DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

FOURTH INTERNATIONAL SYMPOSIUM

ON ANTARCTIC EARTH SCIENCES

REPT.BK.NO. 83/36

GUIDE TO EXCURSION A, ARCHAEAN, PROTEROZOIC AND LOWER PALAEOZOIC GEOLOGY, EYRE PENINSULA AND THE FLINDERS RANGES, SOUTH AUSTRALIA

GEOLOGICAL SURVEY

by

COATS, R.P., DAILY, B., FANNING, C.M.,
FORBES, B.G., OLIVER, R.L. and PARKER, C.M.

MAY, 1983

DME.325/82

FOURTH INTERNATIONAL SYMPOSIUM ON
ANTARCTIC EARTH SCIENCES

EXCURSION GUIDE A

ARCHAEAN, PROTEROZOIC AND LOWER PALAEOZOIC GEOLOGY OF EYRE PENINSULA AND THE FLINDERS RANGES

A1 Eyre Peninsula
Archaean to Middle Proterozoic Geology
by
Fanning[1], C.M., Parker[2], A.J., and Oliver[3], R.L.

A2 Flinders Ranges
Precambrian Geology of the Adelaide Geosyncline
by
Forbes[2], B.G., Coats[4], R.P., and Daily[3], B.

Cambrian of the Flinders Ranges
by
Daily[3], B.

University of Adelaide, South Australia,
August, 1982.

1. Australian Mineral Development Laboratories, Frewville, South Australia, 5063.
2. South Australian Department of Mines and Energy, Parkside, South Australia, 5063.
3. University of Adelaide, Adelaide, South Australia, 5000.
4. Formerly of South Australian Department of Mines and Energy.

Acknowledgements

The authors gratefully thank the S.A. Department of Mines and Energy for its generous provision of drafting and typing facilities and assistance with compilation by C.G. Gatehouse.

Part A1 of the excursion guide is a modification of an earlier guide produced by the S.A. Department of Mines and Energy, Parker *et al.*, 1981.

Part A2 of the excursion guide is a modification of Excursion Guide No. 33A produced by Thomson *et al.*, (1976) for the 25th International Geological Congress.

CONTENTS PAGE

A1 Eyre Peninsula

A2 Flinders Ranges

List of Localities

A1 Eyre Peninsula

1. Kirton Point, Port Lincoln
2. Cape Carnot
3. Sleaford Bay
4. Cape Donington and Cape Colbert
5. Port Neill
6. Poornamookinnie Creek
7. Cleve Council borrow pit
8. Charleston Granite
9. McGregor Volcanics
10. Moonabie Quarry
11. Moonabie Range - Road cutting
12. Mount Laura

A2 Flinders Ranges

13. Depot Creek
14. Oraparinna Asbestos Mine (disused)

15-20. Branchina Gorge Section.

21. Parachilna Formation Stratotype
22. Blinman Diapir

23 & 24. Arkaba Diapir

List of Figures

A1 Eyre Peninsula

INTRODUCTION

Eyre Peninsula comprises the southern part of the Gawler Craton which was cratonised ca 1400 Ma and geologically forms part of the Central Australian Province (Fig. 1). The Gawler Craton consists of a broad variety of Archaean to Early Proterozoic gneisses, granites, and metasediments, and a range of Middle Proterozoic sediments, volcanics and granites. To the south it is bound by a series of faults defining the continental margin formerly connected to Antarctica (ca Commonwealth Bay in George V Land); to the east it is bound by the Adelaide Geosyncline now forming the Delamerian Fold Belt with the Torrens Hinge Zone delineating the actual boundary; and to the north and northwest it is bound by the Musgrave Orogenic Domain.

STRATIGRAPHY

Late Archaean/Early Proterozoic Stratigraphy

The Late Archaean to Early Proterozoic basement of southern Eyre Peninsula is known as the Sleaford Complex (Fig. 2 and 3).

It is composed of two distinct elements: a highly metamorphosed supracrustal sequence, the Carnot Gneisses (Fanning *et al.*, 1979, and 1981), and slightly younger, high level granitoids, the Coulta Granodiorite, the Whidbey Granite, and the gneissic Kiana Granite (Webb and Thomson, 1977; Webb, 1978 and 1979; Parker *et al.*, 1981): see Fig. 3.

The Carnot Gneisses form an extensive layered sequence which crops out in the central portion of southernmost Eyre Peninsula. A thinly (1-3 cm) layered garnetiferous quartzofeldspathic gneiss is the dominant lithology. This is often intimately intercalated with layers a few centimetres thick of leucogneiss, biotite-garnet gneiss, hypersthene-bearing felsic gneiss and basic granulite. The hypersthene gneisses (± garnet) are also found as distinct meso-layers within the sequence. Basic granulites typically occur intercalated with, and forming boundins in the felsic gneisses. Other less abundant but noteworthy felsic lithologies include augen gneiss, plagioclase gneiss, cordierite garnet gneiss and coarse to medium, even-grained, garnetiferous granite gneiss. Minor calc-silicate gneiss is also present.

Banded iron formations are notably absent from the Carnot Gneisses. However, there are magnetite-bearing, feldspathic gneisses in drill core on central Eyre Peninsula and there are Archaean banded iron formations in the northern Gawler Craton (Daly *et al.*, 1978).

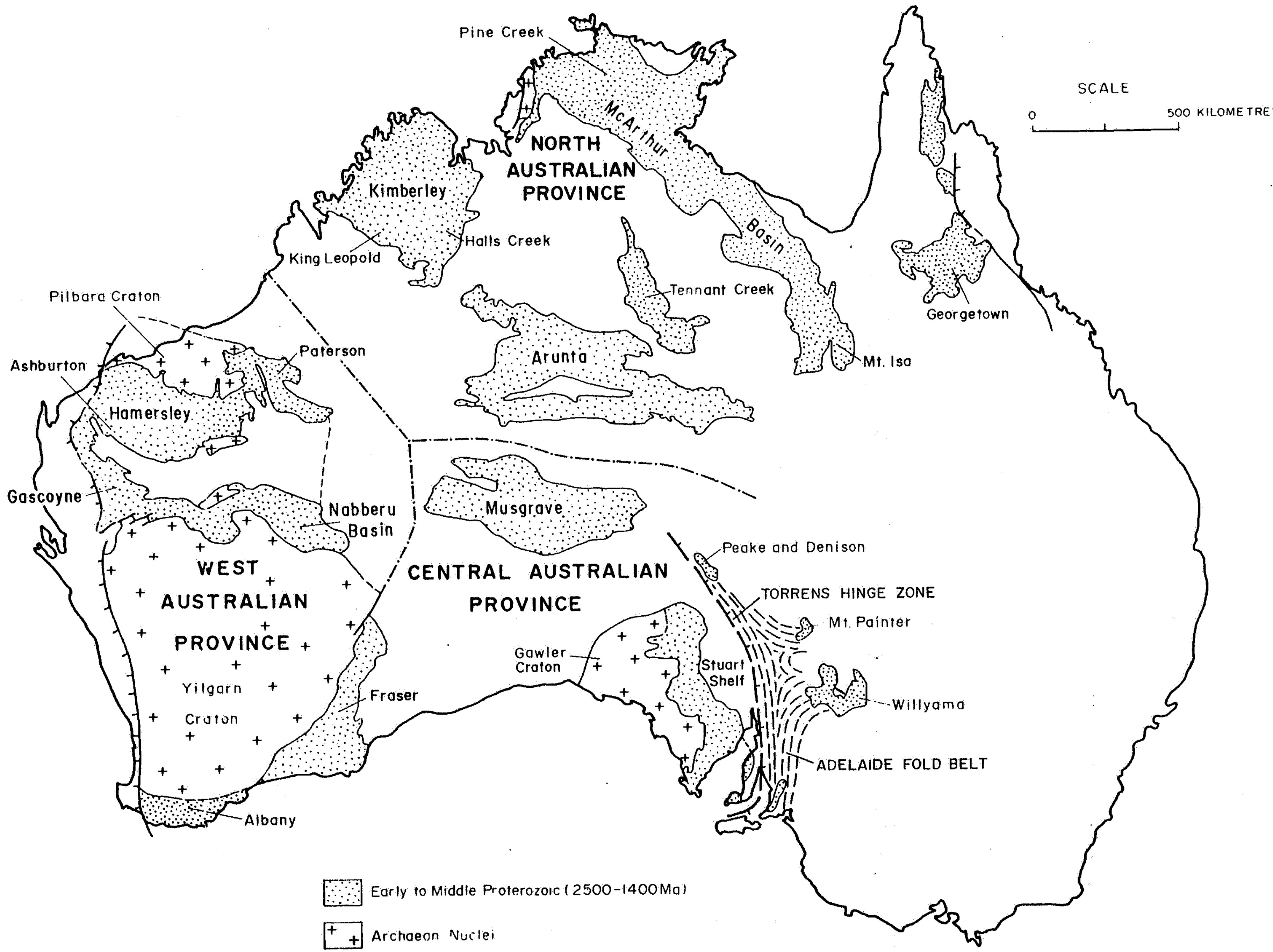

Fig. 1. Setting of the Gawler Craton relative to other Early Proterozoic Provinces of Australia, after Webb et al (in press).

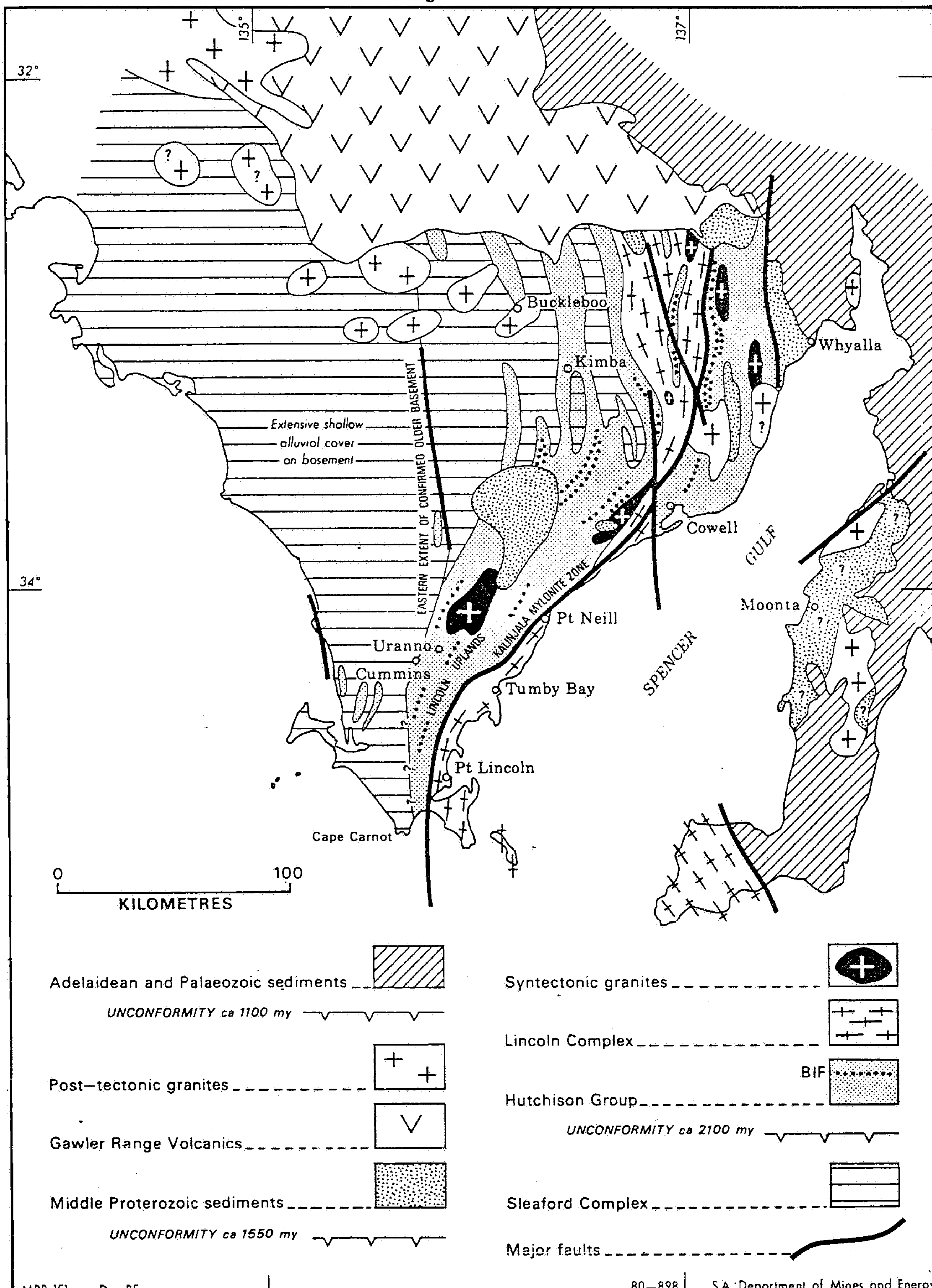

Fig. 2. Regional Precambrian geology of Eyre Peninsula, modified from Rutland _et al_ (1981).

PRECAMBRIAN STRATIGRAPHY OF EYRE PENINSULA

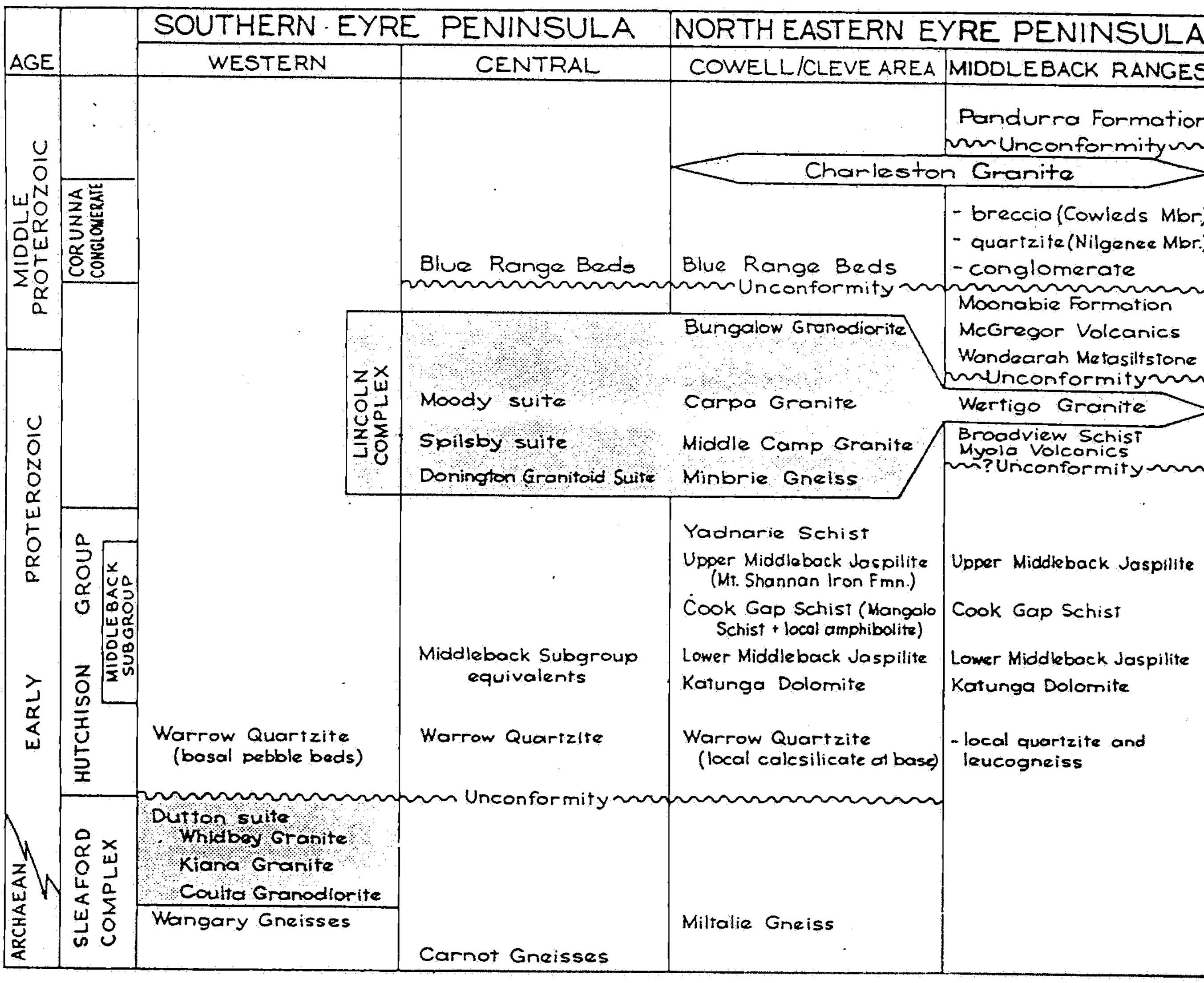

Fig. 3.

The high level granitoids of the Sleaford Complex crop out in the southwest Eyre Peninsula and offshore in the Whidbey Islands (see Fig. 2). These granitoids are intrusive into layered quartzofeldspathic gneisses on Coffin Bay Peninsula and west of Lake Hamilton, however, their relationship to the Carnot Gneisses has not been observed.

In southwest Eyre Peninsula, Webb (1978) has proposed a two-fold subdivision of the granitoids into a northern group which tends to be gneissic with large tabular feldspar phenocrysts (the Kiana Granite), and a southern group which is typically massive and even-grained (Whidbey Granite, see also Webb and Thomson, 1977). This grouping follows closely the distribution of the Rb-Sr analyses of the granitoids on an isochron plot. Those samples assigned to the Kiana Granite define a poorly fitted older isochron, with a calculated age of 2440 $\pm$ 58 Ma and initial ratio of 0.7041 $\pm$ 0.0043 (13 samples, MSWD = 23.8). The Whidbey

Granite samples from the Four Hummocks Islands yield an isochron with little variance outside the expected experimental error (MSWD = 4) and a calculated age of 2387 $\pm$ 65 Ma and initial ratio of 0.7019 $\pm$ 0.0028 (Webb and Thomson, 1977).

Recent mapping in the Marble Range to Point Drummond region (Fanning, in prep.) indicates that there are at least two granitoid types. An earlier granodiorite phase with abundant mafic xenoliths (the Coulta Granodiorite) and a later, intrusive, tabular feldspar granite phase (the Kiana Granite). There are also some granite gneisses of unknown origin. These either represent the basement into which these granitoids intruded, or they could simply be more deformed varieties of the intrusive suite.

Prominent shear zones are seen at Point Drummond and elsewhere on southern Eyre Peninsula. In these zones massive or foliated granitoids are typically transformed into crenulated schists.

Early Proterozoic Stratigraphy

Early Proterozoic metasediments and metavolcanics in eastern Eyre Peninsula are represented by the Hutchison Group, the Myola Volcanics, and the Broadview Schist (Fig. 3).

The stratigraphy has only been clearly resolved in recent years due to the application of detailed structural studies (Parker, 1978; Parker & Lemon, 1982). The Hutchison Group is a mixed clastic and chemical sequence consisting of a basal quartzite unit, the Warrow Quartzite, a number of mixed chemical/clastic units dominated by various carbonates and iron formations collectively referred to the Middleback Subgroup, and an upper psammopelitic unit, the Yadnarie Schist (Fig. 3).

At Marble Range and in adjacent areas on southwest Eyre Peninsula, Warrow Quartzite directly and unconformably overlies Sleafordian basement. The quartzites are massive, locally cross-bedded, and near the base contain distinct quartz pebble conglomerate beds. To the east and northeast sedimentary features have not been observed, but there is a suggestion that this region represents a more distal facies. North of Cleve local calc-silicate/dolomite/podded sillimanite gneiss occurs at the base, and in the upper Warrow Quartzite there are a number of pelitic schist interbeds. Parker and Lemon (1982) believe that the Warrow Quartzite represents a fluvial to marginal marine, sandy arkose sequence with fluvial sediments represented in the west and more distal, progradational marine sediments represented in the east. Mixed chemical and clastic metasediments of the Middle back Subgroup represent a number of cyclic transgressions and regressions across a shelf, or major basin deepening to the east.

The pelitic schist interbeds at the top of the Warrow Quartzite represent the onset of the first transgression. They are overlain sequentially by dolomite (Katunga Dolomite), carbonate facies iron formation, silicate facies iron formation and oxide facies iron formation believed to represent progressively deepening water and more distal sedimentary facies. The iron formations are known collectively as the Lower

Middleback Jaspilite. Regressive sedimentation following this sequence is represented by the influx of clastic sediments seen as the Cook Gap Schist. The Upper Middleback Jaspilite represents a second major transgressive cycle and the overlying Yadnarie Schist represents the return to clastic sedimentation. Minor local perturbations superimposed on these macroscopic facies variations are clearly evidenced by the "meso-banding" well developed in the Upper Middleback Jaspilite. In places, alternating dolomite and jaspilitic chert bands several millimetres thick represent minor cyclic pulses superimposed on the regional cycle. This "mesobanding" may be analogous to mesobanding in classical Hammersley Group iron formations (e.g. Trendall, 1976) and "microbanding" within the chert bands would support this analogy.

Acid volcanics are not known on central and southern Eyre Peninsula, but east of the Middleback Ranges there is a prominent sequence of weakly metamorphosed rhyolites and rhyodacites known as the Myola Volcanics. These are associated with gabbroic amphibolites, fine-grained laminated quartzites, and slaty schists, the Broadview Schist unit. They are believed to represent a volcanosedimentary sequence slightly younger than, but deformed with, the Hutchison Group.

Middle Proterozoic Stratigraphy

Middle Proterozoic sediments and volcanics on Eyre Peninsula are the McGregor Volcanics (ca 1615 Ma), Moonabie Formation, Corunna Conglomerate, Gawler Range Volcanics (ca 1525 Ma) and Pandurra Formation. The McGregor Volcanics occur as steeply-dipping acidic, welded, ash-flow tuffs derived from melting of a lower crustal source, and basaltic lava flows derived from a mantle source (Giles *et al.*, 1979).

Overlying the McGregor Volcanics are massive, very poorly bedded, volcanoclastic grits of the Moonabie Formation. They contain a mixture of acid volcanic and chert clasts in an immature matrix and indicate rapid erosion of the underlying volcanic pile.

In Moonabie Range, the Corunna Conglomerate which is thought to have been deposited synchronously with the lower Gawler Range Volcanics, consists of basal conglomerates overlain by a probable marine, heavy mineral bearing sandstone which intertongues to the east with a rapidly deposited talus breccia. The breccia coarsens eastwards, containing angular clasts up to 0.5 metres in diameter, and was probably deposited from an ancient escarpment perhaps coinciding with the present day Moonabie Scarp (Parker, 1980a).

Deposition of the Corunna Conglomerate, extrusion of the Gawler Range Volcanics, postorogenic granitic intrusion (e.g. Charleston Granite), and local deformation (D_4), represent the final events leading to cratonization of the Gawler Craton.

Middle to Late Proterozoic

The Pandurra Formation is generally regarded as the earliest unit to be deposited on the Stuart Shelf. It unconformably overlies the Roopena Volcanics (basalts) and is in turn, disconformably overlain by the Beda Volcanics and Backy Point Beds regarded as basal Burra Group in this region (Mason et al., 1978). The Pandurra Formation is a fluvial sequence of arenites, commonly feldspathic, kaolinitic and exhibiting characteristic fossil liesegang weathering bands. It was probably deposited in a series of northwest trending grabens and reaches a maximum thickness that exceeds 600 m (Rutland et al., 1981).

N.B. Contrary to earlier beliefs the Roopena Volcanics are considered to be related to Gawler Range Volcanics (Giles and Teale, 1979) rather than early Adelaidean Volcanics. In the Roopena DDH6 drillhole they overlie (though they may interfinger with) conglomerates of Corunna Conglomerate affinity, and these in turn, overlie typical Moonabie Formation grit.

STRUCTURE

Thomson (1980) and Parker and Lemon (1982) have recognised a number of major tectonic subdivisions of the southern Gawler Craton. This excursion will traverse mainly the Cleve Subdomain, an Early Proterozoic orogenic belt ("mobile zone") probably representing a former shelf or basinal depository for the Hutchison Group, prior to its deformation.

Two major periods of complex deformation, metamorphism and plutonism have been recognized in the Cleve Subdomain. They are the Sleafordian Orogeny which culminated ca 2300 Ma and the Kimban Orogeny which extended from ca 1820 Ma to ca 1580 Ma (Webb, 1978; Webb et al., in prep.). The Sleafordian Orogeny was a high-metamorphic-grade gneiss-forming event(s) accompanied by both mafic (early) and acid (late) plutonism. Because of overprinting by the subsequent Kimban Orogeny, resolution of the exact nature of the Sleafordian Orogeny has not been possible, although some specific plutonic events have been dated.

The Kimban Orogeny was very intense within the Cleve Subdomain and three main tectonic events can be identified: an early high-grade upper amphibolite to locally granulite facies metamorphic event, D_1; a high-grade, isoclinal fold event possibly with associated thrusting, D_2; and a lower-grade, open fold event, D_3, with associated development of major mylonite zones (see Fig. 4). Principal structural characteristics of each of these events are outlined by Glenn et al., (1977), Parker (1978), and Parker and Lemon (1982).

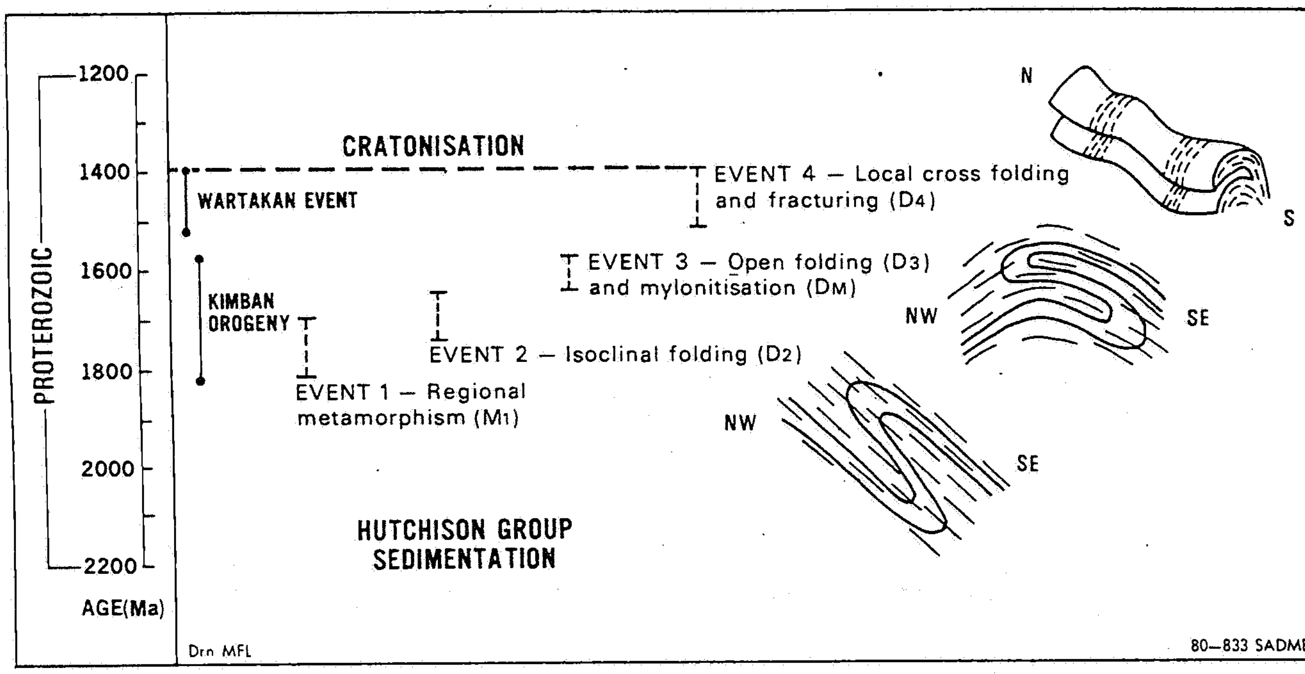

Fig. 4. Proterozoic tectonic evolution of Eyre Peinsula, from Parker and Lemon (1982).

Throughout the Cleve Subdomain there is local evidence for post-D_3 tectonism in the form of cross folding, fracturing and the development of major lineaments and/or shear zones. This event (D_4) is known as the Wartakan Event and affected not only basement but also the Corunna Conglomerate. Nephrite jade at Cowell was formed during this event.

Subsequent tectonism in the southern Gawler Craton is largely restricted to local tensional tectonics such as graben development during the onset of Adelaidean sedimentation (e.g. the Pandurra Formation depository trending northwest of Whyalla), dolerite dyke intrusion probably during late Pandurra to early Willouran time (see A2 of this excursion guide), and block faulting or graben development during Tertiary to Recent time. Cratonization of the Gawler Craton is believed to have occurred ca 1450 Ma so these later tensional effects were intracratonic.

METAMORPHISM

In southernmost Eyre Peninsula, the Carnot Gneisses were subjected to a prograde granulite facies event at ca 2400 Ma (Fanning et al., 1979). Pressure-temperature estimates for this event are 800-900°C at a total pressure of 7-9 Kb. The muscovite-bearing granitoids (Kiana and Whidbey Granites) intruded grey layered, quartzofeldspathic gneisses late during the Sleafordian Orogeny. These layered gneisses perhaps reached low to middle amphibolite facies during this time, but this is uncertain due to the extent of Kimban overprinting, in particular shearing.

The structural and metamorphic development of the Kimban Orogeny is far better preserved due to the stabilisation of the Gawler Craton not long after orogeny. On central Eyre Peninsula, D_1 and D_2 of the Kimban Orogeny were both high grade, pervasive metamorphic events of upper amphibolite facies and estimated P-T conditions are ca 600-700^{0}C at a total pressure of 5-7 Kb. D_3 and D_4 were retrograde events and lower P-T conditions are evident.

The peak, prograde, metamorphic conditions in southern Eyre Peninsula tend to be higher for the D_1 and D_2 events of the Kimban Orogeny. Mortimer et al. (1979) propose that primary crystallisation of the Donington Granitoid Suite took place at ca 900^{0}C and ca 8 kb. However, it is likely that only southernmost Eyre Peninsula was subjected to such high grade conditions early in the Kimban Orogeny.

GRANITOIDS

In the southern Gawler Craton four temporally distinct granitoid suites have been identified: the Late Archaean/Early Proterozoic Dutton suite (Kiana and Whidbey Granites); the Early Proterozoic Donington Granitoid Suite; the slightly younger Early Proterozoic Spilsby and Moody suites; and the post-orogenic Middle Proterozoic Hiltaba suite.

The Donington Granitoid Suite is comprised of a broad spectrum of granitoids which ranges from quartz gabbronorite, through hypersthene granite and late-stage leucogranite (see Localities 1 and 4). Mortimer et al. (1979) consider that these granitoids evolved through a crystal fractionation process and were emplaced at ca 1810 Ma during the first tectonic event of the Kimban Orogeny. Deformation during later events of the Kimban Orogeny has resulted in the development of a folded gneissic fabric and variable retrogression of the primary pyroxenes to hornblendes.

The Spilsby suite crops out in the Sir Joseph Banks Group of islands located in Spencer Gulf east of Port Lincoln. This suite is composed of hornblende granite and tabular feldspar granite which are seen to intrude more deformed, megacrystic granite and granite of the Donington Granitoid Suite. The Spilsby suite is massive to foliated and the presence of shear zones implies emplacement prior to the third tectonic event of the Kimban Orogeny.

Even grained granite, porphyritic granite (with tabular feldspars), adamellite, leucogranite and syenite comprise the Moody suite. These granitoids appear to form a series of related plutons that vary from massive granitoid to a more foliated porphyritic granite with aligned tabular feldspar phenocrysts. The Moody suite contains xenoliths of gneissic material and garnet is common in the Moody Tank outcrop. Rb-Sr whole rock measurements do not yield a unique isochron solution but do suggest a possible age of emplacement between ca 1600 and 1700 Ma, late in the Kimban Orogeny.

The youngest of the granitoids is the post-tectonic suite represented by the circular Charleston Granite pluton. It is a massive, homogenous, phenocrystic granite and intrudes all lithologies up to and including the Corunna Conglomerate. The isotopic analyses present a confusing picture, but the Charleston Granite is correlated with the Hiltaba and Buckleboo Granites for which ages of 1478 ± 38 Ma and 1477 ± 34 Ma respectively have been determined (Webb et al., in prep.).

LOCALITY DESCRIPTIONS, EYRE PENINSULA

LOCALITY 1 (KIRTON POINT, Fig. 5a).

"The most characteristic rocks of the Lincoln area is a coarse grained augen-gneiss which is developed in the type-section of Kirton Point near the jetty of Port Lincoln", Tilley (1921a).

A megacrystic granite gneiss cropsout at the boat ramp. It consists of large microcline and microcline perthite megacrysts, on average 2-3 cm in diameter, set in a coarse-grained matrix of quartz, plagioclase, orthoclase, and biotite. Hornblende may also be present. Typical accessory minerals include apatite, sphene, zircon, magnetite, and ilmenite. The rock has a well developed foliation and appears to have been subjected to at least D_2, D_3 and D_4 of the Kimban Orogeny (cf Fig. 4). The degree of deformation is variable and in places this lithology resembles an augen gneiss (cf Tilley, 1921c).

At least three different types of basic rocks can be recognised at Kirton Point: dolerites, veined and unveined amphibolites. The dolerites are essentially undeformed and preserve primary igneous ophitic textures. Clearly these are late stage basic intrusions.

The relative age of the amphibolites, however, is debatable. Adjacent to the boat ramp there is evidence to suggest that a suite of amphibolites existed prior to the emplacement of the megacrystic granite phase. Veins extend from the granite gneiss into the amphibolite and disrupted blocks of amphibolite can be seen within the granite near the amphibolite margins. Notwithstanding the possibility of back veining of the granite contemporaneous with intrusion of a high temperature basic magma, it is felt that at least some of the amphibolites predate the granitoids (see also Tilley, 1921c; Flook, 1975). Further support for this concept comes from the presence of mafic xenoliths within the granitoids.

Other amphibolites have very sharp contacts with the surrounding granitoids and the foliation direction in the amphibolites parallels that in the granitoids. It is suggested that these amphibolites are intrusive into the granitoid suite and subsequently metamorphosed and deformed.

Flook (1975) describes two types of amphibolite. One has a hornblende ± plagioclase ± quartz + biotite assemblage and can be seen in outcrop to be intensely veined. The other type is not as intensely veined and contains a hornblende + plagioclase + potash feldspar + quartz ± biotite assemblage. In one instance a boundary between these two amphibolite types is cut by a granite gneiss (Flook, 1975). This relationship will be examined.

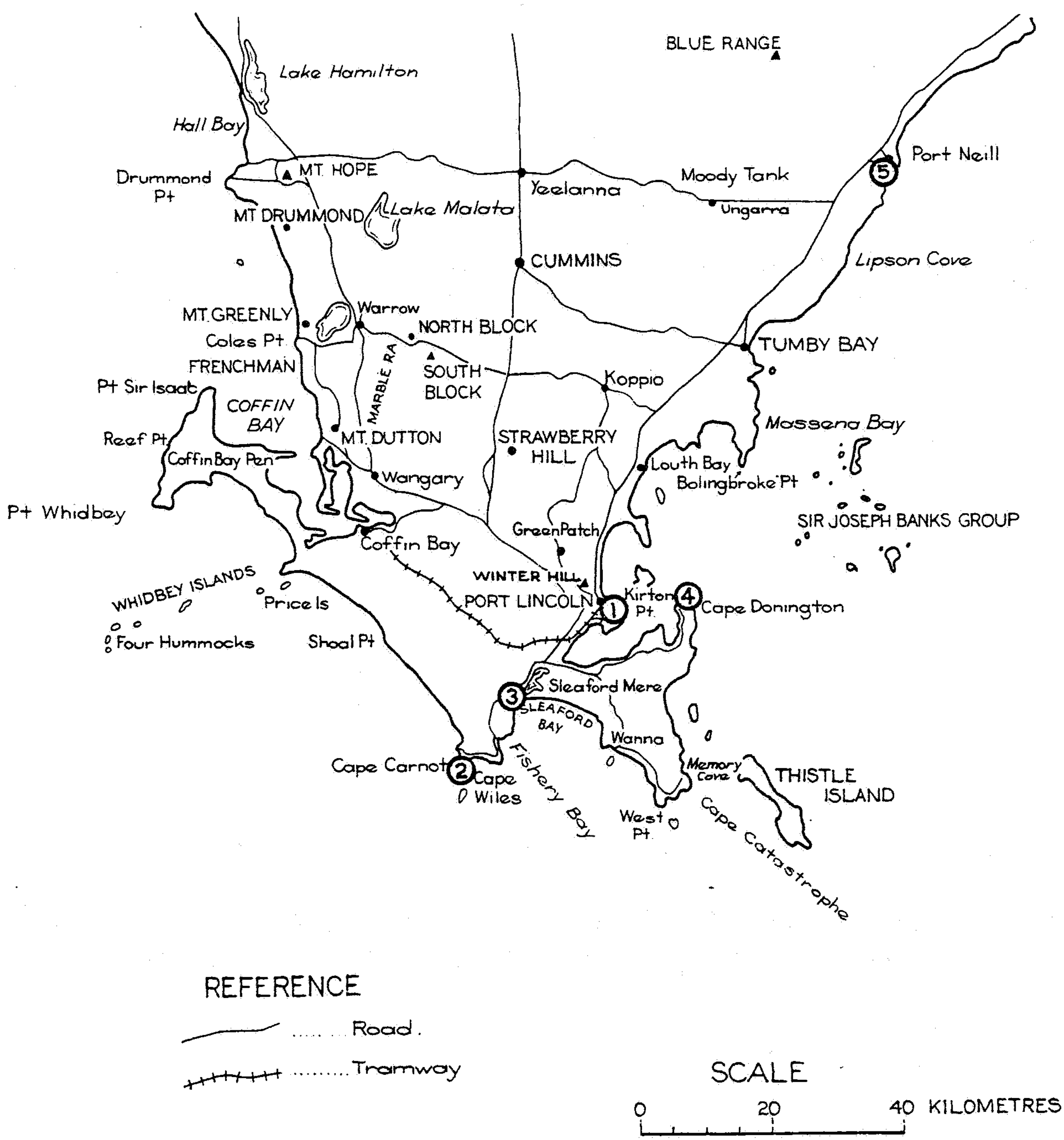

Fig. 5a. Locality plan for southern Eyre Peninsula.

Fig. 5b. Locality plan for northeastern Eyre Peninsula.

The other prominent lithology which crops out at Kirton point is an even-grained granite gneiss. In places this grades into a megacrystic granite gneiss. Mineralogically the even-grained phase consists of microcline, plagioclase (andesine) quartz and biotite, with sphene, magnetite, apatite, and zircon present in accessory amounts. Minor green hornblende may also be present. This lithology bears a close resemblance to the granite gneiss seen to intrude the hypersthene granitoids at Cape Donington (Locality 4).

Aplites and pegmatites constitute later intrusive phases, for the most part preceeding emplacement of the dolerites. Pegmatitic veins within the amphibolites outline D_2 folds whereas within the megacrystic granite gneiss some of the pegmatitic segregations seem to be sweating out along the axial planes of D_4 folds (Fig. 4).

Metamorphism and Age

For the most part it is envisaged that the primary igneous crystallisation conditions are essentially similar to those discussed for Cape Donington (see Locality 4). The general absence of hypersthene within the gneisses and lighter colour of the feldspar has led Mortimer et al. (1979) to suggest that the lower grade amphibolite facies retrogression has had a marked effect at Kirton Point.

Flook (1975) and Cooper et al. (1976) report the results of Rb-Sr measurements on nine samples of the even-grained granite phase. Regression of the nine samples yields a Model 2 isochron age of 1814 ± 22 Ma with an IR of 0.7045 ± 0.0017. An MSWD of 7.9 indicates scatter in excess of that attributable to experimental error alone. Most of this scatter appeared to be due to two samples, and regression of the other seven samples results in a perfect fit isochron (MSWD = 0.90). The age calculated from this grouping is 1816 ± 10 Ma with an IR of 0.7043 ± 0.0008.

Both of the above age calculations are statistically indistinguishable from that reported by Mortimer et al. (1979) for the hypersthene granitoids at Cape Donington (1818 ± 13 Ma with an IR of 0.7055 ± 0.0005). This supports the interpretation that these ages reflect the time of emplacement and crystallisation of the Donington Granitoid Suite. Note however, there is a slight difference in initial ratios (0.7043 ± 0.0008 compared with 0.7055 ± 0.0005).

LOCALITY 2. (CAPE CARNOT, Fig. 6)

The outcrop to be inspected is a small peninsula immediately west of, and adjoining Cape Carnot. The condition of the sea at the time will determine whether this particular outcrop can be examined in detail. Four people have lost their lives in this area as a result of the frequent large Southern Ocean swells, sometimes referred to as freak waves.

ALL MEMBERS OF THE GROUP ARE URGED TO KEEP CLOSE TO THE TOUR GUIDES AND NOT WANDER INDISCREETLY ABOUT THE SMALL PENINSULA.

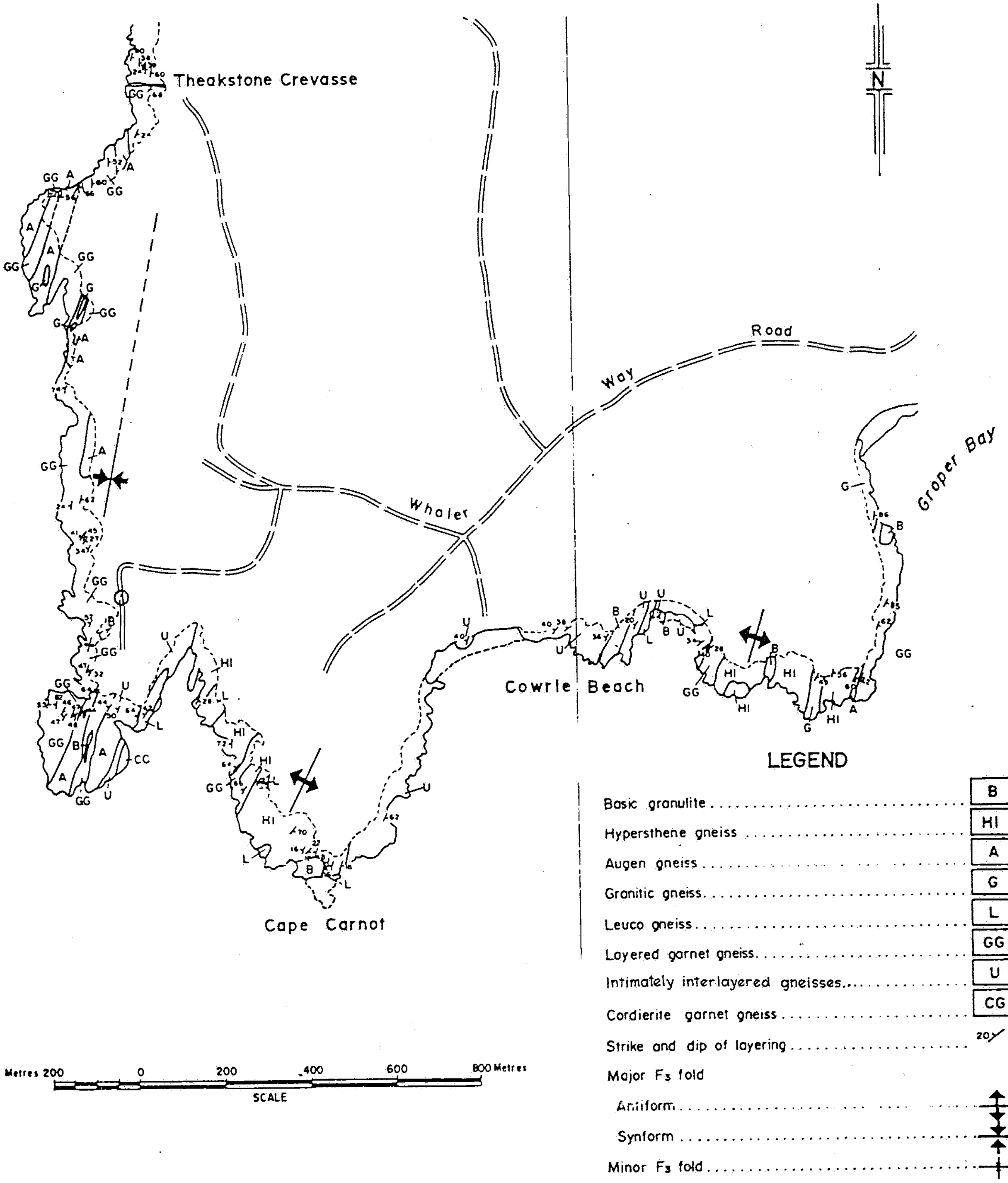

Fig. 6. Geological map of the Cape Carnot area. Locality 2. From Fanning et al (1981).

Geology

The small peninsula and the adjacent point to the east form the type area for the Carnot Gneisses. The major lithologies on the small peninsula are a thinly (1-3 cm) layered garnetiferous quartzofeldspathic gneiss and a garnetiferous augen gneiss. Layered garnet gneiss is the overall dominant lithology of the Carnot Gneisses. In this section it has a granoblastic texture; the main mineralogy consists of perthitic orthoclase, plagioclase (oligoclase-andesine) and quartz with lesser amounts of garnet (almandine-pyrope) and biotite. Minerals present in accesory amounts are zircon, monazite, magnetite, ilmenite, rutile, apatite and traces of sillimanite and spinel (hercynite?). Secondary alteration minerals include sericite and chlorite.

The augen gneiss consists of two types, either with the potash feldspar augen oriented parallel to the regional foliation direction, or with them in random orientation. Mineralogically it has a similar composition to the layered garnet gneiss, except for the presence of some microcline in the augen gneiss. An inequigranular granoblastic texture is observed in thin section.

Biotite garnet gneiss, characterised by high volume percentages of biotite (10-20%) and garnet (up to 25%), is present as small isolated pods in both the augen and layered garnet gneiss. This lithology may contain cordierite and sillimanite and is interpreted as representing relict pods of pelitic sediment.

The easternmost end of the small peninsula consists of cordierite-garnet gneiss. This is a pale fawn coloured rock marked by the presence of dark green cordierite porphyroblasts. In thin section the cordierite coexists with garnet, sillimanite and quartz (± spinel). Potash feldspar and plagioclase are also present, as are the typical accessory minerals mentioned above. Minor pegmatite veins associated with this rock type contain up to 20% sillimanite.

Between the augen gneiss and cordierite garnet gneiss there is a 15 metre wide zone of intimately interlayered gneisses (Fig. 6). The gneisses that comprise this zone vary in composition from leucogneiss (potassium feldspar + plagioclase + quartz with minor biotite and garnet) through layered garnet gneiss (as above) and hypersthene gneiss (potassium feldspar + plagioclase + quartz + hypershtene + garnet ± biotite) to basic granulite (orthopyroxene + clinopyroxene + plagioclase + opaques). They are intimately interlayered to the extent that the lithologies change randomly across strike over a distance of few centimetres. The compositional layering parallels the local foliation trend.

The basic granulites are thought to be originally intrusive into a principally felsic sequence of supracrustals, although all contacts observed within the Carnot Gneisses are essentially concordant. Deformation has resulted in local boudinaging and wrapping of the layering of the felsic gneisses around the larger (1-2 m thick) basic boudins. Thinner (20-30 cm thick) basic bodies have been folded.

The basic granulites are equigranular, granoblastic, and foliated as defined by the parallel orientation of elongate ferromagnesian grains. Mineralogically they consist of orthopyroxene (hypersthene), clinopyroxene (diopside), plagioclase (labradorite) and opaques (magnetite and ilmenite). Variations are provided by the presence in some rocks of hornblende or biotite, or both. The hornblende is considered to be a retrograde mineral, replacing pyroxene. Quartz where present is only a minor constituent. Traces of potash feldspar, zircon and spinel have also been observed.

Two suites of pegmatite are present at Cape Carnot, segregations and veins.

Pegmatitic segregations are developed approximately parallel to the layering and consist of extremely coarse potash feldspar augen, up to 20 cm in length. The contacts between the segregations and the surrounding gneisses are diffuse, implying that they were formed from the gneisses. It is suggested that shears parallel to the layering may have acted as loci for the development of coarse feldspar segregation.

Pegmatite veins are ubiquitous and are characteristically developed in the axial planes of crenulations or flexures of the layering. Aplite veins with mafic rims (biotite) are also discordant younger features.

Prograde metamorphic conditions correspond to those of the intermediate pressure granulite facies. Comparison of the observed mineral assembages with experimentally determined mineral stability curves indicates that prograde metamorphic conditions probably reached 700-900^{0}C and a total pressure of 7-9 Kb. Coexisting pyroxene geothermometry for the basic granulites indicates temperatures in the range 800 to 860^{0}C (using Wood and Banno). However, average garnet-biotite geothermometry for the acid gneisses yields lower temperature estimates in the range 600 to 690°C using Perchuk and 595 to 710°C using Thompson. In places biotite is seen to be orientated parallel to the axial plane of F_3 folds, thus the lower temperature estimates for garnet biotite pairs are most likely a result of later metamorphic events.

Most of the Rb-Sr whole rock age determinations for the Carnot Gneisses have been carried out on samples from the Cape Carnot area, in particular the small peninsula. Five samples of cordierite garnet gneiss yield a near perfect fit isochron of 2412 ± 72 Ma and IR of 0.7060 ± 0.0008 (MSWD = 2.1). It is suggested that this age gives the best estimate for the timing of the granulite facies event. Regression of eleven augen gneiss and two layered gneiss samples indicates scatter in excess of experimental error (MSWD = 24.64), although the calculated age of 2419 ± 151 Ma and IR of 0.7065 ± 0.0057 seem to be recording the granulite facies metamorphic event.

Cooper _et al._, (1976) and Fanning (1975) group selected augen gneiss samples with the two layered gneiss samples to obtain an imperfect fit Model 2 age of 2586 ± 131 Ma with an IR of 0.7012 ± 0.0043 (MSWD = 13.43). This is believed to be a relict age partially recording a geological process earlier than the above granulite facies event. Seven leucogneiss samples have considerable isochron scatter, far beyond experimental error (MSWD = 173). Nevertheless the calculated age, 2776 ± 570 Ma does provide some support for a pre-2420 Ma event.

LOCALITY 3 (SLEAFORD BAY, Figs. 5a, 7).

In the northwest corner of Sleaford Bay an 800 metre wide section of Hutchison Group crops out in the coastal platform (Figs. 3, 5a and 7). This section was first described by Tilley (1920, 1921 a and b). Access to this area is via the road which reaches the coast at the Naval Mine (monument).

The Hutchison Group can be seen to abut against the Carnot Gneisses at the western end of a sandy beach (Fig. 7). Here the Carnot Gneisses consist of a layered hypersthene gneiss that is characterised by euhedral garnets and garnet-quartz symplectitic intergrowths. The main mineralogy of this gneiss is plagioclase, quartz, hypersthene, garnet, biotite, and variable diopside. Layering of the gneiss strikes approximately 010^{0} and dips steeply to the west.

Immediately east of this gneiss a quartzite crops out. This is considered to mark the base of the Hutchison Group and is possibly equivalent to the Warrow Quartzite, see Parker and Lemon (1982). Clay rich bands emphasize the layering of the quartzite which is roughly parallel to the layering in the adjacent Carnot Gneisses. There is a general structural concordance between these two major rock groups in this area.

By analogy with the Hutchison Group sequence of Parker and Lemon (1982), the Sleaford Bay section youngs to the east, away from the quartzite. Near the eastern end of the sandy beach interlayered ferruginous bands, garnet-quartz-feldspar gneiss, forsterite marble and granitic sills crop out in the intertidal zone.

The forsterite marble is a thin, but distinctive lithology and can be equated with the Katunga Dolomite which crops out further north in Eyre Peninsula (Parker and Lemon, 1982). The adjacent ferruginous bands have been intensely altered and in places silicified, but remnant fine scale quartzose and iron rich bands suggest that the primary rock was a banded iron formation.

The prominent headland at the eastern end of this sandy beach consists of a quartz-diopside rock. Interlayered bands of pure diopside and quartz, with variable thicknesses strike roughly north-south and dip steeply to the west. On the western side of this headland, there is a gradation from graphite schist through graphite-quartz-diopside rock to quartz-diopside rock. Hornblende occurs as a minor retrograde metamorphic phase and is also found in tension gashes, perpendicular to the layering, that resulted from the boudinaging of the quartz-diopside rock during the D_3 event (see Fig. 4).

Progressing further east, into the next small bay, there is a 10 to 20 metre wide zone of interlayered scapolite-microcline-diopside rock, diopside rock, graphite schist, thin ferruginous bands and garnet quartz feldspar gneiss. The garnets are visibly zoned in hand specimen corresponding to more grossular rich cores and more almandine rich rims. A ferruginous layer immediately to

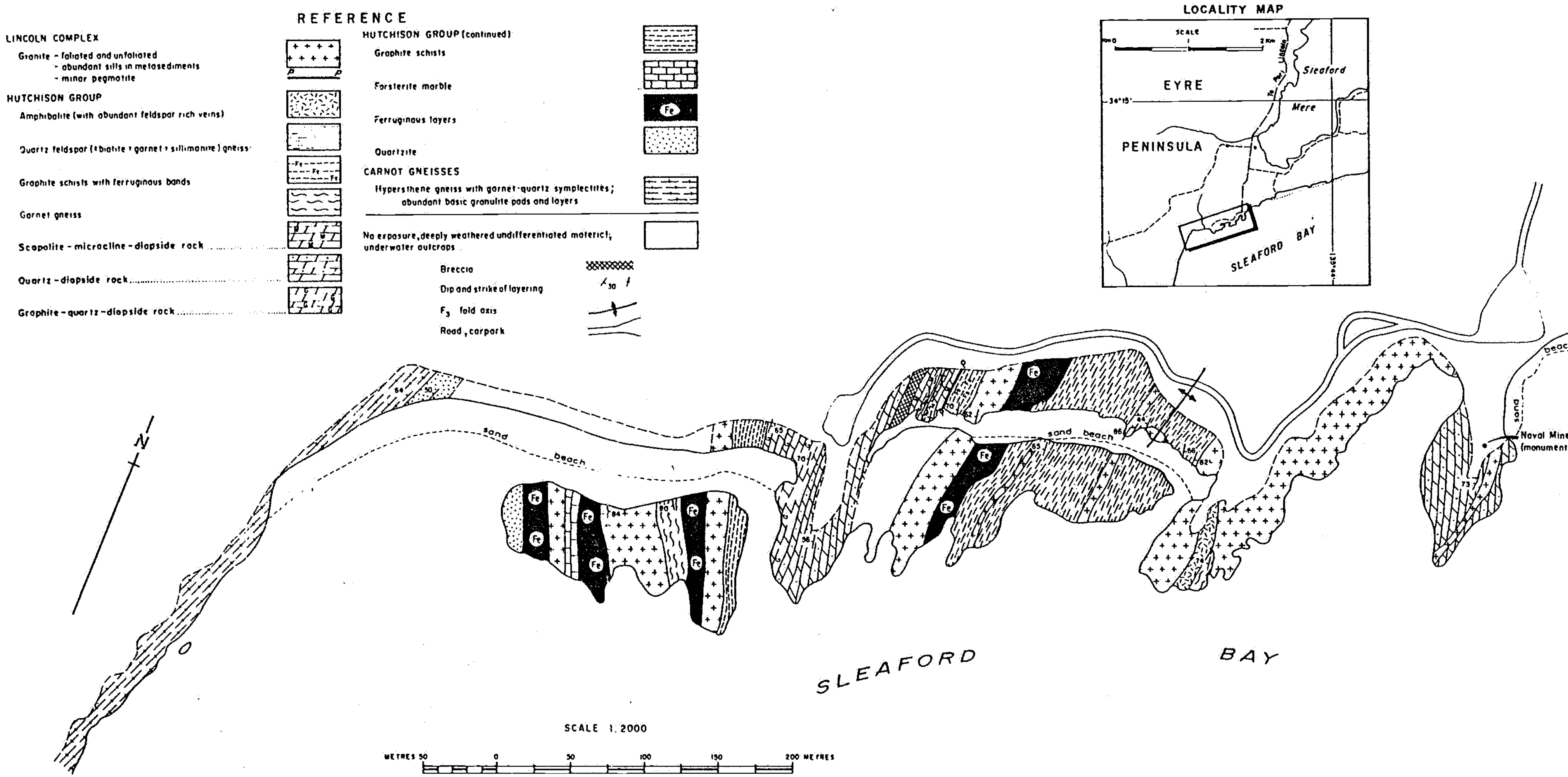

Fig. 7. Geological map of the northwest corner of Sleaford Bay. Locality 3. After Fanning, 1982.

the east marks the upper boundary of the Lower Middleback Jaspilite equivalents in this section (see Fig. 3 and Parker and Lemon, 1982).

Layered quartzo-feldspathic gneisses comprise the remainder of the Hutchison Group exposed at Sleaford Bay. These gneisses have variable amounts of biotite, garnet and sillimanite, most probably a reflection of variations in pelitic content in the original arkosic sediment.

Foliated and unfoliated granite form the next headland to the east. Minor but distinctive constituents of the granite are hornblende, biotite, sphene, apatite and sillimanite. The intrusive nature of the granite is evidenced by the inclusion of a several metre wide tract of garnet quartz feldspar gneiss and a low angle crosscutting relationship with quartz-diospide rock (repeated due to folding) near the Naval Mine (monument). Granitic sills observed within the Hutchison Group metasediments are mineralogically similar to this larger granite body, and are considered contemporaneous.

LOCALITY 4 (CAPE DONINGTON, Figs. 5a, 8)

Two sections of coastal outcrop are to be examined on the northern tip of Cape Donington Peninsula (see Fig. 8). The first section covers Cape Donington proper, in the immediate vicinity of the lighthouse. Part of this area was mapped by Flook (1975). The second section is a westward extension of the first, across a small beach towards Cape Colbert (see Fig. 8). Both sections are part of G.E. Mortimer's Ph.D. thesis area and we gratefully acknowledge his generous assistance in the preparation of the locality description.

A. Cape Donington

From the lighthouse we will walk down a small track to the eastern cove. The outcrop consists of a mafelsic megacrystic granite gneiss*, characterised by the presence of ovoid plagioclase and orthoclase megacrysts, on average 2-3 cm in diameter but ranging up to 4 cm. These feldspars are typically zoned and the cores can be seen in hand specimen to contain mafic minerals. High modal percentages of hornblende and biotite result in the distinctive dark colouration of this gneiss. Orthopyroxene is generally absent, although there are a few patches which do contain hypersthene (G. Mortimer pers. comm.). Xenoliths of mafic material, possibly earlier dolerites or amphibolites, are relatively common.

The term gneiss is applied to the megacrystic granite as there is a well developed foliation, striking approximately 010-020^0. There are also zones of very intense deformation (shears) which strike at a low angle to the local foliation direction and which are of the order of 10-20 cm in width.

*(Note: A more leucocratic megacrystic granite gneiss (i.e. lower mafic content than is seen here) is one of the dominant lithologies that outcrops along the E coast of southern Eyre Peninsula extending from Wanna to Port Neill. This lithology is to be seen at the boat ramp, Kirton Point).

At least two generations of basic rocks crop out along this coastal section, amphibolites and dolerites. The relative age of the amphibolites is not clear (cf Kirton Point). The main phases of the Kimban Orogeny have affected the amphibolites since they are foliated and in places deformed by the D_3 event (see Fig. 4). Mineralogically they consist of plagioclase and hornblende with varying amounts of pyroxene, biotite and opaques. Minor quartz and orthoclase may be present, depending on the extent of retrogression. The dolerites have ophitic textures and are essentially undeformed.

The mafelsic megacrystic granite gneiss is intruded by an even-grained granite gneiss which in places is very intensely deformed. Principal minerals of the granite gneiss are microcline, quartz, plagioclase and biotite. Accessories include sphene, apatite, zircon and opaques. In thin section the texture is typically granoblastic seriate, however quartz forms elongate flattened ribbons in areas of intense deformation.

A folded tract of paragneisses consisting of calc-silicate, semi-pelitic and quartzo-feldspathic compositions, occurs as a xenolithic inclusion within the even-grained granite gneiss at this locality. The semi-pelitic and calc-silicate layers have a strong compositional banding and Flook (1975) reports a variety of assemblages:

quartz - plagioclase - diopside - scapolite (sphene, magnetite, allanite)
quartz - plagioclase (sphene)
quartz - plagioclase - hornblende (sphene, allanite, opaques, zircon)
quartz - sillimanite - muscovite - hornblende - zoisite
quartz - sillimanite - muscovite
quartz - plagioclase - biotite - garnet - sillimanite (fibrolite).

Folded quartzo-feldspathic zones containing microcline megacrysts are also present and it is more likely that these have formed through metamorphism and deformation of the granitoids. Nevertheless the paragneisses undoubtedly represent inclusion of pre-existing crust at the time of intrusion of the granitoid suite.

Immediately west of these folded paragneisses, xenoliths of a quartz gabbronorite gneiss (Mortimer et al., 1979; cf mafic charnockite of Flook, 1975) occur within the even-grained granite gneiss. The main body of the quartz gabbronorite gneiss crops out immediately to the west and extends around the point and into a bay where we shall examine its western margin. Mortimer et al. (1979) consider this lithology to be the earliest intrusive phase of their Donington Granitoid Suite. Mineralogically it consists of zoned plagioclase phenocrysts (oligoclase), augite, hypersthene, biotite and quartz. Accessories include zircon, apatite, magnetite and ilmenite; there is also minor potash feldspar. Blue-green hornblende replacing pyroxene is a result of later retrogression.

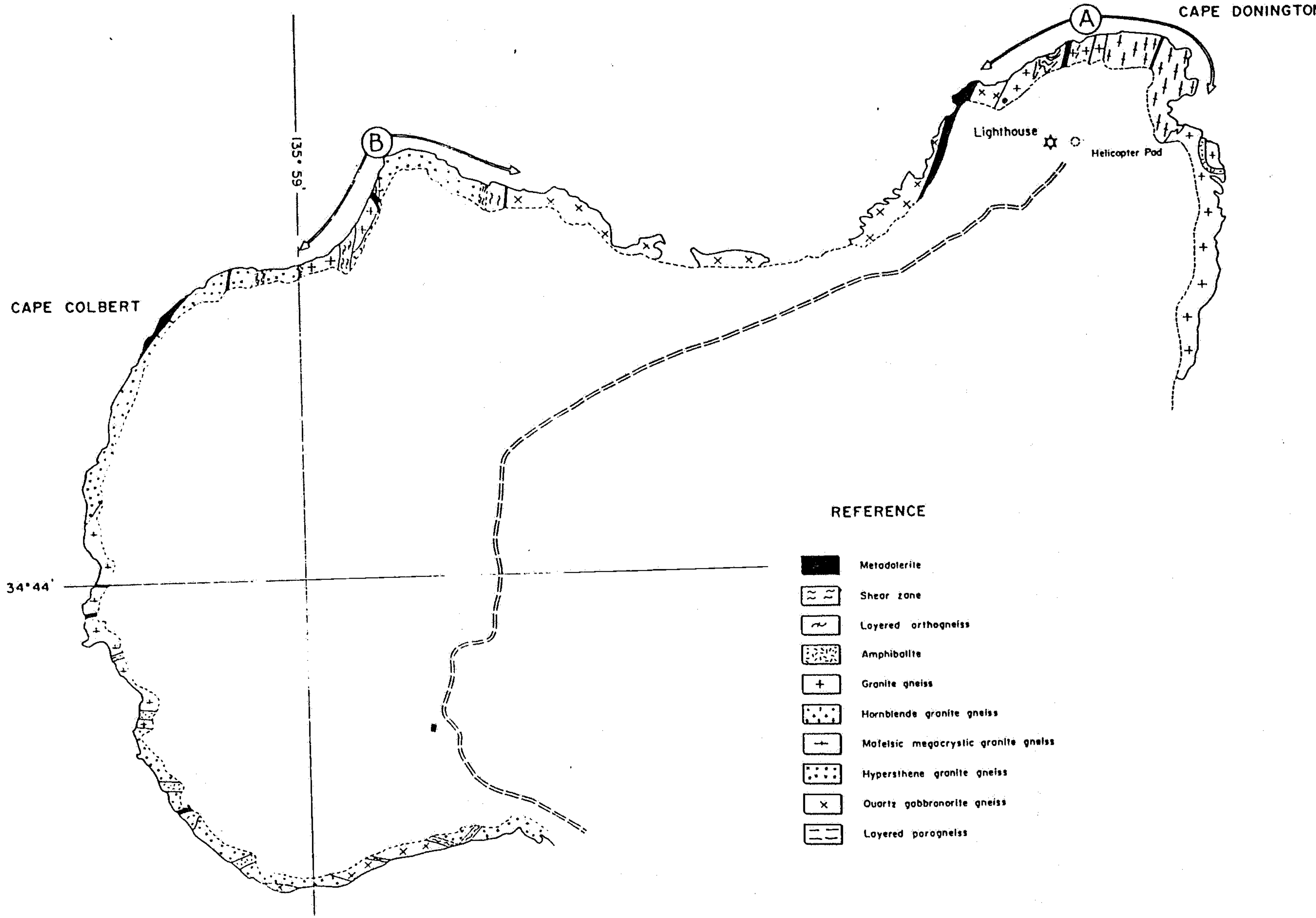

Fig. 8. Geological Map of Cape Donington and Cape Colbert, Southern Eyre Peninsula. Locality 4. After Fanning 1982, Mortimer 1981, and Flook 1975.

B. Cape Colbert

This traverse commences at the western boundary of the quartz gabbronorite examined above. The western boundary of this lithology is marked by very intense deformation, grading into a mylonitic zone of approximately five metres in width. This shear zone obscures the contact between the quartz gabbronorite gneiss and a more acidic, hypersthene granite gneiss which is similarly intensely deformed adjacent to the shear. Some granite gneiss may also have been incorporated into the shear.

The hypersthene granite gneiss* consists of primary igneous plagioclase, hypersthene, and orthoclase phenocrysts in a partly recrystallised matrix of orthoclase, plagioclase, quartz and biotite. Minor hornblende may also be present. Accessories include apatite, magnetite, ilmenite and zircon. Xenoliths of mafic material can be seen in some outcrops.

The hypersthene granite gneiss is intruded to the west by an even-grained granite gneiss of similar composition to that seen at Cape Donington. Note here the absence of the paragneiss xenoliths. A branching metadolerite dyke can be seen to truncate the granite gneiss - hypersthene granite gneiss contact.

A few metres to the southwest this same contact is also truncated by a band of well-layered quartzo-feldspathic gneiss. The quartzo-feldspathic gneiss gradually merges to the west with a more deformed variety of the even-grained granite gneiss and it is suggested that the well layered gneiss was tectonically produced from the surrounding granite gneiss. Thin biotite-rich interlayers occur within the well layered gneiss and these display prominent tight to isoclinal folding. It is possible that the biotite-rich layers were originally amphibolites that have been subjected to intense retrogression during the deformation that formed this well layered zone.

Further west there is another example of the production of a tectonic layering within the granitoids. Through increasing deformation over a distance of two to five metres across strike, quartzo-feldspathic veins within the hypersthene granite gneiss are strung out into parallel orientation, to the extent that a new layering is produced.

Hence in the Cape Donington - Cape Colbert area there is evidence for layered paragnesiess formed by deformation of an original sedimentary xenolithic tract, whereas the layered orthogneisses are derived from deformation of the intrusive granitoid suite.

*(Note: The hypersthene granite gneiss, or charnockite, is a prominent lithology within the Donington Granitoid Suite. It occurs as extensive outcrops in the Memory Cove - Cape Catastrophe area; the 'Memory Cove Charnockite'(MCC) may be used for this lithology.

C. Timing and conditions of formation of the Donington Granitoid Suite

From application of the Wood and Banno pyroxene geothermometer, and the composition of orthopyroxene in the granite gneiss, Mortimer et al. (1979) suggest that primary magmatic crystallisation took place at around 8 kb pressure and in excess of 900^{0}C. They also suggest that a subsequent lower grade amphibolite facies retrogression has affected the suite. The degree of this retrogression is variable, although Mortimer et al. (1979) note a general increase in extent from east to west. This retrogression is typically represented by the replacement of pyroxenes by hornblende.

Seventeen Rb-Sr whole rock measurements of essentially hypersthene-bearing gneiss varieties indicate a Model 3 isochron age of 1818 ± 13 Ma with an initial ratio of 0.7055 ± 0.0005 (MSWD = 2.54). This age is interpreted as representing the time of emplacement and igneous crystallisation of the Donington Granitoid Suite (Mortimer et al., 1979). From calculations using the isochron age and initial ratio, and the mean Rb/Sr ratios, it can be implied that this suite represents a new addition of material to the continental crust during the Proterozoic. It is not derived from the reworking of older continental crustal material such as the Hutchison Group or Sleaford Complex. However, xenoliths within the suite do indicate the presence of continental crust in the area prior to emplacement.

LOCALITY 5 (PORT NEILL: MYLONITE ZONE, Figs. 5a, 9)

This is the type locality for the Kalinjala Mylonite Zone, a major linear zone of intense ductile deformation extending the length of Eyre Peninsula from Sleaford Bay to the western flanks of the Middleback Ranges. The zone at Port Neill is about 3 km wide and displays a variety of textures ranging from incipiently mylonitised gneisses to slaty ultramylonite. S_m is generally oriented ca 030^0 and dips 80 to 85^{0}W.

Clarke (1976) argues that the apparent rotation of blocks or boudins of amphibolite etc. indicate a major component of simple shear and in particular transcurrent movement. However, the presence of intense folding about shallowly plunging axes suggests that the mylonites have formed mainly in response to intense ductile deformation related to D_3 folding. The L_M lineation, which has been interpreted as evidence for transcurrent movement (Clarke, 1976), is closely related to F_M and is, at least in part, an intersection lineation.

LOCALITY 6 (POORNAMOOKINNIE CREEK, Figs. 5b, 10)

Just north of Cleve, the Warrow Quartzite consists of feldspathic and micaceous quartzite with narrow pelitic schist interbands and numerous granitic sills. The quartzite-schist interbanding probably represents primary bedding and dips shallowly to the southwest thus defining the core of a major D_3 antiform.

Granitic sills (and lesser dykes) of massive, leucocratic, off-white to pink, quartz + feldspar + muscovite + garnet granite are prolific in this region. Their conformable nature with the

D_3 folded layering in quartzite suggests that they may have also been folded by D_3, but Parker et al., (1981) believe that there was probably a close spatial and temporal relationship between the two. Pegmatitic veins are diffuse and often occur at sill/quartzite boundaries. There are two generations of pegmatites. One phase is associated with the leucogranite and is garnetiferous, while the other (and later) generation of pegmatites is coarse-grained, more sharply defined, tourmaline bearing and may locally contain andalusite and sillimanite.

At the northwest end of outcrop, quartzite bands are locally boudinaged indicating a tensional regime here in the antiformal core. The boundins are separated by quartz pegmatite aggregates or rods and are often dextrally offset. Local dextral vergence warps in less competent bands are associated with the boudinaging.

LOCALITY 7 (CLEVE COUNCIL BORROW PIT, Figs 10 and 11)

Overlying the Warrow Quartzite is the Katunga Dolomite, the Lower Middleback Jaspilite and the Cook Gap Schist. Generally in the Cleve area, the Katunga Dolomite is a massive to poorly bedded, off-white dolomitic marble while the Lower Middleback Jaspilite is represented by silicate-facies "iron formation" and recrystallised graphitic chert both with a low iron oxide content (Parker & Lemon, 1982).

In the Cleve Council pit the sequence above the Warrow Quartzite is dolomite and opalite, graphitic and tremolitic quartzite, and semipelitic schist. The semipelitic schist (A, Fig. 11) consists of quartz, biotite, muscovite, feldspar and garnet, with scattered psammitic bands and is quartz-veined. The graphitic and tremolitic quartzite unit consists of grey, laminated, very fine-grained quartzite with thin, either graphitic or grunerite-rich bands, and broader interbands (several centimetres wide) of massive tremolite (B). Rare isoclinal, "S" vergence F_2, plunging shallowly southwest are present and these are folded by broad, open F_3. The underlying dolomitic marble of the Katunga Dolomite is best seen at (G) but elsewhere has been partially replaced by opalite, particularly along bedding planes and joints (C). The boundary of dolomite and graphitic chert is gradational with interbands of grey, fine-grained quartzites, tremolite, dolomite and opalite, and occasional pegmatite veins. East of the pits is a coarse-grained pegmatite (D) separating the dolomite unit from the massive to flaggy outcrops of feldspathic quartzite (Warrow Quartzite) at (E). Broad, open, D_3 buckling of the dolomite and graphite units is well exemplified at (F).

LOCALITY 8 (CHARLESTON GRANITE, Fig. 5b)

The Charleston Granite is a massive, post-orogenic, megacrystic granite forming a large pluton with an exposed surface area covering 300 km^2. Potash feldspar phenocrysts, which are mostly microcline, are up to 3 cm in length and comprise about 30-40% of the rock. Some of the phenocrysts are zoned with plagioclase rims. Other constituents are medium-grained (locally coarse to 1 cm) and consist of white to greenish plagioclase, 10-15%, biotite 5%, and clear greyish quartz.

South of Moonabie Hill (see Fig. 12) Charleston Granite intrudes the Moonabie Formation and McGregor Volcanics (Miles, 1954; Smale, 1966; Giles et al., 1979). This is evident from aplitic and granitic veining within the volcanics, recrystallisation of the groundmass within the acid volcanics, and hornfelsing of the volcanoclastic grit within the Moonabie Formation. Also, along the contact with the volcanics, there is a zone less than 20 cm wide in which the granite is finer grained and phenocryst-poor. The adjacent volcanics are also veined by quartz and epidote which emanate from the granite.

Hornfelsing, epidotisation, and quartz + epidote veining also occur elsewhere in the Corunna Conglomerate and indicate that the Charleston Granite postdates sedimentation of the Corunna Conglomerate (Giles et al., 1979).

Geochronology of the Charleston Granite gives diverse results. Compston et al. (1966), from single total rock, biotite, and apatite Rb-Sr analyses, calculated an age of 1556 ± 30 Ma (recalculated value using $^{87}Rb = 1.42 \times 10^{-11}$) which is in close agreement with three K-Ar biotite dates of 1532, 1567 and 1568 Ma reported by Webb et al. (in prep.). However, conflicting with these values are some additional Rb-Sr analyses on 8 total rock samples (Webb et al., in prep.). These samples define an isochron age of 1445 ± 39 Ma with an initial $^{87}Sr/^{86}Sr$ ratio of 0.7133 ± 0.0058. The problem remains unresolved.

LOCALITY 9 (McGREGOR VOLCANICS, Fig. 12)

The McGregor Volcanics are a bimodal suite of acid, ash-flow tuffs and basaltic lava flows. The oldest unit exposed is a rhyolite, exhibiting spherulitic devitrification textures. This is succeeded by a series of both porphyritic and non-porphyritic rhyolitic to dacitic volcanics. Porphyritic dacites contain abundant plagioclase phenocrysts. The groundmass usually consists of a devitrified mosaic after glass showing excellent vitroclastic textures. These, together with the extreme compaction and flattening of the shards, indicate that the volcanics are welded ash-flow tuffs.

Rb-Sr whole rock analyses from two separate localities (see Fig. 12) yield the following isochron regressions (Webb et al., in prep.):

No of samples	MSWD	Age	I.R.
4	1.28	1645 ± 15 Ma	0.7159 ± 0.0021
9	1.93	1615 ± 29 Ma	0.7073 ± 0.0010

For the first group of four samples, the high initial ratio indicates probable assimilation of material enriched in ^{87}Sr. Thus the age of 1615 ± 29 Ma from the other group is considered a better estimate for the age of extrusion, because of the lower initial ratio (Webb et al., in prep.).

Few of the basalts which occur as thin interbands preserve their primary mineralogy. However they do show a wide textural range including ophitic, intersertal, and hyalopilitic textures indicative of their lava-flow origin.

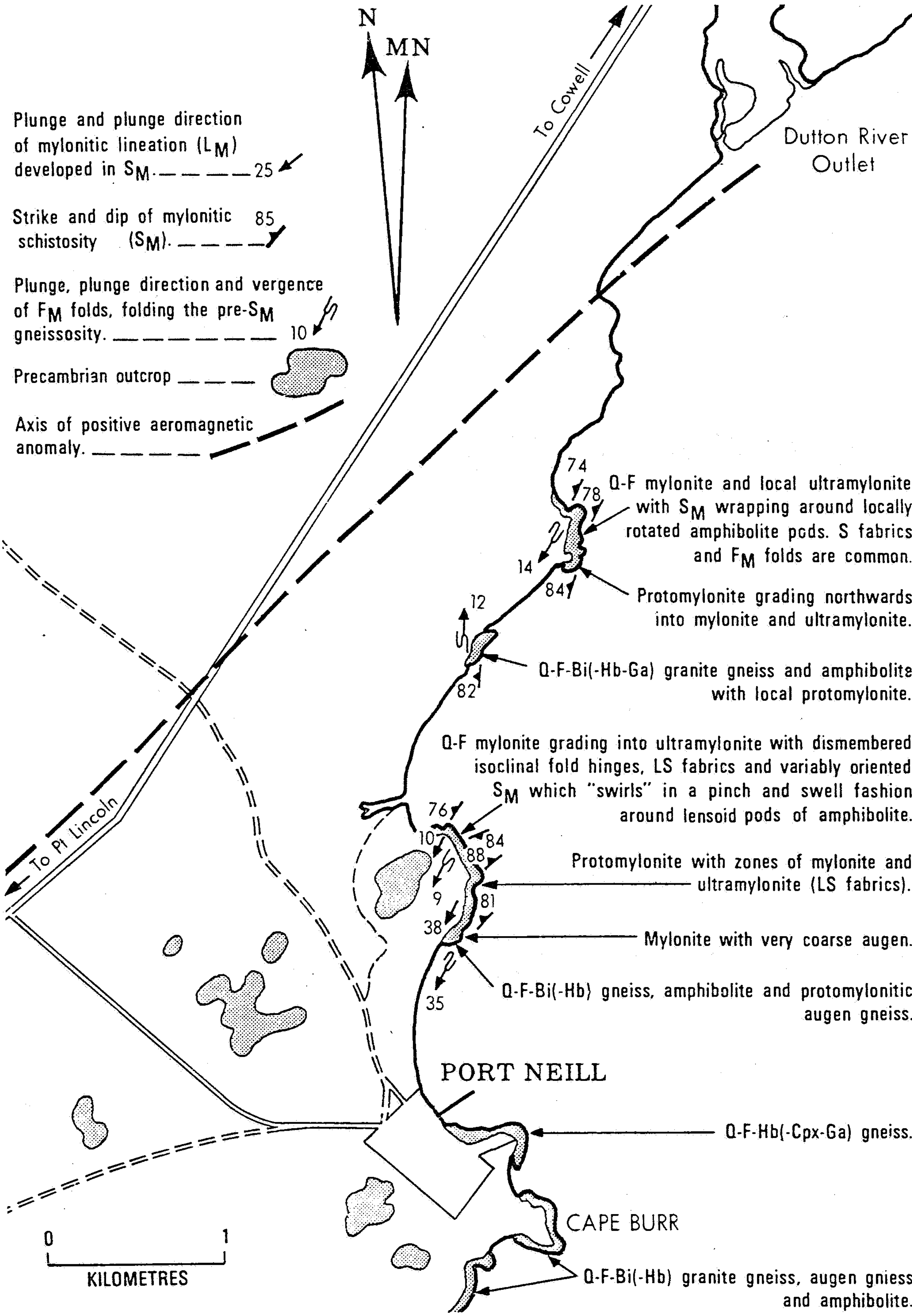

Fig. 9. Type locality of the Kalinjala Mylonite Zone near Port Neill, Locality 5. From Parker (1980b).

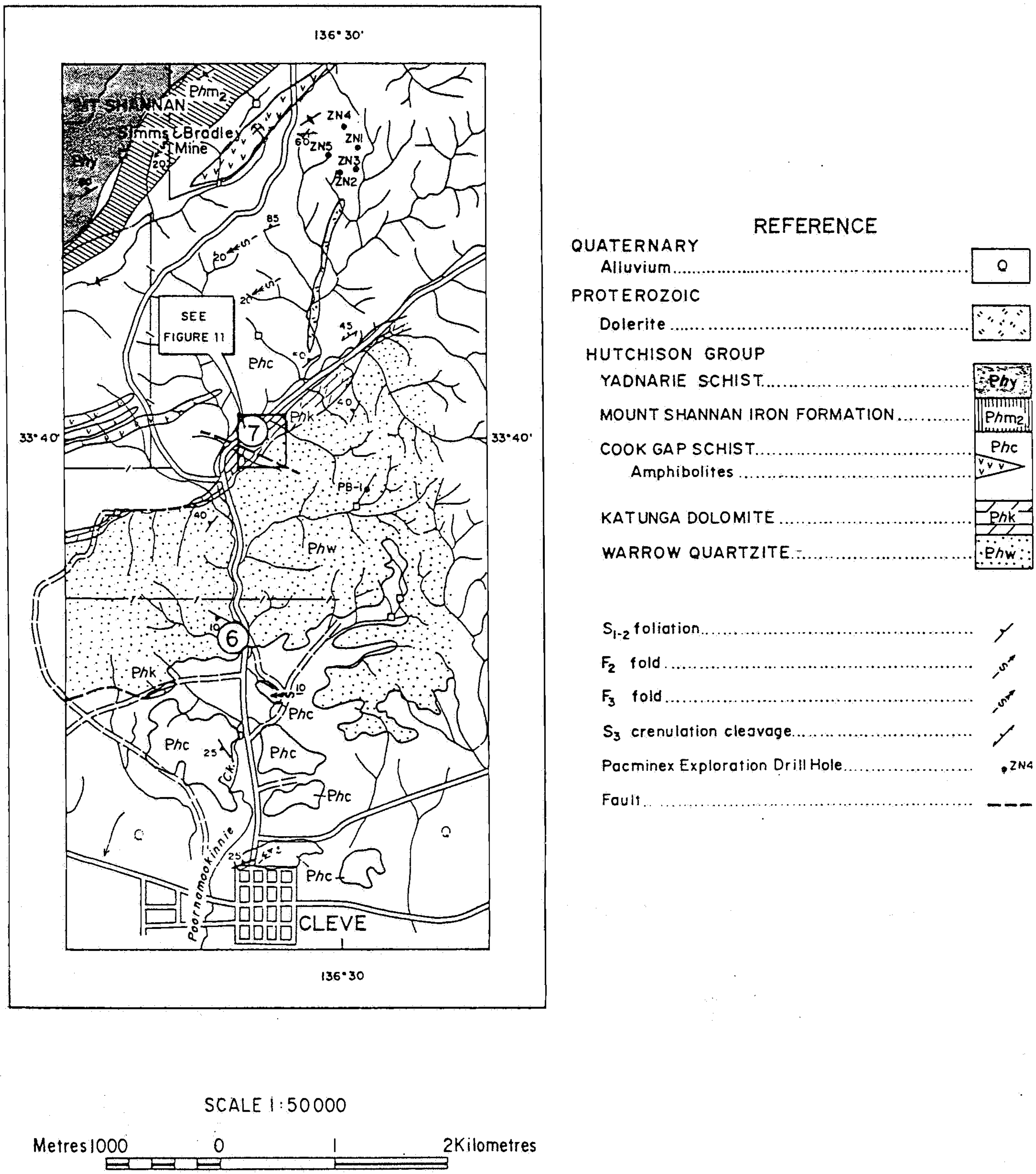

Fig. 10. Geology of the Cleve area, localities 6 & 7.

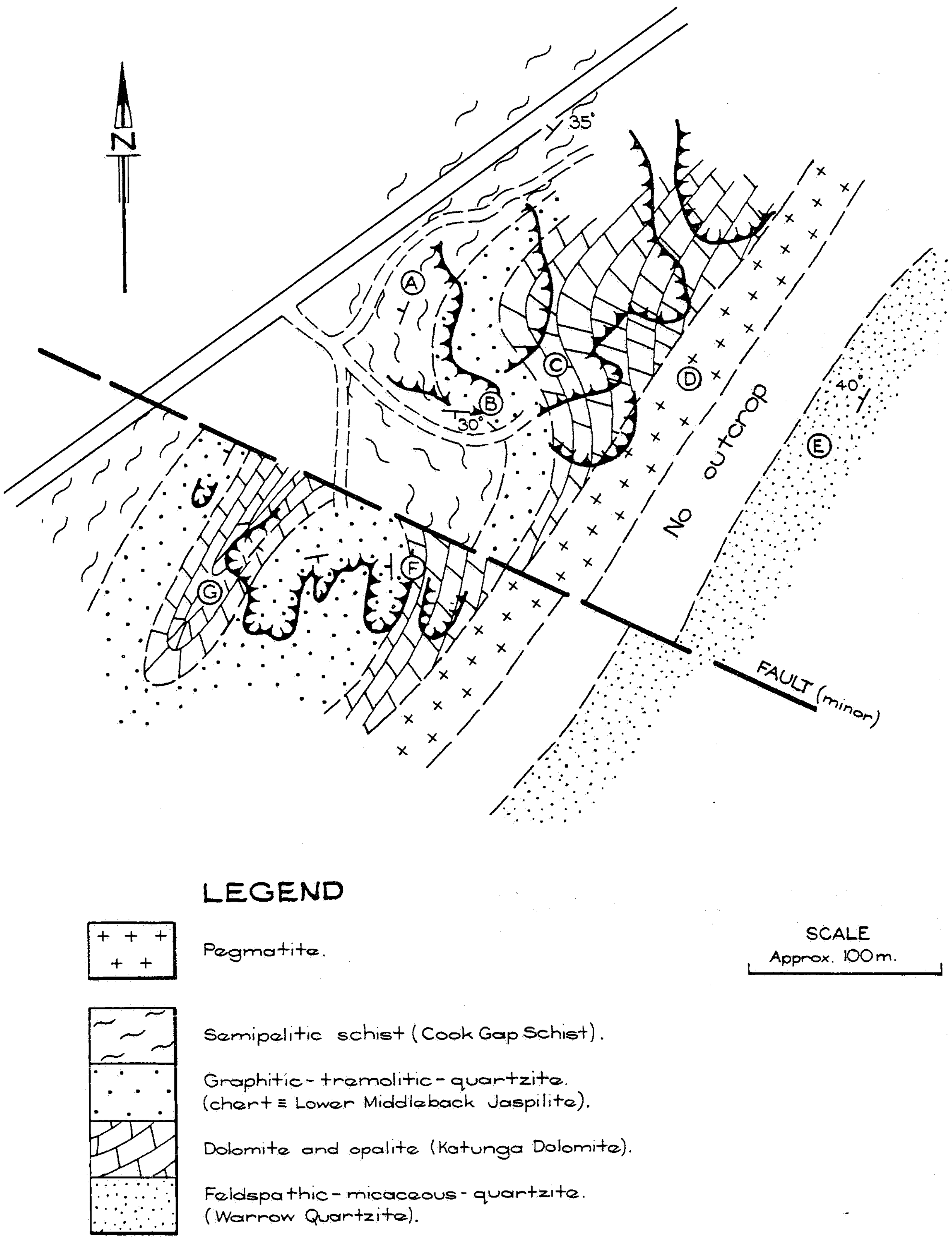

Fig. 11. Geological sketch map of Cleve Council borrow pit, locality 7.

Andesites, which bridge the petrological characteristics of the bimodal suite, are absent. Giles et al. (1979; and in prep.) have suggested that the acid and basic volcanics have different origins. The primary basic magma may have been derived by relatively shallow (<60 km) wet melting of the mantle in which olivine, orthopyroxene, and clinopyroxene are residual. The primary dacite magma probably originated by partial melting of a dry, basic granulitic lower crustal source in which plagioclase, clinopyroxene, orthopyroxene and magnetite are residual. (The above descriptions of volcanics and their origins are from Giles et al. (1979) and Giles, pers. comm.).

Intercalated with the volcanics are heavy mineral-laminated quartzites (with dispersed quartz pebbles) and volcanoclastic grits.

LOCALITY 10 (MOONABIE QUARRY, Fig. 12).

Overlying and probably interbedded with extrusives of the McGregor Volcanics are volcanoclastic grits of the Moonabie Formation (Smale, 1966; Giles et al., 1979). The volcanoclastic grits are massive, dark grey, and have an immature, medium to coarse-grained matrix of quartz, feldspar, sericite and volcanic rock fragments. Bedding is very poorly defined. Rounded to subrounded pebbles are dispersed in the matrix and rarely form distinct lenses. Volcanic clasts dominate and include porphyritic and non-porphyritic, rhyolites to dacites typical of the McGregor Volcanics. Chert clasts are common and vary in grain size from cryptocrystalline to about 0.2 mm.

The volcanoclastic grits are quartz-veined and have been hornfelsed by intrusion of the Charleston Granite.

LOCALITY 11 (MOONABIE RANGE - Road cutting, Fig. 12)

The Corunna Conglomerate (Miles, 1954; Smale, 1966; Lemon & Gostin, 1975; Parker, 1980a) structurally overlies the Moonabie Formation. The basal conglomerate, well exposed in the road cutting, contains abundant rounded to well rounded clasts ranging in size up to 40 cm. Clast types include fine to coarse-grained sandstone and quartzite (not typical of the Warrow Quartzite), banded iron formation (Middleback Jaspilites), acid volcanics (McGregor Volcanics), volcanoclastic grit (Moonabie Formation), and minor silicified, crenulated schist, mylonite and granite. The matrix is sandy and very poorly sorted. Individual conglomerate beds (up to 20 m thick) are massive to poorly layered and are interlayered with well-bedded, fine-grained sandstones. Developed throughout the unit is a mauve and yellow to off-white mottling.

Note on the Middleback Ranges Iron Ore Operation (Kindly prepared by Mr. John Elsetherious of The Broken Hill Proprietory Co. Ltd (B.H.P.)).

In 1899 B.H.P. was granted mining leases at Iron Monarch and Iron Knob to mine flux for smelting ore from Broken Hill at Port Pirie. Initially the ore was transported by bullock dray to Port Augusta and then railed to Port Pirie, but with the building of a tramway ore was railed to Hummock Hill (later called Whyalla) and barged across the gulf to the smelters at Port Pirie. Leases

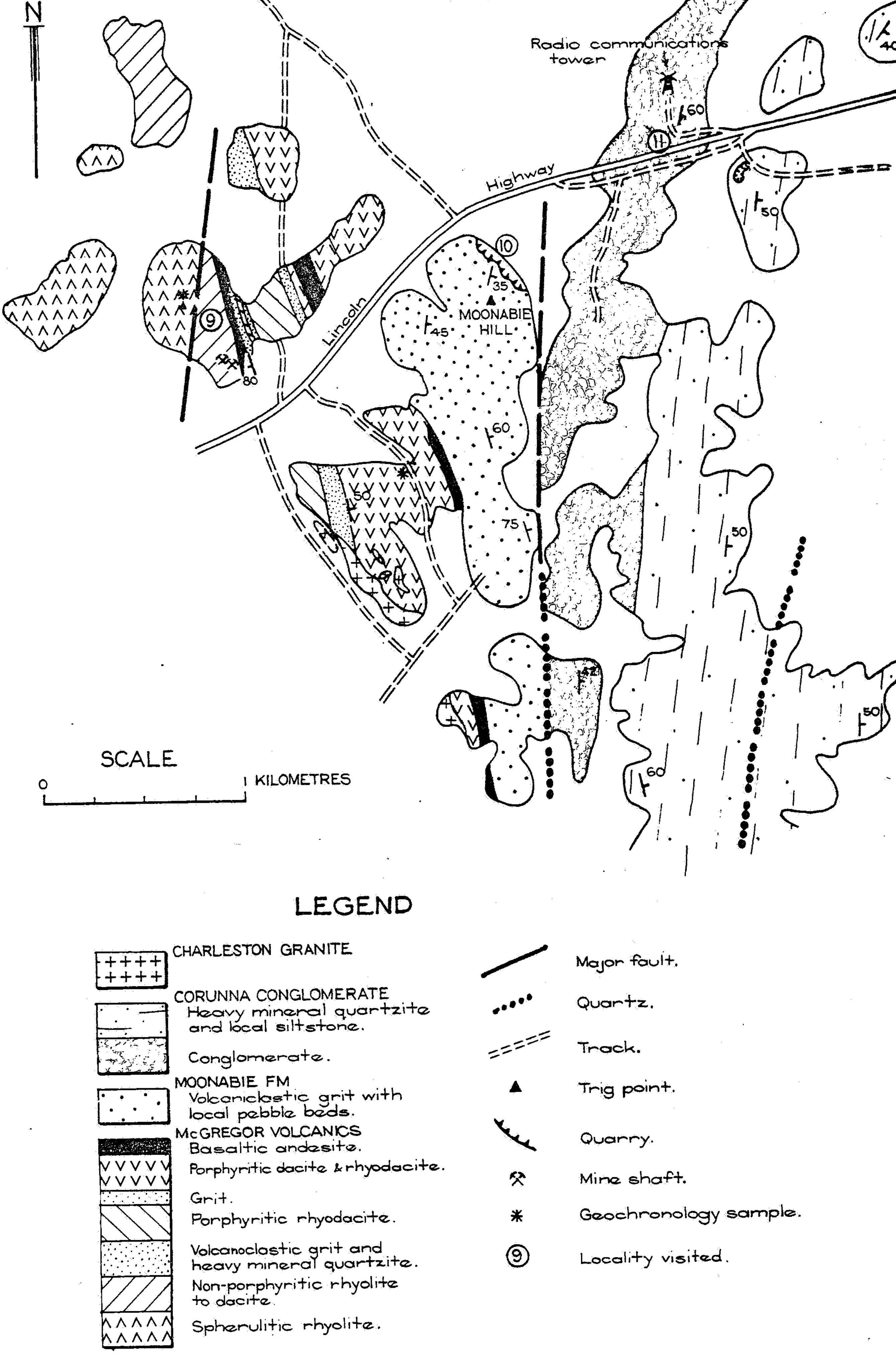

Fig. 12. Geology of the Moonabie Range area, localities 9, 10, & 11, after mapping by N.M. Lemon 1978, C.W. Giles 1979, and J. Parker (1980a).

were extended in 1920 to include the Iron Prince and Iron Baron areas to the south. These deposits became the basis for the establishment of blast furnaces and steelworks at Newcastle (1915) and Whyalla (1941, 1965). Total production of ore from the Middlrback Ranges is 170 million tonnes to end of 1980 and ore is currently being mined at approximately 2.7 million tonnes per annum.

Geology

The Early Proterozoic Middleback Subgroup of the Hutchison Group is represented by dolomites, iron formations and schists in the Middleback Ranges. In the Iron Prince area the Middleback Subgroup is underlain by weathered muscovite-sericite-quartz-feldspar granitic gneisses and feldspathic quartzites with, along the western flanks, common cataclastic and microfaulting textures. (This represents the northern extension of the Kalinjala Mylonite Zone).

The lowest unit of the Middleback Subgroup is the Katunga Dolomite. It comprises a sequence of ferroan and ankeritic dolomites interbedded with chlorite schists, becoming very iron enriched near the dolomite-iron formation boundary.

The dolomite is overlain by the Lower Middleback Jaspilite which is a sequence of banded iron formation approximately 350 m thick but exhibiting marked varitions along strike. The Lower Middleback Jaspilite comprises pyritic dolomite at the base overlain by carbonate ore (a magnetite-carbonate mixture), magnetite-talc schist, talcose carbonate-magnetite jaspilite, magnetite-amphibole jaspilite, grunerite schist and magnetite-siderite amphibole jaspilite. All these rocks are oxidized and silicified near surface and appear in outcrop as hematite and limonite jaspilites.

High grade iron ore appears to have resulted from supergene enrichment of carbonate ore, magnetite-talc schist and to some extent the dolomite.

South of Iron Baron the Cook Gap Schist and the Upper Middleback Jaspilite overlie the Lower Middleback Jaspilite found in the Iron Prince.

The occurrence of primary ore in the Iron Prince is structurally controlled by a tight north to northeast trending syncline crossfolded on a northwest - southeast axis resulting in common pitch reversals. Faulting is common along the limbs of the major northerly folds. Sill and dyke-like emplacement and syn and post-tectonic intermediate and basic rock types (since altered to amphibolites and clays) intrude the mine sequence.

Ore types in the mining areas are blue and red hematite, lesser limonite and minor magnetite with a minimum ore cut-off set at 55% iron. Potentially beneficiable material below this grade are enriched jaspilites, enriched amphibolites, scree and dumped contact material.

All the iron from the Iron Baron area is pelletised before use. Red ore, because of its fine grain size, is restricted to 10% of the pelletizing feed. Impurity levels that require monitoring are alumina, zinc, phosphorous and silica.

magnetite-amphibole jaspilite, grunerite schist and magnetite-siderite amphibole jaspilite. All these rocks are oxidized and silicified near surface and appear in outcrop as hematite and limonite jaspilites.

High grade iron ore appears to have resulted from supergene enrichment of carbonate ore, magnetite-talc schist and to some extent the dolomite.

South of Iron Baron the Cook Gap Schist and the Upper Middleback Jaspilite overlie the Lower Middleback Jaspilite found in the Iron Prince.

The occurrence of primary ore in the Iron Prince is structurally controlled by a tight north to northeast trending syncline crossfolded on a northwest - southeast axis resulting in common pitch reversals. Faulting is common along the limbs of the major northerly folds. Sill and dyke-like emplacement and syn and post-tectonic intermediate and basic rock types (since altered to amphibolites and clays) intrude the mine sequence.

Ore types in the mining areas are blue and red hematite, lesser limonite and minor magnetite with a minimum ore cut-off set at 55% iron. Potentially beneficiable material below this grade are enriched jaspilites, enriched amphibolites, scree and dumped contact material.

All the iron from the Iron Baron area is pelletised before use. Red ore, because of its fine grain size, is restricted to 10% of the pelletizing feed. Impurity levels that require monitoring are alumina, zinc, phosphorous and silica.

Iron Prince and Iron Baron Operations

Production at the Iron Baron and Iron Prince mines is scheduled on a two shift, five day week basis. Blast-hole drilling is carried out by a Bucyrus Erie 45R track mounted drill. The blasting operation uses an ANFO mixture to produce approximately 50 to 100 000 tonnes per blast.

Two 151M Marion 4.5 m^3 electric shovels and two Michigan 475 rubber tyre loaders load broken ore into eleven 65 tonne Haulpack trucks for transport to the crusher. The average haulage distance is 1.6 km.

The ore goes through a primary jaw crusher and two secondary gyratory crushers for reduction to minus 50 mm and is stored in four 1 500 tonne storage bins. This is loaded on 45 wagon ore trains of 2 700 tonnes capacity for the 47 km trip to Whyalla.

The workforce at the Iron Baron/Iron Prince mine is approximately 145. The company township of Iron Baron has a population of 250 people; facilities include company homes, a general store, community hall, swimming pool, primary school, quarters for 100 single men, and a licenced recreation club. Similar facilities exist at the Iron Knob government township which has a population of approximately 450.

Iron Prince and Iron Baron Operations

Production at the Iron Baron and Iron Prince mines is scheduled on a two shift, five day week basis. Blast-hole drilling is carried out by a Bucyrus Erie 45R track mounted drill. The blasting operation uses an ANFO mixture to produce approximately 50 to 100 000 tonnes per blast.

Two 151M Marion 4.5 m^3 electric shovels and two Michigan 475 rubber tyre loaders load broken ore into eleven 65 tonne Haulpack trucks for transport to the crusher. The average haulage distance is 1.6 km.

The ore goes through a primary jaw crusher and two secondary gyratory crushers for reduction to minus 50 mm and is stored in four 1 500 tonne storage bins. This is loaded on 45 wagon ore trains of 2 700 tonnes capacity for the 47 km trip to Whyalla.

The workforce at the Iron Baron/Iron Prince mine is approximately 145. The company township of Iron Baron has a population of 250 people; facilities include company homes, a general store, community hall, swimming pool, primary school, quarters for 100 single men, and a licenced recreation club. Similar facilities exist at the Iron Knob government township which has a population of approximately 450.

LOCALITY 12 (MOUNT LAURA, Figs. 13, 14)

At Mount Laura, Pandurra Formation unconformably overlies folded Middle Proterozoic sediments. The spectacular angular unconformity is best viewed at the northwest end of Mount Laura from the Quarry Industries Ltd. quarry (Section A-B, Fig. 13).

The Middle Proterozoic sediments have previously been correlated with the Moonabie Formation (Nixon, 1975; Thomson et al., 1976) but although typical Moonabie Formation grits outcrop nearby to the southwest and south only the lowermost unit in the quarry may be equivalent. That unit consists of white to light grey, massive, coarse-grained arkose and feldspathic granule conglomerate with subangular to rounded quartz grains and scattered lithic fragments. Feldspar in the groundmass is commonly kaolinised as are some clasts which are thought to be of volcanic origin. There are local pebble beds and some cross bedding within the sequence indicating that the bedding is right-way-up.

The majority of sediments in the quarry above the lowermost unit are more likely equivalent to the Corunna Conglomerate sequence. They consist of interbedded massive to flaggy arkose and quartzite. The arkose is less feldspathic than the lower unit, quartz grains are rounded, and lithic fragments are generally absent. Dark coloured siltstones characterise this sequence and they show fine cross bedding, heavy mineral lamination, and local ripple marks. Similar lithlogies are present in the Corunna Conglomerate at Moonabie Range.

Folding of the Middle Proterozoic sequence(s) is clearly evident in the centre of the quarry's upper bench. It occurs about northwest-southwest trending axes correlated with the Wartakan tectonic event. It clearly predates deposition of the Pandurra Formation.

The Pandurra Formation capping Mount Laura consists of a series of interbedded conglomerates and sandstones at the base grading upwards and to the northeast into a thick sequence of sandstone with minor red siltstone interbeds. The basal conglomerate is of variable thickness reflecting irregularities in the unconformity surface, is purplish in colour grading up into a pink-brown colour, and contains a variety of generally rounded pebbles and cobbles. Most of the clasts are of quartzite similar to the underlying sequence(s). The upper conglomerates and sandstones are massive, cross bedded and pink and brown in colour. They contain local grit bands and maroon siltstone interbeds. Cross bedding and heavy mineral lamination are present and in a borrow pit 3 km southeast large foresets up to 35 m across are present. Local, thin barytes veinlets are developed in the Pandurra Formation.

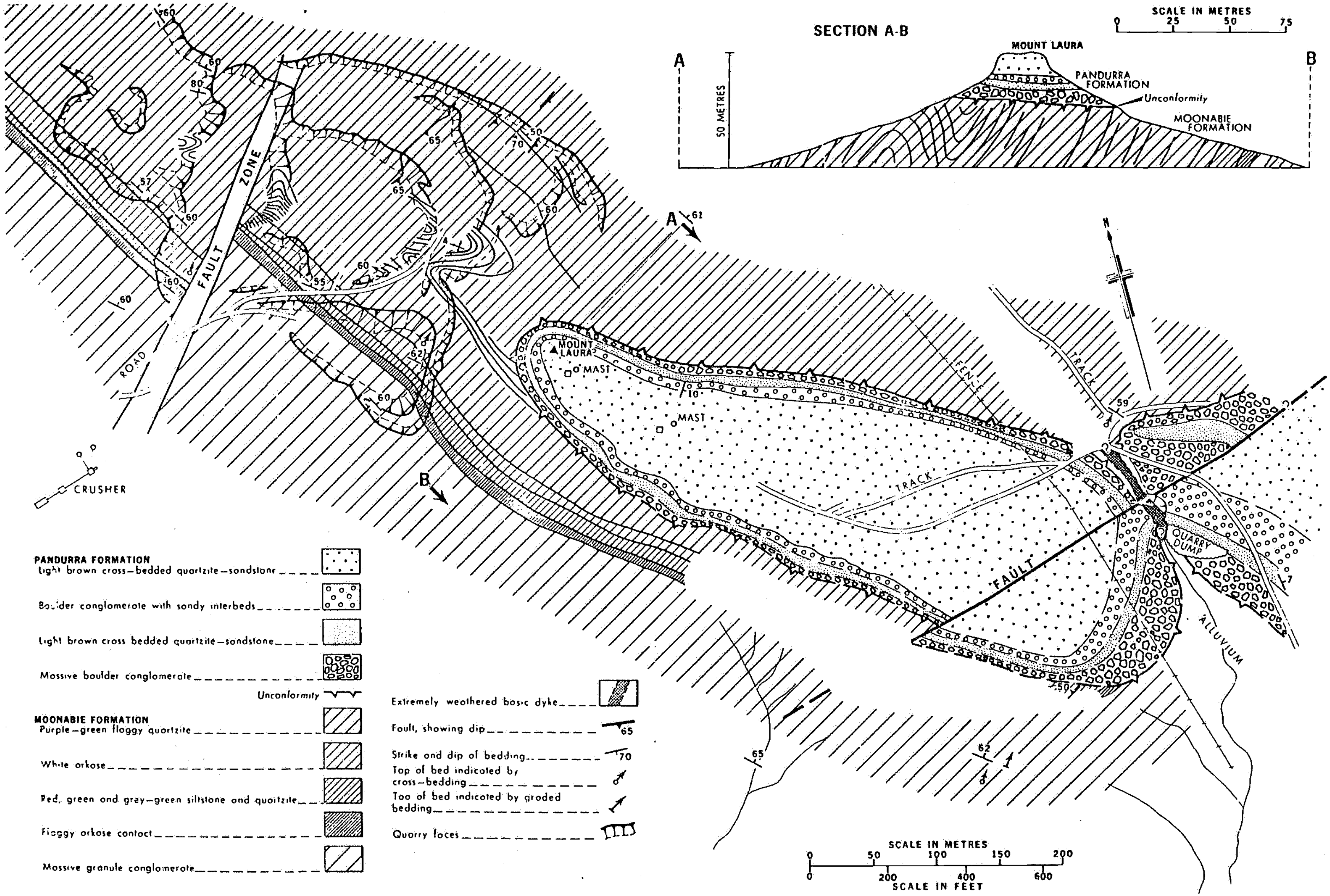

Fig. 13. Geology of the Mount Laura area, after Drexel and Nixon in Thomson et al (1976) Locality 12.

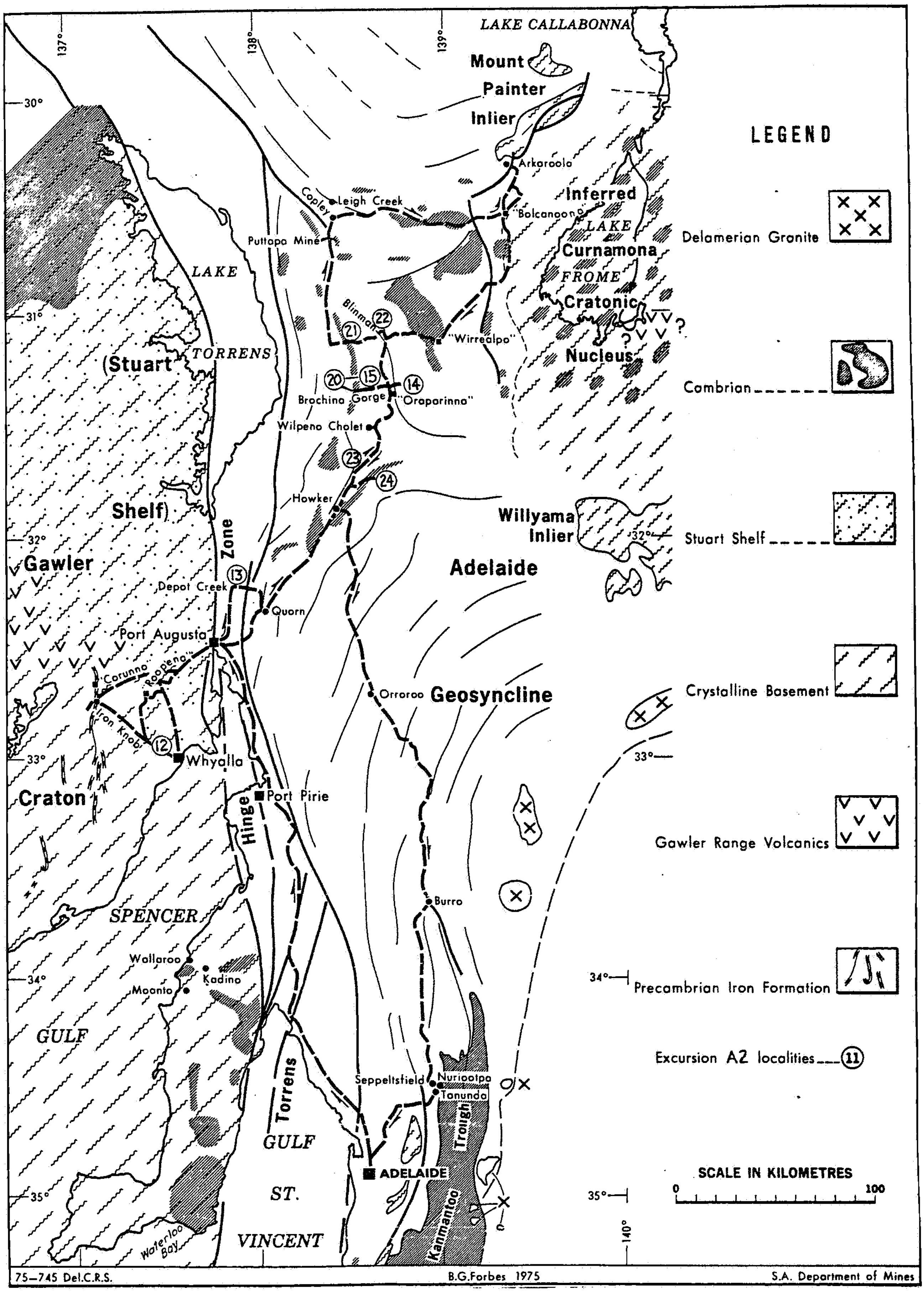

Fig. 14. Route of excursion A2 showing locality numbers and tectonic background.

A2 FLINDERS RANGES

PRECAMBRIAN GEOLOGY OF THE ADELAIDE "GEOSYNCLINE"

The Adelaide Geosyncline is a region of thick intracratonic accumulation of sedimentary rocks of Late Precambrian and Cambrian age, with minor volcanics, of late Precambrian age in South Australia and western New South Wales (Fig. 1). In South Australia, early Cambrian volcanism was limited to the Adelaide region. The term geosyncline is used as a convenient reference to a belt of thick sediments and not in the restricted sense of a trough marginal to a plate. Although partly fault-controlled, the geosyncline bears little resemblance to the aulcogenes of the East European Platform (Bogdanoff et al., 1964). Faults of varying extent, sometimes with associated crush zones and piercement structures, frequently follow northwest to northeast trends and have controlled dramatically in places the thickness and facies of Adelaidean sediments. Present maximum depth to basement within the geosyncline is about 10 km; total thickness of measured sequences (including the Cambrian) in the COPLEY region (Coats, 1973) is over 40 km. The Adelaide Geosyncline thus seems to occupy a fractured and downwarped segment of basement which has been much more mobile than the adjacent Gawler Craton. The Torrens Hinge Zone separates rocks of the fold belt from a thin incomplete and relatively undeformed Late Precambrian-Cambrian cover deposited on the Stuart and Spencer Shelves flanking it to the west. The small Curnamona Cratonic Nucleus east of the Flinders Ranges has an undeformed cover of Cambrian and presumed Adelaidean sediments.

Apart from recycling of sediment derived from uplifted parts of the geosyncline itself, sediment sources appear to have been in the west (Gawler Craton), north (? Muloorina Ridge), northeast (Mount Painter Inlier and Curnamona Cratonic Nucleus), and east (Willyama Inlier). In addition to the broad downwarping of the geosyncline and the variable contribution of sediment from marginal areas there was strong local control of sedimentation by penecontemporaneous faults and movement of diapirs (Coats, 1965). Some examples of this are in the Mount Painter area, around diapirs in the Flinders Ranges, near the Spalding Inlier (facies changes in the lower Burra Group), and across a major fault in the Manunda region.

The oldest sediments of the geosyncline are termed the Callanna Beds, here referring to rocks stratigraphically below the Burra Group (see Figs. 15, 16). The base of the Callanna Beds 6 km east-southest of Mount Painter at the base of the Paralana Quartzite in its type section, is the lower reference point for Adelaidean time (Dunn et al., 1966). The age of this is not known, but on the basis of correlation of the Roopena Volcanics with the Wooltana Volcanics, the inferred age was thought to be about 1 400 million years (Thomson, 1966). However, the revised correlation of the Beda Volcanics found on the Stuart Shelf (age 1 076 ± 34 Ma) with volcanics at Depot Creek and Wooltana occurring in the fold belt suggest the base of the Callanna Beds has an approximate age of 1 100 to 1 150 million years. There is evidence of breaks in deposition between Callanna Beds and Burra Group, and also higher in the Adelaidean.

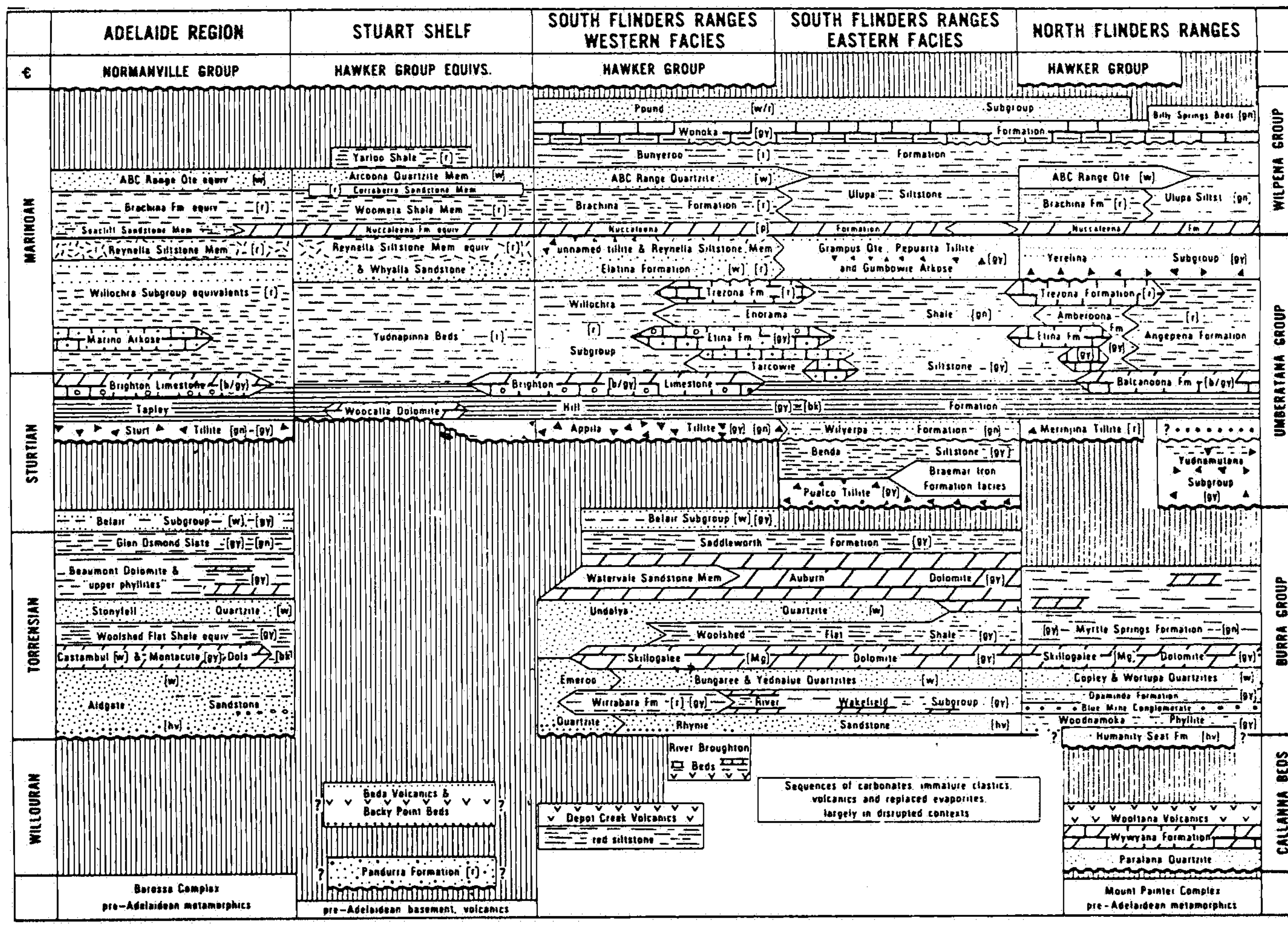

Fig. 15. Simplified Adelaidean time-rock diagram for Adelaide Geosyncline, after Rutland *et al* (1975).

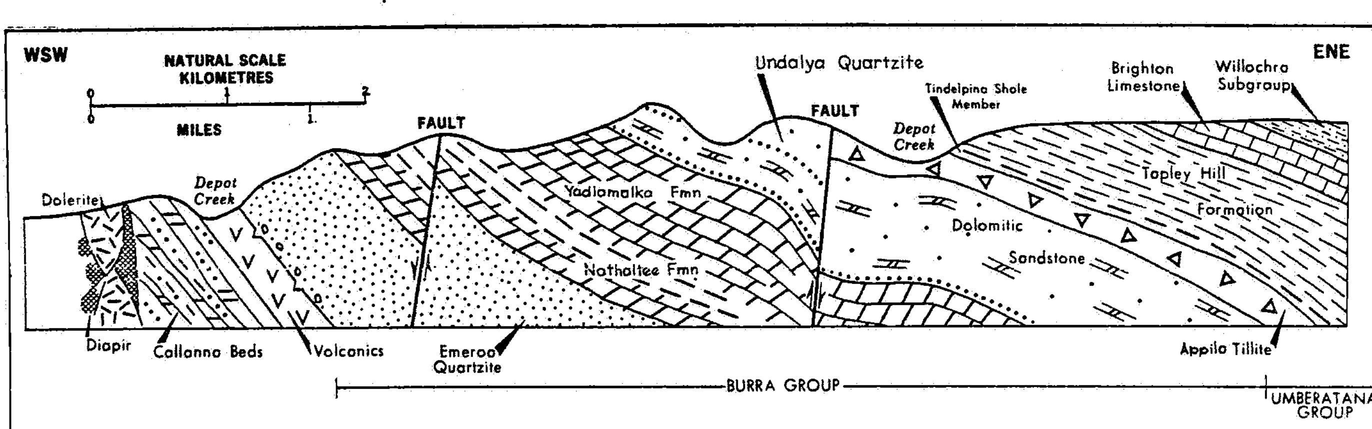

Fig. 16. Geological section along Depot Creek, northwest of Port Augusta, locality 13, modified from Preiss and Sweet 1966.

CALLANNA BEDS*

Similar sequences correlated with the Callanna Beds in the geosyncline are known in the Peake and Denison region, Willouran Ranges, Mount Painter area, Port Augusta area, Spalding Inlier, and Broken Hill area (New South Wales). The rocks are mainly quartzite, siltstone, evaporite carbonate, stromatolitic carbonate, and basic volcanics. Apart from the volcanics, this lithology is broadly similar to that of the overlying Burras Group. The unconformable sedimentary contact with crystalline basement in the geosyncline is known only in the Denison, Mount Painter, and Broken Hill areas. Metamorphic aspect of the Callanna Beds is similar to that of the Burra Group. Disrupted Callanna Beds are known within diapirs over wide areas of the geosyncline. Halite casts and other evaporitic mineral pseudomorphs (Rowlands et al., 1981) are very common in the Callanna Beds and in diapiric breccias derived from them. Such strong evidence for a former evaporitic environment suggests that bedded halite was involved in the decollement of and diapiric intrusion of Callanna Beds.

The Callanna Beds overlie crystalline basement unconformably and transgressively and are a metamorphosed shallow-water sequence of basal sandstone with local conglomerate, dolomitic marble (Wywyana Formation), and volcanics (Wooltana Volcanics) (Fig. 15). Appreciable thickening of the basal quartzite occurred in regions of penecontemporaneous faulting. The dolomitic marble unit was locally mobilised into diapirs. The volcanics (basalt, trachyte, and minor rhyolite) are known to occur over an area of about 250 000 sq. km.

BURRA GROUP

What evidence there is of the base of the Burra Group generally suggests an unconformable relationship with the underlying Callanna Beds (e.g. the base of the Emeroo Quartzite in Depot Creek) (figs. 15, 16). The contact near Spalding may be conformable, but is not widely exposed. Basal sandstone and conglomerate of the Burra Group are characterised by the presence of titaniferous hematite detritus, as in the Emeroo Quartzite. Basal sandstones are thickest east of Port Pirie, and lithology of pebbles and crossbedding indicate derivation from the Gawler Craton to the west. Mud crack structures and salt casts suggest a partly tidal flat or fluviatile environment.

The overlying Mundallio Subgroup (Uppill, 1979) (includes Skillogalee Dolomite on Fig. 15) is an intertonguing complex of shallow water carbonates, shales, and sandstones. The carbonates are dominantly micritic with lesser intraclastic and stromatolitic dolomite interbedded with widespread sedimentary magnesite mudstone and conglomerate, the latter produced by

*Forbes et al (1981) have proposed that the Callanna Beds be given group status with two subgroups, the older Arkaroola Subgroup (type area, Mount Painter region) and the Curdimurka Subgroup (type area, Willouran Ranges). However, one of us (BD) believes that the use of the term group for the Callanna Beds is not justified as no complete stratigraphic sequence is presently known.

reworking desiccated magnesite mudstones. Normal limestones are absent. The carbonates were deposited in very restricted environments, either on extensive marginal marine mudflats or in ephemeral lakes as in the modern day Coorong Lakes in South Australia. Many Burra Group carbonates contain early diagenetic cherts, some of which contain micro-fossils (Schopf and Barghoorn, 1969). Associated evaporites are rare suggesting carbonate derivation from alkaline waters high in magnesium and with sulphate content lower than that for normal sea water.

Areas of greatest thickness were located near Burra, northeast of Port Pirie, and near Copley. Arkosic detritus, derived from the west and north, is prominent in the Port Pirie and Willouran Range areas. A monotonous sequence of silt, carbonate, and sand of shallow-marine origin, the Myrtle Springs Formation, overlies and intertongues with part of the Mundallio Subgroup. In southern areas, such as the Mount Lofty Ranges, the Undalya Quartzite is a prominent unit in this succession. As suggested by Rutland & Murrell (1975), the Burra Group may not have been deposited in the PARACHILNA region.

UMBERATANA GROUP

The Umberatana Group comprises the glacigene and interglacial deposits of the Adelaidean. There is ample evidence of tectonism prior to, and early in, this glacial interval. The earlier, Sturtian glaciation(>750 Ma) provided the thickest known deposits (over 5 000 m in the Umberatana and Manunda region, but elsewhere generally only a few hundred metres) and can be tentatively subdivided into three units.

The lowest unit contains thick diamictites and includes the Bolla Bollana Tillite (Mount Painter region) and the Pualco Tillite (Manunda: Olary region) (Fig. 15). The earliest glacial phase is recorded by about 4 500 m of glaciomarine and marine sediments deposited in an east-trending graben to the northwest of Mount Painter.

A middle unit, sometimes containing hematite beds (e.g. the Braemar Iron Formation and Holowilena Ironstone) contains rare dropstones.

The upper unit is characterised by the presence of reddish quartzite and porphyry boulders probably derived from the Gawler Craton and from the Curnamona Cratonic Nucleus, and lies unconformably on older glacial or preglacial rocks. Correlated with this upper unit is the tillite of Mount Jacob (Wooltana area), the Wilyerpa Formation (Bibliando and Olary regions), the Appila Tillite and the Sturt Tillite (Fig. 15).

The final, Marinoan glaciation (c. 660-680 Ma) in the Umberatana Group is separated from the earlier Sturtian phases by a thick section of mainly siltstone and local carbonate. This reached its greatest thickness of over 6 000 m in the PARACHILNA region (Preiss, 1973). Preiss envisages supratidal (e.g. part of the Brighton Limestone) to marine conditions (Tapley Hill Formation). The Willochra Subgroup is a red shallow-water facies of the upper Umberatana Group.

The upper glacial sequence contains a smaller proportion of coarse detritus that the lower; thickness reaches about 1 300 m in the Umberatana region, where it has been best described (Yerelina Subgroup). In the PARACHILNA region it is represented by the Elatina Formation (in part) and to the south and southeast by the Pepuarta Tillite and associated beds. Complex facies changes involving diamictite, drop-stone facies and other clastics are features of both glacial episodes and have been discussed by Link and Gostin (1981).

The first evidence of post-Callanna Beds diapirism was concurrent with interglacial sedimentation. Islands formed of rising diapiric breccias, presumably mobilised by evaporites within the Callanna Beds, shed tongues of coarse detritus into the surrounding seas until they were transgressed. Evidence of syn-depositional diapirism and erosion continued intermittently into the Early Cambrian. However, most diapirs seen within the fold belt appear to have been emplaced during post-depositional folding.

WILPENA GROUP

The Wilpena Group overlies the Umberatana Group (Fig. 15); the basal unit is commonly the Nuccaleena Formation, a distinctive pale reddish or yellowish laminated dolomite, and is very useful as a marker bed. The Nuccaleena Formation has been correlated with the Mantappa Dolomite of the Broken Hill region (Cooper & Tuckwell, 1971) and is similar to the dolomite unit at the top of the Moonlight Valley Tillite of the Kimberley region, Western Australia. It reaches its greatest thickness of over 50 m in the COPLEY region. The succeeding silty, partly reddish-coloured Brachina Formation has a greenish eastern facies termed the Ulupa Siltstone. Thickness appears to be greatest between the COPLEY and ADELAIDE area. The formation is barium-rich in the Flinders Ranges and forms the country rock for a number of economic barite veins. The ABC Range Quartzite thins markedly away from the Wilmington region and is derived from a source area in the Gawler Craton nearby. Plummer (1978) has recently erected a subgroup, the Brachina Subgroup, to encompass the sequence from the base of the Nuccaleena Formation to the top of the ABC Range Quartzite.

A distinctive feature of the Wonoka and Bunyeroo Formations is evidence for submarine canyons involving erosion of limestones of the lower Wonoka Formation and siltstones of the upper Bunyeroo Formation (Coats, 1964, Von der Borch et al., 1981). In contrast to the ABC Range Quartzite, the Pound Quartzite* reaches its greatest thickness in the COPLEY region and may be related to more northern and northeastern source areas. The Ediacara fossil assemblage is confined to a thin widespread unit in the upper Pound Quartzite, near the top of the Adelaidean (Wade, 1970; Jenkins, 1975).

CAMBRIAN OF THE FLINDERS RANGES

A thin platform cover of flat-lying to gently-folded Cambrian strata rests noncomformably on older Precambrian crystalline rocks on Yorke Peninsula, and disconformably overlies

*The Pound Quartzite (Forbes, 1975) is referred to as Pound Subgroup on Fig. 15 (see Jenkins, 1975).

Adelaidean shelf sediments to the west and northwest of Lake Torrens on the Stuart Shelf (Figs. 1, 17).

East of the Torrens Hinge Zone generally thicker and more complete Cambrian sequences everywhere lie disconformably above Adelaidean sediments. These are preserved in the widely separated fold-belt occurrences in the southern Mount Lofty Ranges/Kangaroo Island region and in the central Flinders Ranges.

According to Daily & Forbes (1969, p. 23), "practically flat-lying Cambrian (and presumably Late Proterozoic sediments below it) occurs in the subsurface around Lake Frome and testifies to the presence of an exceedingly stable platform in this region". Its cover, as far as is known, is simply an extension of rock formations found in the Flinders Ranges fold belt.

The correlation of the Cambrian in the Adelaide geosyncline and on the surrounding stable shelves is shown in figures 17, 18.

BASAL CAMBRIAN

The South Australian basal Cambrian has been documented by Daily (1972a, 1973, 1974, 1976) and its biostratigraphy is summarised in Figure 18. On the COPLEY 1:250 000 sheet the dominantly green, silt-rich Uratanna Formation with its trace-fossil bearing sandstones fills basins and channels cut into the Pound Quartzite sometimes to levels below that of the Ediacara Fauna. Considerable thickness changes suggest that its base is diachronous. The Parachilna Formation (Dalgarno & Johnson, 1962, 1963; Dalgarno, 1964) disconformably succeeds the Uratanna Formation, but where this is absent it rests disconformably on Pound Quartzite. Its rich trace fossils and a shelly fauna represented by the gastropod Bemella Missarzhevsky allow correlation of the Parachilna Formation with part of the Winulta Formation and the upper member of the Mount Terrible Formation (Daily, 1963) as illustrated in Figure 18. According to Daily (1976) the occurrence of the tubular non-shelly fossil Saarina Sokolov and other species of sabelliditids suggests a correlation of the upper member of the Mount Terrible Formation with the Lontova Horizon of the Baltic Stage of the Russian Platform. Daily (op.cit.) suggested a correlation of the middle member of the Mount Terrible Formation (this contains the shelly faunas listed in Fig. 18) with the Uratanna Formation, with the lower levels of the Lontova Horizon below which shelly fossils are unknown, and also with the shelly-rich basal Cambrian Tommotian Stage Rozanov et al. (1969), developed extensively on the Siberian Platform. It would seem then that the South Australia basal Cambrian fold belt occurrences with their shelly and trace-fossil assemblages are of considerable significance in terms of a world reference section for the Precambrian-Cambrian boundary. Investigations made by B. Daily in China in 1979 show that the trace fossils Didymaulischnus and overlying Plagiogmus occur in association with shelly fossils in the basal Cambrian strata of Yunnan and Sechuan provinces.

LOWER CAMBRIAN CARBONATE ROCKS

A prolonged phase of mainly carbonate sedimentation followed upon the deposition of the Parachilna Formation and its temporal

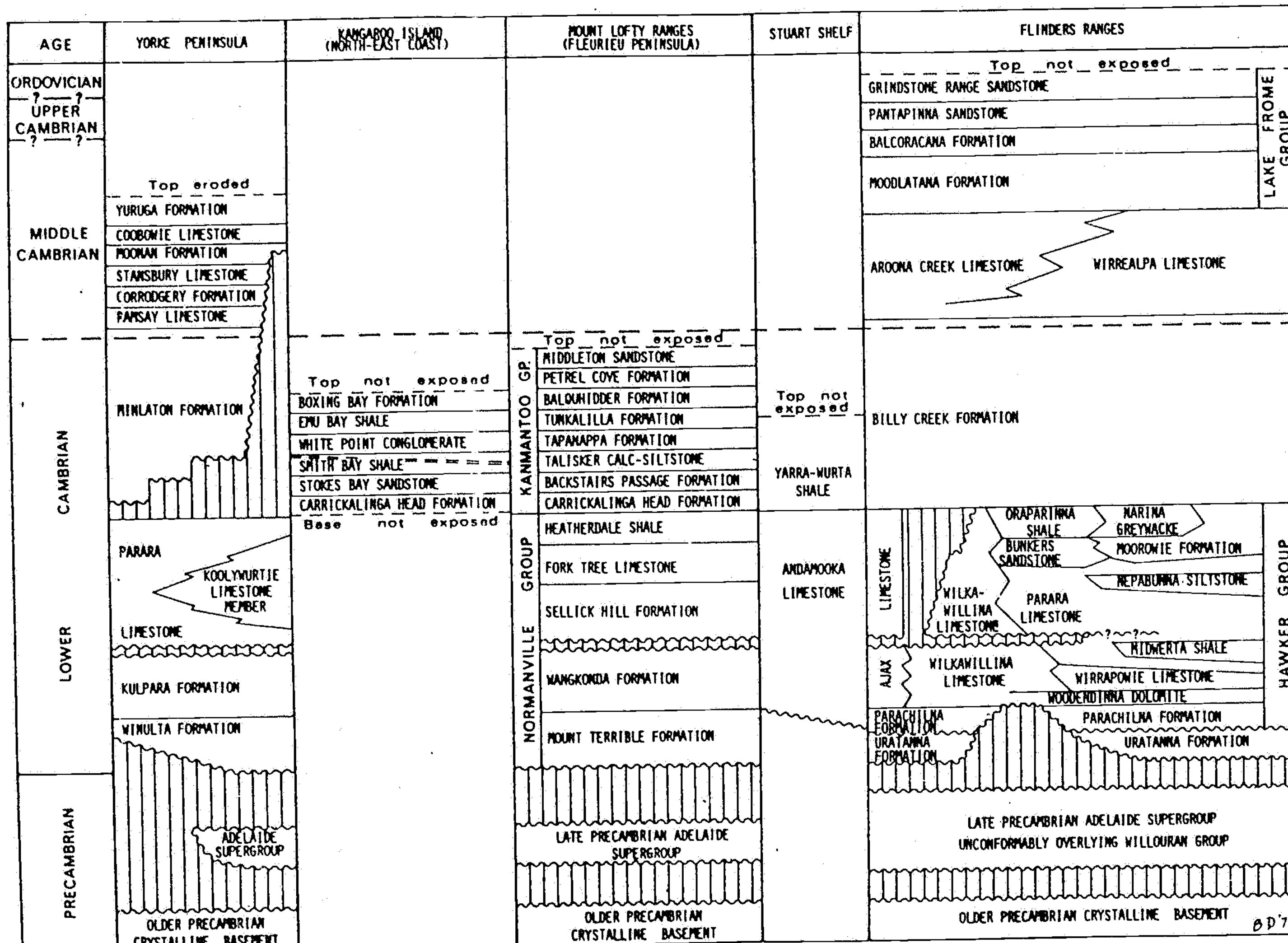

Fig. 17. Correlation of the Cambrian formations developed in the Adelaide geosyncline and on adjacent platforms.

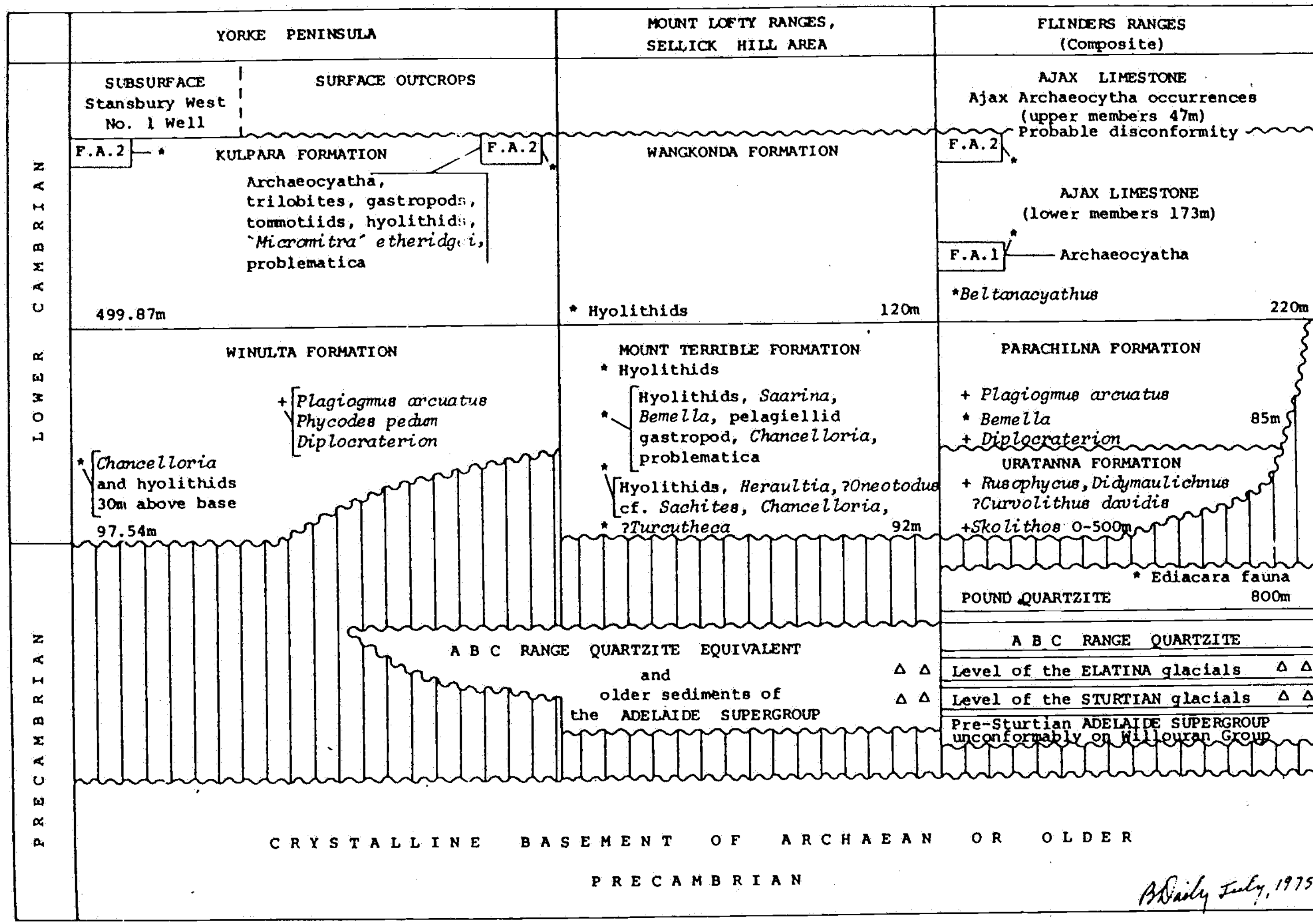

Fig. 18. Correlation of the early Cambrian platform cover on Yorke Peninsula with that found in the Mount Lofty-Flinders Ranges fold belt. *=shelly and body fossils; +=trace fossils; F.A.1=Faunal Assemblage No.1 of Daily (1956); F.A.2=Faunal Assemblage No.2 of Daily (1956).

equivalents. According to Daily (1972b) varying water depths and subsidence rates largely determined the types and thicknesses of the resulting carbonates. In general terms, the lighter coloured formations such as the Kulpara and Wangkonda Formations, and Fork Tree, Ajax, Andamooka, and Wilkawillina Limestones were deposited on relatively stable shelves whilst in the basinal areas and across hingelines where subsidence was more active and the water depths slightly below those of the shelves, much thicker, darker and impure limestone and shale were laid down. Examples are the Parara Limestone and Sellick Hill Formation (the Sellick Hill Limestone of Abele & McGowran, 1959).

The depositional environments of the stable shelf carbonates have been interpreted (Daily, 1972b) using present day models such as Shark Bay, Western Australia (Logan et al., 1970, 1974). The following examples reflect progressively less restrictive conditions and in general a gradual deepening of the depositional environment.

a) Laminoid-fenestral or "bird's-eye" fabrics are suggestive of intertidal to supra-tidal environments. Rarely are such limestones fossiliferous.

b) Flat cryptalgal-laminites, often dolomitic, appear to designate sheltered and restricted intertidal environments. Carbonate desiccation breccias and intraclastic limestones may be associated. Fossils are very rare.

c) Digitate, columnar, and domed stromatolites, oncolites and thrombolites appear to indicate intertidal to very shallow infratidal zones. The restricted hypersaline environments generally excluded faunas. Dolomitisation is common.

d) Ooid grainstones, often associated with intraclastic limestones and fine grained dolomites, appear to have been generated in warm shallow seas with elevated salinities. Dolomitisation and silicification are commonly seen. Fossils are generally rare.

e) Seawards, the latter facies tongue into bioclastic limestones with Archaeocyatha, algae, trilobites, brachiopods and hyolithids being the common fossils. Warm, clear waters with normal salinities and good circulation seem evident.

Small fluctuations in water depth displaced the sedimentary environments laterally; this combined with occasional storm activity to redistribute allochems, gradually built up an intertonguing complex of stable shelf carbonates. Unconformities in the shelf carbonates may be recognised by red weathering surfaces, often with sedimentary dykes wedging downwards from them. Calcreted surfaces, calcrete pisolites, and solution cavities with travertine also have been recognised.

Dark coloured limestones form the bulk of the Cambrian carbonates. The following kinds appear to reflect increasing water depths:

a) Dark grey poorly argillaceous limestones (often with mudcracks), intraformational limestone conglomerates, stromatolitic, thrombolitic and oolitic limestones may intertongue with pale coloured carbonates or basinwards with dark coloured poorly argillaceous mottled limestones.

b) The latter mottled types are variable in character and their genesis is uncertain. They contain sparse faunas, mainly phosphatic brachiopods, Archaeocyatha, sponges, and hyolithids, and intertongue with small archaeocyathid bioherms or biostromes.

c) Fine grained medium to dark grey bedded, mottled and nodular argillaceous limestones carrying mainly trilobites, gastropods and brachiopods formed in shallow basinal environments where good circulation prevailed. At the other extreme the darkest limestones and associated black shales formed in areas of rapid subsidence or where restricted water circulation gave rise to stagnant bottom conditions: Some basinal deposits exhibit graded bedding. Fossils are generally sparse and allochthonous

Lateral and vertical facies changes involving the two contrasting carbonate types may be quite rapid. Notable examples have been documented for the Hawker Group (Dalgarno, 1964) in the area covering the southeastern flank of the Wilkawillina graben (Dalgarno, 1964; Dalgarno & Johnson, 1965; Walter, 1967) and for the area surrounding the Wirrealpa diapir (Dalgarno, Johnson & Coats, 1964; Daily & Forbes, 1969; Haslett, 1969, 1975a and b, 1976). In the latter area, significant changes in facies and thickness occur across the east-trending Wirrealpa Hill hinge zone. Southeast of Wirrealpa Hill, Woodendinna Dolomite (Haslett, 1975b) is overlain by the bioclastic and oolitic Wilkawillina Limestone (Daily, 1956). To the northwest across the hinge zone, Parara Limestone (Tepper, 1879), Bunkers Sandstone (Daily, 1956), and Oraparinna Shale (Daily, 1956) with intertongues of Narina Greywacke (Dalgarno, 1964) disconformably succeed Wilkawillina Limestone. Together, these four formations which postdate Faunal Assemblage No.2 of Daily (1956) are the correlatives of only the upper half of the Wilkawillina Limestone found to the southeast of Wirrealpa Hill.

North of Wirrealpa Hill, Haslett (1975a and b) has mapped thin tongues of Wilkawillina Limestone penetrating the darker coloured shallow-water, stromatolite-bearing Wirrapowie Limestone. Casts of mudcracks, less common than those in the underlying Woodendinna Dolomite, testify to the periodic desiccation of intertidal mudflats. The deeper-water Parara Limestone follows above, the monotony of its lithology being broken by thin tongues of Wilkawillina Limestone, and elsewhere by occasional thick influxes of clastics like the Midwerta Shale (Coats, Callen & Williams, 1973; Coats, 1973) and Nepabunna Siltstone (Leeson, 1967).

This latter sequence appears to be typical of the thick basinal occurrences of Hawker Group mapped on the COPLEY 1:250 000 map sheet, except that Wilkawillina Limestone is either totally absent or occurs only as thin tongues within the darker coloured Wirrapowie and Parara Limestones. Notable exceptions are the region westwards from the Ajax Mine and narrow belts along the eastern margin of the fold belt south to Reaphook Hill.

In the Ajax Mine area, the Mount Scott Range, the Ediacara Range, and near Beltana Hill the thin Ajax Limestone (Taylor, 1910; Daily, 1956) constitutes the Lower Cambrian carbonates. These are shallow-water shelf carbonates, in part glauconitic, and represent a transgressive-regressive sequence punctuated by widespread breaks following upon the time of Faunal Assemblage No. 2 of Daily (1956). Many of the carbonate facies named on the

PARACHILNA 1:250 000 sheet can be recognised in the Ajax Limestone, but there are also distinctive facies that are unknown in that sheet area. Parara Limestone facies does not occur in the formation. It makes an appearance in the Mount Bayley syncline to the south of the Ajax Mine and there it is the temporal equivalent of the silicified Ajax Mine Archaeocyatha occurrences.

The Moorowie Formation (Mount, 1970; Coats 1973; Coats et al., 1973) found on the eastern margin of the fold belt is extremely variable in facies. It consists of biohermal and biostromal archaeocyathid limestones, coarse-grained sandstones associated with carbonate megabreccias, red and green micaceous siltstones and shales, grey flaggy limestones, stromatolitic and "bird's-eye" limestones, and dolomite. It correlates with the Bunkers Sandstone and Oraparinna Shale.

The widespread occurrence of "bird's-eye" limestone, dolomite, and stromatolites near the top of the Andamooka Limestone (Johns, Hiern & Nixon, 1966; Johns, 1968). Ajax Limestone, and in the youngest phases of the Wilkawillina Limestone and the Moorowie Formation points to a general regression of the sea before the influx of redbed clastics which gave rise to the Yarra-wurta Shale (Johns, Hiern & Nixon, 1966: Johns, 1968) and the Billy Creek Formation (Daily, 1956).

LATE LOWER CAMBRIAN CLASTICS

Dalgarno, (1964) has given evidence for disconformity at the base of the Billy Creek Formation in some areas, but in the stratotype and elsewhere there seems to be continuity in deposition across the boundary. It consists predominantly of red to brown (minor green and grey) micaceous shale and siltstone. Mud-cracks and halite casts are common. Evaporites are represented by thin beds of anhydrite. Interbeds of feldspathic sandstone, thin dolomite, limestone, and calc-shale, and thin tuff are also present. Red cross-bedded feldspathic sandstone and arkose are prominent in the uppermost parts of the formation. The sedimentology of the Billy Creek Formation has been thoroughly investigated by Moore (1979a, 1979b, 1979c, 1980).

The widespread tuffs are presumably ash-falls as they occur in the Yarra-wurta Shale, close to Andamooka and for the full width of the fold belt. They are more prominent in the east, suggesting that the source lay in that direction. They may have been derived from the Mount Wright Volcanic Arc (Scheibner, 1972) which lay in the east and where volcanics and sediments of late Early Cambrian age were recorded by Opik (1961).

A paralic environment of deposition for the Billy Creek Formation is envisaged, mainly regressive to restrictive with evaporitic and emergent conditions favouring redbed formation under oxidising conditions. A marine influence is shown by rare trilobite occurrences in green shales and shallow-water, foetid dark-coloured limestone and carbonate-rich tuff. Pocock (1970) described the trilobite Balcoracania flindersi from the lower part of the formation. Gehling (1971) has also reported Balcoracania dailyi Pocock in the lower Billy Creek Formation near Reaphook Hill. This allows a direct correlation with the top part of the 375 m thick White Point Conglomerate (Sprigg, 1955; Daily, 1956) of Kangaroo Island. Pocock (1964) has listed the trilobites of Redlichia Cossman, Estaingia bilobata Pocock, and the phyllocarid Isoxys Walcott from the overlying Emu Bay Shale (Sprigg, 1955) and for which a late Early Cambrian age seems evident.

The shallow-water Kangaroo Island sequence is correlated lithologically with the very thick metaclastics of the Kanmantoo Group, estimated by Sprigg and Campana (1953) to exceed 9 000 m, but this figure seems too high. A review of the group was given by Thomson (1969) and a reappraisal of the type section and revision of the stratigraphic nomenclature was presented by Daily and Milnes (1971, 1972, and 1973).

The Kanmantoo Group and its correlatives were deposited in response to the episodic Kangarooian Movements (Daily & Forbes, 1969), which commenced in the late Early Cambrian, extended into the Middle Cambrian on Yorke Peninsula and later continued and contributed sediments that make up the Lake Frome Group in the Flinders Ranges. Vertical uplifts along faults in Gulf of St Vincent and Investigator Strait gave rise to impressive conglomerates on Yorke Peninsula and Kangaroo Island (Daily, Moore and Rust, 1980). The older conglomerates are composed largely of pebbles and boulders of fossiliferous limestones and dolomites and the younger by dominantly crystalline basement rocks, thus testifying to the progressive stripping of a Lower Cambrian platform cover above a Precambrian crystalline basement comparable to that preserved on Yorke Peninsula. The bulk of the finer clastics were probably derived from crystalline basement rocks further west.

EARLY MIDDLE CAMBRIAN CARBONATE ROCKS

A widespread transgression of the sea ushered in a new phase of carbonate sedimentation following Billy Creek Formation deposition. This commenced with the Aroona Creek and Wirrealpa Limestones (Daily, 1956, Youngs, 1977, 1978) whose basal beds in their type sections are lithologically similar and contain the same fauna, notably Redlichia. The Wirrealpa Limestone contains faunas throughout. Small bioherms with algae, Archaeocyatha, sponges, and occasional stromatolite mounds (some are aligned northwest by current activity) occur in bioclastic and mottled limestones in the type section. By way of contrast, the bulk of the Aroona Creek Limestone is a paler coloured carbonate devoid of faunas, is largely dolomitic, and was deposited in a regressive and restrictive environment. "Bird's-eye" fabrics, flat cryptalgal laminites, and domed stromatolites are common. Near the northwest end of the Mount Scott Range the fossiliferous basal beds appear to have either wedged out or to have changed facies to stromatolitic limestone, there found below a siltstone-dolomite sequence.

On Yorke Peninsula, Redlichia-bearing Ramsay Limestone (Crawford, 1965) and Stansbury Limestone (Daily, 1969) and the overlying Coobowie Limestone (Daily, 1972a) are correlatives of the Wirrealpa Limestone. Red and green clastics are interbedded with the carbonates.

LAKE FROME GROUP

The Lake Frome Group (Daily, 1956) consists mainly of reddish clastics, the source area for most of which appears to have been to the south and west (Stock, 1974), and probably was the Gawler Craton in view of the high percentage of feldspars and metamorphic rock fragments in the sequence.

The Moodlatana Formation (Daily, 1956) consists mainly of red micaceous shale, siltstone, feldspathic sandstone, arkose, and minor dolomite with stromatolites and diagenetic chert. Mud-crack casts indicate periodic emergence. A minor widespread transgression produced fossiliferous dark foetid limestone and green siltstone with metadoxidid trilobites. These units are found in the upper levels of the formation. A Middle Cambrian age is indicated.

Cyclic sedimentation characterises much of the Balcoracana Formation (Daily, 1956). Typically the cycles consist of red, followed by grey-green, micaceous siltstone, and minor feldspathic sandstone, and arkose. Mud-crack and halite casts occur and anhydrite bands have been cut in the subsurface near Lake Frome. Tracks of trilobites are abundant in some beds. The grey-green clastics give way to thin dolomite and limestone, sometimes stromatolitic, which alternate with the thicker clastic intervals. An effaced agnostid trilobite cf. Lejopyge Hawle & Corda occurs in beds assigned to the formation in the subsurface in the Lade Frome area (Daily & Forbes, 1969); otherwise shelly fossils are unknown. A late Middle Cambrian age is suggested for the upper part of the formation.

The cyclic nature of deposition can be interpreted in terms of transgressive-regressive events. The red-beds are part of the regressive stage, with emergence and desiccation frequent happenings. The overlying grey to green clastics and carbonates reflect the restricted, possibly hypersaline and reducing environment which ensued following transgression.

The very thick Pantapinna Sandstone (Dalgarno & Johnson, 1963) consists mainly of cross-bedded pink-brown to white micaceous, and feldspathic sandstone, arkose and minor shale. These were fed into the rapidly subsiding basin by rivers draining a crystalline terrain lying to the west and south. Some may have been shed off the Olary Province south of the Frome Embayment. Large channels with low-amplitude cross-beds, commonly showing evidence of slumping, are notable features in the upper parts of the formation. Stock (1974) regarded the sediments as being laid down under fluviatile conditions but the presence of trilobite traces throughout indicate deposition in a marine environment.

The Grindstone Range Sandstone (Mawson, 1939b) is a quartzose pale-coloured feldspathic sandstone showing cross-bedding, slumping, and mud-cracks in its lower part, with conglomeratic phases associated with cross-bedded sandstone near the top of the formation. Stock (1974) has suggested deposition "in the proximal and distal parts of braided-streams and possibly an alluvial fan". However, trace fossils such as Cruziana show that the sequence is marine in origin. The beds may range into the Ordovician.

Continuity of sedimentation above the Lake Frome Group is unknown in the Flinders Ranges. The record presumably ceased with the onset of the Delamerian Orogeny (Thomson, 1969) of Early Palaeozoic age.

LATER HISTORY

In the Early Cambrian the Kanmantoo Trough which is part of the Adelaide Geosyncline developed in the Adelaide and Kangaroo Island regions. Within this region there accumulated a great thickness of grewacke, arkose and shale. During the Cambro-Ordovician Delamerian Orogeny the contents of the geosyncline were folded, faulted, and metamorphosed. Late Cambrian-Early Ordovician granites (Milnes et al 1977) intruded the eastern part of the Delamerian fold belt, and in some areas followed the main phase of metamorphism. Much of the Adelaidean is of lower greenschist metamorphic facies; in certain eastern areas metamorphism reaches the upper amphibolite facies. In the Mount Lofty Ranges three phases of folding have been identified (Offler & Fleming, 1968) and crystalline basement was folded with the overlying Adelaidean and Cambrian. Particularly in the west, the first phase of folding, which produced east-dipping cleavage and thrust planes, is the most evident. The overall pattern of folding is most easily explained by horizontal compression, but vertical movement along major faults also gave significant control. Jurassic kimberlite pipes and dykes (1980) Thomson are known from parts of the geosyncline and the Stuart Shelf (Colchester, 1972).

The Mt. Lofty and Flinders Ranges which are remnants of the Delamerian fold belt owe their present relief to rejuvenation by late Cenozoic mild compression and faulting.

LOCALITY DESCRIPTIONS FLINDERS RANGES

PORT AUGUSTA TO BLINMAN

The unsealed road connecting Port Augusta and Depot Creek lies within the Torrens Hinge Zone (Fig. 14) which separates the Stuart Shelf to the west from the fold belt to the east. Good views of the contrasting landforms illustrating the three tectonic zones can be seen while driving northwards. On the Stuart Shelf, thin near-horizontal Adelaidean sediments capped by Tertiary silcrete form the prominent mesas north-west of Port Augusta. To the east of the road, steeply dipping Adelaidean rocks in the Emeroo Range form the western margin of the Adelaide "Geosyncline". In the transitional Torrens Hinge Zone occasional glimpses of low hog-backs comprising gently dipping Adelaidean strata can be seen north-west of the road.

Just south of Depot Creek a two wheel track crosses the Port Augusta to Marree railway line and passes through a gate before heading eastwards across Pleistocene alluvial fan deposits and thence into Depot Creek gorge.

Locality 13 (Depot Creek, (Figs. 14 and 18)

At the western entrance to Depot Creek gorge (Figs. 14,18) xenoclasts of dolerite, tremolitic marble, dolomite and clastics are surrounded by carbonate-rich breccias of diapiric origin. According to Thomson et al (1976, p. 27):
"The Callanna Beds, to the east of this, are east-dipping reddish laminated, flaggy to medium-bedded dolomitic siltstone and sandstone with minor dolomite. Sedimentary structures include lenticular bedding, edgewise breccia, ripple marks, mud cracks, load casts, and rare salt casts. Total thickness is about 90 m."

The dolomitic sequence is overlain in the bed of Depot Creek to the east by reddish grey amygdaloidal volcanics. The lower contact of the volcanics is sharp and conformably overlies a thin tuffaceous bed (Preiss & Sweet, 1966). Successive flows can be recognised by the concentration of amygdales at the top of each flow. The volcanics are inferred to have been subaerial. They are of basic composition (48.6% SiO_2) and probably best described as trachytic basalts, now made up largely of hematite, orthoclase, and chlorite, with quartz-filled vesicles. The basalts contain thin lenses of reddish, partly sandy, sediment. Thickness of the volcanics varies from about 90 to 230 m."

The volcanics at Depot Creek which had previously been equated with the Roopena Volcanics (ca.1345 Ma) are currently regarded as correlatives of the Beda Volcanics (ca.1076 Ma, Thomson, 1980) found on the Stuart Shelf.

According to Thomson et al. (1976, p.27)
"The Emeroo Quartzite, locally the basal unit of the Burra Group, overlies an erosion surface on the underlying volcanics, which are (sic) bleached near the contact. The overlying quartzite contains fragments of volcanics up to 20 cm long, and is pale reddish, medium to coarse-grained and laminated. Dark hematite-rich laminae are common. Higher in the Emeroo Quartzite are very pale reddish and pale grey medium to thick-bedded feldspathic quartzites with tabular and trough cross-beds and ripple marks. Total thickness is 360 m."

The onset of Mundallio Subgroup sedimentation is marked by the incoming of dolomite and siltstone. The basal Nathaltee Formation (125 m thick in its type section 1 km south of Depot Creek (Uppill, 1979) cuts the rough track at a point 300 m beyond where it ascends from Depot Creek and again in Depot Creek some 800 m to the northeast due to faulting (Diapiric breccia cuts the formation in Depot Creek). The overlying Yadlamalka Formation which is 258 m thick in its type section in Depot Creek is lithologically similar to the Nathaltee Formation but is notable for the abundance of sedimentary magnesite (11% of the formation's thickness in the type section) which occurs either as intraformational conglomerates, commonly with a dolomitic sandy matrix and frequently displaying reverse grading, or as rare laminated micritic magnesite interbeds. Both formations consist predominantly of laminated dolomite commonly displaying desiccation cracks and rarer tepees and interbeds of intraformational dolomite conglomerates. Stromatolites in dolomite form biostromes and bioherms, commonly current aligned, and may grade laterally into wavy and flat laminated dolomicrites. Oolitic dolomite and oncolitic dolomite can also be found in the Yadlamalka Formation, generally as thin interbeds. Diagenetic chert, commonly pre-compactional, is conspicuous in outcrops of dolomite but it rarely replaces magnesitic beds. Dark cherts are carbonaceous and may contain micro-fossils.

Sandstone and siltstone are more prominent in the Nathaltee Formation than in the Yadlamalka Formation and were brought into the basin by easterly flowing currents.

Available evidence suggests that aragonite and calcite were not the normal carbonate precipitates during the time of deposition of the Mundallio Subgroup. However, in the case of rare oolitic dolomites, aragonite was probably the precursor precipitate and the ooids underwent dolomitisation subsequently. In all other cases it seems that dolomite or protodolomite was the dominant precipitate within the exceedingly shallow intracratonic basin which either had a restricted access to the sea or alternatively was lacustrine in nature. Magnesite deposition took place marginal to the sites of dolomite formation and eroded magnesite crusts were reworked basinwards to produce magnesite conglomerates.

The overlying Undalya Quartzite lacks magnesite but contains interbeds of dolomite near its base. The transition from the Yadlamalka Formation into the Undalya Quartzite can be seen best in the hill overlooking Depot Creek where the latter takes a prominent southerly bend. The quartzite is faulted against the Appila Tillite in Depot Creek but elsewhere the glacial sequence, which is correlated with the Sturtian glacigenes of the Adelaide region, rests disconformably on Undalya Quartzite or on other Burra Group sediments.

The glacial sequence is comprised mainly of clastics derived from the melting of icebergs, the settling of suspended fines, and sands and gravels shifted and concentrated by traction currents.

Diamictites have a variety of clast assemblages and clast frequency with respect to the enclosing gritty and fine grained matrix. Clasts are up to 2 m in length. Many are recognisable fragments of Mundallio Subgroup lithologies. Others include gneiss, schist, granite, and other crystalline rocks of unknown age and provenance.

Laminated to poorly bedded shale and siltstone, sometimes graded, occur as interbeds and commonly carry dropstones. It is the latter facies which testify to the glacial origin of the detritus comprising the formation.

Sandstone and conglomerate increase in frequency towards the top of the formation and were probably derived by winnowing and reworking of the earlier deposited glacigenes. Dolomite and clastics with conspicuous dolomitic matrix occur as interbeds near the top of the Appila Tillite.

The glacial sequence is best interpreted as having been deposited subaqueously, probably in a glaciomarine environment analogous to that surrounding Antartica today.

The contact between the Appila Tillite and dark coloured laminated dolomites and shales (Tildelpina Shale Member) at the base of the Tapley Hill Formation can be seen on the eastern bank of the creek flowing north into Depot Creek gorge. Higher in the sequence the carbonaceous and pyritic shales give way to olive-green finely laminated siltstones. Near the top of this shallowing upwards formation, bands of stromatolitic limestone increase in frequency and with the disappearance of siltstone passes into the Brighton Limestone equivalent of the Adelaide region. Stromatolites are a feature of the formation in the vicinity of Depot Flat. Ooid grainstones, intraformational limestone conglomerates and limestones with fenestral fabrics are interbedded with the stromatolitic limestones and attest to the shallow subtidal to supratidal environments in which the Brighton Limestone was deposited.

Depot Creek to Blinman

The unsealed road from Depot Flat to Quorn runs east across the Umberatana Group and then south. The Dutchmans Stern to the west forms a southerly plunging syncline rimmed by ABC Range Quartzite with underlying siltstones of the Brachina Formation. To the south is Devils Peak capped by Pound Quartzite faulted against ABC Range Quartzite. The Pound Quartzite is the youngest formation of Late Precambrian (Adelaidean) age. The southern most occurrence of the soft-bodied metazoan Ediacara Fauna is found in these sandstones on the western side of Devils Peak.

Northeast of Quorn the sealed road to Hawker traverses the Willochra Plain overlying the Cenozoic terrestrial deposits of the Willochra Basin. West of the road the Pound Quartzite forms the Ragless Range. The road passes through the same formation just north of the Willochra Plain where it forms the Black Jack Range. White breakaways at the foot of the range are in bleached Parachilna Formation, locally the earliest Cambrian deposits. Above is a thick sequence of fossiliferous Lower Cambrian limestones and shales carrying Archaeocyatha and trilobites.

About 20 km northeast of Hawker the irregular terrain of the Arkaba Diapir (Locality 23) is seen west of the road with a backdrop of Pound Quartzite forming the Elder Range. To the north views of the basin-shaped Wilpena Pound rimmed by Pound Quartzite form the skyline.

Immediately after passing the Wilpena Pound Chalet turn-off the unsealed road cuts the much thinned ABC Range Quartzite and after passing through the lower units of the Wilpena Group traverses the Umberatana Group. Laminated siltstone of the Tapley Hill Formation (Umberatana Group) is conspicuous west of "Upalinna" homestead to "Oraparinna" headquarters of the Flinders Ranges National Park. Younger beds belonging to the same rock group are traversed en route to Blinman, formerly the site of a rich copper mine, except for the final 6 km as the road then cuts or skirts the eastern part of the Blinman Diapir.

ORAPARINNA - BRACHINA AREA

After an overnight stay in Blinman the party will drive south and thence east to the disused Oraparinna asbestos mine (Locality 14). The day will be occupied examining the Precambrian - Cambrian section between the mine and the western end of Brachina Gorge (Fig. 19 and 20). The party will return to Blinman via Parachilna Gorge where the Precambrian - Cambrian boundary will be inspected. Most of the information pertaining to localities that will be examined is taken from Thomson et al (1976).

Locality 14 (Figs. 19, 20)

Diapirically intruded rocks of the Umberatana Group form the western end of a section through the upper Umberatana Group, the Wilpena Group, and the Early to Middle Cambrian. Access is by the track leading northeast past the disused Oraparinna asbestos mine. The track leaves the Blinman road about 7.5 km north of "Oraparinna" and reaches outcrops of sandy oolitic limestones of the Etina Formation at a further 2.7 km (wooded area).

The Oraparinna Asbestos Mine is located in the southern part of the Enorama Diapir. Magnesian crocidolite (King, 1961) or magnesio-riebeckite (Mount, 1975) and talc (McBriar, 1949) occur in dolomite.

In a creek to the southeast of the mine there is a sharp, irregular, discordant contact between red diapiric breccias and red to purple diamictite or 'tillite'. Erratics reach a length of 1 m and include abundant quartzite (many are faceted and striated), stromatolitic limestone, gneiss, and basic igneous rocks. Thin interbeds of finely laminated hematite-rich red shale and siltstone occur within the diamictite. Above are similar iron-rich clastics with thin interbeds of sandstone, conglomerate, calc-siltstone, and stringers of jasper. Rare dropstones up to 30 cm diameter occur in the laminated shales of the Holowilena Ironstone (Daily & Forbes, 1969). The ironstone-glacigene association parallels that reported from Late Precambrian glacigenes in South West Africa by Martin (1961) and in Canada by Young (1976).

Farther downstream and to the west of the diapir, olive-green laminated silts, reminiscent of the Tapley Hill Formation, are interbedded with sandstone, conglomerate, breccias, and

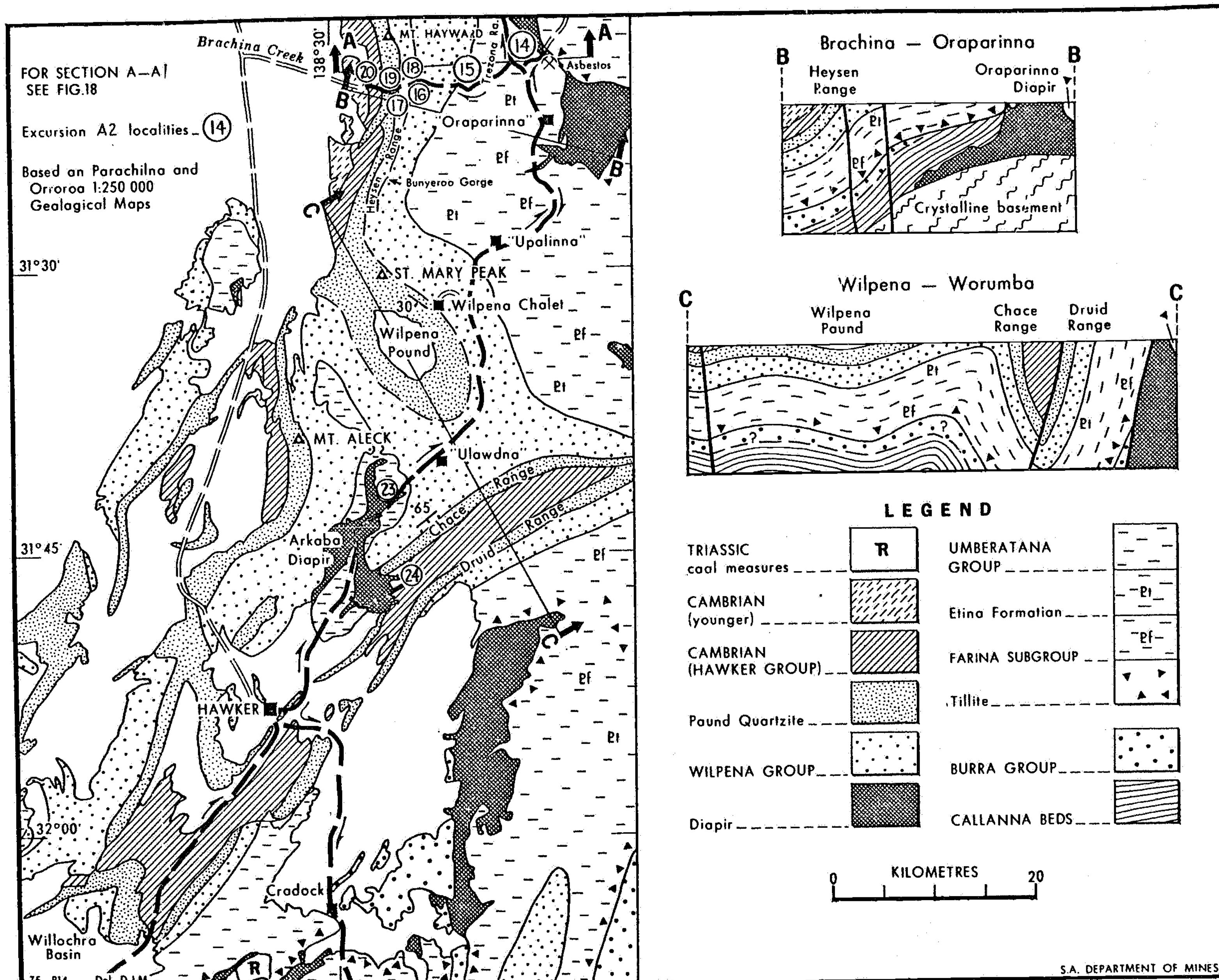

Fig. 19. Generalised geological map and sections, Cradock and Brachina, Localities 14 to 20 and 23, 24

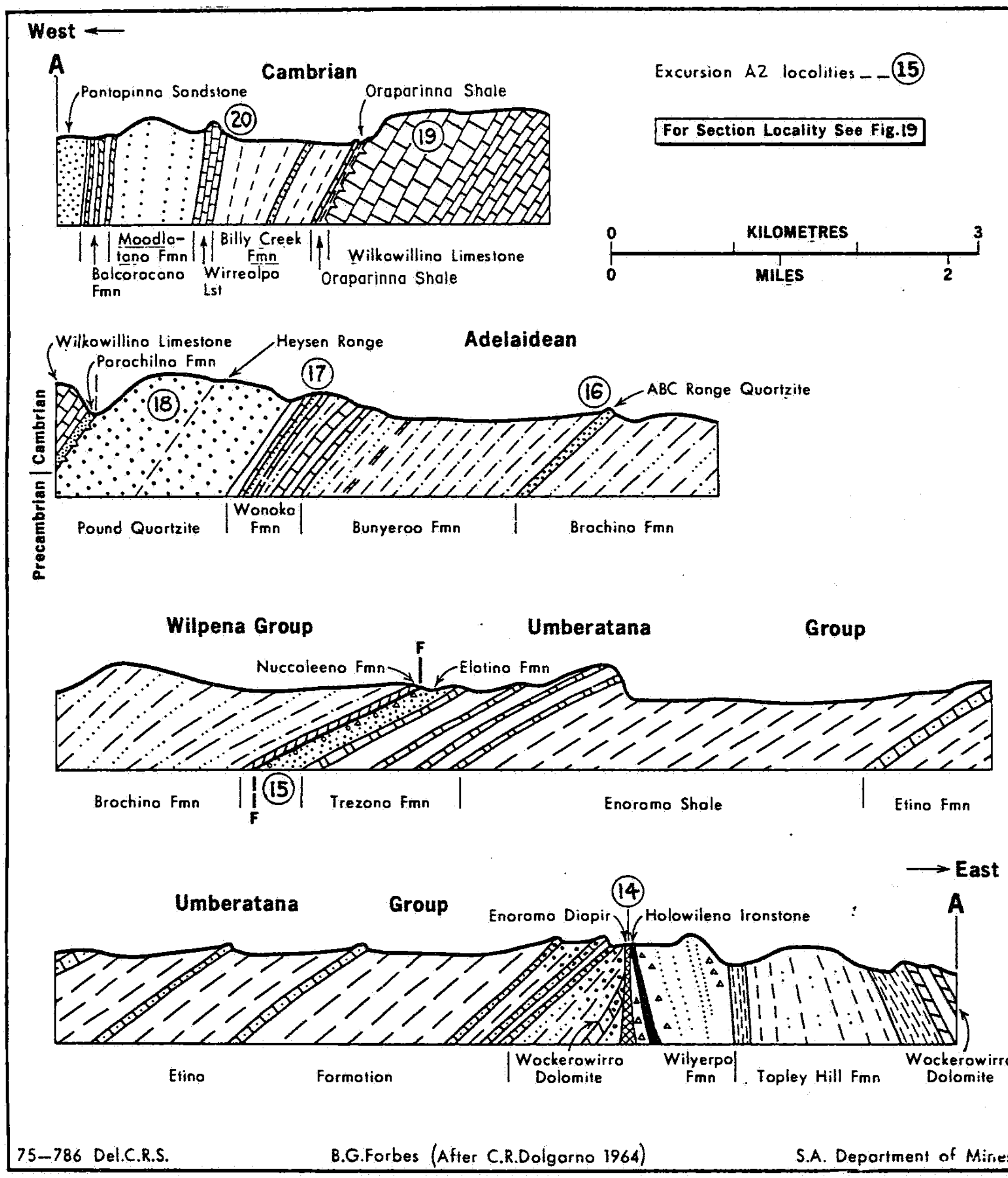

Fig. 20. Geological cross-section, Brachina-Oraparinna area, localities 14 to 20; after C.R. Dalgarno.

granule-rich clastics. Higher in the sequence there are intercalations of micritic silty cross-bedded oolitic and stromatolitic limestones (Etina Formation) whose facies are modified or overwhelmed by influxes of detritus eroded from nearby diapiric highs composed of Callanna Beds and associated dolerites.

Locality 15 (Figs. 19, 20).

The track leading to Brachina Gorge crosses a ridge of Trezona Formation about 7 km southwest of the Blinman road. Note the mud-flake rich pelletal limestones (the Hieroglyphic limestones of Mawson, 1939), the cryptalgal-laminites and associated stromatolites, oolitic limestones, and intraformational limestone conglomerates interbedded in green siltstones.

In a short traverse down Enorama Creek on the north bank of the stream there are fine examples of domed stromatolites elongated and aligned by currents. Associated limestones at the top of the Trezona Formation (240 m) exhibit well developed stylolites.

Further downstream, Elatina Formation red sandstones enclosing two thin purple diamictites cropout on the right bank of the creek. The sandstone facies which is geographically very widespread is characterised by thin pebble and granule trains outlining bedding. Evidence suggesting former frozen ground is given by thin dykes of gravel and sandstone although it is conceivable that the compacted sandy structures may be due to dewatering of the sediments.

Near the top of the predominantly arenaceous Elatina Formation (60 m; top of the Umberatana Group) is a purplish pebbly mudstone with faceted and striated clasts, regarded as a tillite of the youngest and third glacial phase of the Adelaidean (Mawson, 1949). Many of the clasts are lithologically similar to rocks of the Enorama and Oraparinna diapirs. In the northern Flinders Ranges B. Daily and V.A. Gostin have located numerous dropstones up to 1 m in length in a comparable stratigraphic position in the Mount Curtis Tillite of Coats (in Coats & Blissett, 1971). Forbes (1975, p.10) has also reported "sparse pebbles or dropstones" in the Umberatana and Olary regions and has suggested an easterly source. The thin (5 m) but distinctive yellow and pink laminated micritic dolomite of the Nuccaleena Formation (base of the Wilpena Group; Dalgarno & Johnson in Thomson et al., 1964) occurs on the left bank of the creek and is overlain conformably by the brown to reddish and grey-green siltstones and thin current-bedded sandstones of the 1200 m thick Brachina Formation (Dalgarno & Johnson, op.cit). Total thickness of the Wilpena Group is 3 600 m. Partly equivalent beds on the Stuart Shelf are about 500 m thick.

West of Locality 15 the road runs between Brachina Creek (to the north) and Elatina Creek, crosses Brachina Creek and makes a steep ascent cut in Pleistocene lacustrine deposits unconformably above Brachina Formation siltstones.

Locality 16 (Figs. 19, 20)

There is a passage from the shallowing upwards Brachina Formation into the overlying ABC Range Quartzite of Mawson (1939a) which, despite facies changes, can be traced and recognised over the western fold-belt and on the Stuart Shelf. Its shallow-water origin in most occurrences is demonstrated by casts of mud-cracks and associated clay-gall horizons.

Locality 16a is near the next crossing of Brachina Creek near the turn-off to the north to Aroona Valley, where ABC Range Quartzite crosses Brachine Creek. This formation (200 m) may be seen best in the south bank of the creek, but is cut by faults. The common rock is a pale pinkish-grey fine-grained flaggy to medium bedded feldspathic quartzite with rare black heavy-mineral lamination and minor thin interbeds of pale greenish-grey micaceous siltstone.

To the west are reddish and greenish shale and siltstone of the overlying Bunyeroo Formation (700 m thick) which may be seen near locality 16a or farther west at 16b near the turn-off south to Bunyeroo Gorge.

Locality 16b features brownish siltstone and fine sandstone of the Bunyeroo Formation in a creek bank adjacent to the road. Flute casts indicating a west to east blow and ripple mark structures are present.

Locality 17 (Figs. 19, 20)

The Brachina Creek track intersects the Wonoka Formation (510 m; Dalgarno & Johnson, op.cit) just before entering Brachina Gorge. Within the gorge the section is complicated by faulting, but from the vicinity of locality 17 there is a spectacular view of the reddish (lower) and white (upper) sandstone and quartzite members of the Pound Quartzite (890 m thick) dipping west in the south wall of Brachina Gorge.

The Wonoka Formation which is a shallowing upwards sequence consists dominantly of green-grey, mainly calcareous siltstone, shale, and minor sandstone interbedded with grey limestone of shallow-water origin. The latter includes fine-grained limestone, sometimes glauconitic, intraformational limestone conglomerate with flat and rounded clasts to 13 cm in length, and oolitic limestones. Oncolitic and stromatolitic limestones are also present at some localities. Pot holes or toroids filled with intraformational limestone conglomerates will be seen at locality 17. The Wonoka Formation passes without break into the red-coloured feldspathic sandstone and micaceous siltstone of the Bonney Sandstone Member of the Pound Quartzite (Forbes, 1971). This is 300 m thick in its type section in Bunyeroo Gorge to the south. Abundant mud-cracked horizons, flaser-bedding, and associated sedimentary structures point to a tidal-flat to shallow-water environment of deposition for this member.

Locality 18 (Figs. 14, 19, 20)

The Late Precambrian soft-bodied Ediacara faunal assemblage occurs towards the base of the 500 m thick dominantly pale coloured Rawnsley Quartzite Member of the Pound Quartzite.

Locality 18a is near the base of the white Rawnsley Quartzite Member, just east of a bend in the gorge to the northwest. Interbedded quartzite and reddish flaggy siltstone form steep twin gullies on the south side of Brachina Gorge; on the underside of a load-casted quartzite bed and on the soles of the more inaccessible sandstone slabs on the western side of the western gully are rare impressions of forms such as Dickinsonia Sprigg, Parvancorina Glaessner, and Cyclomedusa Sprigg.

Locality 18b. The contact between a clay-gall bearing quartzite at the top of the Pound Quartzite and the disconformably overlying clay-rich arenite, with well rounded quartz grains, of the Early Cambrian Parachilna Formation (Dalgarno & Johnson, op.cit) is visible in a gully on the south side of Brachina Gorge just southwest of the point where the road heads northwest out of the creek bed. Trace fossils found here in the Parachilna Formation include weathered-out crescent or bow-shaped perpendicular burrows, cf. Corophioides Smith, which occur in the basal metre and above, in association with the numerous perpendicular U-shaped Spreiten-burrows of Diplocraterion Torell. The shallow-water carbonates of the Woodendinna Dolomite conformably overlie the highly weathered Parachilna Formation clastics.

Locality 19 (Figs. 19, 20)

a) Abundant Archaeocyatha and calcareous algae occur in pale coloured Wilkawillina Limestone in the bed of Brachina Creek.

b) At the southwestern end of the Brachina Gorge, Dalgarno & Johnson (1965) show Billy Creek Formation redbeds resting unconformably on Hawker Group. The Edeowie Limestone Member is apparently missing at this locality. The sequence and the biostratigraphic information given below modify this and also clarify the situation as reported for the area north of Brachina Creek as given in Dalgarno (1964, p.139).

1. The upper part of the Archaeocyatha-rich Wilkawillina Limestone contains the Faunal Assemblage No. 2 of Daily (1956). This is readily recognised by the presence of the geographically widespread phosphatic-shelled enigmatic fossil redescribed by Walcott (1912) as the brachiopod Micromitra (Paterina) etheridgei (Tate). However, it is not a brachiopod but a new genus related to the problematical Tannuolina multifora Fonin & Smirnova from the Early Cambrian of Tuva, USSR. Lower Cambrian weathering produced a reddening of the upper part of the Wilkawillina Limestone downwards from the unconformity. A period of non-deposition cuts out the equivalent of over 1 000 m of Parara Limestone, Bunkers Sandstone, and most of the Oraparinna Shale present above the stratotype Wilkawillina Limestone some 30 km to the east.

2. About 6 m of limestone conglomerate intercalated with bedded Oraparinna Shale siltstone caps the unconformity surface. The conglomerates include boulders of Archaeocyatha-rich limestone up to 2 m in diameter and are set in a reddish matrix. Some limestone boulders carry the Faunal Assemblage No. 2 and indicate derivation from nearby Wilkawillina Limestone. The thin Oraparinna Shale above is fossiliferous to the east of the gorge where it contains the trilobite Redlichia.

3. Above is the grey flaggy Edeowie Member and this is succeeded by the overlying redbed clastics typical of the Billy Creek Formation.

Locality 20 (Figs. 19, 20)

A good exposure of the nodular and bedded blue-grey limestone and green calc-siltstone of the Wirrealpa Limestone crops out on the west bank of Brachina Creek. Fossils in the formation in the Brachina Creek area include several species of the trilobite Redlichia Cossman, including forms allied to Redlichia versabunda Opik, the gastropod Helcionella aff. rugosa chinensis Walcott, the brachiopods "Obolella" wirrealpensis Etheridge and Eoorthis tatei (Etheridge), the sponge Chancelloria Walcott, abundant hyolithids, and numerous ossicles of eocystids. The fauna is early Middle Cambrian in age or Ordian Stage at the very base of the Middle Cambrian scale as conceived by Opik (1967).

If time permits, a brief examination can be made of the dominantly red-coloured clastics of the Middle to Late Cambrian Lake Frome Group which crop out on either side of the road as it heads west across the dissected pediment and alluvium to cut the Hawker to Parachilna road.

After leaving Parachilna the party will inspect the Precambrian-Cambrian boundary in Parachilna Gorge and then drive down sequence and cross the Blinman Diapir en route to Blinman for overnight accomodation.

Locality 21 (Parachilna Formation Stratotype Fig. 14)

Near the western end of Parachilna Gorge a sharp disconformable contact (Dalgarno, 1962, 1964; Dalgarno and Johnson, op.cit.) separates fine-grained feldspathic Pound Quartzite from the rounded quartzose basal sands and shales of the stratotype Parachilna Formation. Clasts to 20 cm in length and presumably of Pound Quartzite are visible on the contact. The trace fossil Phycodes pedum Seilacher occurs in the basal few metres (Daily, 1973) and is succeeded by numerous bioturbated sandstones with vertical U-shaped burrows of Diplocraterion Torell. The Scandinavian ichnogenus Plagiogmus reported by Daily, Twidale & Alley (1969) from higher levels of the formation in nearby Wilpena Pound remains unlocated in the type section. Shale, sandstone, and oolitic and oncolitic limestones occur higher. There is a passage into the shallow-water carbonates of the Woodendinna Dolomite.

BLINMAN TO ADELAIDE

En route to Adelaide there will be an inspection of the Blinman and Arkaba diapirs.

The Blinman Diapir (Webb, 1961; Coats, 1964) is one of several large piercement structures which intruded Adelaidean and Cambrian sequences in the Flinders Ranges. The diapir is made up of a polymict breccia with a carbonate matrix (calcite, minor dolomite, quartz, muscovite, and traces of anhydrite), and includes several large blocks up to 3 km in length. The dominant clast lithology is quartzite and siltstone frequently ripple

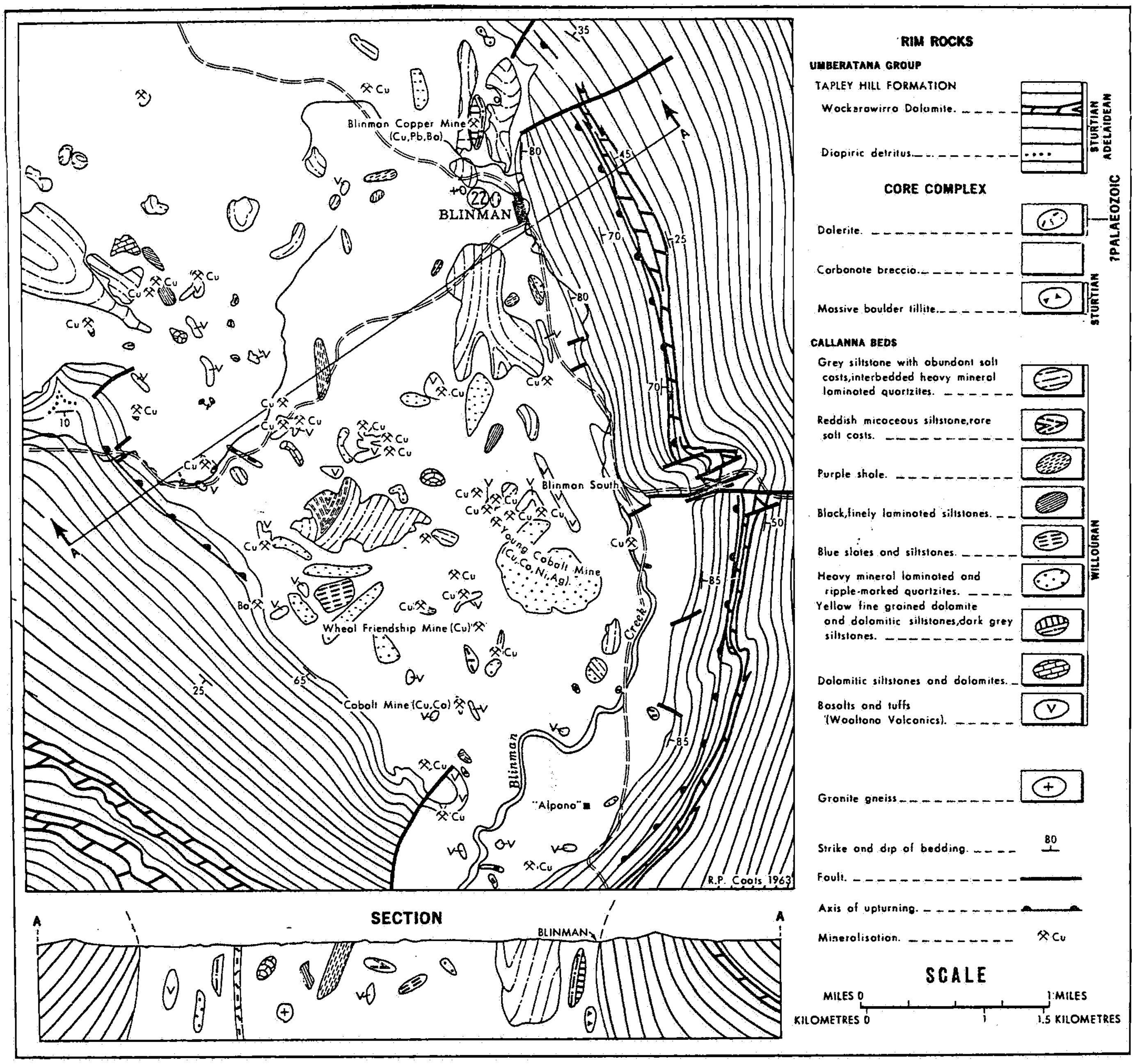

Fig. 21. Geological plan of part of the Blinman Dome Diapir, locality 22.

marked and with salt casts. Other stratigraphically significant raft lithologies, identifying the dismembered sequence as coming from the Callanna Beds low in the stratigraphic column, are basalt (Wooltana Volcanics) and granite and granite gneiss plucked from an underlying crystalline basement. The diapir was rising at the time of sedimentation, as evidenced by detritus in the Sturtian rim sediments. A small gravity low coincides with the structure (Mumme, 1961).

Locality 22 (A large block of crystalline basement, Fig. 21)

Behind Blinman Hotel a large block of granite gneiss measuring more than an acre (0.5 hectares) can be examined. Rafts of brecciated siltstone and interbedded sandstone with halite casts occur in nearby creeks.

The Arkaba Diapir, mapped in detail by Mount (1975), contains many exposures illustrating the nature of the diapiric breccias typical of many of the Flinders Ranges diapirs. One such exposure is at Locality 23, 3 km southwest of the Moralana Scenic Drive turn off, and another at Locality 24, 8 km northwest of "Glen Lyel" near the southeastern termination of the Chace Range.

Locality 23 (Arkaba Diapir, Fig. 19)

On the eastern bank of Arkaba Creek a tongue of flow banded diapiric breccias is in contact with easterly dipping Tapley Hill Formation siltstones. Xenoclasts of sediments including dolomite and sandstone with pseudomorphs after gypsum and halite are aligned in the flow banded breccias. On the western bank of the same stream are xenoclasts of dolerite, volcanics, ironstone, clastics and carbonates assignable to the Callanna Beds. These are enclosed in flow banded breccias. A large xenoclast of contorted Arkaba Hill Beds (Mount, 1980) is in the cliff exposure to the south.

Locality 24 (Fig. 19)

Road conditions permitting, an easterly projecting finger of the Arkaba Diapir can be inspected in the vicinity of the Chace Range. There, diapiric breccias have flowed into the space (up to 0.5 km wide) created by the rupture and separation of the Early Cambrian carbonates which flank them. The Cambrian limestone/diapir contact along the northern boundary of the dyke is sharp, and erosion has produced a wall-like margin. The limestones on the contact are unbrecciated, unaltered, and undeformed. The diapiric breccias and many of the rafts contain low-grade metamorphic minerals. In contrast, the Cambrian limestones show no metamorphic effects, but along the southern margin of the diapir the Wilkawillina Limestone is locally brecciated and dolomitised, the zone of alteration being up to 60 m wide. Flow-bands parallel the diapir/host-rock contacts.

South of Hawker the road crosses folded Adelaidean rocks trending north-northeast, part of the Delamerian fold belt (PARACHILNA, ORROROO and BURRA 1:250 000 map areas).

REFERENCES

Abele, C. and McGowran, B., 1959. The geology of the Cambrian south of Adelaide (Sellick Hill to Yankalilla). Trans. R. Soc. S. Aust., 82:301-320.

Bogdanoff, A.A., Mouratov, M.V. and Schatsky, N.S. (EDS.), 1964. Tectonics of Europe. 22nd International Geological Congress. 360pp.

Clarke, N.G., 1976. Structural analysis of the Port Neill mylonite zone and its country rocks, Port Neill, South Australia. University of Adelaide B.Sc. (Hons.) Thesis (unpubl.).

Coats, R.P., 1964. The geology and mineralisation of the Blinman Dome Diapir. Rep. Invest. geol. Surv. S. Aust., 26:35pp.

Coats, R.P., 1965. Diapirism in the Adelaide Geosyncline. APEA J. pp. 98-102.

Coats, R.P., 1973. COPLEY, South Australia. Explanatory Notes 1:250 000 Geological Series. geol. Surv. S. Aust., 38pp.

Coats, R.P. and Blissett, A.H., 1971. Regional and economic geology of the Mount Painter Province. Bull. geol. Surv. S. Aust.., 43:1-426.

Coats, R.P., Callen, R.A., Williams, A.F., 1973. COPLEY map sheet, Geological Atlas of South Australia, 1:250 000 series. Geol. Surv. S. Aust.

Colchester, D.M., 1972. A preliminary note on Kimberlite occurrences in South Australia. J. geol. Soc. Aust. 19:383-386.

Compston, W., Crawford, A.R. and Bofinger, V.M., 1966. A radiometric estimate of the duration of sedimentation in the Adelaide Geosyncline, South Australia. J. geol. Soc. Aust., 13:229-276.

Cooper, J.A., Fanning, C.M., Flook, M.M., and Oliver, R.L., 1976. Archaean and Proterozoic rocks on southern Eyre Peninsula, South Australia. J. geol. Soc. Aust., 23:387-292.

Cooper, P.F. and Tuckwell, K.D., 1971. The upper Precambrian Adelaidean of the Broken Hill area - A new subdivision. Q. geol. Notes, geol. Surv. N.S.W. 3:6-16.

Crawford, A.R., 1965. The Geology of Yorke Peninsula. Bull. geol. Surv. S. Aust. 39:pp.7-96.

Daily, B., 1956. The Cambrian in South Australia; in Rodgers, J. (Ed.), El Sistema Cambrico, Su Paleogeografia Y El Problema De Su Base. Int. geol. Cong., 20th Sess., Mexico, 1956, 2:91-147.

Daily, B., 1963. The Fossiliferous Cambrian succession on Fleurieu Peninsula, South Australia. Rec. S. Aust. Mus., 14:579-601.

Daily, B., 1969. Fossiliferous Cambrian sediments and low-grade metamorhpics, Fleurieu Peninsula, South Australia. IN B. Daily (Ed.) "Geological Excursions Handbook" pp 49-54. ANZAAS, Section 3, 1969.

Daily, B., 1972a. The base of the Cambrian and the first Cambrian Faunas. Centre for Precambrian Research, Univ. Adel. Spec. Pap. 1:13-41.

Daily, B., 1972b. Aspects of carbonate sedimentation in the Cambrian of South Australia. Abstracts Joint Specialists Meetings, Canberra. Geol. Soc. Aust., C10-14.

Daily, B., 1973. Discovery and significance of Basal Cambrian Uratanna Formation, Mount Scott Range, Flinders Ranges, South Australia. Search 4:202-205.

Daily, B., 1974. The Precambrian-Cambrian Boundary in Australia. Abstracts Specialist Group in Biostratigraphy and Palaeontology, "Precision in Correlation", Hobart, Geol. Soc. Aust., pp.4-8.

Daily, B., 1976. New data on the base of the Cambrian in South Australia. Izv. Akad. Nauk. Ser. Geol., 3:45-52 (in Russian).

Daily, B. and Forbes, B., 1969. Notes on the Proterozoic and Cambrian, southern and central Flinders Ranges, South Australia. In B. Daily (Ed.) "Geological Excursions Handbook", pp.23-30, ANZAAS, section 3, 1969.

Daily, B. and Milnes, A.J., 1971. Stratigraphic Notes of Lower Cambrian fossiliferous metasediments between Campbell Creek and Tungkalilla Beach in the type section of the Kanmantoo Group, Fleurieu Peninsula, South Australia. Trans. R. Soc. S. Aust., 95:199-214.

Daily, B. and Milnes, A.J., 1972. Revision of the stratigraphic nomenclature of the Cambrian Kanmantoo Group, South Australia. J. Geol. Soc. Aust., 19:197-202.

Daily, B. and Milnes, A.J., 1973. Stratigraphy, structure and metamorphism of the Kanmantoo Group (Cambrian) in its type section east of Tungkalilla Beach, South Australia. Trans. R. Soc. S. Aust., 97:213-251.

Daily, B., Moore, P.S., and Rust, B.R., 1980. Terrestrial-Marine transition in the Cambrian rocks of Kangaroo Island, South Australia. Sedimentology. 27:379-399.

Daily, B., Twidale, C.R., and Alley, N.F., 1969. Occurrence of Lower Cambrian sediments in Wilpena Pound, Central Flinders Ranges, South Australia. Aust. J. Sci. 31:301-302.

Dalgarno, C.R., 1962. Basal Cambrian Scolithus Sandstone in the Flinders Ranges. Q. geol. Notes, geol. Surv. S. Aust., 3:6-7.

Dalgarno, C.R., 1964. Lower Cambrian stratigraphy of the Flinders Ranges. Trans. R. Soc. S. Aust., 88:129-144.

Dalgarno, R. and Johnson, J.E., 1962. Cambrian sequence of the western Flinders Ranges. Q. geol. Notes. geol. Surv. S. Aust., 4.

Dalgarno, R. and Johnson, J.E., 1963. Lower Cambrian of the eastern flank of the Flinders Ranges. Q. geol. Notes, geol. Surv. S. Aust., 7.

Dalgarno, C.R. and Johnson, J.E., 1965. ORAPARINNA map sheet. Geological Atlas of South Australia. 1:63 360 Series. Geol. Surv. S. Aust.

Dalgarno, C.R. and Johnson, J.E., 1968. Diapiric structures and late Precambrian - early Cambrian sedimentation in Flinders Ranges, South Australia. Mem. Am. Ass. Petrol. Geol. 8:301-314.

Dalgarno, C.R., Johnson, J.E., and Coats, R.P., 1964. BLINMAN map sheet, Geological Atlas of South Australia 1:63 360 series. Geol. Surv. S. Aust.

Daly, S.J., Webb, A.W., and Whitehead, S.G., 1978. Archaean to Early Proterozoic banded iron formations in the Tarcoola region, South Australia. Trans. R. Soc. S. Aust., 102:141-149.

Drexel, J.F., 1976. The geology of Mt Laura, Whyalla, South Australia. S. Aust. Dept. Mines and Energy report 76/146 (unpubl.).

Dunn, P.R., Plumb, K.A., and Roberts, H.G., 1966. A proposal for a time-stratigraphic subdivision of the Australian Precambrian. J. Geol. Soc. Aust., 13:593-608.

Fanning, C.M., 1975. Petrology, structure and geochronology of some high grade metamorphic rocks at Fishery Bay and Cape Carnot, southern Eyre Peninsula. Univ. of Adelaide. B. Sc. Hons. Thesis, (unpubl.).

Fanning, C.M., Oliver, R.L., and Cooper, J.A., 1979. The Carnot Gneisses, a metamorphosed Archaean supracrustal sequence in southern Eyre Peninsula. In: Parker, A.J. (Compiler), Symposium on the Gawler Craton, Extended Abstracts. Geol. Soc. Aust., Adelaide, pp.13-15.

Fanning, C.M., Oliver, R.L., and Cooper, J.A., 1981. The Carnot Gneisses, southernmost Eyre Peninsula. S. Aust. Dept. Mines and Energy report 81/52 (unpublished).

Flook, M.M., 1975. The geology and geochronology of high grade metamorphic rocks at Kirton Point and Cape Donington, southern Eyre Peninsula. Univ. of Adelaide. B. Sc. (Hons.) Thesis, (Unpubl.).

Forbes, B.G., 1971. Stratigraphic subdivision of the Pound Quartzite (Late Precambrian, South Australia). Trans. R. Soc. S. Aust. 95:219-225.

Forbes, B.G., 1975. Notes on glacial and preglacial sequences of the Adelaide "Geosyncline" South Australia. Abstract. "Proterozoic Geology Convention", Geol. Soc. Aust. Inc. p.10.

Forbes, B.G., Murrell, B., and Preiss, W.V., 1981. Subdivision of lower Adelaidean, Willouran Ranges. Q. geol. Notes geol. Surv. S. Aust. 79:7-16.

Gehling , J.G., 1971. The geology of the Reaphook Hill area. Univ. Adelaide, B.Sc. (Hons.) Thesis, (unpubl.)

Giles, C., Goode, A.D.T., and Lemon, N.M., 1979. Middle Proterozoic volcanism and sedimentation on the northeastern Gawler Block. In: Parker, A.J. (Compiler), Symposium on the Gawler Craton, Extended Abstracts. Geol. Soc. Aust., Adelaide, pp.53-55.

Giles, C.W. and Teale, G.S., 1979. A commparison of the geochemistry of the Roopena Volcanics and the Beda Volcanics. Q. geol. Notes, geol. Surv. S. Aust., 71:7-13.

Glenn, R.A., Laing, W.P., Parker, A.J., and Rutland, R.W.R., 1977. Tectonic relationships between the Proterozoic Gawler and Willyama Orogenic Domains, Australia. J. geol. Soc. Aust., 24:125-150.

Haslett, P.G., 1969. The Cambrian geology north of the Wirrealpa Diapir. Univ. Adelaide B. Sc. (Hons) Thesis (Unpubl.).

Haslett, P.G., 1975a. Lower Cambrian stromatolites from open and sheltered intertidal environments, Wirrealpa, South Australia. In M.R. Walter (Ed.) "Stromatolites". (Elsevier, Amsterdam).

Haslett, P.G., 1975b. The Woodendinna Dolomite and Wirrapowie Limestone - two new lower Cambrian Formations, Flinders Ranges, South Australia. Trans. R. Soc. S. Aust., 99:211-220.

Haslett, P.G., 1976. Lower Cambrian stratigraphy and sedimentology, old Wirrealpa Springs, Flinders Ranges, South Australia. Univ. Adelaide. Ph. D. Thesis (Unpubl).

Jenkins, R.J.F., 1975. An environmental study of the rocks containing the Ediacara Assemblage in the Flinders Ranges. Abstract. "Proterozoic Geology Convention", Geol. Soc. Aust. Inc. pp.21-22.

Johns, R.K., 1961. Geology and mineral resources of Southern Eyre Peninsula. Bull. geol. Surv. S. Aust., 37.

Johns, R.K., 1968. Geology and mineral resources of the Andamooka - Torrens area. Bull. geol. Surv. S. Aust., 41:7-103.

Johns, R.K., Hiern, M.N., and Nixon, L.G., 1966. Andamooka map sheet, Geological Atlas of South Australia, 1:250 000 series. Geol. Surv. S. Aust.

King, D., 1961. The occurrence and comparative mineralogy of South Australia magnesian crocidolites (rhodusites). Trans. R. Soc. S. Aust., 84:119-128.

Leeson, B., 1967. BALCANOONA map sheet, Geological Atlas of South Australia 1:63 360 series, Geol. Surv. S. Aust.

Lemon, N.M. and Gostin, V., 1975. Sedimentology of the Corunna Conglomerate near Iron Knob, South Australia. In: Abstracts, Proterozoic Geology. 1st Aust. Geol. Conv., Adelaide pp.7-4.

Logan, B.W., Davies, G.R., Read, J.F., and Cebulski, D.E., 1970. Carbonate sedimentation and environments, Shark Bay, Western Australia. Mem. Am. Ass. Petrol. Geol., 13:1-223.

Logan, B.W., Read, J.F., Hagan, G.M., Hoffman, P., Brown, R.G., Woods, P.J., and Gebelein, C.D., 1974. Evolution and diagenesis of Quaternary Carbonate Sequences, Shark Bay, Western Australia. Mem. Am. Ass. Petrol. Geol., 22:1-358.

Link, P.K. and Gostin, V.A., 1981. Facies and palaeogeography of Sturtian Glacial Strata (late Precambrian), South Australia. Am. J. Sci., 281:353-374.

McBriar, E.M., 1949. Petrological examination of rocks from the Oraparinna Asbestos Deposit at Oraparinna. Min. Rev. Adelaide 87:179-180.

Martin, H., 1961. The hypothesis of continental drift in the light of recent advances of knowledge in Brazil and in south west Africa. A.L. Du Toit. Mem. Lect. No. 7. Annex to Vol 44 Trans. geol. Soc. S. Afr., pp. 1-47.

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 Sturt Shelf, South Australia. Q. geol. Notes, geol. Surv. S. Aust. 66:1-9.

Mawson, D., 1939a. The Late Proterozoic sediments of South Australia. Rept. ANZAAS, 24, Canberra Meeting. pp.79-88.

Mawson, D., 1939b. The Cambrian sequence in the Wirrealpa Basin. Trans. R. Soc. S. Aust., 63:331-347.

Mawson, D., 1949. The Elatina glaciation. A third recurrence of glaciation evidenced in the Adelaide System. Trans. R. Soc. S. Aust., 73:117-121.

Miles, K.R., 1954. The geology and iron ore resources of the Middleback Range area. Bull. geol. Surv. S. Aust., 33.

Milnes, A.R., Compston, W., and Daily, B., 1977. Pre - to syn-tectonic emplacement of Early Palaeozoic granites in southeastern South Australia. J. geol. Soc. Aust., 24:87-106.

Moore, P.S., 1979a. Stratigraphy of the Early Cambrian Edeowie Limestone Member, Flinders Ranges, South Australia. Trans. R. Soc. S. Aust., 103:101-111.

Moore, P.S. 1979b. Stratigraphy and depositional environments of the Billy Creek Formation (Cambrian), Central and Northern Flinders Ranges, South Australia. Trans. R. Soc. S. Aust., 103:197-211.

Moore, P.S., 1979c. Deltaic sedimentation - Cambrian of South Australia. J. Sedim. Petrology, 49:1229-1244.

Moore, P.S., 1980. Stratigraphy and depositional environments of the Billy Creek Formation (Cambrian), east of the Flinders Ranges, South Australia. Trans. R. Soc. S. Aust., 104:117-132.

Mortimer, G.E., Cooper, J.A., and Oliver, R.L., 1979. Petrological and petrochemical evolution of the 1.82 B.Y. Donington Granitoid Suite of the southeast Eyre Peninsula. In: Parker, A.J. (Compiler), Symposium on the Gawler Craton, Extended Abstracts. Geol. Soc. Aust., Adelaide, pp.37-38.

Mount, T.J., 1970. Geology of the Mount Chambers Gorge region. Univ. Adelaide, B. Sc. (Hons) Thesis (unpubl.).

Mount, T.J., 1975. Diapirs and diapirism in the Adelaide 'Geosyncline' South Australia. Univ. Adelaide, Ph. D. Thesis (unpubl.).

Mount, T.J., 1980. The Arkaba breccia intrusion and the Arkaba Hill Beds, Flinders Ranges. Q. geol. Notes, geol. Surv. S. Aust., 74:4-11.

Mumme, I.A., 1961. Geophysical Investigations of the Blinman Dome. Trans. R. Soc. S. Aust., 85:7-11.

Nixon, L.G., 1975. The stratigraphy and structure of the Moonabie Formation at Mount Laura, South Australia. Q. geol. Notes, geol. Surv. S. Aust., 56:10-12.

Offler, R. and Fleming, P.D., 1968. A synthesis of folding and metamorphism in the Mount Lofty Ranges, South Australia. J. geol. Soc. Aust., 15:245-266.

Opik, A.A., 1961. Cambrian and Ordovician sequence of the Mootwingee Range, northwestern N.S.W. Bur. Miner. Resour. Aust. unpubl. report.

Opik, A.A., 1967. The Ordian stage of the Cambrian and its Australian Metadoxididae. Bur. Min. Resour. Aust. Bull. 92:133-169.

Parker, A.J., 1978. Structural, Stratigraphic and metamorphic Geology of Lower Proterozoic rocks in the Cowell/Cleve district, Eastern Eyre Peninsula. Univ. Adelaide, Ph. D. Thesis, (Unpubl.).

Parker, A.J., 1980a. The six 1:100 000 compilation sheets of WHYALLA - A progress report. S. Aust. Dept. Mines and Energy report 80/93 (unpubl.).

Parker, A.J., 1980b. The Kalinjala Mylonite zone, eastern Eyre Peninsula. Q. geol. Notes, geol. Surv. S., Aust., 76:6-11.

Parker, A.J. and Lemon, N.M., 1982. Reconstruction of the Early Proterozoic stratigraphy of the Gawler Craton, South Australia. J. geol. Soc. Aust., 29:221-238.

Parker, A.J., Fanning, C.M., and Flint, R.B., 1981. Archaean to Middle Proterozoic geology of the Southern Gawler Craton, South Australia. Excursion Guide. S. Aust. Dept. Mines and Energy.

Plummer, P.S., 1978. Stratgraphy of the lower Wilpena Group (Late Precambrian), Flinders Ranges, South Australia. Trans. R. Soc. S. Aust., 102:25-38.

Pocock, K.J., 1964. Estaingia, a new trilobite genus from the Lower Cambrian of South Australia. Palaeontalogy, 7:458-471.

Pocock, K.J., 1970. The Emmuellidae, a new family of trilobites from the Lower Cambrian of South Australia. Palaeontology, 13:522-562.

Preiss, W.V. and Sweet, I.P., 1966. The geology of the Depot Creek area Flinders Ranges, South Australia. Univ. Adelaide, B. Sc. (Hons) Thesis, (unpubl.).

Preiss, W.V., 1973. Palaeoecological interpretations of South Australian Precambrian stromatolites. J. geol. Soc. Aust., 19:501-532.

Rowlands, N. J., Blight, P.G., Jarvis, D.N., and von der Borch, C.C., 1980. Sabkha and playa environments in late Proterozoic grabens, Willouran Ranges, South Australia. J. Geol. Soc. Aust., 27:55-68.

Rozanov, A.Y., Missarzhevsky, V.V., Volkova, N.A., Voronova, L.G., Krylov, I.N., Keller, B.M., Korolyuk, I.K., Lendzion, K., Michniak, R., Pychova, N.G., and Sidorov, A.D., 1969. Tommotian stage and the Cambrian lower boundary problem. AKAD NAUK. SSSR. Geol. Inst. Trudy, 206:1-380. Izdat 'Nauka' Moscow. (in Russian).

Rutland, R.W.R. and Murrell, B., 1975. Tectonics of the Adelaide fold belt. Abstract "Proterozoic Geology Convention". Geol. Soc. Aust. Inc. pp.3-5.

Rutland, R.W.R., Parker, A.J., Pitt, G.M., Preiss, W.V., and Murrell, B., 1981. The Precambrian of South Australia. In: Hunter, D.R. (Ed.), Precambrian of the Southern Hemisphere, Elsevier, Amsterdam, pp. 309-360.

Scheibner, E., 1972. The Kanmantoo pre-cratonic province in New South Wales. Q. geol. Notes Geol. Surv. N.S.W., 7:1-10.

Schopf, J.W. and Barghoorn, E.S., 1969. Microorganisms from the late Precambrian of South Australia. J. Palaeont., 43:111-118.

Smale, D., 1966. The petrology and age relationships of rocks in the Moonabie Range, South Australia. Trans. R. Soc. S. Aust., 90:153-168.

Sprigg, R.C., 1955. The Paint Marden Cambrian beds, Kangaroo Island, South Australia. Trans. R. Soc. S. Aust. 78:165-168.

Sprigg, R.C. and Campana, B., 1953. The age and facies of the Kanmantoo Group. Aust. J. Sci. 16:12-14.

Stock, E.C., 1974. The clay mineralogy, petrology and environments of deposition of the Cambrian Lake Frome Group, Flinders Ranges, South Australia. Univ. Adelaide M. Sc. Thesis, (unpubl.).

Taylor, T.G., 1910. The Archaeocyathinae from the Cambrian of South Australia with an account of the morphology and affinities of the whole class. Mem. R. Soc. S. Aust. 2:55-188.

Tepper, O., 1879. Introduction to the cliffs and rocks of Ardrossan, Yorke's Peninsula. Trans. R. Soc. S. Aust., 2:71-79.

Thomson, B.P., 1966. The lower boundery of the Adelaide System and older basement relationships in South Australia. J. geol. Soc. Aust. 13:203-228.

Thomson, B.P., 1969. The Kanmantoo Group and Early Palaeozoic tectonics. In L.W. Parkin (Ed.) Handbook of South Australian Geology, pp.97-108. Geol. Surv. S. Aust.

Thomson, B.P., Coats, R.P., Mirams, R.C., Forbes, B.G., Dalgarno, C.R., and Johnson, J.E., 1964. Precambrian rock groups in the Adelaide Geosyncline: a new subdivision. Q. Geol. Notes, Geol. Surv. S. Aust. 9:1-19.

Thomson, B.P., (Compiler) 1980. Geological map of South Australia, 1:1 000 000 scale. Dept. Mines and Energy, Adelaide.

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. Excursion Guide No. 33A. 25th Int. geol. Congr., Sydney, 1976.

Tilley, C.E., 1920. The metamorphism of the Precambrian dolomites of southern Eyre Peninsula, South Australia. Geol. Mag., 449-462, 492-500.

Tilley, C.E., 1921a. Precambrian paragneisses of southern Eyre Peninsula, South Australia. Geol. Mag., 58:251-259, 305-312.

Tilley, C.E., 1921b. The graphite rocks of Sleaford Bay, South Australia. Econ. Geol. 16:184-198.

Tilley, C.E., 1921c. The granite-gneisses of southern Eyre Peninsula (South Australia) and their associated Amphibolites. Geol. Soc. London, Quart. J. 77:75-134.

Trendall, A.F., 1976. Geology of the Hamersley Basin. Excursion Guide No. 43A.. 25th Int. geol. Congr., Sydney.

Uppill, R.K., 1979. Stratigraphy and depositional environments of the Mundallio Subgroup (new name) in the Late Precambrian Burra Group of the Mount Lofty and Flinders Ranges. Trans. R. Soc. S. Aust., 103:25-43.

Von der Borch, C.C., Smit, R., and Grady, A.E., 1981. Late Proterozoic Submarine Canyons of Adeliade Geosyncline, South Australia. Bull. Am. Ass. Pet. Geol., 66:332-347.

Wade, M., 1970. The stratigraphic distribution of the Ediacara fauna in Australia. Trans. R. Soc. S. Aust., 94:87-104.

Walcott, C.D., 1912. Cambrian Brachiopoda. U.S. Geol. Surv. Mon. 51:1-872.

Walter, M.R., 1967. Archaeocyatha and the biostratigraphy of the Lower Cambrian Hawker Group, South Australia. J. geol. Soc. Aust., 14:139-152.

Webb, A.W., 1978. Geochronology of the younger granites of the Gawler Craton and its NW margin. Rept. Aust. Mineral Devel. Lab. No. 1215 (unpubl.) (Reproduced as S. Aust. Dept. of Mines and Energy report 78/122 unpubl.).

Webb, A.W., 1979. A geochronological investigation of the tectono-magmatic history of the Gawler Craton. In: Parker, A.J. (Compiler) Symposium on the Gawler Craton, Extended Abstracts. Geol. Soc. Aust., Adelaide, pp.8-11.

Webb, A.W. and Thomson, B.P. 1977. Archaean basement rocks in the Gawler Craton, South Australia. Search, 8:34-36.

Webb, A.W. Thomson, B.P., Blissett, A.H., Daly, S.J., Flint, R.B. and Parker, A.J., in prep. Geochronology of the Gawler Craton. Bull. geol. Surv. S. Aust.

Webb, B.P., 1961. Diapiric structures in the Flinders Ranges, South Australia. Trans. R. Soc. S. Aust. 85:1-6.

Young, G.M., 1976. Iron Formation in glaciogenic rocks of the Rapitan Group, Norwest Territories, Canada. Precambrian Res., 3:137-158.

Youngs, B.C., 1977. The sedimentology of the Cambrian Wirrealpa and Aroona Creek Limestones. Bull. Geol. Surv. S. Aust. 47. pp.11-73.

Youngs, B.C., 1978. The petrology and depositional environments of the Middle Cambrian Wirrealpa and Aroona Creek Limestones (South Australia). J. Sedim. Petrology. 48:63-74.