

THE UNIVERSITY OF ADELAIDE

SEDIMENTOLOGY OF THE MARINOAN TYPE SECTION

MARINO ROCKS TO HALLETT COVE AREA,

SOUTH AUSTRALIA

by

Elinor M. Alexander B.Sc.

November, 1984

COPY 1.

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National Grid Reference 1:100,000 Series

SI 54-6627

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This thesis is submitted as partial fulfilment of the requirement of the Honours Degree of Bachelor of Science in Geology at the University of Adelaide.

Submitted November, 1984

## ABSTRACT

Sections measured in detail through the older part of the late Precambrian Marinoan sequence in the type area of Marino and Hallett Cove, south of Adelaide confirmed a mainly clastic shelfal sequence, which shows the influence of strongly fluctuating sea level. The sequence is dominated by silt deposition, with only occasional, often thin, sandstone intervals. In the relatively small area studied the palaeoshoreline can be interpreted as running north-north-west and south-south-east. Tidal currents at a high angle to the shoreline influenced sedimentation. Alongshore currents and wave action also have played a role in deposition. Storm wave action may have reworked some of the units.

The lower part of the Marinoan type section represents a transgressive sequence from the supratidal mudflat environment of Unit 1 to the below storm wave base silts and shales of Unit 3. The sequence is then dominated by deep water silts and shales, with any minor shallowing episodes recorded in the sandstones of Units 4 and 6.

The Reynella Siltstone Member contains massive diamictites, sandstone channels, rhythmites, granule trains and two possibly ice-wedged palaeosoil horizons. These features indicate that glaciogenic processes played a role in the deposition of this Unit.

The Seacliff Sandstone Member consists of massive sandstone beds, with dewatering structures, and lenses of dolomite and silt. The massive sands were deposited from proximal liquefied flows. The Nuccaleena dolomite equivalent and Unit 13 of the Wilpena Group represent a transgression near the end of the Marinoan sequence in the type area. The interbedded silts and sands of Unit 13 were deposited by distal turbidity currents. The upper part of the Marinoan type section records a regression, as the turbidite sequence shallows upwards to the storm-deposited ABC Range Quartzite.

The fluctuating sea level may reflect eustatic rises and falls in sea level produced by associated glacial, or tectonic activity. The Marinoan glaciation is directly reflected in the Reynella Siltstone Member but the indirect effects of a more prolonged glacial period may have influenced deposition over much of the lower part of the Marinoan-type section.

## A C K N O W L E D G E M E N T S

I wish to thank my supervisors Dr. R. Jenkins and Dr. V. Gostin for initiating this project, and for their assistance and encouragement during the year. The assistance of the technical staff of the Department of Geology and Mineralogy is gratefully acknowledged.

Thanks must also go to my family for their support and encouragement during the year, in particular to my father for assistance in the field and for the use of the family car for commuting to the site each day, and to my mother who was kept occupied with typing for much of the year. Special thanks must go to Mrs. Joan Clark who kindly typed my thesis. Orthophoto maps were provided by the Geology Department.

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## CHAPTER 1 : INTRODUCTION

The Marino Rocks - Hallett Cove area is located 20 km. south-west of Adelaide, South Australia (Figure 1).

Good outcrops of the Marinoan-age sediments occurred along the cliffs and wave-cut platform on the coastline and in the valley of the Field River. A supplementary section of Marinoan-age sediments was measured in the Pedlers Creek area, 32 km. south of Adelaide.

There is a long history of investigations of the area, dating back to 1877 when Tate discovered a Permian glacial pavement at Black Cliff, Hallett Cove. Howchin (1904) described the geology of the Hallett Cove area in his study of the geology of the Southern Mt. Lofty Ranges. David (1922) first proposed the term "the Adelaide series" for "all the strata from the base of the Archaeocyathine limestones to the basal conglomerates overlying the Archaean (?) schistose rocks of Adelaide" (p.7). Howchin (1929) defined the Adelaide region as the type-area for the Adelaide System.

A major period of investigation of the Hallett Cove area was initiated by Segnit (1940), with the publication of his rather controversial paper, "The Geology of Hallett Cove and district with special reference to the distribution and age of the younger glacial till". Some of the conclusions Segnit arrived at were challenged and dismissed by Mawson (1940) and Sprigg (1942). Sprigg (1946) remapped the Adelaidean type area to the south of Adelaide. The Torrensian and Sturtian sequences were remeasured in detail. Mawson and Segnit (1948) published chemical analyses of the distinctive purple slates of the Adelaidean Sequence.

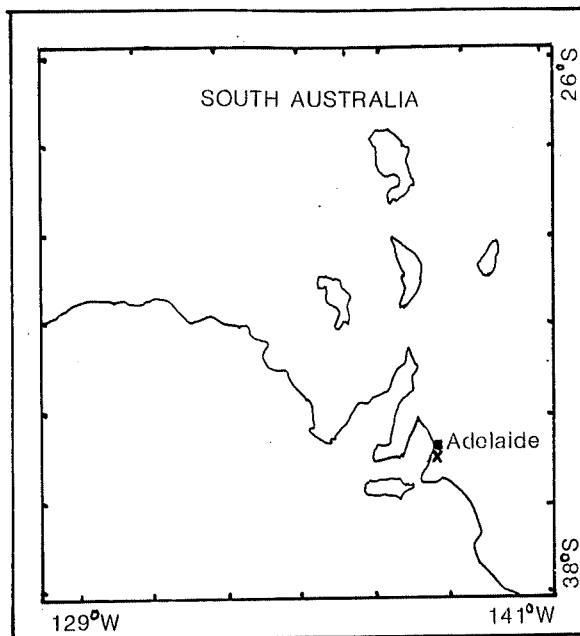
Mawson (1949) discussed the occurrence of "glacial activity at the Elatina horizon of the Adelaide System" (p. 120). Faceted pebbles were collected from the Elatina Tillite in the Elatina area, Flinders Ranges. Mawson proposed that Elatina Tillite was equivalent to part of the sequence outcropping on the coast near Marino Rocks, although no "convincing tillite" had been recorded in the area. /He regarded the sequence near Marino Rocks as being a possible echo of the Elatina Glaciation./

This period of relatively intense study of the area culminated when Mawson and Sprigg (1950) updated the subdivisions of the Adelaide System, and published measured sections of the Torrensian, Sturtian and Marinoan Series. Subsequent attention tended to be focussed on localities in the Flinders Ranges, away from the Adelaide region.

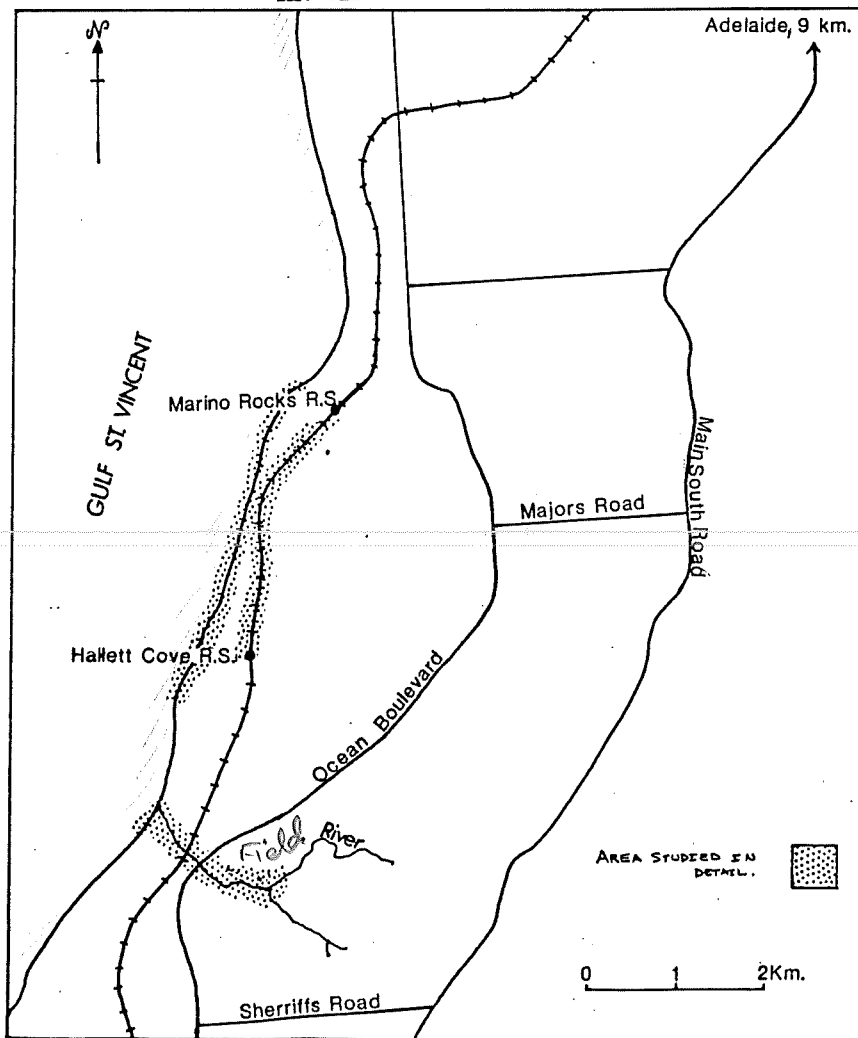
Thomson (1966) described the stratigraphic relationships between the Marinoan-age sediments in the Adelaide region, and correlated the Marinoan-age sediments in the Hallett Cove - Port Stanvac area with sediments on the

# LOCALITY MAPS

## MARINO ROCKS - HALLETT COVE AREA

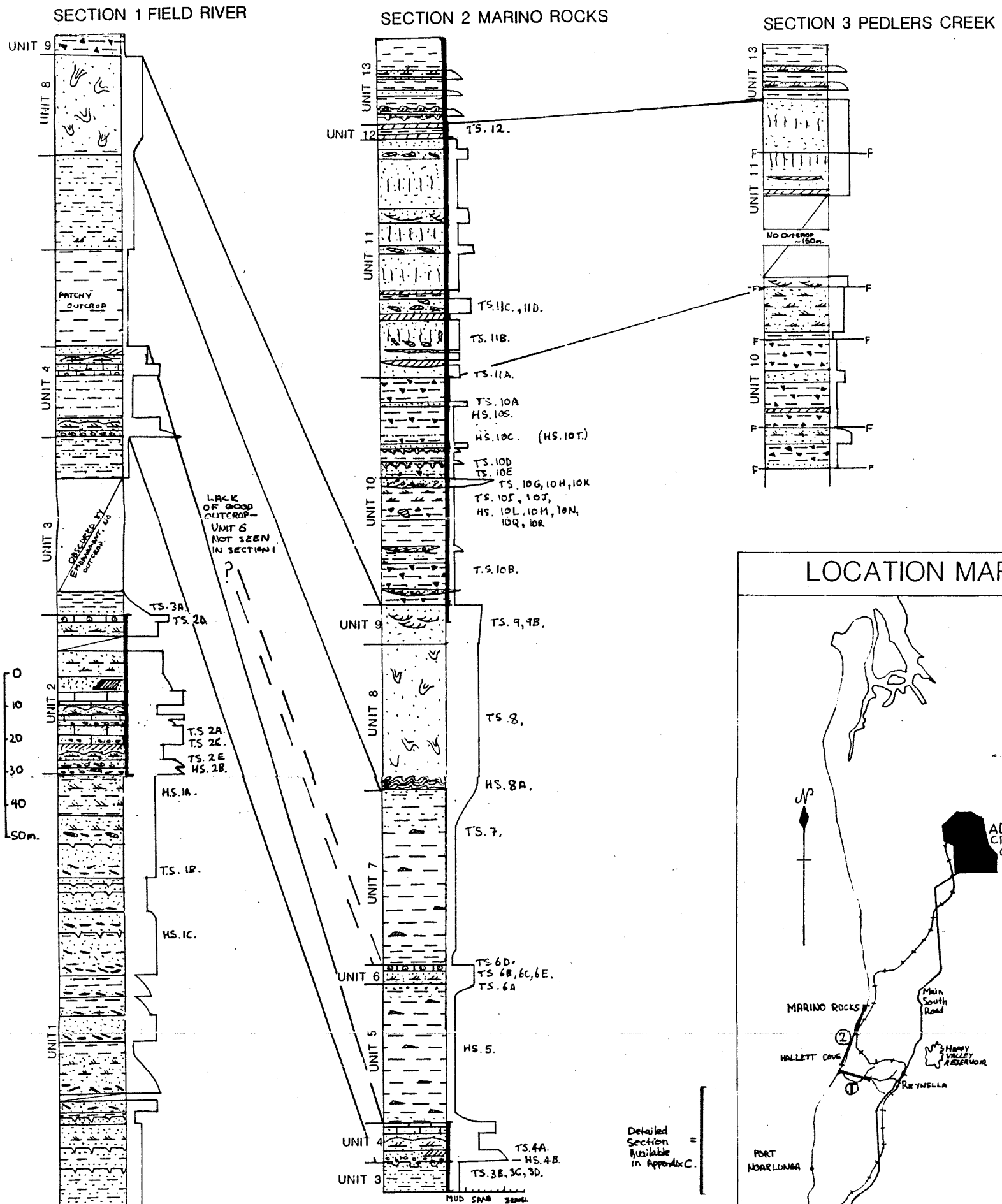


### ENLARGEMENT



Willunga Scarp and at Kulpara (Yorke Peninsula). Miller (1975) measured a section down Waterfall Creek from the Brighton Limestone to the Reynella Siltstone Member and correlated it with a section measured in the Myacca Bluff - Buckaringa Gorge area. More recent studies have concentrated on particular units in the area. Preiss and Kinsman (1978) studied the Brighton Limestone. Dyson, Von der Borch and Gostin (in prep.) made a detailed study of the shales, siltstones and sandstones of the Brachina Sub-group at Hallett Cove. Donaldson and Gostin (<sup>1975</sup>unpub.) have examined dewatering structures in the Seacliff Sandstone Member.

# COMPARISON OF MEASURED SECTIONS



LACK OF GOOD OUTCROP - UNIT 6 NOT SEEN IN SECTION 1

?

TS. 2A, TS. 2C, TS. 2E, HS. 2B

HS. 1A

TS. 1B

HS. 1C

MISSING 45m

BRIGHTON LIMESTONE

MUD SAND GRAVEL

KEY		SAMPLE POINT: Hand Specimen Only: HS 1A (Prefix = 837-)	
Conglomerate		Dolomite Clasts / Mud Flakes	
Sandstone		Tabular Cross Bedding	
Siltstone		Trough Cross Bedding	
Limestone		Ripple Cross Lamination	
Dolomite		Flaser Bedding	
Ooids		Linsen Bedding	
Diamictite		Mudcracks	

## CHAPTER 2 : LITHOLOGICAL UNITS : 2.1 Description of Units

### Brighton Limestone Shaly Dolomite "Member"

The Brighton Limestone was studied in detail by Preiss and Kinsman (1978) and by Miller (1975), so only brief attention was given to the shaly dolomite "member", at the top of the unit.

The shaly dolomite "member" forms a transitional unit between the Sturtian- and Marinoan-age sediments in the Reynella Quarry (Preiss and Kinsman, 1979). The unit consists of interbedded purple shales and dolomicrite beds. The latter contain tepee structures, while the shale interbeds include rounded dolomicrite intraclasts, mud cracks and current ripple marks.

The mud cracks, current ripples and dolomicrite intraclasts imply a supratidal mud flat environment of deposition (Preiss and Kinsman, 1978). The shaly dolomite "member" is transitional between the intertidal and shallow subtidal ooid grainstones of the Oolitic Limestone "Member" of the Brighton Limestone and the supratidal mudflat environment of the Marinoan-age sediments.

### Unit 1.

Unit 1 lies at the base of the Marinoan-age Willochra Subgroup, conformably above the Brighton Limestone, seawards of the Reynella Quarry. This unit is disturbed by faulting and folding along the Field River. Unit 1 is 391 m. thick in this locality. Sprigg (1940) described Unit 1 as consisting of 3 parts: "chocolate siliceous slates with chocolate flakes" (p. 190) succeeded by "chocolate and grey flaggy quartzite and slates" then "Flaggy quartzites".

The lower 300 m. of Unit 1 consists of interbedded purple silts and fine-grained, grey sandstones. The silt and sand interbeds are often on a fine scale, with silt and sand layers under 1 mm. thick. Mudcracks are seen on bedding planes and in section as vertical sand fill between concave upwards mudcracks. (Plate Ib.) Angular purple mudclasts, some of which are curved, occur in grey sand layers. (Sample 837-1B.) Some sand layers are current rippled, sometimes by interference ripples. In places, the rippled sands are covered by a mudcracked silt layer. (Sample 837-1A, Plate XIIa.) Similar curved mudcracks were described as a pseudo trace fossil names *Manchuriophycus* by Glaessner (1969).

Unit 1 becomes sandier towards the top and the uppermost 91 metres contain only thin silt interbeds, giving the sands a flaggy appearance (Plate Ia). Many of the sand layers show current ripples, and abundant interference ripples occur. Thin silt layers drape many rippled bedding surfaces. Mud cracks are less abundant in the upper part of Unit 1, but purple mud clasts occur in many of the sandstone beds. The sandy layers show heavy mineral laminated ripple cross-bedding.

The mud-cracks occurring throughout Unit 1 indicate subaerial exposure of the purple silt and mud layers. Periodically, currents swept the mud-

cracked surfaces, either depositing sand in the shrinkage cracks, or ripping up the curled, angular mud polygons. The mud intra-clasts were transported over short distances (most are still angular and have not been rounded), and redeposited in the grey, rippled sandstones. Some of these sands were covered by shallow water, and reworked, producing interference ripples. Other sand layers had silts, and muds settled on them from still water.

These "cycles" occur throughout Unit 1, and indicate an intertidal to supratidal environment, swept by active tidal or storm currents, and periodically exposed to the air.

## Unit 2. (Marino Arkose)

The name Marino Arkose was first mentioned by Mawson and Sprigg (1950). The Marino Arkose outcrops underneath the Ocean Boulevard bridge on the Field River, and in a nearby railway cutting at Columbia Crescent. The Marino Arkose has been folded in these localities, and partly obscured by a large railway embankment. This has made accurate description and measurement of the upper part of the unit difficult. The Marino Arkose is around 46 m. thick in this locality. Sprigg (1940) measured 55 m. of "Arkose" in this locality, before the bridge and embankment existed.

Unit 2 contains coarse calcareous pebble beds, rich in sub-rounded quartz; fresh, rounded feldspar, and a variety of sub-rounded lithic fragments. (Thin sections 2A and 2C, Plates VIa, b. and c.) Cross-bedded (Plate Ic) and ripple marked sandstones with occasional polygonal mudcracks on silt drapes (Plate Id) are interbedded with thick limestone beds containing cross-bedded coarse sands and pebbles. Dark green rippled sands, with purple silt drapes form flaser-bedded intervals between some limestone beds.

The Marino Arkose represents a more energetic shallow water environment than Unit 1, with pebble conglomerates, and coarse cross-bedded sandstone beds and limestones (Plate Ic). Interference ripples are common in the dark green flaser-bedded sand interbeds, and in the calcareous sandstone beds in the railway cutting near Columbia Crescent.

Interference ripples indicate relatively shallow water conditions with two currents acting at an angle. Possibly a tidal current and a wave-or wind-driven current interacted on these sandstones. A thin silt layer then settled on the interference ripples at slack water.

The flaser-bedded sandstones indicate alternating active currents and quiet water. Flaser-bedding is common on intertidal flats, where sand is periodically transported by tidal currents and waves. During slack water, mud or silt is deposited on the sands from suspension, forming mud drapes (Elliot, 1978).

The cross-bedded sandy and pebbly limestones may represent subtidal sand bodies, transported by active currents. Some of the cross-bedded calcareous sands contain a basal pebble conglomerate, and may represent small tidal channe

which migrated over tidal mudflats.

At the top of the Marino Arkose is a thin, grey coloured ooid grainstone. No cross-bedding is apparent in this layer, which may represent a sheet of ooids swept across the area by a high energy current. The contact with Unit 3 is exposed in the railway cutting. Above the ooid limestone lies a planar-laminated sandstone, which grades up into dark grey coloured finely laminated silts of Unit 3. This sequence represents an end to the shallow supratidal to subtidal environment of Units 1 and 2.

Palaeocurrents were measured on the interference ripples and oscillation ripples, and the orientations of the ripple crests was plotted. Wave oscillation ripple crests have been assumed to run parallel to the strand line or (over a wide area) to the depositional strike (Potter and Pettijohn, 1963) both of which can be parallel to the shoreline. The dominant crest direction in the Marino Arkose is parallel to  $020^{\circ}$ , suggesting that the shoreline was possibly orientated roughly north-south.

A less dominant interference ripple crest direction is parallel to  $130^{\circ}$ . These ripples could have been generated by wind or tide-generated forces, acting at an angle to the shoreline.

### Unit 3.

The silt at the base of Unit 3 is observed in the railway cutting near the road bridge, where it has been tightly folded. Above the silt is a finely laminated green shale, (T.S. 837-3A, Plate VIId) exposed along the Field River, where it has also been folded. A large railway embankment has obscured the lower parts of this unit, where it has been folded by a syncline. These fine-grained silts and shales have not been reworked by currents, and represent deep water deposits. Sprigg (1940) described Unit 3 as "chocolate and grey slates", 60 m. thick (p. 189).

The green shale becomes more sandy upwards, with lensoidal blue-green, fine-grained sand interbeds becoming more frequent. The top part of Unit 3 is excellently exposed along the coast at Marino.

The sand lenses are commonly planar-laminated at the base, with some ripple cross laminations at the top which grade upwards into silts. (Plates IIa and IIb.) Occasionally, sand lenses have a graded sandstone at the base. These structures may be interpreted as the  $T_B$ ,  $T_C$ ,  $T_D$ , and  $T_E$  turbidite divisions of Bouma (1962), with less common  $T_A$  divisions. Ball and pillow structures occur at the base of some of the sand layers. Thin white mud flakes (brecciolas) which show little imbrication, (Plate IIb, T.S.837-3B), occur in some sandy layers. Oxidized iron oxide clots may represent pyrite pseudomorphs.

These sedimentary structures all imply that the sequence represents distal turbidites. However the palaeocurrent pattern does not confirm this.

Dominant palaeocurrent directions run parallel with the implied shoreline

direction, given by the oscillation (wave) ripples in the underlying and overlying sandstone units. A bi-directional palaeocurrent trend occurs at an angle to the shoreline, and may represent tidal currents reworking the sands and silts of Unit 3.

Near the top of Unit 3, the sand bodies become very lensoidal, and are frequently truncated by low angle erosional surfaces. This could indicate gradual shallowing of the sequence, until it was possibly being reworked by storm waves.

#### Unit 4.

Above the blue-green silts and sands of Unit 3, lies a relatively thin (12 m.) sandy and conglomeratic interval, capped by sandy limestone beds. Unit 4 lies above a scoured contact, which forms a small disconformity in the sequence. On the beach at Marino Rocks the contact shows the injection of a basal, tabular cross-bedded arkosic pebble conglomerate (T. S837-4A) into the silts of Unit 3, which must have still been relatively soft. (Sample 837-4B, Plate XIIb).

Along the coastline at Marino, the base of Unit 4 has a distinctive dark green colour possibly due to the growth of chlorite. The pebble conglomerate contains a variety of clasts, including igneous, metamorphic and sedimentary rock fragments, rounded quartz and fresh feldspar grains (T.S.837-4A). Further south the pebble conglomerate is partly replaced by a flaser-bedded, green, coarse sandstone with silt drapes.

The lower part of Unit 4 consists of tabular cross-bedded sands, pebbly intervals and interference rippled sands with silt drapes. Both oscillation and current ripples occur, with cross-bedding. Above the sandstone, lies sandy limestone beds with some cross-bedding.

Shallowing of the depositional area led to the deposition of the thin, coarse-grained, arkosic sandstone and limestone among the silt dominated sequence on the beach at Marino Rocks. The sedimentary features of Unit 4 indicate that it was deposited in an intertidal to subtidal environment.

Horne (1979) found that in areas of tidal channelling, in the Carboniferous coal measures of Kentucky and West Virginia, the offshore silts and muds are truncated by a scoured surface formed at the base of migrating, sandy tidal channels. Above the scour, planar to festoon cross-bedded sandstones occur. Unit 4 shows similar features and may represent a laterally migrating tidal channel, with a scoured base. (Gostin, pers com.).

The palaeocurrent data from Unit 4 consists largely of measurements of interference and oscillation ripple crests. This data may indicate a coastline parallel to  $020^{\circ}$ , like Unit 2. The unidirectional current indicators show a strong trimodal trend parallel to the coastline.

This trend could indicate along-shore wind-generated waves. The tabular cross-beds show a bi-directional trend, parallel to the implied shoreline, with a dominant southerly component.

#### Unit 5.

Unit 5 outcrops of the cliffs to the south of Marino Rocks, where it is 34 m. thick. The base of Unit 5 contains calcareous clasts from Unit 4 and is sandier than the rest of the unit. Fine-grained sand, with some ripple cross-laminae occur at the base of Unit 5. The unit becomes more silty upwards from the base, with only minor sand stringers and starved ripples (linsen beds) occurring in the green silt (Plate IIId).

Linsen beds indicate predominantly quiet conditions, when silt settles out from suspension. Occasionally, relatively active currents deposit isolated sand ripples and thin stringers of fine sand. Linsen beds do occur on intertidal flats (Elliot, 1978), however Unit 5 is dominated by planar laminated green silts, and probably represents deposition in deeper water.

Unit 5 becomes more sandy near the top, where thicker, ripple cross-bedded sand lenses occur (Sample 837-5). Small erosive gutters occur in the thin interlaminated sands and silts at the top of the unit. Partial sand fills occur in starved gutters (Goldring and Aigner, 1982) while others are completely filled with fine-grained sand.

This indicates immediate fill of the eroded gutters. The small gutters appear to be orientated in a roughly east-west orientation, approximately at  $90^{\circ}$  to the implied shoreline. Occasional violent storms may have produced erosion of the substrate by strong seaward-moving rip currents, which carried the channel-fill.

The palaeocurrent measurements of the linsen bedded sand show a strong trend of bi-directional currents at  $90^{\circ}$  to the palaeoshoreline. These may be tidal currents. A smaller component runs parallel to the coastline, with an average bearing of  $190^{\circ}$ , and may represent reworking of sand lenses by weak longshore currents.

#### Unit 6.

The contact between Units 5 and 6 has been affected by faulting on the beach at Marino, and has been weathered badly in a nearby railway cutting. Unit 6 is 5 m. thick in the railway cutting, where it is less disturbed by faulting. The contact between Unit 5 and 6 is relatively sharp, although Unit 5 becomes sandier near the contact.

Unit 6 is a pinkish, heavy mineral laminated medium-grained sandstone, with abundant ripple cross-lamination, highlighted by the heavy mineral layers (Sample 6E, Plate VIIC). Some herringbone cross-laminations occur indicating that tidal currents may have been in operation. An ooid grainstone limestone layer occurs along the coastline (Plate VIIb), at the top of Unit 6. The blue-

grey ooid limestone contains some cross-beds and ripples. Unit 6 represents much shallower, and more energetic conditions than Unit 5.

The palaeocurrent pattern show a strong trend roughly parallel to the palaeocoastline with an average bearing of  $210^{\circ}$ . At an angle to this is a strong bi-directional trend bearing  $160^{\circ}$  and  $330^{\circ}$ , which may represent tidal currents.

#### Unit 7.

The contact between Units 6 and 7 has been disturbed by a bedding plane slip on the coast, and has been weathered in the nearby railway cutting. The contact is however very sharp, with the coarse grained ooid limestone of Unit 6 giving way to a fine-grained, planar laminated shale. Unit 7 is 54 m thick on the coastline, but appears to be absent, or much sandier along the Field River, seawards of the railway embankment.

The lower part of Unit 7 consists of finely interbedded shales and silts, with only minor sand layers. The unit becomes sandier upwards from the base, with thin, linsen-bedded, calcareous sand layers interbedding with the finely laminated silts, (Plate IIIa.) Thin sand lenses, with rippled tops and sharp bases occur. The sandy intervals become more frequent and thicker towards the top of Unit 7 as it grades up sharply into the massive blue-green sandstone of Unit 8.

Unit 7 represents a much deeper, low energy environment of deposition than the intertidal heavy mineral laminated sands of Unit 6. Only thin calcareous sandstone beds and lenses occur in the silty sequence. There is little evidence of extensive reworking of the sandy layers, deposition having occurred below storm wave base. Unit 7 may be analogous to deep water lime muds.

The palaeocurrent data from Unit 7 measured from starved ripples and ripple sand lenses (relatively weak currents) shows a dominant trend to the south-south-west ( $220^{\circ}$ ) with a small component trending in the opposite direction. A clear bi-directional current trends  $270^{\circ}$  to  $90^{\circ}$ , at an angle to the dominant direction, bearing  $220^{\circ}$ . These currents may represent tidal currents, while the dominant current direction runs parallel to the palaeocoastline, and may represent a contourite current.

#### Unit 8.

Unit 8 consists of a blue-green coloured, fine-grained dolomitic sandstone, which contains minor planar-laminated bedding and has a massive appearance. (T.S.837-8). Small slumped bodies of pale yellow, coarser sand occur, and in places convolute bedding occurs. In the railway cutting near "Westcliff" Estate, the sandstone has been strongly weathered and bleached white. However, this has clearly exposed the convolute bedding (Sample 8) and thick, massive sand intervals. There is no evidence of reworking of the sands by current activity, implying it was deposited below storm wave base.

Convolute laminations are thought to be associated with dewatering and consolidation of rapidly deposited sands (Lowe, 1975). Convoluted sediments may have "sufficient strength to resist large-scale liquefaction and fluidization by escaping pore water" but were soft enough to be deformed hydroplastically (Lowe, 1975, p.188). The pale coloured coarser sand bodies represent hydroplastic settling of the coarser sand into the finer, green coloured sand. No water escape structures, like those seen in Unit 11 were observed in this unit.

A likely mechanism of deposition of the thick, massive sand beds and convoluted interbeds is suspension of the sands in a turbidity current and deposition below storm wave base, as the T<sub>A</sub> division of Bouma, or the "Massive Sandstones" Walker (1979) described from the Cambro-Ordovician Cap Enragé Formation, near Quebec.

This unit may represent thick-bedded, massive proximal, high density turbidities, such as those described by Lowe (1982). Unit 8 represents a sudden influx of sandy sediment into the area, possibly as a response to a distant glaciation. Such massive sands can occur by slumping on river delta. Unit 7, 8 and 9 represent a coarsening upwards cycle. Unit 7 may represent offshore prodelta shales and silts, which grade upwards into the slumped sands of Unit 8, and the trough cross-bedded sands of Unit 9, which may represent subaqueous distributary channels. Unfortunately the area of outcrop is too small and there is no other sedimentary evidence, to confirm or deny this idea.

Unit 9.

Unit 9 grades up into 20m. of pink coloured trough cross-bedded sandstone (Unit 9). Some of the trough cross-beds are defined by layers of rounded quartz, feldspar and lithic granules, and brown coloured mud flakes (T.S.837-9, Plates IIIb and Xiic and d). Other cross-beds are defined by brown coloured silty sand and pale silt-free sand layers. (Plate IIIb.)

The mud clasts are very thin and have been curled at the edges. These mud clasts may have originated from an intertidal algal-binded mat (pers. comm. Gostin). This sandstone could thus represent subtidal channels, carrying mud flakes and sand from an intertidal, partly algal-binded mudflat. Unit 9 may represent subaqueous distributary channels or subtidal channels.

Unit 10. (Reynella Siltstone Member)

The Reynella Siltstone Member was named by Thomson (1966) and correlated with the Elatina Formation. Segnit (1940) mistakenly described the unit as "Sturtian Tillite", and described "purplish-grey argillaceous and siliceous shales and slates .... which carry many boulders" (p. 9). Mawson (1949) refuted this, stating that "no other geologist has yet been able to find a convincing tillite in that area" (p. 20).

It is possible that Segnit's "Sturtian Tillite" is a recent beach deposit exposed at low tide, composed of boulders and pebbles, cemented by modern carbonates and containing modern shell fragments (Sample 837-10T). This deposit has the appearance of a tillite, but the modern shell fragments and clasts derived from younger rocks, (e.g. the Seacliff Sandstone Member) indicate otherwise. Mawson (1949) proposed that the "chocolate shales" north of Hallett Cove were a "distant echo" of the Elatina Glaciation in the Flinders Ranges.

The Reynella Siltstone Member outcrops on the wave-cut platform and cliffs near "Westcliff" Estate, where it is 74 m. thick. This unit also outcrops in the railway cutting near Pedler's Creek, where a similar sequence occurs. The contact between Unit 9 and the Reynella Siltstone Member has been disrupted by a series of thick chloritic quartz veins and bedding-plane slippages. However, the contact appears to be gradational.

Unit 10 is dominated by purple silts. A few large cross-bedded sandstone channels around 2 m. thick with angular mud and dolomite clasts occur in the cliffs, (Plate III c and III d.) One large channel is 3 m thick, and extends for 80 m. along the cliff face. The channels have erosive bases which cut down into the silts, producing a concave base. Soft sedimentary slump folds occur at the edges of some channels (Plate IIIe). Small trough cross-bedded pale pink, coarse-grained, mud clast rich sand lenses also occur in the unit. (T.S 837-10g, h, k and Plate VIId.)

Some of the purple silt layers contain coarse sand grains and granules of sub-round quartz, feldspar and lithic fragments. (T.S 837-10A,B,E.) The largest clast observed in the diamictites of Unit 10 is a pebble-sized, rounded clast of microgranite. Such diamictites contain two different grainsize components - fine silt particles which have been transported in suspension and a coarser fraction, which has been directly transported by floating ice (Boulton and Deynoux, 1981). "Clots" of pale pink, coarse-grained sand grains may have been ice-cemented. Thin lenses of coarser grains also occur in the diamictites, and may represent ice-dropped granule trains.

In one diamictite horizon, large (1m. x 0.5m.), pale pink aggregates of dolomite clasts occur. The aggregates of dolomite clasts may have been originally ice-cemented. Unfortunately they lie in a massive diamictite, with no laminations, so it is not possible to confirm that they are glacial drop-stones. Angular pebble-sized clasts of yellow dolomite occur in another layer (Sample 837-10S). The dolomite appears to be penecontemporaneous.

Primary dolomites are associated with many of the Late Precambrian glaciations (Spencer 1971) and there is considerable controversy about the origin of these dolomites (Donnelly, 1981) and Williams (1979, 1981).

Spencer (1975) recorded original or penecontemporaneous dolomite in the late Precambrian glacial sequence of Scotland. He concluded that either the late Precambrian dolomites did not require high temperatures ( $22^{\circ}\text{C} - 55^{\circ}\text{C}$ )

to form, or the Precambrian climatic changes were "extreme and rapid" (p. 235). Wright and Moseley (1975) commented that "Precambrian dolostone genesis could be due to marine environments of very unusual physiochemistry" (p. 310).

Link (1983) described pink dolomites, interpreted as a recrystallized stromatolitic, intertidal or subtidal limestone, associated with tills of the late Precambrian Pocatello Formation of south-eastern Idaho. He concluded that the dolomite was probably diagenetic.

It is worth noting that Bjorlykke et al (1978) recorded Pleistocene cold-water post-glacial carbonates, and that Leonard et al (1981) maintained that it was the rate of clastic supply and carbonate concentration rather than water temperature that controlled carbonate precipitation.

While some of the dolomite clasts appear to be penecontemporaneous in the Reynella Siltstone Member, some dolomite layers have an unusual, irregular appearance and texture, and may be associated with hydrothermal fluids from a nearby shear zone.

Several layers in the Reynella Siltstone Member consists of thinly interbedded shale and very fine grained sand (Plate XIa and T.S 837-10I). These layers have been cut by large, unlaminated silt bodies and disrupted by soft-sedimentary folds and micro-faults (Plate XIb and T.S 837-10J). Some of the laminated units show some cyclicity over 22 silt and shale interbeds and may reflect the effects of the 11 year solar cycle. (Sample 837-10M, 10L.)

Williams (1981 and 1983) studied the laminites occurring in the Elatina Formation at Pitchi Richi Pass, and proposed that rhythmic, varved laminations occurred. He proposed that a connection between "varve cycles" and the 11-year solar sunspot cycle existed in the Precambrian varves.

Most of the interbeds in the locality south of Adelaide show little periodicity, and could be classified as "rhythmites" rather than "varves" (which reflect seasonal deposition of couplets deposited in one year). This is supported by the ripple cross-laminated silt and shale interbeds which occur within the rhythmite horizons. The ripple cross-bedded layers would have been deposited by relatively short-lived currents, and would not reflect annual depositional cycles. The cross-bedded silt and shale may reflect daily cycles of ice melting during the day and freezing at night, affecting the amount of outwash and current strengths over a relatively short period.

Palaeocurrents measured from such ripples show a bimodal pattern. The ripple cross-bedding would have originated in relatively shallow water, possibly on a lake shore or on a tidally influenced shoreline. The palaeocurrents may reflect wind-driven current action, and stream flow from feeder channels originating from distal glacier.

Massive silt layers, without diamictite clasts, may reflect wind-born dust deposited in a lake. Mawson and Sprigg (1948) proposed a "terrestrial loessal origin for the chocolate shale belts of the Adelaide System" (p. 279).

Some of the purple, massive shales and silts in the Reynella Siltstone Member may be of a loessial origin.

Dolomite, possibly originating from a nearby fault, has penetrated more permeable, coarse-grained layers of the purple silt near a small creek outlet south of "Westcliff". This alteration has highlighted wedge-shaped, coarse-grained sand bodies (T.S 837-10P) in a purple diamictite. The wedge-shaped sand bodies are up to 1m. deep and have a polygonal appearance on the bedding plane. Disturbed and folded bedding occurs in some of the sand wedges.

Similar features are produced by ice-wedging or by cryoturbation in the modern permafrosts of North America, Greenland, Scandinavia, Russia and Antarctica. Fossil ice-wedges and involutions have been described in the Quaternary sediments of Europe (e.g. Williams, 1965, and 1975, and by Allen, 1984) Russia (e.g. Kostyaev 1969, Velicko, 1975) and North America (e.g. Washburn, 1980). These features have also been recorded in the late Precambrian Port Askaig Tillite of Scotland (Spencer, 1971 and 1975).

In South Australia, sandstone wedges and involutions have been described in the Mt. Gunson area, on the Stuart Shelf, in sediments of Marinoan age equivalent to the Elatina Formation, and partly equivalent to the Reynella Siltstone Member. Busbridge (1981) studied the sand wedges and involutions occurring in the Cattlegrid Breccia, from the Whyalla Sandstone (equivalent to the Elatina Formation). Tonkin and Williams (1983) also discussed some of these distinctive structures and concluded that they originated in a "Periglacial belt containing permafrost and out-wash sands" (p. 48).

It is unlikely that the Reynella Siltstone Member was directly influenced by eustatic sea-level changes, because it is a monotonous sequence of silts, with only relatively thin sandy intervals and lenses. No marine transgressive or regressive sequences were observed in the sequence, although there is evidence of both subaerial exposure (the possible cryoturbated horizons) and subaqueous deposition (the diamictites, rippled rhythmites and channels).

The Reynella Siltstone Member may reflect deposition in a dominantly glaciolacustrine environment, where the rhythmites, ice-rafted diamictites and massive, possibly loessial, silts were deposited. Shallow water, rippled silts and sands may have been deposited near the lake shore. Glaciofluvial channels, seen as cross-bedded coarse grained sand and gravel-sized mud clast lenses in the silts, fed into the lake.

Proglacial lakes may develop as a result of damming of rivers by ice and by isostatic depressions due to ice buildings. Such lakes may not be extensive but lake deposits can cover large areas when the lakes follow retreating glaciers (Edwards, 1978).

Two possible ice-wedged horizons in the sequence, may have formed in a periglacial belt where permafrosts occurred in the silty soils, after the retreat or draining of a proglacial lake. Silty outwash sands later infilled the wedges. The sequence above the ice-wedged layers may reflect a return to the glaciolacustrine environment.

The sequence at Pedlers Creek is similar to that observed on the coastline, with massive diamictites and silts, gritty layers and lenses and ripple cross-laminated silts and sands. No tillites were observed in either location. Unfortunately the amount of outcrop south of Adelaide in South Australia is not sufficient to confirm glaciolacustrine deposition in the Reynella Siltstone Member

UNIT 11.     (SEACLIFF SANDSTONE MEMBER)

The stratigraphic nomenclature concerning the Seacliff Sandstone Member has been long debated. Thomson (1966) named the unit, and placed it at the base of the Wilpena Group. However, Plummer (1978) regarded the Seacliff Sandstone Member as the uppermost part of the Umberatana Group because it underlay the Nuccaleena Dolomite Equivalent (Unit 12). Forbes (1982) proposed that because the Seacliff Sandstone Member contained dolomite beds at Hallett Cove, it should be regarded as equivalent to the Nuccaleena Dolomite, at the base of the Wilpena Group. Jenkins and Gostin (1983) place the Seacliff Sandstone Member at the top of the Umberatana Group.

The Seacliff Sandstone Member of the Group consists of massive, buff-coloured, fine-grained sandstone beds, (T.S 837-11A) with irregular, lensoidal interbeds of purple sands, silts, shales and dolomite.

The sandstone beds have a massive appearance, with little internal structure. Sand beds commonly have sharp bases on underlying purple shales and silts, with rare sole marks. Some sandstone beds contain angular silt and dolomite clasts, which appear to have originated from the underlying layers truncated by the sandstone bed. Within sandstone beds, load structures often occur, indicating penecontemporaneous partial failure of the sands.

An important, and common feature of these massive sandstone beds was first reported by Gostin and Donaldson (1975), when they discovered dewatering structures in the Seacliff Sandstone Member. Both internal and external dewatering structures occur. The dewatering structures consist of pale, relatively matrix-poor sand in a darker, siltier sandstone bed.

A variety of internal dewatering structures occur. Vertical to sub-vertical parallel sheet structures occur in zones within some beds (Plate IV d.). Laird (1970) described similar features in Wenlockian (Middle Silurian) turbidites from Western Ireland.

Tubular structures exhibit a variety of forms - some are simple subvertical tubes, some thicken upwards to their termination, while others show branching and anastomosing structures. Gostin (pers. comm.) noted that both upward convergence and divergence of branches occurred in some of the massive sandstone beds. Dish structures were "commonly associated with sub-vertical columns and sheets of massive sand termed pillars" in the Pigeon Point Formation (Cretaceous), California and other flysch sequences in western California, Oklahoma and the Southern Appalachians, examined by Lowe and Lo Piccolo (1973). However they are rare in the Seacliff Sandstone Member.

External dewatering structures are less common and are confined to only a few bedding surfaces where they have been preserved. The sand volcanoes similar to those described by Allen (1982) are rounded domes with a central feeder column. The sand volcanoes are usually covered by a thin undisturbed shale or silt layer, deposited after dewatering had finished. The structures within the sandstone beds, and on the bedding surfaces, indicate they were deposited rapidly, producing occasionally violent dewatering. Rare sand dykes also occur in the sequence (Sample 837-11B and Plates XI a. and b.).

The presence of occasional sole marks on the sharp sandstone bases, and the occurrence of quite large (3 cm. x 10 cm.) dolomite and silt clasts distributed within the massive sandstone beds (Sample 837-11D) above their bases imply that some sort of high density, mass flow had occurred. The features seen in the Seacliff Sandstone Member point to possible deposition from a liquefied flow. The liquefied flow may have been triggered by successive failures on a slope, possibly influenced by earthquakes (Lowe, 1975), or caused by tsunamis, storm waves or the weight of rapidly deposited sediments (Rupke, 1978).

After dewatering had occurred, thin silt layers, or interbedded shale and dolomites were deposited in quieter conditions. Considering all the above features, the Seacliff Sandstone Member is considered to have formed in a slope or a proximal turbidite environment. Some reworking of the sands had occurred, producing trough cross-bedded heavy mineral laminae with imbricate silt and dolomite clasts and granules of quartz, feldspar and rock fragments (Plate IVe)

This relatively small scale (30 cm. thick) trough cross bedding could be the result of reworking by residual turbidity currents, after the high-density load was deposited. Lowe (1982) described similar features in the Precambrian Thunderhead Sandstone in the Southern Appalachian Mountains. However the palaeocurrent directions measured appear to trend towards the proposed shoreline. Erosion and reworking of the liquefied flow deposits by storm waves (although no hummocky cross strata were observed) may have produced the trough cross-bedding.

#### UNIT 12.      NUCCALEENA DOLOMITE EQUIVALENT

The Nuccaleena Dolomite becomes lenticular in this locality and lenses of dolomite occur in the Seacliff Sandstone Member, however the Nuccaleena Dolomite Equivalent is thicker (9m.) and more extensive than the dolomite lenses. The contact with the underlying Seacliff Sandstone Member is conformable, although in the Hallett Cove region, it appears to have been either a tectonically disrupted, or an interfingering contact. It seems more likely to be tectonically disrupted, because it is associated with a nearby anticline, in a sequence riddled with bedding plane slips, and small faults.

The Nuccaleena Dolomite consists of thinly interbedded pale pink dolomite layers and purple shale layers [T.S.837-12]. There are no mud cracks or intra-clast breccias to indicate prolonged subaerial exposure of the dolomites and shales, and in this locality, no tepee structures were observed. The Nuccaleena Dolomite in the Hallett Cove area is thus likely to have been deposited in a low energy environment below storm wave base. It grades conformably upwards into a sequence of reddish sand and shale interbeds (Unit 13).

#### UNIT 13.

This sequence of red siltstones and fine-grained sandstones of the Brachina Subgroup has been studied in detail by Dyson et al (in prep.), and only the lower fifty metres of this unit have been measured for this study.

The section measured consists of laminated shales, with extensive sharp-based sand interbeds. Sole marks (including tool marks and flute marks) occur on the base of many sand beds. The heavy mineral laminated sandy intervals typically show parallel bedding at the base, with rippled cross-bedding at the top, which then grade up into shales. Some sand units show climbing ripples. These couplets of sand layers followed by planar laminated silts, are repeated throughout the section measured (Plate Vc).

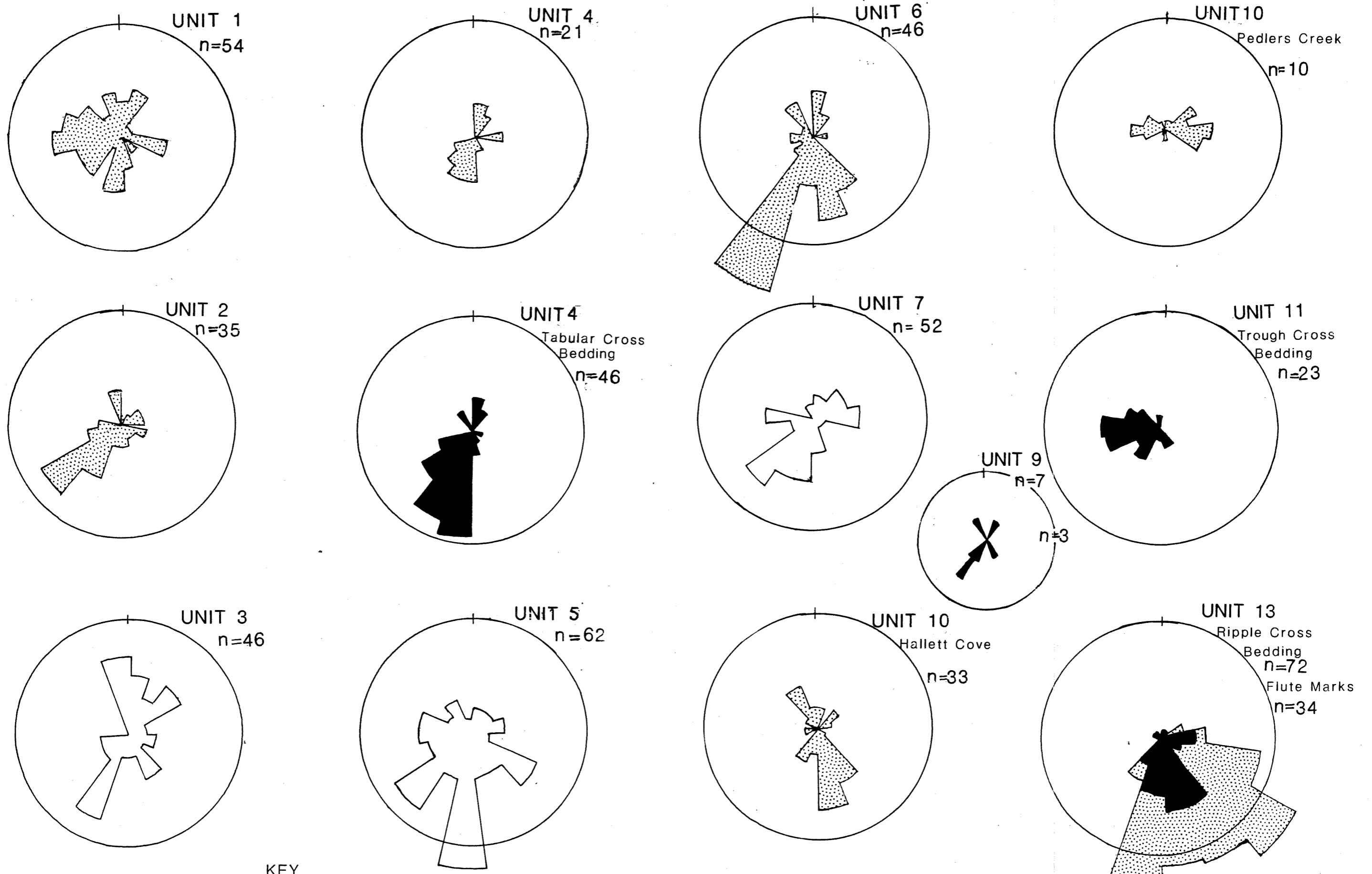
The sequence has been interpreted as comprising turbidites. The planar laminated sands represent the  $T_B$  division of Bouma (1962). The climbing ripples or, more commonly, the rippled sands above the  $T_B$  division represents the  $T_C$  division, and the planar laminated silts and shales represent the  $T_D$  and  $T_E$  divisions. No  $T_A$  divisions (massive, graded sand) occur. Walker (1979) proposed that similar sequences in the Ordovician Cloridorme Formation at Grande Vallee, Quebec were deposited in a distal turbidite environment.

The palaeocurrent pattern shows a distribution typical of turbidites. The flute mark measurements indicate the local downslope direction, which bears south-south-east. This is at approximately  $90^\circ$  to the implied palaeocoastline determined from the oscillation ripple crests of the sandstones of Units 2 and 4.

The turbidites have not been reworked by currents - both the palaeocurrent measurements and field observations confirm this. This indicates deposition below storm-wave-base.

Hummocky cross stratification (HCS) at storm-wave-base first occurs some 200 stratigraphic metres above the top of the Nuccaleena Dolomite Equivalent, further south (Dyson et al, unpubl.). The sequence becomes sandier, and swaley cross stratification (at fairweather-wave-base) first occurs around 550 m. above the Nuccaleena Dolomite Equivalent (Dyson et al, unpubl.). The top of the Brachina Subgroup becomes more sandy with evaporites pseudomorphs occurring in the sandstones (Dyson and Von der Borch, 1983) and grades up into the ABC Range Quartzite at Port Stanvac. This reflects shallowing in the basin of deposition near the end of the Marinoan period, as represented in the type-area south of Adelaide.

PALAEOCURRENT DATA: UNI-DIRECTIONAL INDICATORS



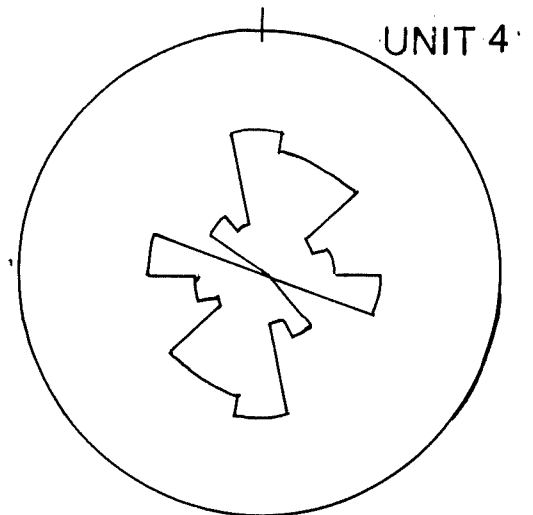
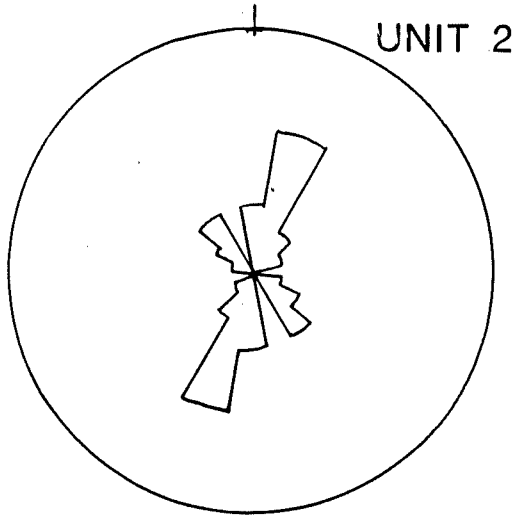
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RADIUS=10

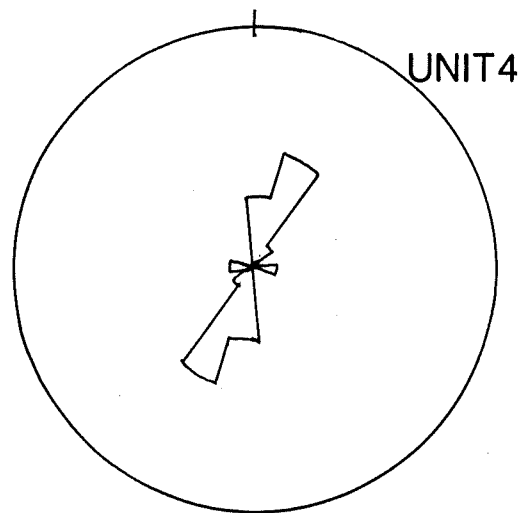
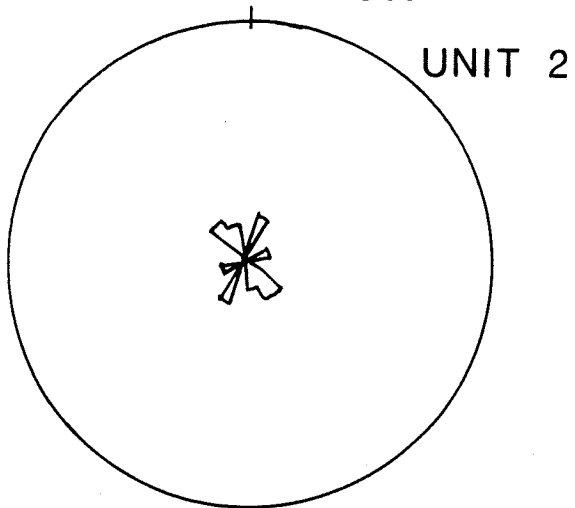
- STRONG CURRENTS  
(cross bedding)
- MODERATE CURRENTS  
(ripple marks)
- WEAK CURRENTS  
(linsen bedding,  
starved ripples)

# PALAEOCURRENT DATA: BI-DIRECTIONAL INDICATORS

## Interference Ripple Crests

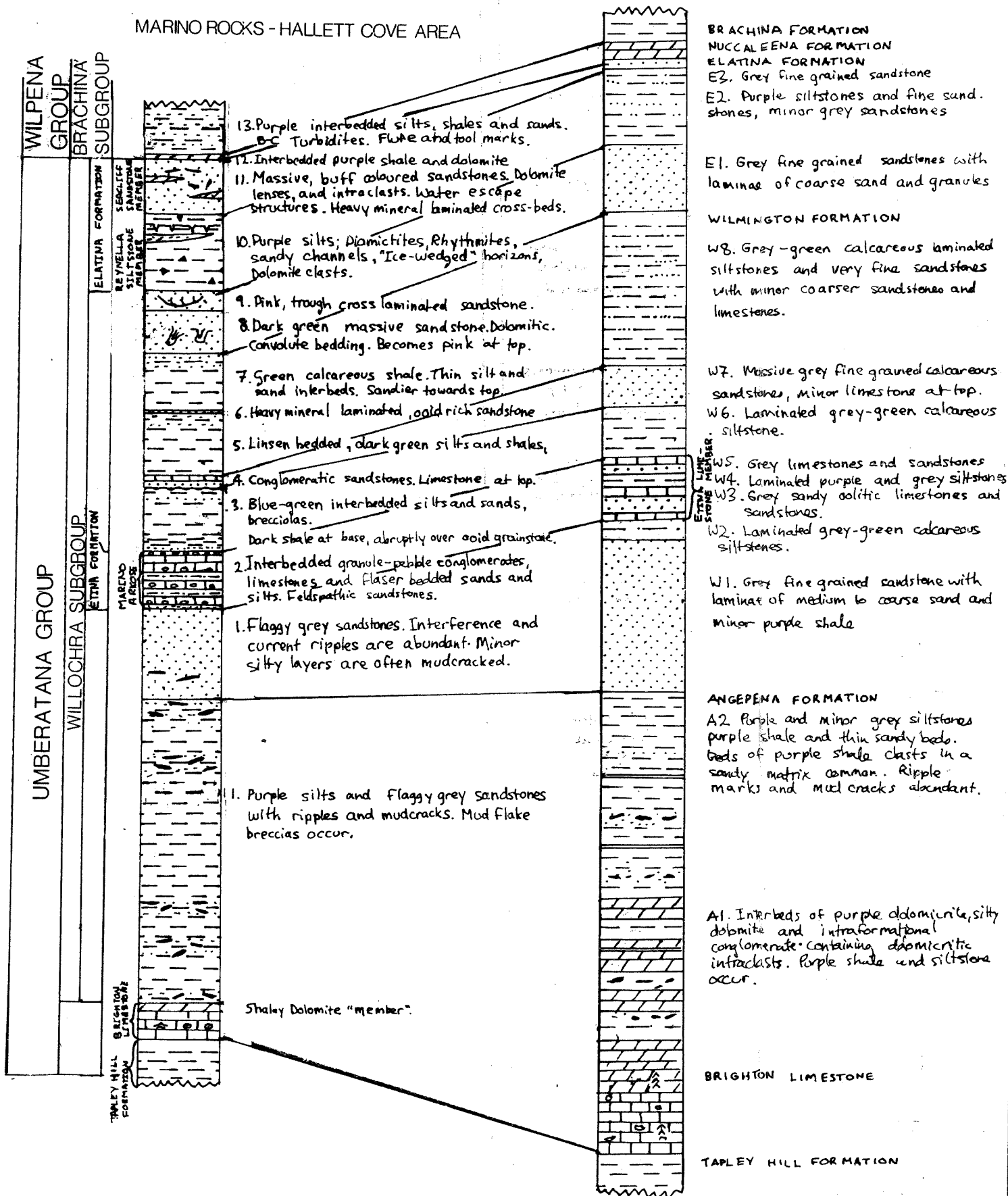


## Oscillation Ripple Crests



CORRELATION WITH LOCALITY IN THE WESTERN FLINDERS RANGES

WYACCA BLUFF -BUCKARINGA GORGE AREA



(From Miller, 1975)

## 2.2 Comparison with the western Flinders Ranges

Miller (1975) measured sections in the Wyacca Bluff-Buckaringa Gorge area in the western Flinders Ranges, 270 km north of Adelaide, and correlated them with sections measured at Waterfall Creek, Hallett Cove, from the Tapley Hill Formation to the base of the Reynella Siltstone Member. Figure 4 is a comparison of the section measured in the Wyacca Bluff-Buckaringa Gorge area with the section measured for this thesis.

The two sections show very similar sequences of alternating sandstones and siltstones. The Seacliff Sandstone Member appears to be much thinner or absent in the Wyacca Bluff area. Miller (1975) correlated Unit E1 with the "massive grey sandstones near the top of the Waterfall Creek Section" (P.17), however it is possible that the Seacliff Sandstone Member equivalent is Unit E.3. which "lies" between the Reynella Siltstone Member and the Nuccaleena Dolomite. Unit 3 consists of a "light grey very fine-grained feldspathic sandstone ... with heavy mineral trough cross-laminae" (Miller, 1975, p.12). Unit E.3. varies from 15m. thick to being absent, in the Wyacca Bluff locality, compared with a thickness of 53 m. at Hallett Cove. Apart from this difference, the two Marinoan sections show very similar sequences. It is thus possible that the cycles of sea level rise and fall recorded in the Marinoan type section have some regional significance.

## 2.3 Tectonic cycles in the Marinoan type section

Jenkins and Gostin (1983) reinterpreted the late Precambrian and Cambrian sequence of the Adelaide fold belt in terms of tectonosedimentary cycles (Fig.5.). The lower part of the Marinoan type section lies in the "Kurna" cycle, which began with the "euxinic" phase of deposition represented by the Sturtian Tapley Hill Formation and ended with the "molasse" phase of deposition represented by the ABC Range Quartzite. (Jenkins and Gostin, 1983, p.41.)

The intervening section, studied in the Marino Rocks - Hallett Cove area for this thesis was shown to reflect glacio-eustatic cycles of basinal conditions followed by short shallowing episodes, superimposed on a trend of "progressive subsidence" (p.42). The ABC Range Quartzite records a shallowing in the basin during the "Molasse" phase, at the top of the Marinoan type section south of Adelaide.

## 2.4 Petrological features of the sandstone units

An unusual feature of the sandstone units and some of the sandy silts is that they contain remarkably fresh, subrounded feldspars. In general, potassium feldspar is more abundant than plagioclase. In the carbonate cemented arkosic layers of Units 2 and 4, only minor sericitization or kaolinization of most of the potassium feldspars has occurred, while the plagioclase has undergone more alteration, however weathered feldspar grains are not abundant. Folke (1968) interpreted similar arkoses as coming from a source area with an arid or cold palaeoclimate.

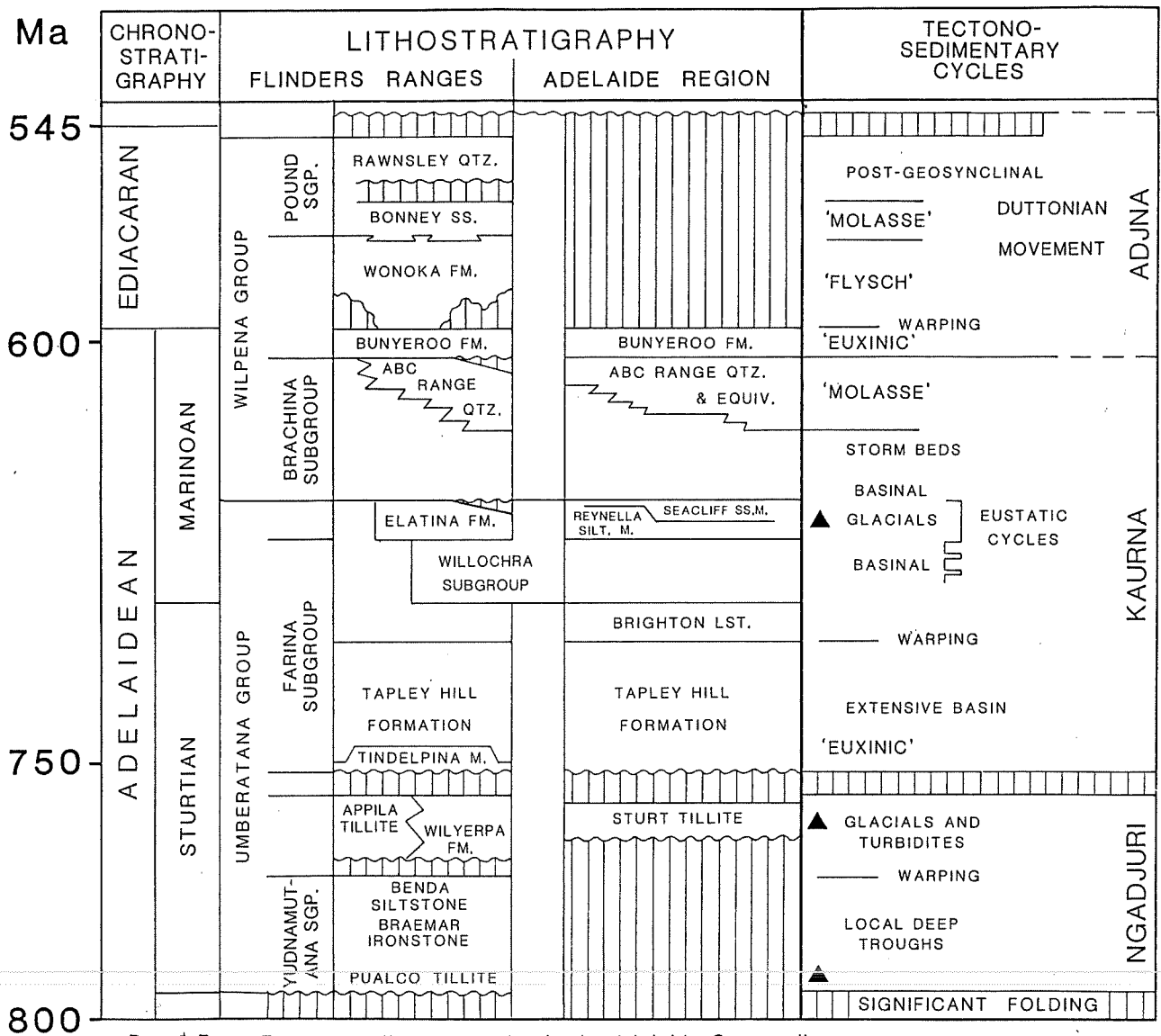


Figure 5: Tectono-sedimentary cycles in the Adelaide Geosyncline. Names used are of aboriginal tribes which inhabited areas where cycles are well displayed, with the exception of ADJNA, Kujani for 'hill'. Arbitrary vertical scale. (FROM JENKINS AND GOSTIN, 1983)

Metamorphic gneissic rock fragments, composite quartz grains, red porphyritic volcanic clasts, minor fine-grained volcanic clasts, "granitic clasts" of quartz and feldspar and sedimentary rock fragments (chert, shale clasts) also occur in the sandstones, indicating a variety of source rocks. It is possible that reworking of older sediments, as well as erosion of relatively fresh granite bodies, gneissic units and volcanic deposits, has produced the diversity of clasts in the sandstones.

The Marinoan glaciation may also have influenced the petrology of the sediments deposited in the Marinoan period. The arid or cold palaeoclimate possibly implied by the petrology of the sandstones could indicate that a prolonged glacial era influenced sediments during deposition of the lower and middle Marinoan type section.

### CHAPTER 3. : PROBLEMS ASSOCIATED WITH THE LATE PRECAMBRIAN GLACIATIONS

Much controversy has existed over the stratigraphic significance of the late Precambrian glaciations, which are represented by the Sturt Tillite and Elatina Formation in South Australia. Schermerhorn (1975) proposed that most late Precambrian tillites were "essentially the product of crustal instability" (p. 241) and represent tectonically controlled mass-movement deposits, some of which were derived from mountain glaciations.

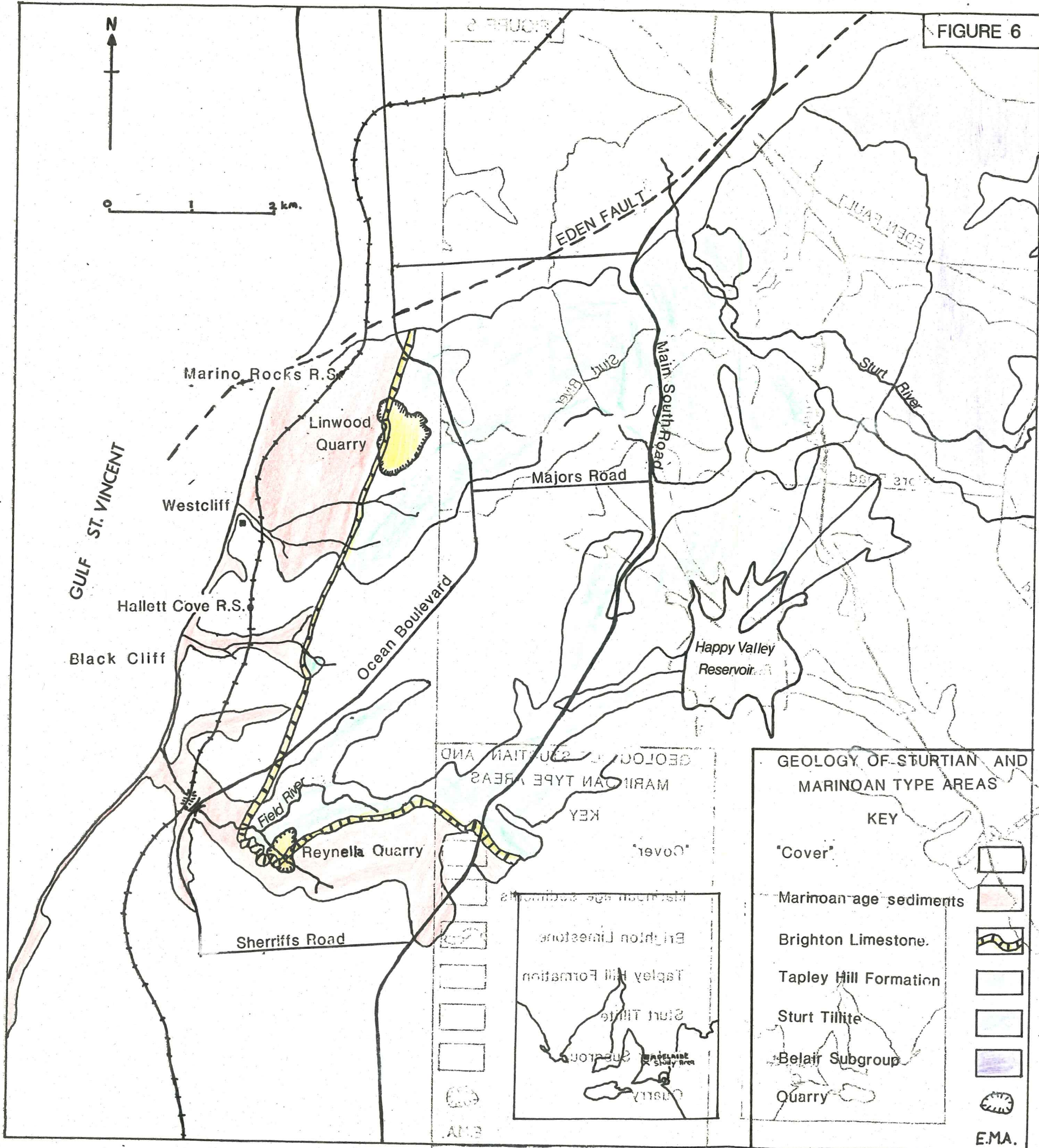
Even if a glaciogenic origin for the late Precambrian "tillites" is accepted, there is still much debate over the stratigraphic significance of tillites. Dunn et al (1971) maintained that the late Precambrian glaciogenic rocks could be used as a "world-wide Precambrian chronostratigraphic unit" (p. 498).

Crawford and Daily (1971) however, held that the late Precambrian glaciations, which occur on every continent except Antarctica (Chumakov, 1981) were not synchronous. They proposed that the glaciations occurred progressively as the poles migrated over the various continents.

Piper (1973) maintained that if the glaciations reached low latitudes, they could be used as stratigraphic marker horizons. He studied the late Precambrian sequence of Africa (900-500 m.a.) and concluded that the tillites of Africa were deposited at low latitude. Wright and Moseley (1975) concluded that Precambrian glacial and volcanic facies are the "most promising" for correlation.

Chumakov (1981) proposed that the "roughly synchronous glacial formations and groups form wide regional glaciohorizons" (p. 373), which are concentrated into two Precambrian Stratigraphic horizons ("glacio-complexes"). He constructed a hierarchy of glacial events, reflecting "the interrupted and oscillatory dynamics of glaciations" (p. 387). The section studied in this project may reflect the indirect effects of such oscillations. The eustatic relative rises and falls in sea level may have occurred in response to waxing and waning of a distant ice-cap. More recently, Trompette (1982) concluded that the "multiplicity of (Precambrian) glaciogenic formations makes their use for worldwide correlations insecure".

FIGURE 6

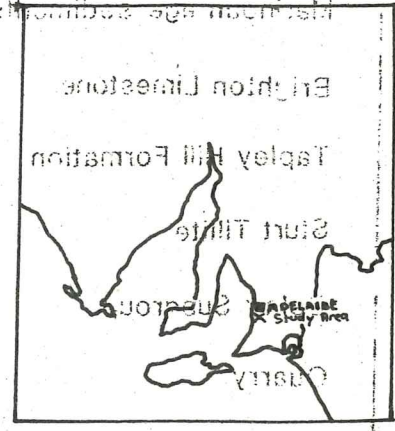


**GEOLOGY OF STURTIAN AND MARINOAN TYPE AREAS**

KEY

- "Cover"
- Marinoan age sediments
- Brighton Limestone
- Tapley Hill Formation
- Sturt Tillite
- Belair Subgroup
- Quarry

EMA.



after Forbes (1983)

after Forbes (1983)

## CHAPTER 4.      STRUCTURE

A number of faults, bedding plane slips, tension gashes and meso-scale folds have deformed the sediments of the Marinoan type-area. These features had to be located and mapped, before accurate sections could be measured. Because this thesis aims to describe the sedimentological aspects of the area, only a brief discussion of the structural features will be made. Ian Clark (in prep.) has recently made a detailed study of the structure of the Hallett Cove area.

The late Precambrian Sequence in the Adelaide area youngs to the west, from the Torrensian Aldgate Sandstone in the Adelaide Hills, to the late Marinoan ABC Range Quartzite Equivalent at Port Stanvac (Figure 6.).

### 4.1      Folding in area

The structure of the area is dominated by a number of southerly plunging folds. The only exception to this trend observed in the area, is a doubly plunging anticline which runs along the coastline in the Marino Rocks area. The axial planar cleavage is well developed in the interbedded silts and sands of Unit 3, which have undergone low grade metamorphism, with the growth of some chlorite and biotite in the core of the fold. Unit 3 is the oldest part of the sequence to outcrop on the coast.

The axial planar cleavage dips  $40^{\circ}$  to the east, indicating that the fold axial plane is inclined to the east. The anticline plunges  $20^{\circ}$  to the south at the closure of the fold on the wave-cut platform 600 m. south of the Marino Boat ramp, and plunges  $10^{\circ}$ N. near the boat ramp.

A southerly plunging syncline has been inferred on the 1:50,000 scale Noarlunga Map Sheet, 500 m. inland in the Marino Rocks area. The syncline has a southerly plunge of approximately  $10^{\circ}$ , with a steeply dipping westerly limb (dip approximately  $80^{\circ}$  E.). The syncline and the adjacent doubly plunging anticline together show "S" vergence indicating that they lie parasitically on the westerly limb of a large southerly plunging anticline.

Another parasitic anticline outcrops in Waterfall Creek, 80 m. from the beach. The anticline plunges  $8^{\circ}$  to the south. In the Hallett Cove the easterly limb of this anticline forms curved dip slopes of the Seacliff Sandstone Member in the coastal cliffs (Plate V c.). On the westerly limb of this anticline a series of meso-scale, tight, angular synclines and anticlines plunging  $12^{\circ}$  south outcrop on the wave-cut platform at Black Cliff.

In the coastal cliffs the southerly plunging folds have shattered the sandstone units, particularly those which are more massive (i.e. Unit 7 and Unit 10). These sandstones have been fractured, and many quartz tension gashes have developed in the Seacliff Sandstone Member. The silt units show a well developed, easterly dipping cleavage.

The sequence along the Field River has been folded into a series of meso-folds, with a southerly plunge, averaging  $10^{\circ}$  south. One of these meso-folds has an overturned westerly limb, which dips steeply east, but young to the west (Plate V d.). This fold lies 75 m. east of the Ocean Boulevard Bridge. These folds were produced by compression at the time of formation of a major southerly plunging anticline, called the "Great Anticline" by Howchin (1904). The anticline outcrops in the Reynella Quarry, and dominates the structure of the study area. The anticline plunges  $10^{\circ}$  south.

The folding seen in the area occurred during the Delamerian Orogeny. The Delamerian Orogeny was a period of folding, faulting, granite intrusion and regional metamorphism, during the late Precambrian to the early Ordovician (Daily et al, 1975).

#### 4.2 Faulting in area

A number of north-south trending faults disturb the sequences along the coastline and the Field River. Two main types of faults are seen, sheared fault zones and more brittle fault breccia zones. Two main periods of faulting have disturbed the sequence. The rocks of the Adelaide region were affected by Palaeozoic faulting, which occurred during the Delamerian Orogeny and brittle Cainozoic faulting associated with the block faulting and tilting which produced the present day St. Vincent Basin (Daily et al, 1976).

To the south of "Westcliff" Estate, a Palaeozoic sheared, normal fault zone has disturbed the Reynella Siltstone Member and the Seacliff Sandstone Member (Plate V b.). The fault plane strikes  $025^{\circ}$  and dips  $65^{\circ}$  to the east. A zone of sheared and dolomitized rock mark the fault. Strongly anastomosing cleavage associated with the fault has developed in the Reynella Siltstone Member on the wave-cut platform.

Prominent yellow dolomite layers extend outwards from the fault across the wave-cut platform, and up a nearby gully. These layers are irregular in shape, and are rich in calcite veins. These dolomites may have originated from hydrothermal solutions associated with the fault. Coarser grained wedge-shaped sand bodies in silts have apparently been preferentially dolomitized, highlighting their appearance.

Tertiary faults can be seen cutting the wave-cut platform between Marino Rocks and Hallett Cove. Prominent fault breccias, cemented by yellow iron-rich dolomite, form resistant outcrops on the wave-cut platforms (Plate 837-Va.) These faults show evidence of more brittle deformation occurring at a shallow depth compared with the older more ductile Palaeozoic faults.

Bedding plane slips, consisting of chlorite covered quartz vein fibres, often occurred at contacts between different rock units. In one locality near "Westcliff", several generations of vein fibres, one on top of the other, record different directions of movement during folding. The occurrence of the bedding plane slips at contacts may reflect the different responses of the sandstones and silts to folding.

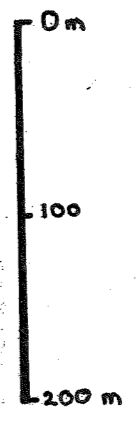
Sedimentary Structures

Unit	Lithology	CLAY SILT FINE SAND M. SAND C. SAND V. C. SAND GRAVEL PEBBLE	Bedding	Tabular Cross Bedding	Trough Cross Bedding	Current ripples	Oscillation ripples	Polygonal mudcracks	Flaser Bedding	Flute marks	TA	TB	TC	TD	TE	Conolute Bedding	Load casts	Inter-fer- ence Ripples	Additional	SUPRA- TIDAL	INTER- TIDAL	SUB- TIDAL	BELOW STORM WAVE BASE
WILPENA GROUP																							
Brachina Subgroup																			Hummocky- Cross-Strata, then Swaley- Cross-Strata with evaporites.				
13			X							X		X	X	X	X		X	X	Climbing ripples, Heavy mineral laminations.				
12			X																Dolomite and sil- t clasts, Devolting structures, sand volcanoes, pillars, tubes etc				
Seacliff Sandstone Member			X		X					X Rare	?						X						
11																			Laminates, crypturbed palaeosols, large channels.				
Reynella Siltstone Member			X		X																		
10			X		X														Mod. Flakes, Slumped bodies of coarse sand, Massive texture				
9																X	?						
8																							
7			X			X																	
6			X																Heavy minerals, Linsen bedding, sand stringers, Gutters near top.				
5			X																				
4			X	X	X	X	X		X								X		Scoured contact				
3			X								X	X	X	X					Breccias, Low angle fractures				
2			X								Less common	?	?	?									
UMBERATANA GROUP																			Ooids				
Marino Arkose			X	X	X	X	X	X	X					X				X					
2																							
			X			X		X										X	Curved Mudcracks on rippled surface				
			X		X														tepees stromatolites				

SUMMARY OF PALAEO-ENVIRONMENTAL INDICATORS AND INTERPRETATIONS.

KEY

- silt
- sandstone
- interbedded sand and silt
- limestone
- dolomite
- diamictite
- mud intraclasts
- pebble conglomerate
- ooids



## CHAPTER 5. DISCUSSION

The Marinoan sequence in the Marino Rocks-Hallett Cove area is dominated by shelfal marine deposition, until the basinal turbidites of Unit 13. The only terrestrial deposits occurring in the sequence are the periglacial outwash plain and glaciolacustrine deposits in the Reynella Siltstone Member.

The Brighton Limestone, at the top of the Sturtian, represents a supra-tidal to intertidal environment (Preiss and Kinsman, 1978). The Brighton Limestone grades up into Unit 1 at the base of the Marinoan section, which represents a continuation of the shallow water, intertidal to subtidal conditions. The Marino Arkose (Unit 2) was deposited in an energetic intertidal environment, with small tidal channel deposits, sandy limestones and flaser bedded sands and silts.

Abrupt deepening of the basin of deposition or a rapid transgression lead to the deposition of dark coloured, laminated silts and then shales of Unit 3 abruptly over a sheet of ooids at the top of Unit 2. Unit 3 becomes sandier upwards, with sharp-based sand lenses interbedded with the silts, representing shallowing upwards possibly to storm wavebase, where the sands were eroded and truncated into discontinuous lenses.

A minor disconformity in the sequence occurs at the scoured contact between the silts of Unit 3 and a coarse basal conglomerate in Unit 4. Unit 4 represents deposition in an intertidal environment during an abrupt and brief shallowing in the basin of deposition.

The linsen bedded siltstones of Unit 5 were deposited below storm wave base, and may reflect a deepening in the basin. A brief episode of shallowing saw the deposition of thin intertidal heavy mineral laminated and ooid-rich sandstone (Unit 6). The thinly interbedded shales, silts and sands of Unit 7 represent a return to below storm wave base deposition. Unit 7 grades up into the thick massive sandstones with convolute bedding. Unit 8 may represent proximal turbidites, deposited below storm wave base.

Unit 8 grades upwards into the intertidal trough cross-bedded sandstones of Unit 9. Units 7, 8 and 9 represent a shallowing of the basin of deposition, through the distal turbidites, (or prodelta shales) of Unit 7, to the proximal (delta slope?) sands of Unit 8 into the trough cross bedded sands (small distributary channels?) of Unit 9.

Unit 9 grades upwards into the Reynella Siltstone Member (Unit 10). Glaciofluvial channels, glaciolacustrine rhythmites and diamictites and two possible cryoturbated soil horizons occur in this unit, indicating terrestrial conditions. Sharply above the purple silts of the Reynella Siltstone Member lies the buff-coloured, fine-grained, massive sand beds of the Seacliff Sandstone Member (Unit 11.). The Seacliff Sandstone Member represents deposition of proximal grainflow sands at or just below storm wave base.

The Nuccaleena Dolomite equivalent (Unit 12), consisting of thinly inter-

bedded dolomite and purple shale, reflects deepening in the basin of deposition. Unit 12 becomes siltier upwards and grades up into the red siltstone and sandstone interbeds of Unit 13. The lower part of this sequence consists of distal turbidites. This unit gradually shallows upwards to the ABC Range Quartzite which represents the top of the Marinoan in the type area.

The fluctuating sea level may reflect eustatic rises and falls in sea level produced by associated glacial activity. The Marinoan glaciation is directly reflected in the Reynella Siltstone Member; however the indirect effects of a more prolonged glacial period may have influenced deposition over much of the lower part of the Marinoan type section. The sequence measured by Miller (1975) in the Wyacca Bluff-Buckaringa Gorge area shows similar cycles of sea level change, indicating that such changes were of regional significance. The rises and falls in sea level could therefore reflect eustatic world-wide sea level changes related to the late Precambrian glaciations.

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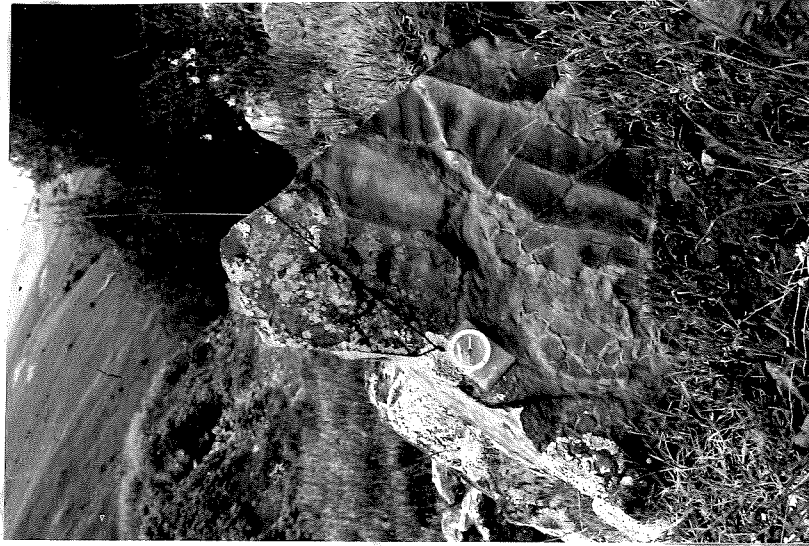
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APPENDIX A : PHOTOGRAPHIC PLATESPLATE 1.

- a. Unit 1 : Flaggy, fine-to-medium-grained sandstone with thin silt interbeds. Small mud flakes occur in the upper sand layers. Both oscillation and current ripples occur in the sandstone layers.
- b. Unit 1 : Subvertical grey sandy mudcrack fills can be seen in profile, cutting purple mudcracked silt layers.
- c. Unit 2 : Tabular cross-bedded, coarse-grained calcareous sand. Several cross-bedded layers occur.
- d. Unit 2 : On the surface of a thick sandstone layer, ladder ripples and polygonal mudcracks occur.



100/100

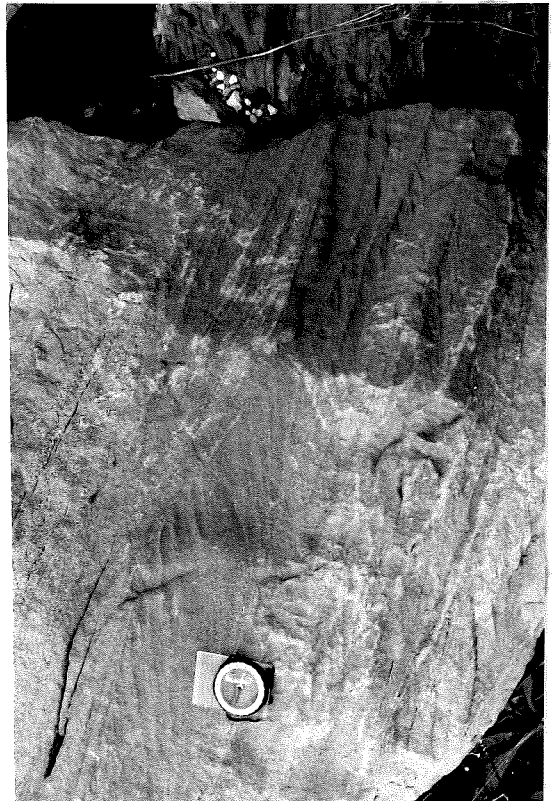
100/100

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A

100/100

## PLATE II

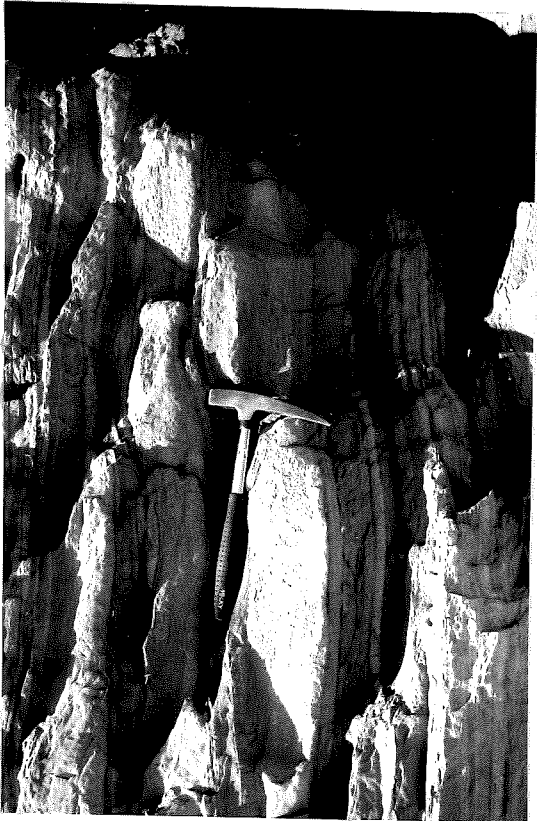
- a. Unit 3 : Sharp-based sandstone lenses, with massive sand at the base, which grade up into silty, ripple cross-laminae. Planar laminated silts cover the sand lenses.
- b. Unit 3 : Sharp-based sandstone layer, rippled at the top. Isolated sand lenses occur in a silty layer, above which is a sand layer containing thin, curled, mud flakes (brecciola).
- c. Unit 5 : Linsen bedded silt, with starved sand ripples and thin cross-bedded rippled sand lenses.



B



C



A

PLATE III

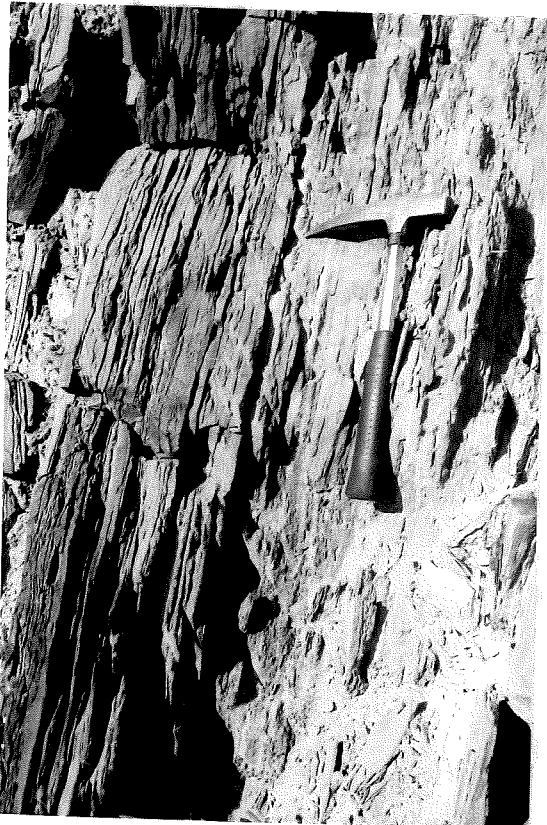
- a. Unit 7 : Thinly interbedded calcareous silts, and fine grained sands. Small, low angle ripple cross-laminae occur in some of the sands.
- b. Unit 10 : General view of cliffs near "Westcliff" (Cliffs are approximately 25m, high). The purple silts contain paler cross-bedded sand channels (1.5m measuring stick at base of cliff).
- c. Unit 10 : A small channel composed of pale pink mud clasts and granules in a silty carbonate cement. Cross-beds occur in the channel, and a slump fold occurs near the channel edge.
- d. Unit 10 : Slump fold at edge of channel.



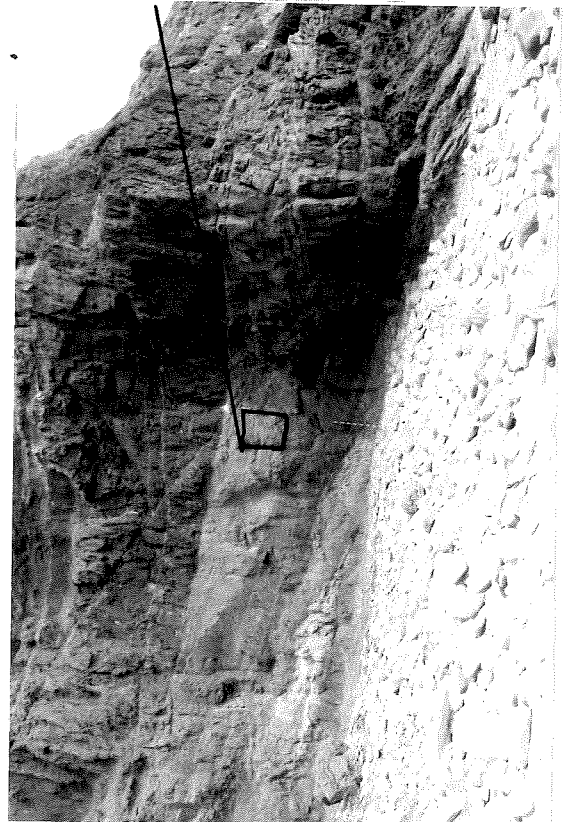
C



E



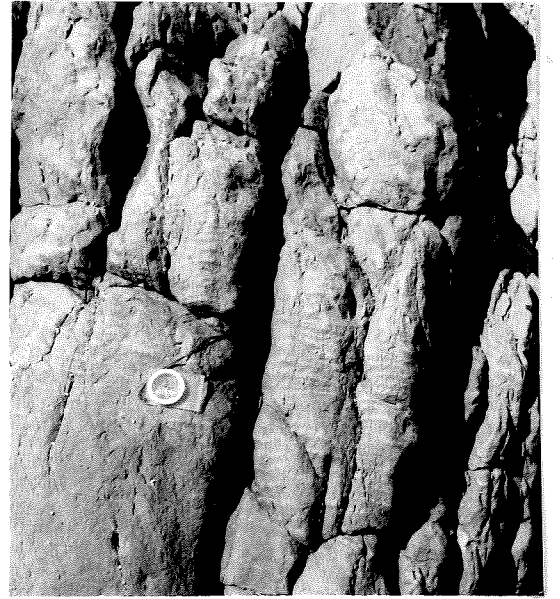
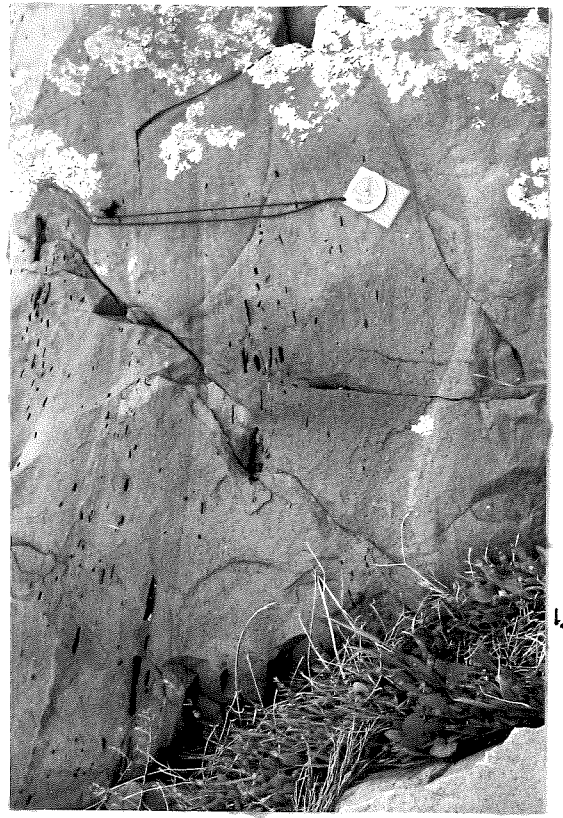
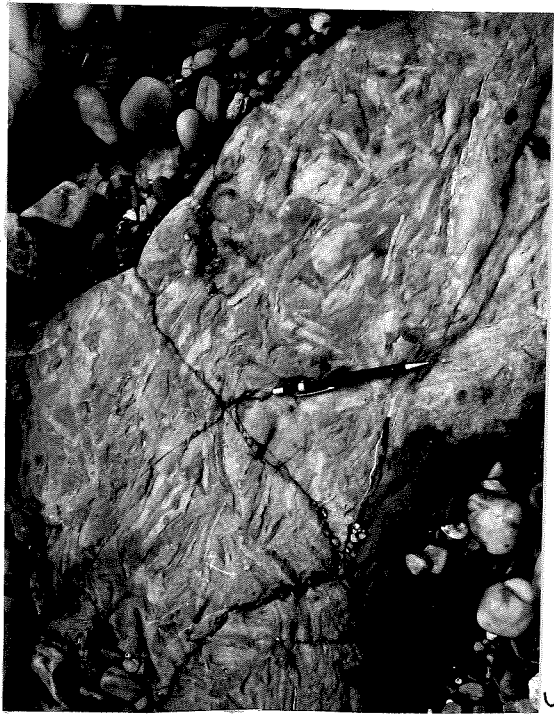
A



D

PLATE IV.

- a. Unit 10 : Dolomitized, buff coloured "frost wedge", around 75 cm. deep, in purple silts.
- b. Unit 10 : Rhythmites consisting of darker coloured shale layers interbedded with lighter coloured sandy layers. There is no obvious cyclicity in these interbeds.
- c. Unit 11 : Randomly oriented matrix supported, yellow dolomite clasts, in a pale coloured massive sandstone. This layer may represent deposition from a grain-flow.
- d. Unit 11 : Pale-coloured matrix poor "sheet" structures in a darker coloured, matrix rich sandstone.
- e. Unit 11 : Trough cross-bedding with imbricate mud clasts, above a massive sandstone layer with water escape structures.



## PLATE V

- a. Tertiary fault breccia, with angular, randomly oriented clasts derived from Unit 6.
- b. Palaeozoic shear zone, near "Westcliff". Paler coloured dolomitized layers occur near the fault zone.
- c. Folded dip-slope at Hallett Cove. The dip-slope is formed by the westerly limb of the anticline which outcrops in Waterfall Creek. The interbedded turbidite silts and sands of Unit 13 have an appearance similar to those described by Walker (1979, Figure 5, p. 93).
- d. Mesofolds in the Field River (75 m. from the Ocean Boulevard Bridge). The anticline has an overturned easterly limb.



B



D



A



C

## PLATE VI

- a. 837-2A : An elongate gneissic metamorphic clast consisting of composite quartz and foliated mica occurs in the centre of the frame. In the top right-hand corner, is a possible volcanic clast, with faint plagioclase laths. "Tartan" twinning in fresh microcline near the top left-hand corner can be seen.

Crossed Polars, 30 XS

- b. 837-2A : There are two main grain sizes in this slide. Vacuolized orthoclase occurs near the top of the photo. A number of twinned plagioclase grains occur.

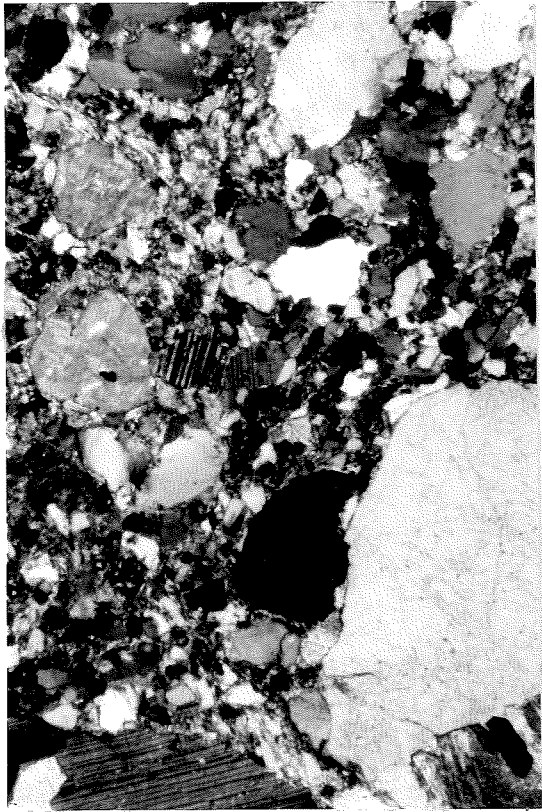
Crossed Polars, 30 XS

- c. 837-2A : Composite quartz, with bubble trains and sutured grains occurs next to a rounded shale (or phyllite) clast.

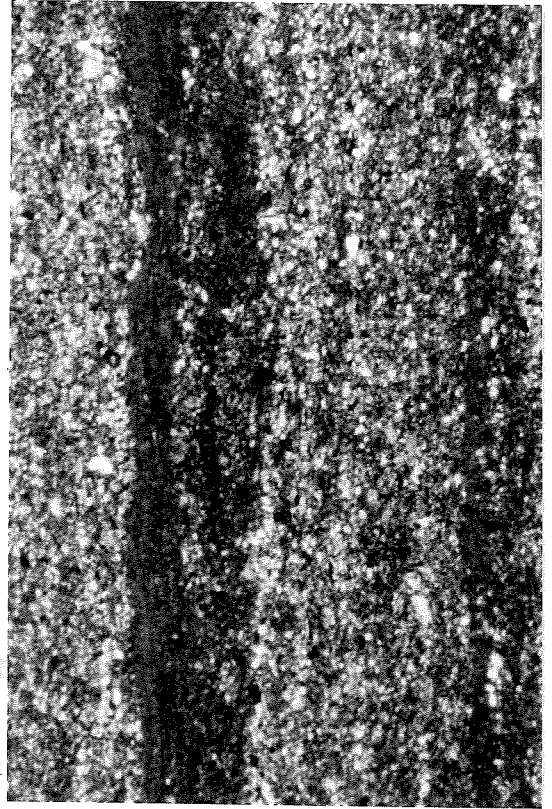
Crossed Polars, 30 XS

- d. 837-3A : Finely laminated shale (dark layers) and silts, from a dark coloured shale at the base of Unit 3.

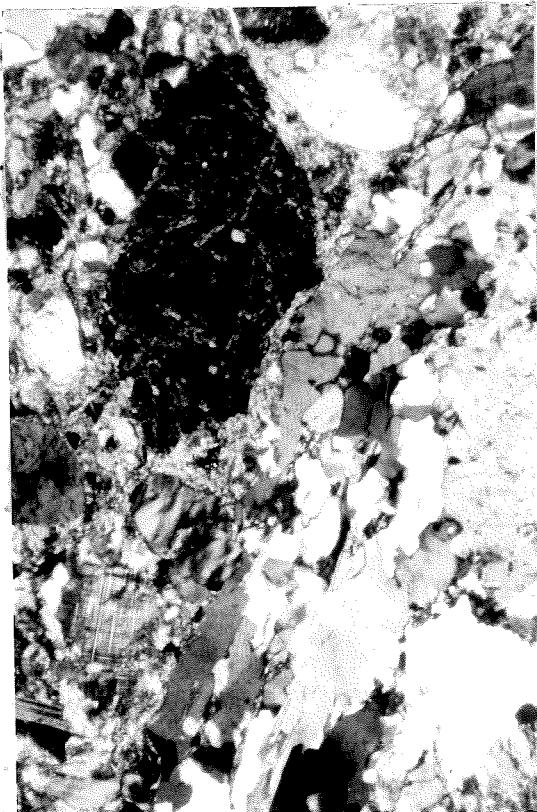
Plane light, 30 XS



B



D



A



C

## PLATE VII

- a) 837-4A : Chert clast surrounded by overgrown quartz grains. Some recrystallization at the edges of the clast can be seen.

Crossed Polars, 30 XS

- b) 837-6A : Micritized ooids in a microsparite cement. Subangular quartz, clasts and heavy mineral grains form the cores of the ooids. The ooids have not suffered major recrystallization.

Plane Light, 30 XS

- c) 837-6B : Heavy mineral laminations occur in an angular to sub-angular sandstone. The opaque minerals are of a much smaller grainsize than the quartz grains.

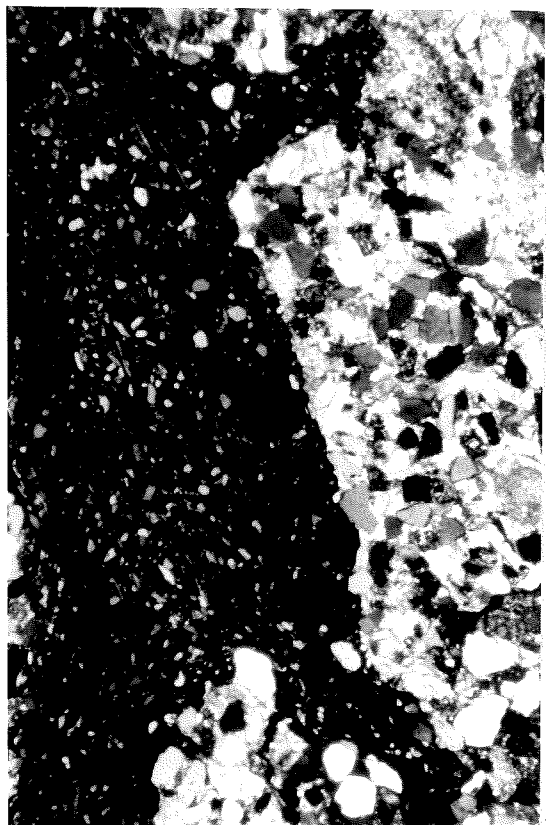
Plane Light, 30 XS

- d) 837-9 : Micaceous, dark brown mud clast at the base of a trough cross bedded sandstone.

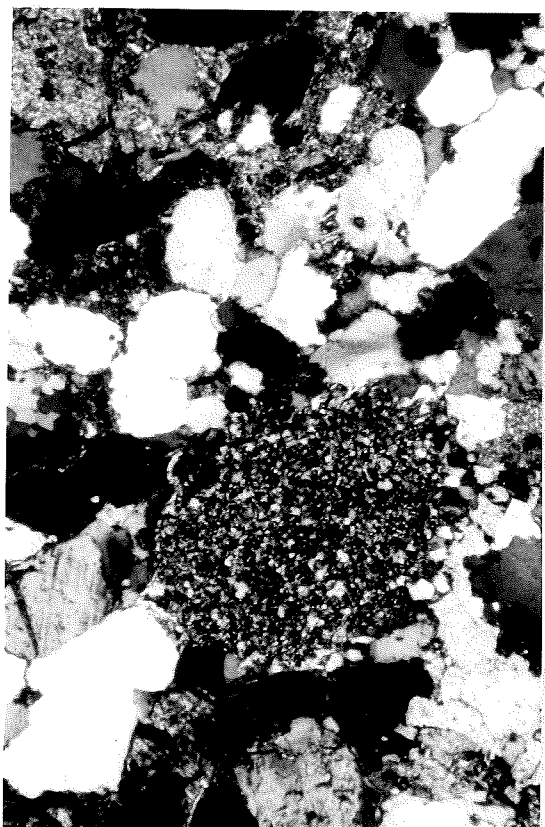
Crossed Polars, 30 XS



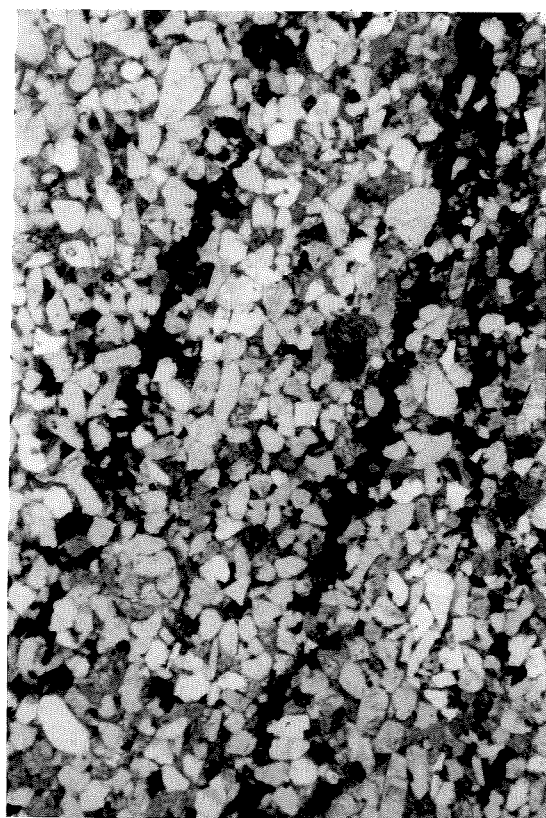
B



D



A



C

## PLATE VIII

- a) 837-10A : Carlsbad twinning in relatively fresh plagioclase, which lies in calcite cement.

Crossed Polars, 120 X S

- b) 837-10B : Subrounded to round quartz, plagioclase, and microcline have a grainstone texture in a silty carbonate cement.

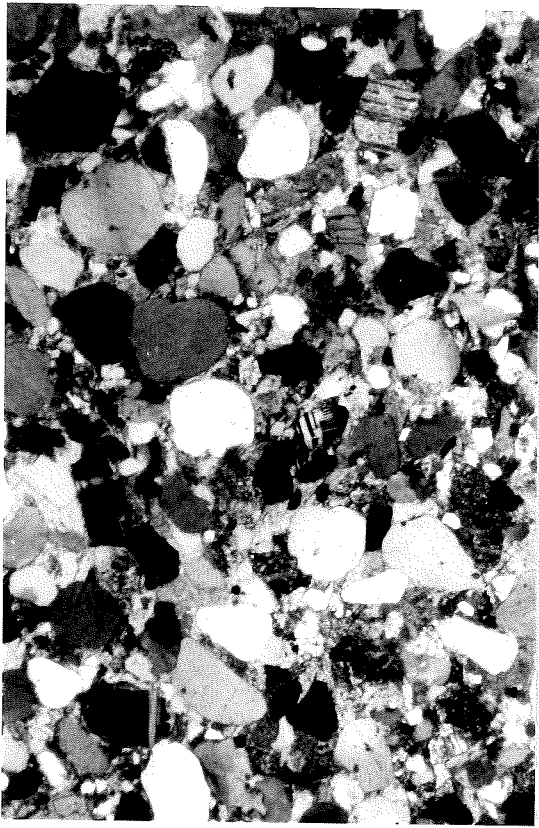
Crossed Polars, 30 X S

- c) 837-10D : Corrosion of quartz grains by calcite. This sample comes from one of the possible cryoturbated horizons altered by dolomite fluids and rich in calcite.

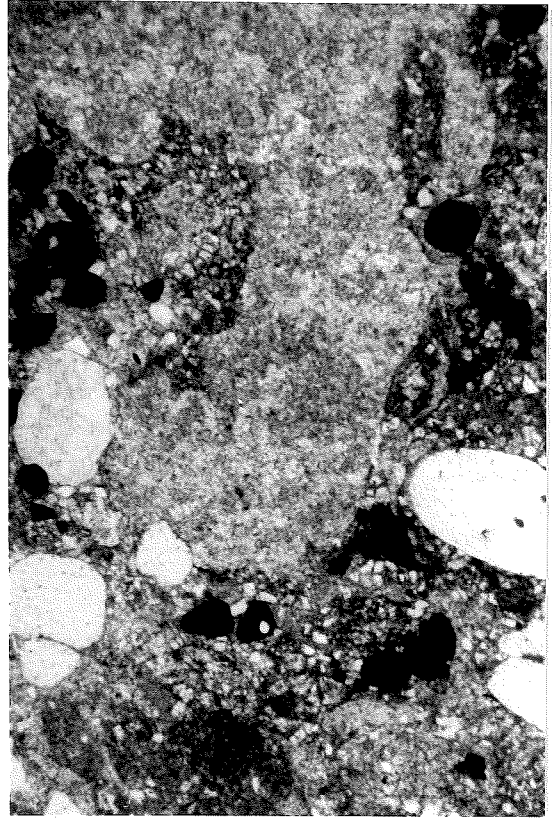
Crossed Polars, 30 X S

- d) 837-10H : Calcareous mud clast, surrounded by subround quartz and subhedral opaques in a silty matrix.

Plane Light, 30 X S



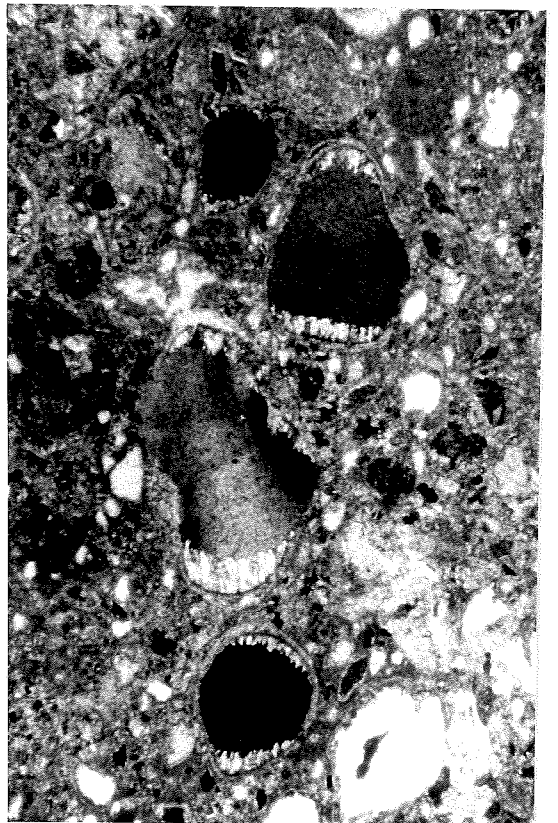
B



D.



A



C

## PLATE IX

- a) 837-10I : "Varve-like" interbeds of silt and mud (dark colour). The layers have sharp bases and tops, however they do not appear to follow the 11-year solar sunspot cycle, and have been classified as "Rhythmites".

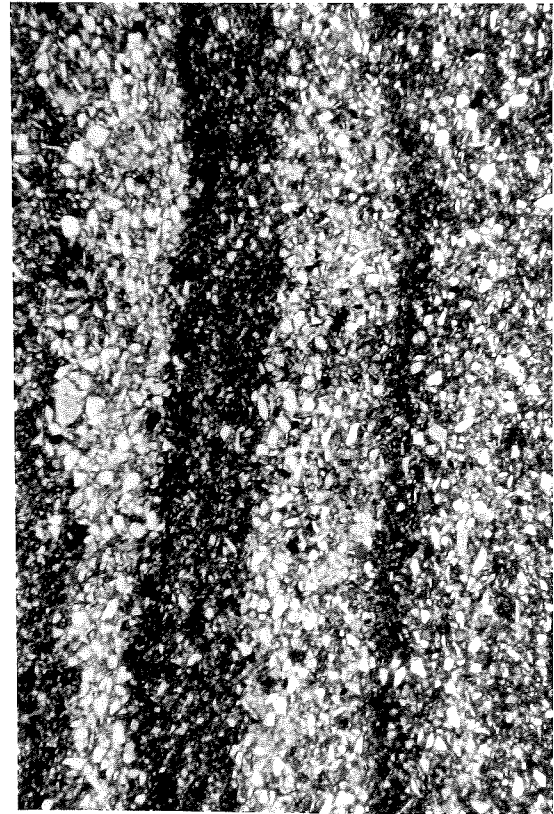
Plane Light, 30 XS

- b) 837-10I : Possible microfault disturbing the interbeds of silt and shale.

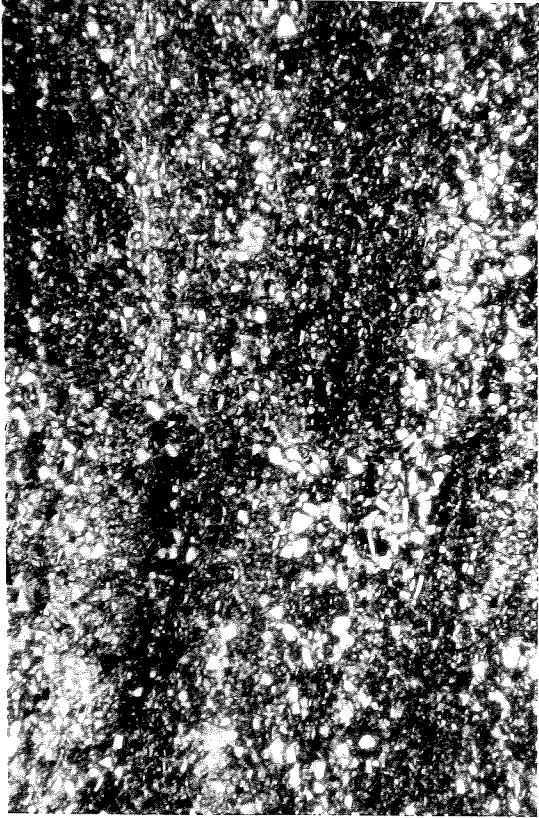
Plane Light, 30 XS

- c) 837-10J : Subrounded microcline and composite quartz grains within a rhythmite. The coarser grains may represent dropstones.

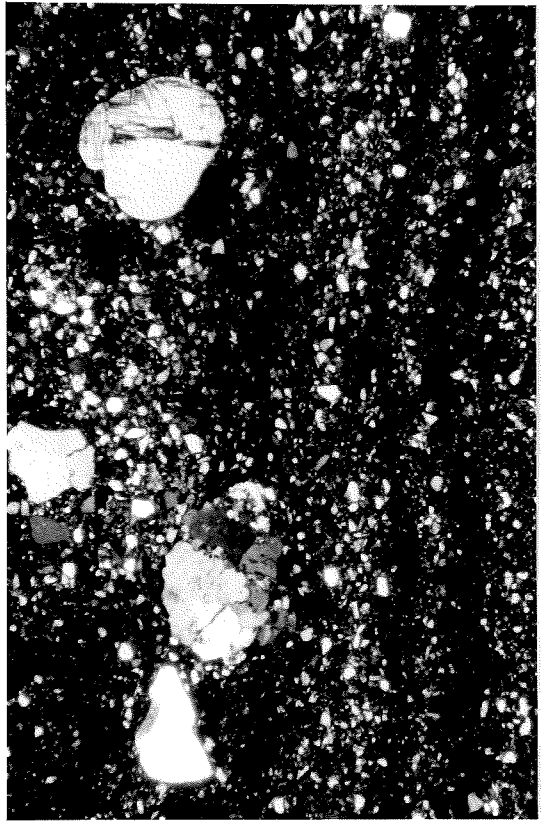
30 XS



A



B



C

PLATE X

- a) 837-11B Edge of sandstone dyke. The contact between the matrix-rich, fine grained host sandstone (L.H.S.) with quartz overgrowths and the coarser grained matrix-poor sandstone dyke, is very sharp.

Cross Polars, 30 XS

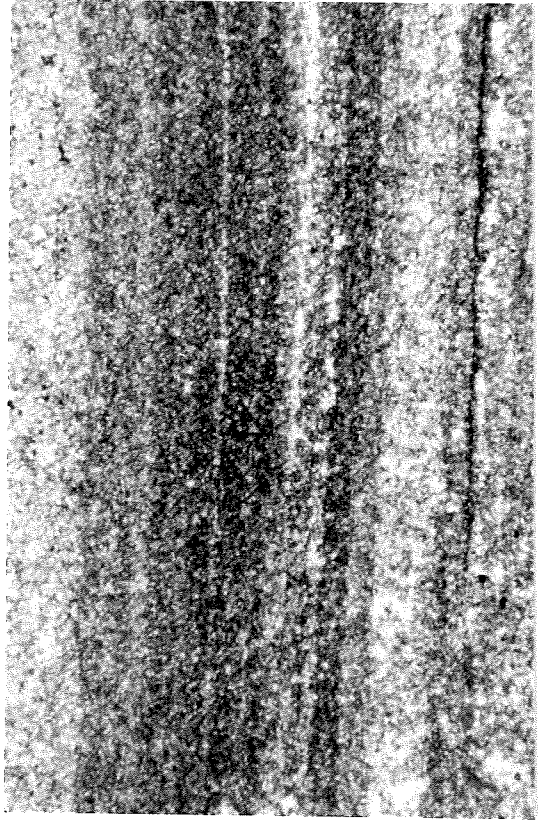
- b) 837-11B : Edge of dyke in Ordinary Light. Silty matrix of host sandstone (L.H.S.) can be distinguished.

Plane Light, 30 XS

- c) 837-12 : Finely laminated purple shale and cream coloured, finely crystalline dolomite layers in the Nuccaleena Dolomite equivalent.



B



C



A

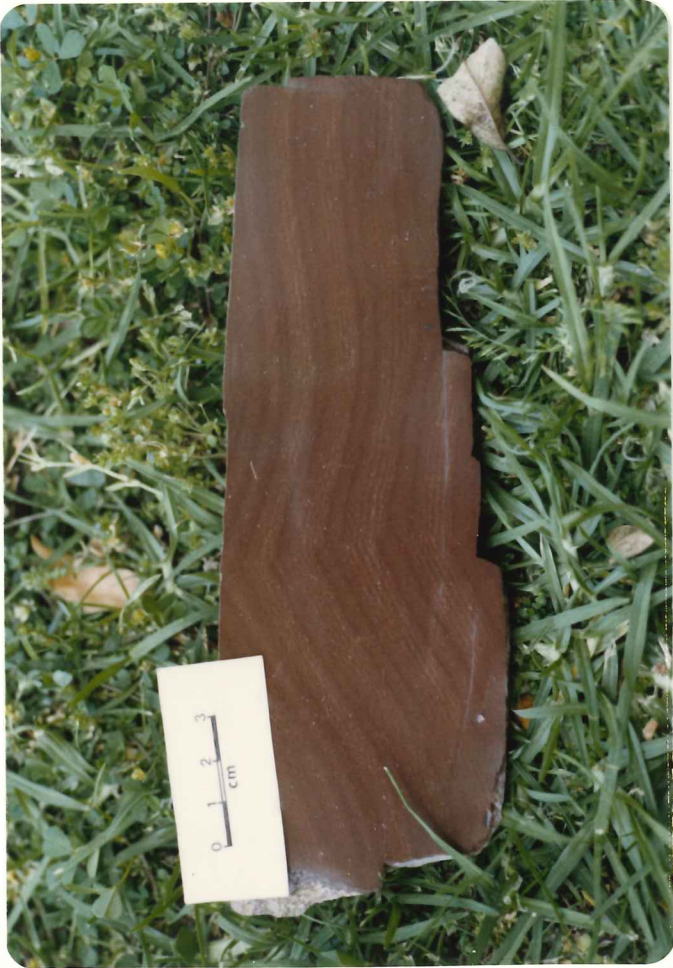
## PLATE XI

- a) 837-1A : Curved mudcracks on a rippled sandstone surface. Similar features were called *Manchuriophycus* - a psuedo trace fossil by Glaessner (1969).
- b) 837-4B : Sand filled scour surface the base of Unit 4. The cleavage and penecontemporaneous injection of the sandstones into the green silts of Unit 3 has exaggerated the scours.
- c) 837-9A : Curled brown mudcracks and coarse granules of pink feldspar, red porphyritic volcanic clasts and clear quartz occur in a trough cross-bedded sand. The cross-beds lie on a pale grey sandstone with minor mud clasts.
- d) 837-9B : The sharp base of a trough cross-bedded, granule rich sandstone can be seen, as it truncated the grey coloured, faintly laminated lower sandstone.



## PLATE XII

- a) 837-10M : A soft sedimentary fold, cut by a few small "faults" occurs in this varve-like interbedded silt and shale. The fault has not completely broken the interbeds. There is some periodicity in the interbeds, which may reflect solar cycles.
  
- b) 837-11B : Cross section of a sand dyke. The darker coloured, matrix rich host sandstone has a sharp, undulating contact with the paler coloured sandstone dyke.



A



B

APPENDIX B : HAND SPECIMEN AND THIN SECTION DESCRIPTIONS

A total of 44 hand specimens and 31 thin sections were chosen to be submitted with this thesis, to be stored in the Geology Department under the accession number 837. Visual estimates of the percentages of all components and grain-sizes were made. The classification scheme is based on Folk (1974).

837-1A UNIT 1. (Field River)

The rippled surface between the two sand layers has been draped with mud, which has been mudcracked (Plate XIa). The mudcracks on the curved surface have lost their polygonal appearance, and resemble the curved pseudo trace-fossil *Manchuriophycus*, (Glaessner, 1969). The ripple cross laminated sands show traces of mud-clasts in cross section.

837-1B UNIT 1. (Field River)

Macro : Purplish mud flakes sit in a fine-grained, grey-brown sandstone, which has some silty interbeds. Some mud flakes are curled, and some have been slightly rounded.

Micro : Sub-angular, fine-grained quartz and microcline grains, with minor euhedral opaques in a reddish coloured silt matrix. The feldspars are relatively fresh, with only minor sericitization and corrosion of grain edges. Mica and lenticular-shaped opaques are associated with the development of cleavage in the rock.

Quartz	50%
Microcline	5%
Mica	2%
Opaques	2%
Silt Matrix	10%
Mudclasts	30%

Name : Mud flake breccia

837-1C UNIT 1. (Field River)

Purple mud flakes sit in a fine-grained, grey silty sand. Minor, thin silt interbeds occur in the sand. Some mud clasts show internal lamination, some are curled.

Name : Mud flake breccia

837-2A MARINO ARKOSE (Field River)

Macro : Subround and round coarse grains, with sub-angular finer grains are cemented with calcite. The pink rounded, potassium feldspar grains show shiny, fresh cleavage surfaces when broken. Metamorphic, volcanic and sedimentary clasts occur.

Micro : Two main grain sizes occur in this slide - granule to small pebble-size grains, with smaller, medium-sand-sized grains. The coarser grains include schistose metamorphic rock fragments with sutured quartz and lineated mica (Plate VIIa), volcanic rock fragments (Plate VIa),

sedimentary rock fragments ( chert, and shale (Plate VIc)) fresh microcline ("tartan" twinning) vacuolized potassium feldspar and plagioclase (Albite twinning) (Plate VIb) and both composite quartz and individual grains occur.

Quartz	40%	
Plagioclase	10%	) 45% feldspar
Potassium feldspar	35%	)
Rock fragments	10%	
Calcite cement, mica and opaques	5%	

Name : Coarse-grained, calcareous, submature, arkosic granule conglomerate.

837-2B MARINO ARKOSE (Field River)

Fine-grained, sub-rounded greenish sand containing large elongate dolomicrite clasts. The dolomicrite clasts have little internal structure.

Name : Intraclastic sandstone.

837-2C MARINO ARKOSE (Field River)

Macro : A granule conglomerate has been deposited on a scoured surface in a fine-grained, green coloured sand. White elongate dolomicrite clasts, red porphyritic volcanic clasts, clear quartz and pink potassium feldspar occur in a calcareous cement.

Micro : Coarse and medium, sub-angular grains occur in a sparry calcite cement. Poorly sorted quartz with corroded edges, vacuolized potassium feldspar, sericitized plagioclase, chert, minor volcanic clasts and composite metamorphic clasts occur in a sparry calcite cement.

Coarse layer :

Quartz	70%
Feldspar	15% (Plagioclase 5%, Microcline 10%)
Rock fragments	5%
Calcite cement	10%

Minor biotite, opaques, mica and zircon.

There is a sharp contact with calcite at the boundary between the coarser and finer layers. The finer layer contains angular to sub-angular grains, and has a well sorted packstone texture.

Finer Layer :

Quartz	75%
Feldspar	8% (Plagioclase 5%, Microcline 3%)
Rock fragments	5%
Opaques	2%
Silty carbonate cement	10%

Minor biotite, chlorite.

Name : Coarse-grained, sub-angular, submature calcareous arkose.

837-2D MARINO ARKOSE (Field River)

Macro : Blue-grey limestone, with isolated subround quartz grains with white alteration rims.

Micro : Matrix of coarse, twinned sparry calcite, with only minor coarse-grained quartz, composite quartz and feldspar. The quartz and feldspar have corroded, embayed rims, and the potassium feldspar is altering to sericite in places. The sample has a packstone texture.

Quartz	20%
Feldspar	10% (Plagioclase 3%, Potassium Feldspar 7%)
Calcite cement	70%

Name : Sandy limestone.

837-2E MARINO ARKOSE (Field River)

Silt rick, calcareous pebble conglomerate with polished and smooth quartz, potassium feldspar, red porphyritic clasts, metamorphic quartzite clasts and sedimentary rock fragments. Angular yellow dolomite clasts and purple mud flakes occur.

The coarser grains sit in a silty calcareous cement, rich in medium-grain sized sand. The rock is poorly sorted with subrounded grains.

Name : Immature calcareous, pebble conglomerate.

837-3A UNIT 3. (Field River)

Macro : Very finely laminated, dark brown coloured shale.

Development of parting lineation and cleavage.

Micro : Greenish coloured, interbedded very fine grained silt and shale. Minor opaques occur, some appear to be cubic in shape and may represent pyrite. Green chlorite has grown in the shale layers, and minor mica occurs parallel to bedding. (Plate VI d.)

Name : Laminated shale.

837-3B UNIT 3. (Marino Rocks Beach)

Macro : Greenish coloured silt, with some parallel laminations.

Stringers of chloritic shale occur. At the base, finely interlaminated shale and silt occurs.

Micro : Silty matrix with calcareous mud clasts - angular shape, some are curled.

Calcareous silt 60%

Mud clasts 40%

Traces of opaques, chlorite, biotite and mica.

Name : Intraclastic siltstone.

837-3C UNIT 3. (Marino Rocks Beach)

Macro : Fine grained greenish sandstone, shows growth of pink mineral, and chlorite parallel to cleavage. Cleavage is well developed in the rock.





A reddish silt clast occurs.

Quartz	80%
Feldspar	5%
Rock fragments	5%
Opagues	5%
Patchy silty cement	5%

Name : Heavy mineral laminated, quartzarenite.

837-6D                      UNIT 6.    (Marino Rocks Beach)

Macro : Pale grey, ooid rich limestone which caps Unit 6 in places. Quartz and feldspar also occur. The rock has a packstone texture with a calcareous cement.

Micro : The ooids in this sample have undergone more recrystallization than those in 6A, with calcite overgrowths obliterating some of the original texture. The ooids have cones of angular quartz which has been corroded mud clasts and opaques.

Ooids	60%
Quartz                      )	in ooid cores 80% Q. 20% F.
Feldspar                    )	
Mudclasts	5%
Calcite Cement	30%
Minor opaque heavy minerals	

Name : Oolitic limestone.

837-6E                      UNIT 6.    (Marino Rocks Beach)

The heavy mineral laminations in the sandstone can be clearly seen in this weathered rock. Ripple cross-laminations and planar heavy mineral laminations occur in the buff coloured calcareous sandstone. The "lumps" in the rock consist of euhedral haematite which has recrystallized from the heavy mineral laminated sandstone.

Name : Heavy mineral laminated sandstone.

837-7                      UNIT 7.    (Marino Rocks Beach)

Macro : Planar laminated grey-green coloured interbedded calcareous silt and very fine sand. The bedding surfaces have a phyllitic appearance due to the growth of mica.

Micro : Fine-grained angular quartz with minor plagioclase and opaques. Mica and chlorite can be seen parallel to bedding. The grains have blurred edges in contact with the green, calcareous shale.

Name : Laminated calcareous siltstone.

837-8                      UNIT 8.    (Marino Rocks Beach)

Macro : Dark green fine-grained, dolomite sandstone, with little internal structure.

Micro : No internal structure can be seen on the micro-scale. The rock has a packstone texture with minor greenish chloritic dolomitic cement.



Micro : Two main grain sizes occur - coarse grained sub-round quartz is surrounded by sub-angular fine-grained sand in a silty and partly calcareous matrix. Both fresh plagioclase, showing Carlsbad twinning (Plate VIII a) and sericitized plagioclase occur. The sandstone has a packstone texture. (Plate VIII b.) The purple silt contains corroded feldspar and quartz grains with Calcite rims.

Quartz	60%
Feldspar	15% - (Plagioclase 5% Potassium feldspar 10%)
Rock fragments	5%
Cement	20%

Name : Immature lithic subarkose.

837-10B REYNELLA SILTSTONE MEMBER (near "Westcliff")

Macro : Purple coloured diamictite with purple-brown silt containing coarse, granule sized sub-round plagioclase, quartz, potassium feldspar and rock fragments. The rock has a packstone texture.

Quartz	10%
Feldspar	5%
Rock fragments	5%
Silt	80%

Name : Diamictite

837-10C REYNELLA SILTSTONE MEMBER (near "Westcliff")

This rock is part of a fault alteration zone near "Westcliff". Yellow silty, ferroan dolomite contains white calcite veins, which almost form a "boxwork" pattern.

837-10D REYNELLA SILTSTONE MEMBER (near "Westcliff")

Macro : This sample is part of a dolomitized, possible ice-wedge. Coarse sand-sized grains with reaction rims occur in a yellow, silty dolomite.

Micro : The quartz grains have been embayed with secondary calcite, which have formed pressure shadows around some of the grains. (Plate VIII c.)

837-10E REYNELLA SILTSTONE MEMBER (near Westcliff)

Macro : This sample is a purple calcareous diamictite with crude bedding and coarse, granule-sized layers. The granule layers contain sub-rounded clear quartz, potassium feldspar, red porphyritic grains and white plagioclase grains. Angular, yellow dolomite clasts are common.

Micro : Sub-round quartz, microcline, plagioclase, silt clasts and rock fragments with corroded boundaries lie in a purple silt matrix. Angular dolomite and silt clasts occur. The slide has a packstone texture.

Quartz	30%
Feldspar (predominantly microcline)	5%
Mud clasts	50%

Rock fragments	5%
Matrix	10%

Name : Diamictite.

837-10G REYNELLA SILTSTONE MEMBER (near "Westcliff")

Macro : This sample is part of a large channel in the cliff face. Imbricate white calcareous silt clasts and coarse granules of sand lie in a calcareous brown silty cement. In the cliff, large scale cross-bedding occurs in the channel.

Micro : Large silt clasts, with embayed quartz, microcline, and rock fragments lie in a silty carbonate cement. Some of the clasts have internal laminations. Composite metamorphic quartz, silt clasts with mud balls (till pellet?) occur.

Silt clasts	30%
Quartz	15%
Feldspar	10%
Rock fragments	5%
Matrix/Cement	40%

Name : Immature Feldspathic sedarenite.

837-10H REYNELLA SILTSTONE MEMBER (near "Westcliff")

Macro : This sample also comes from the large channel. Large mud clasts are surrounded by coarse sand grains in a calcareous silty matrix.

Micro : Calcareous mud clasts, with fine-grained quartz and opaques, have sharp boundaries and are surrounded with coarse sand sized sub-round grains. (Plate VIII d.) Sub-rounded quartz with minor corrosion of grain boundaries, plagioclase, microcline, rounded opaques, composite metamorphic quartz and weathered volcanic clasts (with indistinct plagioclase laths occur.)

Mud clasts	60%
Quartz	20%
Feldspar	3% (Plagioclase 1% Potassium feldspar 2%)
Opaques	2%
Rock fragments	3%
Matrix	12%

Name : Immature sedarenite.

837-10I

Macro : Very thin interbeds of white very-fine sand and brown shale may represent micro-varves.

Micro : In thin section, small sharp micro-faults can be seen, disturbing the interbedded very-fine sand and shale layers (Plate IX b). Elsewhere in the slide, the thin interbeds are undisturbed. Angular, very fine-grained quartz (80%) occur in the silty layers. The muddy layers

contain much less angular sand (20%), and fine-grained mica.  
Boundaries between the two layers are relatively sharp (Plate IX a).

Name : Rhythmite.

837-10J REYNELLA SILTSTONE MEMBER (near "Westcliff")

Macro : Microvarve-like layers have been disrupted by small-scale faults. A coarse, granule-sized layer of dolomite clasts, sub-round quartz, feldspar and porphyritic clasts lies above the "micro-varves".

Name : Rhythmite.

Micro : The micro-varves contain thicker, pale sandy layers than 837-10I coarse-grained microcline, with cross-hatched twinning, quartz with undulose extinction, minor opaques and sub-rounded clasts of silt occur in the coarser layer and as random clasts in the micro-varves.

Name : Rhythmite.

The coarser layer contains :

Quartz	20%
Potassium feldspar	20%
Rock fragments	5%
Shale matrix	50%
Mud clasts	5%

Name : Diamictite.

837-10K REYNELLA SILTSTONE MEMBER (near "Westcliff")

Macro : This sample comes from the large channel in the cliffs near "Westcliff" Pale pink, calcareous mud clasts sub-round clear quartz, pink potassium feldspar and rock fragments occur in a pink, silty calcareous matrix.

Micro : Sub-round to round quartz, composite quartz, and microcline, with coarse micritic silt lie in a dark coloured silty matrix.

Mud clasts	52%
Silty matrix	30%
Quartz	10%
Microcline	5%
Rock fragments	3%

Name : Silty sedarenite.

837-10L REYNELLA SILTSTONE MEMBER (near "Westcliff")

Soft-sedimentary folds have disrupted interbeds of dark brown mud and pale pink very fine sand and silts. Alternating thick (1.5mm) interbeds and thinner (1mm) interbeds occur throughout the rock of the thicker interbedded intervals shows 22 silt and mud interbeds and may reflect the 11 year solar sunspot cycle (Williams 1983). Other finer interbedded intervals show no such relationship.

Name : Rhythmite.

837-10M REYNELLA SILTSTONE MEMBER (near "Westcliff")

A soft-sedimentary fold runs through this sample. The alterations of thick interbeds and thinner interbeds shows some cyclicity. The thicker interbedded layers may reflect an 11 year cycle. (Plate XII a.)

Name : Rhythmite.

837-10N REYNELLA SILTSTONE MEMBER (near "Westcliff")

This sample shows much thicker sandier intervals than the preceding sample, and could be called a "Type III" varve of Ashley (1975). The sandy layers show finer scale internal laminations. Micro-faults have disrupted some of the layers. At the base of this specimen are ripple cross-laminated silt and sand interbeds. Such a ripple would have formed over a period of hours to days and would not be likely to reflect yearly cycles of deposition. This may imply that the overlying "Type III Varves" are not annual varves, but reflect possibly daily cycles of deposition.

837-10Q REYNELLA SILTSTONE MEMBER (near "Westcliff")

This sample occurs in one of the varve-like layers. A starved sand ripple (pale grey) lies in a purple silt. Silt and sand cross-beds also occur.

837-10R

Ripple cross-lamination of interbedded sand and silt layers can be seen. The sand and silt interbeds have a similar appearance to those seen in the "varves"

837-10S REYNELLA SILTSTONE MEMBER (near "Westcliff")

A purple diamictite contains yellow dolomite clasts. The dolomite may be secondary, replacing original calcareous clasts. This sample is part of a laterally extensive layer of dolomite clasts, which runs up the cliff-face. Medium grained, sub-round quartz and feldspar occur in the coarser layer.

837-10T RECENT BEACH DEPOSIT. (near "Westcliff")

A variety of clasts lie in a sandy calcareous cement. Carbonate worm burrows have encrusted this sample, and run through the rock.

837-11A SEACLIFF SANDSTONE MEMBER (Hallett Cove)

Macro : Pale, buff coloured, fine-grained, massive sandstone. The rock has a grainstone texture.

Micro : Poorly sorted sub-angular quartz, plagioclase and rock fragments lie in a patchy matrix. In places quartz overgrowths have cemented grains together. The feldspars are finer grained and better rounded than the quartz. Volcanic rock fragments with indistinct feldspar laths occur.

Quartz	83%
Feldspar	10%
Rock fragments	5%
Opagues	2%
Matrix	5%

Name : Fine-grained immature subarkose.

## 837-11B SEACLIFF SANDSTONE MEMBER (Hallett Cove)

Macro : This sample shows a buff-coloured sedimentary dyke penetrating a purplish sandstone. (Plate XII b.) The dyke is matrix-poor, and has a welded appearance. The host sandstone is matrix-rich.

Micro : The slide shows the edge of the dyke. The dyke has a grainstone texture and is matrix poor. The quartz grains are sutured together by overgrowths. The quartz grains exhibit undulose extinction, with bubble trains. Minor, cloudy plagioclase and microcline also occur. The dyke is well sorted.

<u>Dyke</u> : Quartz	90%
Feldspar	3%
Rock fragments	2%
Cement	5%

With minor opaques.

The host sandstone is poorly sorted, with sub-angular grains sitting in a micaceous, silty matrix, with a packstone texture.

Sandstone :

Quartz	80%
Feldspar	5%
Rock fragments	3%
Matrix	10%
Opaques	2%

Name : Fine-grained, feldspathic sandstone.

Plates X a, X b, show the edge of the dyke.

## 837-11C SEACLIFF SANDSTONE MEMBER (Hallett Cove)

Macro : Pale purple, heavy mineral laminated sandstone with yellow dolomicrite clasts and sub-rounded granules of quartz and pink potassium feldspar.

Micro : Grainstone texture, with minor calcite cement. Sub-angular quartz with minor overgrowths. Rounded heavy mineral grains are randomly distributed in the sandstone. The yellow dolomicrite clasts shows faint laminations.

Quartz	80%
Feldspar	15%
Rock fragments	3%
Opaques	2%

Name : Heavy mineral laminated subarkose.

## 837-11D SEACLIFF SANDSTONE MEMBER (Hallett Cove)

Randomly orientated dolomicrite clasts, with internal lamination lie in a medium grained sandstone. There is very little imbrication of the dolomicrite clasts.

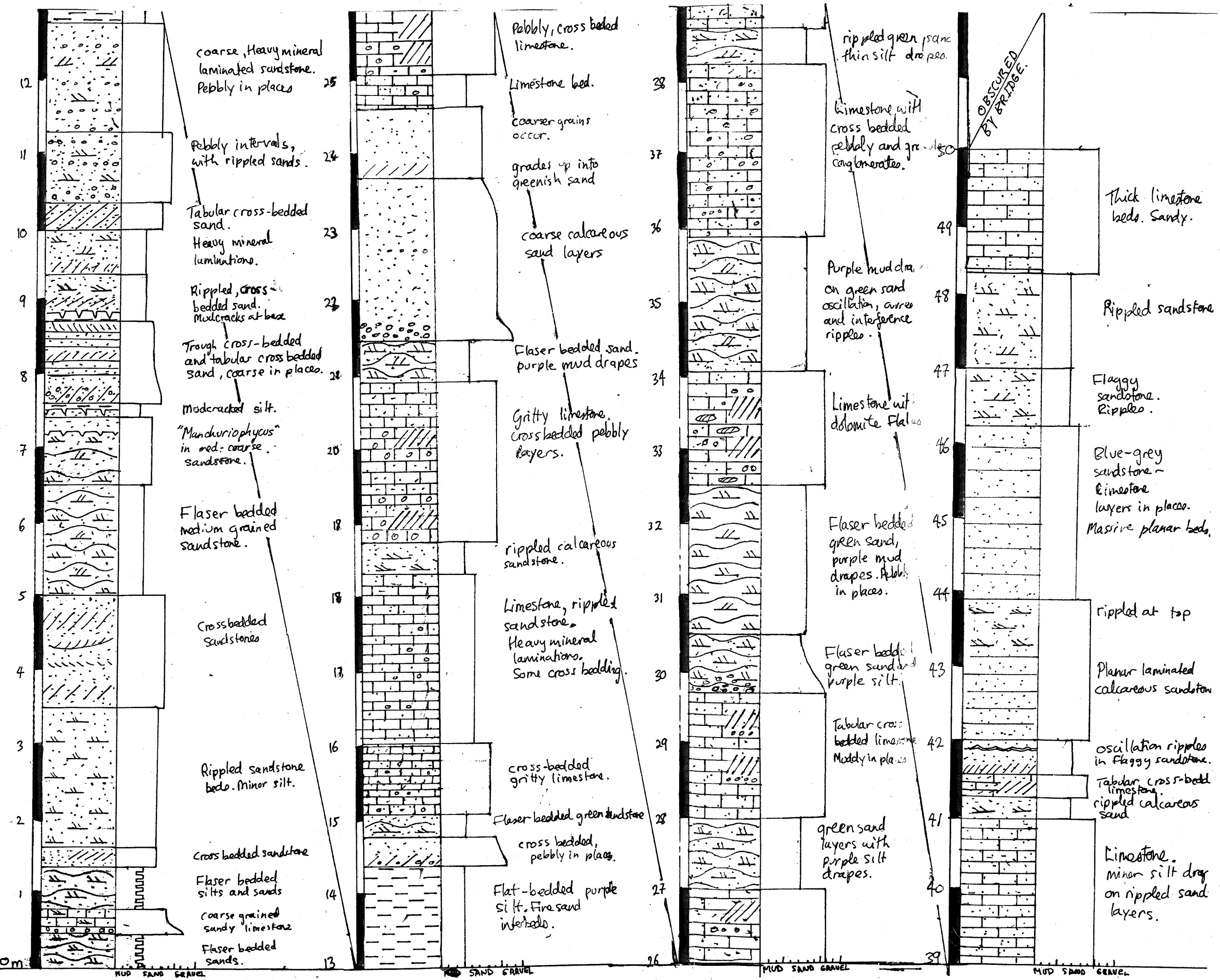
837-12            NUCCALEENA DOLOMITE EQUIVALENT    (Hallett Cove)

Macro : Thin purple silt and shale and white dolomite interbeds. Black iron dendrites occur at the edges of the sample. Minor irregularities in the laminae occur.

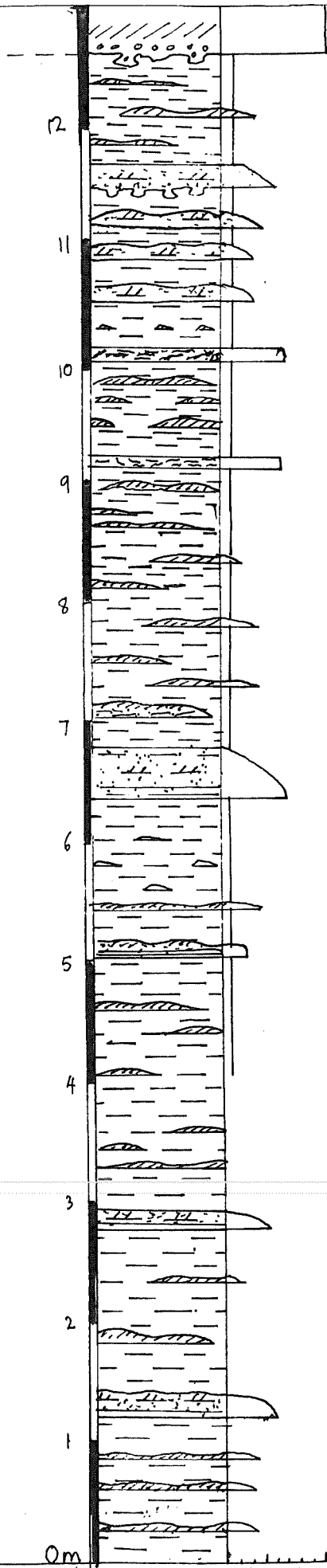
Micro : Finely interlaminated shale and very finely crystalline dolomite layers can be seen with minor growth of chlorite in the shale.

Name : Interbedded dolomite and shale.

# DETAILED SECTION : Unit 2 (Marino Arkose)



# DETAILED SECTION : Unit 3



Basal conglomerate, injection structures. Greenish colour.

Sand lenses, ripple cross laminae, in a blue-green coloured silt.

Sandy interval. Pillow structures. Massive at base.

Rippled sands. silt interbeds.

Sharp based sandstone layers. Gradational tops. Lenticular sandstone interlayers.

Starved sand ripples

'Brecciola', rich in white mud flakes.

Rippled sandstone lenses, in blue-green shale.

'Brecciola' layer.

Sandstone lenses. Rippled, with uneven bases.

Lenticular sandstone bodies.

Sharp bases, gradational tops into silt and shale.

Sandstone layer. Brecciola at base. Rippled at top

Sandstone lens. Planar lamination at base, then ripple cross lamination. Silty at top.

Starved sand lenses in silt.

Thin sandstone layer. Rippled top.

Lenticular sandstones in a blue-green silt

Sandstone lens. Rippled at top.

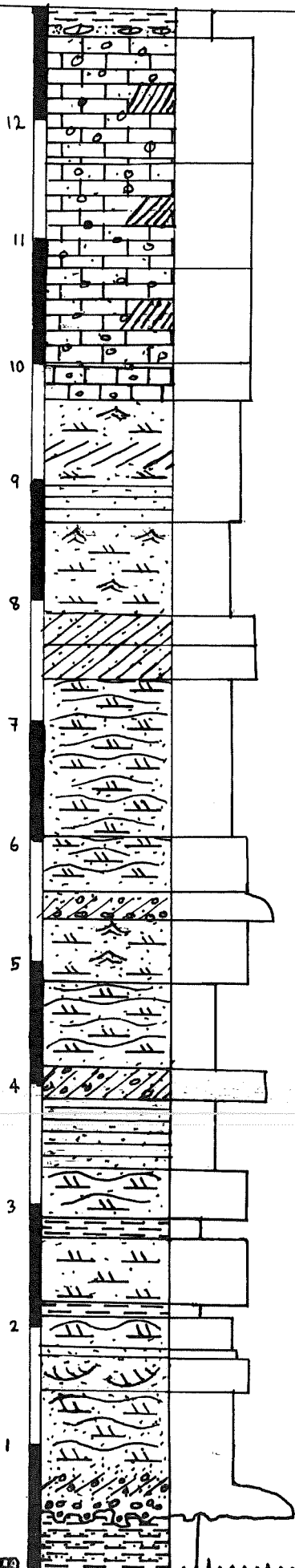
Silt with lenticular sandstones.

Interbedded silt and sandstone

0m

MUD SAND GRAVEL.

# DETAILED SECTION: Unit 4



limestone clasts in green, linsen bedded silt.  
Sharp contact.

limestone beds, with tabular cross bedded,  
subround granules and coarse sand.  
White colour

large tabular cross beds, 75cm high.

Calcareous coarse sand. Cross bedded interval,  
with some current ripples.

Planar laminated coarse sand.

Current rippled, and oscillation rippled sands, with  
thin silt layers.

Cross bedded sand layers. Subround grains.

Thick Flaser bedded interval. Buff coloured.

Rippled sand layers - interference ripples, with  
silt drapes.

Tabular cross bedded granule conglomerate  
Rippled sand. Minor silt. Some oscillation  
ripples

Flaser bedded sand. Sandy, rippled layers, with  
silt and shale drapes.

Cross bedded v. coarse sand - granule conglomerate.

Planar laminated sand.

Flaser bedded sand.

linsen bedded silt. Thin sand layers.

Rippled sandstone bed.

linsen bedded silt. Starved sand ripples.  
Flaser bedded sand layer.

Trough cross laminated

Flaser bedded sandstone/silt.  
Green colour.

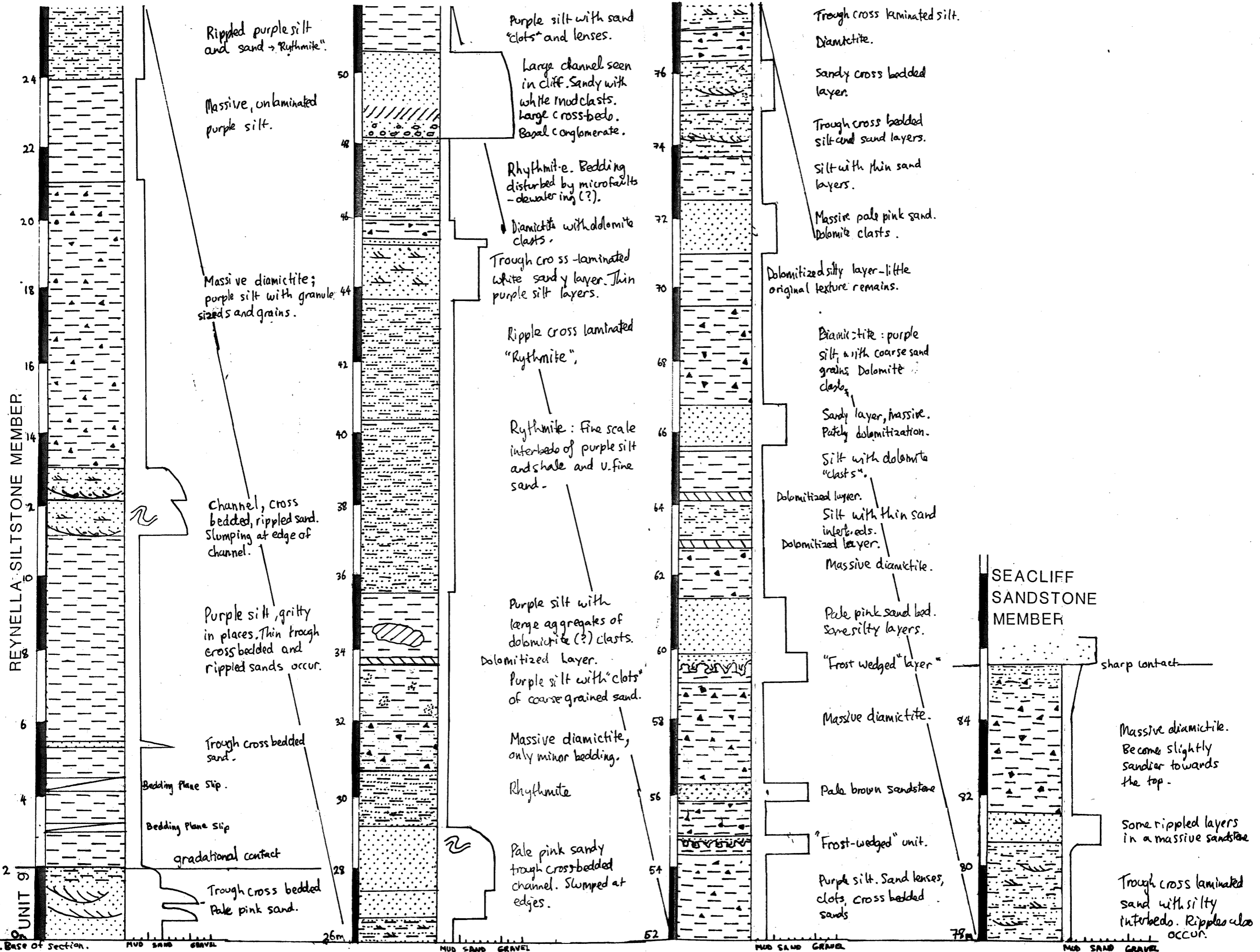
Basal conglomerate. Green colour.  
scoured contact, with injection features.  
Blue-green coloured interbedded silt and fine sand.

0m

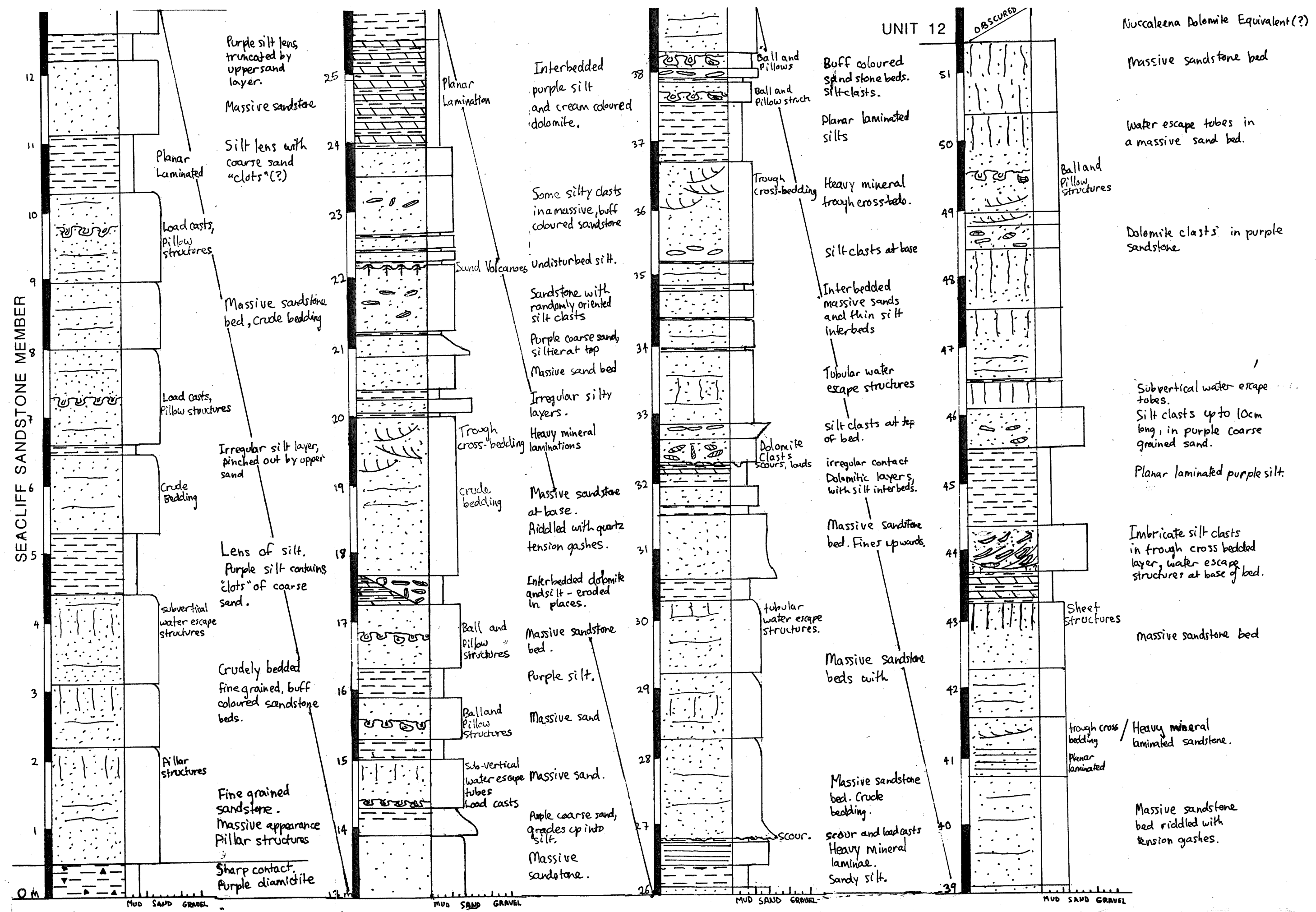
MUD SAND GRAVEL

# DETAILED SECTION Reynella Siltstone Member

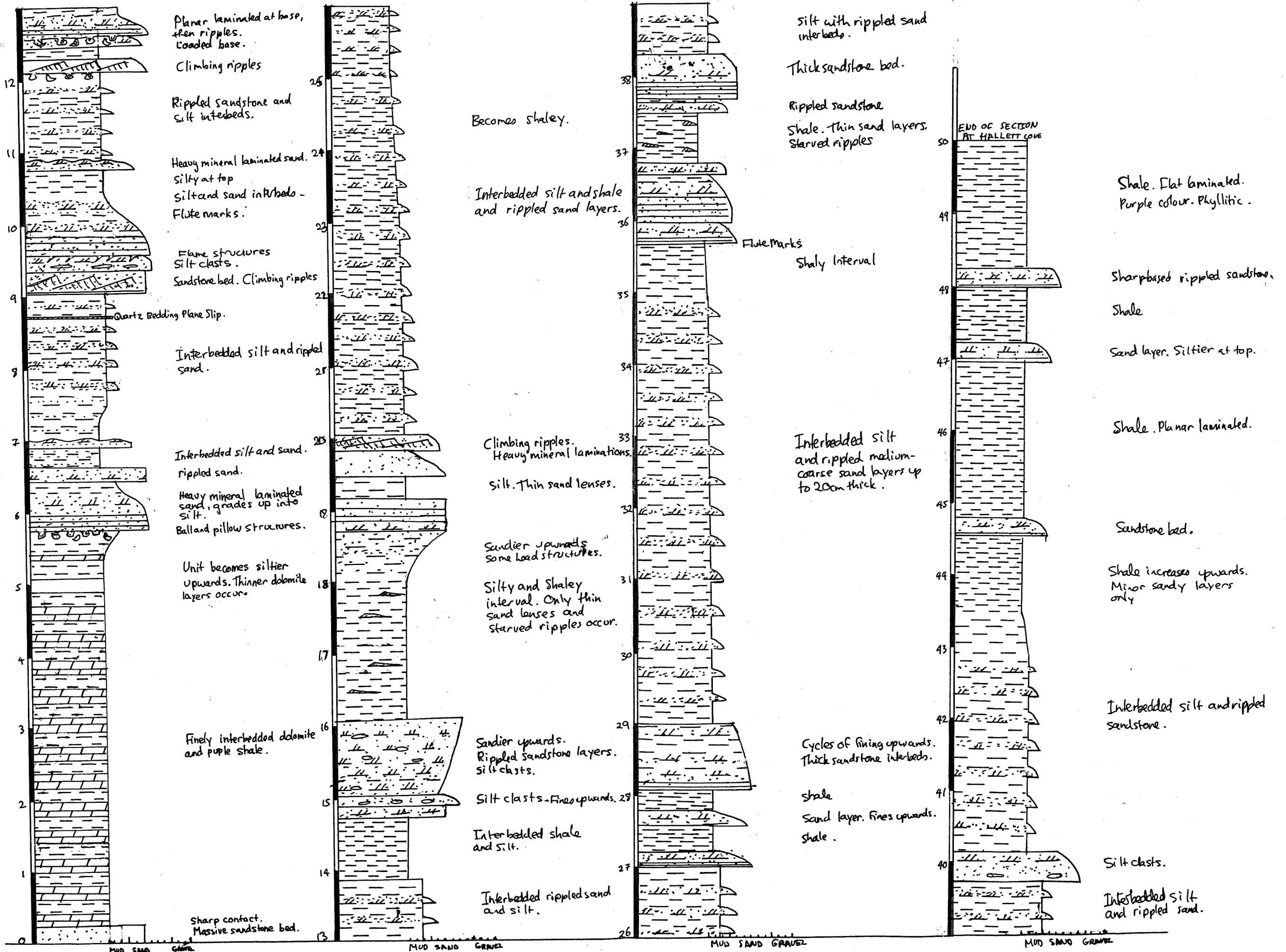
DN-10



# DETAILED SECTION: Seacliff Sandstone Member



# DETAILED SECTION : Unit 13



APPENDIX D : LIST OF THIN SECTIONS AND HAND SPECIMENS SUBMITTED.

	<u>UNIT 1.</u>		<u>UNIT 10.</u> (Reynella Siltstone Member)
837-1A	*		837-10A
837-1B			837-10B
837-1C	*		837-10C *
			837-10D
	<u>UNIT 2.</u> (Marino Arkose)		837-10E
			837-10F
837-2A			837-10G
837-2B	*		837-10H
837-2C			837-10I
837-2D			837-10J
837-2E	*		837-10K
			837-10L *
	<u>UNIT 3.</u>		837-10M *
			837-10N *
837-3A			837-10O *
837-3B			837-10R *
837-3C			837-10S *
837-3D			837-10T *
	<u>UNIT 4.</u>		<u>UNIT 11.</u> (Seacliff Sandstone Member)
837-4A			837-11A
837-4B	*		837-11B
			837-11C
	<u>UNIT 5.</u>		837-11D *
837-5	*		<u>UNIT 12.</u> (Nuccaleena Dolomite)
	<u>UNIT 6.</u>		837-12
837-6A			
837-6B			
837-6C			
837-6D			
837-6E			
	<u>UNIT 7.</u>		
837-7			
	<u>UNIT 8.</u>		* Hand specimen only.
837-8			All others include thin section
837-8A	*		and hand specimen.
	<u>UNIT 9.</u>		
837-9A			
837-9B	*		

# GEOLOGY OF THE MARINO ROCKS - HALLETT COVE AREA .

## KEY

<b>STURTIAN</b>	UMBERATANA GROUP	UNIT 1 UNIT 2 (MARINO ARKOSE)	
	WILLOCHRA SUBGROUP	UNIT 3 UNIT 4 UNIT 5 UNIT 6 UNIT 7 UNIT 8 UNIT 9 UNIT 10 (REYNELLA SILTSTONE MEMBER) UNIT 11 (SEACLIFF SANDSTONE MEMBER)	
<b>MARINOAN</b>	UMBERATANA GROUP	UNIT 12 (NUCCALEENA DOLOMITE)	
	WILPENA GROUP BRACHINA SUBGROUP	UNIT 13	

- Lithological Boundary
  - observed
  - inferred
- Fault
  - observed
  - inferred
- Fold
  - Anticline
    - observed
    - inferred
  - Syncline
    - observed
    - inferred
  - plunge of minor folds
- Bedding
  - inclined
- Cleavage
  - inclined
- Lineation
  - trend/plunge
- Road
- Railway Line
- Park Boundary
- Quarry
- Embankment
- Cutting
- Creek
- Sample Locality

0 200 400m.  
SCALE

