# THE SEDIMENTOLOGY AND STRATIGRAPHY OF THE LATE PRECAMBRIAN POUND SUBGROUP, CENTRAL FLINDERS RANGES, SOUTH AUSTRALIA

by

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## SUMMARY

Facies analysis of the Pound Subgroup has enabled the first detailed environmental interpretation of the Bonney Sandstone and the Rawnsley Quartzite, with particular reference to the Ediacara Member.

A regional disconformity separates the clayey sandstones of the Bonney Sandstone from the overlying, more mature sandstones of the Rawnsley Quartzite. Within the previously defined Rawnsley Quartzite, the Ediacara Member occurs with a marked erosionally unconformable base in the Wilpena Pound area. The fossiliferous facies of the Ediacara Member increase in frequency toward the top.

The red clayey sandstones of the Bonney Sandstone represent a prograding tidal mud flat and delta sand ridge complex passing up into alluvial plain sediments. These are disconformably overlain by clean, current bedded feldspathic sandstones of the Rawnsley Quartzite which are interpreted as shallow marine and intertidal sand flat deposits. The Ediacara Member comprises an anomalous packet of sediments deposited after a spectacular erosional event within the Rawnsley Quartzite, when valleys were incised some 250 metres into the underlying sediments. These southeast trending valleys were filled by a sequence of pelagic silt and proximal turbidite grain-flow sand, passing up into more widespread coarsening upward cycles of bedded silts and sands where storm-surge sands facilitated the preservation of animals of the Ediacara assemblage. Prograding shelf sands capped the sequence, heralding a widespread return to stable, shallow marine and tidal flat conditions.

A review of the relationships of animals of the Ediacara assemblage to their preservational environment suggests that most species were fossilized close to where they lived : either as offshore benthic, free living and sessile forms or from the water column above.

A local palaeogeographic model for the Pound Subgroup envisages a source area to the west or northwest and a tidally swept, north-south trending shelf deepening to the east or south east. Periodic development of local tectonic highs influenced the Bonney Sandstone facies. Following a rapid transgression, early deposition of the Rawnsley Quartzite took place under stable conditions. A submarine erosional event followed tectonic overdeepening on the southeast part of the shelf. Subsequent progradation from the west led to a turbidite fill of the submarine valleys, followed by shallowing up cycles recording the return to tidal shelf deposition. Onshore aeolian dunes, reworking alluvial plains, are suspected as the source of mature sand which comprises much of the Rawnsley Quartzite.

# STATEMENT OF ORIGINALITY

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university, and the thesis contains, to the best of my knowledge, no material previously published or written by any other person, except where due reference is made in the text of the thesis.

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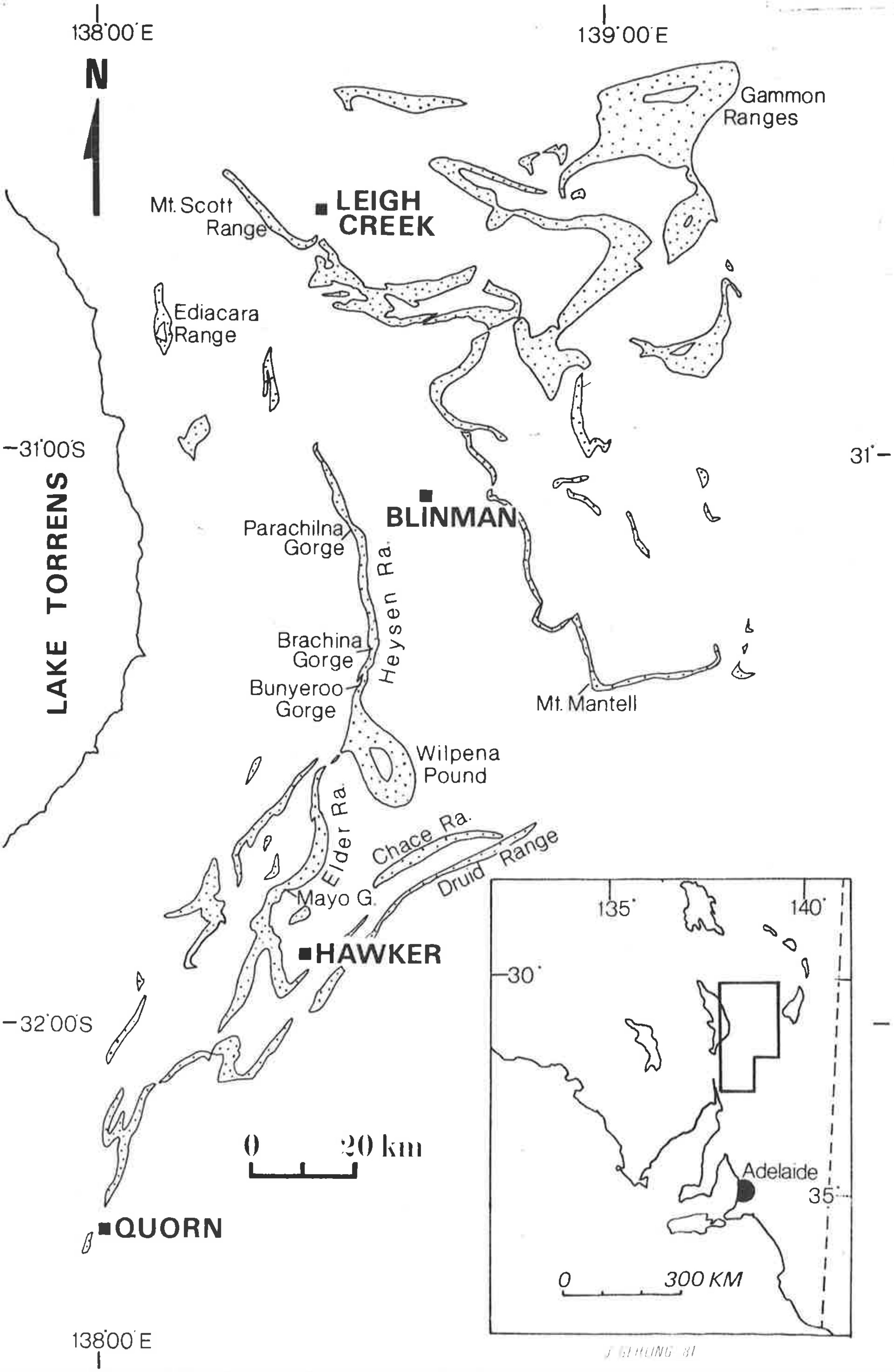
FIGURE 1

Locality map, showing principle outcrops of the Pound Subgroup (undifferentiated). Main area of study was in exposures between Hawker and Blinman.

FIG. 1


138°00′E
139°00′E
N
Gammon Ranges
Mt. Scott Range
LEIGH CREEK
Ediacara Range
31°00′S
31°
LAKE TORRENS
BLINMAN
Parachilna Gorge
Heysen Ra.
Brachina Gorge
Bunyeroo Gorge
Mt. Mantell
Wilpena Pound
Elder Ra.
Chace Ra.
Druid Range
Mayo G.
HAWKER
32°00′S
0 20 km
QUORN
138°00′E
135°
140°
30°
35°
Adelaide
0 300 KM
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## 1. Introduction

The distribution of outcrops of the Pound Subgroup (Jenkins, 1975) indicates that sedimentation originally extended over an area of some 35,000 square kilometres. The principal area of outcrop forms a belt from Devil's Peak, east of Port Augusta, 250 km north to the Gammon Ranges (Fig. 1). Forming part of the Adelaide Fold-Belt, the outcrop consists of fault intersected, elongate synclines, with NNW and NNE striking axes in the south, and east-west axes in the northern Flinders Ranges. Well indurated, thick sections of the Pound Subgroup are the main ridge formers of the Flinders Ranges. The landforms resulting from eroded anticlines and fold closures are responsible for the striking scenic character of this area with its eucalypt lined rocky creeks and native cyprus wooded valleys.

The Pound Quartzite was first formally described by Mawson (1937, 1938 and 1941) who named it after the most prominent landmark : Wilpena Pound. Sprigg (1947, 1949) discovered a rich assemblage of impressions of soft bodied organisms in the Formation at Ediacara Range, and extended studies of these fossils have subsequently been made (Glaessner 1958, 1980; Glaessner and Daily 1959; Glaessner and Wade 1966; Wade 1968, 1972; Jenkins 1975; Jenkins and Gehling 1978). Glaessner (1959) demonstrated a late Precambrian age for the unit. Later Dalgarno (1964) revealed a regional unconformity separating the Pound Quartzite from the overlying Parachilna Formation, which was assigned a Lower Cambrian age on the basis of its trace fossil assemblage. Subsequently, Daily (1972) described the Uratanna Formation which unconformably overlies the Pound Quartzite, and is disconformable below the Parachilna Formation in the northern Flinders Ranges. The Uratanna Formation fills deep channels eroded in

first described by Coats

the Pound Quartzite.

The first detailed sedimentary analysis of part of the Pound Quartzite was made by Goldring and Curnow (1967), who described the stratigraphy and sedimentary characteristics of the thin sequence at Ediacara. Following her recognition of the fossiliferous beds throughout much of the central Flinders Ranges, Wade (1970, page 92) demonstrated that the fossil bearing horizon was stratigraphically "low in the upper member of the Pound Quartzite", and that much of the upper part of the Formation had been locally eroded prior to Cambrian deposition.

A formal naming of the Bonney Sandstone and Rawnsley Quartzite as members of the "Pound Quartzite" by Forbes (1971), was later modified by Jenkins (1975), who elevated the formation to subgroup status, and the members to formation status. The Pound Subgroup is the uppermost unit within the Precambrian Adelaide Fold-Belt and forms a subdivision of the Wilpena Group. Jenkins (1981) formalised an Edicaran Period encompassing the time represented by soft bodied metazoan fossils of the uppermost Precambrian. The sequence nominated as a stratotype consists of the Wonoka Formation and the overlying Pound Subgroup in Bunyeroo Gorge of the central Flinders Ranges.

A detailed sedimentological study of the Pound Subgroup in the southern Flinders Ranges was attempted by Ford, from 1972 to 1974, which led to the proposition that the beds containing the fossils of the Ediacara assemblage represent a discrete unit. The formal description of the Ediacara Member and formations of the Pound Subgroup is the subject of a paper by Jenkins, Ford and Gehling (in prep.), which also presents a reconstruction of the environments of the Ediacara Member, based on field work done prior to the study herein. The aim of the present study was to examine in more detail the stratigraphic and sedimentary relationships of the Ediacara Member to the Pound Subgroup. In practice the study was concentrated in the central Flinders Ranges, where the quality and distribution of outcrop enabled sectional correlations to be made on a smaller scale than previously attempted. This has resulted in the description of certain stratigraphic aspects of the Pound Subgroup, which were not readily apparent from previous field studies relying on widely spaced stratigraphic sections. (Wade 1970).

## 2. Scope and Method of Investigation

This study of the sedimentology and stratigraphy of the Pound Subgroup was quantitatively confined to the central Flinders Ranges (from Hawker, latitude 31° 50'S to Blinman, latitude 31° 5'S and between longitudes 138° 20'E and 139° 00'E) although numerous other exposures have been inspected both to the north and south of this region. From 34 sections[1], measured at sites chosen for spacing and clarity of outcrop (Fig. 22), the facies of both Formations have been described. Details of lateral facies relationships were determined by tracing horizons between sections and by using low-flown, oblique aerial photographs. The technique[2] involved a light aircraft, with the passenger door removed, being flown at a constant height and distance (approximately 500 m) relative to the continuous exposure of the Pound Subgroup, from the Heysen Range around Wilpena Pound and south along the Elder Range (Fig. 1). By positioning the camera in line with the dip direction of a given interval of strata (Ediacara Member) and taking frames at a rate of 6 per minute, overlapping imagery was obtained for a continuous section of some 70 km. This enables facies intervals to be measured and scaled by reference to ground measured vertical sections, spaced along the flight path. Even where ground proofing was prevented by the rugged terrain, facies relationships between measured sections could be determined by direct

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[1] Appendix 1
[2] Appendix 1

reference to the photographic log (Fig. 15, 16, 17, 19).

## 3. Regional Tectonic Setting

In order to obtain a picture of the geometry of the Pound Subgroup, an isopach map was constructed using thicknesses derived from measured field sections and published topographic maps where the unit boundaries and dip were known (Fig. 2). A 500 metre isopach interval was used to avoid unnecessary local variations, which often result from unavoidable inaccuracies due to local tectonic effects. The isopach map highlights certain features of the post and syntectonic setting:

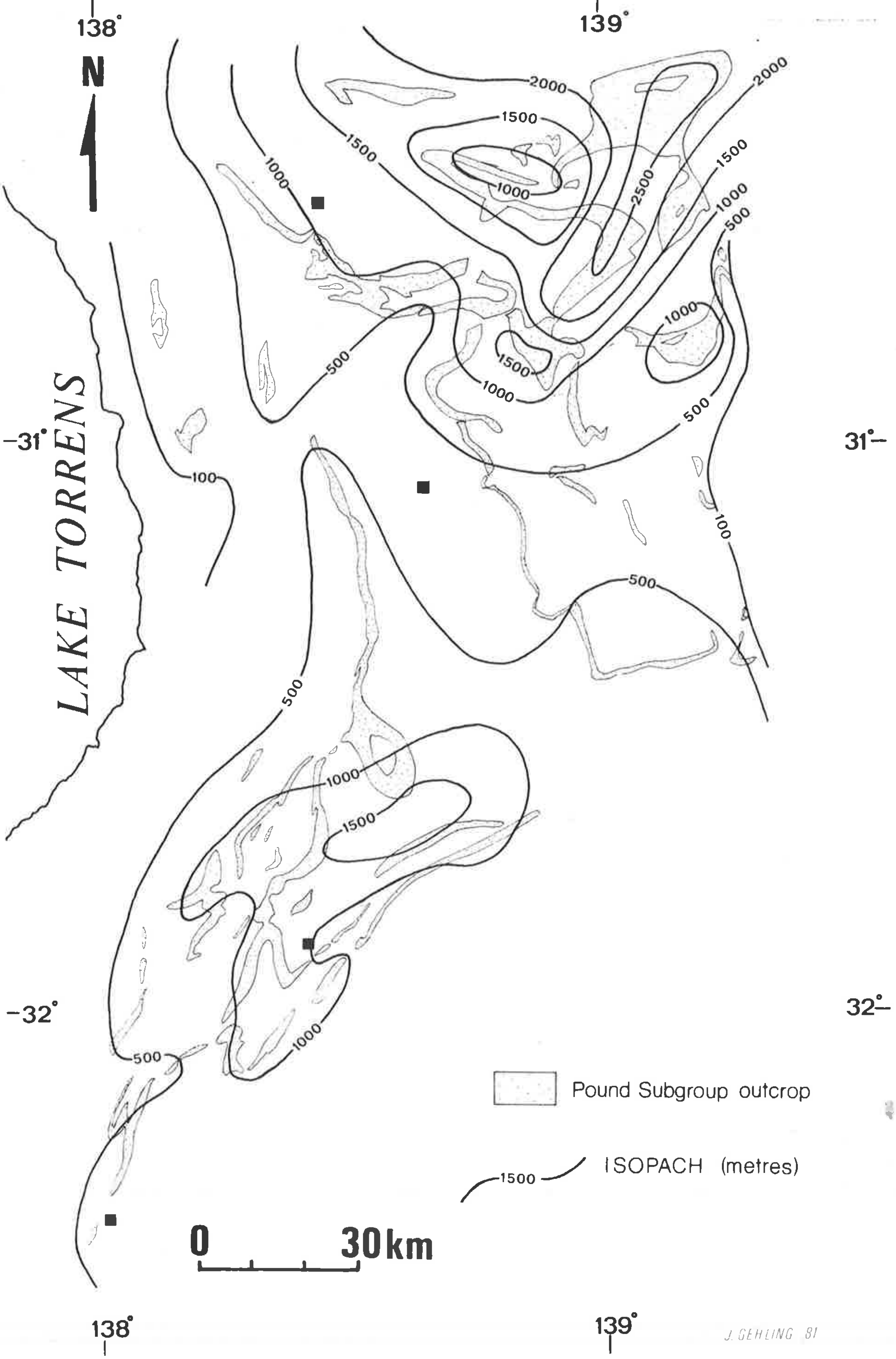
(a) The original south eastern and northern extent of the Pound Subgroup are unknown, due to post orogenic erosion. An isolated outcrop, some 120 km SE at Waroonee Hill, reveals an apparently thinned sequence with deeper water characteristics (C. Ford, pers. comm.).

(b) Rapid thinning occurs east and west of the thickest developments. The Adelaide Fold Belt is bounded to the west by the north trending Torrens Hinge Zone (Thomson 1970), which makes the transition from the stable Stuart Shelf to the subsiding basin. According to Coats (1965a) the Pound Subgroup is not represented on the Stuart Shelf west of the Torrens Hinge Zone. Plummer (pers. comm.) considers that the Tent Hill Formation on the Stuart Shelf is not a correlative of the Brachina Subgroup as suggested by Coats (op.cit.), but is equivalent to the Pound Subgroup. A study of two sections through the Tent Hill Formation, south of Port Augusta, has shown that there are lithological similarities but no palaeontological evidence to support the contention that this pair of reddish and whitish units is a correlative of the Pound Subgroup. Facies consistent with a fluvial environment and easterly directed palaeocurrents suggest that this formation represents a terrestrial edge to a finer grained clastic unit within the Adelaide Fold Belt. As such it might correlate with any of a number of units of the Wilpena

FIGURE 2

Isopach map of the Pound Subgroup, using thickness obtained from field and published map measurements on exposed outcrops. Northern and southern extensions have been largely eliminated by post tectonic erosion. The Subgroup is thought to thin rapidly to the east and west, under younger cover.

**FIG.2**



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Group. To the east of the Flinders Ranges, younger cover obscures the Subgroup, which appears to be thinning or pinching out against the Benagerie Ridge Callen 1973 (Youngs 1978).

(c) The thickest development is in a NNE trending sub-basin in the Gammon Ranges region. Northward it is either eroded away or tongues into the poorly described Billy Springs Beds. The Subgroup exceeds 2,500 metres in thickness in this region, which as yet has received almost no study. Rapid thickness changes appear to parallel major fault zones which are considered to have a long history of synsedimentary movement.

Thomson (1966) postulated that basement block movements controlled deposition within the Adelaide Fold Belt. Examples of rapid thickening of rock units across presumed deep seated faults have been given by Coats (1962, 1965b). In the northern Flinders Ranges a number of local, rapid changes in thickness of Adelaidean units can be correlated with the presence of complex upthrusting megabreccias or "diapirs" which coincide with the intersection of tectonic hinge zones. Dalgarno and Johnson (1968) demonstrated the episodic influence of tectonic movements on facies development during the history of Adelaidean sedimentation. In the northern region, several sections close to diapirs are characterized by lenses of polymictic conglomerate rapidly thinning and decreasing in grain size away from the tectonic contacts (Coats, 1973). In every exposure studied by the author, these conglomerate lenses were restricted to the Bonney Sandstone, and apart from local thinning, there is no evidence that the "diapiric" zones affected the facies of the overlying Rawnsley Quartzite.

(d) As much as 1500 metres of sediment was developed in a northeast to southwest trending sub-basin in the vicinity of Wilpena Pound and the Chace Range. The shape of this basin may be partly a function of post sedimentary orogenic compression, but there is strong evidence for a parallel pattern of pre-orogenic fault development in this central region. Shackleford and Sutton (1981) concluded, from quarry blast seismic studies, that the Moho decreases in depth south of the Druid and Chace Ranges, on the northwestern edge of the Olary Arc. To what extent this reflects pre-orogenic crustal character is not clear, but it coincides with a postulated shelf edge, during Rawnsley Quartzite time (see below).

(e) The north and south sub basins of the Pound Subgroup are separated by a roughly east-west axial high through the Blinman region. Although some depositional thinning of facies is apparent, the reduced thickness can mainly be attributed to erosion prior to Lower Cambrian transgressions, stripping off the entire Rawnsley Quartzite, and leaving as little as 130 metres of the Bonney Sandstone. During deposition of the Lower Cambrian Hawker Group, the areas of maximum thickness shifted somewhat to the east, compared with the Pound Subgroup (Wopfner, 1969). Local development of tectonically controlled sub basins was reflected in rapid thickness and facies changes to an even greater degree than in the Upper Precambrian.

## 4. Stratigraphy of the Pound Subgroup

The Pound Subgroup conformably overlies shallow water, carbonate rich sediments of the upper part of the Wonoka Formation (Fig. 3). A 5 to 20 m thick distinctive grey dolomitic unit forms a readily recognisable marker, the top of which has been chosen by Forbes (1971) as the basal contact of the Pound Subgroup. This marker, which is the last known carbonate unit in the local Precambrian, includes oolitic and stromatolitic facies with at least two distinctive form genera, one of which (*Tungussia c.f. T. julia*, Walter and Krylov) has been closely compared with *Tungussia julia*, Walter

FIGURE 3

Rock relation diagram for Pound Subgroup. Comparison of interpretations of the boundary between the Bonney Sandstone and Rawnsley Quartzite from Forbes (1971), Jenkins (1975), Jenkins (1981) and this study. The Ediacara Member is interpreted herein as a locally thicker unit, bounded below by an erosional unconformity (2). Jenkins (1981) represents the base of the Rawnsley Quartzite at this unconformity (2), but does not recognise an earlier disconformity (1). Within the study area, the Pound Subgroup is unconformably overlain by the Parachilna Formation.

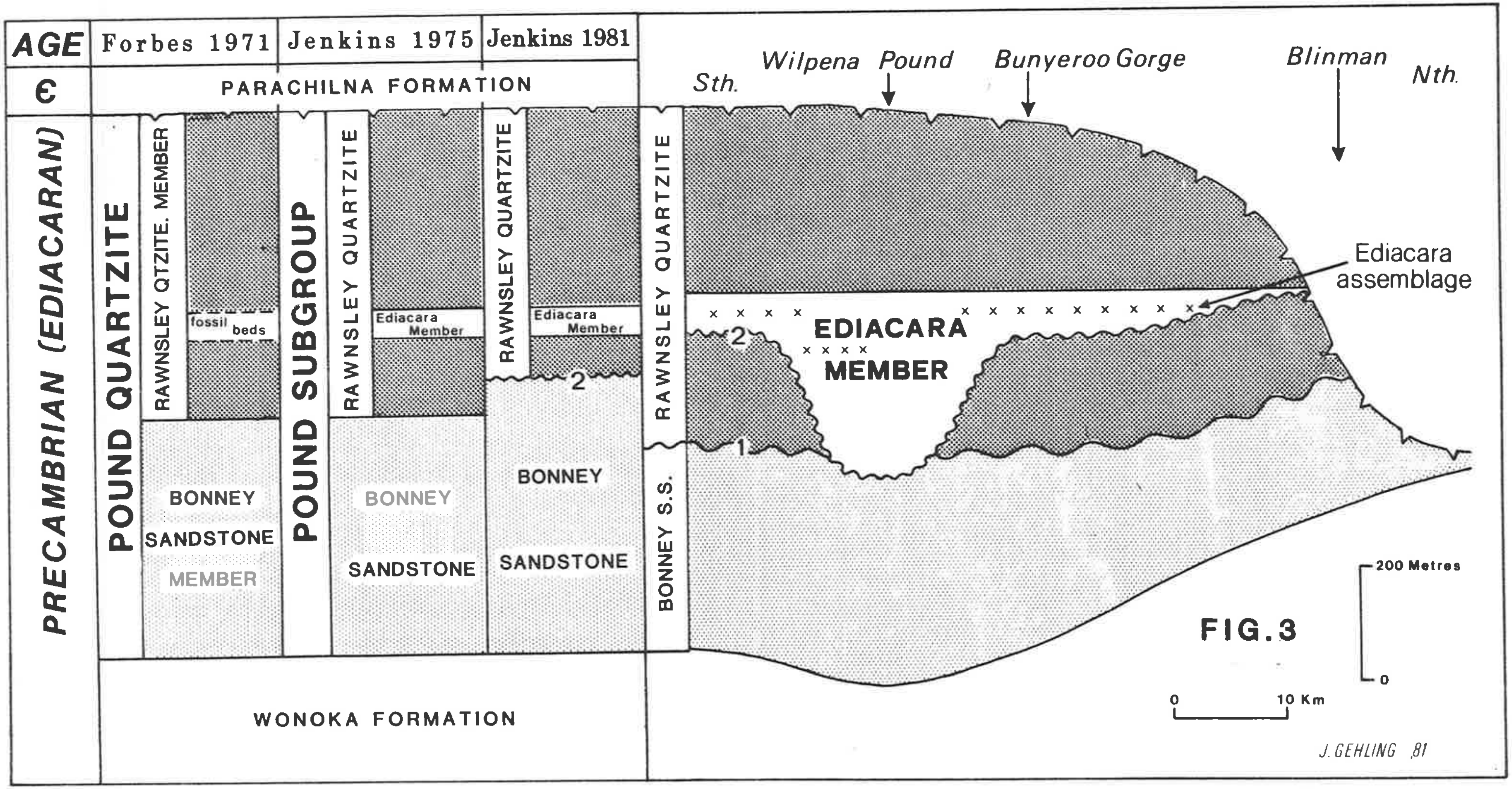
AGE
Forbes 1971
Jenkins 1975
Jenkins 1981
Є
PARACHILNA FORMATION
PRECAMBRIAN (EDIACARAN)
POUND QUARTZITE
RAWNSLEY QTZITE. MEMBER
fossil beds
BONNEY SANDSTONE MEMBER
POUND SUBGROUP
RAWNSLEY QUARTZITE
Ediacara Member
BONNEY SANDSTONE
RAWNSLEY QUARTZITE
Ediacara Member
2
BONNEY SANDSTONE
WONOKA FORMATION
Sth.
Wilpena Pound
Bunyeroo Gorge
Blinman
Nth.
RAWNSLEY QUARTZITE
BONNEY S.S.
Ediacara assemblage
EDIACARA MEMBER
2
1
200 Metres
0
0
10 Km
J. GEHLING ,81

FIG.3

and Krylov, from the same stratigraphic position in Central Australia (Walter et. al., 1979).

The overlying Bonney Sandstone is composed of red clayey siltstones and feldspathic sandstones. It has a maximum development of 450 metres. The locally disconformable upper boundary is marked by the sharp change to cleaner, pink and white sandstones and quartzites which characterize the Rawnsley Quartzite. The granule filled scours that mark this erosional boundary, pass into coarse but fining up sandstone cycles. The Rawnsley Quartzite comprises a quite distinctive group of sandstone facies, which, although often pinkish near the base, have readily distinguishable sedimentary structures and texture.

Forbes (1971) placed the boundary between the Bonney Sandstone and Rawnsley Quartzite at the base of the first white quartzites. This distinction which has proven unreliable in the field, was based on the use of colour and gross lithology by previous workers (Mawson, 1941; Dalgarno and Johnson, 1966; Wade, 1970). Both in the type section for the Pound Subgroup, north of Parachilna Gorge, and in the type section for the two formations, at Bunyeroo Gorge, the facies above and below this boundary are similar but for a progressive decrease in haematite clay staining of the sand grains and an upward increase in induration. Wade (1970, Fig. 4) mistakenly correlated unit '2' immediately below the "fossiliferous beds" from Brachina and Bunyeroo Gorge. Although both feldspathic sandstones, the unit at Brachina Gorge is a massive sandstone of a quite different facies (Facies J) to that in the Bunyeroo Gorge section which is a distinctively ripple bedded sandstone (Facies H and I, see below). By detailed correlation of units in continuous outcrop between thesetwo sections (Fig. 17, S20, S22, S18), it has been demonstrated in this study that a major erosional unconformity separates the two units. However, Forbes (1971) in following the suggested informal boundary of Wade (op.cit.) inadvertently placed the boundary half way between a disconformity (his unit 13-14) and an erosional unconformity (unit 17-18, pg. 221) at Bunyeroo Gorge (Fig. 3). Forbes (pers.comm.) agrees that a placement of the divisional boundary below the first clean, pink coloured feldspathic sandstone would be justifiable on lithological grounds. However, Jenkins (1981) suggests an upward movement of the formation boundary to what is regarded as the erosional base of the Ediacara Member in this study. The informal placement of the boundary above the last clayey red sandstones of the Bonney Sandstone (Unit 13, Bunyeroo Gorge in Forbes, op.cit.) enables a more genetic description of the facies relationships in each Formation.[1] It is anticipated that a further subdivision of the Pound Subgroup will be required to accommodate major lithological changes and unconformities.

The Ediacara Member has been defined, within the Rawnsley Quartzite, by Jenkins (1975), to include the siltstone and sandstone facies associated with fossils of the Ediacara assemblage. The Member is conformably succeeded by facies of the same character as those that preceded it (Fig. 3). In this study the Ediacara Member is redefined to include all those facies above the markedly erosional surface (described below : Facies J to N) up to the top of the prominent, banded white quartzite above the last fossiliferous interval. This uppermost unit of the Member comprises a facies which occurs in up to three cycles within the Member. As such the Ediacara Member forms a readily mappable unit comprising a number of related facies not occurring at any other level in the Rawnsley Quartzite, and extend beyond the boundaries defined by Jenkins (1981) (Fig. 3 ). Where the Ediacara Member is absent, in the northern Flinders Ranges (north and east of Leigh Creek), the contact between the upper and lower facies of the remainder of the Rawnsley Quartzite can only be detected by careful examination. The Rawnsley Quartzite is there-

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[1] See Appendix 5

fore retained as a mappable unit, even though it is considered to include an erosional break at the base of the Ediacara Member. This formation comprises up to 1000 metres of section in the study area, but attains a thickness in excess of 2000 metres in the northern Flinders Ranges.

Within the study area, an unconformity at the top of the Pound Subgroup is marked by a change from indurated sandstones to extensively burrowed argillaceous sandstones of the Parachilna Formation. (Dalgarno, 1964).

## 5. Basal Contact with the Wonoka Formation

The Bonney Sandstone is underlain by the green and grey calcareous siltstones and shales of the Wonoka Formation. Shaley facies near the base of the Wonoka Formation give way to thicker bedded (20 to 60 cm) carbonates of two distinctive facies: fine sandy carbonates with climbing ripple lamination and ball and pillow structures, alternating with finely stylolitized silty limestones (Gehling, 1971). Flute casts and beds of intraformational conglomerate are common. In a number of localities, in the northern Flinders Ranges, the base of the Formation cuts well down into underlying units. Coats (1964) interpreted these as submarine canyons filled with breccias by large scale slumping. Von der Borch, (pers. comm.) has identified turbidite sequences within the canyon-fill facies. The Wonoka Formation is capped by facies in which oscillation ripples, oolitic dolostones, desiccation cracks and rare halite casts indicate a shallowing up sequence. In the western outcrops terrigenous sediments increase toward the top. The final phase of carbonate sedimentation is represented by the previously described, 5-20 m thick, stromatolitic, grey marker dolomite. Apart from *Tungussia c.f. T. julia* another form of stromatolite occurs in Chace Range sections, which is undescribed (Priess, pers. comm.) This form is characterized by 10-15 mm wide vertical columns, composed of coarse laminae, and linked at various levels by wavy laminae. (Plate 1a). The top of this carbonate marker is taken as the base of the Pound Subgroup, although the passage through slightly calcareous, greenish silts and sandstones to red beds demonstrates a transitional boundary with continuous sedimentation. The conformable base of the Pound Subgroup reflects a steadily increasing supply of clastic sediments, derived from the Gawler Platform to the west, (Thomson, 1969), marking an intensified regressive phase of deposition.

## 6. Lithofacies of the Bonney Sandstone

The Bonney Sandstone is a dominantly reddish, feldspathic sandstone with intercalations of clayey siltstones and muddy sandstones. The red coloration is a consequence of interstitial haematite and haematite rich clay. The formation is not as boldly outcropping as the overlying Rawnsley Quartzite, but in the western-central Flinders Ranges the sandy facies develop to the extent of forming a secondary ridge to the Rawnsley Quartzite.

Seven lithofacies can be isolated in the Bonney Sandstone each representing a distinctive combination of lithology and sedimentary structures.

*Facies A :* greenish laminated siltstones and sandstones.
Facies A consists of greenish wavy and irregularly laminated siltstones intercalated with thin micro-crosslaminated and flat bedded, buff sandstones. Surfaces are commonly micaceous. In most sections, the beds become thicker and sandier toward the top. Small ball and pillow structures, although not very common, occur in the upper part of the facies. The facies varies from a total of 12 metres thick in the Heysen and Elder Ranges to some 106 metres in the Chace Range, where it is best developed.

*Facies B :* red, irregularly bedded clayey sandstones.
Facies B consists of purple-red clayey and silty fine grained sandstones with irregular bedding. Surfaces of disrupted sand laminae are clay draped and micaceous. Shale intercalations, commonly bear either desiccation cracks, infilled by sand, or impressions of clay flakes.

Poorly developed flaser and lenticular cross lamination, grades laterally into disruptive and small scale convolution in the sandstone beds. Rippled surfaces tend to be of either the interference or irregular linguoid variety. Otherwise sandstone beds are clay coated with a range of crimpled surfaces, not unlike those described by Reineck and Singh (1973, page 53) as foam and wrinkle marks, attributed to intermittent exposure of the sediment surface.

An array of complex flute marks occur on top surfaces, and as casts on the bottom surfaces of many sandstone flags. A common variety has quite regular bifurcating, straight or curved ridges spaced a few mm apart, and preserved on both upper and lower surfaces of thin sandstones. They strongly resemble the structure described by Glaessner and Walter (1975) as *Arumberia banksi*, from the Arumbera Sandstone in the Amadeus Basin, central Australia. A re-examination of similar material from central Australia (collected by B. Daily and R.J.F. Jenkins) reveals distinct similarities between these structures and those described from turbidite and other facies by Dzulynski and Walton (1965). They interpret these structures as longitudinal current ridges produced by cylindrical turbulent flow at the sediment interface. The structures thus formed in silt, have sharp upward ridges and rounded grooves, and may be moulded by overlying sands. Where this silt or clay film is very thin, counterparts can be moulded by the underlying sands. Allen (1970b, pg. 83) illustrated radiating hydrodynamic flow patterns produced by flute depressions, which resemble the part of *Arumberia* which Glaessner and Walter attributed to the bases of what were considered to be cup-shaped organisms, flattened by compaction between successive sand layers. *Arumberia* is almost certainly a complex set of rill marks produced by turbulent flow over a silt lain sand surface. Brasier (1979) supported this conclusion, referring to the structures as pseudofossils.

This facies does, however, present evidence of animal activity, in the form of epichnial groove, meandering trails on crimpled silty coated sandstones (Plate 2a). These traces, from Brachina Gorge in the Heysen Range, show criss-cross grazing patterns on surfaces that might be the impressions of algal mats. Trails of this type, within the Ediacara assemblage, have been designated as Form B by Glaessner (1969).

The diversity of surface features in this facies is a result of the intercalation of clayey and sandy sediment, with the sands moulding imprints made on soft sediment surfaces. In thick sequences of this facies, beds grade into laminated silts and sandstones of Facies C. Otherwise, they are sharply overlain by the flat and crossbedded sandstones of Facies F.

The dark, red-brown coloration, resulting from haematite-rich clay is observed in all thin sections. The fine to medium sandstones are partly feldspathic, although in most samples feldspars have decayed, leaving only red clayey ghosts of the original grains. Rare accessory minerals observed in thin sections include tourmaline and zircon.

Facies B is best developed in the Druid and Chace Ranges, where it occurs throughout the sequence.

*Facies C :* laminated, maroon siltstones.

Facies C consists of flat, to wavy laminated, clayey, maroon coloured siltstones, with interspersed mica flakes. This weakly outcropping facies lacks induration as a consequence of the haematite rich clayey matrix. The lack of grain size contrast, results in few bedding plane exposures. Careful examination of surfaces has failed to reveal structures attributable to either bedding plane exposure or variable hydro-dynamic depositional conditions.

Characteristically units of this facies are gradational between units Facies A and B. In sections of the Heysen and Elder Ranges Facies C is often sharply overlain by Facies F.

Units of Facies C are rarely more than 10 metres thick. The facies is best developed in the Chace Range.

*Facies D :* red, sandy mudstones.

Facies D is dominantly a poorly bedded, dark red brown, silty and sandy, micaceous mudstone. In certain sections patchy carbonate replacement of matrix occurs. The sediment is characterized by an unsorted mix of clay, silt and sand, resulting in a friable mud supported sandstone. Irregular interbedding of better differentiated sandstones reveal desiccation cracks and mud flakes. Mud cracks may well be a more common feature of the bulk of this facies, but are difficult to distinguish in weathered outcrop which tends to be rubbly and secondarily mottled.

Facies D is most commonly associated with the coarser and better sorted sandstones of Facies E, but can also be recognised as remnants in cycles involving units of Facies F and G.

*Facies E :* granule rich, clayey sandstones.

Facies E consists of poorly sorted, coarse grained sandstone occuring as granule and pebble supported scourfill deposits and lenticular beds with a clay rich matrix. As well as being highly variable in texture, beds of this facies are irregular in thickness, although rarely exceeding 20 cm. Facies E either grades up into the mudstones of Facies D or forms thin units within Facies B (irregularly bedded, clayey sandstones). Isolated units have sharp erosive scour bases and crude trough crossbedding. In some sections these grade up into clayey climbing ripple sandstones. These structures give an indication of either easterly or southerly directed palaeocurrents.

In Section 24 at Parachilna Gorge and Sections 26 and 27, east of Blinman, Facies E contains lithic pebbles, while further south granules are composed of stained quartz and minor orthoclase feldspar. A northerly source area might be suggested for this facies, but it is more likely that the lithic component indicates a proximity to local sources. The polymictic conglomerates (Plate 2b) in the vicinity of "diapiric" mega breccia zones (see Regional Tectonic Setting), are almost certainly the proximal equivalents of Facies E, in the northern Flinders Ranges (Copley 1:250,000 sheet).

*Facies F :* flat and cross-stratified, red feldspathic sandstones.
These prominent, red to brown coloured, micaceous sandstones are fine to medium grained, submature, feldspathic quartz sandstones. Thin sections reveal moderately well sorted quartz grains which often show traces of haematite rich clay coating. Chert grains are not uncommon, and feldspars of microcline and orthoclase composition are often sericitized or even totally replaced by sericite rich clay. Heavy mineral laminations occur rarely. Concretionary nodules of 0.5 to 1 cm in diameter, often seen in outcrop, seem to consist in thin section of diagenetic quartz overgrowths on quartz grains.

In most sections, Facies F beds are sharply based, with either flat or wavy erosional contacts. Bed sets, which generally range from 30 cm to 120 cm in sections, tend to have tabular boundaries. These beds are typically composed of medium scale (greater than 30 cm) sets of low angle planar cross-stratification with tangential bases (Plate 2c). Either medium scale trough crossbedding or flat stratified to massive sandstones with current lineation, truncate the larger scale cross stratification. Less commonly sets of large scale trough based cross stratification form wedging cosets. (Plate 3a). A variety of notable bed forms occur within Facies F. At Brachina Gorge (Section 20) a single set of 1 to 2 metre sigmoidal cross stratification has convolutions and overturning on the untruncated foreset crests (Plate 4c). The recumbent distortion of foresets in these rapidly deposited and poorly dewatered, aggradational megaripple sands is the result of shearing by currents of the next depositional event. Careful examination of some beds has shown oblique climbing ripples comprising the foresets of 30 to 40 cm beds, that might easily have been mistaken for normal low angle cross-stratified sets. Harms (1975, chapter 3) considers such ripples to represent the superimposing of wave action. Similar structures have been described by Clemmensen (1976) from the Kap Stewart Formation of East Greenland. Mud chip impressions were, on occasions, observed both on the planar foresets of beds and as a basal lag.

In certain sections (1, 20, 27) large scale trough cross stratified sets occur where the lower set was truncated by another set with almost reversed facing. However, in most sections reversed sets are not common. Instead, particular sequences have a unidirectional grouping of foreset azimuths, with sequences higher in the section exhibiting reverse directions.

Thick developments of Facies F form cliffs or ridges (Plate 5a), but where it is interbedded with finer grained facies, outcrops are much more subdued, especially where dips are low. In the more prominent sequences of these red sandstones, Facies F forms as repetitive, sharply based units, or grades up into the finer sands of Facies G. These incomplete cycles form multistory sand sheets in a broad arc of sections from Mayo Gorge north through Wilpena Pound and the section of the Heysen Range around Brachina Gorge. That these form roughly elongate sand bodies, is supported by an almost bipolar trend of cross bedding aximuths (Fig. 7).

More complete, but less prominent cycles including Facies F are found in the Chace Range sections to the south east. Here lighter coloured, cleaner units of cross bedded Facies F grade up into Facies G (cross laminated sandstones) and the more clayey beds of Facies B or D. Individual beds of Facies F within these cycles are rarely more than 50 cm thick. The more complete cycles averaging 7 metres in thickness (Fig. 4, Section 11), resemble fining-up cycles from the Abbotsham Beds, figured by Walker (1963).

Facies F has a maximum, aggregate thickness of 120 metres, in the Wilpena Pound and Elder Range sections.

*Facies G :* red, fine grained, cross laminated sandstones.
These fine to very fine grained sandstones are similar in composition to Facies F, but are distinguished by a higher clay to sand ratio and a greater abundance of detrital muscovite flakes. Heavy mineral laminations occur in northern sections. In outcrop, beds of this facies vary in induration according to their clay content. This haematite rich clay, which is interstitial throughout the fabric, tends to concentrate in certain laminae, and gives the fabric its characteristic red-brown to maroon colour. Facies G is characterized by distinctive small scale cross lamination which resemble "Type A and B" climbing ripples of Jopling and Walker, 1968, and also Allen, 1970a (Plate 3c). Laterally and vertically, ripple drift lamination grades into sinusoidal ripple lamination ("Type S" of Allen) (Plate 4a). "Type B" climbing ripples dominate beds where Facies F grades up into this facies. These less clayey beds, having the higher climbing angle of Type B ripples (Jopling and Walker, op.cit.), can be confused with Facies F, due to the false foresets produced by the progradational stacking of the ripple crests. (Plate 4b).

Commonly the climbing ripple lamination is interrupted at 5 to 30 cm. intervals by wavy erosional surfaces on which are preserved small, remnant cross laminated lenses having reverse foreset trends. This style of bedding is distinct from the flaser bedding of Reineck and Wunderlich (1968), in which mud flasers are discrete from sand ripples. In Facies G the clay pervades complete laminae within the sinusoidal ripple lamination, and concentrates on the lee side of climbing ripples. Evidently sediment supply was maintained to a greater degree than would be possible under the intermittent current and wave activity known to be responsible for flaser bedding. Facies G units have a fabric consistent with a bidirectional current regime where one phase was dominant. The dominant current phase varies for different cycles in a given section, but conforms to an overall bimodal distribution of palaeocurrents (Fig. 8).

Facies G is usually coupled with underlying units of cross bedded sandstones (Facies F). In turn they pass up into the irregularly bedded clayey sandstones of Facies B, or are erosively truncated by a new cycle beginning with Facies F.

Individual units of Facies G vary from 20 cm to 15 metres. In the western sections they may account for up to 50 percent of a section through the Bonney Sandstone.

## 7. Facies Relationships in the Bonney Sandstone

A cursory examination of vertical sections through the Bonney Sandstone suggests a three part subdivision:

1) The basal clayey sediments indicate an increase in clastic materials into the basin, to the exclusion of carbonate sedimentation. This sequence involves Facies A, B and C with a coarsening upward trend.

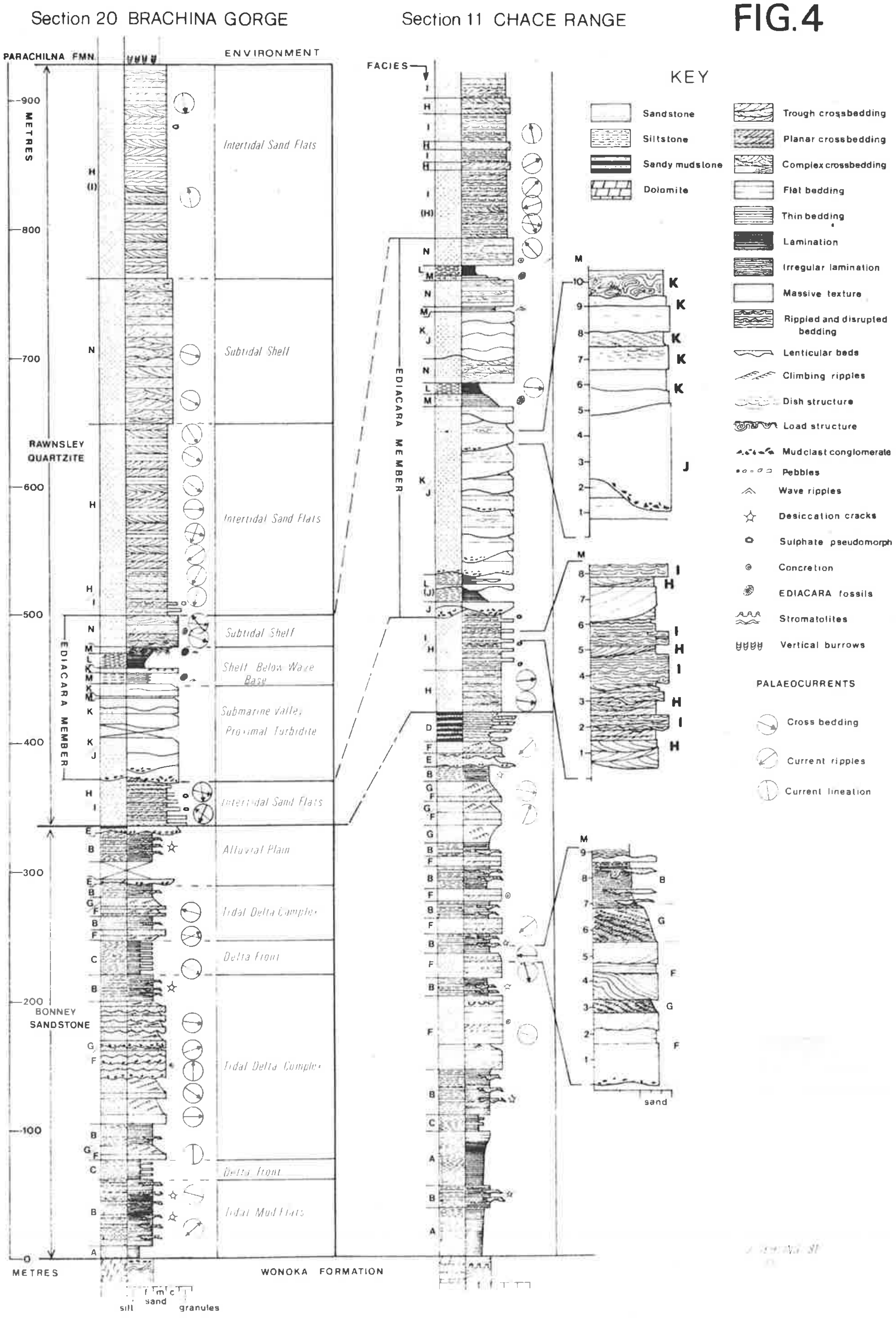
2) The strongly outcropping middle part of the sequence comprises the cleaner arenite Facies F and G, in fining up cycles.

3) The upper part of the sequence comprises a more heterolithic grouping of Facies F and G with the more immature sediments of Facies B, E and D. However, even simplified logs of the vertical sequence (Fig. 4) demonstrate some complex alternations of facies. In order to obtain a clearer understanding of the facies relationships,

FIGURE 4

Simplified vertical sections through the Pound Subgroup illustrating facies relationships and especially variation within the Ediacara Member. Section 20 from Brachina Gorge with depositional environments illustrated. Section 11 from Chace Range with more inserts illustrating detailed vertical facies relationships for : Facies F, G and B (240 m level); Facies H and I (485 m level); Facies J and K (640 m level). Fossils of Ediacara assemblage mainly confined to Facies M within Shelf sequence.

**FIG.4**


Section 20 BRACHINA GORGE
Section 11 CHACE RANGE
PARACHILNA FMN.
ENVIRONMENT
METRES
900
800
700
600
500
400
300
200
100
0
RAWNSLEY QUARTZITE
EDIACARA MEMBER
BONNEY SANDSTONE
Intertidal Sand Flats
Subtidal Shelf
Intertidal Sand Flats
Subtidal Shelf
Shelf Below Wave Base
Submarine Valley Proximal Turbidite
Intertidal Sand Flats
Alluvial Plain
Tidal Delta Complex
Delta Front
Tidal Delta Complex
Delta Front
Tidal Mud Flats
WONOKA FORMATION
silt
f m c
sand
granules
FACIES
KEY
Sandstone
Siltstone
Sandy mudstone
Dolomite
Trough crossbedding
Planar crossbedding
Complex crossbedding
Flat bedding
Thin bedding
Lamination
Irregular lamination
Massive texture
Rippled and disrupted bedding
Lenticular beds
Climbing ripples
Dish structure
Load structure
Mudclast conglomerate
Pebbles
Wave ripples
Desiccation cracks
Sulphate pseudomorph
Concretion
EDIACARA fossils
Stromatolites
Vertical burrows
PALAEOCURRENTS
Cross bedding
Current ripples
Current lineation
M
sand

and thereby establish a local depositional model, an analysis of the facies sequence was attempted for those sections where outcrop was reasonably complete. Facies relationship diagrams were drawn for each section, using the matrix method suggested by Selley (1970) and modified by Harms et.al. (chapt. 4; 1975). Simplified facies relationship diagrams from five sections (Appendix 4 ) were then examined to determine the most common transitions. (Fig. 5). By comparing this diagram with the original vertical distribution of facies and their characteristics, four groups can be identified, which are suggested as having environmental significance. The most prominent of these involves the cross stratified and cross laminated sandstones (Facies F and G) which occur as erosively based, fining up cycles. Facies B (irregularly bedded clayey sandstones) appears to be a transitional facies which might well have been further subdivided. Normally Facies B succeeds Facies F and G in the change to the granule rich sandstones and sandy mudstones of Facies E and D. Facies B is also associated with the siltstones (Facies A) below the main development of the current bedded sandstones (Facies F and G). Facies C (laminated siltstones) generally succeed Facies F and G cycles, but may occur lower in the sequence. The immature sediments of Facies E and D are often incompletely preserved at the top of the Bonney Sandstone, suggesting an environment where sediments are liable to be reworked.

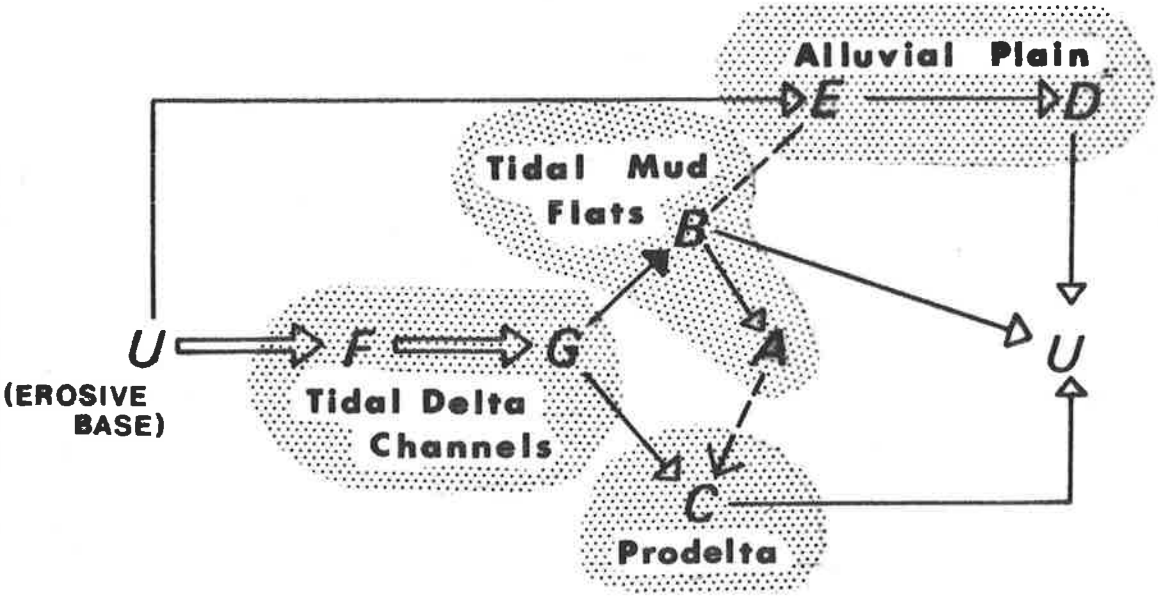


Fig. 5 Net facies relationship diagram derived from a semiquantitative analysis of facies transitions in five sections of the Bonney Sandstone.

## 8. Environmental Interpretation of the Bonney Sandstone

It is apparent from the vertical sequence of facies in the Bonney Sandstone, and the complex relationship between facies (Fig. 5), that a set of interrelated depositional environments was involved.

The most prominent cycles involve the current bedded sandstone (Facies F and G), passing up into irregularly bedded clayey sandstones (Facies B). The erosional based units of Facies F consist of 30 to 40 cm sets of low angle planar cross stratification passing into 10 cm thick trough cross stratification. Each coset is either capped by flat stratified sandstones with current lineation, or symmetrical ripples. Often the units are separated by a thin shale drape. After 2 to 3 metres of these medium grained sandstones, 50 cm to 2 metre units of red, fine grained climbing ripple sandstones (Facies G) occur with erosional surfaces. In the Chace Range sections these cycles are completed with Facies B (irregularly bedded clayey sandstones) resulting in 5 to 9 metre fining up sequences. One such cycle is detailed from about the 230 metre level of Section 11, shown in Fig. 4. There is a general resemblance to fining upward sequences of the Lower Fine-grained Quartzite, from the Precambrian of Scotland, described by Klein (1970) and interpreted as being deposited in tide-dominated environments. They differ in that herringbone cross bedding is not a feature of Facies F and conversely, climbing ripples (Facies G) are relatively uncommon in tidal sediments (Reineck, 1969). Yeo and Risk (1981) describe them in sand flat facies of the Minas Basin System, Bay of Fundy, where presumably the continuity of sediment supply and sustained velocity of water flow provide a somewhat atypical tidal environment. Fining-up sequences, involving cross bedded sandstones overlain by climbing ripple lamination, are widely reported from fluvial sequences. Allen (1964) figures such cycles from the Lower Old Red Sandstone where the planar cross-stratified sandstones have "contorted foresets", much the same as described in Facies F (Plate 4c). Fining-upward cycles in the Abbotsham Beds, North Devon, have the same sequence of facies. (Walker, 1963; De Raaf et.al. 1965). Likewise, the sequence within the channel bar deposits from the Brahmaputra River (Coleman, 1969) differs only in the form of the basal, trough-like, large scale crossbedding. There are however certain important features that distinguish these Bonney Sandstone cycles from fluvial deposits. Firstly, the multistory stacking of these sandstone facies in sections, mainly within the western ranges, does not have an equivalent in thickness or lateral consistency within the described record of braided or meandering fluvial sequences. Facies F and G tend to form extensive sand sheets which can be traced for several kilometres in outcrop. Secondly, although particular cycles are unimodal, successive cycles conform regionally to a bimodal palaeocurrent pattern (Fig. 6). South of the Heysen Range and including Wilpena Pound and the Elder Range, foreset orientations of medium scale cross-stratified sandstones (Facies F) present a bipolar pattern trending at 190°. North of Wilpena Pound the pattern is essentially bipolar trending at 100°. The Chace Range pattern has a dominant north-east mode. Current lineations, when compared with the easterly biased pattern of current ripples, suggest a dominant flow toward the south east (Fig. 6). The overall bimodal current dispersal pattern could be accommodated by either barrier tidal inlets or an estuarine environment (Klein 1967). The lack of evidence for a barrier bar system and associated inlet facies, lends support for a tidal estuary. A tide-dominated delta system is envisaged where linear tidal sand ridges parallel the tidal currents. Such sub-aqueous ridges form immediately seaward of river mouths influenced by high tidal ranges (Coleman and Wright, 1975; Off, 1963). The daily and seasonal fluctuations in dominance of river discharge over the flood tide would produce a combination of fluvial and tidal flat characteristics. Mutually evasive ebb and flood channels, are suggested by Coleman and Wright (op.cit.), which would explain the dominance of one paleocurrent mode in a single cycle. Wright et.al. (1976) describes tidal sand ridges, from the Ord River in Western Australia, which are 10-20 metres high, up to 2,000 metres long and 300 metres wide. The multi-story sandstone beds of Facies F have comparable dimensions (Plate 5a, b). Pettijohn et.al. (1972, pg. 476) point out that such sand bodies would have sharp erosive bases due to tidal scour. As a consequence of the high discharge and sediment carrying capacity of such a tidal estuary, climbing ripple sandstones (Facies G) might succeed the cross stratified sandstones. The frequent erosional breaks and lenses with reversed cross lamination can be explained by flood tidal dominance for short periods.

The clayey sediments characterizing Facies B show abundant evidence of alternate tractional and suspension phases of sedimentation, as well as subaerial exposure. Interference ripples, lenticular and flaser bedding are characteristic of lower intertidal flats, whereas those beds which have mud cracks and irregular and disrupted sandy laminae suggest higher intertidal to supratidal mud flats (Evans, 1965; Wunderlich, 1970; Klein, 1970, 1977a; Sellwood, 1972). These irregularly bedded sandstones could be expected to cap abandoned distributary channel and ridge sand-cycles, as well as extending along the tidal flats away from the estuarine environments.

The basal facies of the Bonney Sandstone comprise wavy and irregularly laminated, greenish siltstones and sandstones (Facies A). They grade up from the stromatolitic dolomites of the upper Wonoka Formation and alternate with the tidal flat sediments of Facies B. Facies A is interpreted as having been deposited in offshore environments away from the influence of the tide dominated river deltas. The greenish colour indicates a less oxidized source of sediment, namely the last phase of shallow marine, mixed carbonate environments which dominated the upper part of the Wonoka Formation.

Facies C (laminated, maroon siltstones) generally occur low in the sequence, although on occasions they interleave with the current bedded sandstones (Facies F and G) (Fig. 4). These siltstones and fine sandstones show no evidence of strong tractional currents or desiccation and as such represent a subaqueous, low energy environment. In the absence of evidence of a barrier protected lagoon, these siltstones must represent suspension sedimentation of the fines winnowed from the tidally reworked delta and deposited in an offshore prodelta environment. Normally Facies C is truncated sharply by prograding sand ridge and channel facies (Facies F and G). (Plate 5c).

The poorly sorted, coarse grained and muddy Facies E and D are involved in remnants of fining-upward cycles, which usually cap the Bonney Sandstone sequence. As can be seen in Fig. 4 (Section 11 and 20) these sediments interleave with the uppermost tidal cycles but have few characteristics in common. In a prograding shoreline Facies E and D might represent alluvial plain sediments, of the delta plain. Braided stream deposits are characterized by gravel and coarse sand filled channels, and the intervening plain with overbank silts and clay. Facies E and D probably form the edge of an alluvial wedge from the west, preserved at the top of the Bonney Sandstone where the transgression and marine reworking of these sediments, represented by the Rawnsley Quartzite, had not destroyed the record.

In summary, the Bonney Sandstone represents deposition in tidally influenced marginal marine environments. An increase in supply of clastics from the west resulted in a thick sequence of tidal dominated delta sand sheets extending from the north western part of the shelf. These NNW to SSE oriented sand sheets prograded south east over deeper water facies of the subsiding sub basin in the Wilpena Pound region. The dispersal pattern, indicated by crossbedding within the sand sheets (Fig. 7); appears to parallel the depositional strike; a trend typical of shallow marine tidal currents (Klein, 1967). Lateral shifting of the funnel like estuaries, characteristic of tide dominated deltas, resulted in the fining up cycles, capped by tidal flat sediments. As the system prograded east-ward, thin alluvial sediments built out over the tidal flat deposits.

The Bonney Sandstone sequence comprises an initial stage of subtidal and intertidal deposition in a subsiding basin, passing up quickly into the better sorted sandstones of tidally reworked deltaic deposits, capped by heterolithic tidal sediments and finally thin alluvium (Fig. 4). This pattern has much in common with a composite stratigraphic column of Ord River Delta, figured by Coleman and Wright (1975). A parallel in ancient deposits is described by Eriksson (1979) from the Archaean Moodies Group of South Africa.

FIGURE 6

Grouped palaecurrent measurements from major crossbedded facies in the Pound Subgroup. Bonney Sandstone is represented by Facies F crossbedding and Facies G crosslamination, which together indicate a general NS bias. The major current lineation trend of Facies F gives a NNW to SSE trend. Sub-regional trends indicate bidirectional current systems (see Fig. 7 and 8). The overall Rawnsley Quartzite trend is to the ESE. Facies H shows no significant variation between sequences above and below the Ediacara Member. The polymodal pattern of the Ediacara Member is dominated by the complex crossbedding of Facies N (Fig. 10).

FIG.6 Palaeocurrent Measurements

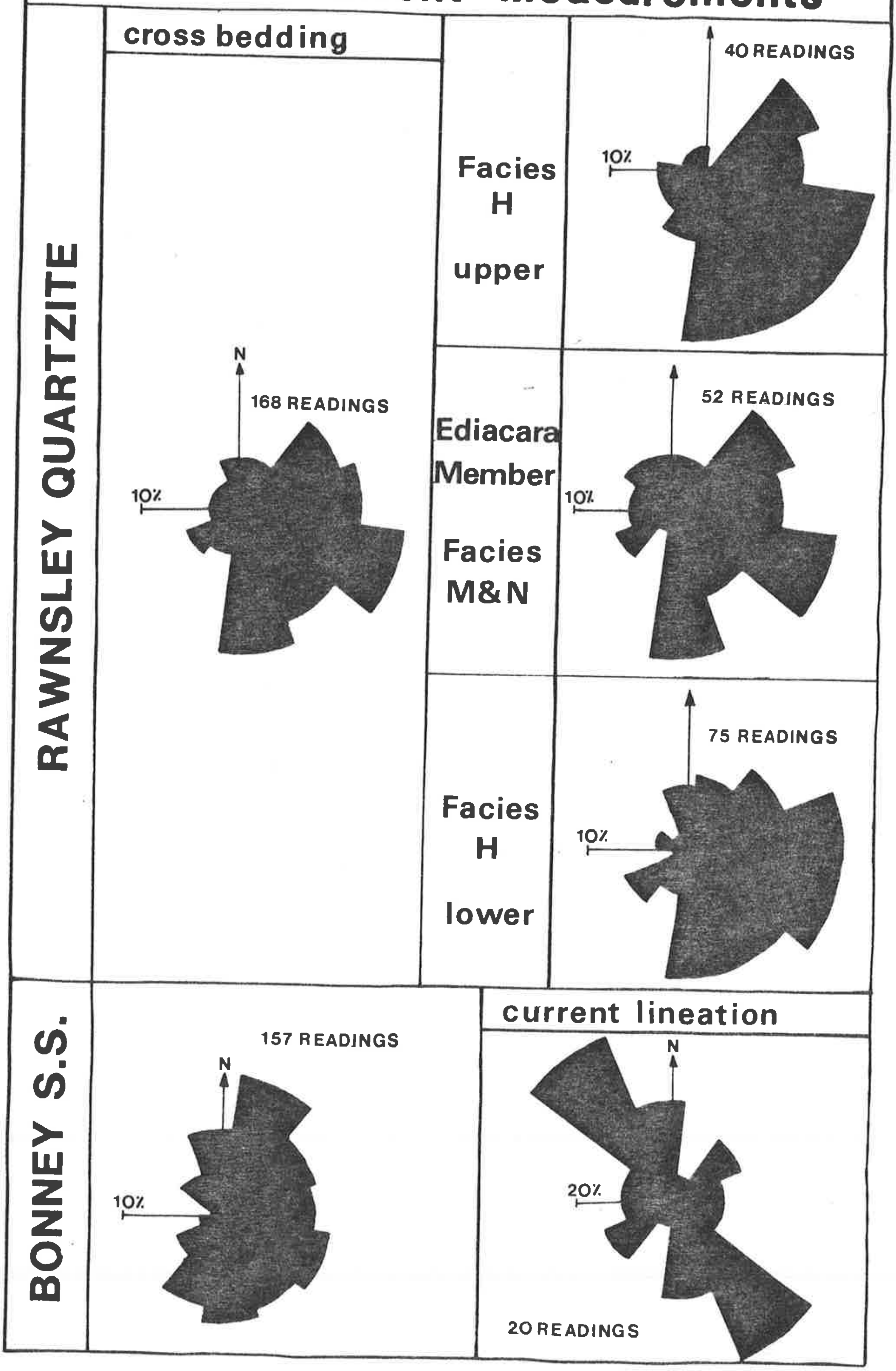


FIGURE 7

Current roses for Facies F crossbedding (Bonney Sandstone). The trend north of Wilpena Pound is NW-SE; for Wilpena Pound and Elder Range : NNE-SSW; for the Chace and Druid Ranges : dominantly (offshore?) NE.

FIG.7

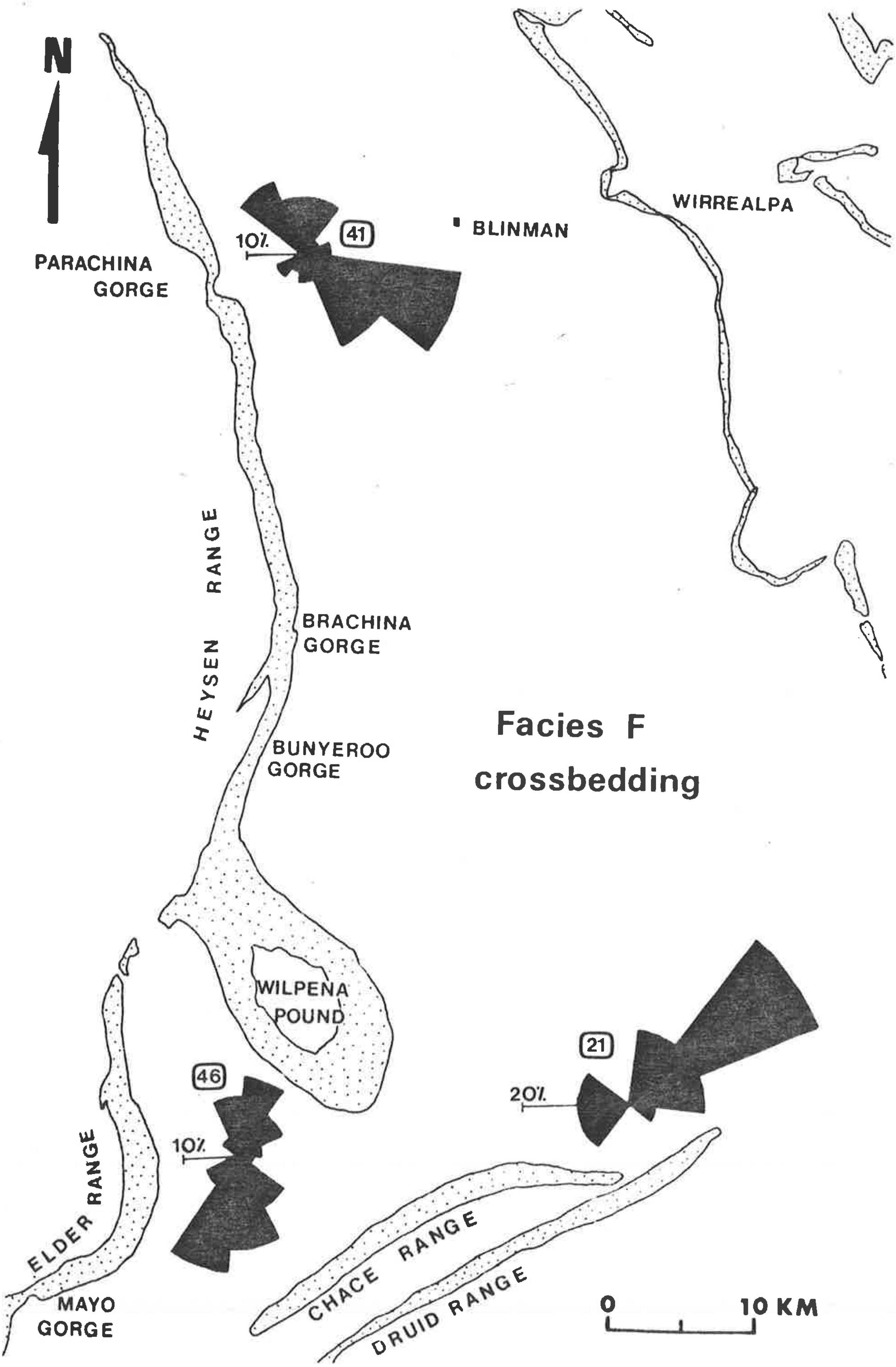
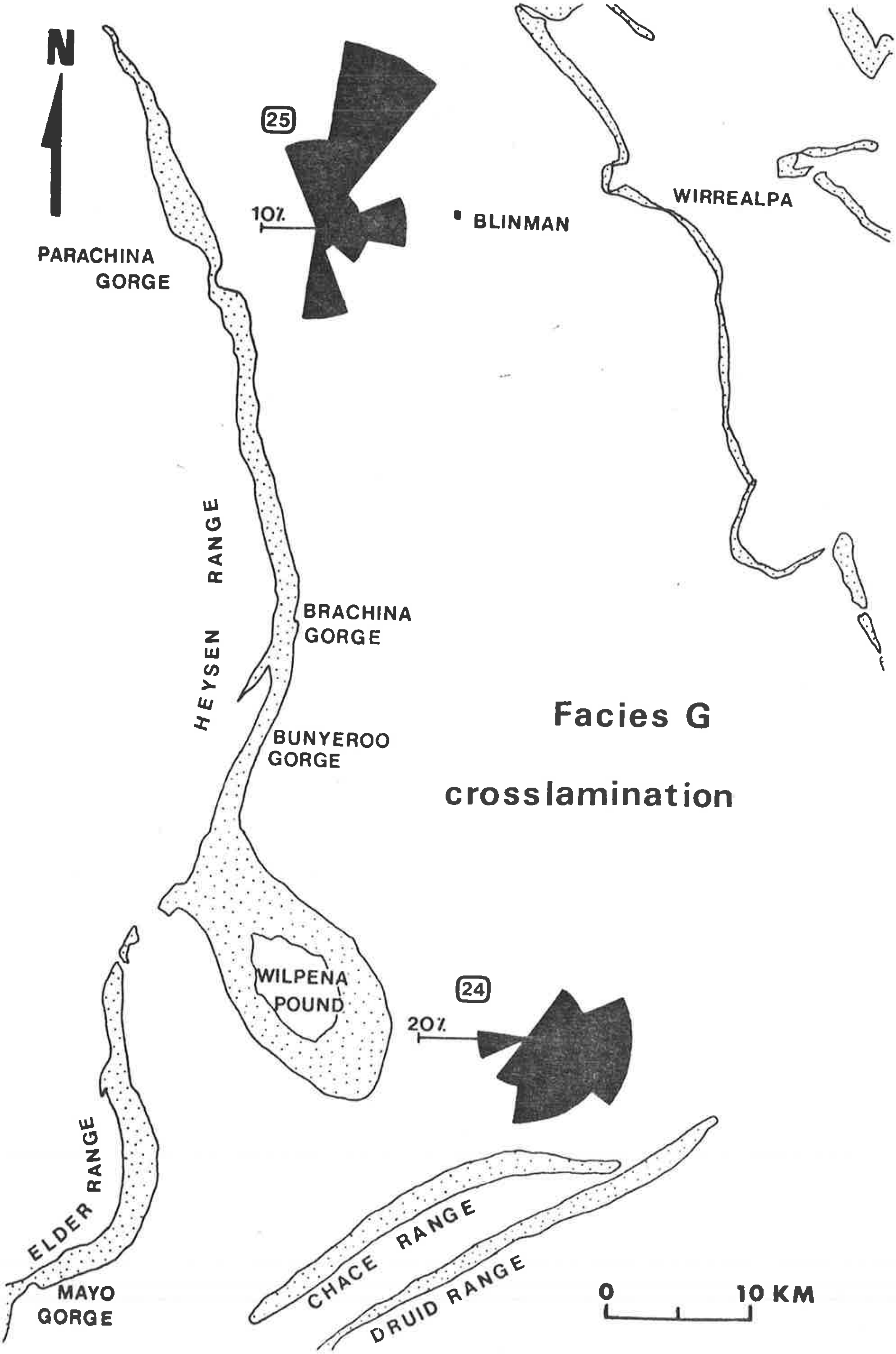

N
PARACHINA GORGE
10%
41
BLINMAN
WIRREALPA
HEYSEN RANGE
BRACHINA GORGE
BUNYEROO GORGE
Facies F crossbedding
WILPENA POUND
46
10%
21
20%
ELDER RANGE
MAYO GORGE
CHACE RANGE
DRUID RANGE
0
10 KM

FIGURE 8

Current roses for Facies G crosslamination (Bonney Sandstone). North of Wilpena Pound : dominantly NNE; Wilpena Pound and southern outcrops : dominantly ESE.

FIG.8



Facies G

crosslamination

FIGURE 9

Current roses of Facies H crossbedding (lower part of the Rawnsley Quartzite). North of Wilpena Pound : trimodal (east bias); Wilpena Pound and south : bimodal (easterly).

FIG.9

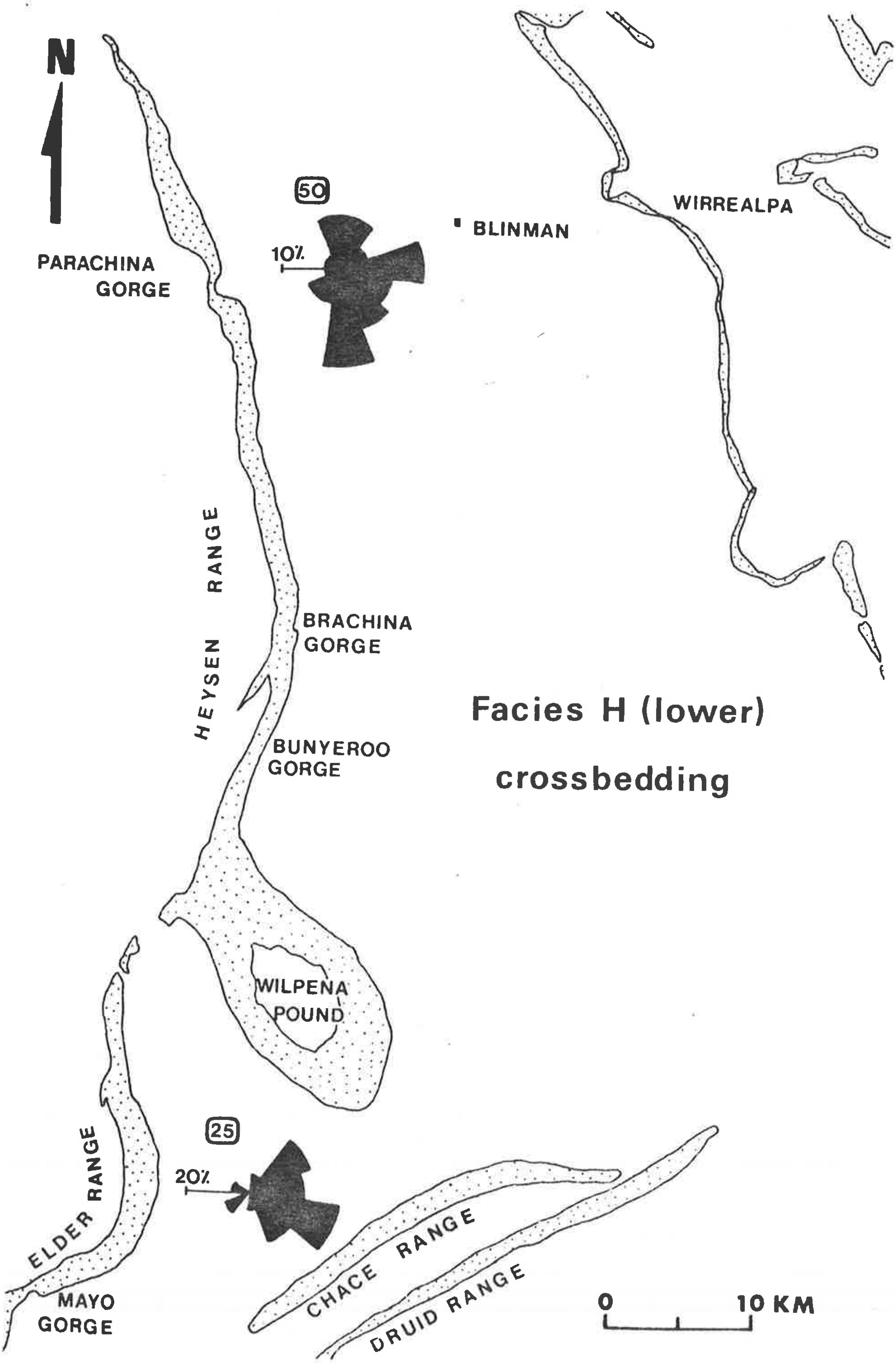

N
50
10%
BLINMAN
WIRREALPA
PARACHINA GORGE
HEYSEN RANGE
BRACHINA GORGE
BUNYEROO GORGE
Facies H (lower) crossbedding
WILPENA POUND
25
20%
ELDER RANGE
MAYO GORGE
CHACE RANGE
DRUID RANGE
0
10 KM

FIGURE 10

Crossbedding roses for Facies N, Ediacara Member, Rawnsley Quartzite. Derived from medium-scale trough and planar crossbedding : polymodal. Large scale imbricate sheets (not included) dip SE.

FIG. 10

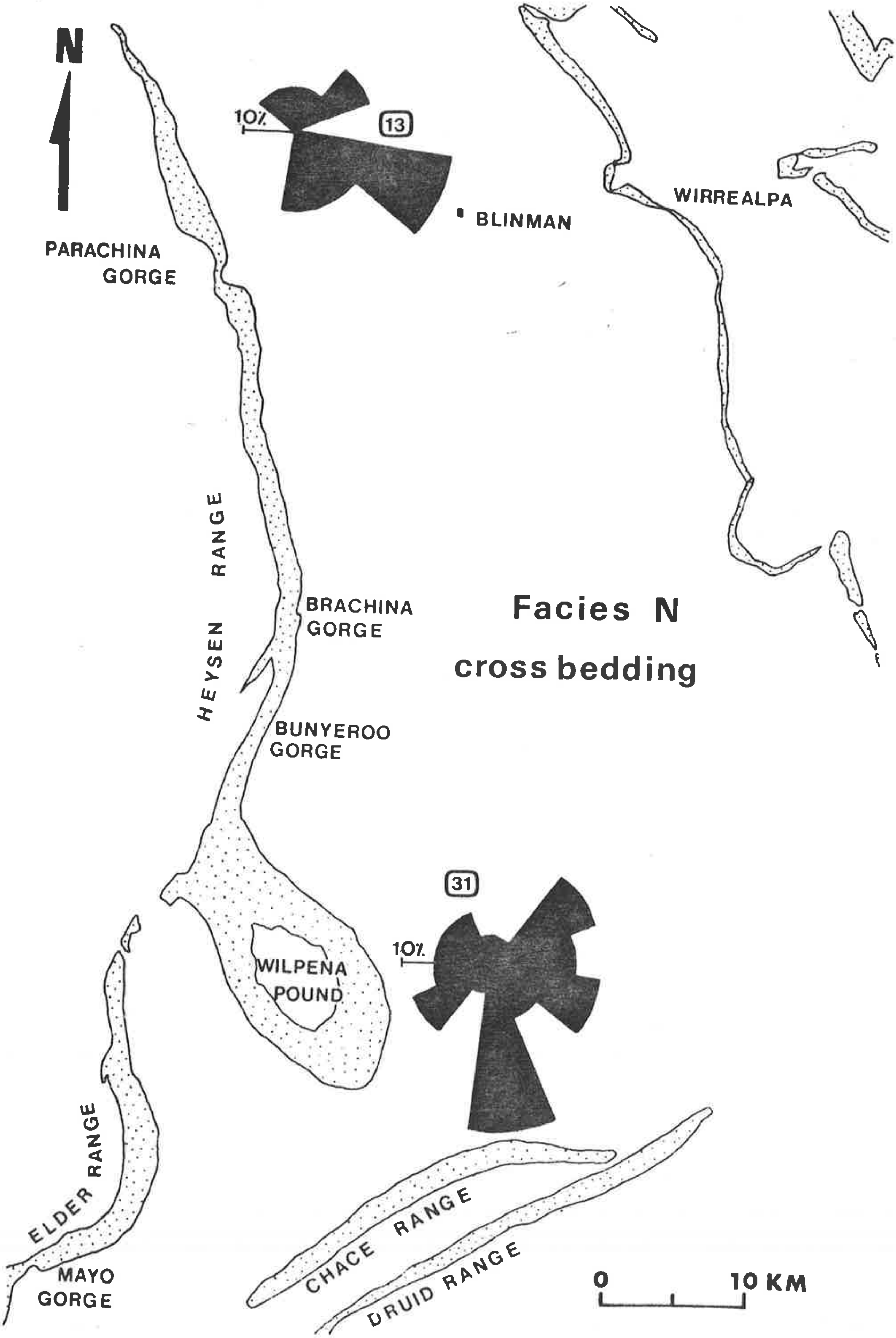
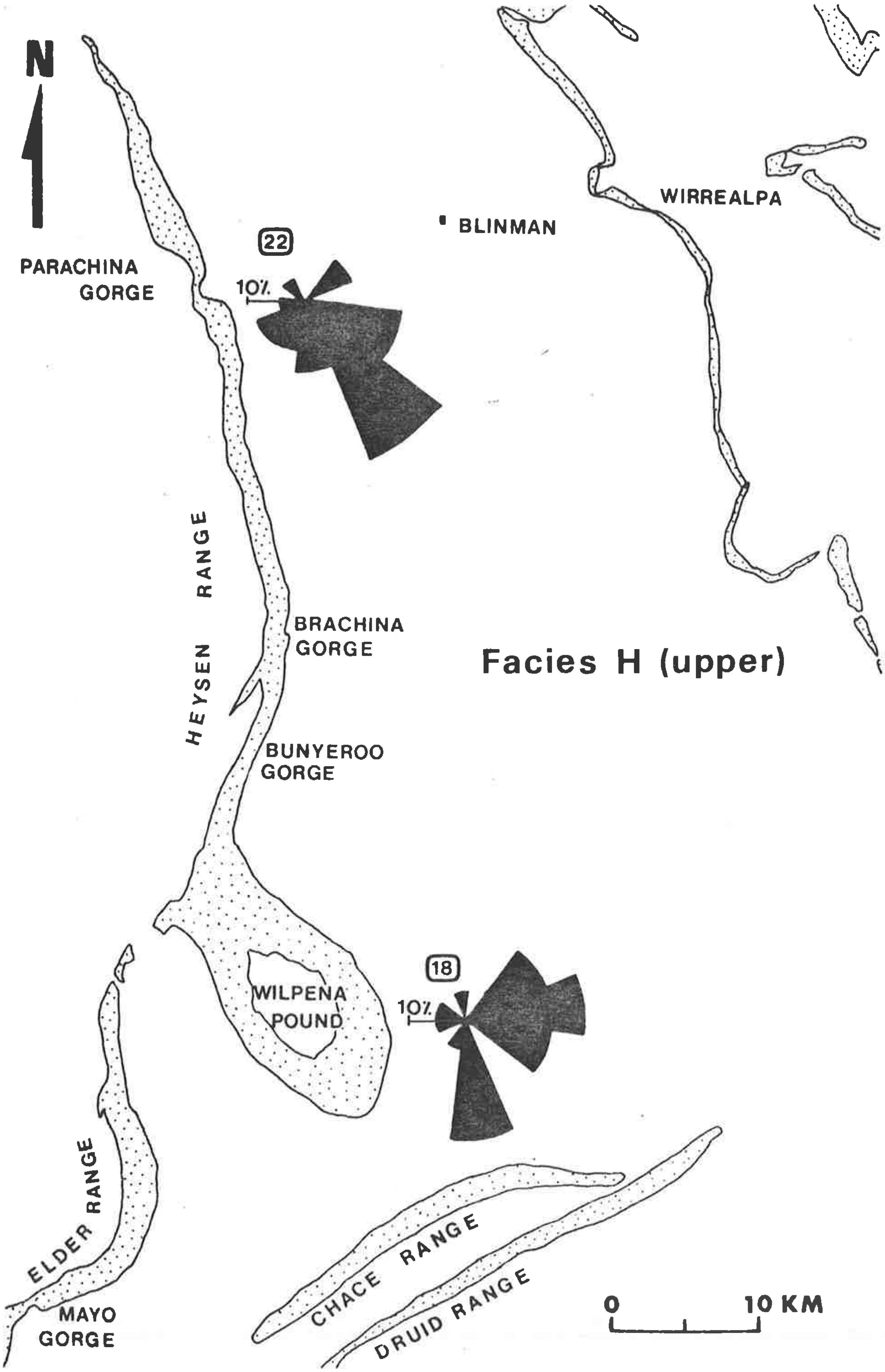

N
10%
13
BLINMAN
WIRREALPA
PARACHINA GORGE
HEYSEN RANGE
BRACHINA GORGE
BUNYEROO GORGE
Facies N
cross bedding
31
10%
WILPENA POUND
ELDER RANGE
MAYO GORGE
CHACE RANGE
DRUID RANGE
0
10 KM

FIGURE 11

Current roses from Facies H crossbedding (above the Ediacara Member). North of Wilpena Pound : SE dominant trend; Wilpena Pound and south : bimodal, with more prominent east trend.

FIG.11


N
PARACHINA GORGE
22
10%
BLINMAN
WIRREALPA
HEYSEN RANGE
BRACHINA GORGE
BUNYEROO GORGE
Facies H (upper)
WILPENA POUND
18
10%
ELDER RANGE
MAYO GORGE
CHACE RANGE
DRUID RANGE
0
10 KM

## 9. Lithofacies of the Rawnsley Quartzite

The Rawnsley Quartzite is characterized by clean, white, feldspathic sandstones and quartzites, which dominate the landscape of the central and northern Flinders Ranges.

Seven lithofacies are described from the Rawnsley Quartzite, five of which comprise the Ediacara Member. The facies are labelled H to N, with Facies H and I making up the sequence above and below the Ediacara Member, which consists of Facies J, K, L, M and N. In the field, these facies can be recognised as measurable units, which represent distinctive depositional conditions.

*Facies H :* low angle, trough cross-stratified sandstones.
Facies H consists of pink to white, fine to coarse grained, low angle, J type cross-stratified sandstones. Cross bedding occurs in sets of up to 2 metres thick, but average 20 cm. Bedding contacts vary from tabular to elongate troughs (Plate 6a). In certain cosets, basal sets are unidirectional, but the upper sets may show near reverse directions. Current roses, based on trough directions, are fan-shaped with a mean ESE trend, for sequences above and below the Ediacara Member (Fig. 6). Basal beds, above the disconformable contact with the Bonney Sandstone, are feldspathic with a considerable red clay content in an otherwise well rounded sand and granule rich fabric. Higher in the member, interstitial clay is almost absent, but foresets may be marked by mud clasts (Plate 6b). The percentage of unstable minerals decreases up the sequence and away from the western sections. In most cosets of cross bedding, individual laminae vary considerably in grain size. Basal sets feature coarse sand and granule trains, and also some unusual erosional mounds which are some 20 cm in diameter and up to 12 cm high (Plate 6c).

*Facies I :* disrupted and ripple bedded sandstones.
Facies I is composed of thin to medium bedded, fine to coarse grained, ripple bearing sandstones with disrupted laminae. Grading up from Facies H (cross-bedded sandstones) these beds are generally light coloured and poorly sorted sandstones. In certain sections there are traces of carbonate cement and

replacement of feldspars by calcite and sericite. Granule trains are common where the facies occurs low in the sequence. Besides a variety of wave-oscillation (Plate 7a), ladder and double crested ripples (Plate 7b), Facies I is characterized by distinctive, disrupted laminae. In cross section "burst through" structures or blister shaped domes are evenly spaced along a layer (Plate 7c, 8a). Rarely do the structures line up in successive layers. On bedding surfaces they can be seen to be linear disrupted ridges which follow rough polygonal patterns (Plate 8b, c). They resemble the convolute lamination described by De Boer (1979), as being produced by gas entrapment in intertidal sand shoals. Furthermore, De Boer (1980) has demonstrated that the binding action of algae on tidal sand flats of S.W. Netherlands increased the threshold for migration of bedforms. The deformation of the finer grained sand layers, within Facies I, may have been enhanced by doming of algal mats binding the sand, due to gas pressure. The folding back of disrupted layers has been observed, which must indicate the presence of a binding agent. Desiccation of domed algal-bound sand layers may have produced the curled up edges and polygonal surface patterns, normally characteristic of desiccation mud cracks.

Except for beds low in the sequence, clay is absent from the matrix of these sandstone. Laminae are alternatively fine and medium to coarse grained. The higher porosity of coarse laminae is reflected in the presence of cavities, often partly filled with calcite. These pore spaces may have been filled with trapped air or gas from the decay of organic matter which produced the initial convolution of the overlying fine grained laminae (De Boer, 1979).

Deformation developed during sedimentation, as demonstrated by planed off convolutions and granule filled hollows. Where this facies occurs high in the Rawnsley Quartzite, sand rosettes, 1 to 3 cm in diameter (Plate 9a) weather out within rippled and disrupted laminations. They are identical in form to sand barite crystals common in younger sandstones (e.g. Conybeare and Crook, 1968, Plate 59b). In thin section the rosettes are composed of silica cemented quartz sand. They might also be sand pseudomorphed gypsum rosettes (Von der Haar, 1978). Beds packed with rosettes, similar in appearance to those in Facies I, have been identified by Rowlands et.al. (1980), within beds forming part of a hypersaline suite in the late Proterozoic Callana Beds from the Willouran Ranges of South Australia, and are considered to be pseudomorphs after diagenetic sulphates.

Near the top of the Rawnsley Quartzite, this facies is dominantly a ripple bedded sandstone, devoid of structures attributable to exposure. Enigmatic, 20 cm diameter, disc impressions occur with current interference marks on rippled surfaces at Wirrealpa (Section 27). The only other evidence within the facies of structures which might be attributed to organisms is the rare occurrence of surface trails resembling Form B (Glaessner, 1969) from the same section.

Low in the Rawnsley Quartzite Facies H and I occur together in repetitive cycles, which, where complete, range from 1.9 - 6.8 metres in thickness. The cycles can be described as low angle trough cross-bedded sets with some reverse trends, grading up into rippled and disruptive - laminated sandstones (Fig. 4, Section 11, 480m level, expanded section).

Below the Ediacara Member the combined thickness of the facies, composing the lower part of the Rawnsley Quartzite, varies from 0 to 255 metres. Above the Ediacara Member, up to 500 metres of Rawnsley Quartzite are preserved in the study area.

The Ediacara Member, which comprises the facies described below, has a maximum thickness of 415 m, but for the most part is less than 200 m thick.

*Facies J :* massive, mudclast bearing, channelized sandstone.

Facies J is a massive, nongraded, medium to coarse grained, mud clast bearing, channel-fill sandstone. These thick lenticular, convex based beds are devoid of tractional features. They occur as mutually erosive beds, 1 to 14 metres thick, forming amalgamated sets up to 40 metres thick (Plate 10a). Mudstone clasts and cavities (Plate 10b) are concentrated in basal parts of channels, but may be scattered throughout the fabric, or compose the entire fill of selected channels. The sharply based, steep sided channels cut cleanly into the underlying sandstones of Facies H and I (Plate 10c). Angular, partly indurated clasts of these underlying sandstones, up to 30 cm long, form sand supported conglomerates in the basal sections of Facies J in some Chace Range sections (Plate 11a). The lack of bedding lamination and grading, in this moderately well sorted coarse sandstone, is suggestive of the resedimentation of a mature sand, by a "grainflow" mechanism, proposed by Stauffer (1967) and Walker (1978).

*Facies K :* massive amalgamated sandstones.

Facies K is a massive, thick to very thickly bedded medium to coarse grained sandstone. These light coloured, multistory beds, gradationally succeed Facies J channel sands in 10-20 metre cycles (Plate 11b, 17c). They resemble Walker's (1978) A.A.A.A. sequences, in reference to the Bouma model. The fabric, although only moderately well sorted is free of a fine grained matrix. In some sections beds have a wispy, discontinuous lamination, often only defined by concretionary nodules and cavities of unknown origin. In Chace and Druid Range sections massive sandstones pass up into finer grained, climbing ripple sandstones at the tops of rare cycles (Plate 11c). Occasionally dish structures occur in the massive sandstones (Plate 12a). In Section 35 (Chace Range), massive sandstones 1 metre thick were overlain by beds which were massive, but for 5 to 10 cm diameter dish structures, passing up into fine sandstones bearing faint climbing ripples. Rautman and Dott (1977) note that dish structures mainly occur in poorly sorted sands, which would account for their paucity in Facies K. Evidence that these beds were deposited by a fluidized or "grain flow" mechanism, despite the rarity of water escape structures, comes from sections where successive units show foundered and scoured bedding contacts. In places deep, irregular scours can be mistaken for foundering in massive sands such as described by Morris (1974, pg. 260) from the Jackfork Group of Arkansas. However, foundering is unmistakable where Facies K directly overlies siltstones of Facies L. Here, 1 to 10 metre diameter ball and pillow load structures lie in distorted siltstones (Plate 12b). Foundering varies from sagging contacts (Plate 12c) to detached sand balls. Casts of shrinkage cracks are sometimes preserved on the basal surface of such load structures (Plate 13a). These incomplete parallel sided cracks, not uncommon on the bases of load casts (Plummer, 1978; Plummer and Gostin, 1981) are synaeresis cracks.

*Facies L :* laminated and massive siltstones.

Facies L consists of laminated to massive, clayey and sandy, khaki coloured siltstones. In thick sequences, where outcrop has been freshly exposed, this facies is pale green to khaki, but alters to a maroon colour in weathered outcrop and toward the top of sequences, where sandy laminae increase in frequency (Plate 13b). This fine grained facies varies from a coarse silt to a very fine sandstone, inter-laminated with micaceous clay. Trains of well rounded, fine to medium grained sand and 5 cm long lenticular sand biscuits, occur within these laminated siltstones (Plate 13c). High in sequences, where the sand content increases, micro cross bedding can be identified. These more sandy beds resemble the "laminated sand-streaked muds" of de Raaf et.al. (1977) in their wave generated sequences. In thick sequences, intrastratal sagging of laminae occurs. Where these silts intertongue with or are abruptly overlain by massive sands of Facies

K, or bedded sands of Facies N, their thixotropic character is apparent (Plate 14a). Bedding surfaces are almost entirely featureless, but for rare diffuse, circular or tabular impressions and sinuous trails in the form of concave grooves and broader convex moulds (Form B and Form F, Glaessner, 1969). In certain sections, where Facies L units are sandwiched between massive sand facies, they consist of a maroon coloured massive, clayey sandstone. The fabric consists of rounded medium grained sand, similar to that of the enclosing massive sandstones, but supported in an unlaminated muddy matrix. The common association of this part of the facies with post depositional load structures in overlying beds, indicates an intrastratal fluidizing process, following deposition of the overlying sandstones.

Facies L has a maximum measured thickness of 180 metres, for a single uninterrupted sequence, in the Chace Range.

*Facies M :* silty parted, wavy bedded, fossiliferous sandstones.
Facies M consists of silty parted, wavy and ripple bedded, fossiliferous, medium grained sandstones. Beds vary from 1 to 5 cm, but may range up to 30 cm in thickness, near the top of sequences. Characteristically they are smooth, undulose to flat based with irregular, rippled tops (Plate 14b). Where crosslamination is preserved, azimuths are highly irregular. Most ripples are irregular interference forms, derived from the superimposing of starved current ripples and wave oscillation ripples. Although locally haematite stained, sandstones are generally clean, moderately well sorted feldspathic quartz arenites, contrasting with the inter-bedded, suspension deposited, siltstones. In most sections, Facies L laminated siltstones grade up into regularly interbedded siltstone and thin sandstone (Plate 14c). The thickness and sorting of sandstones increases up the section, as the argillaceous interbeds reduce to single laminar partings of sericitized clay

and silt. Facies M resembles the "linsen" variety of lenticular bedding described as wave-dominated, storm-lain sands by de Raaf et.al. (1977) and the "sublittoral sheet sands" of Goldring and Bridges (1973). Goldring and Curnow (1967) have described this facies from the Ediacara Range, in some detail.

The smooth undersurfaces of wavy flagstones were formed by sand mantelling of a clayey silt substrate, thereby moulding the detailed surface features of soft bodied animals (Plate 15a) and a variety of lebensspuren (animal traces). Top surfaces are always rougher textured and rarely have preserved impressions of organisms. The mechanisms of soft bodied animal preservation and reconstruction were detailed by Wade (1968). Impressions of the soft bodied metazoa,form when sand buries specimens lying on clay or silt sized sediment. After the entombed animal disintegrates, the sand collapses into the hollow made by the organism as it was pressed into the underlying fine substrate, thereby forming a convex relief cast on the sandstone base. More resistant animals support the overlying blanket of sand until it has set, forming a concave external mould of the specimen's upper surface.

A variety of penecontemporaneous, large scale (50 cm to 3 metres) load structures occur within some sequences of these silty parted sandstones (Plate 15b), especially where there has been a rapid vertical change from underlying Facies L siltstones. A variety of forms of synaeresis cracks (Plate 15c) occur in association with these beds (Glaessner, 1969).

*Facies N :* complexly cross-stratified, white quartzites.

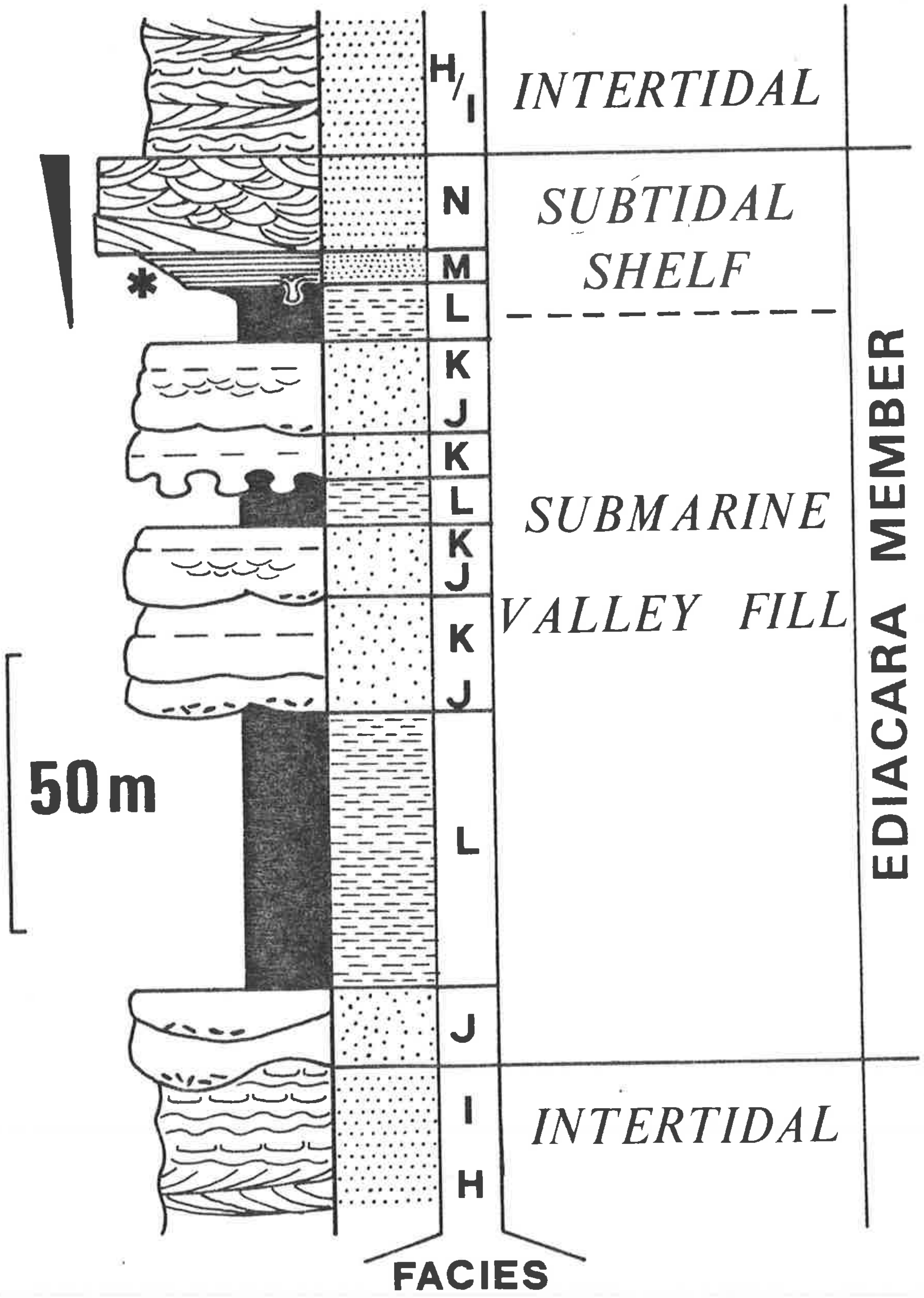
Facies N is composed of low angle planar, and complex trough cross-stratified, medium to coarse grained sandstones. They have the bold outcrop and banded white aspect of a well indurated quartzite, in most sections. The fabric

FIGURE 12

Generalized vertical section of the Ediacara Member within the Rawnsley Quartzite, showing typical facies sequence. Facies H and I, above and below the Ediacara Member, interpreted as intertidal cycles. Facies J, K and L interpreted as a submarine valley fill : proximal turbidite sands and pelagic silts (Fossils occur on bases of rare thin sandstones). Facies L, M and N interpreted as a subtidal shelf sequence, which most commonly form coarsening and thickening upward cycles. Fossils of Ediacara assemblage occur within Facies M (silty parted sandstones).✱

# GENERALIZED VERTICAL SECTION

FIG.12



JGG 81

FIGURE 13

Measured vertical sections representing a profile through a SE trending submarine valley, filled by facies of the Ediacara Member. From north to south, Section 2 : thin sequence of Member, Mt. Mantell; Section 18 : part of type section for Rawnsley Quartzite at Bunyeroo Gorge; Section 21 : thick sequence of Facies L (siltstones) at Mt. Abrupt, north end of Wilpena Pound; Section 16 : massive sandstones of Facies K dominate this thick sequence which cuts down into Bonney Sandstone, just north of Point Bonney on the east wall of Wilpena Pound; Section 7 : Beatrice Hill, west wall of Wilpena Pound; Section 6 : Moralana Creek, north end of Elder Range. Note: down cutting erosional base of Ediacara Member intersects disconformable boundary between Bonney Sandstone and Rawnsley Quartzite.

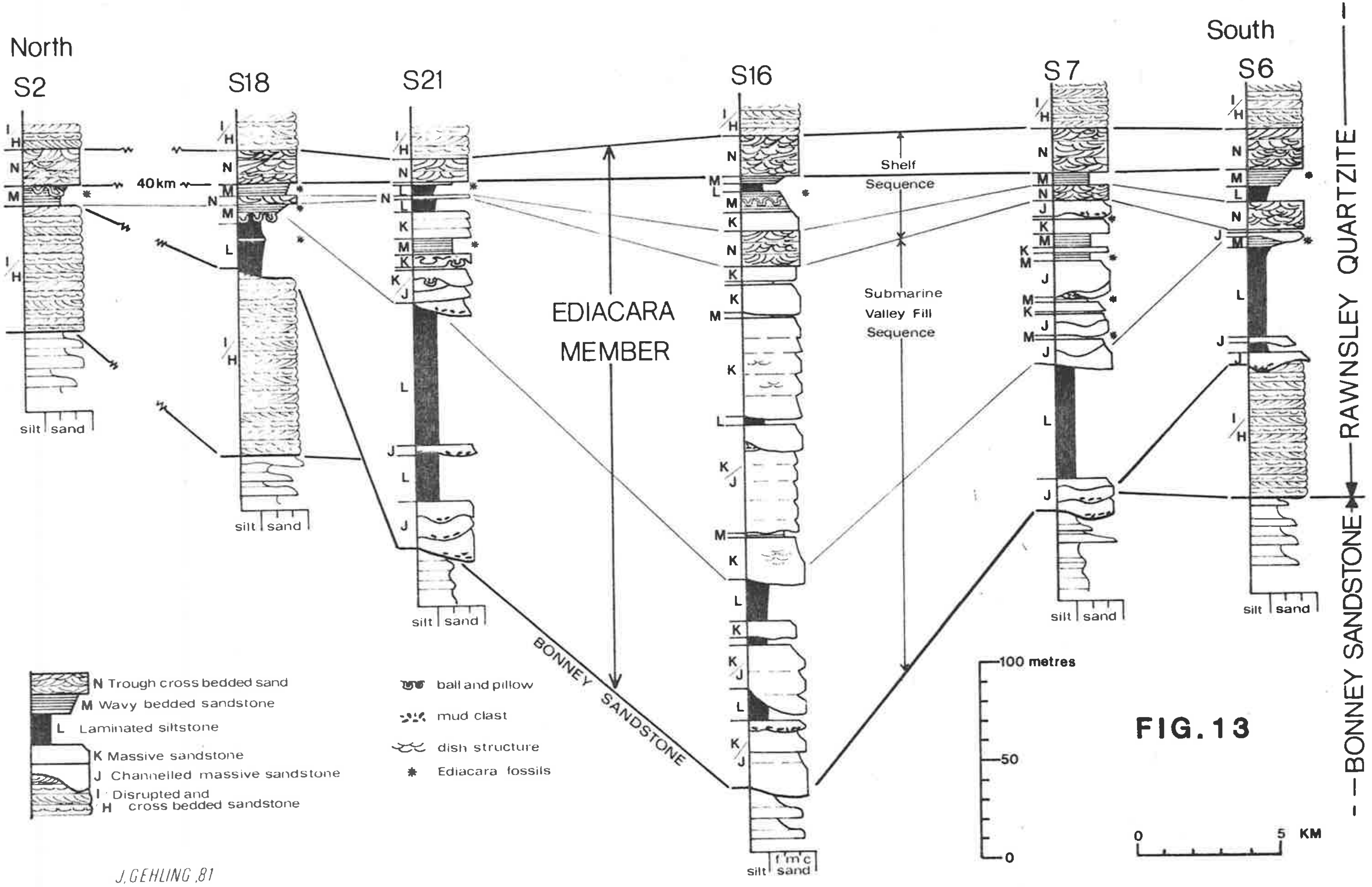

North
South
S2
S18
S21
S16
S7
S6
40km
EDIACARA MEMBER
Shelf Sequence
Submarine Valley Fill Sequence
BONNEY SANDSTONE
RAWNSLEY QUARTZITE
BONNEY SANDSTONE
I/H
N
M
L
K
J
silt sand
f m c
N Trough cross bedded sand
M Wavy bedded sandstone
L Laminated siltstone
K Massive sandstone
J Channelled massive sandstone
I Disrupted and
H cross bedded sandstone
ball and pillow
mud clast
dish structure
* Ediacara fossils
100 metres
50
0
0
5 KM
J. GEHLING ,81

**FIG. 13**

is composed of mature, silica cemented, feldspathic quartz sandstones. White or brown, 3 to 5 cm spheroidal concretions are common in certain sections (Plate 16a). These beds, which grade up from Facies M, are distinguished by an absence of silty partings and the presence of two distinctive forms of crossbedding. Flat to low angle, planar cross-stratification, in beds between 50 and 150 cm thick, pass up into 30-80 cm sets of variable, trough cross stratification. Megasets of (Facies N) low angle cross stratified beds occur as imbricate sheets, 5 metres thick and dipping to the ESE, within the walls of Wilpena Pound (Plate 16b). These beds resemble the Eocene, Roda Sandstone, a sand wave complex (Nio, 1976) and some aspects of the offshore, sand-bar complex in the lower Palaeozoic Peninsula Formation, South Africa (Hobday and Tankard, 1978). In the unit of Facies N which caps the Ediacara Member, complex trough crossbedding is the dominant feature. The current rose derived from Facies N is polymodal with the dominant modes lying between 35° and 185° (Fig. 10). Goldring and Curnow (1967) who described this facies as "the cross-statified and flat stratified sandstone" tentatively indicated NNE to north west palaeocurrent trends in the Ediacara Range.

## 10. Facies Relationships in the Rawnsley Quartzite

The Rawnsley Quartzite, characterized by its seemingly monotonous bedded, light coloured sandstones and quartzites (Plate 9c), stratigraphically encloses the distinctive group of facies comprising the Ediacara Member (Fig. 12).

The fine to coarse grained, medium to thick bedded, feldspathic, quartz sandstones of the Rawnsley Quartzite, are described as two facies (H and I) which occur above and below the Ediacara Member (Fig. 13). The low angle trough and ripple bedded sandstones of Facies H and I form repeated cosets, which vary only in induration and textural maturity (Plate 9b).

FIGURE 14

Location diagram and legend for cross sections (Fig. 15-21) detailing facies relationships in the Ediacara Member for the central Flinders Ranges. Sections O-O', P-Q, Q-R and R-S were constructed with the aid of low-flown oblique aerial photos.

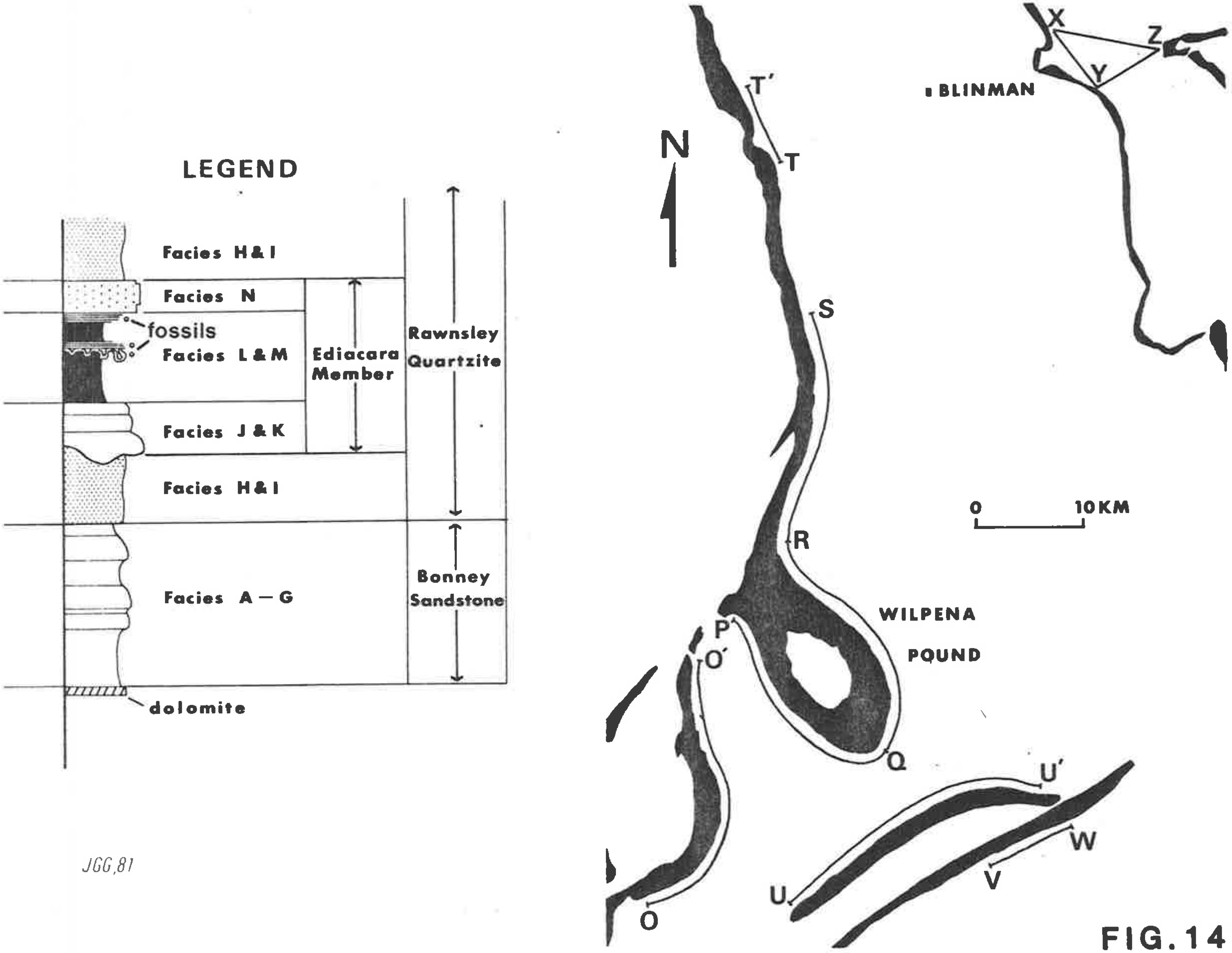
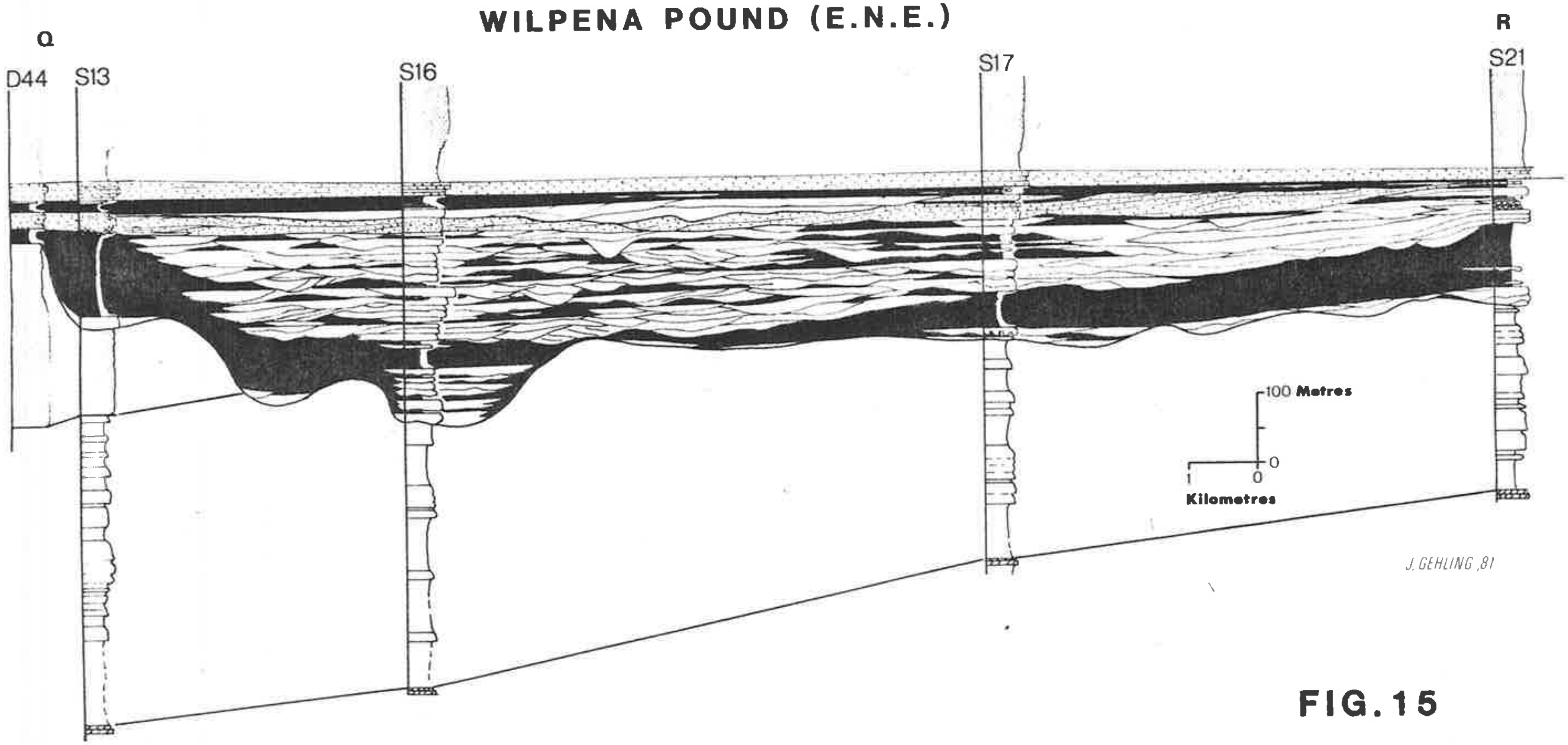

LEGEND
Facies H&I
Facies N
fossils
Facies L&M
Facies J&K
Facies H&I
Facies A – G
dolomite
Ediacara Member
Rawnsley Quartzite
Bonney Sandstone
JGG,81
N
T′
T
S
R
P
O′
O
Q
U′
U
W
V
X
Y
Z
BLINMAN
WILPENA POUND
0 10KM

FIG. 14

FIGURE 15

Cross section Q-R of the Ediacara Member in the east wall of Wilpena Pound. Gives an oblique section through a SE trending submarine valley. Facies J and K occur as channelled lenses cutting into siltstones of Facies L or forming amalgamated sequences. Two cycles of subtidal shelf facies (L, M and N) cap the sequence. For location of vertical sections see Fig. 22. See also Plate 17b and 16c.



WILPENA POUND (E.N.E.)

FIG. 15

FIGURE 16

Cross section P-Q in the SW wall of Wilpena Pound, represents the edge of a submarine valley fill sequence. Vertical section locations on Fig. 22.

# WILPENA POUND (S.W.)

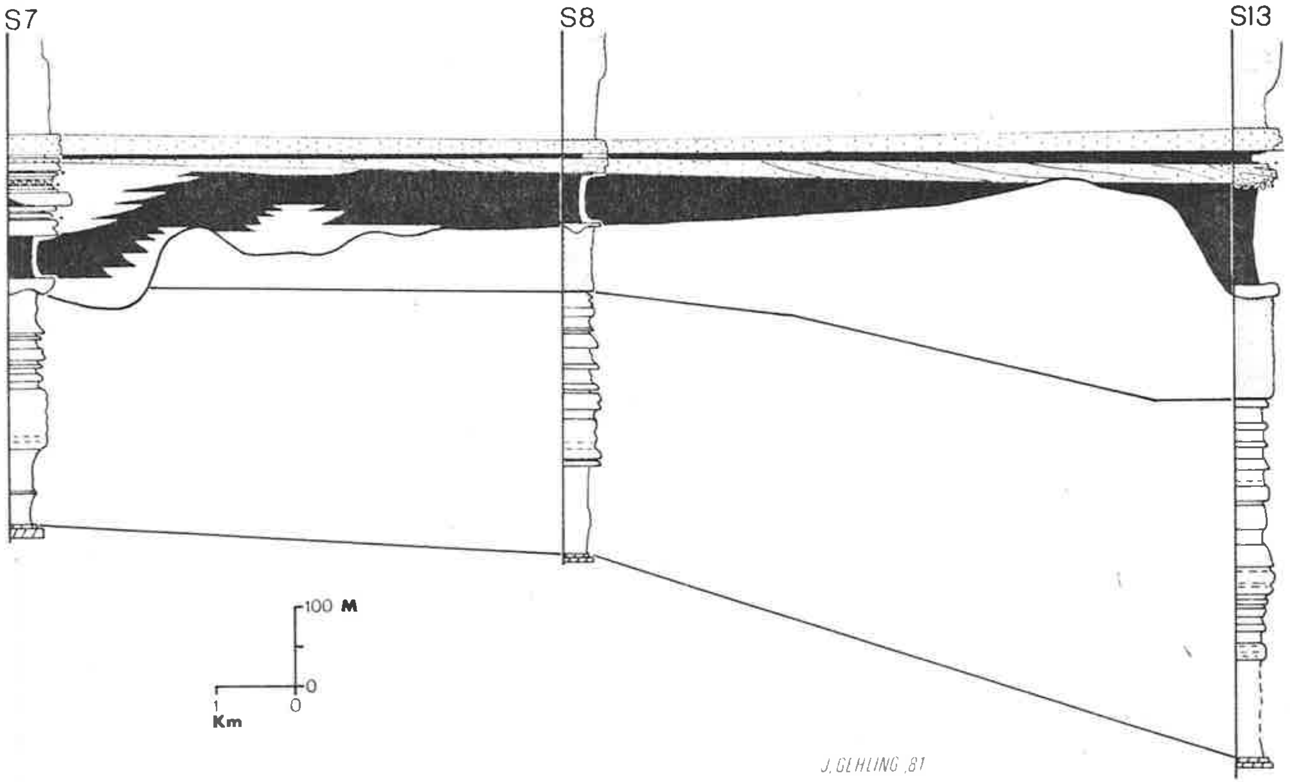


FIG. 16

FIGURE 17

Cross section R-S of the Ediacara Member from the north end of Wilpena Pound along the Heysen Range. Section 18 is type section for Bonney Sandstone and Rawnsley Quartzite (Forbes, 1971). For detail of Section 20 see Fig. 4. The depth of the "valley" between D69 and S23 is uncertain.

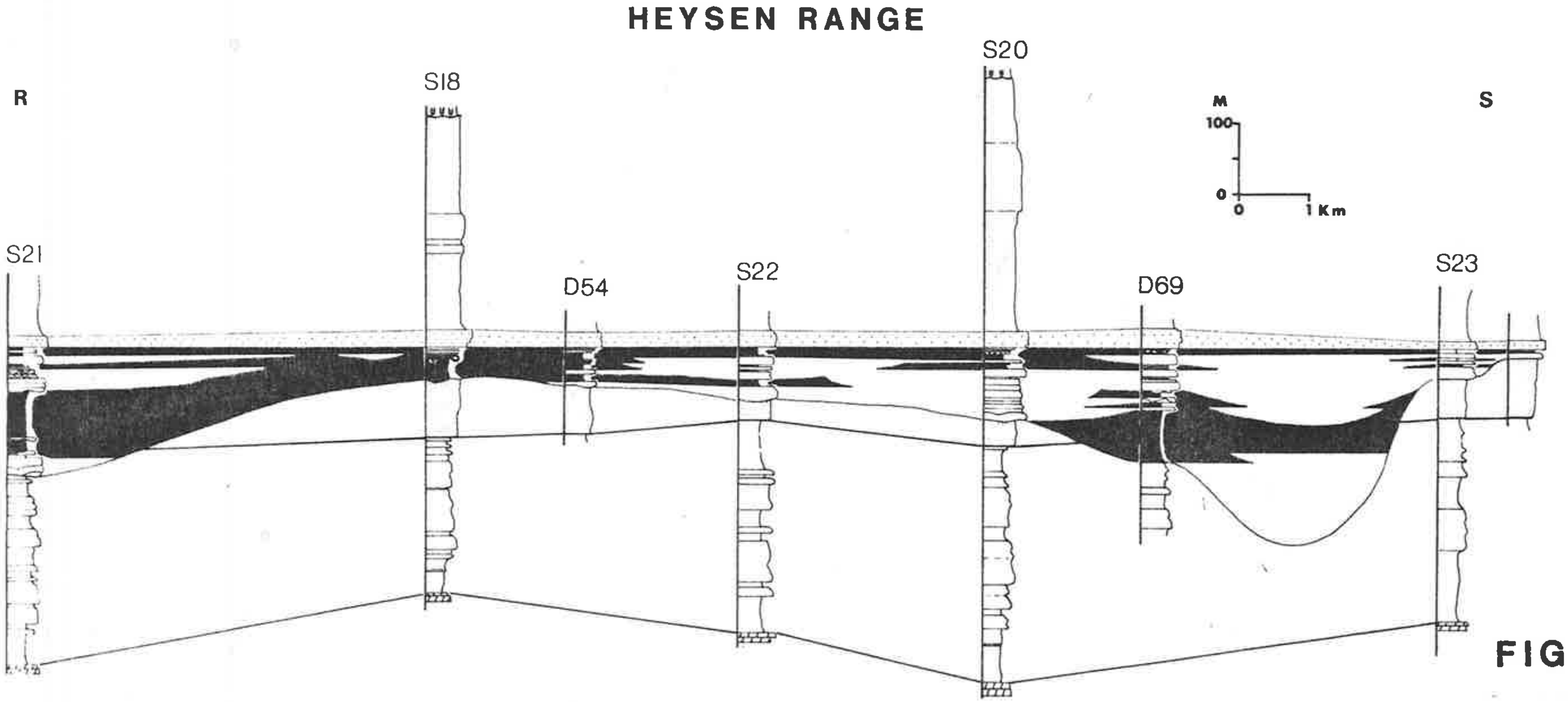


FIG.17

J.GEHLING ,81

FIGURE 18

Cross section T-T' near Parachilna Gorge, north Heysen Range. Section 28 is approximately in the position where Mawson (1937) first described the "Pound Quartzite". Section R-S ends 14 km south.

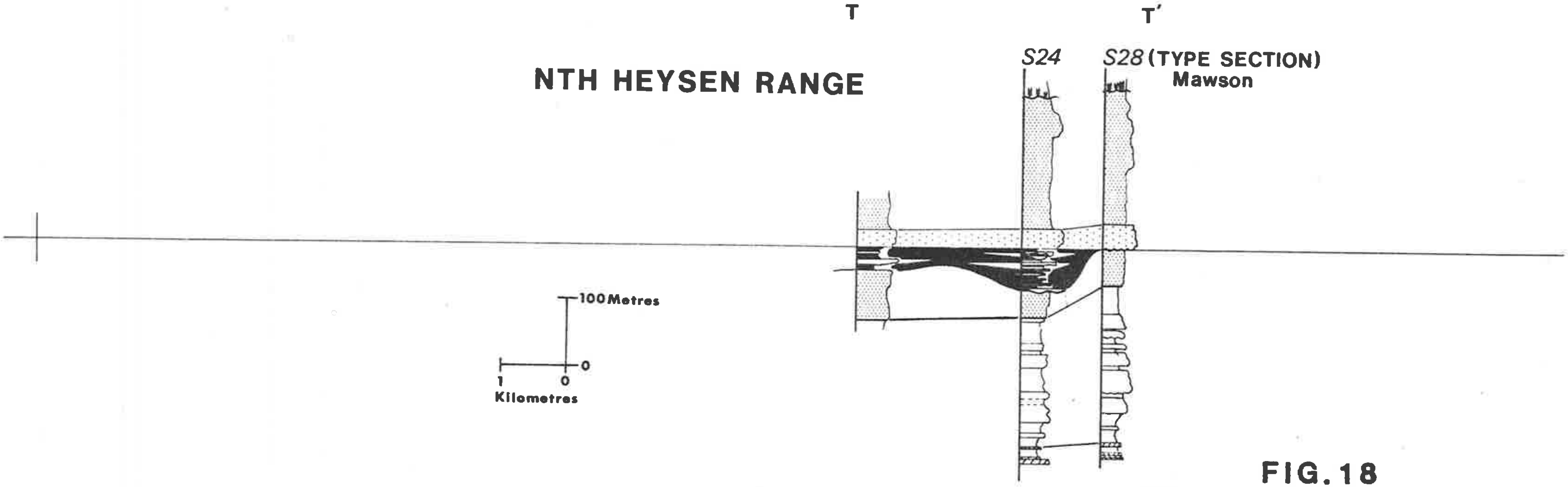

T
T′
S24
S28 (TYPE SECTION)
Mawson
NTH HEYSEN RANGE
100 Metres
0
1
0
Kilometres

FIG. 18

JGG,81

FIGURE 19

Cross section O-O' along the Elder Range. Note thick sequence of Facies H and I below Ediacara Member between Section 1 (Mayo Gorge) and Section 4 (Mt. Aleck).

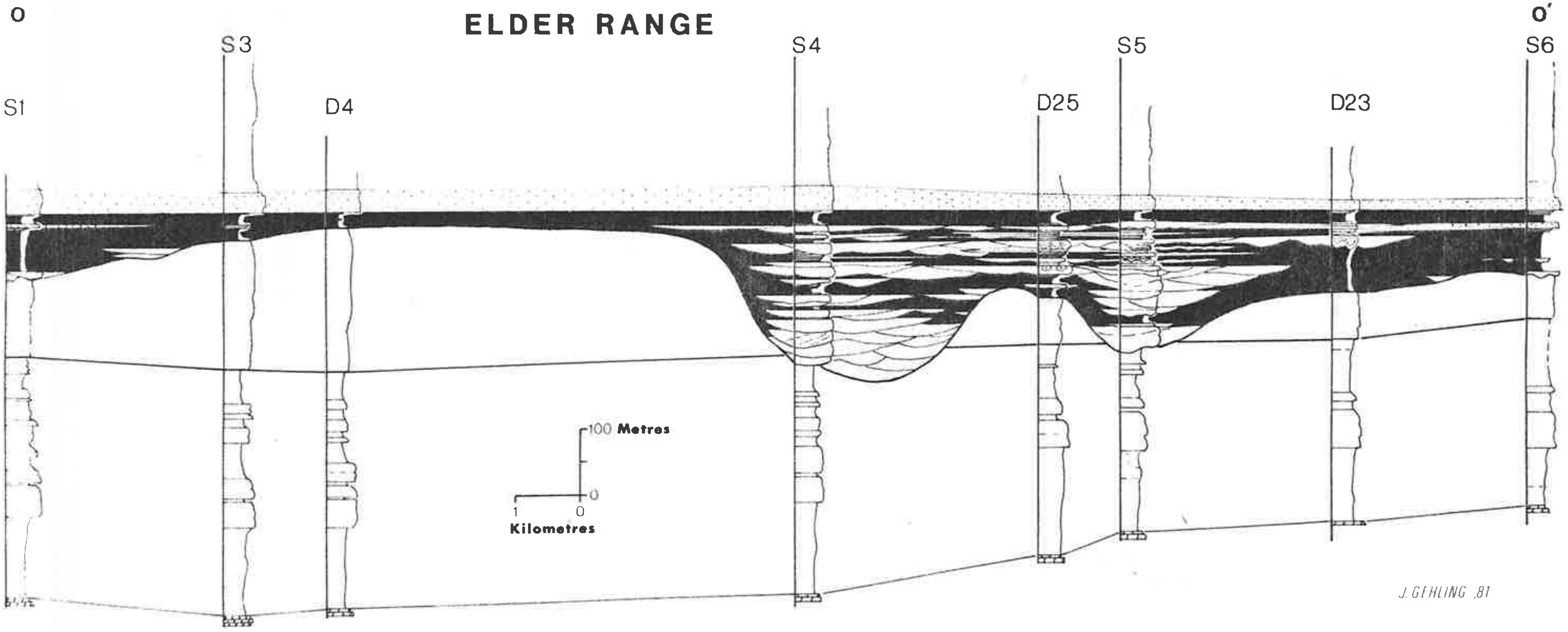

O
ELDER RANGE
O′
S3
S4
S5
S6
S1
D4
D25
D23
100 Metres
0
1
0
Kilometres
J. GEHLING '81

FIG.19

FIGURE 20

Cross section U'-U along the Chace Range. For location of vertical sections see Fig. 22. Note three cycles of Facies N (M and L), interpreted as prograding shelf cycles, capping proximal turbidite sand cycles (Facies J, K, and L).

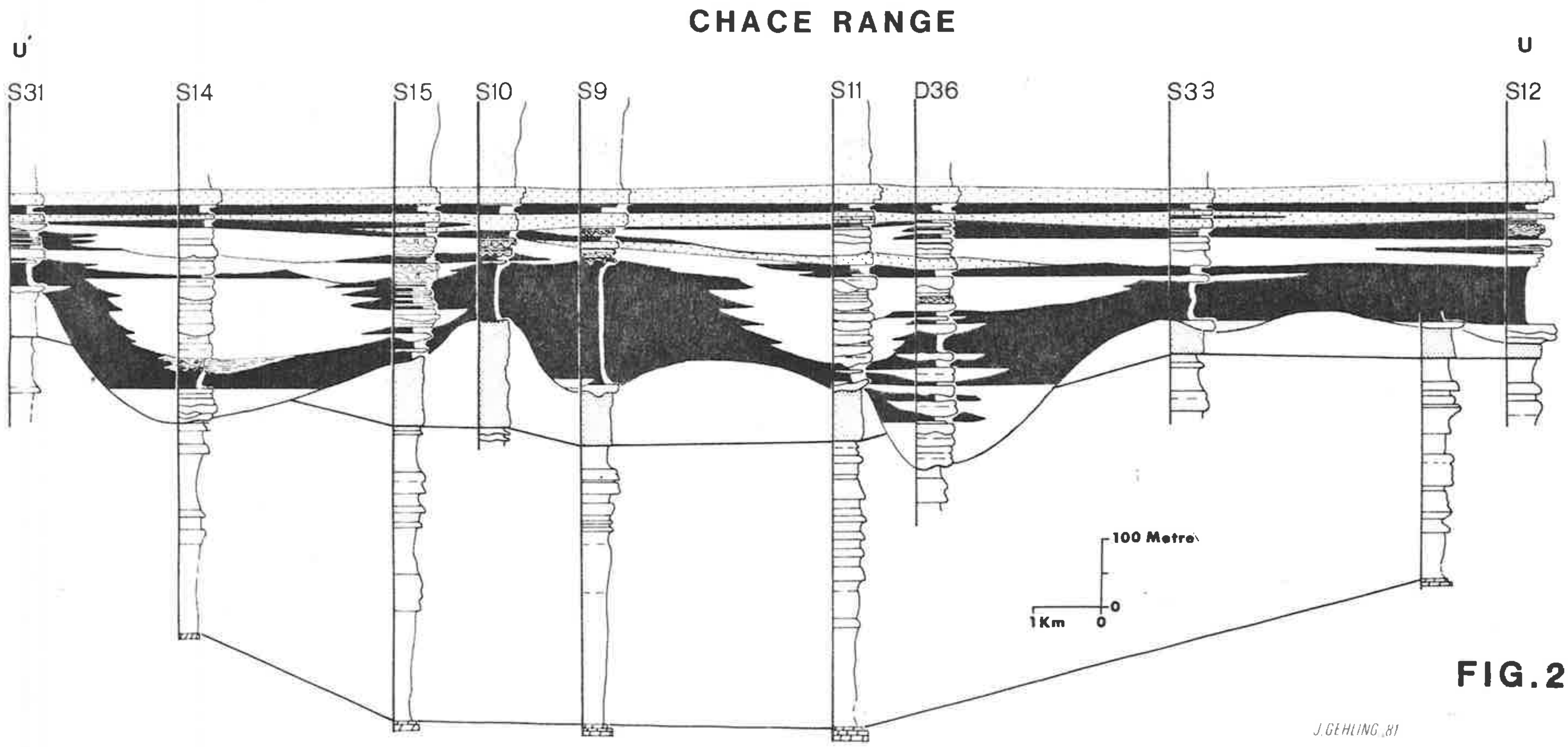


FIG.20

J.GEHLING '81

FIGURE 21a

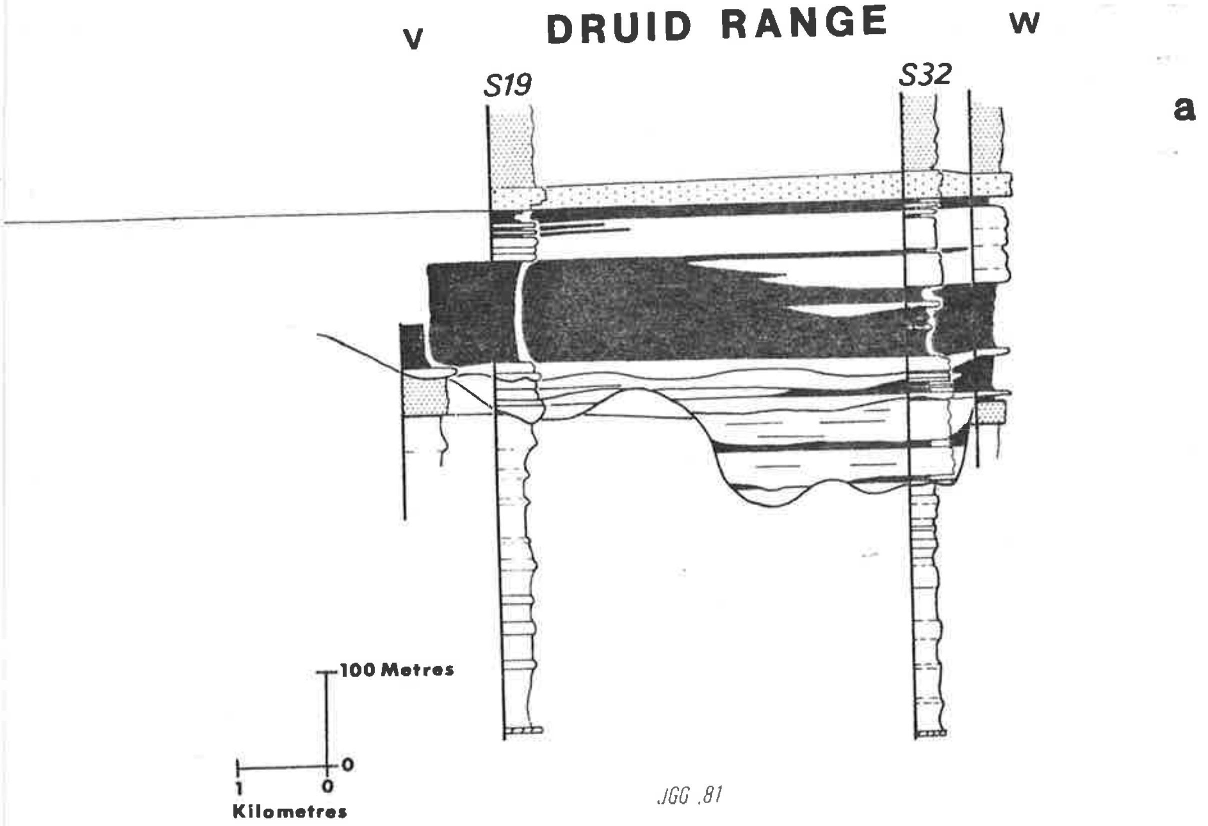
Cross section V-W, east end of Druid Range. Most distal sections of Ediacara Member.

FIGURE 21b

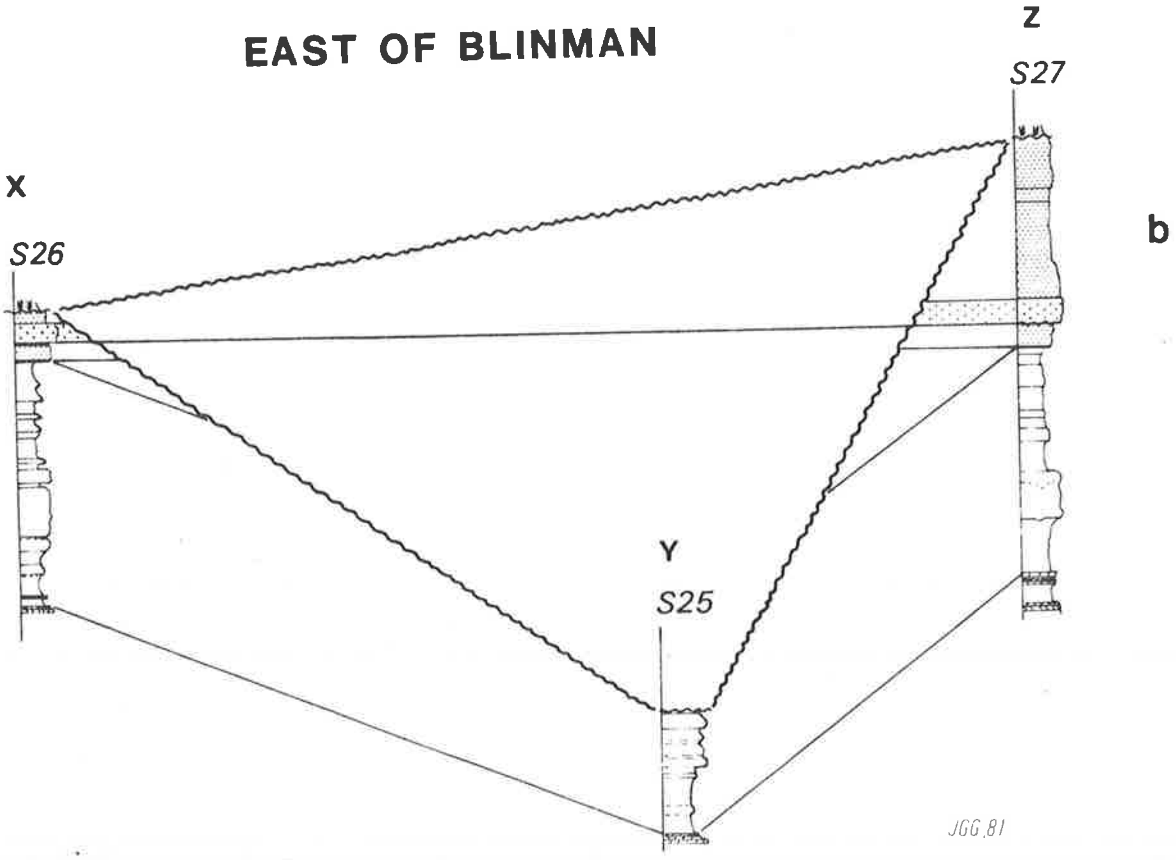
Fence diagram for sections east of Blinman. Facies N (?) only remnant of Ediacara Member. Pound Subgroup truncated by erosional unconformity marking base of Cambrian; Parachilna Formation overlying.

**FIG.21**

DRUID RANGE



EAST OF BLINMAN



In the lower part of the Rawnsley Quartzite these facies are erosively truncated by the Ediacara Member, which in turn is overlain conformably by the greatest development of Facies H and I (Fig. 4 and 17). These facies are nowhere included in the Ediacara Member.

The Ediacara Member is here redescribed to include massive and amalgamated sandstones, previously believed to overlie or laterally replace the Ediacara Member (Wade 1970; Jenkins et.al., in prep). Cross sections constructed from oblique aerial photos and measured vertical sections (Fig. 15 and 18) show that from Section 18 at Bunyeroo Gorge to Section 16 on Wilpena Pound, the fine grained beds of Facies L progressively give way to cycles dominated by Facies K (massive sandstones). The sequence involves cycles of Facies J, K, L, M and N in distinctive combinations, but is everywhere capped by Facies N. (Fig. 12). Massive channelized sands of Facies J usually begin the sequence. Thick cycles of Facies J and K, (massive, amalgamated sands) lense, without grading, into monotonous sequences of laminated silts of Facies L. In the upper part of the Member, cycles mainly involve the fossiliferous, wavy-bedded sands of Facies M, complexly crossbedded sands of Facies N and the silts of Facies L. The major changes in thickness of the Member reflect a progressive fill of some 300 metres, cut into the underlying sediments of the Rawnsley Quartzite. This erosional truncation of the underlying facies by the Ediacara Member is dramatically revealed in Fig. 13, a cross section through Wilpena Pound, based on measured stratigraphic sections. The Member is capped by a distinctive cycle of Facies L, M and N which is readily traceable, and acts as a datum for all cross sectional diagrams linking measured vertical sections (Figs. 4, 13, 14-22) that involve the Ediacara Member.

## 11. Environmental Interpretation of the Rawnsley Quartzite

Excluding the Ediacara Member, the Rawnsley Quartzite, consists of cross and ripple bedded sandstones, free of clayey sediments. The well defined bedding, often with alternation of very coarse and medium to fine sand, indicates shallow water, traction sedimentation. Cycles of Facies H, crossbedded sands, passing up into rippled and disrupted sands of Facies I resemble the "B-C cycles" of Klein's (1970) tidal sequence (Plate 9b). The low angle J type trough crossbedding of Facies H, occurs in cosets, with herring bone sets near the top. They have affinities with the lower intertidal to subtidal crossbedded sands described by Sellwood (1971) and Klein (op.cit.). The dominance of one current direction in larger scale sets reflects the stronger (ebb) tidal current vector (De Raaf and Boersma, 1971). These foresets, often bearing mud clasts (Plate 6b), show an overall mean azimuth trend toward the ESE (Fig. 6). Assuming that they represent ebb tidal flow, open water would have been toward the south or east.

The double crested and ladder ripples, alternating coarse and medium grained lamination, and the wavy (Plate 7a) and lenticular bedding of Facies I are indicative of tidal sand flat environments, resembling examples described by Wunderlich (1970), Evans (1965) and Van Straaten (1954). The absence of clayey laminae, in the form of flaser bedded sands, distinguishes these from other mid-tidal sand flat sediments described from ancient and modern environments. The well rounded grains and lack of unstable minerals and clay, suggest recycling of mature sediments. On shore, dune fields may have been a source for tidal flat reworking in a transgressive sea. The polygonally disrupted laminae possibly represent desiccation of algal-bound sand (Plate 8b, c), and escape of entrapped gas (De Boer 1980). What may be pseudomorphs of sulphate crystals,crowding beds of Facies I in parts of the sequence,suggest a near supratidal environment. Miller (1975) describes the growth of gypsum rosettes in sediments of the Laguna

Madre tidal flats, Texas, which produce disrupted bedding not unlike that of Facies I. Riedel (1980) considers the occurrence of barite to be indicative of pre-evaporitic conditions. The rippled and disrupted sandstones (Facies I) are interpreted as mid and upper intertidal sand flats, devoid of large scale bed forms and colonized by algal and bacterial mats. Scoured out tidal run-off channels, connecting with sub tidal mega ripple sand fields account for thick developments of Facies H.

While cycles of Facies H and I vary from 2 to 6 metres in thickness (Fig. 4, detailed from 490 m level, Section 11), in many parts of the sequence, one or the other facies dominates. With reference to Klein's (1971) tidal range model, the most complete cycles indicate a minimum tidal amplitude of 2 metres.

A wide, tide dominated shelf, free of barrier islands, is envisaged, with a continuous supply of sand, delivered by arid terrestrial dunes and rivers from a cratonic foreland.

The Ediacara Member is composed of thick sequences (10-130m) of massive sandstones, intercalated with thick siltstones, which together are capped by a number of cycles of coarsening, thickening up units of thin wavy bedded sandstones and thick crossbedded quartzites. An isopach map of the Ediacara Member in the Wilpena area (excluding the capping unit of Facies N) (Fig. 22), shows a strong east to south-east trend with thinning to the NE and SW. The sharp, erosional base of the member is prominent in the east wall of Wilpena Pound (Plate 16c), where from Rawnsley Bluff to Illuka Peak, 4 kilometres north, the base of the Ediacara Member reduces the facies of the underlying Rawnsley Quartzite from 250 metres to zero thickness. In outcrop the contact is sharp and usually overlain by the channelized massive sands of Facies J, bearing shale and sandstone clasts (Plate 10b, 11a). The lower part of the

FIGURE 22

Isopach map of the Ediacara Member (excluding capping unit of Facies N). Thicknesses from measured sections as located (e.g. S21). Sections prefixed "S" represent continuous, measured sections to 1m accuracy. Sections prefixed "D" were only measured for major facies intervals, or had significant parts of the section covered. Isopach interval 100m.

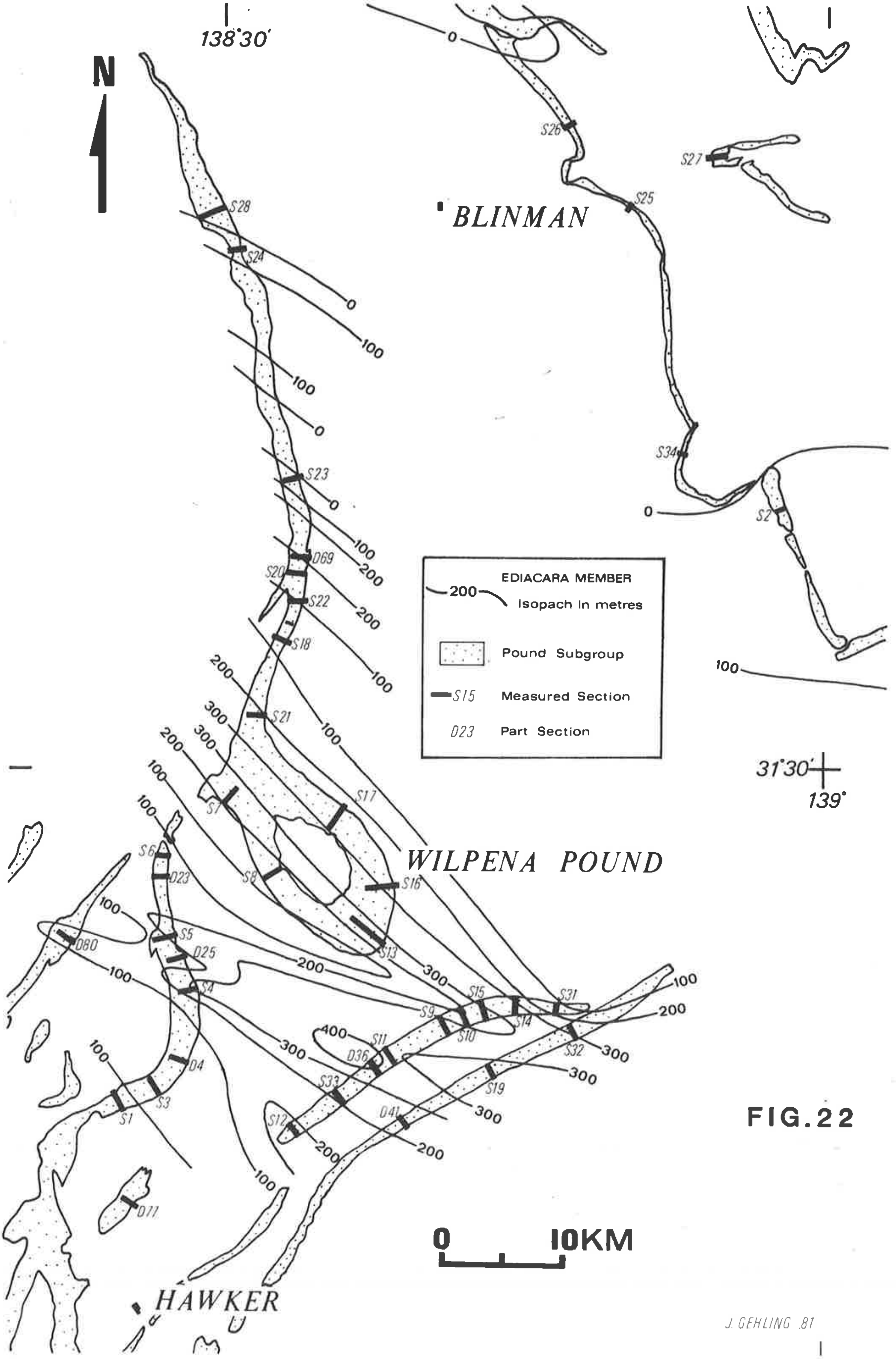


**FIG.22**

J. GEHLING .81

Ediacara Member fills what best can be described as valleys cut into the underlying Rawnsley Quartzite. The valley exposed in Wilpena Pound (Fig. 15) extends from the Heysen Range to the Druid Range (Fig. 17 and 20, 21) or at least 50 km when tectonically restored. This south east trending valley is at least 250 metres deep and some 12 km wide. The NW and SE extent cannot be determined, but valleys appear to broaden in the Druid Range where sections are interpreted as more distal than those in Wilpena Pound. The correlation of this erosional feature between Wilpena Pound and the Chace and Druid Ranges is supported by the direction of smaller channels cut into the erosional surface, and numerous groove casts (Plate 17a). Tilbury and Fraser (1981) describe modern submarine valleys, on the Ceduna Terrace off the South Australian coast, which have similar dimensions. They vary from 5 to 10 km in width at the shallow end, to 20 km wide at the terrace edge, with a relief of some 200 m and a length of up to 140 kms. The facies deposited in Ediacaran valleys are characterised by a lack of tractional sedimentary features. The massive (Facies J) sandstones fill channels cut in the valley floor. Further up the sequence Facies J and K sequences form multi-story sand cycles in valley axes (Plate 17b, c). The laminated and massive siltstones of Facies L are thickest on the valley margins (Fig. 13 and 20). Contacts between these contrasting facies are sharp, and where the sands overlie the silts, deformational structures are common. Together, Facies J and K strongly resemble "the resedimented coarse-clastic family" described by Walker (1978, page 932). For such sandstones, where tractional structures and grading are rare or absent, Stauffer (1967) proposed a "grain-flow" mechanism in which there is an equilibrium between fluid support and grain collision. Stanley et.al. (1978) considered these sandstones to have deposited as "quick" beds from concentrated under-flows of turbidity currents moving down submarine canyons, or feeder channels. The channelized sands, which are relatively free of internal structures, reflect more concentrated sand flows, where grain support was sufficient to enable fluid to escape without disruption, or where sorting was too good for "dish" structures to be preserved (Walker and Mutti, 1973). It is generally recognised that the Bouma sequence is not really applicable to such massive sandstones cycles (Walker, 1978; Ingersoll, 1978), in that they represent "channelled suprafan" (Walker and Mutti, 1973) or "mid-fan" (Ingersoll, 1978) environments of the submarine fan model. The Bouma model applies to the "lower" or "outer fan". The recognition of dish bearing sandstones and the rudiments of fining up cycles with climbing ripples in the Chace Range (Fig. 4, Section 11 expanded section, 650 metre level) suggest that we are viewing sections through the proximal end of a sand rich turbidite sequence, such as described by Walker (1978). The Chace and Druid Range sections represent slightly more distal sequences, but the bulk of the classic turbidite sequence would have occurred to the south east, of which there is now no record. The south eastern trend of the Adelaide Aulocogene, proposed by Kätz (1976) would allow the possibility of deepening in that direction, as suggested in this study.

Texturally these massive sands are like other sand facies of the Rawnsley Quartzite, in being more mature than the deep water sands described by van de Kamp et.al. (1974), Morris (1974), Ingersoll (1978) and Ghibaudo (1980).

These massive sandstones, described variously as "braided mid-fan", "fluxo-turbidite" and "proximal turbidites", form part of more classic turbidite fan deposits set in "arc-trench related basins" with "immature clastic sediment supply" (Ingersoll, 1978). By contrast the Wilpena Group, of which the Ediacara Member is a part, is dominated by quartz rich arenites derived from the Gawler Craton to the west. Dickinson and Suczek (1979) describe sandstones, compositionally of the Rawnsley

Quartzite type, as typical of a continental cratonic source. With reference to coarse grained turbidites, Nelson and Kulm (1973, pg. 68) suggest a tectonic setting of "restricted basins in continental boarderlands and marginal seas". Forbes and Coats (1976) consider the setting of the Adelaide "Geosyncline" sediments to be intracratonic.

The khaki laminated and massive siltstones of Facies L dominate marginal sections of the valley fill, where uninterrupted sequences of up to 180 metres have been measured. Laterally the massive sands described above, lense into these siltstones. Vertically the facies change is characterized by spectacular load balls and pillows of Facies K into Facies L (siltstones) (Plate 12b). The upper contacts, where silts succeed massive sands, are flat. The hydroplastic deformation produced by density contrasts between the thixotropic clayey silts and the overlying saturated coarse sands, point to suspension sedimentation of the fine silts and rapid deposition of the "grain flow" sands on top of them. They resemble, in scale and form, the pillow structures described by Howard and Lohrengel (1969) from the Upper Cretaceous Star Point Formation of Utah. Pettijohn et.al. (1972, pg. 124) considered that their formation in turbidites reflects rapid successive sediment flows, giving no time for dewatering of the subjacent sediments. Stanley et.al. (1978) describe large load structures on the bases of coarse massive sandstone units from their "Submarine Fan Facies" in the Annot Sandstone. In some sections penecontemporaneous deformation appears to persist through thick sequences of the massive sands. Deformed bedding contacts in massive sands are difficult to distinguish from deep, irregular scoured contacts (Morris, 1974). Experiments by Kuenen (1965) suggest that earthquakes may trigger thixotropic transformations of the kind represented here.

The monotonous, thick sequences of Facies L have few discriminating characteristics. Rare clayey partings exhibit crude sinuous and crossing trails in the form of concave moulds on upper or lower surfaces. They resemble Form F trails described from Facies M sandstones at Ediacara Range, by Glaessner (1969). Such "Nereites"-like forms support the impression that this facies is a pelagic siltstone (Walker and Mutti, 1973), deposited by suspension during times of channel abandonment. Walker (1978) suggested that this might occur in response to relative rises in sea level, resulting in a local cut in supply of sand sediment. Facies L shows a general increase in very fine sand laminae toward the top of thick sections, accompanied by some micro-crosslamination. Shallowing up, accompanied by weak tractional currents is indicated. The facies includes massive units up to 10 metres thick of mudstone, with medium grained sand supported in a clay and silt matrix. These units represent channels filled by a thixotropic slurry of sand and silt displaced from higher up the slope, in a manner described by Morris (1974).

The thick sequences and general absence of sedimentary structures other than lamination, liken Facies L to the "pelagic facies" which Morris (1974) describes from Carboniferous "proximal turbidites" in Arkansas (also Walker and Mutti, Facies G, 1973). Facies L represents hemipelagic suspension sedimentation below wave base, interrupted by submarine sand flows derived from a storm and tide scoured shelf. The packet of sediments incorporating Facies J, K and L constitute the *Submarine Valley Fill Sequence* of the Ediacara Member (Fig. 12).

Where the relative depositional level reached wave base, the onset of wavy bedded sandstones (Facies M) represents the base of the *Subtidal Shelf Sequence*. This upper part of the Ediacara Member is widespread : from Mt. Scott in the northern Flinders Ranges to Devil's Peak east of Port Augusta. Sequences succeed either massive channelized sands of Facies J or siltstones of Facies L. In either case they grade up into silt interbedded, wavy and rippled sandstones of Facies M. These well bedded sandstones are most notable for the impressions that they bear of animals of the Ediacara assemblage. Goldring and Curnow (1967) considered this facies to represent "the sub-beach, off shore neritic zone". Likewise, Wade (1968) considered that the preservation of the soft bodied metazoans involved a sub-aqueous mechanism with no evidence of emergence of the sediment surface. Glaessner (1961) implied that many of the organisms might have lived in close proximity to the preservational environment as evidenced by animal trails and the varying size range of certain species. Unfortunately, few species in the assemblage have affinities with modern forms, but there is some evidence that at least one group, the pennatulid like forms, may have lived and been preserved in an offshore environment more than 15 metres deep (see discussion below).

Prior to the work of Goldring and Curnow, Sprigg (1947, 1949) and Glaessner (1961) considered the depositional environment for the fossiliferous strata as tidal flats or beach. More recently, Jenkins (1981, pg. 187) referred to these beds as "tidal, back-barrier or lagoonal". Jenkins (1975) considered that the resemblance of Facies M to the flaser and wavy bedding of Reineck and Wunderlich's (1968) "tidal bedding", together with the recognition of certain interference-ripple surfaces and shrinkage cracks, as strong evidence for an intertidal, back barrier environment. However, it is well documented that flaser, lenticular and wavy bedded sandstones are also common in sub-littoral environments subject to wave action during storms. (De Raaf et.al., 1977; Reading, 1978, pg. 234; Klein, 1977, pg.90; McCave, 1971).

Facies M beds show a characteristic increase in sandstone thickness, decrease in silt interbeds and better developed current and wave ripples, up the sequence. Tidal sediments described by Klein (1970), Sellwood

(1972) and Evans (1965), show the opposite trend, reflecting decreasing energy conditions up the sequence, from lower to upper intertidal environments. The lower part of Facies M cycles, where thin bedded sands grade up from Facies L silts, can be likened to the "silty streak" and "sandy streak" facies that De Raaf and others (1977) described as sub-littoral storm agitated deposits.

Typically, a single wavy sandstone bed of Facies M is 5 cm thick, with massive sand composing the basal 1 cm, grading up into low angle wispy crosslamination which develops starved unidirectional current ripples or irregular oscillation ripples on the upper surface (Plate 14b). Each such unit represents a waning storm current carrying sand down from shallower environments, with partial reworking by wave oscillation.

The desiccation cracks mentioned by Jenkins (1975) are equivocal in that synaeresis cracks are a common feature of these beds (Glaessner, 1969). Goldring and Curnow (1967) found no proven desiccation cracks in their study at Ediacara. It is impossible to distinguish between the various, incomplete shrinkage cracks with any certainty. No classical V-sided, concave up, polygonal mud crack casts have been found. All shrinkage cracks can be accounted for by subaqueous dehydration of clay, whether at the sediment interface, or intrastratally in association with the deformation of sand beds into thixotropic silts (Plummer and Gostin, 1981).

Sole marks, such as flute and groove casts, which occur on the bases of sandstone beds in the Chace and Druid Ranges, give consistent south east current directions (Plate 18a). These represent the direction of the "deeper" basinal setting into which sediments are prograding.

Facies M represents a combination of storm wave-base agitation and sub-littoral tidal currents which intermittently mantled the offshore silty bottom with sand, eroded from shallower shelf environments. The combination of starved current ripples, overprinted by oscillatory wave agitated sand, produced irregular and interference ripple topped, thin sandstones. Organisms, whether sessile, or foraging close to the silty substrate during periods of calm, could be rapidly overcome and buried or transported a short distance, by storm-surge sands. Odd interspersed shallow, massive sand filled channels represent inner slope feeders for Facies J and K down slope.

The rapid upward change to Facies N (complexly cross-stratified, white quartzites) reflects further shoaling in a tidally influenced sub beach environment. The upward coarsening and thickening of sand units from Facies L through M to N resemble the pattern described by Berg (1975) for the Lower Cretaceous Sussex Sandstone. Pryor and Amaral (1971) describe large scale, low angle, cross-stratified sets from the Ordovician, St Peters Sandstone, not unlike those found in the lower of two cycles of Facies N. In the sections of Wilpena Pound, 5-10 metre thick, imbricate sand sheets dip south east, parallel to the inferred downslope trend for the valley fill sequence. Despite the variability, overall palaeocurrent trends for Facies N in the central Flinders Ranges have an ESE bias (Fig. 6), reflecting the net transport direction. The sand sheets are interpreted as front sets of large scale sandwaves prograding out across the shelf in response to storm surge and tidal ebb currents. Reworking by fair weather waves may have produced offshore tilting boundaries between successive sheets (Plate 16b). Hobday and Tankard (1978) recognise sand bar complexes of similar areal extent and internal structure, from the Peninsula Formation, which they consider to have accumulated under storm conditions. Like those in the St Peters Sandstone, complex trough cross-beds, higher in the facies, show no consistent orientation. The St. Peters Sandstone is considered to represent "submarine sandwaves, dunes and ridges" on a shallow marine shelf swept by tidal currents and wave action (Harms, 1975, pg. 125). A similar model is proposed for Facies N, accounting for the supply of sand to the more distal valley fill sequence. This shelf sequence was probably fed by wave and tide reworked sands from fluvial and dune systems to the west and northwest.

The last cycle of Facies N, which is capped by the intertidal sandstones (Facies H and I), forms a remarkably uniform unit of a constant thickness (20 to 25 metres) in all sections, which may represent the effective depth of water across the shelf, from stormwave base to low tide. The progression from this subtidal shelf sequence back into the intertidal sands of Facies H and I, marks the top of the Ediacara Member. Facies N can be recognised within the upper part of the Rawnsley Quartzite, but is not easily distinguished from the shallow trough crossbedded sands of Facies H.

## 12. Distribution of the Ediacara Assemblage

Wade (1970) gave the first account of the geographic distribution of fossils of the Ediacara assemblage, within the Flinders Ranges. At that time it appeared that the fossiliferous beds were restricted to the western side of the Flinders Ranges, from Mt Scott near Leigh Creek and Ediacara, south as far as Mayo Gorge in the Elder Range. Since then these fossils have been discovered in localities on the eastern side of the Ranges and in the southern most outcrop at Devils Peak, east of Port Augusta (Wade, 1972a ;Jenkins and Gehling, 1978).

In measuring sections for this study, fossils have been discovered at numerous localities, including many considered to be barren by Wade (1970). Largely, limitations previously placed on the distribution of the fossiliferous beds were the result of a restricted view of the stratigraphy of the Ediacara Member, which can now be shown to be up to 400 metres thick and distributed within the whole of the central and southern Flinders Ranges outcrops of the Pound Subgroup (Fig. 22). Potentially fossils of the Ediacara assemblage can be found whenever the Ediacara Member outcrops although the conditions for preservation are less common in the lower part of the Submarine Valley Fill Sequence. In practice there are also certain geomorphological and superficial factors which determine the likelihood of discovering fossils in a particular outcrop.

Wade (1970) in proposing a palaeogeographic explanation for the presence of fossiliferous strata, relied heavily on diapiric activity for the creation of "barriers reducing wave action". The alternative of "deepening of the water column" was briefly considered but rejected (Wade 1970, pg. 100). There is no feasible model that would enable the use of "diapiric barriers" to explain the presently known distribution of fossiliferous beds. Furthermore sedimentological evidence for pronounced uplift by diapirs during the deposition of sediments of the Rawnsley Quartzite is lacking. Wade's suggestion of a deepening water column in practice affords a better explanation of the pattern of sedimentation, as outlined in this study.

As detailed by Wade (1968), the preservation of these soft bodied metazoans was a function of the mantelling of a silty or clayey substrate with sand. Where ever these sedimentological conditions existed, and animals were present, fossilization was a possibility, whether as body fossil impressions or as traces of animal activity. Within the very thick sequences of the Ediacara Member, the potential for preservation and discovery of fossils is a function of the frequency of silty partings in sandstones. This is, of course, most encountered with cycles of Facies M (silty parted, wavy bedded sandstones) which generally increase in frequency and thickness toward the top. Correspondingly the frequency of fossils increases up the section of the Ediacara Member (Appendix 6) to a maximum below the datum (used in section diagrams) where Facies M is succeeded by the highest and most prominent unit of Facies N (complexly cross-stratified, white quartzites). The Subtidal Shelf Sequence, represented by cycles of Facies M and N succeeds the Submarine Valley Fill Sequence (Facies J, K and L) which are generally unfossiliferous as a consequence of the smaller number of suitable horizons (Fig. 12). Trace fossils and unidentifiable impressions occur within Facies L, but well defined body fossil impressions are excluded by the lack of contrast in grain size of succeeding laminae. The massive sandstones (Facies K) rarely preserve external moulds (Wade 1968, pg. 256; 1971) but in general must be considered a poorly prospective facies.

The lowest recorded, identifiable species *(Phyllozoon hanseni,* Jenkins and Gehling) occurred 105 metres below the datum line (see above) and represents the greatest stratigraphic range of the Ediacara assemblage (Fig. 4, Section 11). Two other species having almost as great a stratigraphic range are *Rugoconites enigmaticus* Glaessner and Wade, and *Ovatoscutum concentricum* Glaessner and Wade. Several new, as yet undescribed forms, some having no affinities with previously described members of the Ediacara assemblage, occur together with rare small specimens of well known species, in the lower half of the known stratigraphic range. (Appendix 6)

Too few specimens have been recorded to enable a valid assessment of biases in geographic distribution of species although some interesting trends are worth a mention. Species of the frond-like organisms, related to modern Pennatulacea, are locally concentrated on single bedding planes (e.g. Section 18) but are regionally uncommon. *Ovatoscutum concentricum,* previously known from two whole and one fragmentory specimen, was recorded in four sections south of Wilpena Pound although only one specimen was complete. *Dickinsonia costata* Sprigg and *Cyclomedusa davidi* Sprigg remain as the most widely distributed and common species.

## 13. Contribution of the Ediacara Assemblage to Environmental Interpretation

Glaessner (1961) described, in general terms, the possible modern affinities of some of the major groups of fossils from the Ediacara assemblage. While it may be possible to ascribe a number of the forms to known phyla and classes, little information of environmental significance has been derived from this, the oldest diverse assemblage of metazoans.

The main problem concerns the relationship of body fossils to their preservational environment. If, as Wade (1968, pg. 266) suggested, this is an assemblage of organisms, not associated during life and brought together after death, then all that can be said is that the environment was marine and that the ocean supported diverse forms of metazoa. Jenkins (1975) also considered that most organisms were preserved after "stranding" away from their normal habitat. In their analysis, Goldring and Curnow (1967, pg. 208) described the fossil beds as "a facies in which life was supported on a sedimentary surface over which only sporadic currents flowed", implying that there might be environmental associations. Glaessner (1961), conceded that *Spriggina, Dickinsonia* and *Parvancorina* Glaessner could have lived near the sedimentary beds. He based this on the observation that these species are found "in varying size and growth stages". A study of bedding surfaces in a wide range of sections, has shown that each of these distinctive forms can occur on single surfaces as groups of individuals with a variety of growth stages. Wade (1972a) considered that *Dickinsonia costata* Sprigg was a swimmer with a nekto-benthonic habit. *D. costata,* as one of five related species of extinct errant worms from the assemblage, is by far the most common readily identifiable species (Plate 19a). Wade (1968) specified the features of its dorsal and ventral surface thereby facilitating a study of their orientation at the time of preservation. If this and other species were transported to the site of burial, after death (Wade, 1968) the preserved aspect, of this essentially flat organism, should be randomly distributed for the dorsal and ventral side up. Fifty eight well preserved specimens were examined, and the ventral-side-up aspect out numbered the dorsal-side-up by 39 to 19 (a probability of less than 0.01 of this occuring due to chance alone). As *D. costata* has no morphological features which would cause dead or near dead specimens to land on the substrate with one side up due to hydro-dynamic selection, it is proposed that the biased orientation is a function of its life position close to the substrate. That this worm was preserved roughly in its life position is further supported by the occurrence of some well preserved specimens showing muscular contraction after burial (Wade 1972a). Runnegar (pers. comm.) suggested that the muscular reaction of *Dickinsonia* might be expected as a response to sudden blanketing by sands deposited during a storm, and that this worm may have been a "benthic glider". The absence of traces attributable to its locomotion or grazing was cited by Wade (1968) as evidence of its non association with the beds on which it is preserved. In practice a soft bodied nekto-benthonic, flattened, worm would not be expected to leave traces of its locomotion as it glided over even the most fine grained substrate. Furthermore, the "ventral" surface of *Dickinsonia costata* should be considered to be the life position dorsal side.

Frond like fossils have long been noted for their gregarious occurrence and apparent current alignment on bed surfaces of groups attached to the substrate (Glaessner 1959; Wade 1968) but were generally considered to have been uprooted from their life positions and transported. Recently the frond like form, *Charniodiscus arboreus* Glaessner, 1959, has been found associated with a buried disc, interpreted as an anchoring device

(Jenkins and Gehling, 1978, Fig. 3). The bedding plane on which this specimen was preserved exhibits no less than 30 other fronds, in a strike distance of 100 metres. Many of these specimens were apparently preserved in place, attached to the substrate. Species of the order Pennatulacea commonly have been observed in off shore sand shoals, 15 to 30 metres deep, in gulf waters of South Australia. These tidally swept shelf sands represent the most common habitat of one modern pennatulid *(Sarcophyllum grande)* (Plate 18c) which is one of the few benthic forms capable of living in this energetic environment. Marshall (1978) photographed dead specimens of the sea pen *Stylatula elongata,* as they were found, uncovered by a sediment slump in Scripps Submarine Canyon on the Californian shelf. It therefore seems possible that not only are sea pens most common in off shore sandy habitats, but that they are quite likely to be buried and preserved in sediments on the shelf margin.

Medusoids are the most prolific organisms in the Ediacara assemblage, often found in numbers in excess of 20 on a single exposed bedding plane (Plate 19b). *Cyclomedusa davidi* Sprigg, easily the most numerous of the identifiable medusoids is according to Wade (1972b), known only from its aboral or exumbrella side. Wade considered the possibility that this genus may have been either a floating or an attached Hydrozoan. In considering specimens of *Cyclomedusa* preserved with a transverse furrow, Wade (op.cit.) rejected twinning in favour of juxtaposing of specimens. However there are now a few specimens where both twinning and fourfold dividing are apparent on the one bedding plane. Chance symmetrical juxtaposing of four individuals must be rejected. The significance of such divisions on an individual, may be in the resemblance to the twinning of modern Anthozoan anemones, which are adapted to a variety of benthic environments. One relatively uncommon Cnidarian in the assemblage, *Conomedusites lobatus* Glaessner and Wade was considered by Glaessner (1971) to represent preservation in life position : oral side up on the substrate, with tentacles displayed.

Most evidence points to the preservation of animals close to their habitats together with pelagic forms which settled out of the water column after death. What remains, is to consider the variation in fossil bearing surfaces attributable to the sedimentary process.

The frequency of fossil occurrence on bedding planes provides some sedimentological clues to the optimal conditions for entombment. While thick and relatively uniform sequences of Facies M commonly reveal a wide variety of trace fossils, few well preserved body fossils are to be found. However, when relatively thin sequences of thickening up beds of Facies M (5 m or less) are abruptly overlain by Facies N, the frequency of fossiliferous bedding planes and the density of fossils on these surfaces, is at a maximum. Such intervals at Brachina and Bunyeroo Gorges have produced the richest finds and the best quality of preservation (Plate 19c). The association of such intervals with evidence of thixotropic deformation, in the form of ball and pillow structures, indicates that they represented periods of rapid inundation of poorly dewatered siltstones (Facies L) by prograding sandsheets (Facies M and N).

There are two types of fossiliferous surfaces between which there is little overlap : either surfaces are covered by trace fossil markings and unidentifiable "blobs", or they are relatively clean, with a scattering of well preserved impressions of soft bodied animals. The preferred association of the latter with rapid sedimentation and shallowing up cycles, suggests that trace fossil covered surfaces represent horizons exposed to the water column for longer periods of time. In other cases these surfaces appear to be the site of endo-benthic, bedding interface (intrastratal) scavangers (Glaessner, 1969). The paucity of unequivocal vertical burrowing traces in these and other Late Precambrian sediments (Glaessner, op. cit.) suggests that this behavioural adaptation had not yet evolved. As such it would seem unsound to give these facies a palaeobathymetric label. Sepkoski (1979) suggests that the diversification of infaunal animals late in the Precambrian "shut an early taphonomic window" (pg. 232). Thus well preserved impressions may owe their integrity to either thelack of a vertical bioturbation habit by scavangers, or to such rapid burial that the primitive burrowing forms were not able to cope. But it is possible that the absence of vertical burrows is indeed a factor of the depositional environment, as implied by the previous point. The tendency away from a vertical burrowing mode is apparent as the hydrodynamic energy of the surface of the sediment decreases (usually with depth) (Seilacher, 1967). Glaessner (1969) interpreted the trace fossil assemblage as representative of Seilacher's *Cruziana* facies, while explaining away such meandering varieties as Form B and Form C as expressions of mud flats protected by wave action. Form B and C are most often associated with the fine sandstone beds at the top of cycles of Facies L (siltstones). It is suggested that they represent deeper *Zoophycos* facies below the reach of storm wave action.

Fossils of the Ediacara assemblage are largely confined to beds of Facies M. If these were intertidal flat and back barrier lagoonal sediments as proposed by Jenkins (1975, 1981),it would be necessary to transport the delicate organisms through tidal inlets before either deposition in the lagoon or stranding on tidal flats. Alternatively, if the animals inhabited a lagoonal system, it would need to have been deep enough to preserve an un-interrupted sequence of up to 200 m of siltstones (Fig. 20, Facies L, S9), without reworking by waves or bottom currents. Furthermore, if as proposed by Jenkins (op.cit.) many of the fossils represent stranding on associated tidal flats, the majority of specimens might be expected to be distorted and fragmented. Apart from rare occurrences of reported tears in medusoids (Wade, 1972b) and fragmentation of some frond-like fossils (Wade, 1968) the assemblage is represented by a collection of remarkably undeformed specimens. The shape and tissue structure of many species would have made them hydrodynamically unstable in any environments influenced by constantly shifting tidal currents. The only soft bodied animals inhabiting such environments today are those adapted to an infaunal, burrowing habit, for which the Ediacaran animals were certainly unsuited. In the absence of evidence for dehydration of either the animals or the sediment surface, prior to burial, a tidal flat mode of preservation seems unlikely whether the animals lived nearby or were transported in.

Another factor weighing against an intertidal origin for the fossil beds is the striking lack of fossils, other than the rare occurrence of surface trails, in what are interpreted as intertidal sands above and below the Ediacara Member (Facies H and I). Even in the Bonney Sandstone where the necessary clayey laminae are interbedded with sandstones bearing odd trail like forms (Facies B), there is a total absence of body fossil impressions.

In the opinion of the author the palaeontological evidence can best be accommodated using a model of an offshore preservational environment, below normal fair weather wave base (Facies M), where at least part of the assemblage lived prior to entombment. In this respect, there now appear to be parallels with the preservation of Ediacaran fossils in both England and Newfoundland. In both sequences a moderately deep environment, characterized by turbidite derived gray-wackes and silt-stones is indicated (Brasier, et.al. 1978; Misra, 1969).

FIGURE 23

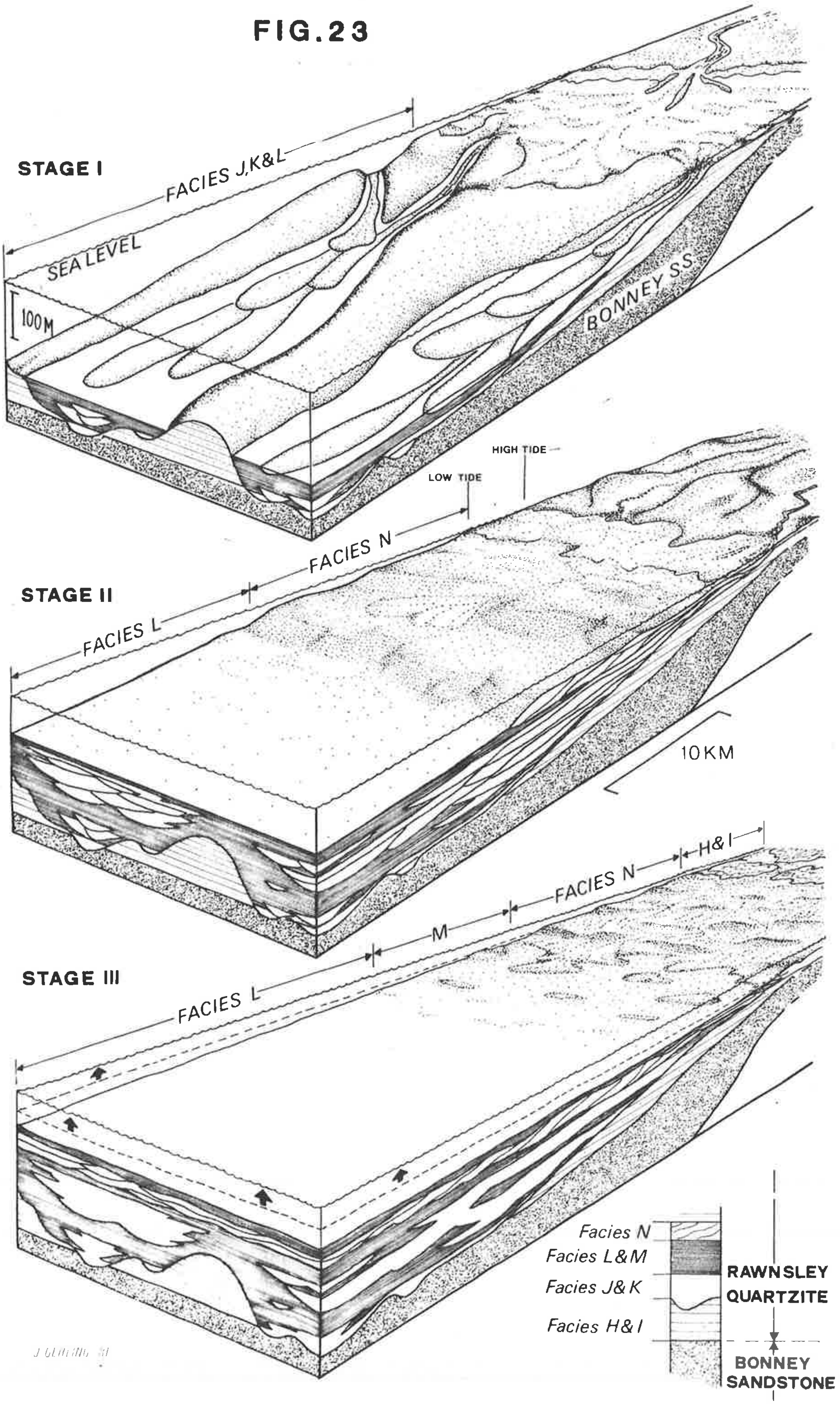
Block diagrams representing the reconstruction of depositional environments of the Ediacara Member.

Stage I : Submarine fill of erosional valleys by pelagic siltstones (Facies L) and "fluidized" or "grain flow" proximal turbidite sands of Facies J and K, derived from shallow marine and terrestrial mature sands.

Stage II : Envelopment of submarine valleys and subsequent progradation of storm surge sands and shallow marine, subtidal shelf sands. Fossils of Ediacara Member preserved by storm sand blanketting of animals on silty surfaces.

Stage III: Following relative sea level rise, a second cycle of shelf progradation begins, which caps the sequence and gives way to shallow marine and tidal sand flat conditions (Facies H and I).

FIG.23


STAGE I
FACIES J,K&L
SEA LEVEL
100M
BONNEY S.S.
HIGH TIDE
LOW TIDE
STAGE II
FACIES L
FACIES N
10KM
STAGE III
FACIES L
M
FACIES N
H&I
Facies N
Facies L&M
Facies J&K
Facies H&I
RAWNSLEY QUARTZITE
BONNEY SANDSTONE

## 14. Depositional History of the Ediacara Member

From numerous sections in the central Flinders Ranges, the Ediacara Member has been described by vertical facies analysis, palaeocurrent and thickness studies. Essentially the Member represents the submarine fill of a discomformable relief surface, produced by rapid deepening to the SE and the consequent submarine erosion of valleys which cut into the shelf. A north-east to south-west arcuate hinge, south-east of the Druid Range is postulated to have marked the distal edge of the shelf slope (Fig. 24). Progradation of shelf sands finally restored shallow marine conditions to the region.

The environmental reconstruction of the Ediacara Member must take into account: 1) the erosion of SE trending valleys into the underlying shallow marine sediments. (Fig. 23).

2) the filling of these valleys by siltstones and numerous tongues of massive sandstones (Facies J, K and L). (Fig. 23).

3) blanketing of the sequence by two cycles of siltstones and crossbedded sandstones (Facies L, M and N). (Fig.23).

The absence of outcrop, south-east of the Druid and Chace Ranges has limited the reconstruction to what is interpreted as the proximal end of a submarine valley-fill environment.

The lower part of the Rawnsley Quartzite comprises intertidal sand flat deposits, transgressively deposited on a broad shelf from Quorn in the south to the Gammon Ranges in the north. These beds are truncated by a discomformable surface which in places cuts down below them into the Bonney Sandstone. Fig. 22, an isopach map of the succeeding Ediacara Member presents a pattern of southeast to northwest thickness trends, coinciding with maximum erosion of the underlying sediments. The

FIGURE 24

Block diagram reconstruction of the palaeogeography during the onset of deposition of the Ediacara Member for the region from Port Augusta to Leigh Creek. The dune fields and alluvial environments to the west are hypothetical, but would account for the constant supply of mature quartz sand. The deepening across an arcuate tectonic hinge to the SE is postulated to account for the formation of the erosional unconformity and SE trending valleys over which the sediments of the Ediacar Member prograde. An outlying outcrop of Pound Subgroup at Waroonee Hill has facies characteristic of deeper water, reducing environments. "Islands" NE of Blinman represent nondepositional intervals at this time. Information about the NE sector is sparse, but the Ediacara Member appears to be absent east of Leigh Creek.

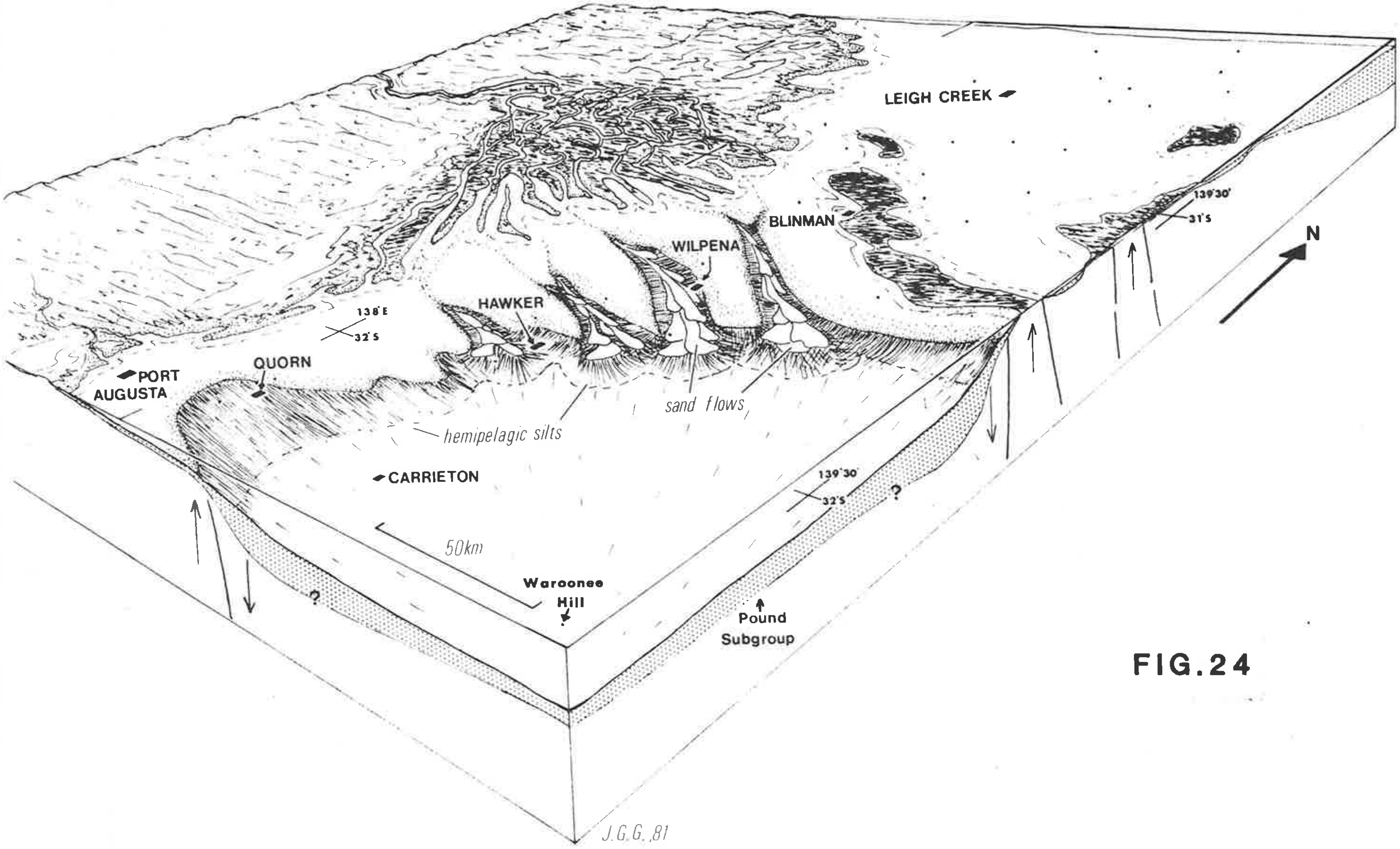

LEIGH CREEK
139°30'
31°S
N
BLINMAN
WILPENA
HAWKER
138°E
32°S
QUORN
PORT AUGUSTA
sand flows
hemipelagic silts
CARRIETON
139°30'
32°S
?
50km
Waroonee Hill
Pound Subgroup
?
J.G.G. ,81

FIG.24

isopach map contours the thickness of the Member, from the erosional base to the top of the last cycle of Facies N. As such it represents a palaeogeographic map of the surface over which the Ediacara Member was deposited. The "valleys" here outlined, subsequently form the depository for deeper water facies of the Ediacara Member. Wilpena Pound provides an oblique section through one of these valleys, which was some 12 km wide and at least 30 km long (Fig. 15). Transverse sections are exposed in the Chace (Fig. 20), Druid (Fig. 21), Elder (Fig. 19) and Heysen Ranges (Fig. 17), indicating a relief of as much as 250 metres on the disconformity. Valley walls have an approximate gradient of 1 in 8, which distinguishes them from submarine canyons. (Shepard, 1973, p.305).

Following a relative fall in base level of at least 300 metres caused by a postulated tectonic deepening to the south east, submarine erosion of the shelf, left valleys draining toward the south east into the distal part of the basin (Fig. 24). Almgren (1978) described "canyons" of similar dimensions, from the Tertiary of California. In successive cycles, canyon erosion and subsequent deep marine deposition shallowing up to transgressive sandstones, were explained by Almgren as a product of tectonic uplift followed by subsidence. As there is no hard evidence for exposure at the base of the Ediacara Member (in the form of bleaching or fossil soil profiles on the erosional surface), a relative fall in sea level has not been proposed as a viable alternative to the development of a tectonic deep.

A depositional reconstruction of the Ediacara Member in the Wilpena area is presented as a local model:

Stage I (Fig. 23)

Sands reworked from the dissected plain, and replenished from the hinterlands to the west, were entrained into the heads of submerged valleys. The relative maturity of these sands represented a homogenous source of mature quartz sand, from the shelf and forelands. Storm and tidal action on the shallow shelf mobilized these sands which spilled down the valley tributaries forming flows of fluidized sand which initially etched out braided channels on the valley floor. Hemipelagic siltstones, and semiconsolidated sandstones forming the valley floor, were ripped up and included as clasts of mud and sandstone in the channelized massive sands (Facies J). During calm periods on the shelf, deposition of silts and clay continued forming monotonous, thick sequences on the valley margins (Facies L). Where successive sand flows settled in the axes of valleys, channelization gave way to thick lobes of massive sands with rare dewatering structures being preserved (Facies K). Flows of sand coming to rest without reworking underlying siltstones were later involved in hydroplastic deformation, with resulting ball and pillow structures.

### Stage II (Fig. 23)

As the submarine landscape was progressively enveloped by these regressive sand and silts, shelf sands prograded further out over the slope, capping the submarine valley fill sequence with imbricate sheets of cross and flat bedded subtidal sands (Facies N). The well-sorted quartz arenites reflect a consistent supply of medium grained sand, perhaps from extensive foreland subaerial dunes.

### Stage III (Fig. 23)

A general sealevel rise, or accelerated subsidence resulting in a local relative rise in sea level, led to a transgression with distal, offshore silts blanketing the sequence, reflecting a base level below wave base. With stabilization of sea level, the subtidal shelf sands (Facies N) once again rapidly prograded out over the deeper water siltstones.

The leading edge of the shelf sandstones represents the zone of shoaling, where storm waves impinge on the substrate. Here, thin ripple bedded sands mantled with silt during calm periods, form the preservational environment for transported and insitu animals of the Ediacara assemblage (Facies M). This environment was represented wherever intermittent blanketing of the offshore silts with thin sands, was possible. This last subtidal shelf cycle is almost exactly 20 metres thick, indicating an effective wave base of 20 metres below low tide.

As the subtidal sands (Facies N) prograded out over the shelf in this final phase, they were succeeded by intertidal sand-flat deposits (Facies H and I). Shelf conditions persisted in the region for the remainder of the time represented by the Rawnsley Quartzite.

APPENDIX 1

## METHOD OF FIELD STUDY

Initially the two formations were studied closely at two localities : Parachilna Gorge and Mayo Gorge. From section logs, detailed to the nearest 10 cm, the variation in lithology, grain size and sedimentary structures was considered to enable a preliminary subdivision into lithofacies which could be logged to an accuracy of 50 cm and recognised in isolated outcrops. By trial and error 14 lithofacies were erected, 7 in each formation.

In all, 35 sections were measured at sites chosen for spacing and clarity of outcrop (labelled S17 etc). Several other sections were examined and measured for gross thickness of facies only (labelled D35 etc). It was not possible to measure to the top of the Rawnsley Quartzite using either a jacob staff or a tape, as most sections ran over ridges incorporating a significant dip slope. Only in sections measured where a gorge cut through the ranges, could a complete sequence be quantified. Accuracy of the jacob staff measurements was checked by field location of upper and lower stratigraphic boundaries of the Pound Subgroup on 1:50,000 topographic maps, and then by calculating the absolute thickness using measured dips of strata. In most cases field measurements were 5% less than thicknesses calculated using maps. As no case could be made for other than relative accuracy between sections, a correction factor was not applied. Re-measurement of a given section using a jacob staff showed an error of about 2%. Tape measurements were found to be impractical in all but flat creek beds.

In the process of measurement, samples were collected and palaeocurrent measurements made together with dip and strike, for later stereo restoration. Palaeocurrent measurements were only taken where un-ambiguous directional sedimentary structures were encountered. No more than one measurement was taken from each bed and no more than 5 from each coset. The lack of time available for each section prevented a more extensive pattern of measurements along strike in a particular facies. Cross stratification was measured by obtaining the dip and strike of bedding planes within the outcrop, and then measuring the dip and dipdirection of foresets where these could be traced in the third dimension. After stereo restoration, any foresets with angle of repose of $35^{o}$ or more, were rejected as indicative of measurement error.

Where a facies was encountered which, from experience, was found to be fossil bearing, a brief search of outcrop was made up to 30 metres each side of the line of section. Any specimens discovered were photographed or at least recorded (species and size). In cases where specimens were rare or new an attempt was made at collecting the material, except where this was impossible due to the nature of the strata or where the section lay within a National Park. In such cases, "silastic" moulds were made for later study, and the specimens remain in the field.

Where two or more adjacent sections had been measured in total or part, attempts were made to trace out important horizons or lithologic boundaries. In certain exposures, the almost vertical cliff faces and dense undergrowth made lateral movement impossible. So that facies relationships might be detailed between sections in rugged terrain (e.g. Wilpena Pound, Elder Range) a light aircraft was hired for the purpose of photographing the outcrop. These oblique aerial photos were taken from the open door of the aircraft flying at a constant distance from the ridge face and at the same height as a stratigraphic datum at the top of the Ediacara Member. The resultant transparencies were projected onto a frosted glass screen, from which details were traced on a continuous chart. The dominant features were condensed and used to draw cross-sections between vertical measured sections on continuous outcrop (Fig. 14-22). The Ediacara Member formed the subject of the majority of this detailed cross sectional analysis. Black and white, normal, 1:80,000 aerial photos, produced by the South Australian Department of Lands were used for cross-sections where outcrop dip was vertical. They were also used to accurately position sections in the field.

## APPENDIX 2

## COORDINATES OF MEASURED SECTIONS

Sections measured in detail or part, which have been used in Figures 15-21, are represented on Figure 22. The map coordinates of the sections are listed below:

| Section Number | Title | Coordinates | |
|---|---|---|---|
| | | Latitude | Longitude |
| S1 | Mayo Gorge | 31°44.3'S | 138°24.4'E |
| S2 | Mt Mantell North | 31°19.2'S | 138°57.7'E |
| S3 | Sth Elder Range | 31°44.0'S | 138°25.3'E |
| S4 | Mt Aleck | 31°39.5'S | 138°28.3'E |
| S5 | Nth Mt Aleck | 31°37.1'S | 138°27.0'E |
| S6 | Moralana | 31°33.8'S | 138°26.9'E |
| S7 | Beatrice Hill | 31°31.2'S | 138°30.0'E |
| S8 | Dick Nob | 31°35.1'S | 138°32.2'E |
| S9 | Chace Range | 31°40.5'S | 138°40.7'E |
| S10 | Chace Range | 31°40.5'S | 138°41.6'E |
| S11 | Chace Range | 31°41.6'S | 138°38.5'E |
| S12 | SW Chace Range | 31°45.3'S | 138°33.6'E |
| S13 | Nth Rawnsley Bluff | 31°37.0'S | 138°38.1'E |
| S14 | Mt Havelock | 31°39.7'S | 138°44.5'E |
| S15 | Chace Range | 31°40.0'S | 138°42.3'E |
| S16 | Tumburru Peak | 31°34.5'S | 138°38.1'E |
| S17 | Mt Boorong | 31°30.8'S | 138°34.5'E |
| S18 | Bunyeroo Gorge | 31°25.0'S | 138°32.6'E |
| S19 | Druid Range | 31°43.2'S | 138°43.7'E |
| S20 | Brachina Gorge | 31°20.6'S | 138°34.1'E |
| S21 | Mt Abrupt | 31°28.0'S | 138°31.8'E |
| S22 | Heysen Range | 31°22.7'S | 138°33.8'E |
| S23 | Nth Mt Hayward | 31°17.2'S | 138°33.5'E |

| Section Number | Title | Coordinates | |
|---|---|---|---|
| | | Latitude | Longitude |
| S24 | Parachilna Gorge | 31°07.4'S | 138°30.6'E |
| S25 | Ereganda | 31°06.0'S | 138°50.5'E |
| S26 | Nildottie Spring | 31°02.9'S | 138°47.3'E |
| S27 | Wirrealpa Hill | 31°03.8'S | 138°54.7'E |
| S28 | Nth Parachilna (Type Section) | 31°06.9'S | 138°30.6'E |
| S29 | Reaphook Hill | 31°22.9'S | 139°16.5'E |
| S30 | Lincoln Gap | 32°34.0'S | 137°37.2'E |
| S31 | East Chace Range | 31°40.1'S | 138°46.1'E |
| S32 | East Druid Range | 31°41.7'S | 138°47.1'E |
| S33 | Chace Range | 31°43.3'S | 138°36.0'E |
| S34 | Wilkawillina Gorge | 31°16.1'S | 138°52.7'E |
| D4 | Sth Elder Range | 31°43.6'S | 138°22.6'E |
| D23 | Nth Elder Range | 31°35.4'S | 138°26.9'E |
| D25 | Elder Range | 31°37.7'S | 138°27.3'E |
| D36 | Chace Range | 31°42.2'S | 138°38.1'E |
| D41 | Druid Range | 31°45.3'S | 138°38.4'E |
| D69 | Sth Haywood Bluff | 31°19.6'S | 138°33.9'E |
| D77 | Wonoka Hill | 31°49.2'S | 138°24.8'E |
| D80 | Hell's Gate | 31°37.1'S | 138°22.o'E |
| D44 | Rawnsley Bluff | 31°37.5'S | 138°37'E |
| D54 | Mt Rupert | 31°24.2'S | 138°33.3'E |

## APPENDIX 3

## THIN SECTION DESCRIPTIONS

Introduction: Representative samples were collected in conjunction with the measurement of sections in the field. These handspecimens were labelled according to the section number and stratigraphic distance from the base. (e.g. S3/396). Selected specimens were prepared for thinsection description.

The following descriptions represent a selection designed to be representative of the described facies within the Pound Subgroup. The descriptive terminology follows Pettijohn et al (1972, pg. 158). Generally the aim of thinsection examination was to estimate the relative proportions of quartz, feldspar, lithic fragments and matrix. The composition of feldspars and accessory minerals was noted where possible. Using the method suggested by Pettijohn et al (op cit) an estimate of sandstone maturity was based on clay content, sorting and roundness. Sorting was quantified using the figures of Folk (1968) in Pettijohn et al (pg. 585).

S20/53 Brachina Gorge Facies B

Hand Specimen:

Purple, brown sandstone with prominent bands of red and white granules and small pebbles. A poorly sorted rock which is predominantly fine grained. Small bleached patches are calcareous.

Thin Section:

A fine grained subarkose with granule trains. Quartz and feldspar grains are generally stained by haematite rich clay which fills some grain spaces. Rare patches of fine grained calcite appear to have a secondary origin. No quartz overgrowths.

| | | | |
|---|---|---|---|
| grain size: | granule laminae: | | 1-2.5 mm |
| | remainder of fabric: | | bimodal (a) 0.06 mm |
| | | | (b) 0.3 mm |
| sorting: | moderate to poor, for total sample | | |
| roundness: | subangular to rounded | | |
| composition: | quartz (50% undulose) | | 70% |
| | polycrystaline quartz | | 5 |
| | feldspar | microcline | 5 |
| | | plagioclase | 3 |
| | | untwinned | 7 |
| | matrix: | iron rich clay | 8 |
| | | calcite | 2 |

Diagnosis: Granule bearing, fine grained subarkose.

## S24/180 Bunyeroo Gorge Facies D

Hand Specimen:

Red brown poorly laminated, to massive clayey sandstone. The sample represents a more sandy layer in an otherwise friable clayey sandstone. It has a mottled appearance and is partly calcareous.

Thin Section:

An irregularly laminated fabric with dark red clayey flakes. While the fabric is grain supported the matrix is notable in that alternate laminae have sericite with haematite rich clay and patchy calcite cement. Much of the calcite appears to replace sandsize grains.

grain size: 0.1 - 0.5 mm
sorting: poor to very poor
roundness: angular to subangular
composition: sandsize grains
  quartz 65%
  feldspar 10%
  ferromagnesium 2%
matrix
  iron rich clay 12%
  calcite 8%
  muscovite 3%

Diagnosis: reddish coloured, immature, calcareous, finegrained feldspathic quartz arenite.

## S3/396 South Elder Range Facies E

### Handspecimen

A granule rich fine grained conglomerate with a sandy matrix. Quartz is the most common composition of granules.

### Thin Section

A course grained fabric composed of quartz and feldspar granules in a sandy matrix. Sericitized and almost completely altered feldspars are iron stained. Many cavities appear to represent the plucking of clay replacing feldspar.

grain size: 0.1 - 2.5 mm
sorting: moderate
rounding: rounded
composition: quartz 80%
(including clear and strained quartz,
quartzite and siltstone granules)
feldspar 15%
(microcline and plagioclase)
accessories 5%
(tourmaline, mica)

Diagnosis: feldspathic, fine grained quartz conglomerate.

**S25/34** **Eregunda Creek** **Facies E**

Hand Specimen

A red coarse grained sandstone with a high lithic component. Shale clasts are irregularly distributed, but the fabric has a high porosity.

Thin Section

The fabric is dominated coarse sand sized grains with an almost opaque haematite rich clay matrix.

Two mm. thick by 10 mm. wide red clayey siltstone clasts lie roughly parallel to bedding. Despite considerable quartz over-growths, clayey outlines show that the original grains were quite angular. The grain supported fabric is bimodal with medium to very coarse grained sand and fine grained sand and silt derived from the broken up siltstone clasts. Feldspars are highly altered, and both quartz and feldspar commonly bear inclusions. Lithic fragments include siltstone and chert.

grain size: siltstone clasts 0.05 - 0.1 mm
sand 0.4 - 1.3 mm
sorting: poor
rounding: angular to subrounded
compositic: quartz (grains) 50%
lithic fragments 20%
feldspar 15%
(mainly K-feldspar)
accessories 2%
(pyroxene)
haematite clay matrix 8%
porosity 5%

Diagnosis: coarse grained sublithic arenite

### S26/217 Nildottie Springs Facies F

Hand Specimen

A red brown, medium grained sandstone with clayey and micaceous flecks indicating altered feldspars.

Thin Section

A well sorted fabric with minor haematite rich clay coating on grains and in grain spaces. Feldspars are strongly altered to sericite. Seritic linings of cavities, of the same order of size, suggest plucking of these altered feldspars. Quartz overgrowths are common.

grain size: 0.2 - 0.6 mm
sorting: well to very well sorted
rounding: subrounded to wellrounded
composition: quartz 70%
(with strong overgrowths)
chert (kaolinized) 3%
feldspar 20%
(sericite alteration of oligoclase, microcline)
matrix 5%
(haematite clay)
accessories 2%
(muscovite and tourmaline)

Diagnosis: medium grained, subarkosic arenite.

## S23/120 Heysen Range - Aroona Facies F

### Hand Specimen

A medium grained red sandstone. The fabric has a mottled appearance due to 2 mm sized light patches and sandsized white flecks of clay.

### Thin Section

The fabric is even grained with strong quartz overgrowths. Original grain outlines are marked by haematite clay. Feldspars comprise unweathered plagioclase and microcline, and strongly altered orthoclase. Lithic grains include siltstone and chert. Coarse grained muscovite flakes are not uncommon.

grain size: 0.1 - 0.3 mm
sorting: well sorted
rounding: subangular to rounded
composition: quartz 65%
feldspar 20%
(microcline, plagioclase and orthoclase)
lithic grains 8%
accessories 1%
(haematite, muscovite, zircon)
matrix 3%
(iron rich clay)
pore space 3%

Diagnosis: fine to medium grained subarkosic arenite.

S1/13 Mayo Gorge Facies G

Hand Specimen

Red, fine grained, low angle climbing ripple laminated sandstone. Laminations are alternately dark red and light coloured, Clay flasers occur infrequently. Microcrosslamination is apparent in small lenses.

Thin Section

A fine grained clayey sandstone with laminations alternately fine sand, relatively free of clay and very fine sand rich in haematite clay and mica flakes.

Quartz overgrowths are common in the clean, coarser grained laminae. Unusually thin elongate grains of quartz may be replacements of muscovite.

| | | |
|---|---|---|
| grain size: | 0.05 - 0.2 mm | |
| sorting: | not applicable - immature | |
| rounding: | angular | |
| composition: | quartz | 55% |
| | feldspar | 15% |
| | (unweathered plagioclase, sericite altered orthoclase) | |
| | matrix | 20% |
| | (haematite rich clay and sericite) | |
| | detrital muscovite | 8% |
| | accessories | 2% |

Diagnosis: fine grained micaceous, laminated arkosic wacke.

## D39/3 Southwest Chace Range Facies G

Hand Specimen:

Reddish fine grained, micaceous sandstone. Wavy fine laminations are weakly distinguished by clayey partings.

Thin Section

A relatively even grained fabric with a sericitic matrix and haematite rich clay coating of grains. Muscovite plates, elongate quartz and feldspar grains lie parallel to laminations, with a common tendency to tilt in a direction taken to be the original up current orientation.

| | | |
|---|---|---|
| grain size: | 0.05 - 0.15 mm | |
| sorting: | moderate | |
| rounding: | angular to subangular | |
| composition: | quartz | 65% |
| | chert | 10% |
| | feldspar | 10% |
| | (mainly altered, minor plagioclase) | |
| | matrix | 8% |
| | (Fe clay and sericite) | |
| | detrital muscovite | 6% |
| | opaques | 1% |

Diagnosis: fine grained, micaceous feldspathic arenite.

S21/66 Mt Abrupt Facies G

Hand Specimen

Purple, reddish heavy mineral crosslaminated sandstone. An even grained fabric distinguished by dark flat and cross lamination.

Thin Section

A relatively clean, fine grained fabric. Sandgrains are outlined in red clay, but sericite is the most common matrix component. Cross laminations are represented by single lamina trains of opaques (haematite) with a higher matrix concentration of iron rich clay. Accessories such as tourmaline and zircon are prominent in H.M. laminations. Detrital muscovite occurs throughout the section.

grain size: 0.06 - 0.15 (median 0.1 mm)
sorting: moderate
rounding: subangular
composition: quartz 60%
feldspar 12%
(microcline, plagioclase and altered orthoclase)
matrix 7%
(mainly Fe stained kaolinite)
chert 6%
muscovite (0.2mm) 5%
accessories 5%
(tourmaline, zircon)
opaques (haematite) 5%

Diagnosis: fine grained, heavy mineral laminated feldspathic arenite.

## S20/388 Brachina Gorge Facies H

### Hand Specimen

A pink-brown coloured sandstone comprising rough bands of very coarse sand in an otherwise medium grained fabric. Laminae are poorly defined, with coarse grains appearing to float in a sand matrix. Feldspars are represented by sand size clay filled cavities.

### Thin Section

A clean fabric with a strongly bimodal texture. Well rounded coarse sand grains in a fine to medium sand "matrix" gives way to a single modal texture of medium to coarse sand. Most grains are rounded to well rounded with a faint coating of red clay, giving the hand specimen a colour which is hardly apparent in thin section. Quartz overgrowths are best developed in unimodal band.

grain size: (bimodal band) (a) 0.05 - 0.30 mm
(b) 0.8 - 2.00 mm
(unimodal band) 0.2 - 1.2 mm
sorting: trimodal 0.1, 0.5, 1.3 mm
rounding: (coarser fractions) rounded to well rounded
composition: quartz 70%
(including 10% overgrowths)
feldspar 15%
(microcline and altered orthoclase)
lithic fragments 8%
(chert and meta-siltstones)
matrix 5%
(stained kaolinite)
accessories 2%
(tourmaline, haematite, muscovite)

Diagnosis: fine to very coarse grained subarkose.

S1/130 Mayo Gorge Facies H

## Hand Specimen

Red to maroon coloured sandstone with irregular banded bleaching. The fabric is fine to medium grained with rare coarse grains, and is poorly indurated due to the lack of quartz overgrowths and the alteration of feldspars.

## Thin Section

A red clay stained matrix of sericite is present except in the bleached bands. As the majority of grains are somewhat angular the texture is immature. Rare rounded coarse grains of quartz suggest a separate source. Cavities appear to represent plucking of altered feldspars. Diffuse banding of grainsizes is apparent.

grainsize: 0.05 - 0.7 mm
(modes at 0.1 and 0.5 mm)
sorting: partly moderate
partly poor
rounding: subangular to rounded (coarser mode)
composition: quartz 70%
(ind. 5% polycrystaline)
feldspar 13%
(plagioclase, microcline and sericitized orthoclase)
lithic fragments 5%
(mainly chert and siltstone)
matrix 10%
(Fe clay and sericite)
accessories 2%
(opaques, tourmaline, muscovite)

Diagnosis: immature, fine to coarse grained subarkose.

S1/138 Mayo Gorge Facies H

Hand Specimen

White to cream, feldspathic, medium to coarse grained sandstone. Bedding lamination is absent. Feldspars are apparently altered to clay.

Thin Section

A salt and pepper texture derived from a significant proportion of altered feldspars and lithic fragments. The fairly even grained fabric is cemented by secondary quartz and grains are outlined in kaolinite. Pore space relates to the loss or partial loss of altered feldspar.

grain size: 0.1 - 1.0 mm
sorting: moderate
rounding: rounded to well rounded
composition: quartz 77%
lithic fragments 4%
(siltstone, chert)
feldspar 10%
(altered K feldspar?, plagioclase)
accessories trace
(iron oxides)
pore space 6%
cement 3%
(quartz, kaolinite, sericite)

Diagnosis: medium grained subarkose.

S2/270 Mt Mantell Facies I

## Hand Specimen

Grey to white banded, medium to coarse grained feldspathic quartz arenite. The porous texture appears to be due to the loss of clay derived from feldspars. Alternating thin beds of coarser and finer sand form disruptive "teepee" structures.

## Thin Section

Laminations vary from 2 mm to 6 mm thick, with diffuse boundaries. Porosity is high throughout the fabric. The shape of cavities and sericitic outlines indicate that many correspond to the loss of altered feldspar. Certain laminae of coarser sand grains are well cemented by secondary quartz overgrowths. A yellowish staining of patches of quartz cement may represent leaching of iron oxides from the matrix. Overgrowths are not in optical continuity.

While discrete laminations are fairly well sorted, less defined layers are bimodal. Overall the fabric is bimodal with particular modes concentrated in alternating laminae.

grainsize: (mode 1) 0.08 - 0.1 mm
(mode 2) 0.3 - 0.6 mm (0.4 median)
sorting: well sorted (fine or coarse) in certain laminae
poorly sorted overall
rounding: coarser mode subrounded to rounded finer mode angular to subangular
composition:

| | |
|---|---|
| quartz | 75% |
| lithic fragments<br>(chert, siltstone, meta-quartz) | 5% |
| feldspar<br>(may be artificially low) | 5% |
| porosity | 14% |
| accessories<br>(zircon, tourmaline) | 1% |

Diagnosis: very fine to medium grained quartz arenite

## S5/530 North Elder Range Facies I

### Hand Specimen

Brown to white coarse grained sandstone with sand pseudomorphs after barite or gypsum. The fabric appears to be porous due to weathering out of clay altered feldspars.

### Thin Section

A clean fabric in which the well rounded grains are outlined in yellowish sericite cement. Well indurated patches, where quartz over-growths dominate, correspond to the crystal pseudomorphs. The only traces of feldspar are highly sericitized. Lithic grains are more common than feldspar.

grainsize: 0.2 - 0.8 mm (median 0.4)
sorting: well sorted
rounding: rounded to well rounded
composition:
- quartz 75%
- lithic fragments 5% (chert, meta siltstones)
- feldspar 1%
- accessories 1% (haematite, zircon)
- matrix (cement) 5% (silica overgrowths, sericite, yellowish kaolinite)
- porosity 13%

Diagnosis: mature, medium to coarse grained quartz arenite.

S6/350 Moralana Facies I

Hand Specimen

A coarse grained, grey, sugary textured sandstone. The fabric is characterized by rounded grains and a porous texture with traces of white clay.

Thin Section

An extremely clean fabric with only traces of sericite lining in pore spaces. Although grains are all surrounded by quartz overgrowths, boundaries between overgrowths are distinct (etched), which accounts for the sugary texture in the hand specimen. Porosity is low except in certain patches.

| | |
|---|---|
| grain size: | 0.3 - 1.2 mm (median 0.8) |
| sorting: | well sorted |
| rounding: | rounded to well rounded |
| composition: | quartz (incl. cement) 85% |
| | lithic fragments 5%<br>(chert, siltstone, tuff?) |
| | accessories trace<br>(tourmaline, pyroxene) |
| | porosity 9% |
| | feldspar (altered) 1% |

Diagnosis: mature, coarse grained quartz arenite.

## S1/192 Mayo Gorge Facies I

### Hand Specimen

Reddish, feldspathic (?) sandstone with light coloured laminae and secondary bleaching in patches. Certain layers are coarse grained with weathering out, altered feldspars.

### Thin Section

A clean fabric, with little trace of colouring in the cement. The section shows diffuse laminations representing two grainsize modes. Coarser grains are relatively well rounded and surrounded by quartz overgrowths which are not generally in optical continuity. Feldspar grains are generally altered to kaolinite and patchily replaced by calcite, which occurs irregularly as a cement.

| | | |
|---|---|---|
| grainsize: | (mode 1) | 0.3 - 1.3 mm (median 0.7) |
| | (mode 2) | 0.05 - 0.2 mm |
| sorting: | poor to moderate | |
| rounding: | rounded to well rounded | |
| composition: | quartz | 70% |
| | feldspar (altered) | 5% |
| | matrix<br>(kaolinite and stained calcite) | 8% |
| | porosity | 10% |
| | lithic fragments<br>(chert, siltstone, meta siltstone) | 7% |
| | accessories<br>(tourmaline) | trace |

Diagnosis: coarse to fine grained, calcareous, quartz arenite.

S13/592 Rawnsley North Basal Facies J

Hand Specimen

Yellow to red-brown mottled, coarse grained sandstone with poorly defined lithic fragments. The fabric is massive (without bedding lamination). Altered feldspars or lithic fragments contribute to a moderate porosity.

Thin Section

Grains are outlined by traces of iron stained clay, thus revealing a high degree of rounding. Lithic fragments comprise small rounded grains of chert and fine grained quartzite as well as 2 to 4 mm poorly defined clasts of fine sandstone. These larger fragments appear to have been incompletely lithified at the time of deposition. Feldspar is mainly orthoclase which has been patchily altered to an iron stained clay.

| | | |
|---|---|---|
| grainsize: | 0.1 - 1.0 mm (bimodal) | |
| sorting: | moderate (if fine sandstones are clasts) | |
| rounding: | rounded to well rounded | |
| composition: | quartz | 75% |
| | lithic fragments<br>(chert, meta-siltstone) | 5% |
| | intraformational fine grain sandstone clasts | 10% |
| | feldspar<br>(microcline and altered orthoclase?) | 7% |
| | porosity | 2% |
| | accessories<br>(tourmaline, iron oxides) | 1% |

Diagnosis; coarse grained feldspathic, quartz arenite.

S12/26 S.W. Chace Range Basal Facies J

Hand Specimen

Pale, red-brown sandstone composed of large angular clasts of red sandstone (greater than 2 cm) in a lighter coloured sand matrix. The sandstone is medium to coarse grained with weathering out feldspar grains.

Thin Section

(a) Red sandstone clasts : Well defined fine to medium sand, without quartz overgrowths in an iron rich clayey matrix. Feldspars are fairly well preserved although much of the orthoclase is partly sericitized. These clasts have poorly defined boundaries, suggesting only partial lithification before re-erosion.

| | | |
|---|---|---|
| grainsize: | 0.08 - 0.4 mm | |
| sorting: | poor | |
| rounding: | subangular to subrounded | |
| composition: | quartz | 80% |
| | feldspar | 12% |
| | matrix (clay) | 5% |
| | lithic fragments | 3% |

Diagnosis: fine to medium grained subarkose (Facies F ?).

(b) Remainder of specimen: Well indurated, coarser grained sandstone. Clay defined, rounded grain boundaries are clear through the secondary quartz overgrowths. Most feldspars are partly altered. The matrix is free of the haematite rich clay that permeates the clasts floating in this sand.

| | | |
|---|---|---|
| grainsize: | 0.1 - 0.9 mm | |
| sorting: | moderate | |
| rounding: | rounded to well rounded | |
| composition: | quartz | 80% |
| | feldspar | 8% |
| | lithic fragments | 4% |
| | matrix<br>(mainly secondary quartz) | 6% |
| | porosity | 2% |

Diagnosis: medium to coarse grained subarkose.

**S5/290** **North Mount Aleck** **Basal Facies J**

Hand Specimen.

Grey, coarse grained, feldspathic sandstone.

Thin Section

Well indurated sandstone with poorly defined grain boundaries and strong quartz overgrowths. Significant porosity due to loss of altered feldspars.

| | | | |
|---|---|---|---|
| grain size: | 0.1 - 0.8 mm (median 0.4) | | |
| sorting: | moderate | | |
| rounding: | rounded | | |
| composition: | quartz | 85% | |
| | feldspar | 2% | |
| | porosity | 7% | (weathered feldspar?) |
| | accessories | trace | (tourmaline) |
| | lithic fragments | 5% | (chert) |

Diagnosis: medium grained, feldspathic quartz arenite.

S11/578a Chace Range Facies J

## Hand Specimen

Grey, medium grained feldspathic sandstone. Feldspar is suggested by clay patches.

## Thin Section

Fabric characterized by somewhat eroded grain boundaries and a wide range of grain sizes. Pore spaces appear to relate to the loss of altered feldspars. Pale clay fills the gaps between grains, not overgrown by secondary quartz.

| | | |
|---|---|---|
| grain size: | 0.05 - 1.0 mm (median 0.5) | |
| sorting: | poor | |
| rounding: | rounded | |
| composition: | quartz | 85% |
| | lithic fragments<br>(chert, siltstone) | 3% |
| | feldspar | 2% |
| | matrix (kaolinite) | 3% |
| | accessories | trace |
| | pore space | 7% |

Diagnosis: fine to coarse grained quartz arenite.

S17/436 Mt Boorong Facies K

Hand Specimen

White, medium grained sandstone. Altered feldspar clay specks.

Thin Section

Bimodal grainsize fabric, almost free of iron stained clay. Quartz grain boundaries etched with limited secondary quartz overgrowths. Pale kaolinite traces grain outlines. The high porosity represents loss of altered feldspar, as indicated by fragments marginal to pore spaces.

grain size: 0.05 - 0.6 mm (mode 1:0.2; mode 2:0.4)

sorting: poor

rounding: subrounded to rounded

composition:

| | |
|---|---|
| quartz | 78% |
| feldspar | 10% |
| lithic fragments<br>(meta siltstone) | 3% |
| porosity | 7% |
| accessories<br>(tourmaline) | trace |
| matrix (clay) | 2% |

Diagnosis: fine to medium grained subarkose.

**S7/388** **Beatrice Hill** **Facies K**

Hand Specimen

Mottled, reddish to white medium grained sandstone with a speckled, altered feldspar texture.

Thin Section

A medium grained fabric with etched and overgrown quartz grain boundaries. Altered grains are either feldspar or volcanic fragments (?). Pore space relates to loss of altered feldspar. Small patches of iron stain clay are scattered throughout the fabric.

| | | |
|---|---|---|
| grainsize: | 0.05 - 0.6 mm (median 0.3) | |
| sorting: | moderate | |
| rounding: | rounded | |
| composition: | quartz | 75% |
| | feldspar (altered) | 7% |
| | lithic fragments | 3% |
| | porosity | 10% |
| | accessories (tourmaline) | trace |
| | matrix (iron stained kaolin) | 5% |

Diagnosis: medium grained subarkose.

S12/144 SW Chace Range Facies K

Hand Specimen

A grey, dense, fine grained sandstone.

Thin Section

A fine grained sandstone with strong secondary quartz overgrowths, obscuring grain boundaries. Feldspars almost entirely altered to a yellowish clay. Most of the pore space is related to loss of clay after feldspar.

grainsize: 0.05 - 0.3mm
sorting: well sorted
rounding: indeterminant
composition: quartz 75%
feldspar 20%
(plagioclase, microcline and altered feldspar)
porosity 5%

Diagnosis: fine grained arkosic arenite.

## S1/276 Mayo Gorge Facies L

### Hand Specimen

Khaki to buff coloured siltstone with diffuse lamination.

### Thin Section

Fine to very fine sandstone fabric with a clayey and sericitic matrix. Mica grains lie within 30° of bedding lamination. Certain laminae have rounded grains of 0.3 to 0.4 mm in diameter.

| | | |
|---|---|---|
| grain size: | 0.03 - 0.15 mm (median 0.1) | |
| sorting: | poor | |
| rounding: | angular to subangular | |
| composition: | quartz | 80% |
| | matrix | 14% |
| | (sericite, kaolinite, iron oxides) | |
| | feldspar | 5% |
| | accessories | 1% |
| | (tourmaline, zircon) | |

Diagnosis: clayey and silty fine grained quartz arenite.

S9/740 Chace Range Facies L

Hand Specimen

Khaki to buff, finely laminated siltstone.

Thin Section

A roughly laminated fabric with alternating very fine sand rich and clay rich layers 0.5 mm thick. Laminae have coarser bases and grade up to the clay rich laminae. Much of the clay has altered to sericite. A small but prominent amount of pleochroic green mineral with cleavage (pyroxene?) is present.

| | | |
|---|---|---|
| grain size: | 0.02 - 0.12 mm | |
| sorting: | poor | |
| rounding: | angular to subrounded | |
| composition: | quartz | 83% |
| | matrix | 12% |
| | accessories | 2% |
| | (iron oxides, tourmaline, pyroxene) | |
| | feldspar | 3% |

Diagrams: fine grained sandy quartz siltstone

S5/330 North Mt Aleck Facies L

Hand Specimen:

A red brown sandstone. A massive texture free of bedding lamination.

Thin Section

A bimodal fabric with medium grained, rounded sand supported in a clayey fine to very fine sand matrix. Texture: patches of the fine sand are free of the coarser grains and other patches of the coarser sand are grain supported. The fabric resembles the mixture of the two modes of sediment in a fluidized state. The coarser sand contains 10% feldspar.

grainsize: (mode 1) 0.03 - 0.12 mm
(mode 2) 0.3 - 0.6 mm
sorting: very poorly sorted
rounding: (mode 2) rounded to well rounded
composition: quartz (coarse and fine) 72%
feldspar 10%
(plagioclase, microcline and altered grains)
matrix 12%
(sericite, iron rich clay)
lithic fragments 5%
(chert, meta-siltstone)
accessories 1%
(tourmaline, pyroxene)

Diagnosis: sandy quartz wacke (clayey siltstone).

Note: Fabric is typical of a mixture of Facies L and Facies K.

S11/530 Chace Range Facies L

Hand Specimen

A red brown clayey siltstone, with very diffuse lamination.

Thin Section

An iron oxide rich clay matrix with sericite flakes freely dispersed. Sand grains vary from silt to fine sand with medium to coarse grains sparsely distributed in certain laminae. Laminations are only apparent at low magnification or by the distribution of the odd coarse sand grains.

| | |
|---|---|
| grain size: | 0.01 - 0.1 mm<br>(coarse grains: 0.3 - 0.6 mm) |
| sorting: | poor |
| rounding: | (coarse grains) subangular to well rounded |
| composition: | quartz 83%<br>matrix 15%<br>(iron rich clay, sericite)<br>feldspar (coarse grains) 2% |

Diagnosis: sand bearing clayey quartz siltstone

## S9/728 Chace Range Facies M

Hand Specimen

Thinly bedded, grey coloured, fine grained, feldspathic sandstone. A well indurated fabric with a relatively smooth base (preserving impressions of soft bodied animals).

Thin Section

A clean fabric with interlocking quartz grains. Grain outlines are not well preserved due to secondary quartz overgrowths. Reverse grading is apparent at the base of the bed. Few feldspars are preserved, their presence marked either by sericitic clay patches or clay linedpore spaces.

grainsize: 0.08 - 0.3 mm
sorting: well sorted
rounding: probably subangular to subrounded
composition:
quartz 80%
lithic fragments 5%
feldspar 3% (most grains altered)
porosity 8%
matrix 3%
(sericitic clay)
accessories 1%

Diagnosis: fine to medium grained quartz arenite.

S10/254 Chace Range Facies M

## Hand Specimen

Grey-white fine grained feldspathic sandstone.

A well indurated, non laminated fabric.

## Thin Section

A clean fabric, strongly overgrown by secondary quartz. Grain boundaries are difficult to distinguish due to lack of iron oxide stained clay. The traces of clayey matrix are sericitic. Feldspars are mainly altered to clay, and the large number of pore spaces in an otherwise overgrown fabric betray a significant proportion of feldspar, originally.

grain size: 0.03 - 0.2mm
(small fraction at 0.4)
sorting: moderate
rounding: probably subangular
composition:

| | |
|---|---|
| quartz | 76% |
| feldspar | 20% |
| (including plagioclase and ghost grains) | |
| matrix | 3% |
| (sericitic clay) | |
| accessories | 1% |
| (tourmaline) | |

Diagnosis: fine grained subarkose.

S13/744 Rawnsley North Facies N

Hand Specimen

Pale yellow coarse grained sandstone. Speckled appearance due to clay after feldspar.

Thin Section

A medium to coarse grained fabric, with grains outlined by traces of red stained clay. Feldspars are all partly altered.

| | | |
|---|---|---|
| grain size: | 0.1 - 1.0 mm | |
| | (mode 1 at 0.3; mode 2 at 0.8) | |
| sorting: | moderate | |
| rounding: | mode 1 | well rounded |
| | mode 2 | sub rounded |
| composition: | quartz | 80% |
| | feldspar | 12% |
| | (plagioclase, microcline, orthoclase) | |
| | lithic fragments | 4% |
| | (chert and siltstone) | |
| | matrix | 2% |
| | (iron rich clay) | |
| | porosity | 2% |

Diagnosis: fine to coarse grained subarkose.

S6/435 Moralana Facies N (lower)

Hand Specimen

White to yellow, coarse grained feldspathic sandstone.

Feldspar is now altered to clay.

Thin Section

A clean fabric with grain outlines etched out by a pale yellow clay which is isotropic. Feldspar is rare, but the altered grains remaining are similar in size to the pore spaces and clay filled cavities. Accessory minerals are noticable by their absence. Lithic fragments are more common.

grain size: 0.2 - 0.5 mm
sorting: sell sorted
rounding: rounded to well rounded
composition: quartz 85%
(including secondary quartz)
lithic fragments 4%
feldspar 1% (?)
pore space 5%
matrix 5%
(mainly yellow clay (?) in cavities)

Diagnosis: medium grained quartz arenite.

D39/4 S.W. Chace Range Facies N

Hand Specimen

White coarse grained feldspathic sandstone. The fabric is patchily well indurated.

Thin Section

A clean well indurated fabric with strong secondary quartz overgrowths. Traces of yellow clay mark well rounded grain outlines. Feldspars are conspicuously absent. Lithic fragments include chert and siltstone grains. Chert grains are altered in some cases.

| | | |
|---|---|---|
| grain size: | 0.3 - 0.8 mm (median 0.6) | |
| sorting: | well sorted | |
| rounding: | rounded to well rounded | |
| composition: | quartz | 88% |
| | lithic fragments | 5% |
| | pore space | 7% |
| | accessories | trace |

Diagnosis: medium to coarse grained quartz arenite.

## S24/325 Parachilna Gorge Facies N

### Hand Specimen

White feldspathic sandstone with yellow, iron stained mottles. Diffuse bedding parting is apparent. The fabric is fine to medium grained.

### Thin Section

A well indurated fine grained fabric with secondary quartz overgrowths. Irregular partings of iron oxide stained clay and sericite occur. Feldspars occur in various stages of alteration. Plagioclase grains are least altered.

grain size: 0.08 - 0.3 mm

sorting: well sorted

rounding: subangular to sub rounded

composition: quartz 75%

feldspar 15%

(plagioclase, orthoclase)

lithic fragments 5%

porosity 5%

accessories trace

(tourmaline)

Diagnosis: fine grained subarkose.

## APPENDIX 4

## ANALYSIS OF FACIES SEQUENCE - BONNEY SANDSTONE

Using a simplified transition matrix analysis suggested by Selley (1970) and Harms et.al. (1975) analysis of facies sequence was made from five sections through the Bonney Sandstone.

A tally matrix was compiled from observed facies transitions. Letters represent described facies units (Facies A to G) with obviously erosional bases being represented by U. In some sections the contacts between facies were not as clearly exposed as others, resulting in fewer "erosional base" transitions than may actually have been present. Numbers outside the box are row and column totals. The total number of observed transitions occurs in the lower right hand corner of the upper matrix.

A "difference matrix" was then constructed by finding the difference between the observed number of transitions and the predicted number for a random sequence.

Section 1 - Mayo Gorge

| | U | A | B | C | D | E | F | G | |
|---|---|---|---|---|---|---|---|---|---|
| U | | | | | | 2 | 13 | | 15 |
| A | | | 1 | | | | | 1 | 2 |
| B | 2 | 1 | | 1 | | | | 4 | 8 |
| C | 3 | | 1 | | | | | | 4 |
| D | | | | | | | | 2 | 2 |
| E | 1 | | | | 1 | | | | 2 |
| F | | | 2 | 2 | | | | 10 | 14 |
| G | 9 | | 4 | 1 | 1 | | 1 | | 16 |
| | 15 | 1 | 8 | 4 | 2 | 2 | 14 | 17 | 63 |

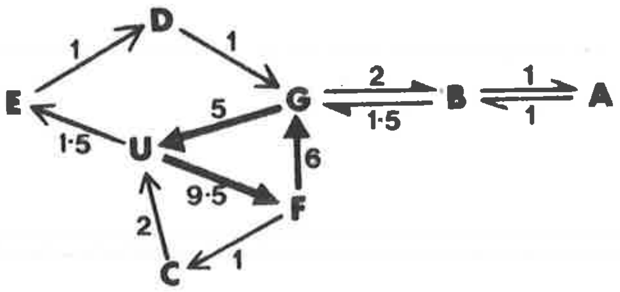
Tally matrix of facies transitions

(Note: U represents a sharp, erosional base.)

TOTAL

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| U | | | | | | 1.52 | 9.67 | |
| A | | | 0.75 | | | | | 0.46 |
| B | 0.09 | 0.87 | | 0.49 | | | | 1.84 |
| C | 2.05 | | 0.49 | | | | | |
| D | | | | | | | | 0.92 |
| E | 0.52 | | | | 0.94 | | | |
| F | | | 0.22 | 1.11 | | | | 6.22 |
| G | 5.2 | | 1.97 | -2.05 | 0.49 | | -2.56 | |

Matrix showing observed - minus - predicted number of facies transitions



## Section 3 - Elder Range

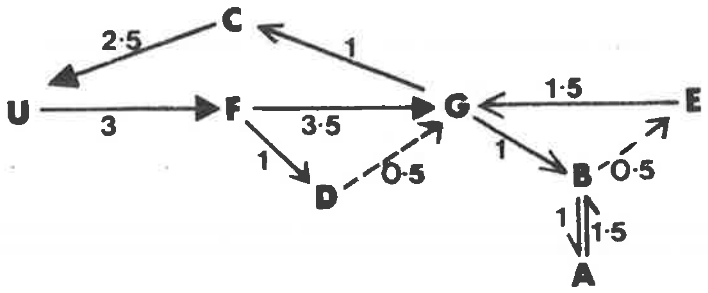
|  | U | A | B | C | D | E | F | G |  |
|---|---|---|---|---|---|---|---|---|---|
| U |  |  |  |  |  |  | 4 |  | 4 |
| A |  |  | 2 |  |  |  |  |  | 2 |
| B | 1 | 1 |  |  |  | 1 | 1 | 2 | 6 |
| C | 3 |  |  |  |  |  |  |  | 3 |
| D |  |  |  |  |  |  |  | 1 | 1 |
| E |  |  |  |  |  |  |  | 2 | 2 |
| F |  |  | 1 | 1 | 1 |  |  | 6 | 9 |
| G |  |  | 3 | 2 |  | 1 | 5 |  | 11 |
| TOTAL | 4 | 1 | 6 | 3 | 1 | 2 | 10 | 11 | 38 |

Tally matrix of facies transitions

(Note: U represents a sharp, erosional base.)

|  | U | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|---|
| U |  |  |  |  |  |  | 2.93 |  |
| A |  |  | 1.68 |  |  |  |  |  |
| B | 0.37 | 0.84 |  |  |  | 0.68 | -0.58 | 0.26 |
| C | 2.68 |  |  |  |  |  |  |  |
| D |  |  |  |  |  |  |  | 0.71 |
| E |  |  |  |  |  |  |  | 1.42 |
| F |  |  | -0.42 | 0.29 | 0.76 |  |  | 3.4 |
| G |  |  | 1.26 | 1.14 |  | 0.42 | 2.11 |  |

Matrix showing observed - minus - predicted number of facies transitions



Section II Chace Range

| | U | A | B | C | D | E | F | G | |
|---|---|---|---|---|---|---|---|---|---|
| U | | | | | | | 6 | | 6 |
| A | | | 1 | 1 | | | | | 2 |
| B | 3 | 1 | | | | 1 | 4 | 1 | 10 |
| C | | | 1 | | | | | | 1 |
| D | | | | | | 1 | | | 1 |
| E | 2 | | | | | | | | 2 |
| F | 1 | | 5 | | | | | 5 | 11 |
| G | 1 | | 3 | | 1 | | 1 | | 6 |
| | 7 | 1 | 10 | 1 | 1 | 2 | 11 | 6 | 39 |

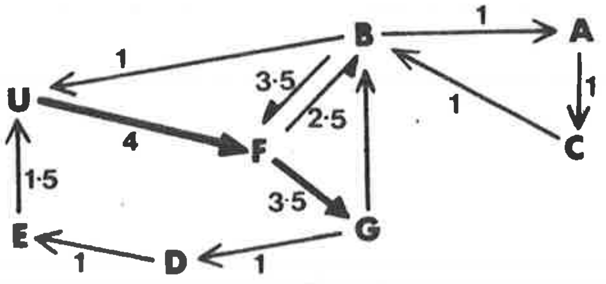
Tally matrix of facies transitions

(Note: U represents a sharp, erosional base.)

TOTAL

| | U | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|---|
| U | | | | | | | 4.12 | |
| A | | | 0.51 | 0.95 | | | | |
| B | 1.05 | 0.76 | | | | 0.51 | 3.46 | -0.46 |
| C | | | 0.76 | | | | | |
| D | | | | | | 0.95 | | |
| E | 1.61 | | | | | | | |
| F | -1.15 | | 2.32 | | | | | 3.4 |
| G | -0.17 | | 1.54 | | 0.85 | | -0.61 | |

Matrix showing observed - minus - predicted number of facies transitions



Section 20 Brachina Gorge

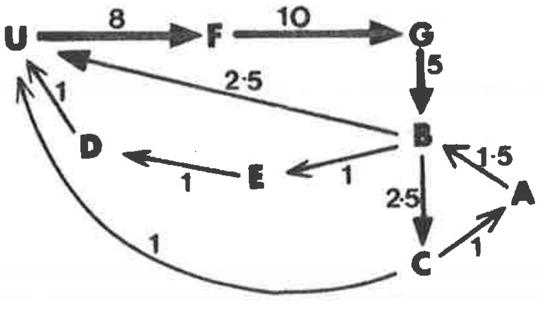
Tally matrix of facies transitions

(Note: U represents a sharp, erosional base.)

| | U | A | B | C | D | E | F | G | |
|---|---|---|---|---|---|---|---|---|---|
| U | | | | | | 1 | 12 | 3 | 16 |
| A | | | 2 | | | | | | 2 |
| B | 5 | | | 3 | | 1 | | 1 | 10 |
| C | 2 | 1 | | | | | | 1 | 4 |
| D | 1 | | | | | | | | 1 |
| E | 1 | | | | 1 | | | | 2 |
| F | 2 | | | | | | | 15 | 17 |
| G | 6 | | 8 | 1 | | | 5 | | 20 |
| TOTAL | 17 | 1 | 10 | 4 | 1 | 2 | 17 | 20 | 72 |

Matrix showing observed - minus - predicted number of facies transitions

| | U | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|---|
| U | | | | | | 0.56 | 8.2 | -1.44 |
| A | | | 1.72 | | | | | |
| B | 2.64 | | | 2.44 | | 0.72 | | -1.78 |
| C | 1.06 | 0.95 | | | | | | -0.11 |
| D | 0.76 | | | | | | | |
| E | 0.53 | | | | 0.97 | | | |
| F | -2.01 | | | | | | | 10.28 |
| G | 1.28 | | 5.22 | -0.11 | | | 0.23 | |



## Section 24 Parachilna Gorge

| | U | A | B | C | D | E | F | G | |
|---|---|---|---|---|---|---|---|---|---|
| U | | | 1 | | | 3 | 4 | | 8 |
| A | | | 2 | 1 | | | | | 3 |
| B | 1 | 2 | | 2 | 1 | | | | 6 |
| C | 2 | | 3 | | | | | 2 | 7 |
| D | 3 | | | | | 1 | | 1 | 5 |
| E | | | | | 3 | | | 1 | 4 |
| F | | | | | | | | 8 | 8 |
| G | 2 | | | 4 | 1 | 1 | 4 | | 12 |
| | 8 | 2 | 6 | 7 | 5 | 5 | 8 | 12 | 53 |

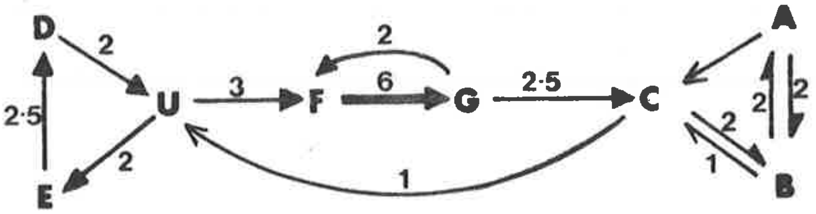
Tally matrix of facies transitions

(Note: U represents a sharp, erosional base.)

TOTAL

| | U | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|---|
| U | | | 0.10 | | 2.25 | 2.8 | | |
| A | | | 1.66 | 0.60 | | | | |
| B | 0.10 | 1.77 | | 1.21 | 0.40 | | | |
| C | 0.94 | | 2.21 | | | | | 0.42 |
| D | 2.25 | | | | | 0.51 | | -0.13 |
| E | | | | | 2.62 | | | 0.10 |
| F | | | | | | | | 6.2 |
| G | 0.19 | | | 2.42 | -0.13 | -0.13 | 2.19 | |

Matrix showing observed - minus - predicted number of facies transitions



APPENDIX 5

## BASE OF THE RAWNSLEY QUARTZITE

The inclusion of the lower sequences of Facies H and I in the Rawnsley Quartzite is based on a number of stratigraphic and historical points:

1) The lower beds are genetically related to those above the Ediacara Member (NE of Blinman they form an apparently continuous sequence, separated only by a thin clayey parting or red stained thin sandstone, which is easily overlooked).

2) The lower beds of Facies H and I are separated from the underlying Bonney Sandstone by a disconformity, characterized by a sharp change from red clayey sandstones (Facies D or B) to predominantly clean, pink coloured feldspathic sandstones, the basal beds of which are granule filled.

3) Mawson's (1941) original distinction between the informal lower and upper members includes these lighter coloured sandstones in the upper division.

4) Wade (1970) placed the member boundary half way up the lower sequence on the basis of a change in colour from pink to white, rather than using sedimentary characteristics of a more reliable nature.

5) Forbes (1971) formally named the members of the "Pound Quartzite" referring them to a subsiduary section at Bunyeroo Gorge. He followed Wade's placement of the boundary, although it is evident from the descriptions in his appendix that Units 15 at Bunyeroo and 5 at Parachilna are separable from the succeeding units by colour only.

6) Jenkins (1975) referred to these beds as the lowest of the Rawnsley Member, with no mention of colour. In his later review (1981) Jenkins referred to Forbes' boundary as erosive, but proceeded to describe an unfigured section from south of Parachilna Gorge where the erosive base, which he considers to be that of the Rawnsley Quartzite, cuts down into the underlying beds of Facies H and I which Forbes (1971) included in the Rawnsley Quartzite.

7) Moving the base of the Rawnsley Quartzite up to the base of the Ediacara Member would alter the original intent of the subdivision (Mawson 1941, Wade 1970). Moreover it would not be possible to readily recognise the boundary in sections where the Member is absent. On the other hand, placing the boundary at a disconformity below the lowest beds of Facies H and I, is more in keeping with the original descriptions (Mawson, op cit).

8) The Stratigraphic Code (Article 6) states that a formation is:

> "a genetic unit formed under essentially uniform conditions or under alternation of conditions".

The Rawnsley Quartzite as described in this study will inevitably require subdivision into three units: one embracing the lower sequence of Facies H and I; another constituting the Ediacara Member and one for the upper sequence of Facies H and I. These would fill the requirement of genetic integrity and have boundaries determined by unconformities or marked lithological change.

## APPENDIX 6

## STRATIGRAPHIC DISTRIBUTION OF FOSSILS OF THE EDIACARA ASSEMBLAGE

Identifiable species of the Ediacara assemblage were recorded when found on or close to measured stratigraphic sections.

Using the base of the capping unit (Facies N) of the Ediacara Member as a datum (see Fig. 13 and Fig. 4, Section 20, 470 m. level), the number of occurrences of each species in 10 metre intervals below this datum has been tabulated.

No attempt was made to record the occurrence of trails and poorly preserved impressions that might have been referable to the assemblage.

| Species | Metres below Datum | | | | | | | | | | | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | |
| Dickinsonia costata | 6 | 3 | 1 | 1 | 1 | 2 | | | | | | 14 |
| D. brachina | 1 | | | | | 1 | | | | | | 2 |
| D. elongata | 2 | | | | | | | | | | | 2 |
| D. lissa | | 1 | | | | | | | | | | 1 |
| D. tenuis | 1 | | | | | | | | | | | 1 |
| Cyclomedusa davidi | 6 | 3 | 3 | 1 | 2 | | | | | | | 15 |
| C. plana | 1 | | | | | | | | | | | 1 |
| C. radiata | 1 | 1 | 1 | | 1 | | | | | | | 4 |
| Ediacaria flindersi | 1 | 2 | 3 | | | | | | | | | 6 |
| Parvancorina minchami | 3 | 2 | 2 | | | 1 | | | | | | 8 |
| Spriggina floundersi | 3 | 2 | 2 | | | 1 | | | | | | 8 |
| Marywadea ovata | | 1 | | 1 | | | | | | | | 2 |
| Rugoconites enigmaticus | 4 | 1 | 1 | 1 | | | | 1 | | | | 8 |
| R. tenuirugosus | 1 | | | | | | | | | | | 1 |
| Ovatoscutum concentricum | 1 | | | | 1 | 1 | | | 1 | | | 4 |
| O. sp. nov. | | | | | | 1 | | 1 | | | | 2 |
| Tribrachidium heraldicum | 1 | 1 | | 1 | 1 | 1 | | | | | | 5 |
| Phyllozoon hanseni | 3 | 1 | | | | 1 | | | | | 1 | 6 |
| Conomedusites lobatus | | | 1 | 1 | | | | | | | | 2 |
| Charniodiscus arboreus | | 1 | 1 | 1 | | | | | | | | 3 |
| C. oppositus | | 1 | | | | | | | | | | 1 |
| C. longa | 1 | | | | | | | | | | | 1 |
| Kimberella quadrata | 1 | 1 | | 1 | | | | | | | | 3 |
| Medusinites asteroides | | | | | | | | | 1 | | | 1 |
| Brachina delicata | | | | | | 1 | | | | | | 1 |
| Eoporpita medusa | 1 | | 1 | | | | | | | | | 2 |
| Precambridium sigillum | 1 | | | | | | | | | | | 1 |
| Mawsonites spriggi | 1 | | 1 | | | | | | | | | 2 |
| new species 1 | | | | | | 1 | | | | | | 1 |
| new species 2 | | | | | | 1 | | | | | | 1 |
| | 40 | 21 | 17 | 8 | 6 | 12 | 0 | 2 | 2 | 0 | 1 | 109 |

## APPENDIX 7

### DREAMTIME ORIGIN OF WILPENA POUND

According to aboriginal myth, Wilpena Pound owes its genesis to two mythical snake beings or Arkaru. The story involves the kingfisher man, Yulu, who in travelling from the north, lit fires in the Leigh Creek area, the charcoal of which remains as the coal now being mined from this basin. On the way he named Brachina Gorge (or rather - Vachina) after "crankey" birds arguing over a grindstone. A Malkara or circumcision ceremony was in progress at Wilpena when Yulu arrived and managed to convince Wahla, the wild turkey man, that a sharp flint was more effective than a burnt stick for the traditional operation. Meanwhile two Arkaru (snake beings) were approaching and the eye of one was mistaken for a bright star in the west. They set upon and consumed all the people, except for two circumcised men who escaped to the east. Today the Arkaru can still be seen as the north and south walls of Wilpena Pound, the highest point of which is St Mary's Peak - the head of the female serpent.

The contemporary model is a less colourful, but perhaps to some, a no less mythical genesis for this landscape, than the legend of the Adujamathana ("hill-people") society. A flexible imagination is indeed required to envisage that this area was once an ocean floor, swept by tides and gouged by turbidity currents, and the habitat of our oldest ancestors before they were turned to stone by the moving continents. The very walls that to the aborigines represented petrified serpents, do in fact bear the enigmatic impressions of the oldest complex marine invertebrates known.

(drawn from an article by A.C. Robinson, 1978. South Australian Parks and Conservation. 1 : 4 - 12.)

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Plate 1a : Columnar stromatolites with connecting laminae of an undescribed form genus from the marker bed at the top of the Wonoka Formation in Section 11, Chace Range.

Plate 1b : Sericitized, desiccated clay lamination in Facies B, Section 26.

Plate 1c : Interference and small ladder ripples in Facies B, Section 20, Brachina Gorge.

Plate 1a

Plate 1b

Plate 1c

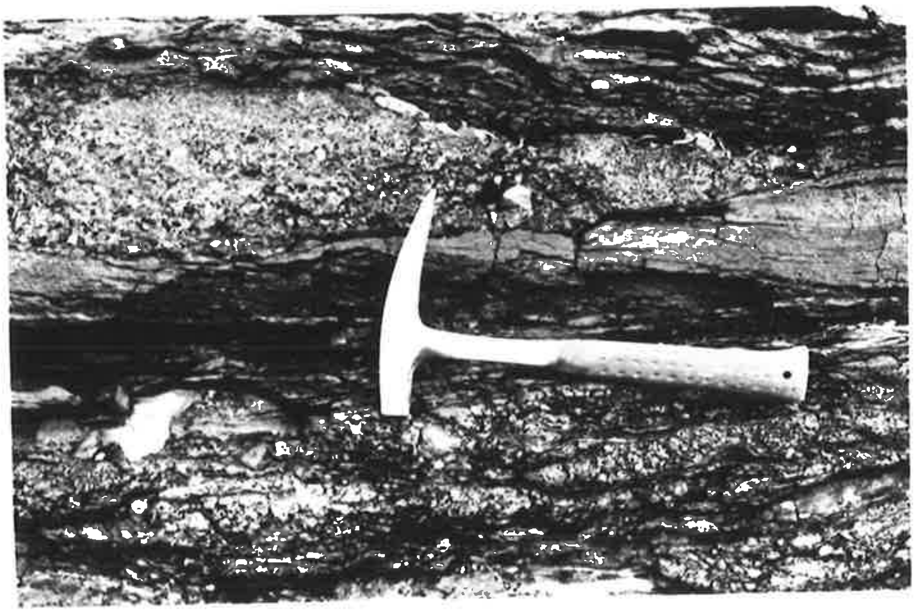
Plate 2a : Meandering trails (Form B) on a silty crimpled surface of Facies B from Section 20, 260 m level, Brachina Gorge. Scale in cm.

Plate 2b : Polymictic conglomerate lenses thinning away from Mt Frome Diapir in Facies E. Hammer 32 cm. (east of Wirrealpa).

Plate 2c Medium scale, low angle, planar, tabular cross-stratification with reactivation surface. Facies F, Bonney Sandstone, Section 34, Wilkawillina Gorge.

Plate 2


a


b

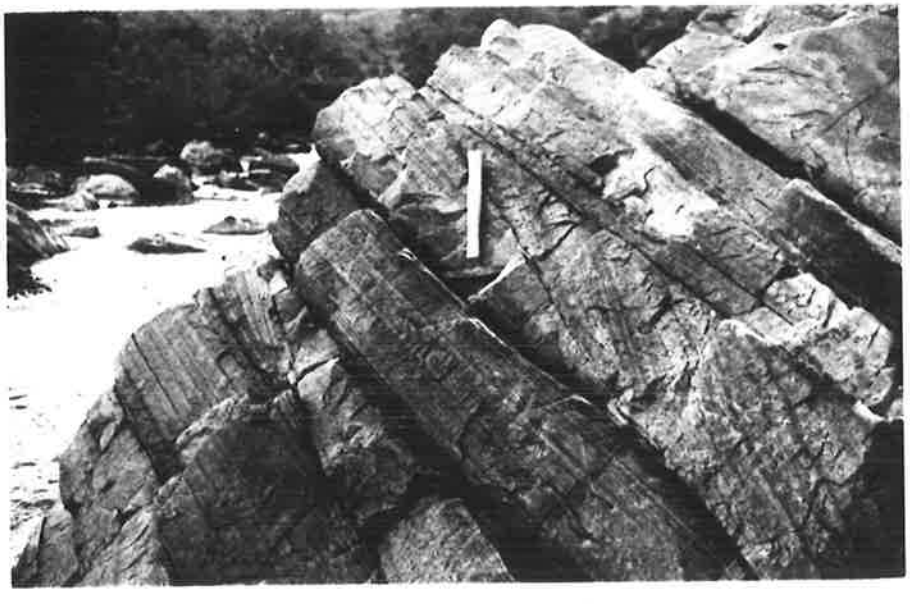

c

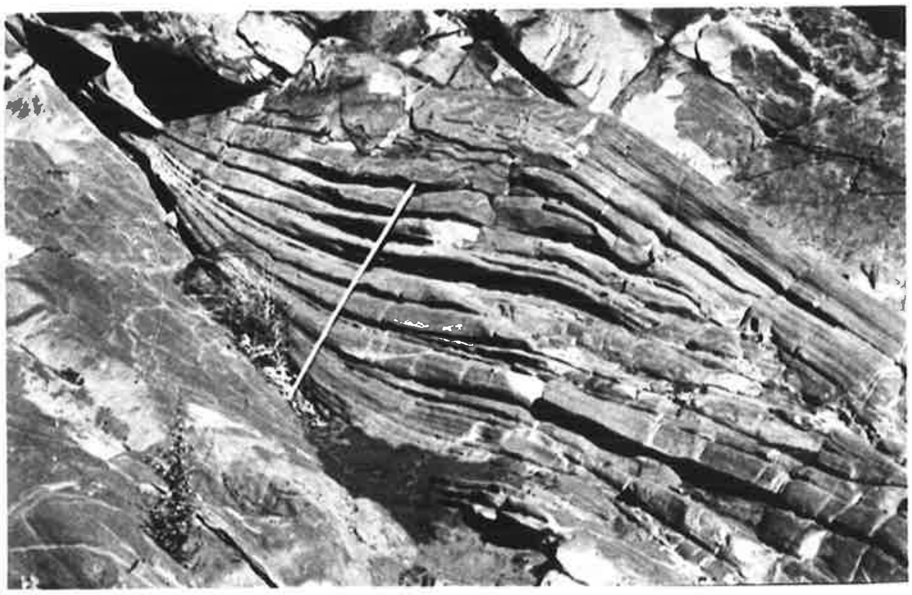
Plate 3a : Larger scale wedge sets of cross-stratification. Facies F, Bonney Sandstone, Section 27, Wirrealpa.

Plate 3b : Sigmoidal cross stratification, Facies F, Section 20, Brachina Gorge (1 m scale).

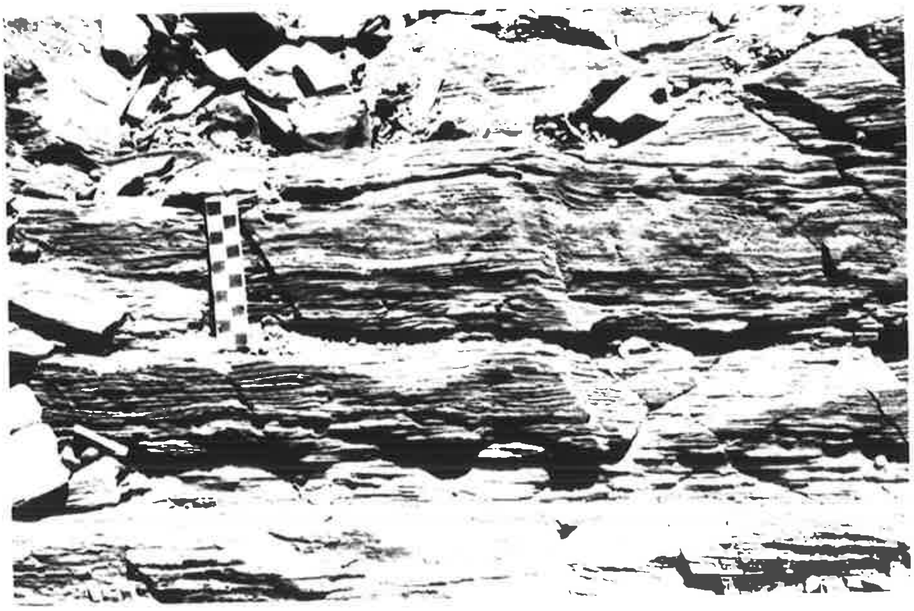
Plate 3c : Low angle climbing ripples grade into sinusoidal ripple lamination; Facies G, 145 m level, Section 18, Bunyeroo Gorge.

Plate 3

a



b



c

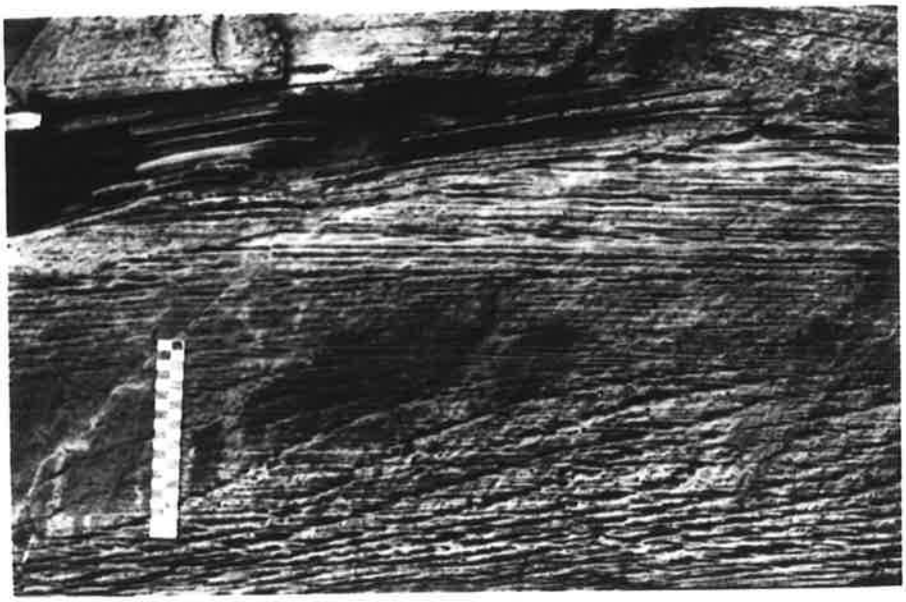
Plate 4a : Sinusoidal ripple lamination, Facies G, Section 1, Mayo Gorge.

Plate 4b : False foresets produced by progradational stacking of climbing ripples; Facies G, Section 25.

Plate 4c : Deformed foresets on large scale low angle cross-stratification in Facies F; Brachina Gorge.

# Plate 4

a



b

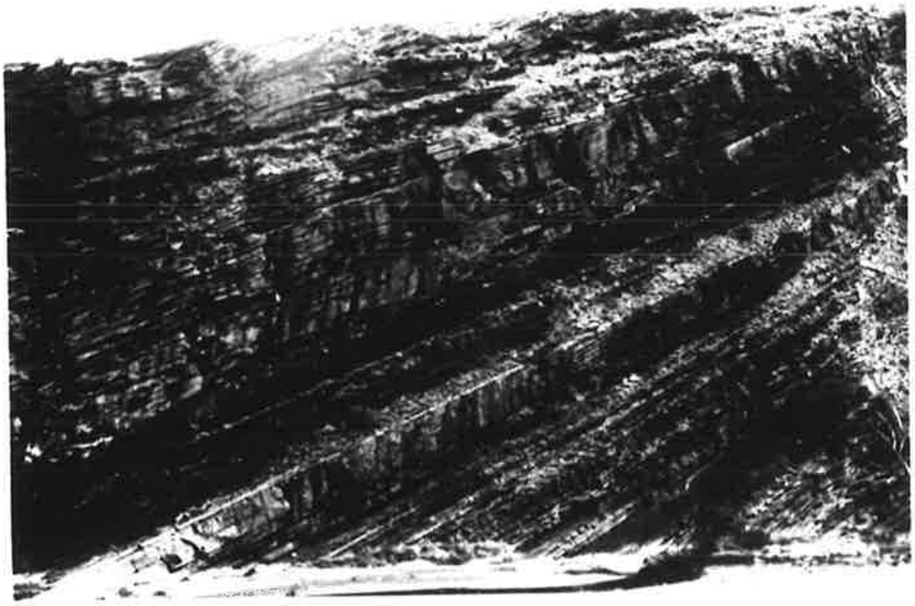
c

Plate 5a : Multistory sand sheets of Facies F, Bonney Sandstone, Wilkawillina Gorge.

Plate 5b : Thick cross stratified sequence of Facies F, Wilkawillin Gorge.

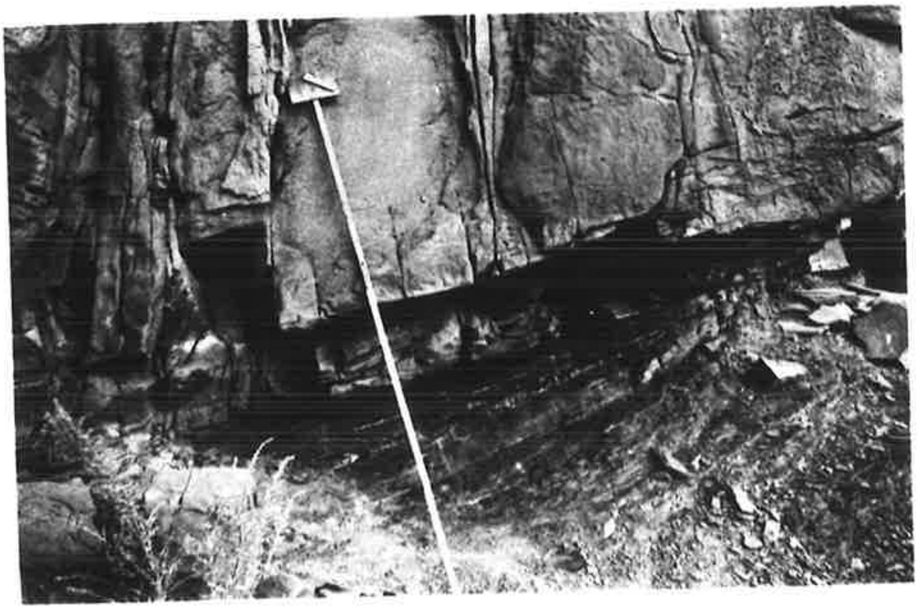
Plate 5c : Facies C (laminated siltstone) sharply (erosively?) overlain by thick beds of Facies F (sandstones), Section 25.

Plate 5



a

b



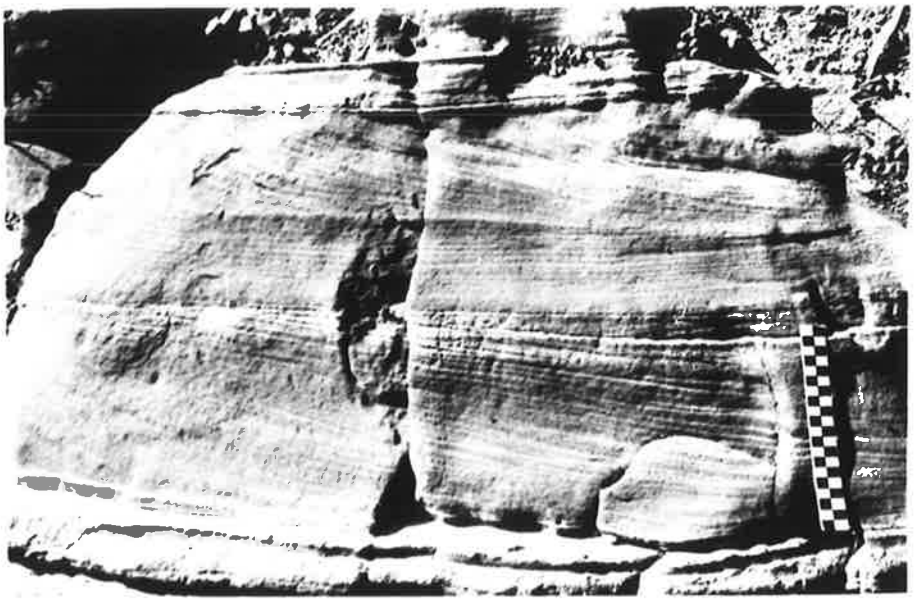
c

Plate 6a : Facies H, planar sets of low angle cross stratification; Section 1, 436 m level, Rawnsley Quartzite, Mayo Gorge.

Plate 6b : Low angle trough crossbedding with mud chip cavities on foresets; Facies H overlying disrupted sandstones of Facies I; Section 24, 355 m level (above Ediacara Member), Parachilna Gorge.

Plate 6c : Remnant, erosional "sand mounds" (20 cm diameter), underlying cross-stratified sandstones of Facies H; Section 24, 230 m level, Parachilna Gorge.

Plate 6



a

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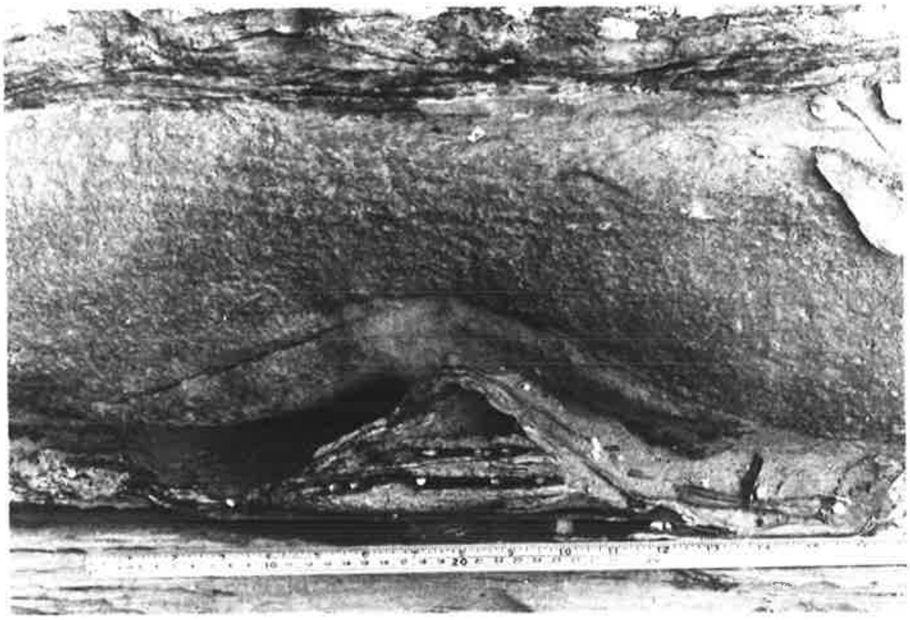


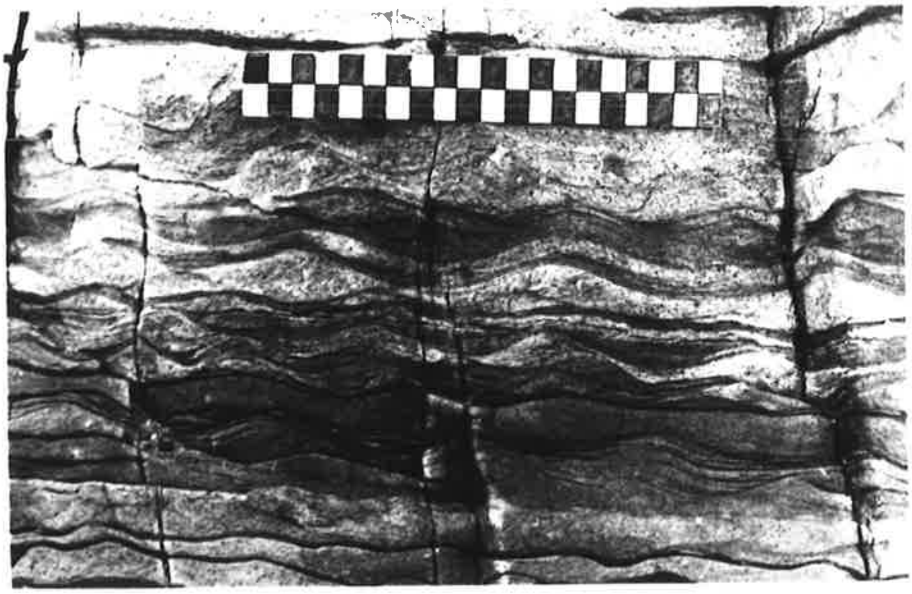
c

Plate 7a : Facies I, wavy bedded sandstones, formed from wave oscillation ripples; Section 24, Parachilna Gorge.

Plate 7b : Moulds of double crested ripples; Facies I, Section 24, Parachilna Gorge.

Plate 7c : Disrupted and convoluted lamination in Facies I. Section 1, 464 m level, Mayo Gorge.

Plate 7



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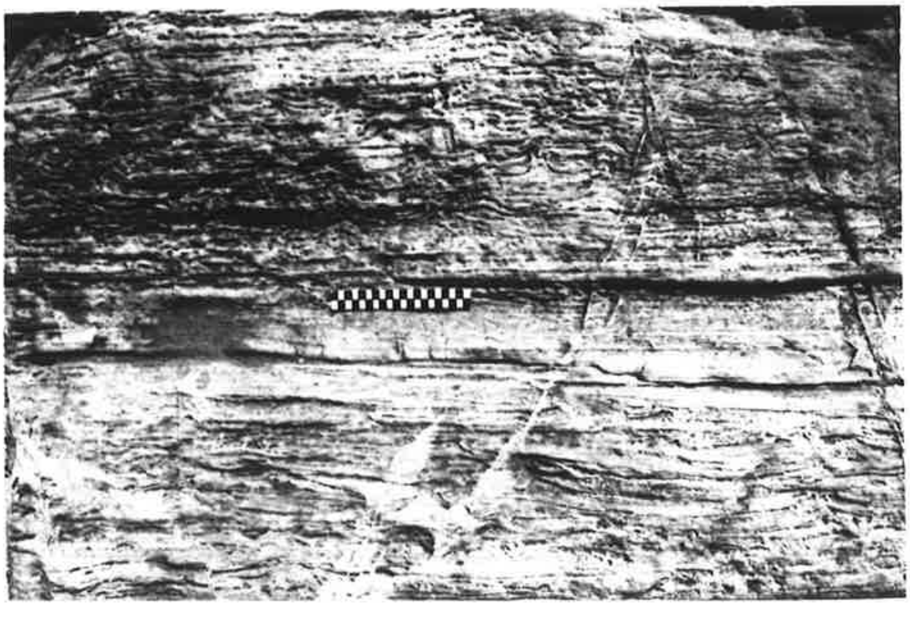


c

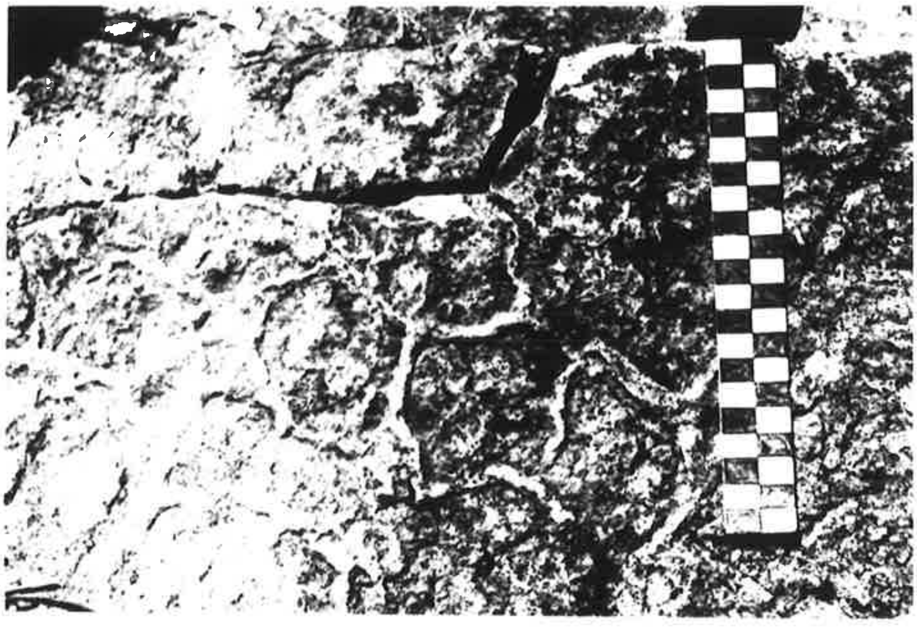
Plate 8a : Disrupted fine grained sandstone lamination interleaved with coarse grained lamination; Facies I, Rawnsley Quartzite, Section 18, 290 m level, Bunyeroo Gorge. Lens cap 5 cm.

Plate 8b : Polygonal ridges, interpreted as desiccated algal-bound sand laminae; Facies I, Section 5, Elder Range.

Plate 8c : Sinuous disrupted sand ridges; Facies I, Rawnsley Quartzite, Mt Frome east of Wirrealpa.

## Plate 8

a



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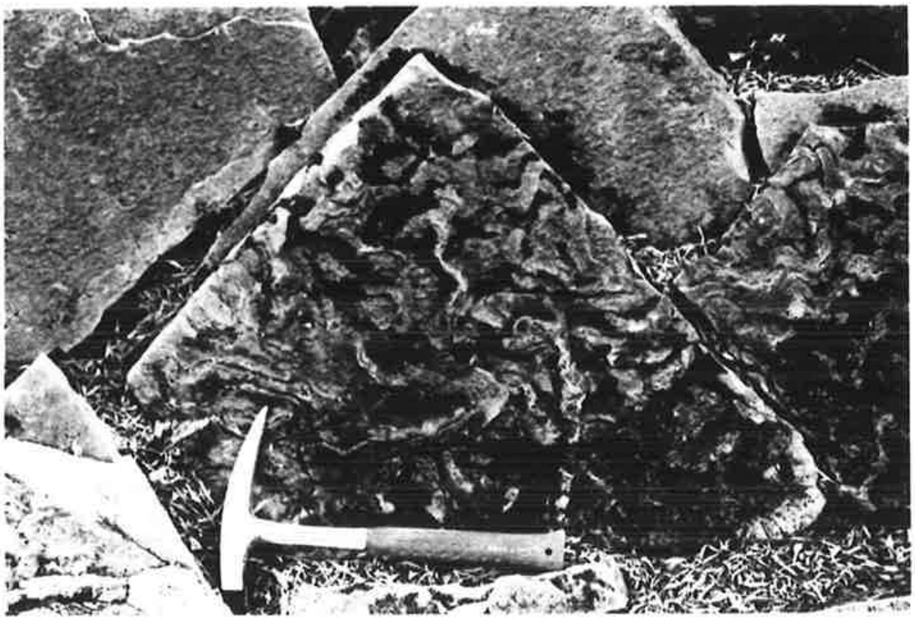


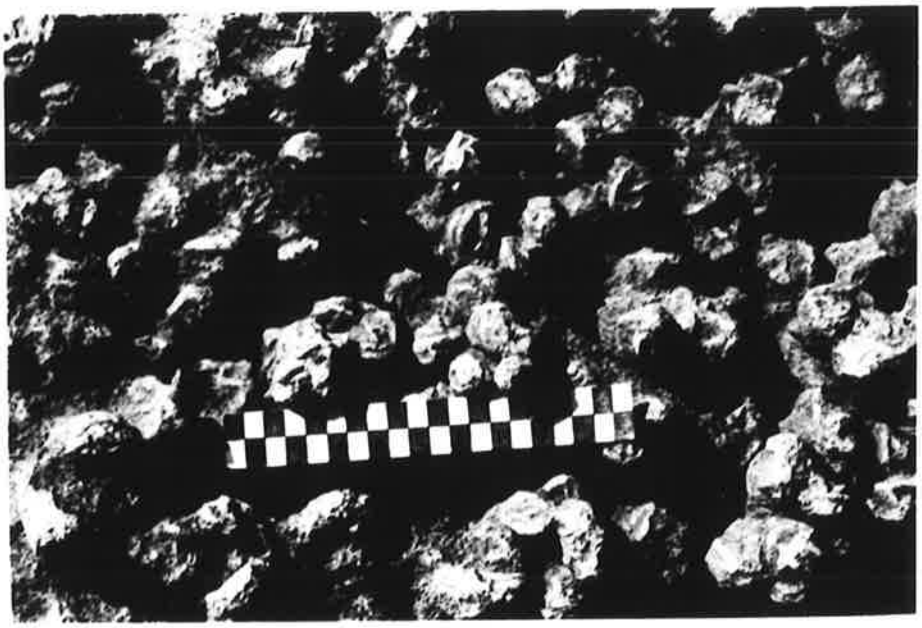
c

Plate 9a : Facies I, sandstone rosettes, pseudo-morphed after sulphate crystals (barite or gypsum). Section 5, 534 m level, Elder Range.

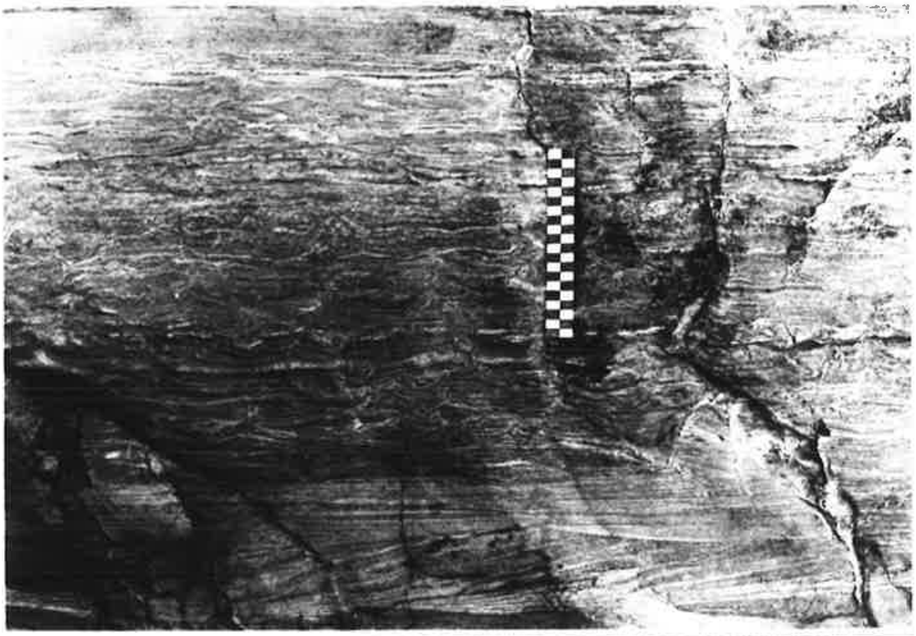
Plate 9b : Cycle of Facies H (cross bedded sandstones) passing up into Facies I (disrupted sandstones). Section 24, Parachilna Gorge.

Plate 9c : Thick sequence of cross bedded and rippled sandstones (Facies H and I) comprising more than 500 metres of section in the Rawnsley Quartzite, Wirrapowie Gorge 50 km NE of Blinman.

Plate9



a



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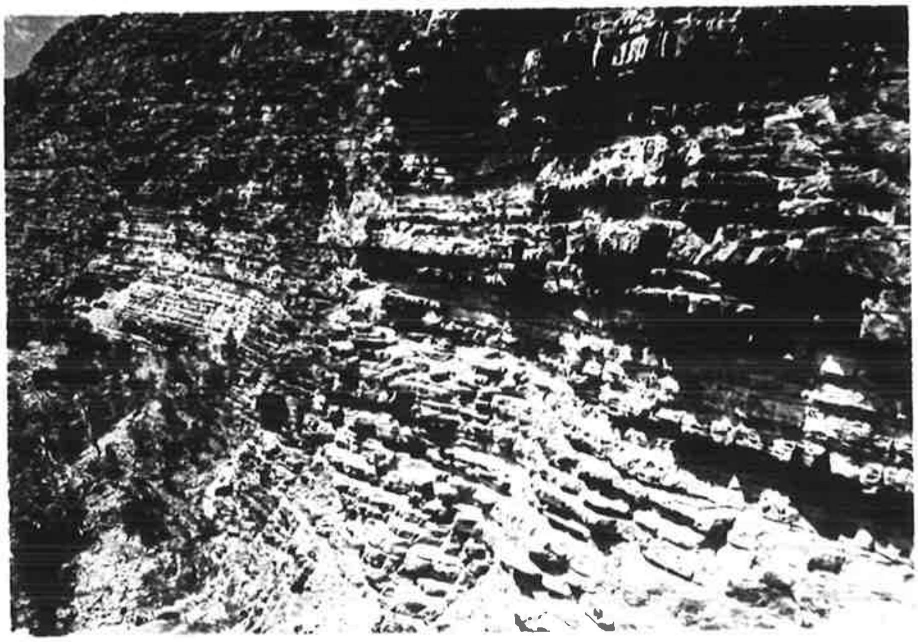
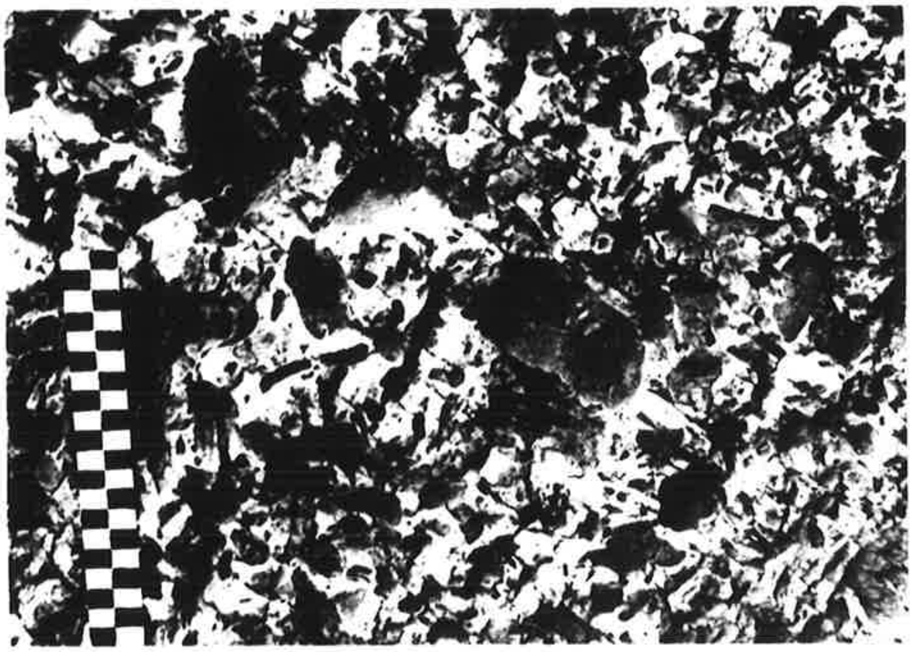


c

| | |
|---|---|
| Plate 10a : | Lower cross and ripple bedded sandstones (Facies H and I) of Rawnsley Quartzite, erosively succeeded by massive sandstones of Facies J. (Ediacara Member), Section 20, 375 m level, Brachina Gorge. |
| Plate 10b : | Cavities from a mud clast conglomerate filling a channel in Facies J (see centre of Plate 10a). |
| Plate 10c : | Steep wall contact of a Facies J, massive sand filled channel, cut into wavy and disruptive beds of Facies I (right hand side), south Elder Range. |

Plate 10

a



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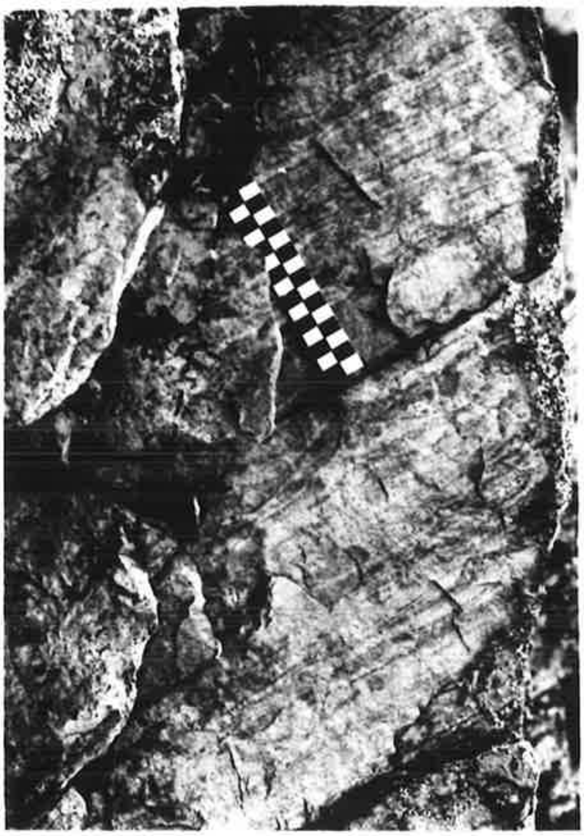


c

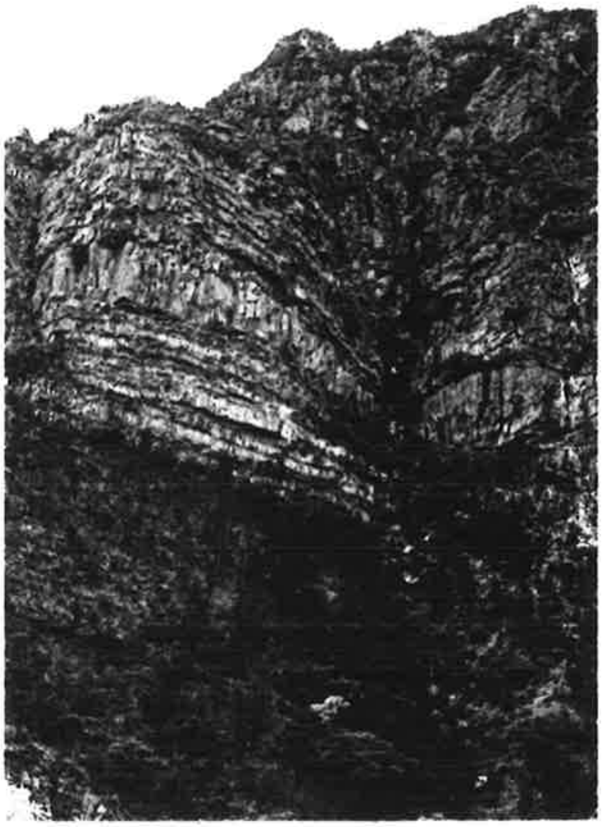
**Plate 11a :** Angular sandstone clasts of Facies H and I fill the basal part of Facies J - channel sandstones, in the Chace Range. (hammer 32 cm long).

**Plate 11b :** Thick sequence of massive, amalgamated sandstones (mainl Facies K), Ediacara Member, Section 7, 370-460 m., SW Wilpena Pound. Note 16 m thick massive unit of Facies K

**Plate 11c :** Climbing ripple in beds overlying massive sandstones. Facies K, Section 11, 630 m, Chace Range.

Plate 11


a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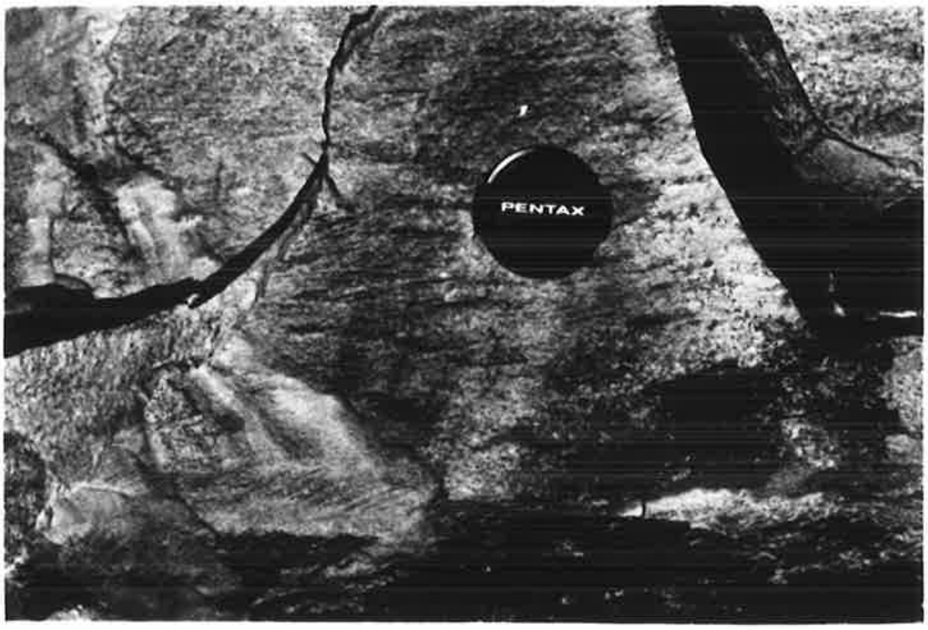


c

Plate 12a : Dish structures in otherwise massive sandstones of Facies K, Section 11, 570 m level, Chace Range.

Plate 12b : 3 m balls of Facies K in distorted clayey siltstones (Facies L). Section 13, 720 m level, Wilpena Pound.

Plate 12c : Foundering of massive sandstone beds, Facies K, Section 10, 660 m level, Chace Range.

Plate 12

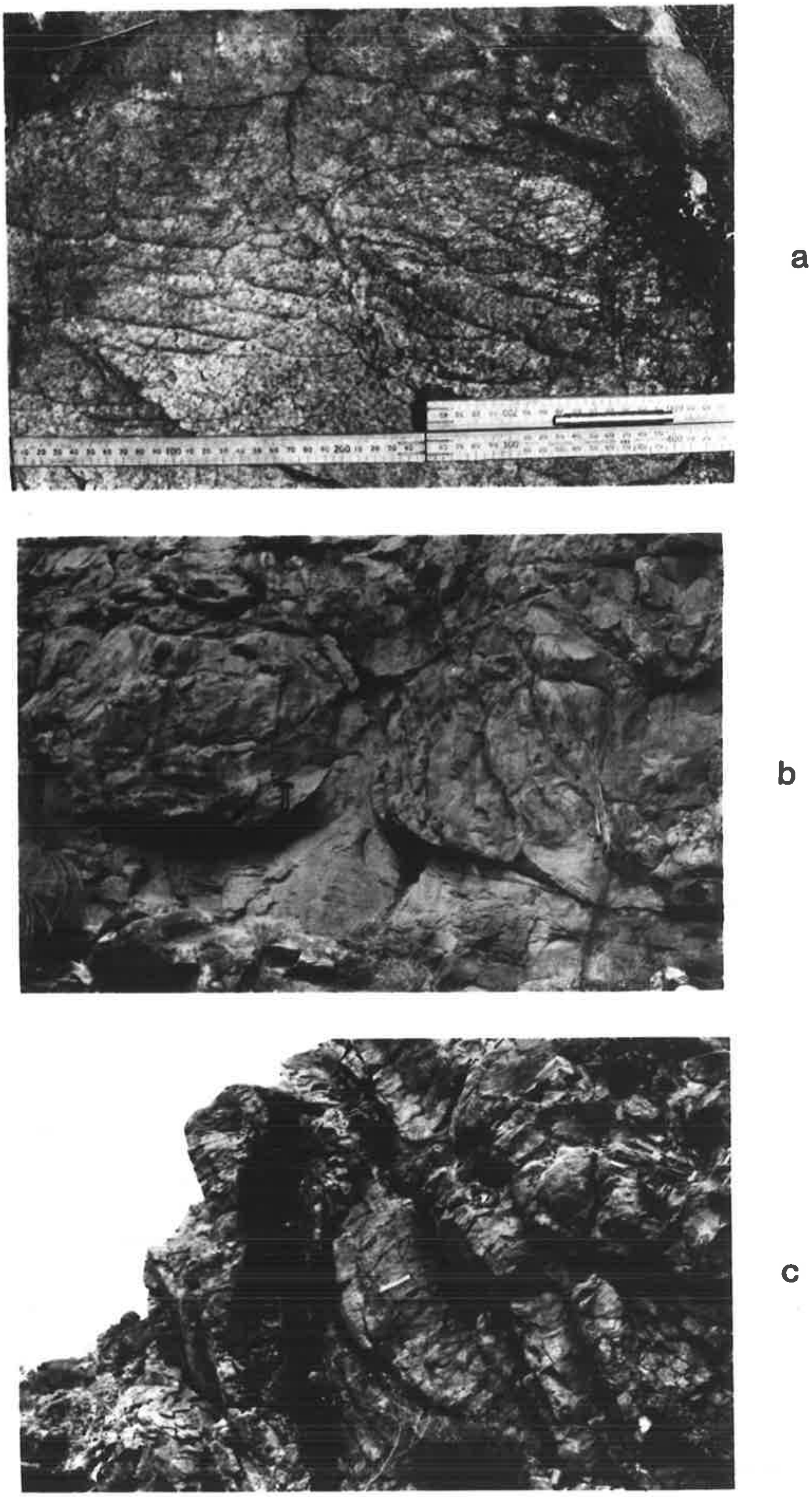
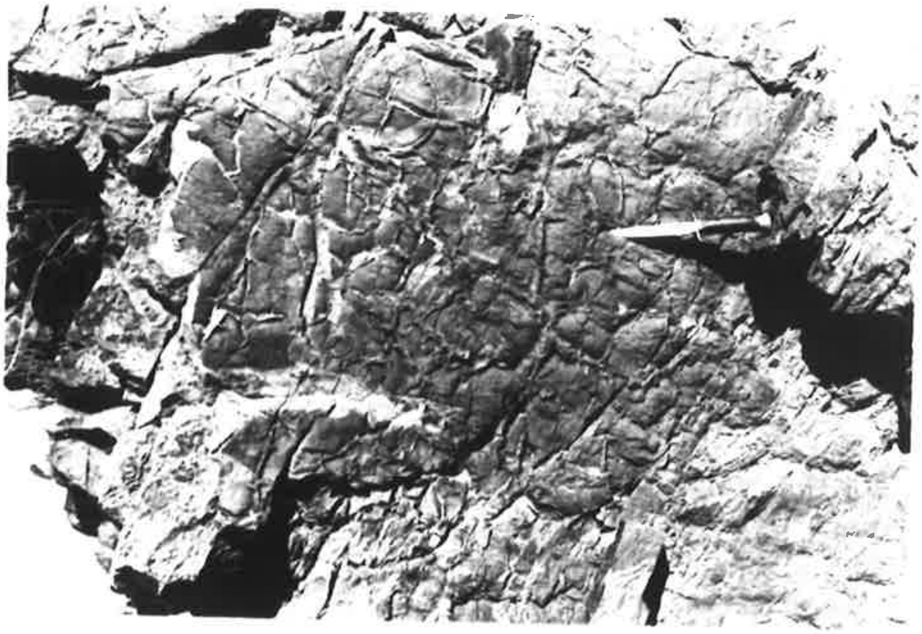


Plate 13a : Casts of shrinkage cracks (synaeresis) on the base of a large scale Facies K ball structure, south of Parachilna Gorge (knife 20cm).

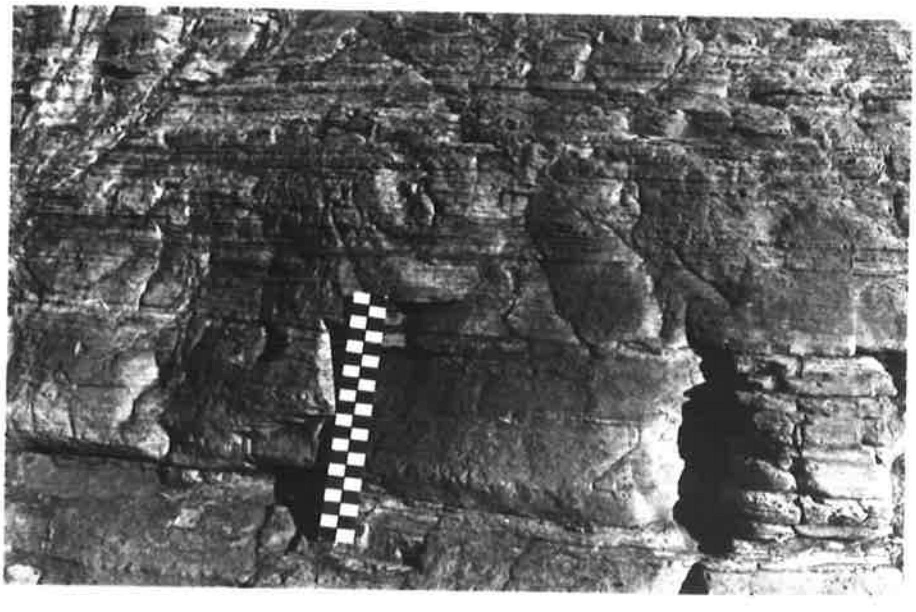
Plate 13b : Laminated siltstones (Facies L) with sand laminae increasing upward; Section 1, 566 m level, Mayo Gorge.

Plate 13c : Laminated fine sandstone with lenticular sand biscuits of clean medium grained sand (Facies L); Hell's Gate, D80, west of Elder Range.

## Plate 13



a



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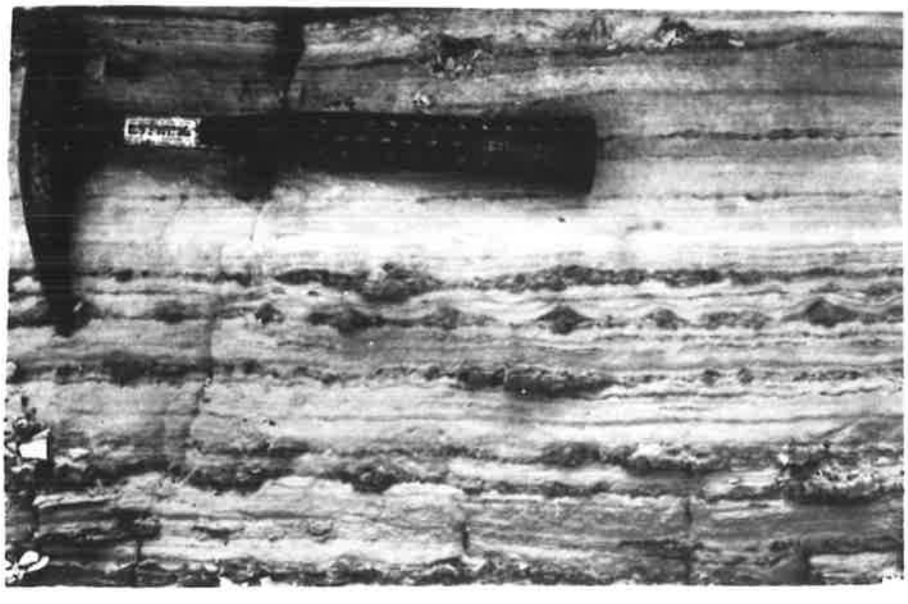


c

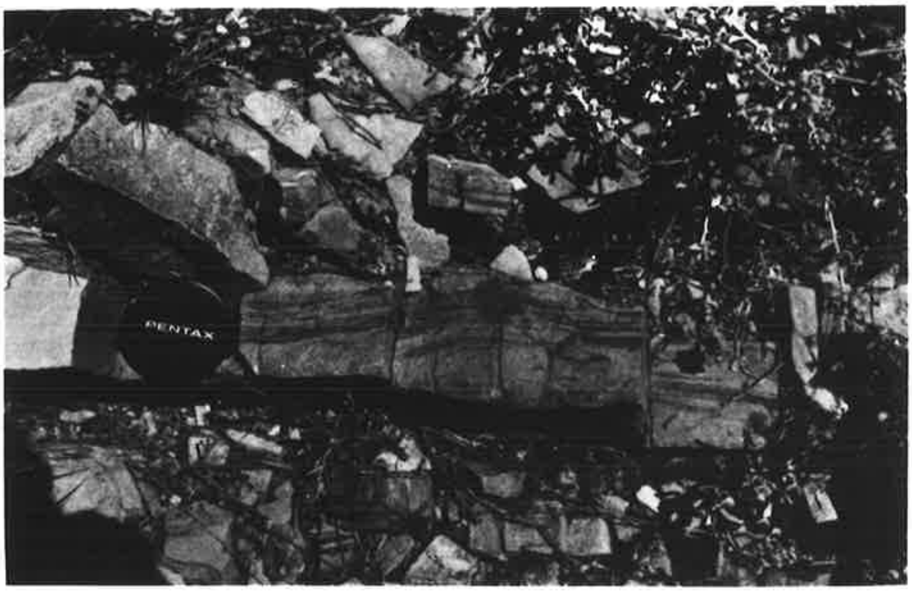
Plate 14a : Thixotropic deformation of Facies M (fossil bearing sandstones) into sandy siltstones of Facies L. Section 20, 475 m level, (Fig. 4), Brachina Gorge. (lens cap 5 cm).

Plate 14b : Cross sectional exposure of Facies M bed (fossil bearing sandstone) : massive to flat laminated sand at base grades into bundles of wispy crosslamination. Section 31, Chace Range.

Plate 14c : Interbedded laminated siltstones (Facies L) and thin, wavy to lenticular sandstones (Facies M). Ediacara Member, D80, Hell's Gate west of Elder Range.

# Plate 14


a



b

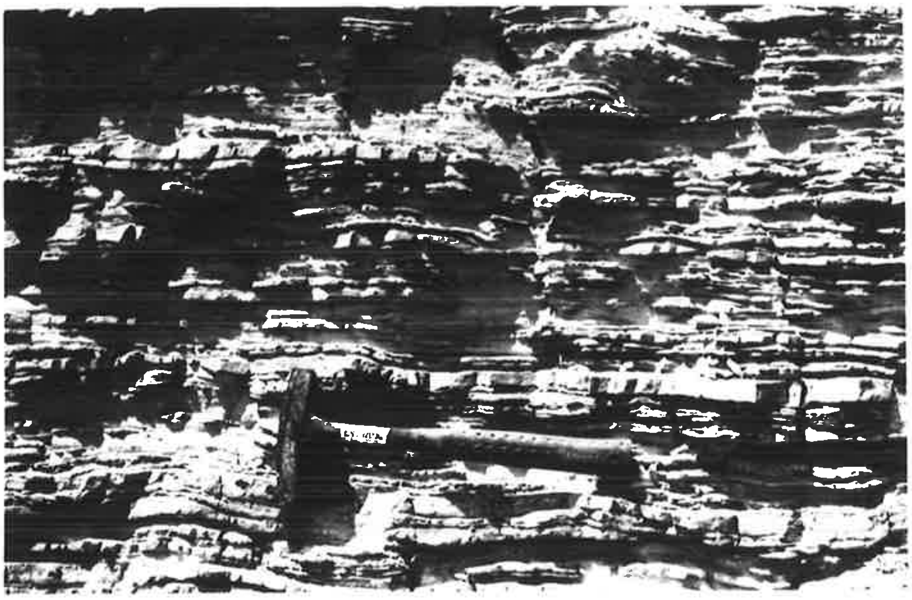
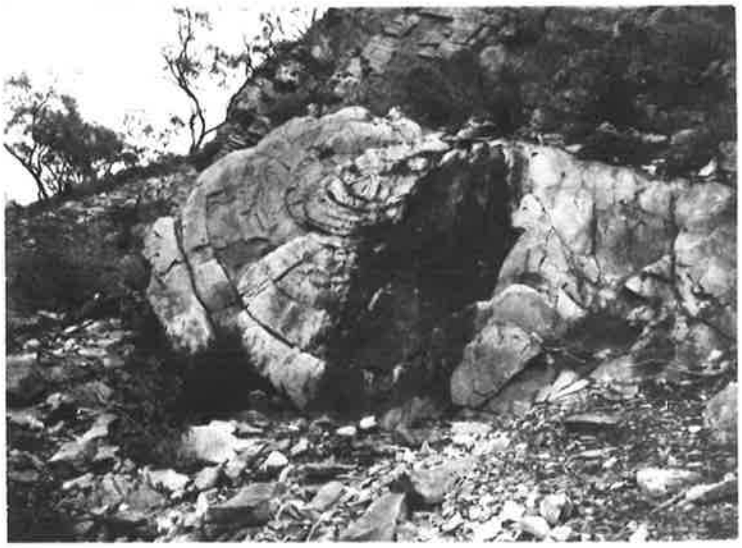

c

Plate 15a : *Cyclomedusa* sp.; typical preservation as a positive relief cast on the base of a thin sandstone bed of Facies M; Elder Range.

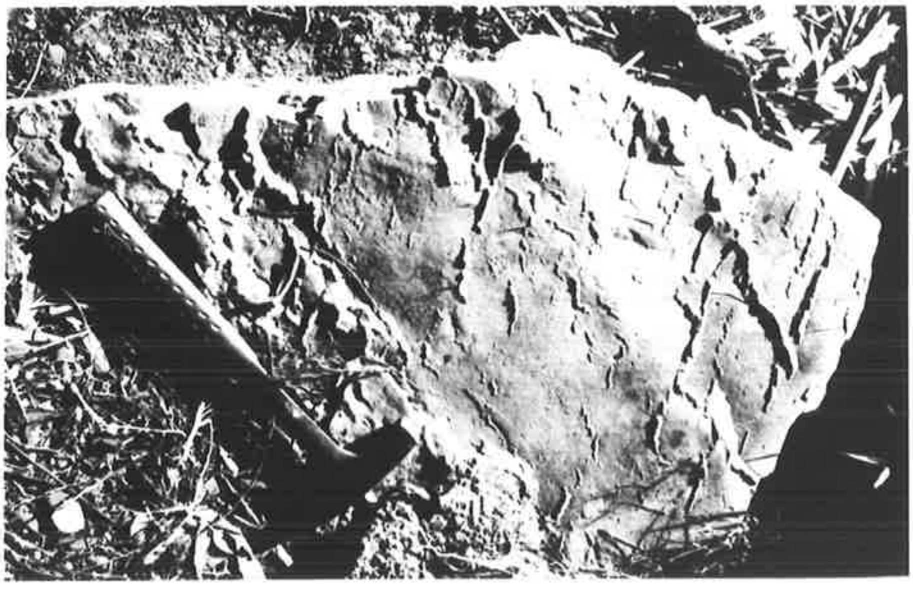
Plate 15b : Load ball, (2.5 x 4 m) comprising thick beds of Facies M over Facies L (siltstones), Section 18, 338 m level Bunyeroo Gorge.

Plate 15c : Synaeresis cracks cast on the base of Facies M (medium grained sandstone) Section 20, 476 m level, Brachina Gorge.

a



b



c

Plate 16a : Facies N, complex medium scale cross stratificated, banded white quartzite, with spheroidal concretions; Section 3, south Elder Range.

Plate 16b : Two prominent cycles of Facies N, M and L capping the Ediacara Member. Facies N composed of ESE dipping imbricate sandstone sheets. Succeeded by thick sequence of Facies H and I. Section 13, south end Wilpena Pound, (looking SSW).

Plate 16c : Base of Ediacara Member cuts down through a thick sequenc of Facies H and I from left to right. Comprises siltston of Facies L capped by two cycles of Facies N (parallel bands of outcrop, see Plate 16b). Thin sequences of fossilferous Facies M underlie each unit of Facies N. Rawnsley Bluff, Wilpena Pound.

Plate 16


a


b

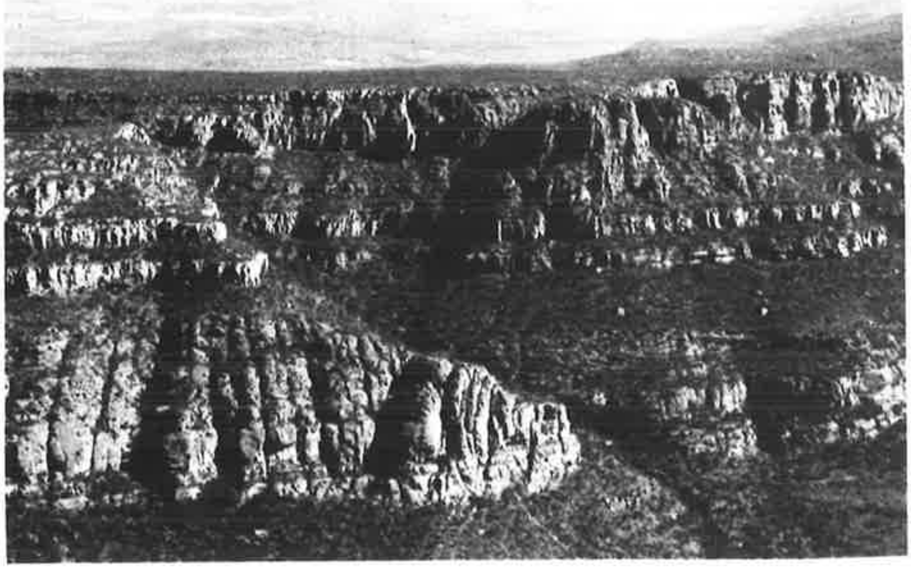

c

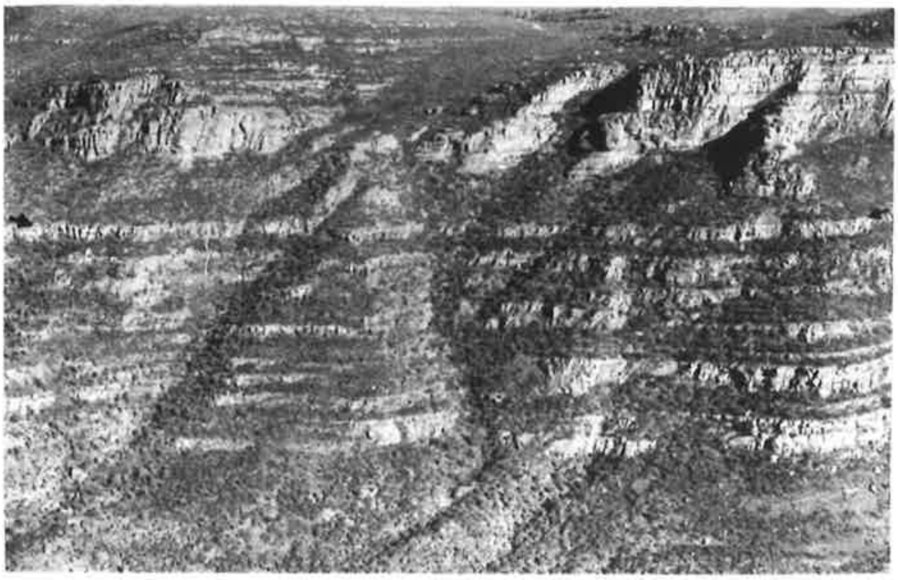
Plate 17a : Grove casts preserved on base of Facies J conglomeratic, channel fill deposits (SE-NW orientation); Section 33, 37 m above base of Rawnsley Quartzite, Chace Range, (compass 15 cm).

Plate 17b : Multistory sand cycles (mainly Facies K) of the Ediacara Member, capped by Facies N (above midline of photo). 250 m of section, succeeded by Facies H and J. East wall of Wilpena Pound.

Plate 17c : Ediacara Member : basal Facies J, siltstones of Facies L, followed by 200 m of Facies J and K (massive sandstone cycles. Total 300 m below capping cycles. Section 14, Chace Range.

Plate 17

a



b

c

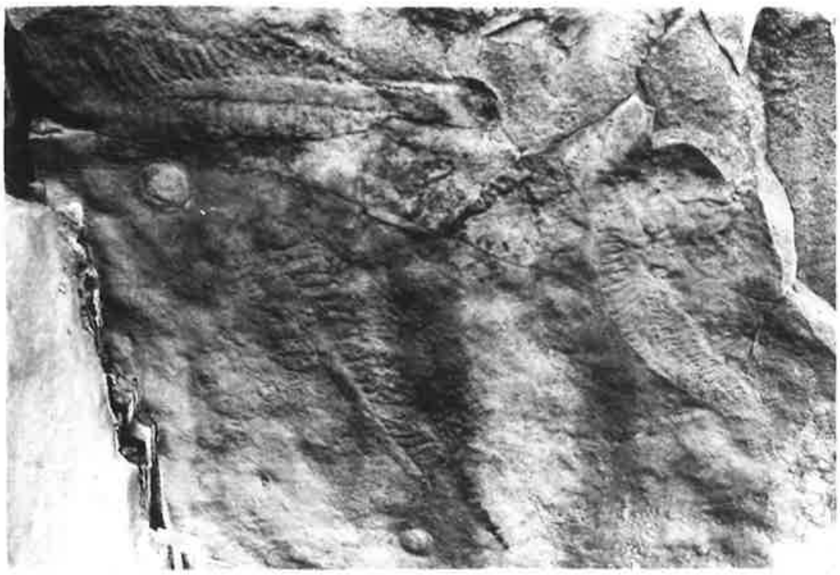
Plate 18a : Fleur-delys structure (mould) indicating a current direction from left to right. Base of Facies M bed, Section 31, 213 m level, Chace Range.

Plate 18b : Fossils of soft bodied octacorals (pennuatulids) preserved on the base of a thick sandstone bed of Facies M (species of *Charniodiscus* Ford), south Heysen Range. (top specimen 36 cm).

Plate 18c : *Sarcophyllum grandis*, occurs on coarse sandy substrate in tidally influenced waters from 10-30 m deep; St. Vincent Gulf, S.A.

Plate 18

a



b

c

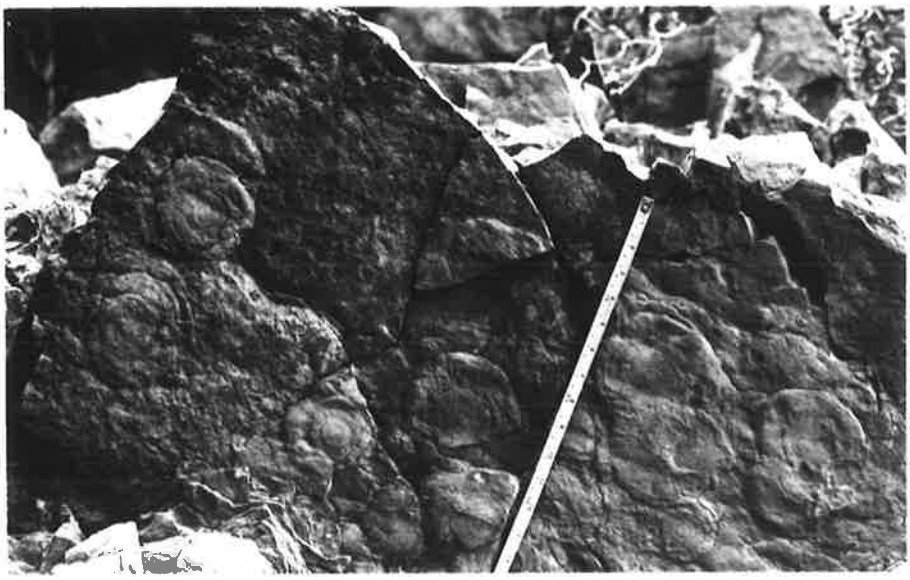
Plate 19a : Polychaete worm fossils, *Dickinsonia costata* Sprigg dorsal view, i.e. axial ridge interrupts segmental divisions. (ventral side has continuous segmental boundaries); external moulds; same horizon as Plate 18b (x 0.75).

Plate 19b : Numerous casts of medusoids : *Cyclomedusa davidi* (?) Sprigg; Facies M, south Heysen Range. Scale 37 cm.

Plate 19c : Thickening upward cycles involving fossiliferous sandstones of Facies M, Section 20, 450-500 m interval, Brachina Gorge.

Plate 19

a



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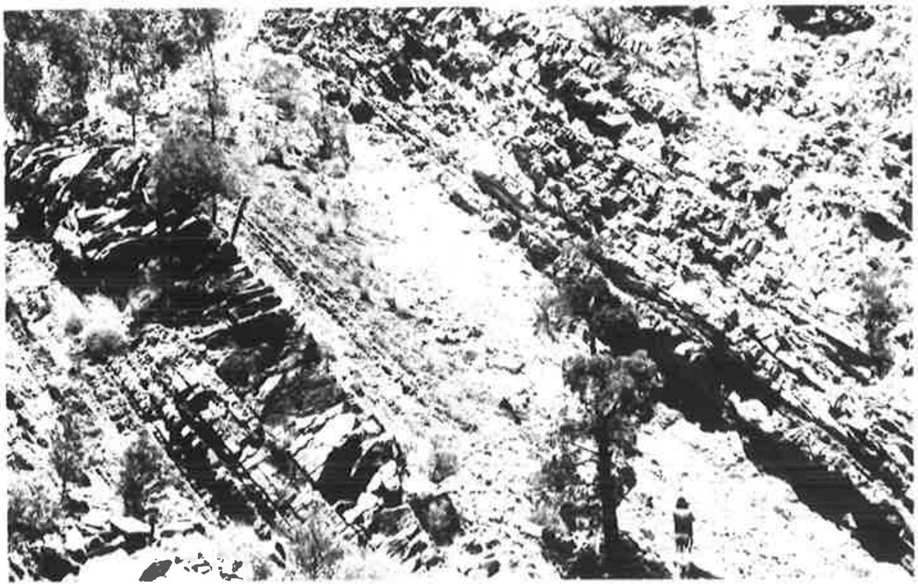

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