THE LATE PRECAMBRIAN GEOLOGY OF THE WYACCA BLUFF - BUCKARINGA GORGE AREA, FLINDERS RANGES, SOUTH AUSTRALIA

by
Robin K. Miller, B.Sc.

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ABSTRACT

Detailed lithostratigraphic mapping of the Late Precambrian sequence extending from the Tapley Hill Formation in the Umberatana Group, to the A.B.C. Range Quartzite in the Wilpena Group in the Wyacca Bluff - Buckaringa Gorge area, has indicated 18 mappable units. These may be lithologically uniform, or contain several distinct or gradational lithologies, ranging from almost pure carbonates to clastics with only minor carbonate content. Stromatolite growth proliferated during deposition of the Brighton Limestone and the morphology of these stromatolites is described. Minor stromatolite growth occurred during deposition of the upper parts of the Tapley Hill Formation and Etina Limestone Member respectively.

Deposition occurred under shallow marine conditions, in environments ranging from below wave base, to supratidal. Comparison with the Hallett Cove - Marino area suggests that similar environments prevailed in both areas, although not necessarily synchronously.

The sequence is located on the eastern side of a shallow southerly plunging anticline, which has been truncated on the western side by Wyacca Fault.

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INTRODUCTION

The Wyacca Bluff - Buckaringa Gorge area is located 27Km north of Quorn on the western margin of the southern Flinders Ranges, between latitude 32°03' and 32°06's, and longitude 138°01'E and 138°04'E (Figure 1). The topography of the area studied, which comprised 15 square Km, varied from very subdued in the north-east, to slightly rugged in the south. Wyacca Bluff flanks the western side, and the low range through which Middle Gorge, Buckaringa Gorge and Warren Gorge have been cut, forms the eastern boundary.

Vegetation is mainly grasses with minor small bushes and scrub. Large gums (Eucalyptus camaldulensis) line the larger creeks, and native pines are also present. All creeks are ephemeral, although springs are present. Rainfall averages 480mm per year, and temperature ranges from an average minimum of 2°C in July to an average maximum of 31°C in January.

Studies have been carried out in this region by Howchin (1928) and Mawson (1947), both of whom were concerned with the stratigraphic sequence developed on the western margin of the Flinders Ranges. The area has been mapped as part of the regional mapping programme for the S.A. Department of Mines by Webb and Von der Borch (1962) and Binks (1968, 1971).

Mapping for this study was carried out using Department of Lands aerial photographs. Outcrop was generally good, enabling many formation and unit boundaries to be followed, but in the north east only scattered outcrop was available, and as a result, positioning of boundaries is less certain. Mapping was supported by study of thin sections, hand specimens and acetate peels, and enabled the following descriptive stratigraphy and palaeoenvironmental interpretation to be made.

Fellow Honours student, Helen Jablonski, mapped an area to the south of the writer's study area.

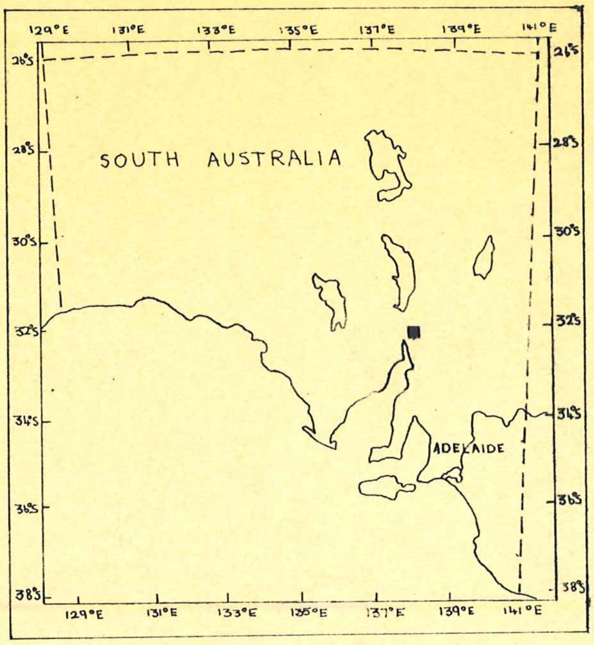
REGIONAL SETTING

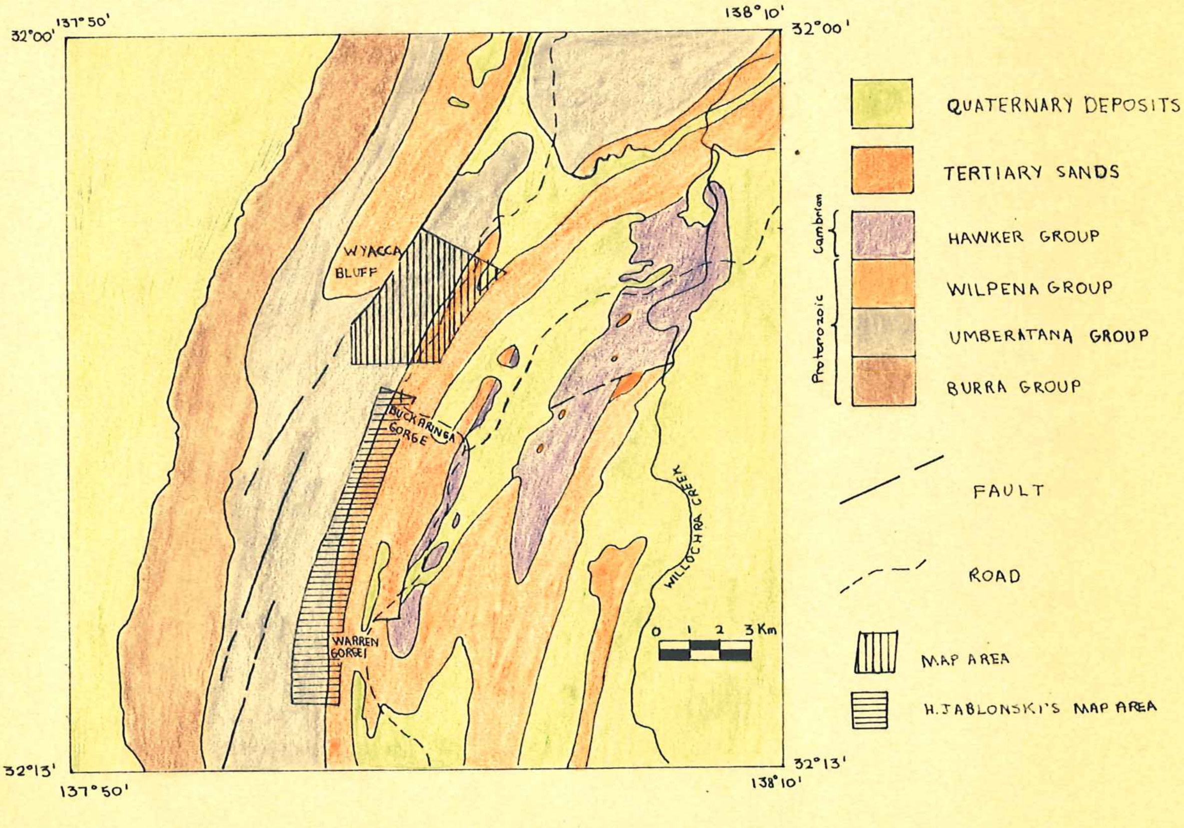
The area studied in this thesis occurs on the western margin of the Adelaide "Geosyncline" in which a sedimentary sequence developed as basement cover in the Later Precambrian and Cambrian. The Late Precambrian sequence or Adelaide System, which has been divided into four time-rock units, the Willouran (Sprigg, 1952), Torrensian, Sturtian and Marinoan Series (Mawson

FIGURE 1

LOCALITY MAP AND REGIONAL GEOLOGY

WYACCA BLUFF BUCKARINGA GORGE AREA, FLINDERS RANGES, SOUTH AUST.





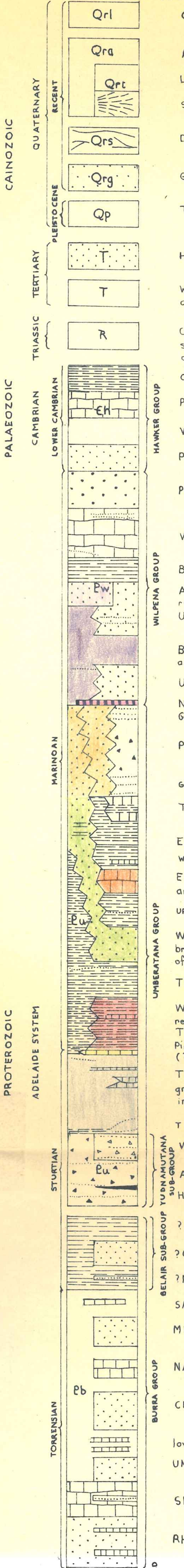
FROM THE ORROROO AND PORT AUGUSTA 1:250,000 GEOLOGICAL MAP SHEETS

R.K.M. 1975

FIGURE 2

STRATIGRAPHIC TERMINOLOGY

ORROROO (1:250 000 MAP AREA)



Gypseous clays, silts and quartz sands of lakes (normally dry).

Alluvium of drainage channels and flood plains.

Low angle slope deposits.

Scree deposits.

Dune sands and sand spread.

Gypseous sands and silts.

TELFORD GRAVEL.

High level silcreted gravels.

White sands and silts, locally coarser-grained and cross-bedded; ferricreted and silcreted.

Carbonaceous shales and argillites with impure coal seams and interbedded fine-grained sandstone. Local conglomerate at base.

ORAPARINNA SHALE

PARARA LIMESTONE

WILKAWILLINA LIMESTONE

PARACHILNA FORMATION

POUND QUARTZITE

WONAKA FORMATION

BUNYEROO FORMATION

A.B.C. RANGE QUARTZITE: White quartzite with interbedded red-brown and grey-green siltstones near base.

ULUPA SILTSTONE

BRACHINA FORMATION: Reddish well laminated siltstone and shale occurring in west of area.

ULUPA SILTSTONE

NUCCALEENA FORMATION: Lenticular pink dolomite.

GRAMPUS QUARTZITE

PEPUARTA TILLITE

GUMBOWIE ARKOSE MEMBER

Passes west and north-west into: ELATINA FORMATION: Red brown sandstone and silt-with occasional small granules.

TREZONA FORMATION

ENORAMA SHALE

WAUKARINGA SILTSONE MEMBER

ETINA FORMATION: Buff weathering, grey, sandy and oolitic limestone.

UROONDA SILTSTONE MEMBER

WILLOCHRA FORMATION Unnamed upper member Red-brown and blue-grey sandstones and siltstones with lenses of granular sand and sandy limestone.

TARCOWIE SILTSTONE

WILLOCHRA FORMATION: Unnamed lower member Flaggy red brown siltstone with ripple marked shale partings. Thin interbeds of granule sandstone and sandy limestone. Pink and grey dolomite and limestone with algae. Locally sandy. (? BRIGHTON LIMESTONE EQUIVALENT

TAPLEY HILL FORMATION Flaggy, well laminated, blue-grey siltstone. Calcareous near top with thin bands of interbedded limestone.

TINDELPINA SHALE MEMBER

WILYERPA QUARTZITE

APPILA TILLITE

HOLOWILA IRONSTONE

? KADLUNGA SLATE

?GILBERT RANGE QUARTZITE

?MINTARO SHALE

SADDLEWORTH FORMATION EQUIVALENT

MINBURRA QUARTZITE

NACKARA DOLOMITE

CRADOCK QUARTZITE

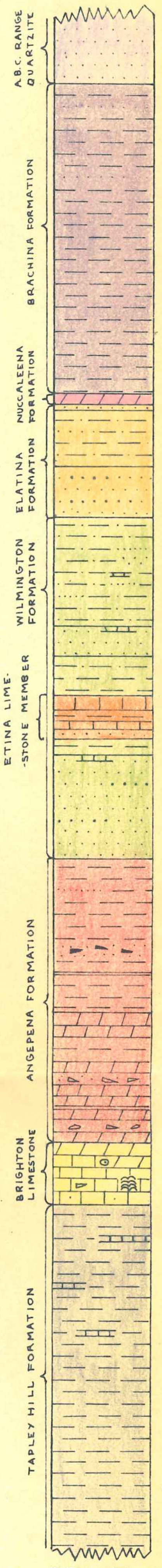
lower AUBURN DOLOMITE EQUIVALENT

UNDAL YA QUARTZITE

SKILLOGALEE DOLOMITE

RHYNIE SANDSTONE

WYACCA BLUFF-BUCKARINGA GORGE AREA



White and pink massive quartzites with abundant heavy mineral lamination.

Laminated purple, and minor green siltstones, with interbeds of fine sandstone.

Laminated pink dolomite and purple shale.

Purple siltstones and fine sandstones, and minor grey fine sandstone.

Grey fine sandstone with laminae and thin beds of coarse sand and granules.

Grey-green laminated siltstones and fine sandstones with beds of massive fine to coarse grained sandstone. Generally calcareous. Minor limestone.

Massive grey-green calcareous fine sandstone, minor limestone at top.

Purple and grey-green laminated calcareous siltstone.

Sandy oolitic limestones, stromatolitic limestones, sandstones and calcareous siltstones.

Laminated grey-green calcareous siltstones.

Grey fine grained sandstone with laminae of medium to coarse sand, and minor purple shale Minor sandy limestone.

Laminated purple and grey siltstones, purple shale, and thin sandy beds. Beds of purple shale clasts in a sandy matrix common. Ripple marks and mud-cracks abundant

Interbeds of purple dolomicrite, silty dolomite and intraformational conglomerate containing dolomitic intraclasts. Purple shale and siltstone occur.

Oolitic and intraclastic limestone, stromatolitic limestone and dolomite sandy limestone and calcareous sandstones and siltstones.

Dark grey laminated calcareous siltstones, with lenses of grey intra-clastic limestone and minor stromatolitic dolomites.

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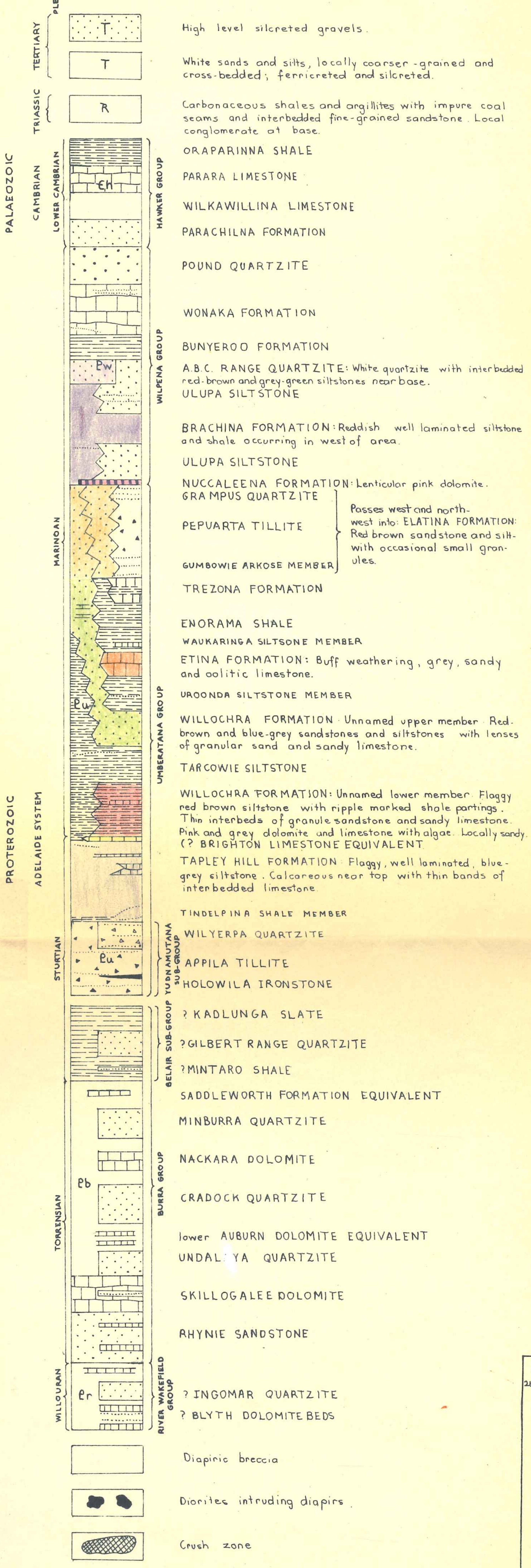
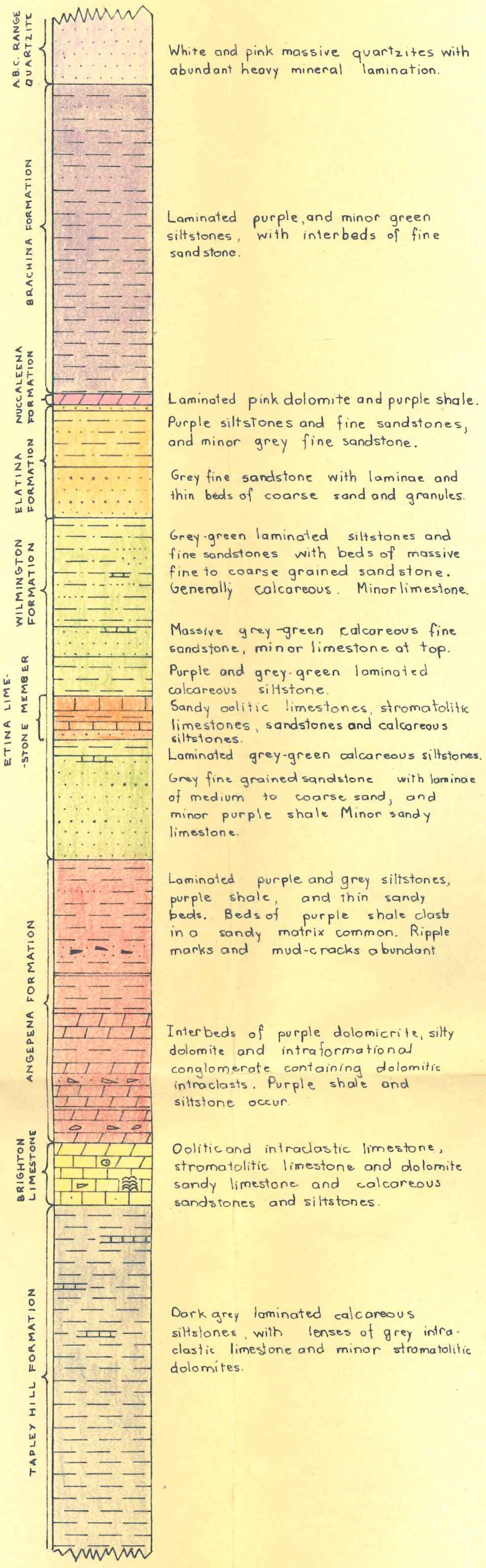


WYACCA BLUFF-BUCKARINGA GORGE AREA



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LOCALITY

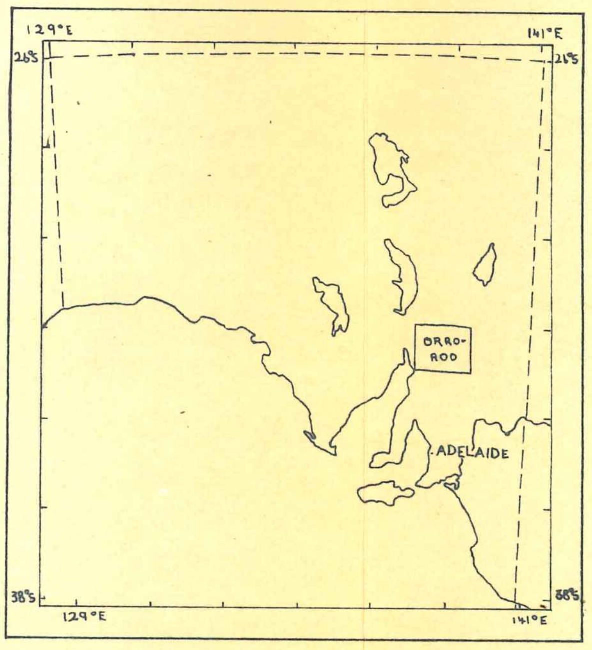

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FIGURE 3

GEOLOGICAL AND LITHOFACIES MAP WYACCA BLUFF—BUCKARINGA GORGE AREA

FLINDERS RANGES, SOUTH AUSTRALIA

REFERENCE

Creek alluvium

White and pink massive quartzites with heavy mineral lamination, abundant clay galls, cross-bedding, ripple marks and mud cracks.

Laminated purple and minor green siltstones, with fine sandstones becoming increasingly common higher in the formation Ripple marks and cross laminations occur.

Laminated pinkish-yellow muddy dolomites and purple dolomitic shales

UNIT E3 Light grey trough-cross-laminated fine grained sandstone with rare coarse sand and granules

UNIT E2 Complex unit of purple calcareous siltstone and fine sandstones with scattered coarse grains, and well laminated fine grained grey sandstones.

UNIT E1 Grey fine grained sandstones with laminae and thin beds of coarse sand, granules and minor pebbles

UNIT W8 Grey-green laminated calcareous siltstones and fine sandstones with beds of massive fine to coarse grained sandstones, often cross-bedded, and minor limestone

UNIT W7 Massive grey fine grained calcareous sandstones with minor oolitic limestones at the top

UNIT W6 Purple shales and siltstones coarsening upwards into grey-green laminated siltstones and fine sandstones Small lens of sandy oolitic limestone.

UNIT W5 Light grey sandy oolitic limestones, dark grey stromatolitic limestones, grey fine grained sandstones and siltstones

UNIT W4 Purple and grey-green calcareous siltstones.

UNIT W3 Sandy and granular oolitic limestones, often with tabular cross-beds, fine grained grey sandstones and lighter coloured coarse grained sandstones.

UNIT W2 Grey-green and minor purple calcareous siltstones, lens of light grey calcareous medium grained sandstone in south.

UNIT W1 Grey fine grained sandstone with laminae of medium to coarse sandstone and minor purple shale Some heavy mineral trough cross-laminated medium grained sandstones and minor sandy limestone.

UNIT A2 Laminated purple and grey siltstones and purple shale, with some thin sandy beds. Beds of intraformational conglomerate contain purple shale clasts in sandy matrix. Frequent ripple marks and mud cracks.

UNIT A1 Interbeds of purple dolomicrite, silty dolomite and intraformational conglomerate containing dolomite intraclasts. Purple shale and siltstone occur.

UNIT B2 Purple and pink sandy oolitic and intraclastic dolomites and white dolomitic sandstones.

UNIT B1 Complex unit of intraclastic and oolitic limestones, sandy limestones, pale grey-green stromatolitic calcareous dolomites, red stromatolitic and micritic dolomites and minor calcareous siltstones and sandstones.

Dark grey laminated calcareous siltstones with small lenses of grey intraclastic limestones and minor stromatolitic dolomites.

GEOLOGICAL BOUNDARIES
FAULT
BRECCIATED SILTSTONES
BEDDING
CLEAVAGE
ROAD
TRACK
EPHEMERAL STREAM
DAM
SPRING

R.K.MILLER 1975

and Sprigg, 1950), consists of shallow marine clastics and carbonates, and glacial sediments. The major source area was probably the Gawler Craton to the west.

Deposition was episodically interrupted by tectonism, resulting in the development of widespread unconformities. Major tectonic activity resulted from the Cambro-Ordovician Delamarian orogeny, and renewed activity occurred in the Tertiary with major block faulting.

STRATIGRAPHY

GENERAL

The stratigraphic sequence studied in this thesis extends from the Tapley Hill Formation (base not exposed) in the Umberatana Group, to the A.B.C. Range Quartzite in the Wilpena Group (Figure 2). Each formation has generally been divided into a number of mappable units, which may show further internal lithologic variation. The distribution of the units mapped is shown on the geological map (Figure 3 - in folder at back). The boundaries shown are lithostratigraphic, and do not necessarily imply time equivalence. Stratigraphic nomenclature used is after Parkin ((ed.), 1969), Binks (1971) and Forbes (1971).

UMBERATANA GROUP

This group, which spans the Sturtian - Marinoan boundary, is composed of a lower glacial sequence, a thick non-glacial sequence of shallow marine sediments, and an upper sequence of variable glacial influence. In the study area, the lower glacial sequence does not outcrop.

Farina Sub-Group

This sub-group consists of the Tapley Hill Formation and Brighton Limestone.

Tapley Hill Formation

The Tapley Hill Formation has been described by Binks (1971, p.34) as consisting "typically of well laminated blue-grey flaggy siltstones". In the study area, the dominant lithology is a dark grey, finely laminated calcareous quartzose siltstone (T.S. 463/020)*, which becomes increasingly calcareous higher in the

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*T.S. 463/... and 463/... refer to thin section and hand specimen descriptions respectively, details of which are given in Appendix 2.

formation to the extent that the carbonate content may exceed 50%. Lamination is essentially planar, but cross-lamination and straight crested symmetric ripple marks with wavelength up to 8cm occur (Plate IIa). Polygonal mudcracks, 1cm in size, were observed at the top of the formation (Locality 1, see Figure 10).

Dark grey, finely crystalline and pyritic, intraclastic limestones with dominantly dolomitic intraclasts (T.S. 463/194), occur as small lenses up to 10m long and 2m thick, although more continuous beds may occur. Columnar stromatolites (Plate Ia) associated with intraclastic carbonates, occur in a small erosional hollow at Locality 2. They show a rather streaky microstructure consisting mainly of dolomite, but irregular patches of calcite, and pyrite euhedra occur. Some intraclasts within the limestones may be stromatolitic fragments. The occurrence of dolomite intraclasts within limestones, indicates a reworking of early lithified and dolomitized sediments.

Brighton Limestone

This formation, the top of which marks the Sturtian - Marinoan boundary, "consists of grey to pink limestone and dolomite .... and is frequently sandy" (Binks, 1971, p.36). In the study area the thickness is relatively constant, ranging from 80 to 95m.

Unit B1: The boundary with the Tapley Hill Formation was generally placed at the first occurrence of pseudocolumnar stromatolites. However the transitional nature of the change from the Tapley Hill Formation to the Brighton Limestone is indicated by the increase in carbonate content in the Tapley Hill Formation, and the occurrence of calcareous siltstones in the lower part of the Brighton Limestone. A variety of lithologies is present. These include terrigenous clastics, oolitic and intraclastic limestones, stromatolitic limestones and dolomites, and micritic dolomites.

The terrigenous clastics include calcareous siltstones and sandstones which may grade into silty and sandy limestones. Their occurrence is greatest in the northern third of the area (see Appendix 1, Section 1). Further south, siltstones, near the base of the formation are the only clastics present. Outcrop is generally massive, although some lamination is apparent (T.S. 463/218). However elongate grains, including muscovite, do not show any preferred orientation parallel to the lamination. Minor intraclasts, usually aphanic carbonate (?), occur, but oolitic intraclasts may be significant. Trough cross-beds, up to 50cm thick occur in the sandy lithologies, and both sandstones and siltstones are interbedded with intraclastic and stromatolitic limestones.

Intraclastic limestones are generally grey, and contain yellow and grey intraclasts of variable size and proportion. Some elongated large clasts are arranged parallel to bedding. The intraclasts are mainly a mixture of aphanic dolomite (these include stromatolitic fragments of early diagenetic origin) and finely crystalline limestone (T.S. 463/135). Oolitic intraclasts (T.S. 463/137), consisting of ferroan dolomite and minor ferroan calcite, are generally confined to the upper half of this unit, where they are up to 3cm in size. Ooids, which are generally recrystallized, consist of a dolomite core and calcite rim, and are generally associated with the oolitic intraclasts. In the anticlinal hinge area, complete dolomitization of intraclastic limestones has sometimes occurred.

Texturally, all these intraclastic limestones are grainstones. The grains are dominantly allochemical types. Only a few terrigenous grains are present, and often these have overgrowths. Rarely ooids are the only major constituent (T.S. 463/226, Plate Va).

Stromatolite bioherms (Plate Ib) which weather yellow in outcrop, are composed of pale grey laminae of ferroan calcite, and pale green and yellow laminae of ferroan dolomite (T.S. 463/033 and T.S. 463/126). They are common in the northern and central parts of the outcrop zone of this unit (further stromatolite characters will be discussed later). Southward similar stromatolites have been completely dolomitized to pale grey ferroan dolomite, although texturally the lamination is similar to that involving calcite and dolomite. In the anticlinal hinge area, further alteration, possibly associated with faulting has occurred. Stromatolite lamination is indicated by yellow microcrystalline and brown aphanic dolomite (T.S. 463/229). Both detrital, and secondary polygonal quartz occurs.

The dolomite and calcite in those lithologies already described, is predominantly ferroan. However red and yellow dolomicrites in the uppermost part of this unit consist of non-ferroan dolomite. Yellow dolomites, with minor red micritic, and grey stromatolitic dolomites occur in the north of the area. Sandy laminae may occur (T.S. 463/187), and mottled grey and yellow pyritic dolomites were observed (Locality 3). Southward pale red dolomicrites with scattered sand grains replace the yellow dolomites. Bedding or lamination is generally lacking, but stromatolites (see later) are common (T.S. 463/169). On the western side of the anticline, red stromatolitic dolomites occur almost at the base of this unit, and are associated with other buff micritic, (T.S. 463/162) and oolitic dolomites. Dolomites appear to dominate on this side of the anticline, although pseudo-columnar stromatolites with limestone-dolomite lamination are still present at the base of the Brighton Limestone.

Unit B2: Oolitic dolomites and dolomitic sandstone outcrop almost continuously at the top of the Brighton Limestone. Thicknes of this unit is generally less than 10m, but rarely may exceed 20m. Interfingering with red dolomites of the underlying unit occurs.

Oolitic dolomites dominate in the north. Texturally they are grainstones consisting of ooids, composite ooids, dolomite intraclasts and sand, which are enclosed in a sparry dolomite cement of which two generations may occur (T.S. 463/221). Intraclasts include micritic and finely crystalline dolomite. Beds composed dominantly of oolitic intraclasts indicate cementation near the depositional interface. Southward white, dolomitic, poorl sorted, medium to coarse subarkoses (T.S. 463/163) are more common. Partial replacement of quartz and feldspar by dolomite is common. Trough cross-bedding in sets 10 to 15cm thick, occurs in both the oolitic and sandy beds.

The preservation of concentric structure of the ooids and crystal structure in the cement, indicates that dolomitization occurred without significant recrystallization. However the completeness suggests that it was post lithification. The development of authigenic feldspar overgrowths may be associated with dolomitization.

Willochra Sub-Group

This sub-group consists of the Angepena Formation, Wilmington Formation and Elatina Formation.

Angepena Formation

This formation, defined in the Copley area, is equivalent to the unnamed lower member of the Willochra Formation on the Orroroo 1:250,000 map area, where it consists of "flaggy red-brown siltstones with mud-cracked and ripple marked shale partings" (Binks 1971, p.37). In the study area it has been divided into a lower predominantly dolomitic unit, and an upper terrigenous clastic unit.

Unit A1: The lower unit has a maximum thickness of 175m in the northern part of the area, and thins to less than 100m further south. It consists of interbedded purple micritic dolomite, finely crystalline silty dolomite, siltstone, shale, and intraformational conglomerate with dolomite intraclasts up to 12cm in size in a matrix of sand, silt and dolomite (T.S. 463/016, Plate IIb). The latter beds may rest on an erosional base and be graded. Beds of intraformational conglomerate consisting of close packed dolomitic intraclasts in a dolomite cement and lacking sand, are up to 21m thick.

Sedimentary structures include tepees (463/233), small polygonal mudcracks, slightly sinuous symmetric ripple marks with bifurcated crests and wavelength up to 5cm, fenestrae filled with dolomite and quartz (T.S. 463/225) and climbing ripples (Locality 4).

In the northern part of the area the change upwards from a predominantly dolomitic to a largely terrigenous clastic sequence is relatively distinct. Southward, the change is more transitional and terrigenous clastics exceed 50% at a lower stratigraphic level, although dolomite is significant to approximately the same level as further northward. Because of this extremely transitional contact between Units A1 and A2, as compared with the distinct lower boundary of Unit A1, these dolomites have been included in the Angepena Formation, although Preiss (1972) and Plummer (1974) have included similar dolomites in the Brighton Limestone.

Unit A2: This unit which is 205m thick in the northern part of the area, thickens southward to 400m. Purple and grey siltstones dominate, but purple shale, and sandy beds also occur, with dolomite interbeds in its lower part. The sandy beds are poorly sorted, with silt and rounded sand grains up to very coarse sand size. Commonly they contain elongate, angular intraclasts of purple mudstone up to 5cm in length (T.S. 463/207, Plates Ic,Vb). A carbonate matrix is generally present. Clay also occurs, and the purple colour is probably due to ferric oxides in this size fraction.

The siltstones are well laminated, and commonly lenticular.

Symmetrical, and less abundant asymmetric ripple marks occur. These have straight to slightly sinuous crests, with wavelength of 1 to 5cm, and amplitude less than 0.75cm. Polygonal mud-cracks, 1 to 15cm in size are common, and rarely sinuous discontinuous mud-cracks occur.

Wilmington Formation

The type section of the Wilmington Formation is in Horrocks Pass, where it comprises "red and grey sandstones with abundant grit bands and occasional gritty limestones" (Parkin (ed.), 1969, p.70). Eight mappable units have been distinguished within this formation. Units W3 to W5 inclusive comprise the Etina Limestone Member (defined in Parkin (ed.), 1969, p.70). Some units have been repeated by faulting. Thickness varies from 390m in the north to 560m in the south.

Unit W1: This unit, whose lower contact with the Angepena Formation is transitional over 5 to 10m, consists dominantly of grey, fine grained feldspathic sandstones (T.S. 463/009), with laminae of medium to coarse sand. Purple shale laminae have been dessicated to give thin flakes which appear to have experienced minimal transport. Symmetric and asymmetric ripple marks, and less commonly interference ripples occur (Plate IIIa). Wavelength varies from 1.5 to 10cm, and the bifurcated crests are straight or slightly sinuous. Dessication cracks are dominantly sinuous and occur in shale laminae in ripple troughs (Plate IIIc). Polygonal mud-cracks are less common.

Light greyish-pink fine to medium grained feldspathic sandstones with heavy mineral laminae (T.S. 463/101) occur at the top of this unit and less commonly at lower stratigraphic levels. Calcareous medium grained feldspathic sandstones (T.S. 463/052), and sandy limestones may occur above the heavy mineral laminated sandstones.

Unit W2: This unit, which thickens southward from 20 to 70m has a sharp contact with the underlying sandstones, and consists of laminated grey calcareous siltstones and very fine sandstones, with minor purple shale (T.S. 463/107). A lenticular calcareous feldspathic sandstone (T.S. 463/251) similar to the calcareous sandstones of Unit W1 occurs, and contains tabular cross-beds up to 40cm thick and symmetric ripple marks.

Etina Limestone Member - Unit W3: This complex unit of sandy oolitic limestones and sandstones with minor purple shale, increases in thickness southward from 32 to 45m.

Light grey, and less commonly pinkish sandy oolitic limestones (T.S. 463/107A) form massive outcrop with stylolites up to 5cm thick. Ooids, which are generally recrystallized, and the enclosing sparry mosaic are composed of ferroan calcite. The limestones, in which the terrigenous fraction ranges from 20% to 50%, grade into calcareous sandstones. The latter are frequently very coarse and conglomeratic sandstones in which the largest grains are fragments of red volcanics and porphyries. Lenses and thin beds of finely crystalline limestone which have been reworked to give scattered intraclasts, contain little silt and sand. Tabular cross-bedding (Plate IIIb) is common, with sets up to 1.0m thick, although they are generally less than 0.5m. Dip of the foresets is moderately steep (15° to 30°). Trough cross-bedding is less common.

Although limestones are generally more conspicuous, feldspathic sandstones predominate and are of two distinct types.

(a) Dark grey fine grained feldspathic sandstones, fairly well sorted, and with heavy mineral trough cross-laminae, form massive outcrops. Carbonate may be the dominant matrix component, but clays and silica may predominate (T.S. 463/213).

(b) Lighter coloured medium to coarse grained feldspathic sandstones cemented by silica (T.S. 463/215).

<u>Etina Limestone Member</u> - Unit W4: Finely laminated purple and minor grey-green calcareous shales and siltstones make up this unit. Its lower and upper contacts are sharp. The thickness appears relatively constant and does not exceed 20m.

<u>Etina Limestone Member</u> - Unit W5: Sandy oolitic limestones and sandstones, similar to those in Unit W3 occur in this unit which is generally less than 20m thick, although it appears to lens out to the north east.

Light grey sandy oolitic limestones (T.S. 463/047) and associated calcareous sandstones, often conglomeratic generally occur at the base and top of this unit. They contain thick stylolites, and minor tabular cross-bedding in sets up to 50cm thick. Lenticular beds and laminae of crystalline limestone with minor silt (T.S. 463/060) occur in the sandy limestones.

Convolute bedding is present in some of the beds.

Stromatolites occur in small domal bioherms with dimensions generally less than 1m, and in larger, more lenticular bioherms up to 4.5m thick. Stromatolite columns are barely visible in outcrop but cut surfaces expose irregular columns with indistinct laminae (T.S. 463/130). The dark grey limestone comprising the stromatolites, consists of ferroan calcite with up to 10% silt and sand.

The various limestones have experienced penecontemporaneous erosion, to give intraclastic limestones (T.S. 463/246). The irregular shape of some stromatolitic fragments indicates minimal transport (Plate Id), although other clasts show better rounding. Hence cementation close to the depositional interface is indicated, and this would have provided a consolidated substrate for stromatolite growth.

Grey fine grained feldspathic sandstones with heavy mineral trough cross-laminae are similar to those in Unit W3. The matrix may be calcareous or partially siliceous (T.S. 463/182). Coarser grained non-calcareous whitish sandstones are only a minor component. Laminated grey-green calcareous siltstones may also be significant, especially in the more easterly outcrops of this unit.

Unit W6: Thickness of this unit is relatively constant at 50m. The contact with the underlying limestones is sharp, and purple calcareous siltstones coarsen upward into grey-green laminated calcareous silty very fine sandstones (T.S. 463/076). A lens of oolitic sandy limestone (T.S. 463/240) composed of ferroan calcite occurs, and reaches a maximum thickness of 6m.

Unit W7: Well laminated very fine sandstones at the top of Unit W6 pass gradationally into massive grey fine grained calcareous feldspathic sandstones. Indistinct planar lamination and heavy mineral trough cross-lamination are sometimes discernible.

Lenticular oolitic limestones (T.S. 463/240) at the top of the unit contain ooids of ferroan calcite floating in non-ferroan calcite (Plate Vd), but recrystallization has destroyed some of the original texture. Thinly bedded medium grained sandstones may occur between the limestones and massive sandstones.

Unit W8: This unit thickens southward from 65 to 150m. Laminated grey-green calcareous silty fine sandstones (T.S. 463/202A) are dominant, and may contain purple shale laminae. The lamination is often lenticular and slightly coarser laminae delineate starved ripples. Both asymmetric and symmetric ripple marks occur, with maximum wavelength of 10cm. Trough shaped structures are also present. Quartz is the major component but feldspar is significant. Chlorite occurs as large flakes which have formed by replacement of muscovite, as well as a component of the matrix.

Interbedded with the well laminated sandstones are coarser, more massive sandstones. Fine to medium grained sandstones with heavy mineral trough cross-laminae occur in the northern two-thirds of the area in beds up to 2m thick. However thicker sandstone bodies occur further south.

The lowermost sandstone has a sharp base with the underlying laminated siltstones. A tabular cross-bed, 1.5m thick occurs at its base and carries rounded quartz, feldspar and red porphyry grains. Overlying sandstones contain tabular cross-beds up to 20cm thick, and are followed by fine grained sandstones with heavy mineral trough cross-laminae. The second sandstone body which is about 10m thick, also has a basal cross-bed, exceeding 2m in thickness (Plate IIId). Currents directed to the north and north-east are indicated, but smaller cross-beds climbing the foreset of the larger structure indicate opposing currents. The sandstones are grey and calcareous with coarser beds of quartz, feldspar, red porphyry grains and limestone fragments up to granule size, alternating with fine and medium grained sandstone. Tabular cross-beds up to 0.5m thick, and indicating currents directed north-easterly and southerly occur in the overlying medium grained sandstones. Finer grained grey calcareous sandstones (T.S. 463/192) contain heavy mineral laminae.

The third sandstone body is approximately 4m thick and consists of grey fine grained calcareous sandstones forming a massive outcrop. Tabular cross-bedding occurs in slightly coarser sandstones. A massive lenticular limestone (T.S. 463/190) constitutes a further interbed which is approximately 10m thick.

Elatina Formation

Binks (1971, p.41) describes the Elatina Formation as consisting of "cross-bedded, red-brown feldspathic sandstone with interbeds of red-brown massive siltstone. Granule grains up to 2 to 4mm are common". Three units have been mapped within this formation which ranges in thickness from 100 to 150m.

Unit E1: This unit has gradational lower and upper boundaries, although the thickness is fairly uniform (50 to 65m). It consists of fine grained grey feldspathic sandstones with laminae and thin beds of coarse sand, granules and minor pebbles (Plate IId). Coarse grains are scattered randomly in the fine sandstones (T.S. 463/204). Lithic fragments including "granitic", red porphyries, metamorphic, iron ore and carbonate types are more prominent in the coarser laminae. Sedimentary structures include tabular cross-beds in isolated sets up to 1m thick, and soft sediment folds.

Unit E2: Thickness of this unit is variable ranging from 15m to in excess of 70m. A variety of rock types are present. The finest grained are finely laminated purple shale and purplish-grey siltstone. They are generally only minor except where this unit is thickest. The purple shale has sharp boundaries with the wavey silty laminae. Truncated laminae indicate penecontemporaneous erosion. Asymmetric ripple marks have wavelength up to 30cm, and amplitude 1.5cm.

Purple and purplish grey laminated siltstones and fine sandstones are common rocktypes. Generally they are calcareous and may contain scattered intraformational mud clasts, coarse sand and granules.

Sedimentary structures include

(a) asymmetric ripple marks with maximum wavelength of 45cm, amplitude of 1.5cm. They may be markedly sinuous,

(b) climbing ripples and trough cross laminae in purplish grey siltstones,

(c) lenses of coarse quartzo-feldspathic sand apparently filling scours. Load casts are also present.

Unlaminated purple calcareous siltstones and very fine sandstones are prominent (T.S. 463/085) and form massive outcrops often with a coarse cleavage. Poor sorting is generally characteristic, with scattered coarse sand and granules, including quartz, feldspar, red porphyries, iron ore and carbonate clasts.

Grey very fine grained sandstones (T.S. 463/180) contain purple shale laminae less than 1mm thick, which may be planar, or delineate climbing ripples in sets up to 30cm thick, and with thinner stoss side than lee side laminae.

Yellowish and greenish very fine grained sandstones (T.S. 463/090) carrying pyrite pseudomorphs occur as thin beds from a few centimetres to 2m thick. The irregular boundaries of some beds suggest that they have been formed by leaching of the enclosing lithologies.

Unit E3: The uppermost unit of the Elatina Formation is a light grey very fine grained feldspathic sandstone (T.S. 463/248) with heavy mineral trough cross-laminae. Coarser sand and gravel up to 1cm in size (Location 5) occur, and appear to be confined to particular beds or laminae. This sandstone reaches a maximum thickness of 15m, but may be absent.

WILPENA GROUP

This group which consists of siltstones, shales, quartzites and minor limestones is the uppermost group of the Adelaide System. Only three lower formations of the group are represented in the map area.

Nuccaleena Formation

This formation which was established on the Copley 1:250,000 geological map sheet "consists typically of a cream, well bedded dolomite overlain by purple shales with occasional dolomite bands" (Binks, 1971, p.42). There is a sharp contact at the base of the 12 to 24m thick Nuccaleena Formation in the study area. It generally consists of interlaminated yellowish-pink dolomite and purple dolomitic shale (T.S. 463/053). However immediately north of Section 7 (see Figure 10), purple shale with dolomite nodules occurs for about 250m along strike, with the laminated dolomite reaching a minimum thickness of 1m. Lamination in the shale passes continuously through the nodules but is slightly expanded within them (463/183). A diagenetic origin appears most likely for the nodules (see Henningsmoen, 1974). Laminated dolomites occur immediately to the north and south of the nodular dolomites, and are laterally equivalent to them. Hence the origin of the laminated dolomites may be partly diagenetic also. Alternatively the nodules may have formed by dissolution.

Brachina Formation

The type section of the Brachina Formation is in Brachina Creek where the formation consists of 1300m of "red and green siltstones with ripple marks, small scale slump structures and heavy mineral layering" (Parkin (ed.), 1969, p.74). In the study area the formation forms an area of subdued topography and is about 420m thick. Laminated dolomites of the Nuccaleena Formation pass gradationally into purple, and minor green laminated siltstones (T.S. 463/091). The confinement of red and green colours to particular layers suggests that this is a depositional or early diagenetic feature associated with the oxidizing conditions of the environment. Pale yellow beds with pyrite pseudomorphs suggests that at times conditions were reducing. Purple fine grained sandstones are abundant higher in the formation.

Lamination may be planar or lenticular. Current activity has produced symmetric and asymmetric ripple marks with wavelength between 5 and 20cm, cross-lamination and cross-bedding. Other sedimentary structures include trough shaped structures, pillows, flute casts(?) and graded bedding.

A.B.C. Range Quartzite

"This flaggy white quartzite .... is cross bedded and has heavy mineral bands" (Parkin (ed.), 1969, p.75). In the study area, it forms a ridge on the eastern side of the area, and consists of white and pink quartzites (T.S. 463/095), often with heavy mineral laminae. Sedimentary structures include tabular cross-beds, ripple marks, mud cracks and abundant clay galls. Petrologically the quartzites are quartz arenites and hence can be contrasted with the sandstones of the Umberatana Group which contain more feldspar.

STROMATOLITES IN THE BRIGHTON LIMESTONE

An empirical stromatolite biostratigraphy has been successfully applied to Middle and Late Precambrian basins of the U.S.S.R. (Cloud and Semikhatov, 1969; Raaben, 1969). This biostratigraphy has been extended to Australian Late Precambrian sequences (Glaessner etal., 1969; Preiss, 1972; Walter, 1972), although some unsolved problems remain (Preiss, 1972). This application implies that stromatolite morphology is controlled at least to a certain extent by sediment trapping blue-green algae, and that evolutionary trends occurred within the blue-green algae.

It has been proposed that microstructural features are biologically controlled, where-as macrostructural features are determined by environmental factors (Serebryakov and Semikhatov, 1974; Gebelein, 1974). However stromatolites are built by communities of organisms (Cloud and Semikhatov, 1969; Gebelein,

1969) and changes in microstructural features may be due to changes in communities as a result of environmental changes rather than evolutionary changes (Gebelein, 1974).

Macro- and micro-structural features of the stromatolites in the Brighton Limestone which can be determined from observation on outcrop, hand specimen and thin section are described. Identification of stromatolite "group" and "form" is not attempted as time was unavailable for the rigorous three dimensional reconstruction necessary. Descriptive terminology used is that of Hofmann (1969, Fig 13).

Pseudocolumnar and columnar layered stromatolites occur within the sandy and oolitic-intraclastic carbonates of the Brighton Limestone, and columnar types within the dolomites at the top of Unit B1.

At the base of the Brighton Limestone, pseudocolumnar stromatolites (Plate IVa) 5-15cm wide, and less commonly stratiform laminae occur in tabular and domal bioherms. Laminae which are smoothly convex, rectangular or geniculate consist of

(a) pale green or yellow micritic ferroan dolomite with minor quartz silt,

(b) pale grey finely crystalline ferroan calcite with deeply embayed quartz and feldspar, 0.03 to 0.25mm in diameter making up to 15% of the laminae.

Thickness of the laminae is between 0.2 and 3mm. Elongate intraclasts may occur between the domes. Calcareous siltstones, and silty and intraclastic limestones enclose the bioherms and each sediment type may provide a substrate for stromatolite growth which occurred as relatively flat laminae increasing in convexity upwards. Growth occurred in a shallow subtidal environment with moderate but persistent agitation shaping the elongate body.

The pseudocolumnar stromatolites are replaced by bioherms which contain columnar stromatolites, but these generally grow from linked stromatolites and are replaced by linked domes or relatively flat laminae. Columns, 1 to 5cm in width, generally have bridging laminae extending over several adjacent columns. Only a few millimetres of relief occurr between columns and interspace sediment. Columns are rounded to lobate in plan, and location within the bioherm probably afforded protection from currents and elongate columns did not form. Compositionally the laminae are similar to those already described and are up to 2mm thick.

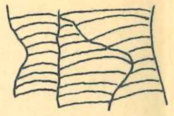
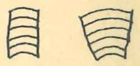
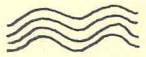
Columnar stromatolites replace the previously described types and occur in domal bioherms generally with continuous laminae on the boundaries. Slender columns, 1 to 6cm in width, exhibit vertical growth within the bioherm and inclined on the margins. Branching is digitate but coalescing columns are common. Numerous bridging laminae (Plate IVb) indicate that these stromatolites may be better described as columnar layered in preference to columnar, although more discrete columns occur in the highest occurrences. Bridging laminae also indicate that sedimentation virtually kept pace with stromatolite growth. Lamination is streaky and pale green laminae of ferroan dolomite, alternate with pale grey laminae of ferroan calcite. The interspaces contain abundant sand in the uppermost occurrences of these stromatolites, indicating that currents became active enough to transport substantial amounts of sand across the bioherm. Associated sediments include sandy, intraclastic and oolitic limestone, indicating that growth occurred in a strongly agitated, shallow subtidal environment.

The origin of the dolomite laminae is problematical. The presence of dolomitic intraclasts of stromatolitic origin in the surrounding sediment indicates that it is a primary or very early formed feature. However a detrital origin seems precluded as interspace sediment, deposited virtually at the same time as the adjacent dolomite laminae lacks dolomite. An origin related to algal growth may be more likely.

The second stromatolite type has been completely dolomitized as has the surrounding sediment. These columnar stromatolites are composed of red dolomite and less commonly grey. Alteration may have destroyed some stromatolites, as very indistinct columns were observed. Stylolites parallel to lamination are common. Columns, 1.5 to 10cm wide, frequently show swellings and constrictions and are closely spaced (Plate IVc). There is little branching except to form small projections. Lamination is horizontal to gently convex and slightly wavey. Laminae of aphanic dolomite, 0.2 to 3mm thick, with scattered patches of finely crystalline dolomite, alternate with laminae of finely crystalline dolomite which has been partly replaced by coarser calcite. Quartz, feldspar, muscovite and opaques 0.03 to 0.5mm

FIGURE 4

CHARACTERISTICS OF BRIGHTON LIMESTONE STROMATOLITES

	Macrostructural				Both biologic and non-biologic control.		Microstructural			Associated Sediments	
	Mode of occurrence	Attitude of columns	Linkage	Plan outline	Column shape	Margin structure	Branching	Relief along laminae	Lamination	Interspace sediment	Enclosing sediment
Type 2 Columnar	? Domal bioherms	Vertical to near horizontal	Only minor bridging laminae	? but probably irregular	Columns show numerous swellings and constrictions 	Unwalled  niche and projection	Rare - digitate	Near horizontal to gently convex laminae, some with second order curvature.	Completely dolomitized - alternating aphanic and finely crystalline dolomite.	Dolomite with some sand, silt and intraclasts.	Dolomicrite with scattered sand grains and rare sandy laminae.
Type 1 Columnar (layered)	Regularly and irregularly domed bioherms. 	Vertical in the centre of bioherms and inclined on margins	Many bridging laminae 	Variable - rounded ○ elongate ⬭ crescentic  lobate  (especially when branching)	Slender - cylindrical to turbinate 	Unwalled, many overhanging laminae  (fimbriate to tuberculate)	Digitate, but coalescing as frequent 	May have 2nd order curvature 	Streaky dolomite and calcite laminae as below.	Laminated limestone which may be silty, some intraclasts and sand	Sandy limestone and oolitic, intraclastic limestone.
Pseudo columnar	Tabular and domal bioherms.	Vertical to inclined 	Linked 	Elongate	not applicable	not applicable	not applicable	Only 1st order curvature, smoothly convex rectangular or geniculate 	Alternating dolomicrite (pale green and yellow) and finely crystalline calcite (pale grey)	Minor intraclasts	Silty limestone calcareous siltstone, intraclastic limestone.

R.K.M. 1975

in size occur on both types of laminae. The interspace sediment is finely crystalline dolomite, but rounded sand grains and dolomite intraclasts occur. The associated sediments are red and yellow dolomicrites with scattered sand and silt. Deposition appears to have occurred in an intermittently agitated, subtidal environment.

The above discussion is summarized in Figure 4.

STRUCTURE

Although the main emphasis in this thesis is on sedimentological aspects, the structural features will now be considered briefly. A moderately steeply easterly dipping sequence on the eastern limb of an anticline, the hinge of which is located on the western side of the area, is present. Relatively shallow dips are generally encountered on the western limb. Minor folding is located in the Elatina Formation, and sinistral folds in the Brachina Formation may have wavelength up to 30m.

Figure 5 illustrates a contour density plot of poles to bedding* and a shallow southwesterly plunge is indicated, conforming with the southerly closure of the anticline. A westerly dipping cleavage associated with folding shows its most extensive development near the hinge zone, and in the massive siltstones of the Elatina Formation. The folding which is reclined is related to the Cambro-Ordovician Delamarian orogeny.

Wyacca Fault whick marks the western boundary of the study area, is a high angle fault on which the A.B.C. Range Quartzite and the Brachina Formation on the western side, have been down faulted against the Tapley Hill Formation on the eastern side. Wyacca Fault truncates a NNE trending fault in the south-west corner of the map area. Brecciated carbonates mark this fault and consist of yellow ferroan dolomite, white ferroan calcite, and a dark brown calcite, the colour of which is due to iron oxides along cleavage planes. This may be due to an expulsion of iron from an originally ferroan calcite.

A second major fault extends over most of the study area (see Figure 3). This normal fault which has caused repetition of part of the Wilmington Formation is dipping steeply to the west. Most displacement has been horizontal and is of the order

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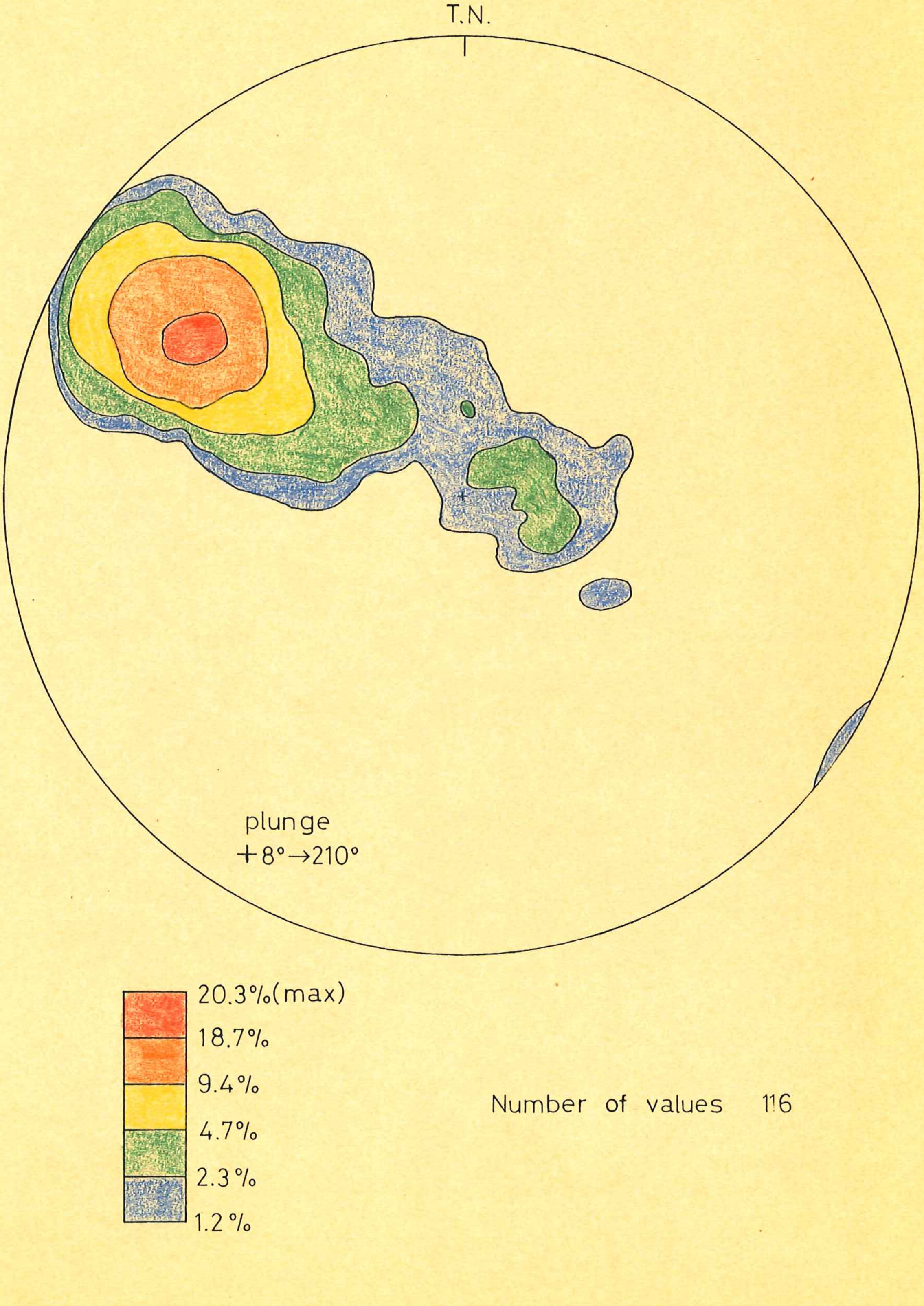
* This was determined using the computer program of Bridges and Etheridge (1974).

FIGURE 5

STEREOGRAPHIC PLOT

POLES TO BEDDING



Number of values 116

R.K.M. 1975

of 1300m, with a smaller vertical displacement of the order of 200m. Drag folding has occurred in the siltstones and limestones adjacent to the fault, although the sandstones have behaved in a more brittle manner and may be brecciated. A shallow south-westerly plunge is apparent on all drag folding, possibly suggesting some relationship to the major folding.

COMPARISON BETWEEN THE WYACCA BLUFF - BUCKARINGA GORGE AREA AND THE HALLETT COVE - MARINO AREA.

The Hallett Cove - Marino area occurs about 16Km south of Adelaide and is located near the western margin of the Adelaide "Geosyncline". The subsequent discussion is based on observations at Waterfall Creek, Hallett Cove, and along the coastline between Marino Rocks and Hallett Cove. A lithological correlation is presented in Figure 6. The correlation lines are lithostratigraphi not necessarily implying time equivalence.

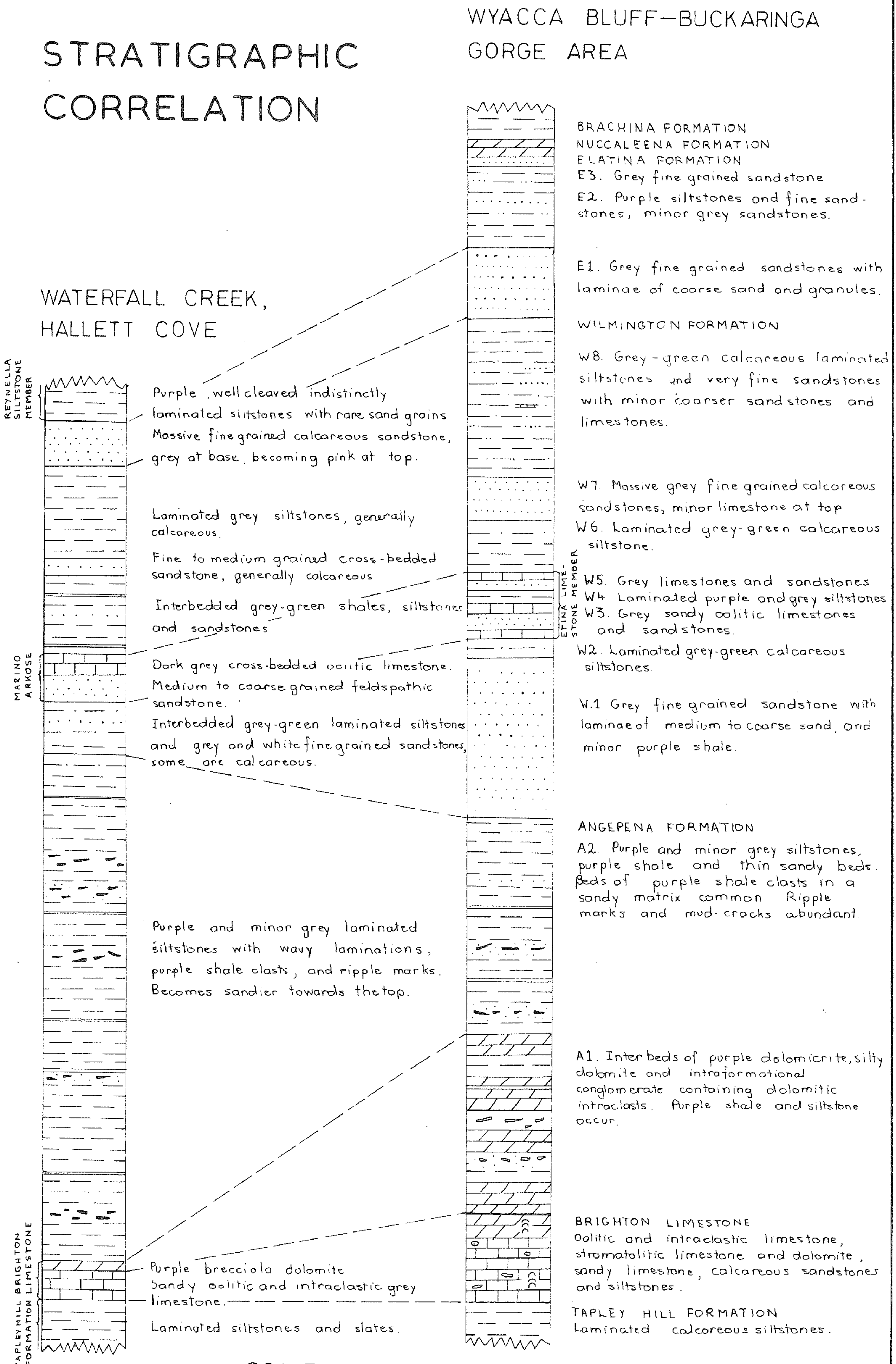
A gradational boundary between the Tapley Hill Formation and the Brighton Limestone occurs in both areas, and the Brighton Limestone contains similar lithologies. In Waterfall Creek pink dolomites with intraformational conglomerate and tepee structures a the top of the Brighton Limestone, are strikingly similar to Unit A1. Deposition in intertidal to supratidal environments in both areas has produced these similarities, although in the Wyacca Bluff - Buckaringa Gorge area, dolomite deposition outweighed clastic deposition for a longer period. The sequence of purple siltstones overlying the Brighton Limestone in Waterfall Creek contains less sand than Unit A2, possibly because of closer proximity to source in the Wyacca Bluff - Buckaringa Gorge area.

The overlying sequence of sandstones and siltstones in Waterfall Creek has similarities to the Wilmington and Elatina Formations. Feldspathic sandstones and oolitic limestones of the Marino Arkose probably represent similar environments of deposition as the Etina Limestone Member. Petrologically these sandstones (T.S. 463/A3) are similar to those of the Etina Limestone Member, containing quartz, feldspar and a variety of lithic fragments including red porphyry grains, "granitic" fragments containing quartz and more than one variety of feldspar, iron ore, schist, and a variety of polycrystalline quartz grains.

Massive grey sandstones near the top of the Waterfall Creek Section lack abundant coarse sand and granules. However they

FIGURE 6

STRATIGRAPHIC CORRELATION



WATERFALL CREEK, HALLETT COVE

Purple, well cleaved indistinctly laminated siltstones with rare sand grains

Massive fine grained calcareous sandstone, grey at base, becoming pink at top.

Laminated grey siltstones, generally calcareous.

Fine to medium grained cross-bedded sandstone, generally calcareous

Interbedded grey-green shales, siltstones and sandstones

Dark grey cross-bedded oolitic limestone.

Medium to coarse grained feldspathic sandstone.

Interbedded grey-green laminated siltstones and grey and white fine grained sandstones, some are calcareous.

Purple and minor grey laminated siltstones with wavy laminations, purple shale clasts, and ripple marks. Becomes sandier towards the top.

Purple brecciola dolomite

Sandy oolitic and intraclastic grey limestone.

Laminated siltstones and slates.

WYACCA BLUFF—BUCKARINGA GORGE AREA

BRACHINA FORMATION

NUCCALEENA FORMATION

ELATINA FORMATION

E3. Grey fine grained sandstone

E2. Purple siltstones and fine sandstones, minor grey sandstones.

E1. Grey fine grained sandstones with laminae of coarse sand and granules.

WILMINGTON FORMATION

W8. Grey-green calcareous laminated siltstones and very fine sandstones with minor coarser sandstones and limestones.

W7. Massive grey fine grained calcareous sandstones, minor limestone at top

W6. Laminated grey-green calcareous siltstone.

W5. Grey limestones and sandstones

W4. Laminated purple and grey siltstones

W3. Grey sandy oolitic limestones and sandstones.

W2. Laminated grey-green calcareous siltstones.

W.1 Grey fine grained sandstone with laminae of medium to coarse sand, and minor purple shale.

ANGEPENA FORMATION

A2. Purple and minor grey siltstones, purple shale and thin sandy beds. Beds of purple shale clasts in a sandy matrix common. Ripple marks and mud-cracks abundant.

A1. Interbeds of purple dolomicrite, silty dolomite and intraformational conglomerate containing dolomitic intraclasts. Purple shale and siltstone occur.

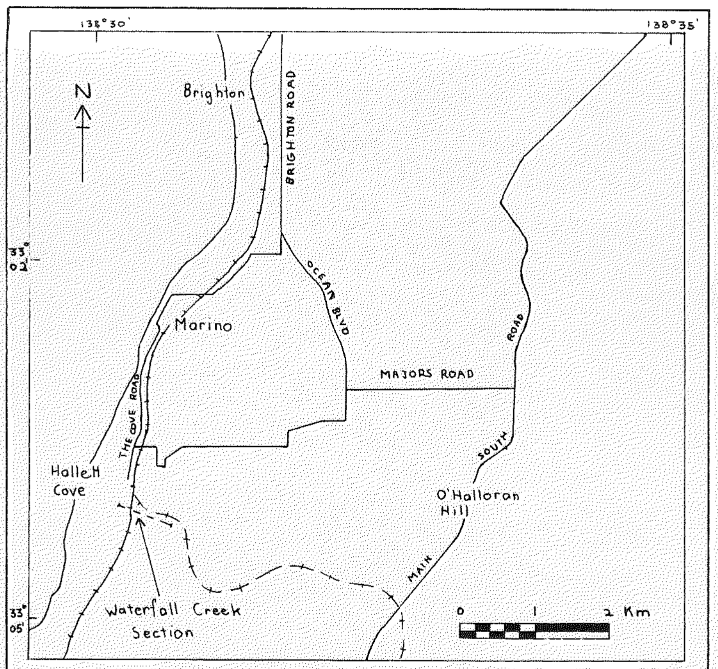
BRIGHTON LIMESTONE

Oolitic and intraclastic limestone, stromatolitic limestone and dolomite, sandy limestone, calcareous sandstones and siltstones.

TAPLEY HILL FORMATION

Laminated calcoreous siltstones.

SCALE 1,5000



LOCALITY MAP

WATERFALL CREEK SECTION

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are abundant in the sandstone where it outcrops along the coast, thus reinforcing the correlation with Unit E1. The overlying massive purple siltstones of the Reynella Siltstone Member contain scattered sand and granules giving the siltstones a poorly sorted appearance. Bedding is more important higher in the member indicating that they are at least partly water laid. Lenses of massive and intraclastic limestone occur in the siltstones.

The vertical lithological changes within these two widely separated areas reflect changes in the depositional environment, and it appears that similar changes occurred in these areas which are both located close to the western margin of the Adelaide "Geosyncline". This may indicate that the environmental changes are due to variations in external factors such as tectonics, source area and climate. Local conditions were probably important to a certain degree, but the gross features of the sequences have been determined by more widespread factors.

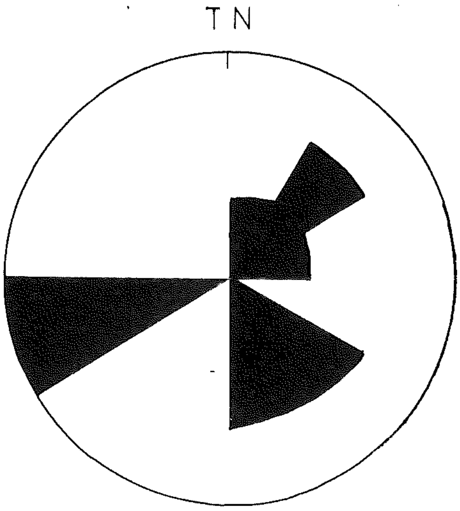
PALAEOENVIRONMENTAL INTERPRETATION

Any paleoenvironmental model proposed is partly limited because of the smallness of the area studied. Similarly palaeocurrent directions (Figure 7 and 8) may not necessarily be indicative of shoreline and source direction, because local irregularities may have exerted a more dominant influence in such a small area. However a model is presented, determined from consideration of lithologies and sedimentary structures (summarized in Figure 9), and similarities between the Hallett Cove - Marino area and the study area, as already discussed, suggest that it may be relevant to other parts of the Adelaide "Geosyncline". Deposition appears to have occurred entirely in the marine realm, but environments fluctuated from supratidal to the zone below active wave action.

Deposition of the finely laminated siltstones of the Tapley Hill Formation occurred dominantly below wave base. The presence of stromatolites, indicates a relatively shallow environment, although the occurrence of stromatolites to depths of 45m in the Devonian of Western Australia (Playford and Cockbain, 1969), indicates that it may not have been markedly shallow. However currents were at times active enough to produce small erosional hollows in which intraformational conglomerate was deposited, or stromatolite growth occurred. The presence of currents able to

FIGURE 7

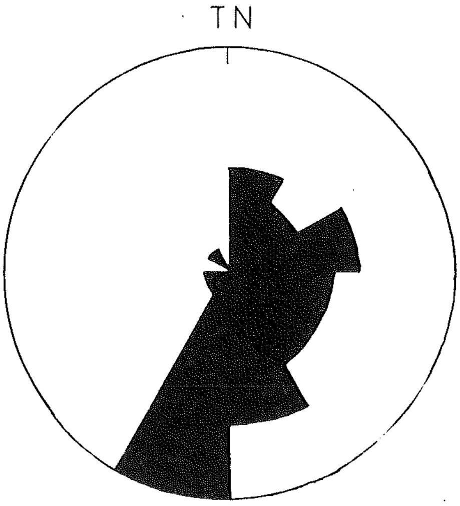
PALAEOCURRENTS : CROSS BEDDING



BRIGHTON LIMESTONE

No of measurements = 11

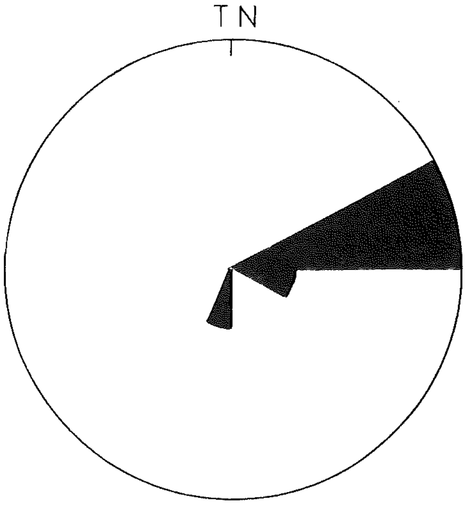
Circle radius = 3 measurements



WILMINGTON FORMATION

No of measurements = 38

Circle radius = 9 measurements



ELATINA FORMATION

No of measurements = 6

Circle radius = 4 measurements

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FIGURE 8

PALAEOCURRENTS RIPPLE MARKS

(a) Symmetric (∓180°)
(b) Asymmetric
n = no of measurements

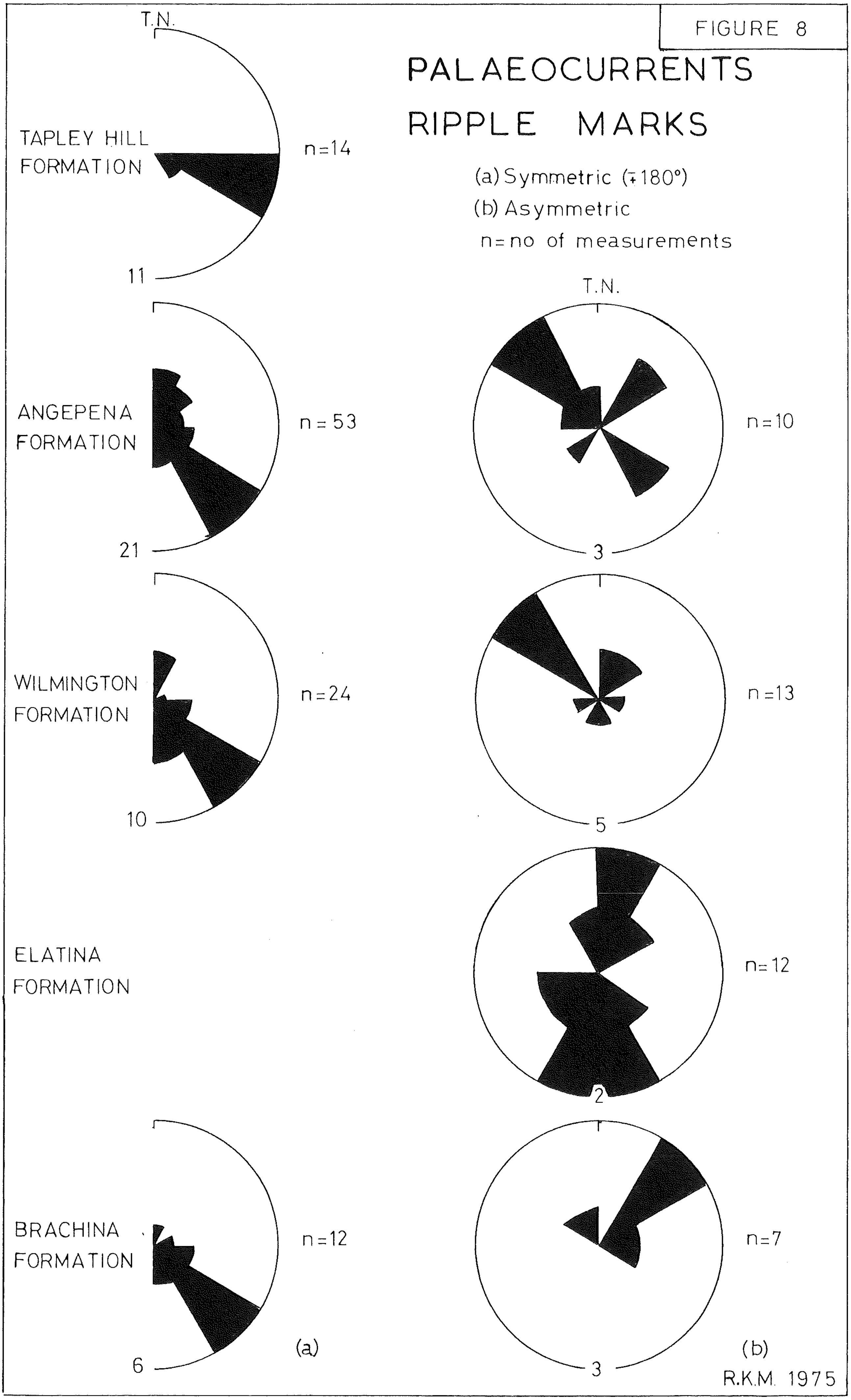
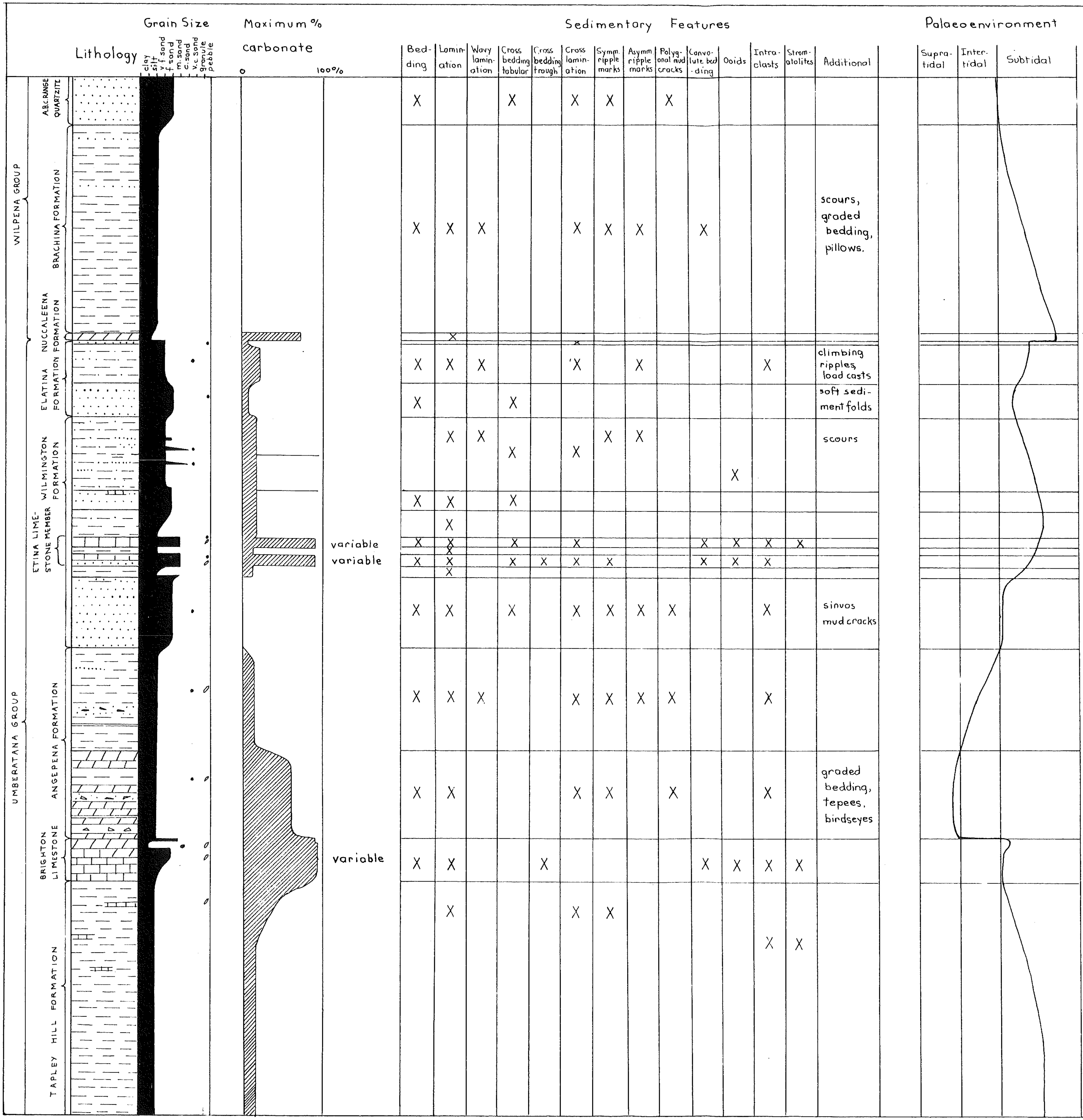


FIGURE 9

SUMMARY OF PALAEOENVIRONMENTAL INTERPRETATION



N.B. In environmental interpretation, depths are relative only.

Lithologic Key

⁙	Sandstone.
▤	Silty sandstone and sandy siltstone.
☰	Siltstone
▦	Limestone
▨	Dolomite
═	Shale
⊿ ⊿	Intraclasts

Scale of column 1:8,000

R.K.M. 1975

transport carbonate fragments several centimetres in size, suggests that the fine grained nature of this formation may be due to a starved source. Pyrite euhedra are common within the intraformational conglomeratic limestones, but occur mainly in the dolomite intraclasts, and in the stromatolitic dolomites. Hence reducing conditions prevailed after deposition, and the formation of ferroan carbonates may be associated with this. Symmetric ripple marks occur towards the top of this formation, indicating some wave influence.

Regression resulted in conditions becoming more amenable to carbonate deposition, and this tended to outweigh the limited clastic deposition, and deposition of the Brighton Limestone commenced. Pseudocolumnar stromatolites grew in a moderately agitated environment, in which relatively continuous agitation produced elongate domes. With continued regression, columnar stromatolites grew in a very shallow and strongly agitated subtidal zone. Wave action caused erosion of stromatolite columns, and produced an abundance of stromatolitic fragments between the bioherms where well washed intraclastic and ooid grainstones accumulated. The presence of sandy facies, most commonly in the north, occurred due to periodic or more continuous influxes of sand into localized areas. The general lack of features indicating exposure, indicates that deposition occurred in a very shallow subtidal environment, although limited periods of exposure may have caused dolomitization of ooid grainstones.

The deposition of lime mudstones above the ooid, intraclastic and sandy facies, suggests that a protected environment was formed, possibly due to the development of an offshore ooid bank or sandbar. The predominance of sandstones in the southern part of Unit B2, suggests that the dominant influx of sand had shifted southwards. Rejuvenation of the source may have produced the introduction of coarser sand at this time. Localization of wave action on this bank, resulted in a protected environment of lime mud deposition occurring behind it, but adequate circulation maintained oxidizing conditions in which stromatolite growth proliferated. Onshore movement of this ooid shoal interrupted the overall regressive phase.

Measurement of trough cross-beds within the Brighton Limestone indicates a trimodal distribution (Figure 7), but some of this variability may occur because generally trough axes could not be measured.

Continued regression produced high intertidal to supratidal conditions and deposition of the Angepena Formation commenced. Penecontemporaneous or early diagenitic dolomites formed in the supratidal environment and dolomitization of the upper part of the Brighton Limestone may be associated with the prevalence of supratidal conditions which are also indicated by polygonal mud-cracks, tepees and possible birdseyes. Beds of poorly sorted intraformational conglomerate were deposited by storm waves carrying a wide range of grain sizes. However beds of dolomitic intraclasts in sparry dolomite cement, may represent deposition in tidal channels in which currents winnowed out the sand, silt and mud.

The dolomitic lower unit of the Angepena Formation was replaced by purple siltstones deposited in an intertidal environment. Sandy storm layers with purple mud clasts formed by ripping up desiccated mud layers, were deposited. The composition of the sand fraction in the Angepena Formation which includes quartz, feldspar in which the plagioclase is albite, "granitic" fragments and red porphyries, suggests that the source was the Gawler Craton to the west.

Small symmetric ripple marks are the dominant hydrodynamic structure in the Angepena Formation, and indicate that the major sediment movement was by waves in a NW—SE direction. Slow subsidence accompanied deposition of the Angepena Formation, enabling 400m of supratidal and intertidal sediments to accumulate.

Transgression resulted in deposition of the well sorted sandstones of Unit W1 of the Wilmington Formation in very shallow subtidal conditions. Occasional influxes of coarser detritus produced laminae of coarse sand. Minor periods of exposure still occurred however, and were accompanied by the settling of mud from suspension as the water shallowed, and the development of mud cracks. Interference ripples also indicate that at times the environment was very shallow. Deposition of heavy mineral laminated sandstones occurred in an agitated littoral environment. A cessation in deposition is indicated by the sharp contact of the sandstone with the overlying laminated siltstones.

Deposition of the sandstones and limestones of the Etina Limestone Member is envisaged as occurring as offshore sandbars and ooid shoals in an actively agitated zone, into which there was considerable influx of coarse detritus. However supersaturation with respect to carbonate was maintained so that at times ooid deposition outweighed that of sand. Stromatolite growth occurred while the environment remained agitated as indicated by coarse sand between the columns. Submarine cementation at the depositional interface was a common feature.

The laminated siltstones of Units W2 and W4 were mainly deposited in environments protected by these sandbars, and hence in a relatively shallow environment despite their lack of current formed features.

The overlying siltstones of Unit W6 were also deposited in a low energy environment, below the zone of continued wave agitation, but shallowing may have produced the transition to the sandstones of Unit W7 which were deposited continuously in a uniform environment. Minor development of ooid shoals succeeded sandstone deposition.

Laminated siltstones and silty sandstones of Unit W8 were deposited in the lower part of the wave agitation zone, giving rise to ripple marks and wavy lamination. However, the fineness of the sediment may be due to restrictions on source. Offshore sand bars formed with large scale crossbeds at the base due to migration of the bar, with sediment avalanching down the foreset.

Continuing, although non-uniform subsidence accompanied deposition of the Wilmington Formation, and appears to have been greatest in the south. A dominantly northerly source is indicated (Figure 7), but longshore and onshore currents may also have been active. Symmetric wave ripples are oriented NW-SE as in the Angepena Formation. The sandstones of the Wilmington Formation are dominantly subarkoses, and hence indicate an elevated source area or one in which conditions were not conducive to chemical weathering.

The lower unit of the Elatina Formation is characterized by its planar bedding and general lack of current features, and its uniformity suggests uniform depositional conditions were produced following a shallowing of the environment. The presence of fine grained sandstones with coarser laminae and scattered coarser grains, suggests that two sources may have contributed. The finer grained sandstone is moderately well sorted and the coarser fraction was generally sorted into laminae by current and wave action, although strong influxes also resulted in it being scattered within the fine sand. The coarseness of the sediments suggests deposition in a shallow environment, in which easterly flowing currents occurred as indicated by the limited cross-bedding data. These may correspond to longshore currents as data from the Wilmington Formation suggests an E-W to NE-SW shoreline.

A rise in sea level, possibly associated with retreat of the ice sheet in the east of the Adelaide "Geosyncline" where tillites accumulated at this time, resulted in the deposition of finer grained sediments. Lateral and vertical lithofacies changes indicate that the introduction of sediment was non-uniform, but massive poorly sorted beds, and climbing ripples within the laminated sediment indicate an abundant sediment supply. Gradually uniform conditions were attained to produce deposition of the fine grained sandstones of Unit E3. Bimodal currents are indicated by the asymmetric ripple marks in Unit E2 and lend further support to an easterly trending shoreline.

A sharp contact between the Elatina and Nuccaleena Formation suggests that a depositional break occurred. Terrigenous and lime mud were deposited slowly below wave base following a deepening of the environment. However the accumulation of sediment produced gradual shallowing of the environment and purple siltstones of the Brachina Formation accumulated near wave base. Slow subsidence probably accompanied deposition, but this was gradually outpaced by the rate of deposition, leading to a shallowing of the environment, and deposition of the A.B.C. Range Quartzite in high subtidal to intertidal conditions.

CONCLUSIONS AND RECOMMENDATIONS

Detailed stratigraphic mapping indicates that a sequence of shallow marine clastics and carbonates were deposited under both regressive and transgressive conditions. Environments varied from one of slow clastic deposition below wave base during deposition of the Tapley Hill Formation, to high intertidal and supratidal in which dolomites of the lower part of the Angepena Formation were deposited. Stromatolite growth occurred during the dominantly carbonate phase of deposition of the Brighton Limestone, but was confined mainly to the shallow subtidal zone.

Comparison between the study area and the Hallett Cove - Marino area, indicates that a similar suite of environments prevailed in both areas. Further detailed study on the western margin of the southern Flinders Ranges and in the Adelaide region may elucidate the similarities further and enable determination of the causes of environmental changes on the western margin of the Adelaide "Geosyncline".

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PLATE I

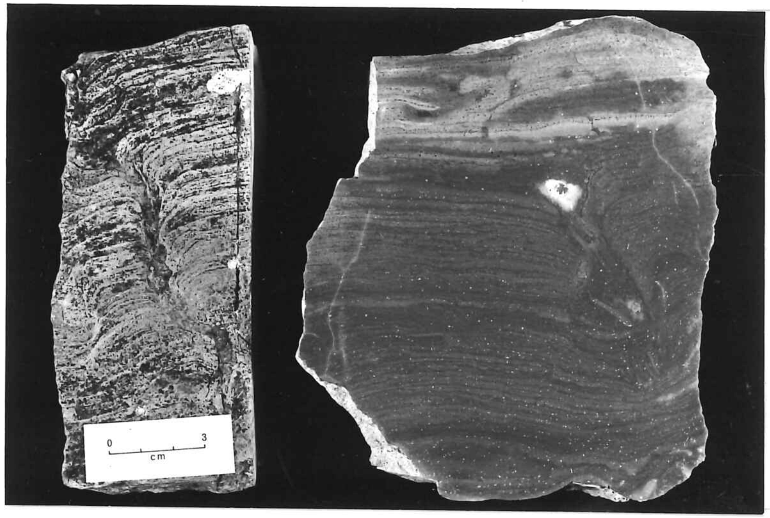
General

a. Weathered (left) and cut (right) surfaces of stromatolites in the Tapley Hill Formation. Intraclasts occur in the interspace area.

b. Small bioherm of columnar stromatolites enclosed in intraclastic limestone in the Brighton Limestone. Scale in cm.

c. Laminated siltstones of the Angepena Formation with sandy beds containing shale clasts. Pen is 14cm long.

d. Very irregular shaped stromatolitic fragments in sandy oolitic limestone, Wilmington Formation, Unit W5.



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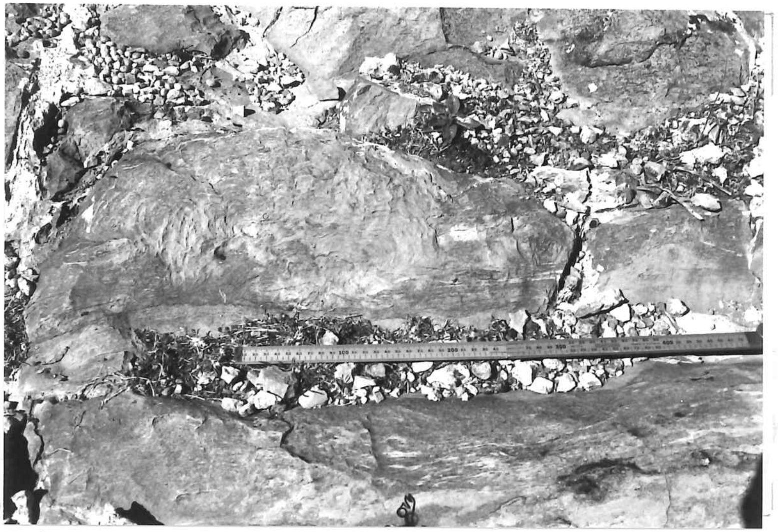

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Plate I

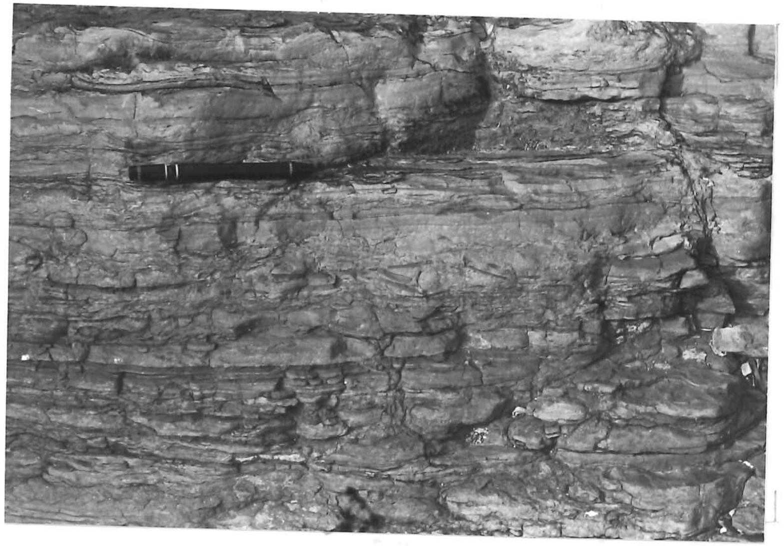

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PLATE II

Sedimentary Features

a. Straight crested ripple marks in the Tapley Hill Formation.

b. Beds of intraformational conglomerate and small tepee structures in dolomites of Unit A1, Angepena Formation.

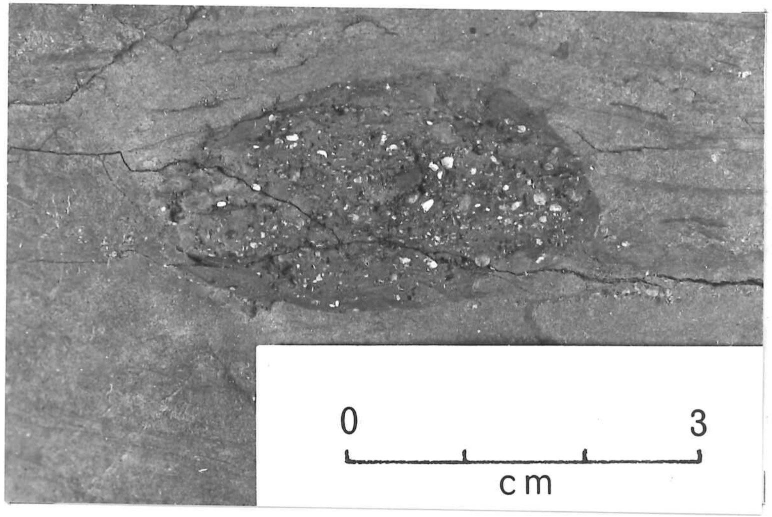
c. Mud ball enclosing sand grains in siltstones of Unit A2, Angepena Formation.

d. Laminae and thin beds of coarse sand in fine sandstones of Unit E1, Elatina Formation. Pencil is 16cm long.

a

b

Plate II



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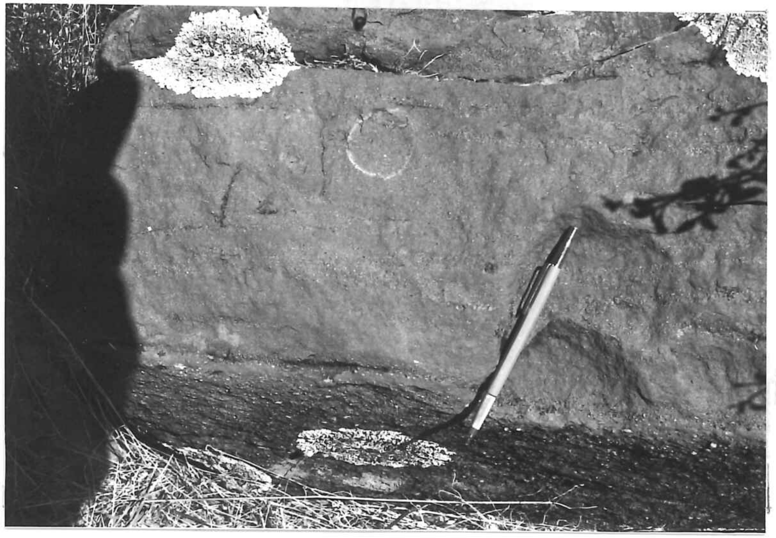

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PLATE III

Sedimentary Structures

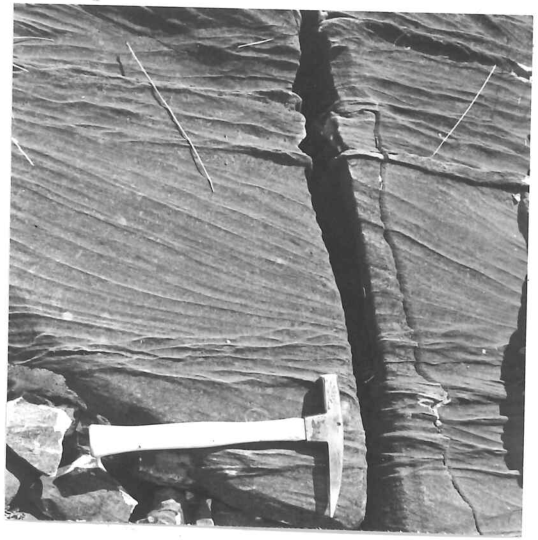
a. Two sets of superimposed ripple marks in Unit W1, Wilmington Formation.

b. Tabular cross-bedding in sandy oolitic limestones of Unit W3, Wilmington Formation. Coarse stylolite occurs at the top of the set.

c. Sinuous cast of mudcracks in purple shale covering a rippled marked surface with bifurcated crests, Unit W1, Wilmington Formation.

d. Large scale tabular cross-bedding in coarse sandstones of Unit W8, Wilmington Formation.

a



b

Plate III

c

d

PLATE IV

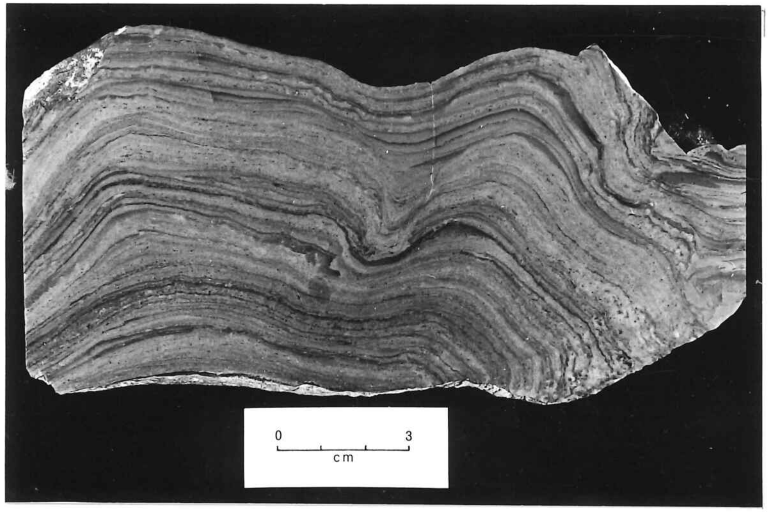
Brighton Limestone Stromatolites

a. Linked domal stromatolites near the base of the Brighton Limestone.

b. Columnar stromatolites showing numerous bridging laminae and coalescing columns.

c. Closely spaced columnar stromatolites with irregular margins near the top of Unit B1.

Plate IV



a

b

c

PLATE V

Photomicrographs

a. Recrystallized dolomitic ooids with a coating of dolomitic cement. Coarser cement is calcite. Unit B1, Brighton Limestone. X60.

b. Elongate mud clasts enclosed in a matrix of sand and silt, Unit A2, Angepena Formation. X10.

c. Silica cemented sandstones in which original grain shapes are still discernible, Unit W1, Wilmington Formation. X60.

d. Finely crystalline and coarsely crystalline ferroan calcite occupy the centre of the ooids, whereas the rim which still shows some concentric structure, and the sparry mosaic are non-ferroan calcite, Unit W7, Wilmington Formation. X60.

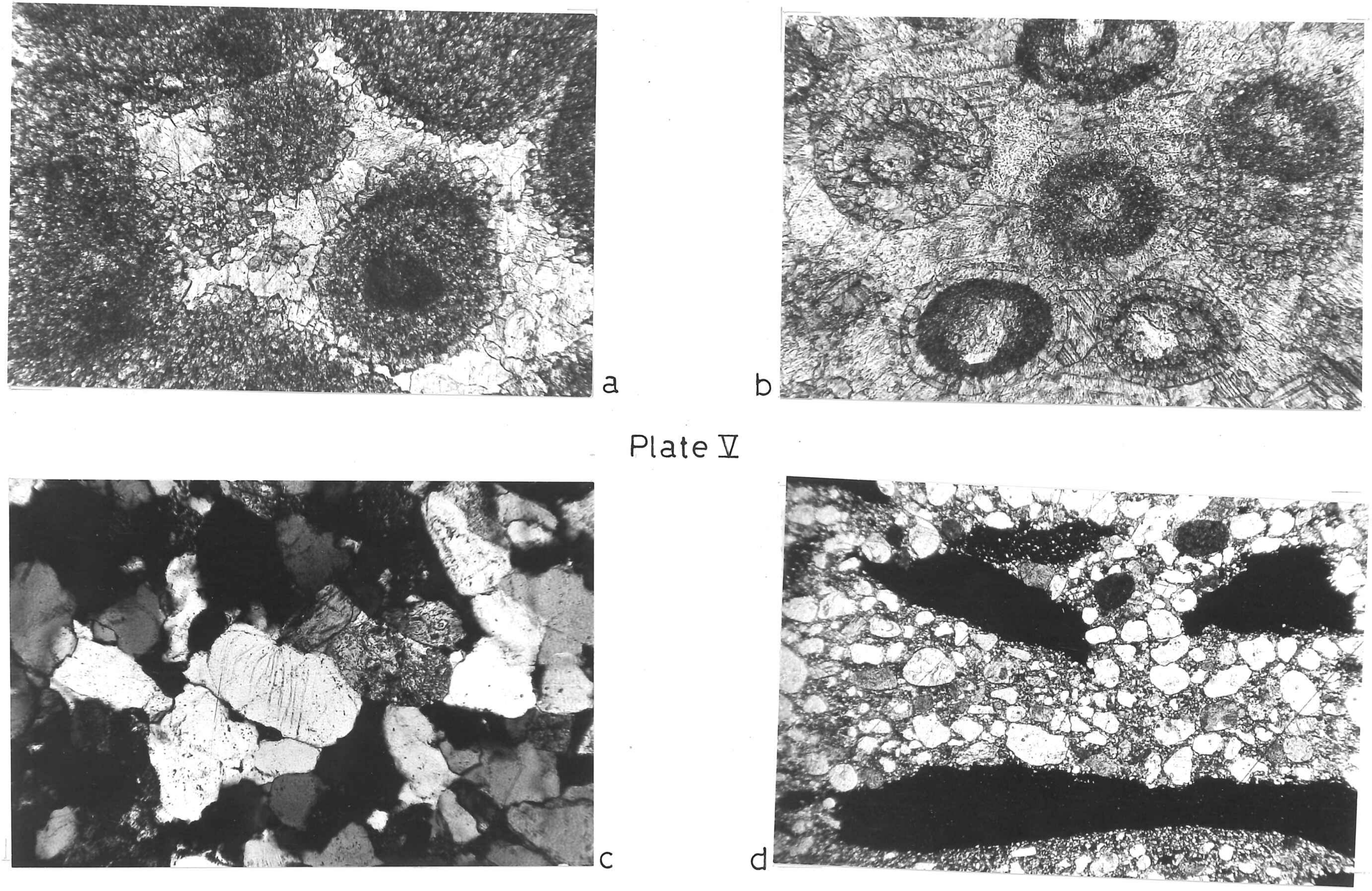
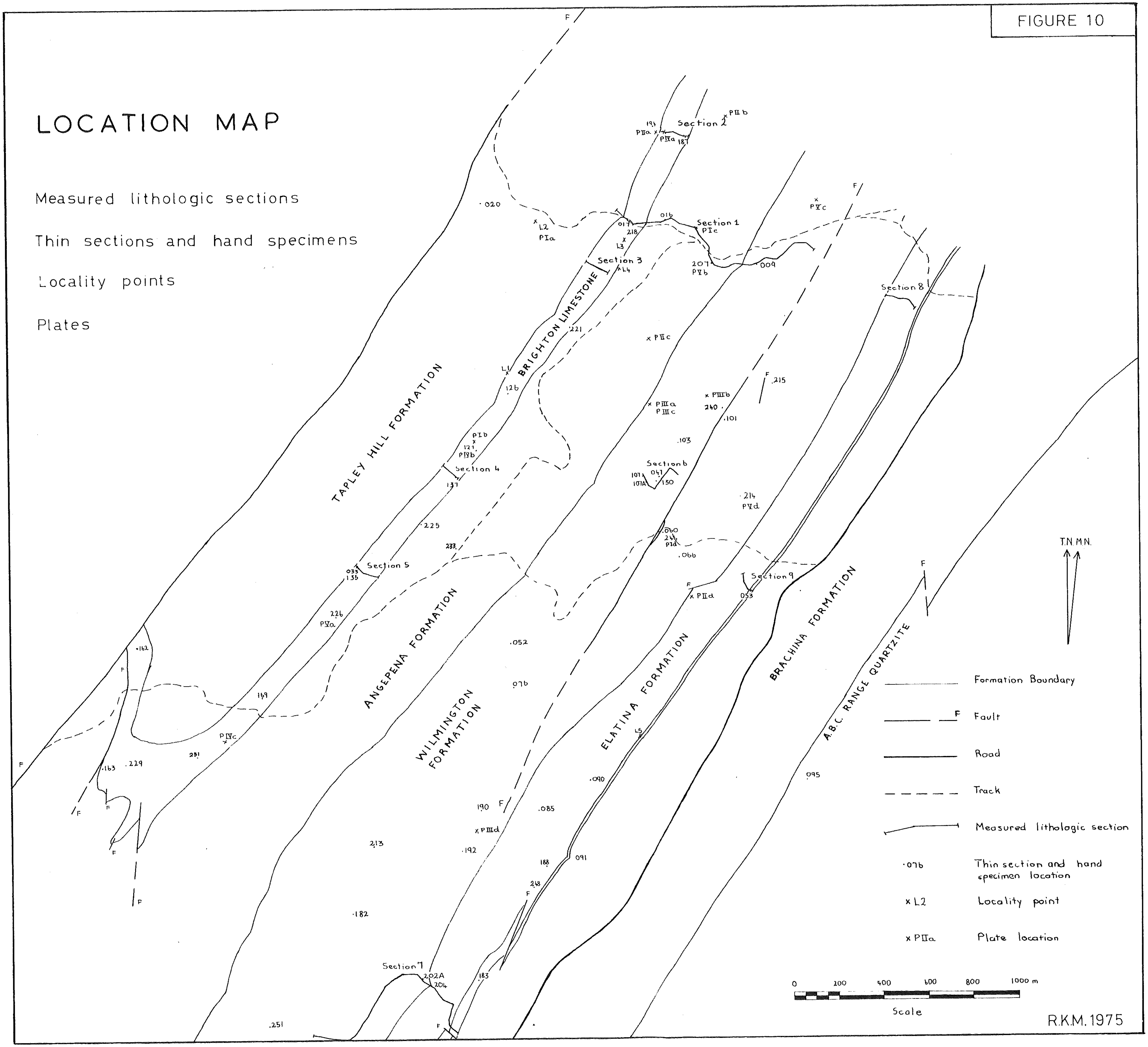


Plate V

APPENDICES

FIGURE 10

LOCATION MAP



APPENDIX I: MEASURED LITHOLOGIC SECTIONS

(For location of all sections, see Figure 10)

Section 1: Tapley Hill Formation (upper part) to Wilmington Formation (Unit W3). Total thickness = 706m.

Section 2: Brighton Limestone (Unit B1). Total thickness = 85m.

Section 3: Brighton Limestone (Unit B1). Total thickness = 76m.

Section 4: Brighton Limestone (Unit B1). Total thickness = 76m.

Section 5: Brighton Limestone. Total thickness = 88m.

Section 6: Wilmington Formation (Unit W2 to W6). Total thickness = 122m.

Section 7: Wilmington Formation (upper part of Unit W6 to W8), Elatina Formation and Nuccaleena Formation. Total thickness = 350m.

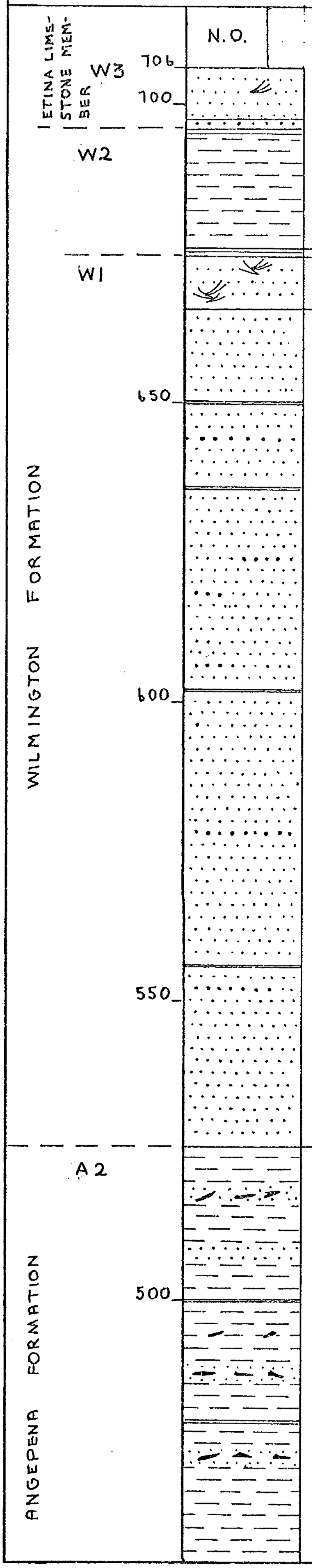
Section 8: Elatina Formation (Unit E1 to E3 - top not reached). Total thickness = 136m.

Section 9: Elatina Formation (Units E2 and E3) and Nuccaleena Formation. Total thickness = 76m.

Some units have been measured in duplicate, in order to indicate the varied lithologies within them, both laterally and vertically.

SECTION 1: TAPLEY HILL FORMATION TO WILMINGTON FORMATION(UNIT W3)

Formation Unit m Lithologic Description



No outcrop

Fine grained, pinkish white sandstone with some heavy mineral cross lamination.

Coarse grained white sandstone.

Laminated greenish-purple siltstone becoming mainly grey-green siltstones upward and with some purple shale at the top. The siltstones are calcareous.

Weathered yellow and purple shales

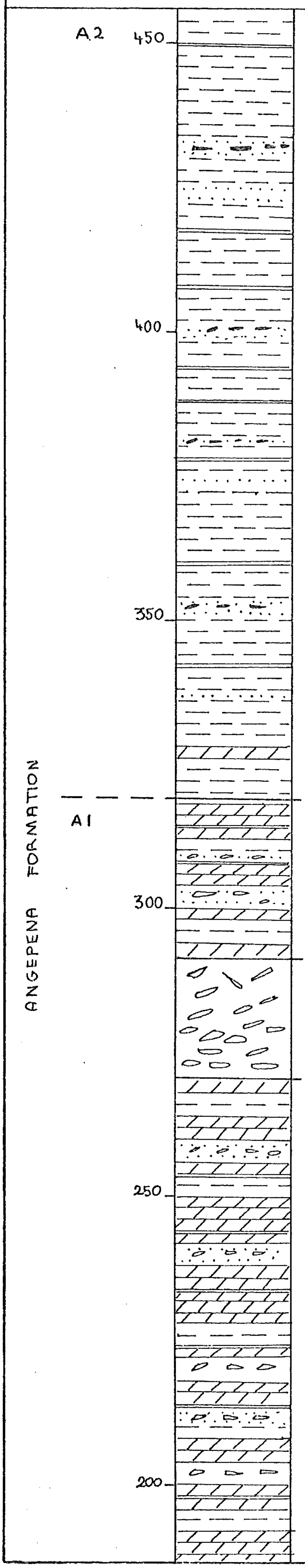
Fine to medium grained whitish sandstone with heavy mineral trough cross lamination.

Fine grained grey sandstone with laminations, at times lenticular, of medium to very coarse sand. Purple shale laminae occur, and some have been brecciated. to give thin purple shale flakes. Symmetric ripple marks are common, and cross bedding occurs rarely.

Light pinkish-grey fine sandstones replaced by grey sandstones.

Laminated and thinly bedded purple and grey siltstones, with lenses and thin beds of medium to coarse sandstone, and purple shale laminae. Beds of intraformational conglomerate containing purple shale intraclasts enclosed in sand and/or silt common. Ripple marks, mainly symmetric and polygonal mud cracks occur.

Formation Unit m Lithologic Description



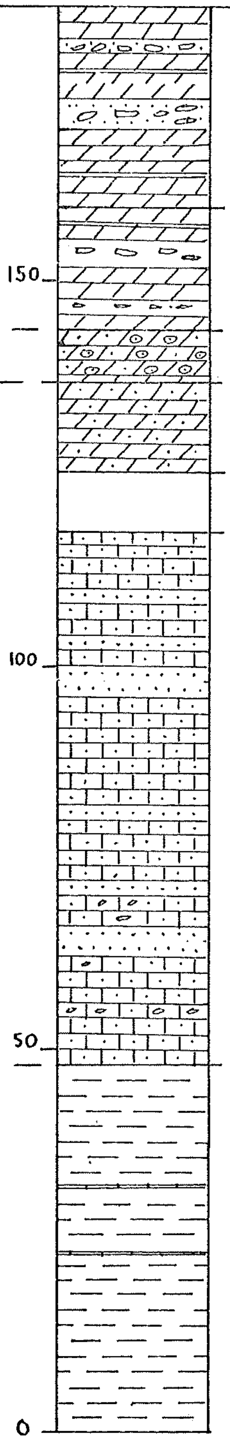
Laminated and thinly bedded purple and grey siltstones, with lenses and thin beds of medium to coarse sandstone, and purple shale laminae. Beds of intraformational conglomerate containing purple shale clasts enclosed in sand and/or silt are common. Ripple marks, mainly symmetric, and polygonal mud cracks occur. Thin beds of purple dolomite and purple dolomite intraclasts occur towards base.

Dolomite beds thinner and purple siltstone and shale are more common

Interbedded dolomites as below

Massively outcropping purple intraclastic dolomite, with some veins and vugs infilled with white dolomite and quartz

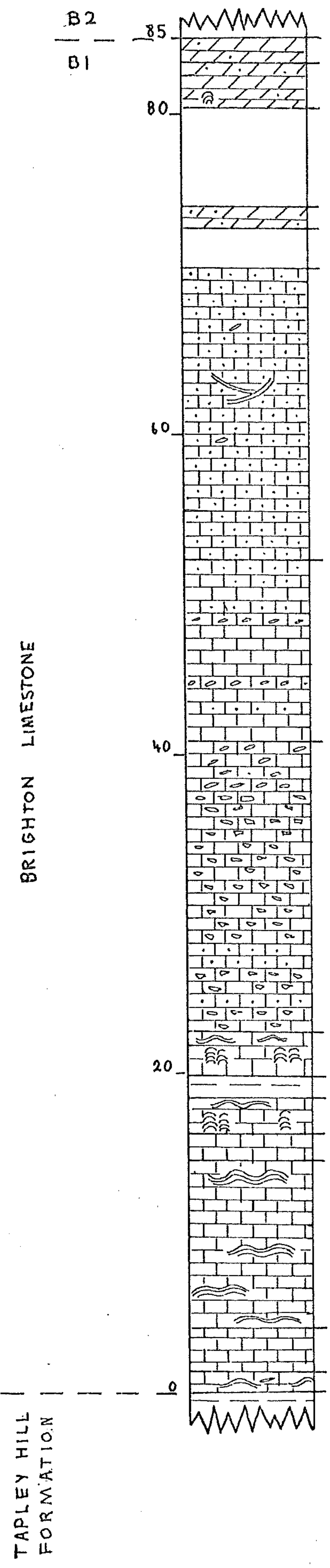
Interbeds of purple dolomicrite, silty dolomite, and intraformational conglomerate containing dolomite intraclasts in a sandy and dolomitic matrix. Purple shale and siltstone occur. Teepee structures, ripple marks and small polygonal mudcracks present



Formation	Unit	m	Lithologic Description
ANGEPENA FORMATION	A1		Interbeds of purple dolomicrite, silty dolomite and intraformational conglomerate, purple shale and siltstone laminae
			Weathered outcrop of above
BRIGHTON LIMESTONE	B2		Purple oolitic sandy dolomite which is thinly bedded
	B1		Massively outcropping greyish yellow sandy dolomite with some thin interbeds of sandstone.
			Very weathered outcrop of carbonate
			Grey sandy limestone and calcareous fine grained sandstone. Outcrop is massive, but laminations and trough cross bedding occur. Some interbeds of intraclastic limestone A thin bed (0.8m) of stromatolitic limestone at the base.
TAPLEY HILL FORMATION			Finely laminated grey calcareous siltstone with some limestone interbeds (? stromatolitic).

SECTION 2 : BRIGHTON LIMESTONE

Formation Unit m Lithologic Description



Purple sandy oolitic dolomite

Red dolomicrite with isolated sandgrains

Grey dolomite with some columnar stromatolites with sand between columns

Scattered outcrops of weathered dolomite

Buff coloured dolomite with sandy beds and laminae

Weathered outcrop of carbonate

Laminated sandy limestone with trough cross bedding, isolated elongate intraclasts. Terrigenous sand content approaches 50 %

Laminated grey limestone with concentrations of sand in some laminae and thick stylolites. Beds of intraclastic limestone occur.

Grey intraclastic limestone in which the amount of intraclasts varies from bed to bed. Some fine grained sand present, and interbeds of laminated sandy limestone occur in the lower 10 m.

Grey stromatolitic limestone in which narrow columns pass up into larger linked domes.

Laminated grey calcareous siltstone

Grey stromatolitic limestone with narrow columns which are replaced by linked domes and almost flat laminae.

Laminated silty limestone

Stromatolitic limestone with linked domes with grey, green and yellow laminations.

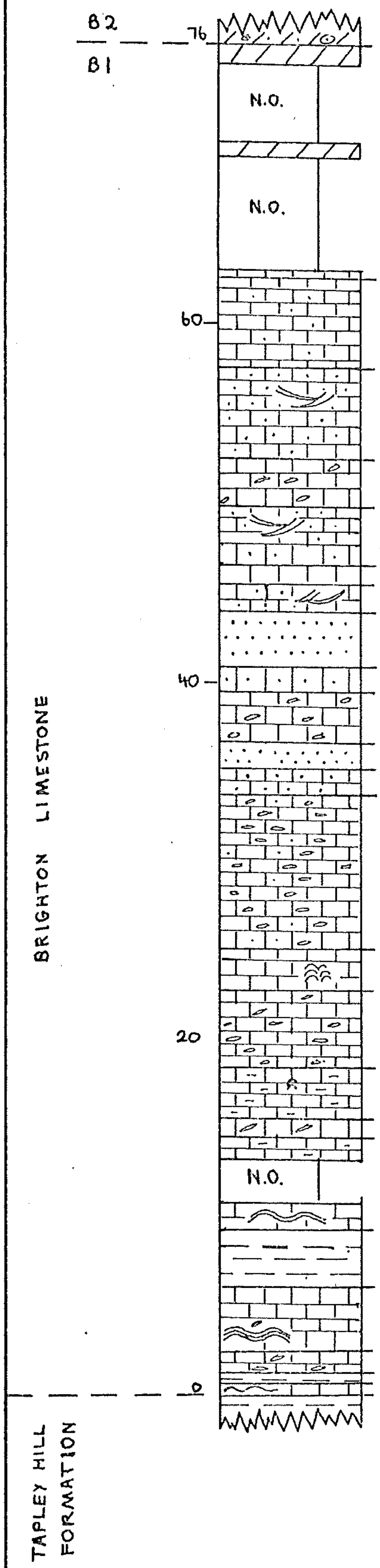
Pale grey silty limestone, massive outcrop but laminations present

Grey pyritic limestone with linked stromatolites

Laminated grey calcareous siltstone.

SECTION 3 : BRIGHTON LIMESTONE

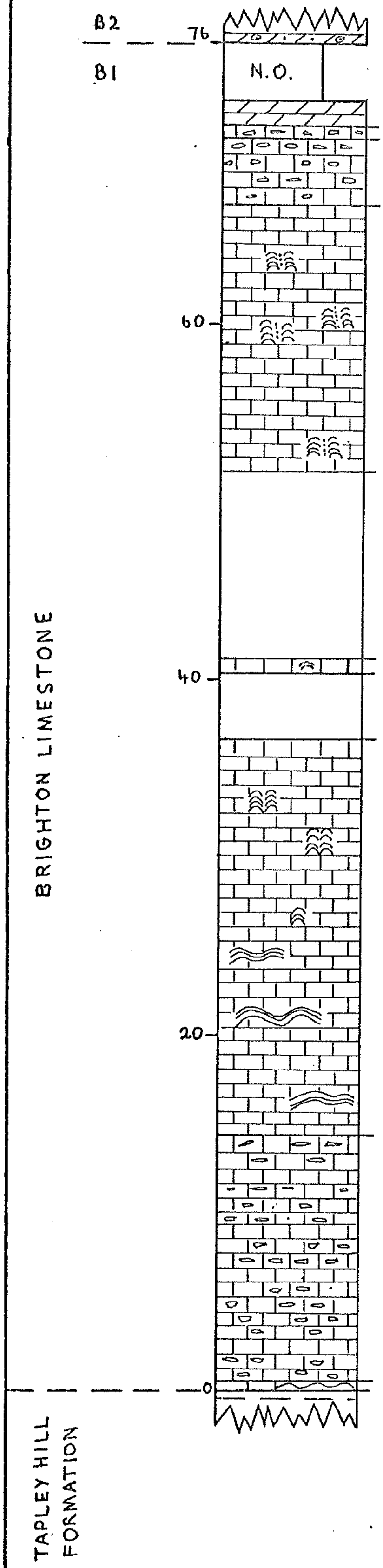
Formation Unit m Lithologic Description



Purple sandy oolitic dolomite
Dark pink dolomicrite with scattered sand grains
Pale pink dolomicrite
Yellow limestone
More massive grey limestone with occasional laminations
Laminated grey sandy limestone with trough cross bedding
Intraclastic limestone
Laminated grey sandy limestone with trough cross bedding
Massive grey limestone without lamination
Trough cross bedded sandy limestone
Grey calcareous sandstone
Laminated sandy limestone
Grey intraclastic limestone
Calcareous sandstone
Laminated sandy limestone
Grey intraclastic limestone with only minor sand
Stromatolitic limestone with stromatolite columns 2-6cm wide
Intraclastic limestone
Laminated silty limestone with ·5m thick stromatolite bioherm
Intraclastic limestone
Laminated silty limestone
Stromatolitic limestone with linked domal stromatolites
Weathered grey calcareous siltstone
Stromatolitic limestone with domed and relatively flat laminae, and minor intraclasts
Grey intraclastic limestone with yellow intraclasts
Calcareous siltstone
Stromatolitic limestone with linked domes
Laminated calcareous siltstone

SECTION 4 : BRIGHTON LIMESTONE

Formation Unit m Lithologic Description



Sandy oolitic purple dolomite

Red dolomite
Yellow intraclastic limestone with dolomite intraclasts
Grey intraclastic limestone in which the size and percentage of clasts increases upwards.

Grey stromatolitic limestone in which columns are 1-2cm in width, and sand forms a high proportion of the interspace sediment.

Scattered, weathered outcrop of stromatolitic limestone

Stromatolitic limestone with columnar stromatolites

Scattered, weathered outcrop of stromatolitic limestone

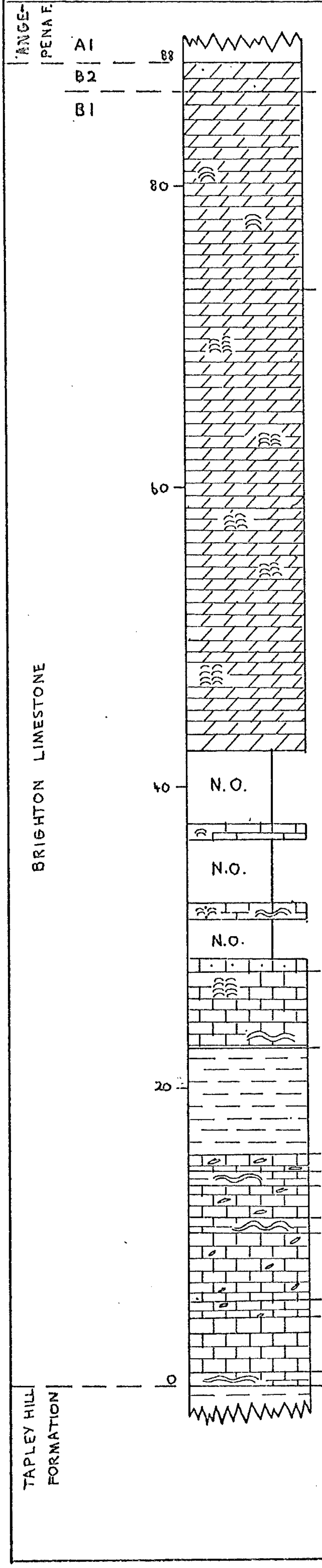
Grey stromatolitic limestone - in the first 11m mainly domal linked stromatolites occur, these are replaced by columnar stromatolites a few cms. in width.

Grey intraclastic limestone with elongate yellow clasts and minor fine sand, minor interbeds of laminated silty limestone without clasts occur

Stromatolitic limestone with linked domes up to 15 cms wide
Laminated calcareous siltstone

SECTION 5: BRIGHTON LIMESTONE

Formation Unit m Lithologic Description



Purple brecciola dolomite.

Purple sandy dolomite.

Pale red dolomite in which columnar stromatolites are sometimes apparent.

Weathered pale grey stromatolitic dolomite.

Stromatolitic limestone in which flat laminae pass into columnar stromatolites which are replaced by flatter laminae.

Stromatolitic limestone with columnar and laterally linked stromatolites, some sand between columns.

Laminated grey sandy limestone.

Grey stromatolitic limestone with columnar stromatolites 1-3 cms wide, with sand between columns and linked domal stromatolites.

Planar laminated grey calcareous siltstone with scattered carbonate intraclasts.

Grey intraclastic limestone.

Grey limestone with linked domal stromatolites.

Grey intraclastic limestone.

Grey limestone with linked domal stromatolites.

Intraclastic, silty limestone.

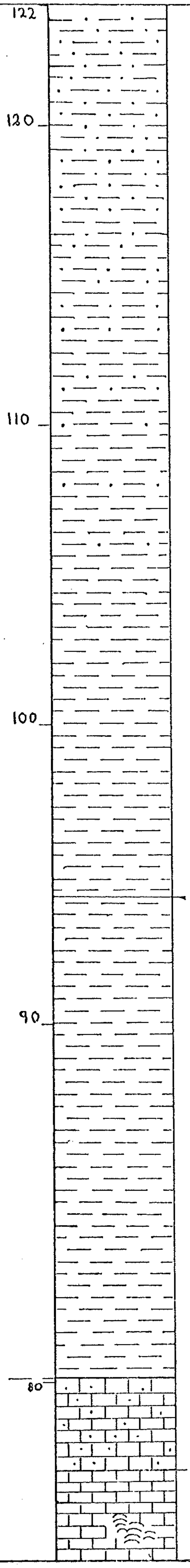
Intraclastic limestone with yellow intraclasts.

Massive grey silty limestone with scattered intraclasts.

Stromatolitic limestone with flat and linked laminae and some intraclasts.

Laminated calcareous siltstone.

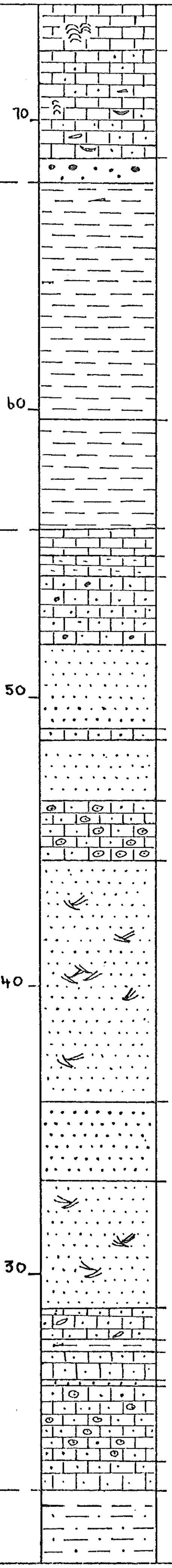
SECTION 6 : WILMINGTON FORMATION (UNITS W2 TO W6)



Formation	Unit	m	Lithologic Description
WILMINGTON FORMATION	W6	122	Grey green planar laminated calcareous siltstones which coarsen upward into interlaminated fine sandstones and siltstones
			Planar laminated purple calcareous siltstones passing gradationally into grey-green siltstones above
ETINA LIMESTONE MEMBER	W5	80	Massive grey crystalline limestone containing some fine sand
			Dark grey fine grained limestone with mottled outcrop and composed of irregular columnar stromatolites.

Formation | Unit | m | Lithologic Description

WILMINGTON FORMATION
ETINA LIMESTON MEMBER



W6

Dark grey limestone with mottled outcrop and composed of irregular columnar stromatolites

Extremely variable limestone - includes sandy oolitic limestone, lenses of very fine-grained non-sandy limestone, isolated stromatolites and intraclastic limestones.

Coarse sand and granules (60%) in a calcite cement (40%)

W5

Purplish grey siltstones, less calcareous than below and horizontally laminated.

Grey-green horizontally laminated siltstones

W3

Grey crystalline limestone

Silty limestone, yellowish green on weathered surface.

Grey sandy limestones with conglomeratic lenses and beds containing rounded granules and small pebbles of quartz and feldspar, minor cross bedding

Sandstone which is poorly sorted at the base, passing up into a better sorted fine grained calcareous sandstone

Sandy limestone with some purple shale laminae

Grey calcareous fine grained sandstone

Pinkish sandy oolitic limestone with some indistinct tabular and trough cross bedding and rare intraclasts up to 5cms in size

Fine grained grey calcareous sandstone with massive outcrop but some indistinct trough cross laminae occur

Coarse grained non calcareous sandstone

Fine grained grey sandstone with parallel and trough cross laminae defined by heavy minerals

Planar bedded sandy limestone with some intraclasts

Purple siltstone with some intraclasts

Sandy limestone with lenses of fine grained non-sandy limestone

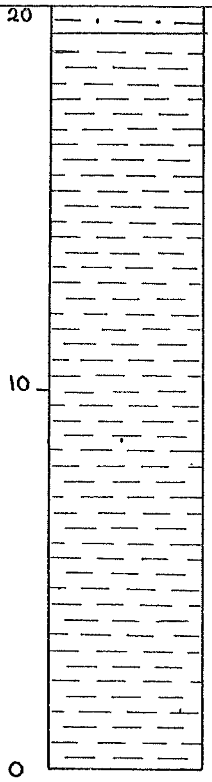
Fine grained grey sandstone

Oolitic limestone also containing coarse sand and granules and tabular cross bedding

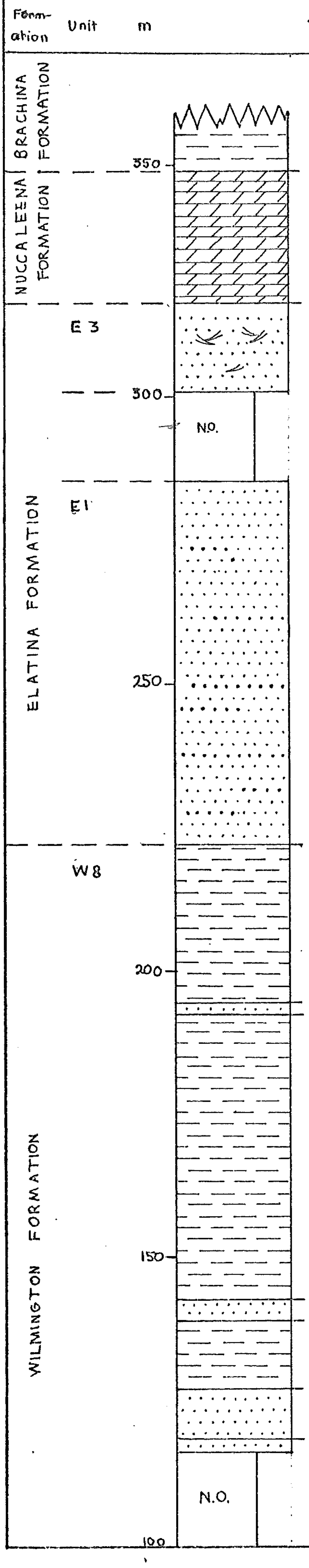
Grey limestone with fine sand

W2

Interlaminated purple shale and grey calcareous very fine grained sandstone

Formation	Unit	m	Lithologic Description
WILMINGTON FORMATION	W2		Interlaminated purple shale and grey calcareous very fine grained sandstone. Grey green planar laminated calcareous siltstones passing gradationally into above lithology.

SECTION 7: WILMINGTON FORMATION (UNIT W6) TO NUCCALEENA FORMATION



Lithologic Description

Laminated purple siltstones

Planar laminated purple and pink, muddy dolomites and dolomitic shales.

Grey fine grained sandstone with some heavy mineral trough cross laminae

Similar sandstone as below but only rare granules and fewer laminae of coarse sand

Fine grained grey sandstone which may be poorly sorted, and contains laminae and beds of coarser sand and granules

Grey green siltstones and fine sandstones as below

Fine grained grey sandstone with lenses of coarse sand

Laminated grey-green calcareous siltstone and fine sandstones. Some purple laminae may be present. Laminae are generally wavy, and ripples occur

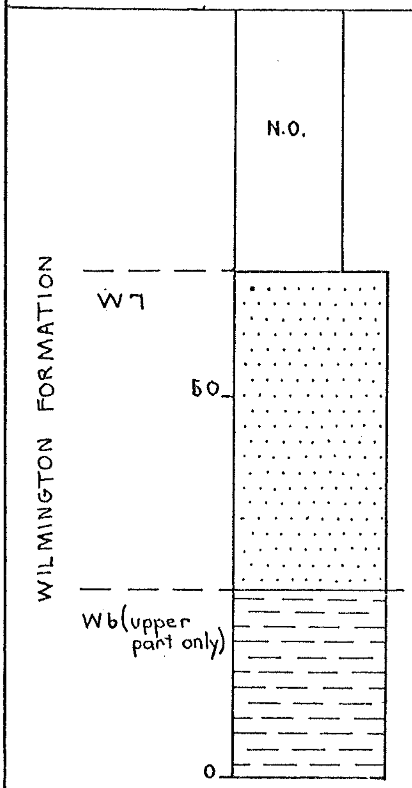
Massively outcropping grey, calcareous fine to medium grained sandstone with tabular cross bedding

Laminated grey-green calcareous siltstones and fine sandstones

Massively outcropping grey calcareous fine to medium grained sandstone, with tabular cross bedding in the coarser beds

Very weathered yellow fine to medium grained sandstone

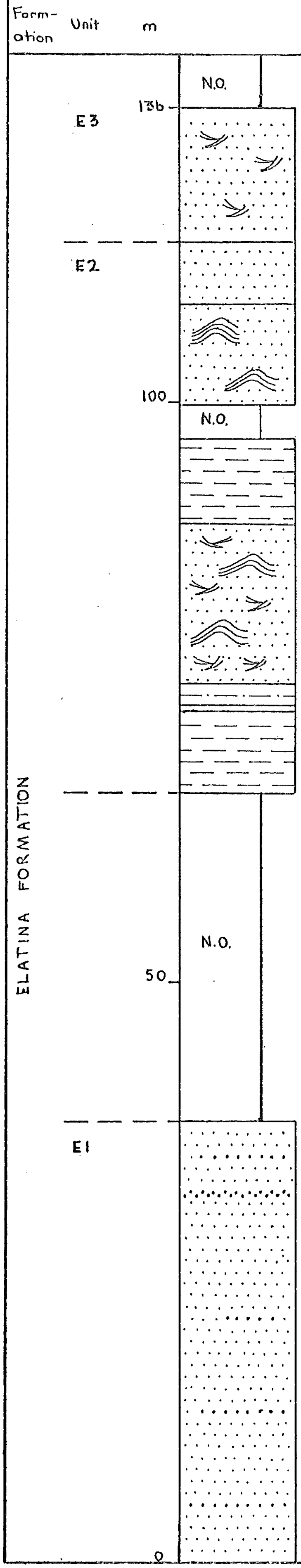
Formation Unit m Lithologic Description



Massively outcropping grey-green calcareous fine grained sandstone with some indistinct lamination

Laminated, calcareous very fine grained sandstones and siltstone

SECTION 8: ELATINA FORMATION



Lithologic Description

Fine grained whitish pink sandstone with trough cross laminae which are often indistinct.

Similar sandstone as below but laminae much less distinct.

Purplish grey very fine sandstone with purple shale laminae and climbing ripples.

Cleaved purple siltstone with wavey laminations.

Purplish grey very fine grained calcareous sandstones with purple shale laminae defining trough cross laminae and climbing ripples.

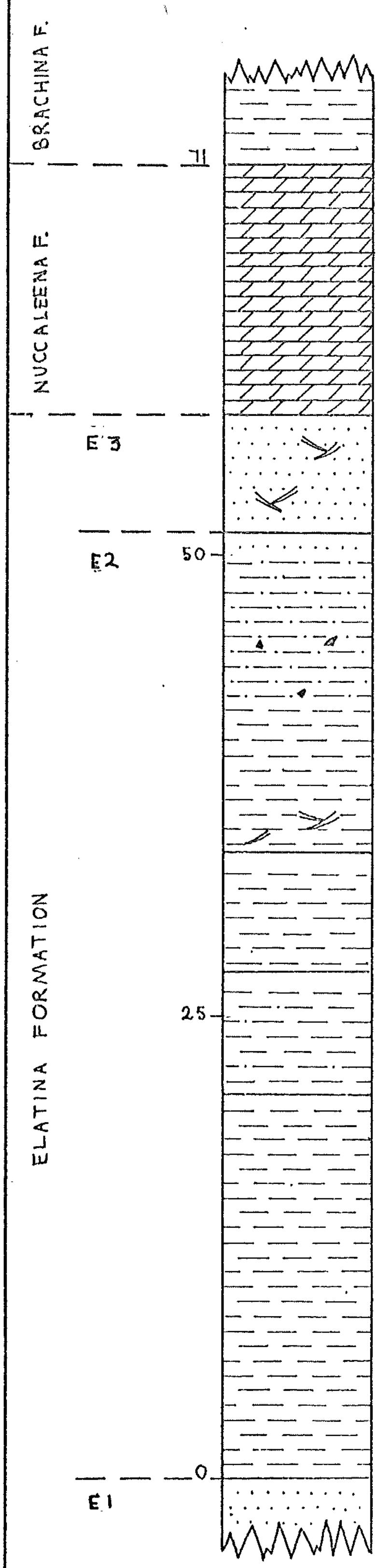
Laminated purple siltstones and fine sandstones.
Wavy laminated purple siltstones.

Planar laminated, but massively outcropping purple and minor grey calcareous siltstones.

Fine grained greyish pink fine sandstones, which may be poorly sorted and contain lenses and thin beds of medium and coarse sand.

SECTION 9 : ELATINA AND NUCCALEENA FORMATIONS

Formation Unit m Lithologic Description



Laminated purple and minor green siltstones.

Planar laminated pinkish and purple, muddy and silty dolomites and dolomitic shales.

Fine grained whitish sandstone with some heavy mineral trough cross laminae.

Light purple siltstones which coarsen upwards into fine grained sandstones. Some trough cross laminae near the base and mm sized shale clasts higher in sequence.

Weakly calcareous cleaved purple siltstone with indistinct lamination.

Light purple siltstone forming massive outcrop and containing a few sand grains.

Weakly calcareous cleaved purple siltstones with indistinct lamination.

Pink fine grained sandstone.

APPENDIX 2: THIN SECTION AND HAND SPECIMEN DESCRIPTIONS

A total of 91 thin sections were studied, and the 48 descriptions presented include most of the significant lithologies present in the map area. Carbonate thin sections have been stained with alizarin Red S and potassium ferricyanide (Dickson 1965, 1966) in order to distinguish ordinary calcite, ferroan calcite, ordinary dolomite and ferroan dolomite. Percentages of all components, and grain sizes have been visually estimated.

The additional hand specimens have been included to show particular features which are not illustrated in the thin sections and their accompanying hand specimens.

THIN SECTION DESCRIPTIONS

Tapley Hill Formation

463/020

Macro: This dark grey siltstone shows horizontal laminations and very fine carbonate veins.

Micro: Subangular quartz, grain size 0.01 to 0.1mm, is the major detrital component, and is enclosed in a matrix of carbonate and brown indeterminate clay material. Lamination is 0.2mm to 6mm thick, and a weak cleavage has developed at an angle of about 45° to the lamination. A cross cutting set of carbonate veins, each less than 1mm thick contain fibrous, or more equant crystals.

Composition:	Quartz	65%
	Carbonate	16%
	Brown clay	15%
	Muscovite	3%
	Opaques	1%
	Chlorite, Tourmaline	minor

Calcareous siltstone.

463/194

Macro: Elongate yellow intraclasts, 3cm to less than 1mm in size occur in a dark grey carbonate.

Micro: Irregular and elongate clasts of aphanic dolomite and minor quartz silt, are enclosed in very finely crystalline ferroan calcite which has been partially replaced by more coarsely crystalline ferroan and non-ferroan calcite. Both types of calcite may occur in a single crystal. Some replacement by calcite has occurred in some clasts, and secondary polycrystalline quartz may be associated with this replacement. Pyrite euhedra, 0.03 to 0.75mm, often surrounded by elongate crystals of ferroan calcite, occur within these clasts, in the matrix they generally fall in the size range 0.02 to 0.04mm.

Composition:	Calcite	74%
	Dolomite	25%
	Pyrite	1%
	Quartz	minor

Intraclastic dolomitic limestone.

Brighton Limestone (Unit B1)

463/017

Macro: This rock is a grey intraclastic limestone with elongate intraclasts up to 2cm in length.

Micro: Oolitic and very finely crystalline intraclasts occur in a calcitic silty matrix containing a few individual ooids. Oolitic intraclasts contain ooids of ferroan calcite 0.3 to 0.9mm in size, and enclosed in sparry calcite or less commonly dark brown haematitic clay. The matrix contains subangular quartz, 0.03 to 0.125mm in size, muscovite and minor opaques.

Composition:	Clasts 50%	-	48%	calcite
			2%	quartz and feldspar
	Matrix 50%	-	25%	quartz
			22%	calcite
			2%	brown clay
			1%	muscovite

Intraclastic limestone.

463/033

Macro: This stromatolitic rock shows alternating light grey and green laminae.

Micro: Laminae of ferroan calcite which is finely crystalline (0.05mm), quartz of predominantly silt, and also sand size, minor plagioclase and opaques, alternate with laminae of aphanic ferroan dolomite containing only minor silt. Calcite laminae are 0.2 to 2.5mm thick, and dolomite laminae are 0.2 to 3mm thick. Terrigenous grains are highly embayed by the carbonate.

Composition:	Dolomite	50%
	Calcite	47%
	Quartz	3%

Stromatolitic calcitic dolomite.

463/126

Macro: Streaky grey and green laminae outline stromatolites in this specimen.

Micro: Stromatolite columns consist mainly of dolomite, but contain irregular areas of calcite. Lamination, 0.2 to 1mm thick is due to a variation in the amount of terrigenous grains and a slight variation in the crystal size of the dolomite which is ferroan. The quartz and feldspar are dominantly silt size, although maximum grain size is 0.15mm. The interspace contains ferroan calcite, silt, a dolomite intraclast and an area of secondary quartz, and more coarsely crystalline calcite.

Composition:	Dolomite	70%
	Calcite	15%
	Quartz	15%
	Feldspar, Opaques	minor

Stromatolitic dolomite.

463/135

Macro: Yellow intraclasts up to 1cm in size occur in a grey limestone.

Micro: Intraclasts of aphanic dolomite which are elongate and rounded, and intraclasts of very finely crystalline calcite which may be elongate, or much less regularly shaped, are enclosed in sparry calcite. Some of the cement is very finely crystalline, similar to the intraclasts. Some recrystallized calcite has developed in veins and is cross cutting intraclasts.

Composition:	Calcite	95%
	Dolomite	5%
	Chert	minor

Intraclastic limestone.

463/137

Macro: This specimen is a yellowish pink intraclastic limestone with maximum clast size in excess of 1cm.

Micro: Ooids and intraclasts are enclosed in a sparry mosaic of ferroan calcite. Ooids, 0.2 to 1mm in size generally consist of ferroan calcite on the margins, and often have dolomite in the core. Intraclasts consist mainly of dolomite and are generally oolitic with minor sand. Recrystallization to coarser dolomite, or replacement by coarser ferroan calcite has occurred in some intraclasts.

Composition:	Calcite	55%
	Dolomite	43%
	Quartz	2%
	Opaques	minor

Intraclastic dolomitic limestone.

463/162

Macro: Irregular stylolites are apparent on the weathered surface of this buff coloured dolomite.

Micro: This section consists mainly of very finely crystalline dolomite, generally lacking lamination, and showing slightly variable grain size. Veins of more coarsely crystalline dolomite and polygonal quartz occur. Indistinct and irregular seams, showing a concentration of quartz, 0.04 to 0.1mm in size and dolomite slightly coarser than the ground mass, may represent the stylolites visible on weathered surface.

Composition:	Dolomite	98%
	Quartz	2%
	Opaques, Muscovite	minor

Microcrystalline dolomite.

463/169

Macro: This specimen is a red algal dolomite showing lenticular lamination.

Micro: Irregular laminations, 0.2 to 3mm thick of aphanic dolomite, alternate with laminae of finely crystalline dolomite of similar thickness. Quartz and opaques 0.02 to 0.5mm occur in aphanic laminae and, quartz, muscovite, feldspar and opaques occur in coarser laminae. Sand is only minor however. Veins of fibrous silica occur on some laminae boundaries.

Composition:	Dolomite	82%
	Quartz	15%
	Calcite	2%
	Opaques	1%
	Feldspar, Muscovite, Zircon	minor

Stromatolitic Dolomite.

463/187

Macro: Sandy beds occur in this specimen which is dominantly a buff coloured dolomite.

Micro: Sand, including quartz, potassium feldspar, plagioclase and microcline, is concentrated at the lower end of this section and shows a decreasing percentage upwards. Grain size varies from 0.06 to 0.5mm, but many grains have been embayed by the enclosing dolomite. Texturally the sandy layer is a wackestone, and grades into a mudstone of aphanic and very finely crystalline dolomite.

Composition:	Dolomite	80%
	Quartz	15%
	Feldspar	5%
	Muscovite, Opaques	minor

Sandy dolomicrite.

463/218

Macro: Laminae up to 3mm thick occur in this grey calcareous siltstone.

Micro: Lamination results from a variation in grain size and amount of terrigenous grains. Grain size varies from 0.03 to 0.4mm. Quartz, potassium feldspar and plagioclase are represented, and their margins are embayed by the ferroan calcite which occurs as a sparry mosaic enclosing grains. Some rounded very finely crystalline carbonate intraclasts are present.

Composition:	Calcite	48%
	Quartz	45%
	Feldspar	5%
	Opaques	2%
	Muscovite, Chlorite	minor

Fine grained calcareous sandstone.

463/226

Macro: Pale yellow oolitic carbonate containing both calcite and dolomite.

Micro: Dolomitic ooids, 0.3 to 1.5mm in size, and with indistinct concentric structure, occur with intraclasts and composite ooids in a calcite cement. The first episode of cementation is by dolomite however, as each grain has a rim of dolomite cement, with the major part of the interstices being subsequently infilled with calcite. Hence it appears that dolomitization occurred before the final cementation.

Composition:	Dolomite	80%
	Calcite	20%
	Quartz, Feldspar	minor

Oolitic dolomite.

463/229

Macro: This specimen is a yellow and brown irregularly laminated stromatolitic dolomite.

Micro: Irregular aphanic reddish brown laminae, alternate with lighter coloured finely crystalline laminae. Some areas of secondary quartz and more coarsely crystalline iron stained dolomite occur in the brown laminae. Detrital quartz, generally of silt size, occurs in both laminae. Patchy areas of opaques and rare polygonal grains are present. Some of the dolomite is ferroan.

Composition:	Dolomite	87%
	Quartz	10%
	Calcite	3%
	Muscovite	minor

Stromatolitic dolomite.

<u>Brighton Limestone</u> (Unit B2)

463/163

Macro: Homogeneity characterizes this white dolomitic sandstone.

Micro: Quartz, feldspar and a variety of lithic fragments show a grain size range of 0.1 to 1mm, although most grains are in the medium to coarse sand size range. Both quartz and feldspar are embayed by the enclosing dolomite, but some feldspar grains have overgrowths. Sericitization of feldspars is common. Lithic fragments include schistose, "granitic" (quartz plus feldspar), and quartzite with opaques. Allochemical components include dolomite intraclasts and rare ooids. The sparry dolomite enclosing grains occurs in two forms

(1) elongate crystals perpendicular to some grain boundaries
(2) anhedral crystals in intervening areas.

Composition:

Composition:	Quartz	40%
	Dolomite	35%
	Feldspar	15%
	Lithic fragments	8%
	Allochemical constituents	2%
	Opaques	minor

Coarse grained dolomitic feldspathic sandstone.

463/221

Macro: Purple and pink intraclasts up to 1cm in size, and ooids occur in a white dolomitic cement.

Micro: Ooids, a variety of intraclasts and terrigenous sand, occur in a dolomite spar. Grains are frequently not in contact, and it appears as if early cementation was virtually contemporaneous with deposition. The first phase of cementation is represented by "saw-tooth" crystals on grain boundaries, with later infill of pores by more equant dolomite. Elliptical, circular and cresentic ooids, consisting of dolomite, and rarely with nuclei of terrigenous grains, vary in size from 0.25 to 1.25mm. Intraclasts include oolitic, silty and aphanic dolomite and may have oolitic coatings. Terrigenous grains, 0.3 to 1.7mm in size, include quartz, potassium feldspar, microcline and lithic fragments (red porphyries and "granitic").

Composition:	Dolomite	90%
	Lithic fragments	5%
	Quartz	3%
	Feldspar	2%

Oolitic dolomite.

<u>Angepena Formation</u> (Unit A1)

463/016

Macro: This purple laminated and bedded specimen consists of intraclastic beds with clasts up to 1.6cm in size, and laminated dolomite and siltstone.

Micro: A variety of layers are represented including

(1) laminated siltstone with quartz, feldspar and micas in a matrix of clay and dolomite.

(2) laminated dolomite with fine sand and silt.

(3) graded layers containing intraclasts of aphanic and silty dolomite, quartz, potassium feldspar, plagioclase, microcline, "granitic" lithic fragments, opaques and zircon, with grain size from silt to very coarse sand. These occur in a dolomitic matrix, and grading is indicated by a decrease in grain size, and an increase in the amount of matrix.

Composition:	Dolomite	60%
	Quartz	20%
	Clay	10%
	Feldspar	5%
	Lithic fragments	5%
	Muscovite, Opaques, Zircon	minor

Intraclastic dolomite.

463/225

Macro: This purple dolomite contains darker purple laminae and birdseyes (?) up to 2mm in length and approximately elongate parallel to the lamination.

Micro: Finely crystalline dolomite is the dominant component of this section which is indistinctly laminated. Quartz is dominantly silt size, although it varies from 0.03 to 0.1mm. Muscovite is arranged parallel to the lamination, as well as being more randomly oriented. Birdseyes(?) are both elongate and equant in shape and are infilled with turbid dolomite, polycrystalline quartz, or both.

Composition:	Dolomite	71%
	Quartz	27%
	Opaques	2%
	Muscovite, Chlorite	minor

Silty dolomite.

<u>Angepena Formation</u> (Unit A2)

463/207

Macro: Laminated purple siltstone comprises the upper part of the specimen, the lower part is sandy and intraclastic with maximum size of intraclasts being 3cm.

Micro: The sandy part of the specimen is represented in this section. Grain size distribution appears bimodal, with medium to coarse sand and very fine sand to silt being the two size fractions. The range in grain size is 0.03 to 1mm, although shale intraclasts are up to 1cm. Sandsize quartz is rounded to subrounded with the finer fractions being more angular. Feldspar shows better rounding than quartz. Lithic fragments include "granitic" types and red porphyries. Carbonate, with minor chlorite is the matrix.

Composition:	Quartz	60%
	Carbonate	13%
	Feldspar	10%
	Intraclasts	10%
	Lithic fragments	5%
	Opaques	1%

Composition (Contd.)

Chlorite	1%
Muscovite, Tourmaline	minor.

Wilmington Formation (Unit W1)

463/009

Macro: Laminae of medium to coarse sand, and shale flakes characterize this grey fine grained sandstone.

Micro: Subrounded and subangular quartz, 0.04 to 0.5mm in size, is the major component in this moderately well sorted fine to very fine grained sandstone. Feldspar, which includes weathered and sericitized potassium feldspar, and fresher plagioclase and microcline, generally shows better rounding than quartz. Clay minerals including chlorite, occurs as narrow seams along many grain boundaries, and also fills some of the larger interstices.

Composition:

Quartz	65%
Feldspar	22%
Clay minerals	10%
Opaques	3%
Tourmaline, Muscovite, Zircon	minor

Very fine grained calcareous feldspathic sandstone.

463/052

Macro: Isolated grains up to 3mm in size occur in this light grey medium grained sandstone.

Micro: The grains show a variation in grain size from 0.06 to 1.6mm, with modal grain size in medium sand range. They are enclosed in sparry, slightly ferroan calcite, in which they at times appear to be floating. Both quartz and feldspar, which is represented by potassium feldspar, plagioclase and microcline, are embayed by calcite, so that only rare rounded grains occur. Feldspar overgrowths are present. Lithic fragments include "granitic" types and red porphyries.

Composition:

Quartz	45%
Calcite	40%
Feldspar	14%
Opaques	1%
Lithic fragments, Tourmaline, Zircon	minor

Medium grained calcareous feldspathic sandstone.

463/101

Macro: Concentrations of heavy minerals define trough cross-laminae in sets up to 1cm thick in this pinkish white sandstone.

Micro: Quartz, 0.06 to 0.5mm in size is subangular and subrounded, whereas feldspar is subrounded and rounded. Weathering is more common for potassium feldspars than plagioclase or microcline. Heavy mineral laminae, 0.1 to 1mm thick are composed of opaques, zircon, tourmaline and sphene. A thin seam of clay minerals including chlorite occurs on some grain boundaries, but sutured grain contacts and quartz overgrowths are also present.

Composition:	Quartz	75%
	Feldspar	15%
	Clay minerals	5%
	Opaques	4%
	Zircon, Tourmaline, Sphene, Lithic fragments	1%

Fine grained feldspathic sandstone.

Wilmington Formation (Unit W2)

463/107

Macro: Finer grained purple laminae, 0.25m to 1mm thick, alternate with coarser grey laminae up to 5mm thick in this siltstone.

Micro: Brown shale laminae of clay, silt and very fine sand, are interlaminated with silt and very fine sand in a carbonate cement. Elongate muscovite and quartz grains are oriented parallel to the lamination.

Composition:	Quartz	70%
	Feldspar	10%
	Carbonate	10%
	Clay	7%
	Muscovite	2%
	Opaques	1%
	Chlorite, Zircon, Biotite	minor

Laminated calcareous siltstone.

463/251

Macro: This massive, light grey calcareous sandstone contains rare chalcopyrite grains.

Micro: Grain size in this poorly sorted sandstone, ranges from 0.1 to 2mm. Some rounded grains are present, but both quartz and feldspar are embayed by carbonate. Overgrowths occur on both quartz and feldspar grains, but overgrowths also show partial replacement. Some sericitization of feldspars has occurred. Lithic fragments include "granitic" types, red porphyries, and chert. The carbonate spar consists of anhedral crystals which as well as filling interstices, is partly a replacement of grains.

Composition:	Quartz	60%
	Carbonate	30%
	Feldspar	10%
	Lithic fragments, Opaques, Tourmaline	minor

Medium grained calcareous feldspathic sandstone.

Wilmington Formation (Unit W3)

463/107A

Macro: Rare heavy mineral laminations occur in this pale pink sandy limestone.

Micro: Sand grains and ooids are enclosed in sparry calcite, and some grains are "floating". Ooids, 0.2 to 0.6mm in size, consist of ferroan calcite. Finely crystalline rims generally surround coarser calcite which in some instances has entirely enveloped the rim. Most ooids show partial or complete recrystallization. Rarely quartz or feldspar grains occur as nuclei. Quartz grains, 0.1 to 0.75mm, and feldspar generally have margins which have been embayed by the enclosing sparry ferroan calcite. The original texture was probably that of a grainstone.

Composition:	Calcite	80%	Ooids	25%
			Spar	55%
	Quartz	15%		
	Feldspar	5%		
	Muscovite, Opaques, Tourmaline	minor		

Sandy oolitic limestone.

463/213

Macro: This grey fine grained sandstone appears homogeneous in hand specimen.

Micro: Some very indistinct heavy mineral laminae occur in this section which is a moderately well sorted fine grained sandstone, although range in grain size is 0.05 to 0.75mm. Quartz is the dominant component and some overgrowths are present. The matrix consists of low birefringent clay minerals including chlorite, but a minor amount of carbonate, which is replacing grains, is present.

Composition:	Quartz	73%
	Feldspar	13%
	Clay minerals	10%
	Opaques	3%
	Carbonate	1%
	Tourmaline, Zircon, Muscovite, Biotite	minor

Fine grained feldspathic sandstone.

463/215

Macro: White homogeneous sandstone.

Micro: This section is a coarse grained sandstone with variation in grain size from 0.1 to 1.2mm. There is only minor matrix, with overgrowths on quartz grains resulting in the formation of an interlocking mosaic. The majority of the feldspar grains are extensively sericitized, although some fresh plagioclase and microcline is present. Lithic fragments include "granitic" types which rarely show myrmeketic igneous textures, red porphyries and chert.

Composition:	Quartz	85%
	Feldspar	13%
	Lithic fragments	2%
	Opaques, Tourmaline, Zircon	minor

Coarse grained feldspathic sandstone.

Wilmington Formation (Unit W4)

463/103

Macro: This specimen is a planar laminated greyish purple shale.

Micro: Lamination is indicated by a variation in the amount of clay. The maximum grain size is 0.4mm (muscovite), but most grains are silt or clay size, with quartz being the dominant silt size component. Elongate grains are arranged parallel to lamination. Some carbonate is present and is mainly concentrated in irregular lenses.

Composition:	Quartz	43%
	Clay	40%
	Carbonate	10%
	Muscovite	5%
	Opaques	2%
	Chlorite, Biotite	minor

Shale.

Wilmington Formation (Unit W5)

463/047

Macro: Minor intraclasts occur in this light grey sandy, oolitic limestone.

Micro: Ooids, sand grains and a limestone intraclast are enclosed in sparry calcite. Texturally, the rock is a grainstone. The ooids, 0.25 to 1.5mm in size, consist of ferroan calcite which is finely crystalline on the margins, and more coarsely crystalline in the centre. Quartz grains, feldspar and lithic fragments occur as nuclei for some ooids, and some of the quartz grains have overgrowths. A line of calcite inclusions along original grain boundaries, and partial replacement of ooids by overgrowths, suggests that overgrowths formed subsequently to the ooids. The sparry mosaic is slightly ferroan calcite, while a secondary vein is ordinary calcite.

Composition:	Calcite	92%
	Quartz	7%
	Feldspar	1%
	Lithic fragments, Opaques, Tourmaline	minor

Sandy oolitic limestone.

463/060

Macro: Wavey and lenticular laminations of coarse sand to silt occur in this limestone.

Micro: Laminae, 0.1 to 5mm thick, consist of oolitic limestone, siltstone with scattered sand grains, and finely crystalline calcite with only minor silt. Sand and silt includes quartz, feldspar, opaques, muscovite and red porphyry grains. Much of the muscovite has altered to or is altering to chlorite. The ooids generally consist entirely of calcite. The enclosing crystalline calcite is finely crystalline and is ferroan calcite.

Composition:	Calcite	80%
	Quartz	18%
	Lithic fragments	1%
	Feldspar	1%
	Muscovite, Opaques	minor

Laminated limestone.

463/130 (not stained)

Macro: A dark grey limestone with irregular stromatolite columns.

Micro: The lamination is indistinct and shows little variation in crystal size of the finely crystalline calcite, but is defined by a variation in the amount of aphanic material. Scattered sand grains, up to 0.6mm in size, and more commonly silt, occur in the stromatolitic laminae. The interspace sediment consists of more evenly crystalline calcite, sand and silt, although it may be crossed by more finely crystalline laminae.

Composition:	Calcite	76%
	Aphanic material	20%
	Quartz	3%
	Opaques	1%
	Feldspar, Muscovite	minor

Stromatolitic limestone.

463/182

Macro: Scattered pink blebs and lenses occur in this grey-green fine sandstone.

Micro: Grain size in this well sorted sandstone is 0.05 to 0.2mm, although some of the zircon in the indistinct heavy mineral laminae is much smaller. In some areas of the section, cementation by silica is complete, although generally both silica and chlorite occur, and this corresponds to the grey-green part of the hand specimen. Very minor carbonate cementation has occurred.

Composition:	Quartz	74%
	Feldspar	20%
	Chlorite	5%
	Opaques	1%
	Zircon, Muscovite, Tourmaline, Carbonate, Biotite	minor

Fine grained feldspathic sandstone.

463/246

Macro: This intraclastic limestone contains elongate intraclasts up to 2.5cm in length.

Micro: A variety of carbonate intraclasts including oolitic, stromatolitic and finely crystalline silty and clayey limestones, occur. Some have partly recrystallized. A clast containing oolitic limestone and part of a finely crystalline limestone fragment indicates a previous reworking. Ooids 0.25 to 2mm in size are also present, and often show concentric structure. Quartz. occasionally showing overgrowths and feldspar may occur as nuclei for ooids. Secondary chlorite associated with clay rich veins has developed.

Composition:	Calcite	90%
	Quartz	7%
	Chlorite and Clay	2%
	Feldspar	1%
	Opaques, Lithic fragments	minor

Oolitic intraclastic limestone.

Wilmington Formation (Unit W6)

463/076

Macro: Planar laminated olive-green siltstone.

Micro: Clay rich laminae , 0.2 to 1.2mm thick, alternate with carbonate cemented laminae, 0.2 to 6mm thick. Grains vary in size from 0.3mm (muscovite) to 0.03mm, with very fine sand size being dominant. Quartz is embayed by calcite, and rarely has overgrowths. Elongate muscovite grains are oriented parallel to the lamination, and many muscovite grains are partly altered to pale green chlorite.

Composition:	Quartz	60%
	Clay matrix	6%
	Carbonate	5%
	Feldspar	3%
	Opaques	2%
	Muscovite	2%
	Chlorite	2%
	Zircon, Tourmaline	minor

Very fine grained laminated calcareous sandstone.

463/240

Macro: Buff coloured homogeneous sandy limestone.

Micro: Sand grains (0.05 to 2mm) and ooids (0.2 to 1mm) are enclosed in a sparry calcite mosaic. Both quartz and feldspar are embayed by calcite, but overgrowths also occur. Ooids are fairly indistinct and generally have finely crystalline calcite rims surrounding coarser calcite. Terrigenous grains rarely occur as nuclei. Ooids and calcite spar are ferroan, but isolated areas of iron stained ordinary calcite showing undulose extinction occur.

Composition:	Calcite	55%
	Quartz	35%
	Feldspar	10%
	Opaques, Tourmaline, Zircon, Lithic fragments	minor

Sandy oolitic limestone.

Wilmington Formation (Unit W7)

463/066

Macro: Grey homogeneous calcareous sandstone.

Micro: Grain size is 0.05 to 0.4mm, however sorting is moderately good, with most grains in very fine to fine sand size. Quartz is subangular, and feldspar (potassium feldspar, plagioclase and microcline) is slightly better rounded. Minor quartz overgrowths are present but pore space is mainly infilled by carbonate. Sutured and concavo-convex grain contacts indicate some compaction.

Composition:	Quartz	67%
	Feldspar	15%
	Carbonate	15%
	Opaques	2%
	Chlorite	1%
	Tourmaline, Zircon, Muscovite	minor

Fine grained calcareous feldspathic sandstone.

463/214

Macro: Some fine stylolites occur in this grey oolitic limestone.

Micro: Elliptical ooids (0.3 to 0.8mm) of ferroan calcite, often partly replaced by non-ferroan calcite are "floating" in a sparry mosaic of non-ferroan calcite. A finely crystalline rim, sometimes showing concentric structure, encloses more coarsely crystalline calcite, or rarely quartz and feldspar. Some concentric structure may be preserved in the non-ferroan calcite where it has replaced margins of ooids. Two stylolites, which are approximately linear, consist of quartz and feldspar embayed by the enclosing calcite.

Composition:	Calcite	93%	Non-ferroan	68%
			Ferroan	25%
	Quartz	7%		
	Feldspar, Opaques		minor	

Oolitic limestone.

Wilmington Formation (Unit W8)

463/190

Macro: Irregular seams of creamy coloured carbonate occur in this pale grey limestone.

Micro: Most of this section consists of sparry calcite. Both ferroan and non-ferroan types occur, and often within a single crystal. Possibly some relict ooids are present, but extensive recrystallization has occurred. Quartz and feldspar, both extensively embayed by calcite are a minor component. Irregular veins of more finely crystalline ferroan calcite and some sand are present.

Composition:	Calcite	95%	Non-ferroan	60%
			Ferroan	35%
	Quartz	5%		
	Feldspar, Opaques, Zircon		minor	

Recrystallized limestone.

463/192

Macro: Grey sandstone with trough cross laminae.

Micro: The dominant grain size is fine sand, although quartz and feldspar show a variation from 0.06 to 0.4mm. Heavy minerals including opaques, zircon, sphene and tourmaline, are concentrated in trough cross laminae. Interstices are filled by chlorite and carbonate which has slightly embayed some grains. Brown aphanic material occurs as discrete grains and as more irregular areas.

Composition:

Quartz	65%
Feldspar	15%
Carbonate	14%
Heavy minerals	3%
Chlorite	3%

Fine grained feldspathic sandstone.

463/202A

Macro: Wavy green laminae are present in this grey-green very fine grained sandstone.

Micro: The wavy laminae consists mainly of chlorite which occurs as very fine grains or flakes up to 0.5mm in length. The remainder of the section consists of quartz and feldspar (0.04 to 0.2mm), in a carbonate cement with minor chlorite. Minor heavy mineral laminae are present. Some of the larger chlorite flakes have formed by alteration from muscovite, and composite grains of muscovite and chlorite occur.

Composition:

Quartz	52%
Chlorite	15%
Carbonate	15%
Feldspar	15%
Opaques	2%
Muscovite	1%
Zircon, Tourmaline	minor

Very fine grained calcareous feldspathic sandstone.

<u>Elatina Formation</u> (Unit E1)

463/204

Macro: Grey poorly sorted sandstone with laminae and more randomly scattered coarser grains up to 4.0mm in size.

Micro: Over half of this section consists of very fine to fine sand, but scattered in it is a coarser component ranging from medium sand to granules 4mm in size. Both quartz and feldspar which includes perthitic grains occur in this wide range of grain sizes. A variety of lithic fragments occurs including volcanics, red porphyries, iron ore(?), calcareous sandstone, and a variety of carbonate clasts which are mostly very fine grained, but some have partly recrystallized. The matrix is low birefringent clay minerals including chlorite, with minor carbonate.

Composition:

Quartz	58%
Feldspar	15%
Lithic fragments	15%
Clay minerals	10%
Opaques	2%
Muscovite, Tourmaline	minor

Poorly sorted fine sandstone.

Elatina Formation (Unit E2)

463/085

Macro: No bedding or lamination is present in this purple fine grained sandstone which contains scattered coarse sand and granules.

Micro: The grain size ranges from 0.05 to 1.2mm but only a minor component is coarser than fine sand. Carbonate is the main cementing agent and has slightly embayed the quartz and feldspar. Some brown clay is also present, and some rounded brownish grains, possibly composed mainly of clay are also present.

Composition:	Quartz	75%
	Carbonate	15%
	Feldspar	5%
	Clay	5%
	Opaques, Tourmaline, Muscovite, Chlorite	minor

Fine grained calcareous sandston

463/090

Macro: This yellow sandstone contains limonite(?) pseudomorphs after pyrite.

Micro: A well sorted appearance characterizes this sandstone in which grain size ranges from 0.05 to 0.2mm. Polygonal shaped grains up to 1mm in size of black and reddish opaques are randomly scattered in the section, and greenish biotite has formed on the boundaries of some of these grains. Subangular to subrounded quartz is the major component, and is enclosed in a matrix of low birefringent clays.

Composition:	Quartz	78%
	Feldspar	10%
	Clay minerals	10%
	Opaques	2%
	Tourmaline, Muscovite, Biotite	minor

Fine grained feldspathic sandstone.

463/188

Macro: Grey very fine grained sandstone with purple planar, and cross laminations.

Micro: Clay rich laminae are up to 1mm thick, but generally between 0.1 and 0.2mm. Subangular quartz (0.03 to 0.2mm) is the major constituent, but plagioclase and potassium feldspars also occur. Carbonate is present in the laminae in which clay is only a minor component.

Composition:	Quartz	70%
	Carbonate	15%
	Clay	10%
	Feldspar	4%
	Opaques	1%

Very fine grained calcareous sandstone.

Elatina Formation (Unit E3)

463/248

Macro: Indistinct trough cross laminae occur in this light grey sandstone.

Micro: Grain size in this very fine grained sandstone ranges from 0.06 to 0.5mm. Quartz is the major constituent. Plagioclase also occurs and is generally quite fresh whereas potassium feldspar may be extensively weathered. The matrix consists of low birefringent clay minerals, with minor carbonate. Some pore spaces are filled with brownish clay (? limonite) with rhombic, rectangular or less regular outlines, and may contain cores of carbonate.

Composition:	Quartz	72%
	Feldspar	15%
	Clay minerals	6%
	Carbonate	4%
	Brown clay	2%
	Opaques	1%
	Tourmaline, Zircon, Muscovite	

Very fine grained feldspathic sandstone.

Nuccaleena Formation

463/053

Macro: Purple laminae less than 1mm thick alternate with yellowish pink dolomitic laminae up to 5mm thick.

Micro: Very finely crystalline carbonate is the dominant component. Laminae composed mainly of carbonate alternate with dark laminae containing clay and carbonate. Coarser detrital components are only a minor component and are confined to silt size.

Composition:	Carbonate	75%
	Clay	20%
	Quartz	3%
	Opaques	2%
	Plagioclase, Muscovite	minor

Silty dolomite.

Brachina Formation

463/091

Macro: Purple cross laminated siltstone.

Micro: Heavy mineral cross laminae up to 0.2mm thick occur in silt consisting mainly of subangular quartz, elongate muscovite up to 0.2mm in length and opaques in a clay matrix.

Composition:	Quartz	75%
	Opaques	10%
	Clay	10%
	Muscovite	5%

Laminated siltstone.

A.B.C. Range Quartzite

463/095

Macro: Homogeneous pink quartzite.

Micro: Fine grained sand is dominant although grain size varies from 0.1 to 0.6mm. Silica overgrowths on rounded quartz grains have cemented the grains and make up about 20% of the section. Brown clay occurs on some grain boundaries.

Composition:	Quartz	96%
	Feldspar	2%
	Opaques	1%
	Clay	1%
	Tourmaline, Zircon, Muscovite	minor

Fine grained quartzite.

Marino Arkose - Location: Marino Rocks

463/A3

Macro: White homogeneous calcareous sandstone with a lens of greenish yellow shale.

Micro: This sandstone is poorly sorted and the grain size varies from 0.1 to 1.2mm. Both quartz and feldspar (potassium feldspar, plagioclase and microcline) are extensively embayed by the enclosing calcite so that some irregular shaped grains occur. A variety of lithic fragments, including "granitic" types in which more than one variety of feldspar, and quartz occur, red porphyritic grains and schist. Calcite which includes elongate crystals perpendicular to grain boundaries is the enclosing cement and contains a brown aphanic mineral (? limonite) in irregular patches or along grain boundaries.

Composition:	Quartz	55%
	Calcite	30%
	Feldspar	10%
	Lithic fragments	3%
	Limonite(?)	2%
	Muscovite, Opaques, Tourmaline	minor

Coarse grained calcareous feldspathic sandstone.

Hand Specimen Descriptions.

Brighton Limestone

463/127

Stromatolitic limestone with columns showing branching, coalescing and bridging laminae. Lamination is gently convex and up to 1mm thick. It is predominantly pale green and yellowish green, with much streakier pale grey laminae. The interspaces are filled with pale grey carbonate.

463/231

A cut and etched surface reveals closely spaced irregular columns oriented in an inclined position. Small projections occur on the margins of some columns. Laminae which are entirely composed of pale red dolomite are very gently convex and slightly wavy. Stylolites occur parallel to the lamination.

Angepena Formation

463/233

A tepee structure occurs in this specimen and the upthrust layers are continuous or fractured at the apex. Alternating layers consist of silty dolomite, intraformational conglomerate and very fine grained dolomite.

Nuccaleena Formation

463/183

Yellowish dolomite nodules which are not completely separated occur in this purple shale, and the lamination is continuous from the nodules into the shale.