	Australian Selection Pty Ltd	2703	215.9	-	-	-	-	-	-	246+
SAR-9	Australian Selection Pty Ltd	3245	330.5	-	-	-	335.4	393.5	-	-
WHD-1	Western Mining Corporation	6562	515.87	618.34	-	621.14	629.69	-	631.98	-
SLT-107	Delhi International Oil Corp.	3769	735.8	-	-	-	-	-	809.3	-
PRL-9	Australian Selection Pty Ltd	2703	110	-	-	-	-	-	-	118+
BK-12	CSR Ltd	3025	73	-	-	-	-	-	-	96+
BK-8	CSR Limited	2627	80	-	-	-	-	-	-	226.1
YD-4	Pacminex Pty Ltd	2564	50	-	-	-	-	-	-	64+
YD-8	Pacminex Pty Ltd	2564	27	-	-	-	-	-	-	42+
YD-6	Pacminex Pty Ltd	2564	24	-	-	-	-	-	-	36+
EX-162	Pacminex Pty Ltd	3024	180	-	-	-	-	-	-	196+
EX-161	Pacminex Pty Ltd	3024	78	-	-	-	-	-	-	100+
EX-160	Pacminex Pty Ltd	3024	66	-	-	-	-	-	-	88+
PDH-12	Australian Selection Pty Ltd	2992	64	-	-	146	156	-	191+	-
PDH-15	Australian Selection Pty Ltd	3635	42	66+*	-	66+*	-	-	-	-
PDH-14	Australian Selection Pty Ltd	3635	68	82+*	-	82+*	-	-	-	-
PDH-5	Australian Selection Pty Ltd	2992	22	148	-	208+	-	-	-	-

TABLE 1 DRILLHOLE STRATIGRAPHIC SUMMARY

DRILLHOLE	COMPANY	ENVELOPE	DEPTH TO BASE (METRES)							
				PANDURRA FORMATION						
			CAINOZOIC TO BEDA VOLCANICS/ BACKY POINT BEDS	MEMBER 4	MEMBER 3A	MEMBER 3	MEMBER 2	MEMBER 1A	MEMBER 1	MEMBERS UNASSIGNED
PDH-6	Australian Selection Pty Ltd	2992	24	-	-	110	140	-	196	-
PDH-8	Australian Selection Pty Ltd	2992	28	-	-	-	52	-	60+	-
PDH-2	Australian Selection Pty Ltd	2992	12	-	-	-	28	-	40+	-
FH-1	Afmeco Pty Ltd	3994	27	-	-	-	-	-	60	-
FH-4	Afmeco Pty Ltd	3994	13	-	-	105	120	-	150	-
FH-5	Afmeco Pty Ltd	3994	7.5	83	-	143	156	-	167.5	-
PDH-1	Australian Selection Pty Ltd	2992	60	-	-	-	-	-	68+	-
EX-173	Pacminex Pty Ltd	3552	121	-	-	-	-	-	-	134+
EX-182	Pacminex Pty Ltd	3552	4.5	66*	-	66*	72.5	-	73.5	-
EX-181	Pacminex Pty Ltd	3552	41	116+*	-	116+*	-	-	-	-
EX-24	Pacminex Pty Ltd	2273	7.5	81*	-	81*	88	-	-	-
EX-109	Pacminex Pty Ltd	2273	3	-	-	-	-	-	-	77+
EX-110	Pacminex Pty Ltd	2273	4	-	-	-	-	-	-	72+
EX-31	Pacminex Pty Ltd	2273	6	-	-	-	-	-	52	-
EX-115	Pacminex Pty Ltd	2273	6	-	-	-	-	-	23	-
EX-33	Pacminex Pty Ltd	2273	30	-	-	-	-	-	78	-
EX-184	Pacminex Pty Ltd	3552	82	-	-	-	-	-	-	104+
6333X-1	Pacminex Pty Ltd	2564	65	-	-	-	-	-	90+	-
PSH-2	Australian Selection Pty Ltd	3410	208	230+*	-	230+*	-	-	-	-
PSH-3	Australian Selection Pty Ltd	3410	288	324*	-	324*	332	-	340+	-
EX-168	Pacminex Pty Ltd	3552	62	-	-	-	-	-	-	80+
EX-41	Pacminex Pty Ltd	2273	41	-	-	-	-	-	-	65.5+
EX-163	Pacminex Pty Ltd	3552	246	-	-	-	-	-	-	272+
EX-82	Pacminex Pty Ltd	2273	3	45	-	90+	-	-	-	-
EX-84	Pacminex Pty Ltd	2273	3	69*	-	69*	72	-	87+	-
EX-57	Pacminex Pty Ltd	2273	6	49*	-	49*	52	-	53	-
EX-58	Pacminex Pty Ltd	2273	3	25.5*	-	25.5*	41.5	-	64+	-

TABLE 1 DRILLHOLE STRATIGRAPHIC SUMMARY

			DEPTH TO BASE (METRES)							
				PANDURRA FORMATION						
DRILLHOLE	COMPANY	ENVELOPE	CAINOZOIC TO BEDA VOLCANICS/ BACKY POINT BEDS	MEMBER 4	MEMBER 3A	MEMBER 3	MEMBER 2	MEMBER 1A	MEMBER 1	MEMBERS UNASSIGNED
6322J-11	Pacminex Pty Ltd	2564	39	-	-	-	51	-	69.5+	-
6322J-21	Pacminex Pty Ltd	3024	92.2	-	-	-	-	-	-	106.9+
6332J-15	Pacminex Pty Ltd	3024	1	-	-	-	-	-	-	120+
6332J-18	Pacminex Pty Ltd	3024	7	-	-	-	-	-	-	81+
6332J-20	Pacminex Pty Ltd	3024	-	-	-	-	-	-	-	66+
Roopena 5	SADME	-	-	-	-	-	-	-	-	400+
UB-1	Dampier Mining Co. Ltd	3828	137.88	-	-	-	-	-	-	161.2+
UB-12	Dampier Mining Co. Ltd	3917	106.04	-	-	-	-	-	-	139.5+
PUB-52	Australian Selection Pty Ltd	3072	62	-	-	144+	-	-	-	-
PTR-1	Australian Selection Pty Ltd	2784	172	-	-	-	-	-	-	198+
CU-3	Dampier Mining Co. Ltd	3917	204	-	-	-	-	-	-	240+
CU-10	Dampier Mining Co. Ltd	3917	207	-	-	-	-	-	-	232.5+

NOTES (1) Interpretation of members within Pandurra Formation largely by author.

(2) Only drillholes with a significant intersection of Pandurra Formation included; numerous holes with short intersections southeast of Woomera are excluded.

(3) Holes in which Pandurra Formation members are unassigned have a poor log, are distant from holes in which the member sequence is established, or intersect a non-diagnostic part of the formation.

(4) * = lower or both members may be present.

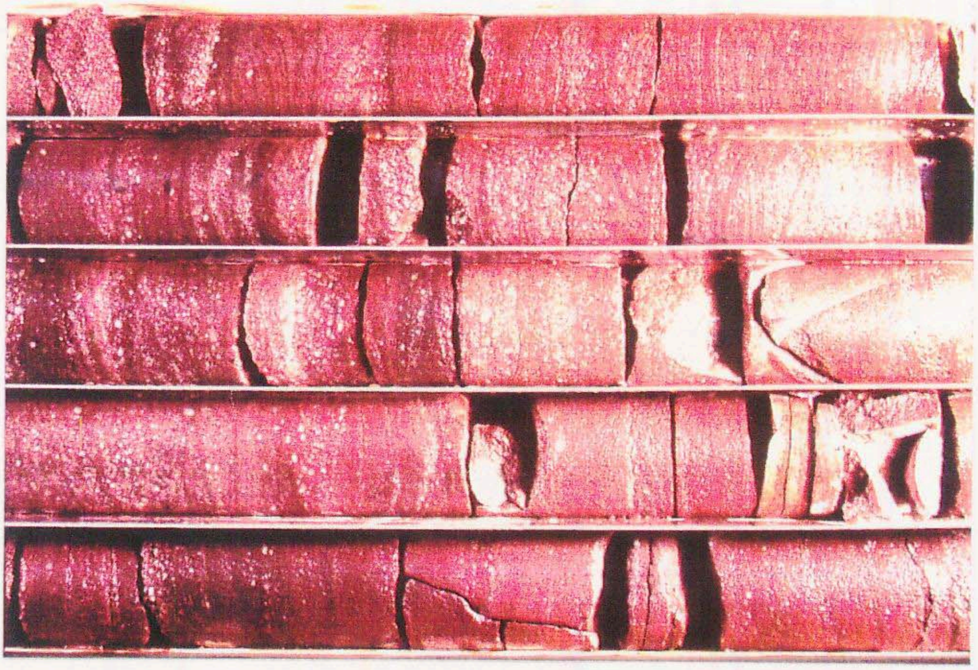
(5) + = hole bottomed in this member.

(6) Holes are arranged approximately from northwest to southeast.

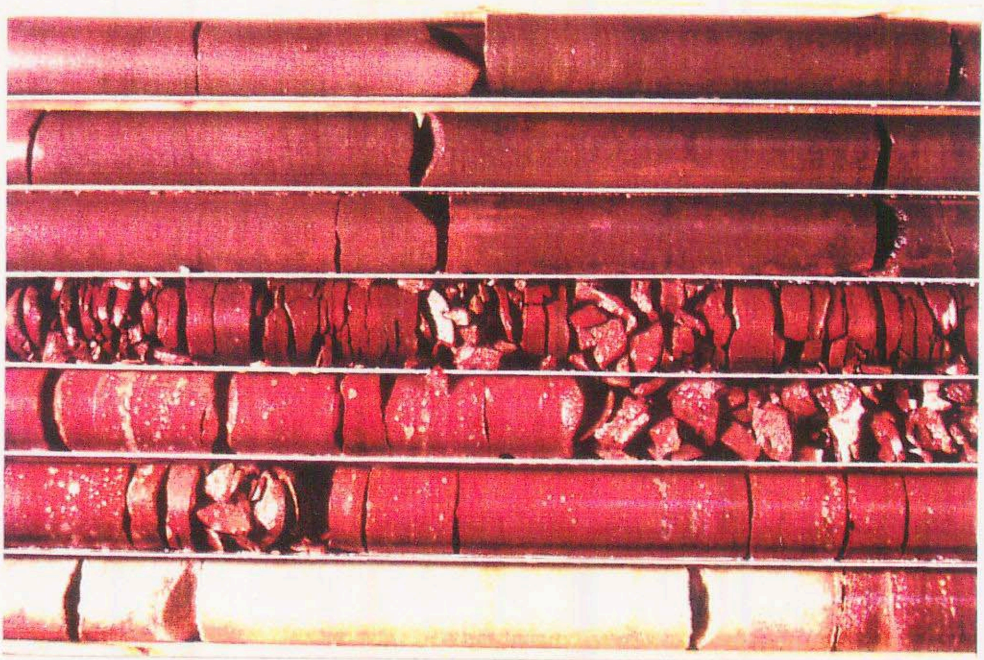
PLATE CAPTIONS

PLATE NO.		PHOTO NO.
1.	CSR PY-1, 50.2 - 54.5m, Member 4. Silicified, coarse to very coarse-grained sandstone with quartz granules, 10-15 m below unconformity with overlying Tapley Hill Formation. Note curvilinear liesegang banding in two upper rows of core, crosscutting bedding.	39217
2.	CSR PY-1, 612.1-618.7m, Member 1A (of Tonkin, 1980). Medium-grained well-sorted sandstone; red-brown shale; red shale and siltstone with scattered granules; off-white (bleached) medium to coarse-grained sandstone.	39218
3.	CSR EC-21, 451.6-458.8m, Member 1A (of Tonkin, 1980). Medium-grained sandstone with numerous bleached bands and blebs.	39219
4.	CSR PY-1, 646.7-653.8m, Member 1 (of Tonkin, 1980). Coarse-grained to fine-pebbly, maroon to grey sandstone. Clasts mainly of quartz and siltstone, minor feldspar.	39220
5.	CSR PY-1, 590.5-597.6m, Member 2. Bright orange-red shale, with reduced green-cream spots and bands.	39221
6.	CSR EC-21, 433.3-439.2m, Member 2. Bright orange-red shale, with thin off-white sandstone interbeds. Disrupted edding in upper two rows of core.	39222
7.	CSR PY-1, 562.2-569.2m, Member 3. Medium-grained, moderately well-sorted sandstone with interbeds and small intraclasts of red-brown shale.	39223
8.	CSR PY-1, 393.7-400.6m, Member 4. Poorly sorted, coarse-grained to granule sandstone displaying typical off-white bleached mottling and indistinct bedding.	39224
9.	CSR PY-1, 85.4-92.4m, Member 4. Poorly sorted, coarse-grained to fine-pebbly sandstone. Clasts are dominantly quartz.	39225

PLATES



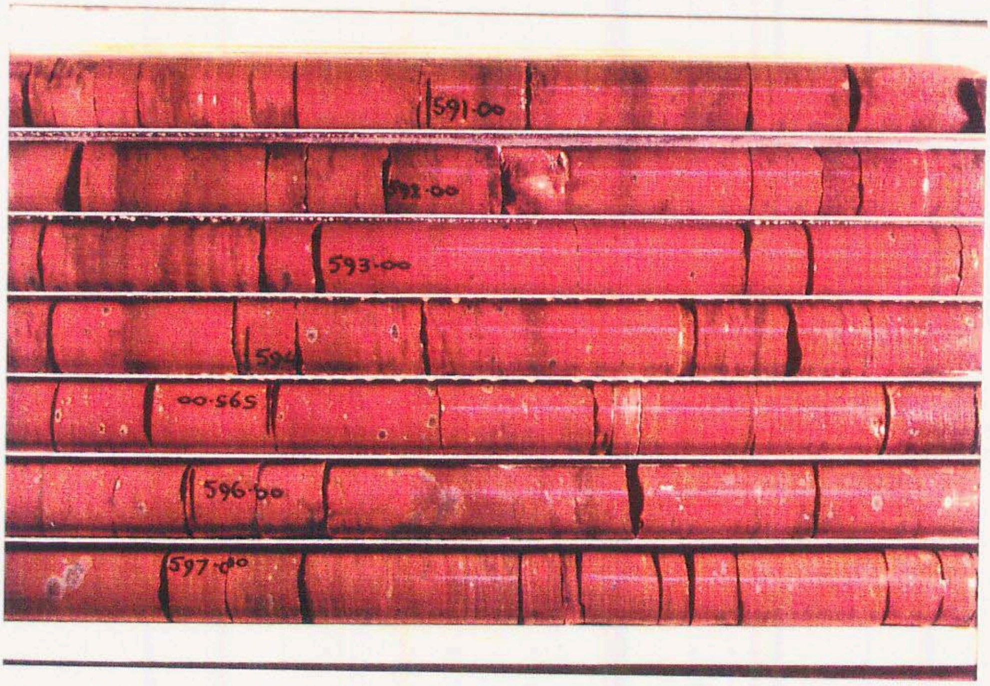
1



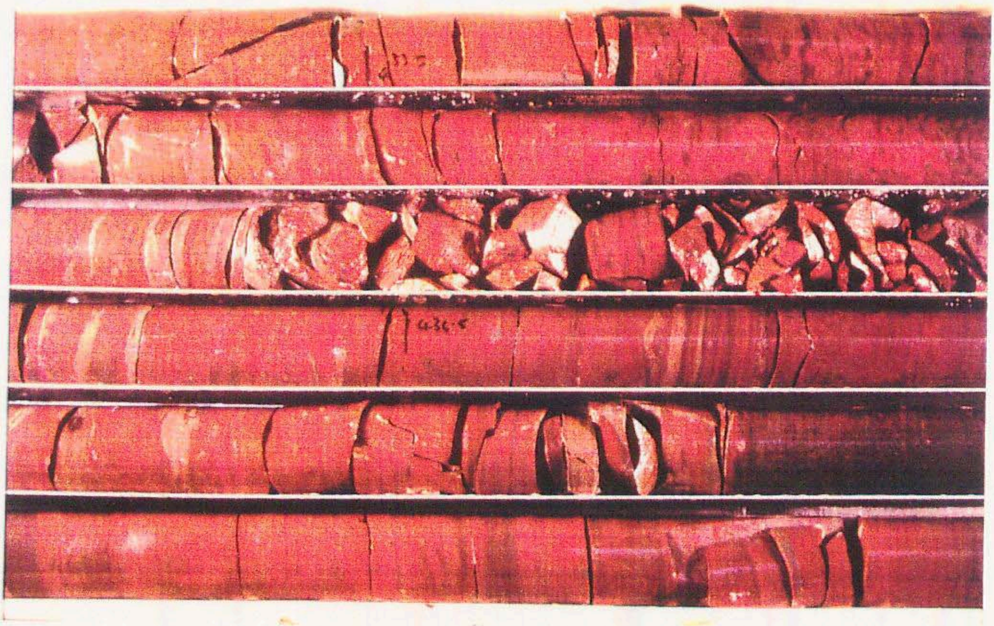
2

3

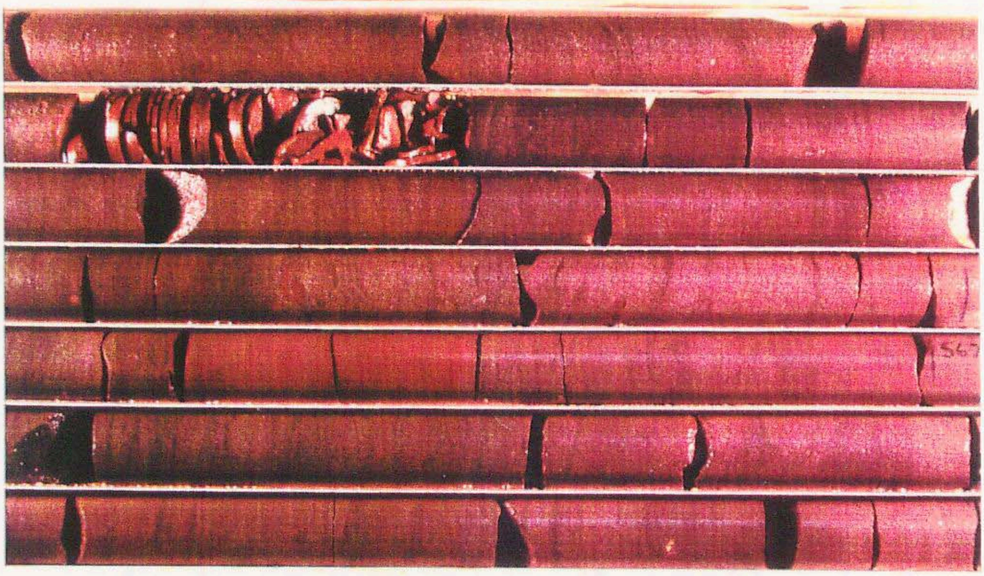
4



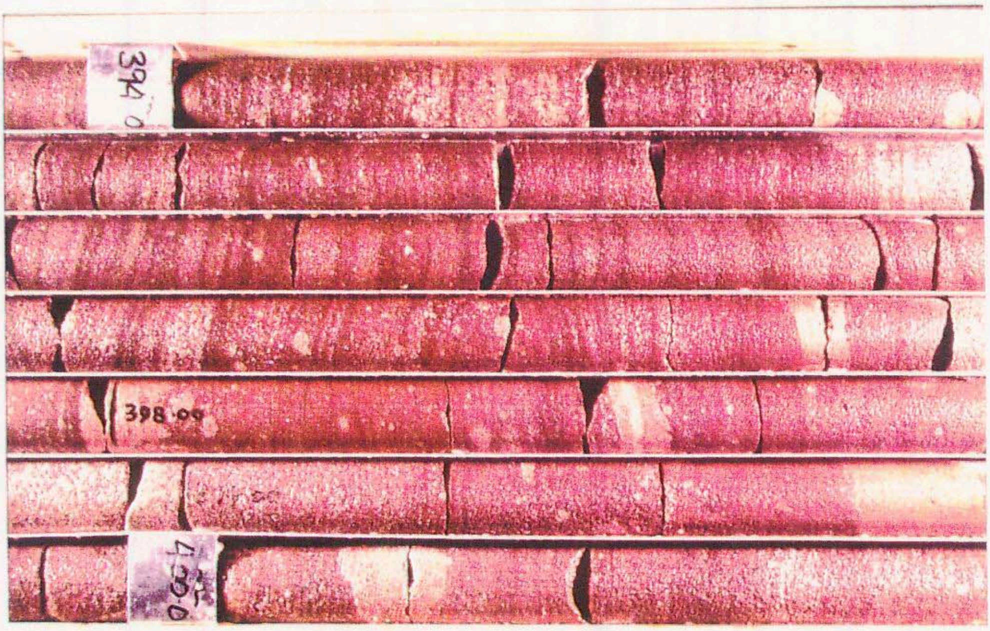
5



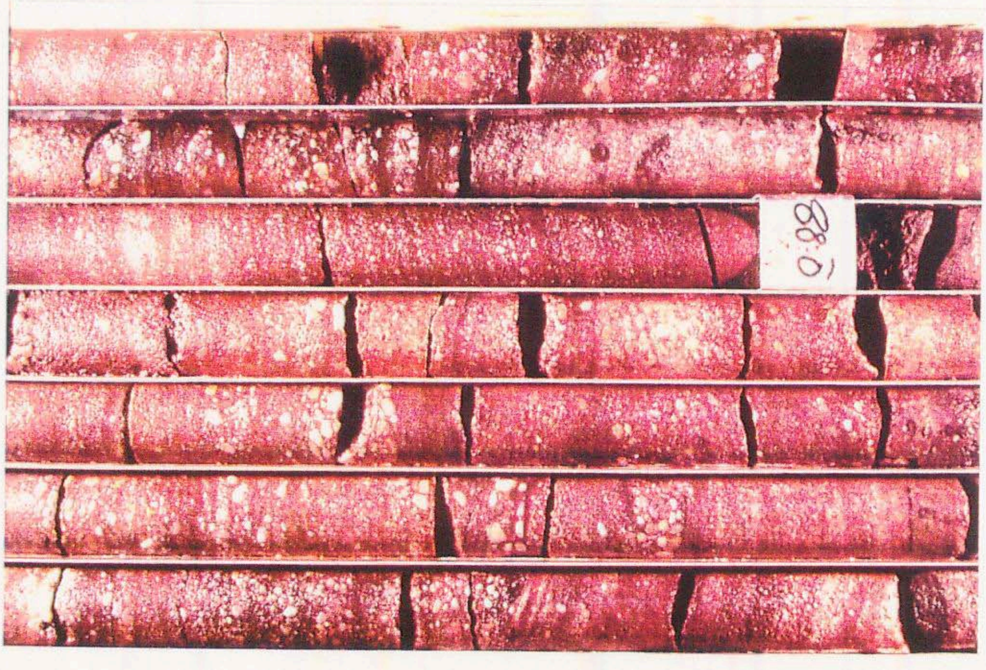
6



7



8



9

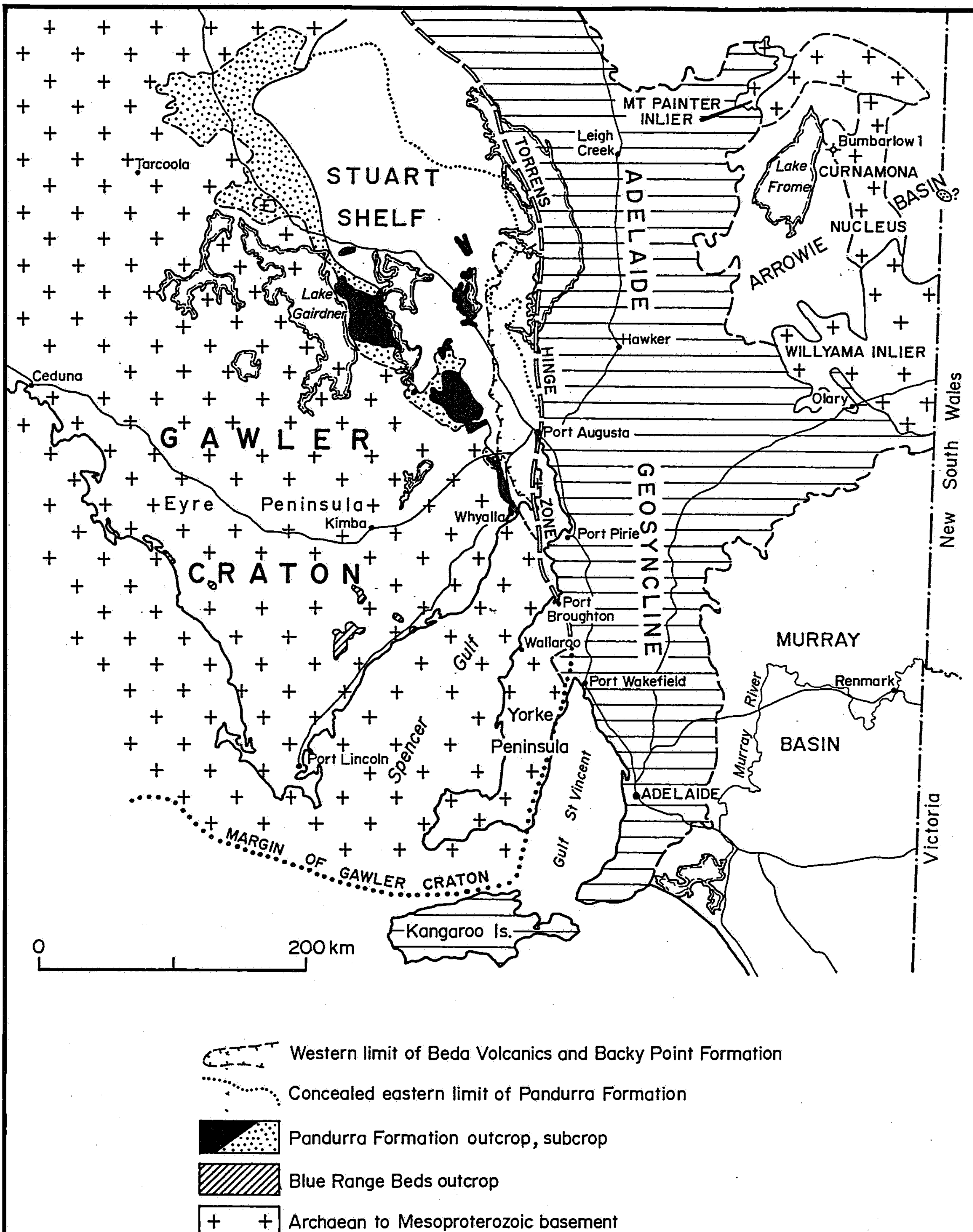
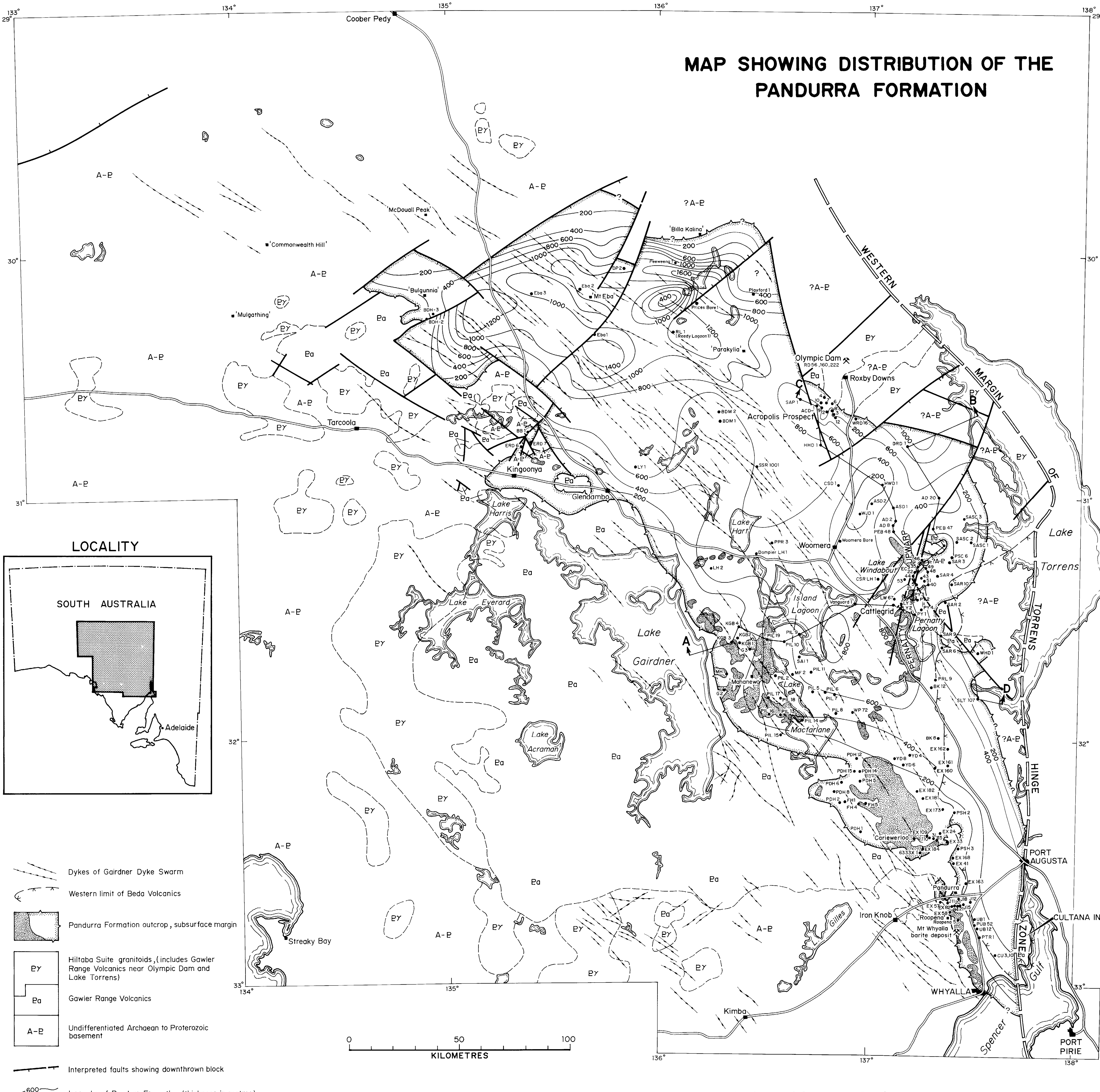


Figure 1

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

REGIONAL LOCALITY MAP OF THE PANDURRA FORMATION	COMPILED W. Cowley	C.D.O. DATE 18·1·91
	DRAWN A.F.	SCALE
	DATE 1·11·90	PLAN NUMBER S21781
	CHECKED	

5137

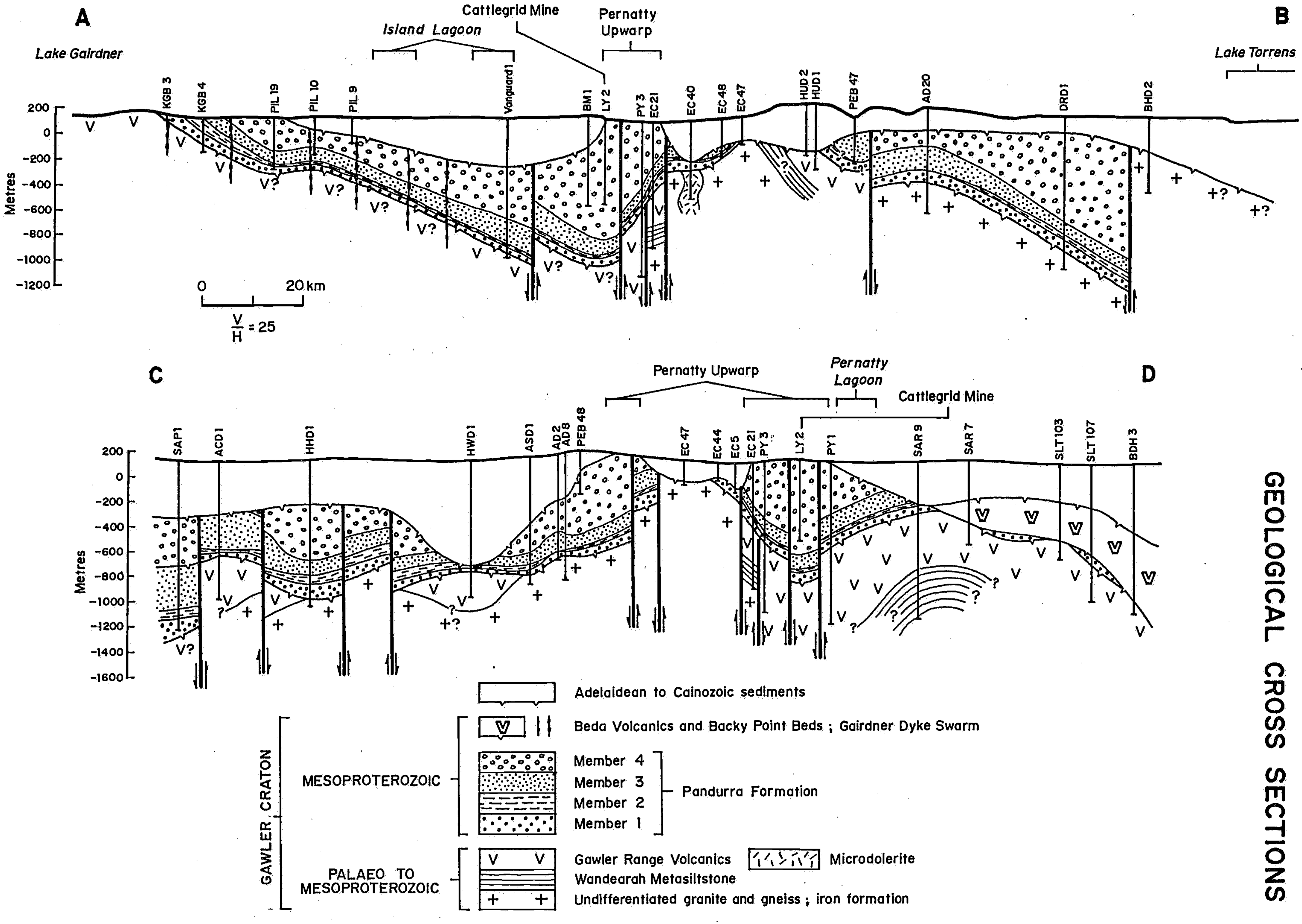


Note: Sections A–B and C–D are shown on figure 4, plan number S 21783

Figure 2

W. M. Cowley, Geologist November 1990

SADME 90-826



PANDURRA FORMATION GEOLOGICAL CROSS SECTIONS

Figure 4
SADME S21783

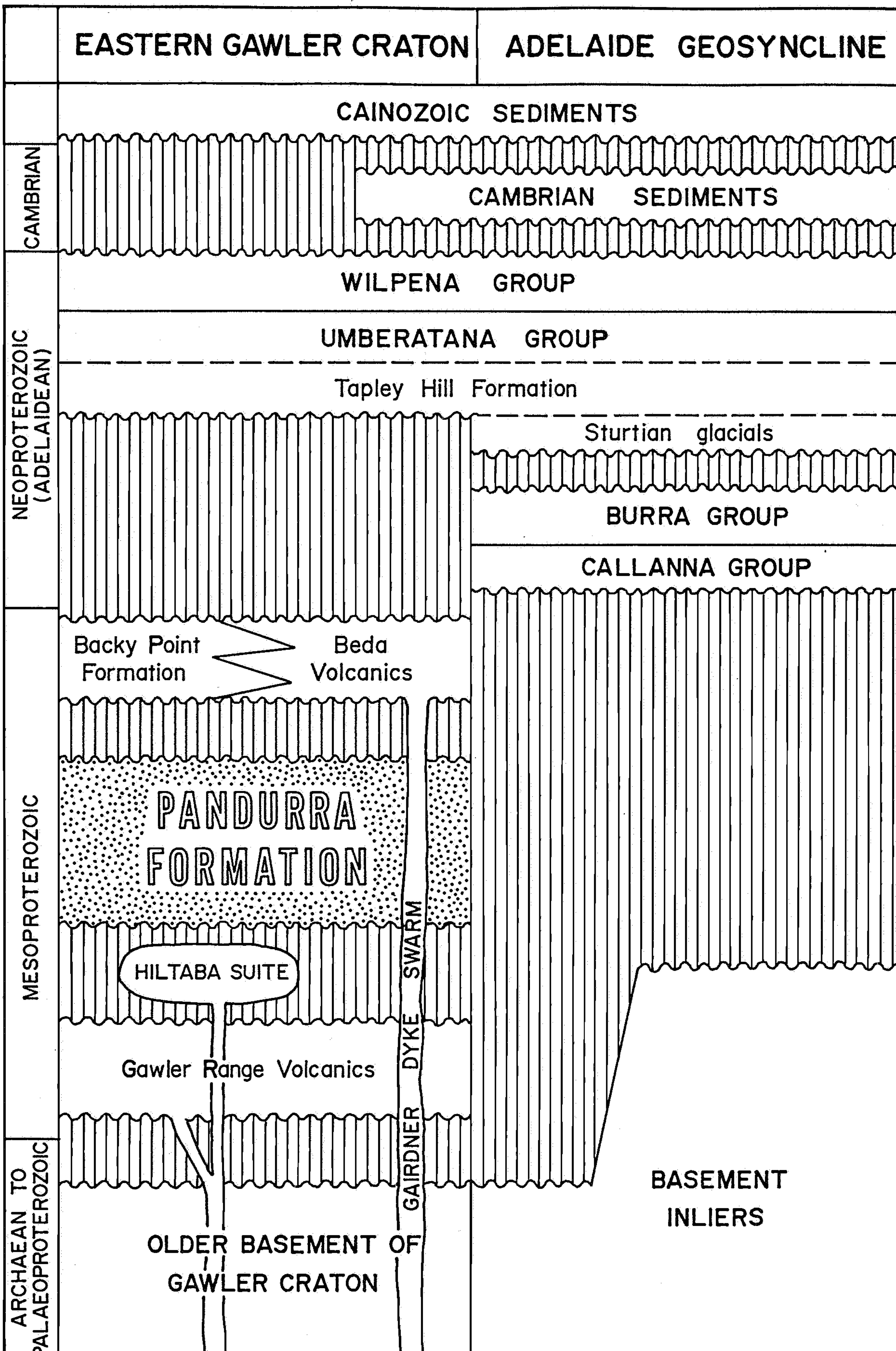


Figure 3. Regional stratigraphy of the Pandurra Formation

SADME S21782

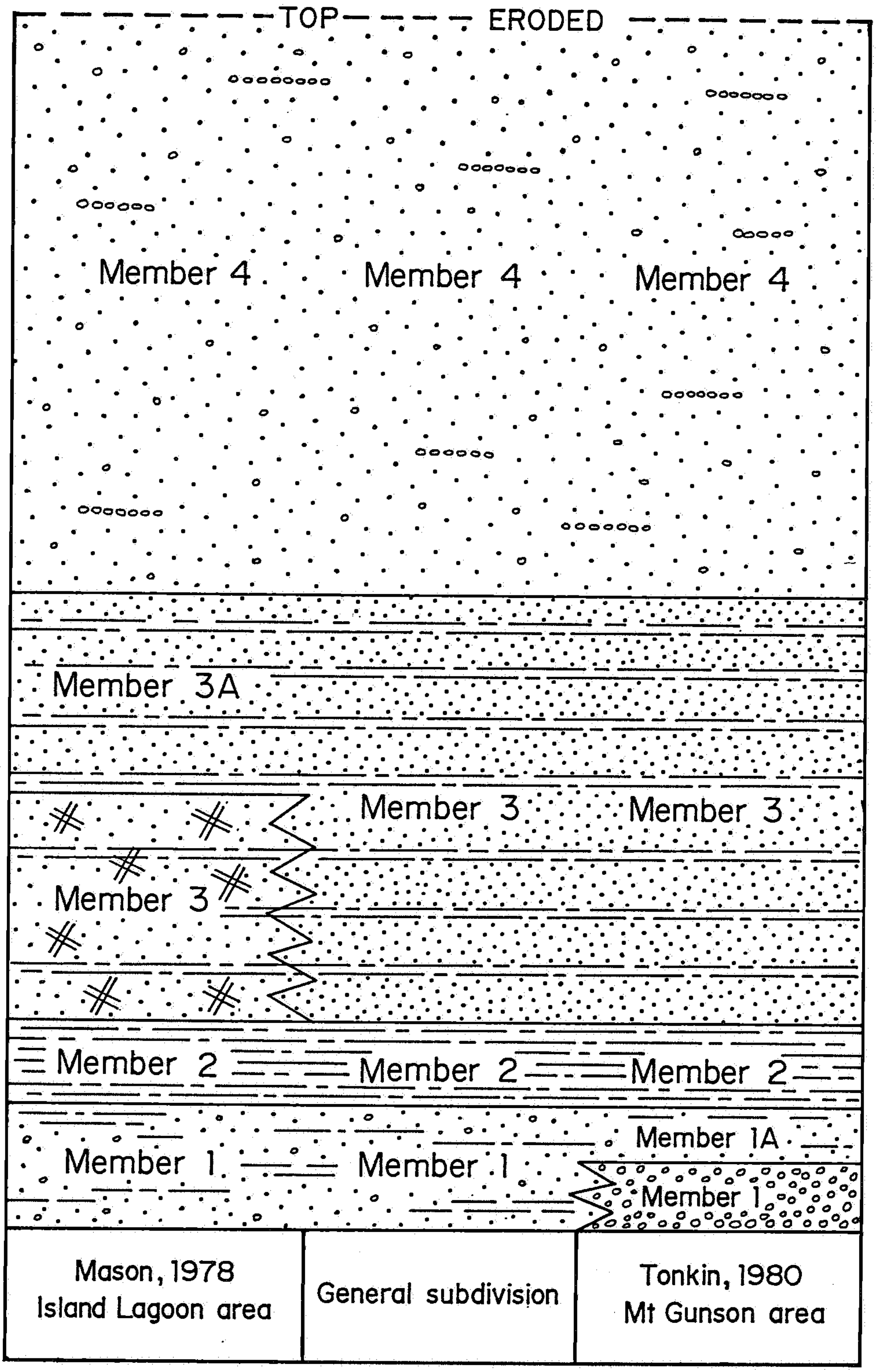


Figure 5. Subdivisions of the Pandurra Formation

SADME S21784