# THE GEOLOGY OF PORTION OF THE PRECAMBRIAN LOWER GLACIAL SEQUENCE IN THE MT. SHANAHAN AREA OF THE MT. PAINTER REGION, SOUTH AUSTRALIA.

By

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ABSTRACT

An area in the Mt. Painter region was investigated, in which the lower portion of the Sturtian Lower Glacial Sequence overlies the Proterozoic crystalline basement, with pronounced unconformity.

Sedimentation was initiated by subsidence in a large trough controlled by marginal faulting. A thick section of southward onlapping shallow marine Fitton Formation, showing evidence of ice-rafting of megaclasts in the upper two-thirds by shore or river ice, was mapped. This sequence passes transitionally upward into the glacial marine Bolla Bollana Formation.

Regional metamorphism in the greenschist facies produced recrystallization of muddy matrices, quartzarenites and arkoses. Tremolite-talc assemblages formed in dolomitic clasts and interbeds, and abundant scapolite porphyroblasts were produced in favourable units. A contact metasomatic zonation in metasedimentary amphibolites in the southwest is tentatively proposed.

Folding on an east-west trend, faulting and some shear dislocation at the basement-cover contact, are evident.

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APPENDICES

## LIST OF FIGURES AND PLATES

# 1. INTRODUCTION

This dissertation comprises a report on the field and laboratory study of an area in the Mt. Painter region of the Northern Flinders Ranges. (see Figure 1 and Figure 6). Approximately 30 square kilometres total area, in the vicinity of Mt. Shanahan, were investigated.

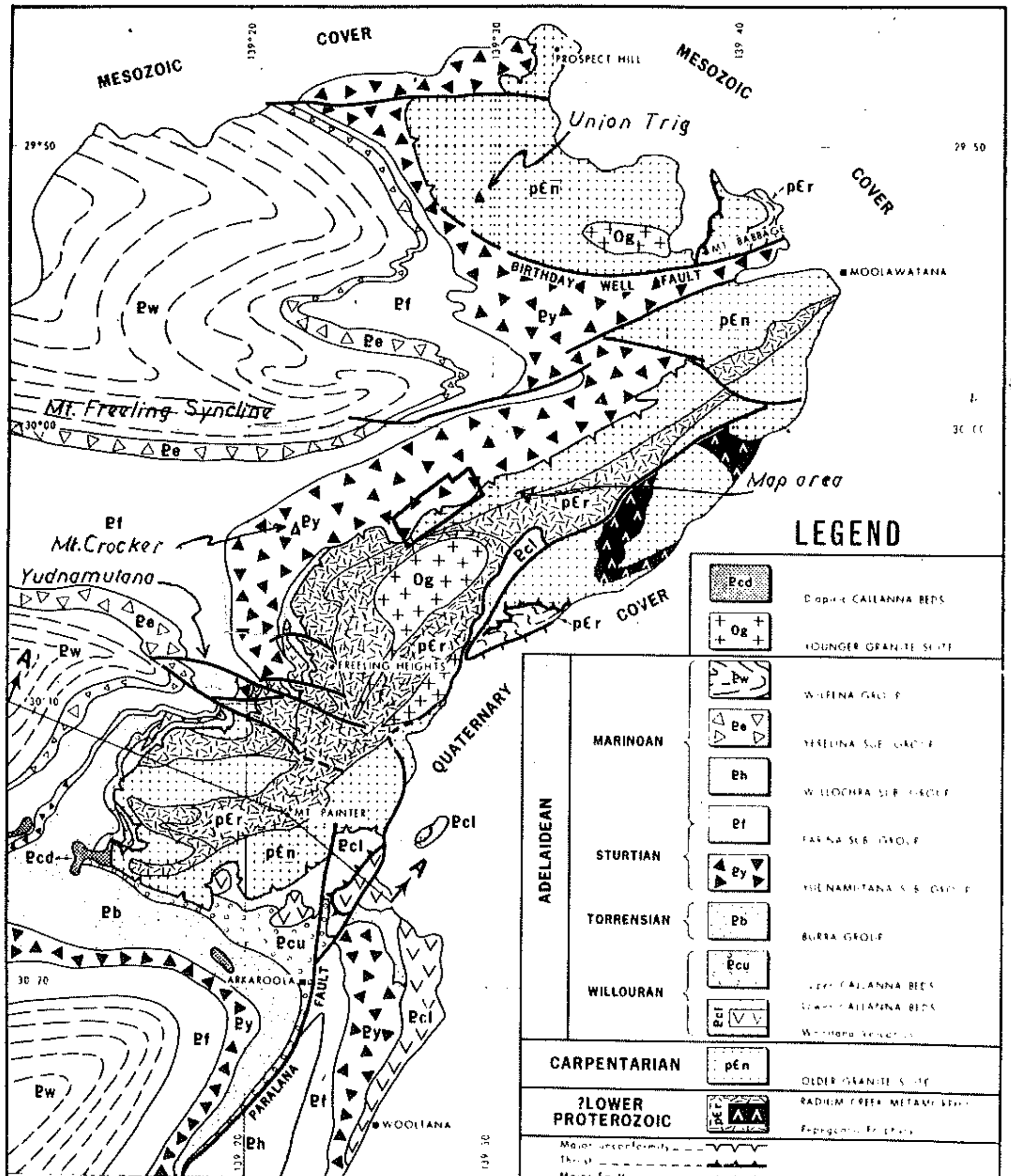
The map area is dominated topographically by a series of ridges and valleys of moderate relief, which strike generally north-east south-west correlating with the geological strike. Outcrop in general is adequate, with numerous cross-cutting smaller stream channels providing limited sections of excellent exposure. Higher standing, more resistant geological units produce abundant scree such that the immediately adjacent units frequently are obscured.

The aridity of the climate inhibits the growth of all, but hardy native shrubs and grasses, although good stands of red river gums are encountered in the almost perennially dry beds of major streams. The low annual rainfall makes water a scarce commodity but supplies were made available by the generous grazier on whose land field work was undertaken.

Field work was carried out during the latter half of May, all of June and the early part of July and involved general mapping, photographing and sampling of the area. Base mapping was executed on enlargements of black and white aerial photographs, obtained from the Department of Lands, South Australia. (Survey 1022 photographs 7285, 7333)

Laboratory time was occupied in the preparation and description of 55 thin sections, the major element analysis of 6 rock specimens by x-ray fluorescence and flame photometry, the description of hand specimens and the preparation of maps, figures and plates necessary for the illustration of material presented.

Extensive work, especially regional stratigraphic and structural mapping, has been done in the Mt. Painter region by the Geological Survey of South Australia. This investigation culminated in the publication of a compilation of information obtained, in 1971




after R.P.Coats 1968.

REGIONAL GEOLOGY OF THE MOUNT PAINTER PROVINCE

FIGURE I.

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by Coats and Blissett. Contained in their volume are numerous references to individual pieces of work performed by the Survey and by private individuals, and the interested reader is referred to their bibliography.

Several private companies, especially North Flinders Mining Company, have worked and are working on leases in the region, and although no major economic discovery has been made, much detailed knowledge has been accumulated by them. Exploration regulations specify that this become available to the general public in the future.

The nomenclature of sedimentary lithologies is that devised by Folk (1968).

# 2. STRATIGRAPHY

## 2.1 General

The nomenclature of all major stratigraphic units adopted in this thesis follows that used by Coats in Coats and Blissett (1971).

In the map area rocks assigned to the Yudnamutana Sub-Group of the Sturtian Umberatana Group, overlie, with pronounced unconformity, elements of the Mt. Painter Complex comprising the Radium Creek Metamorphics and the Older Granite Suite. (see Figure 1.) The Yudnamutana Sub-Group is represented by the Fitton Formation and portion of the overlying Bolla Bollana Formation, while below the unconformity the Freeling Heights Quartzite of the Radium Creek Metamorphics is intruded by the Terrapinna Granite of the Older Granite Suite. The age of the Older Granite Suite has been determined at approximately 1500 million years, using the Rb-Sr technique, by Compston, Crawford and Bofinger (1966), thus indicating a Carpentarian age for these granites. The Radium Creek Metamorphics tentatively have been assigned to the Lower Proterozoic.

Campana and Wilson (1955) recognised two major glacial phases, separated by an interglacial phase, in the Adelaidean sequences of the Flinders Ranges. The corresponding rock units in the Mt. Painter region, were defined by Coats (1964) as the Umberatana Group. This Group terminology was extended throughout the central part of the Adelaide Geosyncline by Thomson (1964), because of the "broad lithogenetic unity of the sequence," even though the component formations vary from place to place and commonly are restricted to their type localities.

The Yudnamutana Sub-Group corresponds to the lower glacial sequence of Campana and Wilson (op.cit.). The Fitton Formation is restricted to its type locality, while equivalents of the Bolla Bollana Formation are recognisable elsewhere in the Adelaide Geosyncline.

For the purpose of this thesis, particular attention was focussed on the Fitton Formation, with a lesser accent on the Bolla Bollana Formation, while the Mt. Painter Complex rocks were not investigated in any detail at all. This will be reflected in the following discussions.

## 2.2 Freeling Heights Quartzite

According to Coats (1971), this unit comprises the uppermost formation of the supposed Lower Proterozoic metasedimentary sequence, the Radium Creek Metamorphics. Two areas of outcrop of this formation occur in the map area. (see Figure 6.)

In its more easterly area of outcrop the unit consists of foliated, muscovite-rich, crenulated, metamorphosed argillaceous quartzarenites. (see Appendix II, T.S. 410/52M)

Further west interbeds of massive metaquartzarenites, often showing heavy mineral laminations, and rocks similar to T.S.410/52M are observed.

The latter of these two outcrops has been assigned to the lower unnamed member of the Freeling Heights Quartzite by Coats (op.cit.), and the present author does not dispute this. However the former area of outcrop is not depicted by Coats on the map accompanying his publication. From descriptions within the publication it seems likely that this outcrop also is part of the lower unnamed member.

## 2.3 Terrapinna Granite

This granite is one member of the Carpentarian Older Granite Suite, which intrudes the Radium Creek Metamorphics. In the map area, wherever contacts between the Terrapinna Granite and the Freeling Heights Quartzite are exposed, the contact appears sharp and presumably intrusive.

Dominating the appearance of the granite are large ovoidal alkali feldspar megacrysts, with lesser round, clear quartz megacrysts also present. A subordinate quartzo-feldspathic matrix, along with scattered biotite flakes, is also present. Weathering and associated disintegration of the rock frequently results in the production of a coarse gravelly mantle of feldspar ovoids and quartz-feldspar fragments.

In thin section large ovoidal microcline and microcline perthite megacrysts are very common as are rounded quartz megacrysts showing undulose extinction. Small patches of myrmekitic quartz-alkali feldspar intergrowth are commonly observed. These features frequently occur in detrital elements overlying the Mt. Painter Complex.

## 2.4 Fitton Formation

This formation is unknown outside of the Mt. Painter region where the presence of a deep trough between Yudnamutana and Union Trig (see Figure 1.) permitted the accumulation of a large thickness of the formation (Coats, 1962).

In the map area, the Fitton Formation can be subdivided into seven somewhat arbitrary sub-units, (a), (b), (c), ..., (g), some of which have been given purely descriptive names. The lower four of these sub-units are fairly well-defined, but the upper three are often difficult to assign.

### (a) Granite Conglomerate

This sub-unit generally immediately overlies the Mt. Painter Complex basement and is composed of dominantly granitic, granule to boulder sized clasts set in a now-schistose muscovite-biotite, presumably originally muddy, matrix. (see Plate 1.) Minor quartzitic, schistose and schistose quartzitic clasts are present. The larger clastic elements exhibit good rounding often, while smaller clasts may be more angular.

Petrographically and in hand specimen, the granitic clasts show marked similarities to the granites of the Older Granite Suite. (see Appendix I and II, T.S.410/9F, H.S.410/122F, 257F) This is particularly indicated by the ovoidal microcline and perthitic alkali feldspars, the round quartz megacrysts and the myrmekitic quartz-feldspar intergrowths. Thus derivation from the immediately underlying granitic basement seems most likely.

Some of the quartzitic clasts appear similar to the Freeling Heights Quartzite, although this may not be so. In general the black schist clasts are of unknown provenance, although T.S.410/54F is perhaps relatable to the Brindana Schist. This is indicated by Coats's comments on page 117 of Coats 1971. Thus a very local provenance seems to be

Plate 1. Lower Fitton Formation

A Typical Granite Conglomerate, Sub-unit (a).
(Note deformed clast near hammer point)

B Possible Dropstone in Sub-unit (a).

C Interbedded phyllitic silts and conglomerate, Sub-unit (a).

Please note :
Locations of all photographs are indicated on map accompanying Appendix 1.

A

B

C

PLATE I.

indicated.

Common phyllitic silt interbeds are present in this sub-unit, and show fairly small-scale intertonguing relationships with the conglomeratic facies, although exposure is not good enough to follow these relationships in detail. The presence of the silt interbeds is apparently related to the configuration of the floor of the depositional basin, as they occur in depressions but are not seen on local basement highs. In extreme western outcrops, where the sub-unit wedges out onto the basement, no silt interbeds are present and the conglomerate thins markedly.

In this western area also, a much higher proportion of quartzitic clasts, relatable to the underlying Freeling Heights Quartzite in this locality, indicates the local provenance and sensitivity to basement lithology, of the sub-unit.

Immediately adjacent to Mt. Shanahan (see Figure 6.) a black muddy silt unit with scattered pebbles and cobbles of ovoidal feldspars, granite and quartz, forms the upper portion of this sub-unit. To the west this quickly tongues out, but eastwards it carries on to the limit of the map area although diverging from the bulk of the sub-unit with an intervening muddy silt becoming apparent. This relationship is apparently related to the existence of a basement depression immediately to the east of the map area.

(b) This sub-unit is commonly very poorly exposed due to the shedding of scree by the underlying and overlying sub-units (a) and (c). The limited outcrop available does indicate minor facies variations laterally within a dominant "background" sedimentation of mud and silt. Phyllitic silts commonly are observed and thin quartzitic bands appear near the top in some places. Thin bands of granite pebbles are present in the lower portion, at least in the vicinity of Mt. Shanahan, and indicate a passage upwards into this sub-unit from the underlying sub-unit.

Also near Mt. Shanahan a two metre thick pebbly arkose band is present which disappears quickly to the west, although it carries on to the east to the extremity of the map area. Conversely amphibolitic bands first become evident in this sub-unit to the west of Mt. Shanahan and become more prevalent further west.

Some degree of intertonguing of this sub-unit with sub-unit (a) seems to occur, especially in the basement depression in the central map area, and probably is related to the configuration of the unconformity surface. An unusual relationship with sub-unit (a) is noticed further west again, where sub-unit (b) wedges out onto sub-unit (a).

(c) Pebbly Arkose

This sub-unit succeeds sub-unit (b) very abruptly, although the base is not always exposed. Sub division into a westerly facies and an easterly facies is possible, with a transitional zone occurring between.

The easterly facies is generally represented by a topographically prominent, massive, white pebble conglomerate, containing a few cobble sized clasts as well. Only a very minor fine-grained matrix is evident. The dominant clastic elements are granitic in composition and in thin section show marked similarity to members of the Older Granite Suite. (see Appendix II, T.S.410/12F, 29F) Minor proportions of other clast lithologies are present, such as quartzite and black biotite schist.

Recrystallization of this quartzo-feldspathic rock has occurred, variably along strike, such that original detrital shapes have been obliterated on a fine scale. Thus in places the sub-unit has a granite-like appearance.

In its more westerly facies the sub-unit generally consists of a green-black biotite-actinolite rich rock containing abundant clasts of a similar nature to those in the easterly facies. This mafic matrix is present to a lesser or greater extent, with T.S.410/68F and 74F showing this. The shapes of many of the alkali feldspar are reminiscent of the feldspar ovoids of the Older Granite Suite. It is probable that the presence of the mafic matrix may be correlated with the original presence of a muddy matrix, most probably calcareous, and the response of this to metamorphism. (see Section 3.2.)

Plate 2. Middle and Upper Fitton Formation

A "Nest" of boulders, sub-unit (d), probably dropped from overturned ice-berg.

B } Typical pebbly mudstones, Sub-unit (d).
C } (Note patchy clast distribution)

D Photomicrograph (10X), Sub-unit (d), possible glacial ice-derived sediment pellets. T.S. 410/158F

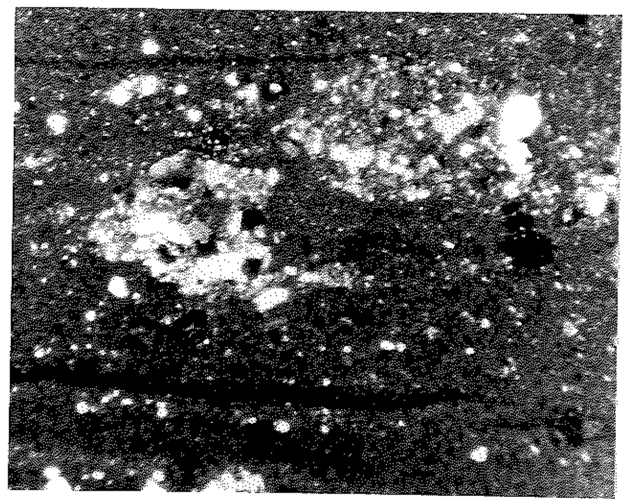
E Quartzite boulder in pebbly mudstone, Sub-unit (d).

F Isolated rounded boulders in siltstone, Sub-unit (e). (photograph in approximate plane of bedding)

A

B

C



D

E

F

PLATE 2.

The change from one facies to the other is not abrupt but an irregular transitional zone is observed. Thus, along strike, alternate outcrops in this zone show characteristics of one facies or the other, or both.

As in the case of sub-unit (b) this sub-unit wedges out to the extreme west, onto sub-unit (a). This relationship of sub-unit (a) to (b) and (c) indicates that (a) is to some extent diachronous.

(d) Overlying sub-unit (c) is a thick sequence of variable lithologies. The dominant rock-type is black muddy siltstone. Attempts to devise a workable sub-division of this sequence were frustrated by the lack of continuous marker horizons and hence the inability to correlate across faults with confidence.

In the eastern portion of the map area, the sequence consists of black massive to laminated commonly scapolitic and calcareous, muddy siltstones. The laminated bedding in these siltstones is often contorted and often strongly slumped, showing evidence of soft sediment deformation. (see Plate 3C,B) Occasional exposures of small possible load casts are seen, when sand sized sediment overlies mud (see Plate 3A), and small-scale cross-stratification is observed in thin, more sandy units.

Frequent massive light to dark coloured orthoquartzite (quartzarenite) units, less than three metres thick, are interspersed through the section. Occasionally poor bedding is observed in these, and very occasionally cross-stratification.

Also dispersed through the sequence are frequent horizons, generally less than ten metres thick, of massive pebbly to bouldery, often sandy, mudstones. Much difficulty was experienced in trying to trace these pebbly mudstones laterally due to their poor outcrop habit, lack of a well-defined strike direction and apparent patchy distribution of clasts. (see Plate 2B,C,E) At least one good example of a "nest" of boulders approximately two metres long by fifty centimetres thick was observed. (see Plate 2A).

The dominant clast lithology throughout the bulk of this sub-unit is quartzite, with minor granite, granodiorite and dolomite.

Near the base of the sub-unit a well-defined, although patchy horizon of white granite clasts, ranging in size from small pebbles to large boulders up to four metres in length, is noticed. Conversely small dolomite marble boulders only become common near the top of the sub-unit. (see Section 2.6)

A probable original facies change is evident in the lower half of this sub-unit towards the western end of the map area. This is indicated in Figure 2 where a thick section of massive to layered amphibolitic rocks occur in the west but not in the east. (see Appendix II, T.S.410/63F, 75F, 86F, 119F, 126F, 127F, 220F, 239F, 258F, 310F) It is considered most likely that these units represent the metamorphic equivalents of originally muddy carbonate sediments. This is further indicated by the presence of abundant calcite in some of the amphibolites (see T.S.410/86F), and the presence of at least two very thin tremolitic, dolomitic marble interbeds, of limited lateral extent, within this sub-unit a little to the east of the main amphibolite mass. (see T.S.410/268F) These amphibolites are discussed more fully in Section 3.2.

Also in this western area are intercalated, two bands of grey-brown phyllitic silt, up to twenty metres thick.

(e) This sub-unit has a somewhat arbitrary lower limit in many places, but a definite contrast with the underlying sub-unit is evident, mainly with respect to an increase in frequency of thin massive quartzite bands.

Generally the sequence comprises thin dark shaley silts with interbedded thin massive quartzarenites. Minor laminated silts and poorly bedded quartzites are also included. Fairly common thin pebbly silt bands, up to 10 centimetres thick are noticed, which often have associated small boulders with diameters much greater than the thickness of the band itself. Scattered isolated boulders also occur in the silts. (see Plate 2F)

One exposure of a rippled upper surface of a coarse silty unit was observed and photographed. (see Plate 3B)

Clast types observed in this sub-unit are dominantly fairly well-rounded quartzite clasts varying from pebbles to moderate sized boulders.

Other sedimentary rock fragments are present, as well as minor granitic types but these constitute a minor fraction only, of the megaclastic population.

(f) The distinction between this sub-unit and the underlying sub-unit (e) is minor, but does represent an increase in the proportion of quartzite bands over siltstone.

The dominant constituent of this sub-unit is generally massive light-coloured quartzite occurring in thin bands and with fairly common thin siltstone interbeds. The silts frequently are dark-coloured and shaley and in many places are obscured by the abundant débris shed by the quartzites. Rarely are the siltstones laminated, but more common are thin pebbly bands with occasional associated small boulders.

As in sub-unit (e), the most common clast lithology is quartzite, with minor proportions of others. Larger, boulder sized clasts especially, are generally rounded although smaller clasts may be sub-angular.

(g) Contained within this sub-unit is a passage from the Fitton Formation to the Bolla Bollana Formation. This is indicated by the transition from dominantly silty sedimentation to unsorted massive diamictites.

The dominant clast lithologies present in this sub-unit are quartzites and dolomites with minor quartzitic conglomerates, shales and other sedimentary rock fragments. Cobble and boulder sized clasts are often fairly well-rounded while smaller clasts may show some angularity.

In the lower part of the sub-unit common massive thin quartzites are interspersed within massive black to blue-black silts, which often are shaley and which often contain pebbly bands with associated outsized boulders. A few isolated boulders also are observed. At least one conglomeratic quartzite unit a few metres thick generally is present, although minor variations in this unit, as well as in other units, are noticed. These variations generally involve the degree of lateral persistence and the thickness of component units.

Plate 3. Middle and Upper Fitton Formation

A Small load cast, Sub-unit (d).

B Rippled upper surface of siltstone, Sub-unit (e).

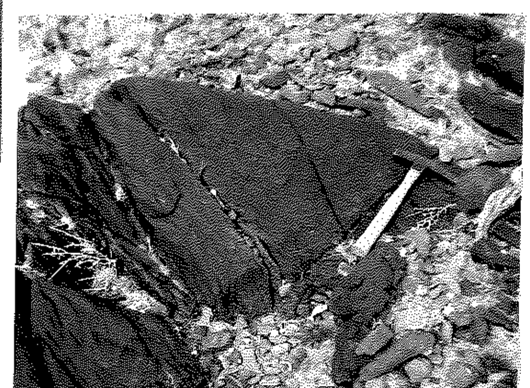
C Contorted laminations in siltstone, Sub-unit (d).

D Slumped siltstone, Sub-unit (d).

A

B

C



D

PLATE 3.

The upper part of the sub-unit contains only a few quartzite bands and the silts become more blue-black to green-black and variably shaley to sandy, with frequent horizons of diamictite containing pebble to boulder sized clasts. These diamictites soon become more prevalent until finally diamictite persists and no shaley silts without clasts are present. At this point the boundary of the Fitton Formation and the Bolla Bollana Formation is drawn by the present author.

Unbeknown to the present author, Coats (1964), in his definition of the Yudnamutana Sub-Group, had designated this boundary as the first appearance of diamictite of this type. Thus Coats (op.cit.) has drawn his boundary slightly lower in the stratigraphic section, although no marked spatial difference occurs.

It is maintained by the present author that as there is a transition between the two formations, the choice of an actual boundary between the two is arbitrary. As a matter of precedence, and for the sake of consistency, it is recommended that future workers revert to Coats's scheme.

## 2.5 Bolla Bollana Formation

An intertonguing relationship is observed between the Fitton Formation and Bolla Bollana Formation in the vicinity of Valley Bore. (see Figure 6.) This was originally described by Coats (Coats and Blissett, 1971), and the present writer agrees with the concept. The actual configuration of this intertonguing is not agreed upon by the two writers, however. It is most probable that the bulk of this difference can be attributed to the different criterion adopted by the different writers, for drawing the formation boundaries.

However the concept is more important than the configuration, and the concept is in no way disputed.

Only the lower portion of the Bolla Bollana Formation was investigated. It was found that the lowermost diamictite units of the formation passed abruptly into a group of quartzites which then passed abruptly back into diamictite. Thus the description is in two parts, with (a) being devoted to diamictite and (b) devoted to quartzites.

(a) This portion of the formation consists of massive green-black to blue-black diamictites, containing varying proportions of megaclasts, sand and mud. These variations result in a crude stratification, most noticeable with respect to megaclast proportion.

Large boulders up to two metres, and rarely up to four metres, in diameter are frequently encountered, and generally are sub-rounded to rounded although some appear to be angular to a slight degree. No definite facetted or striated megaclasts were observed, but the present writer does not dispute their possible existence.

The abundant megaclasts are almost entirely sedimentary rock fragments. The most common of these is quartzite with lesser amounts of conglomerate, dolomitic marble, and others. In some horizons fairly angular shale and siltstone rock fragments are abundant. (see H.S.410/416B)

Higher in the sequence very occasional massive thin quartzite bands, of fairly significant lateral extent are encountered. Moderate scale lenticularity of some of these quartzites is apparent.

(b) Included within these diamictites is a westerly thickening group of interbedded thin massive to poorly bedded quartzarenites and sublitharenites. In the eastern extremity of the map area this group is very thin, but near Valley Bore a fairly thick sequence, with interbeds of diamictite and at least one conglomeratic quartzite, is noted. A rapid lensing out of this group immediately east of Valley Bore is indicated.

West of Valley Bore a different group of interbedded quartzites and diamictite is present in a similar stratigraphic position, such that the two groups are correlated. The previously mentioned intertonguing relationship of the Fitton Formation and Bolla Bollana Formation is indicated largely by these units.

## 2.6 Clast Types and Provenance

As has been indicated in Sections 2.4 and 2.5, the lithological associations of clast types varies up through the stratigraphic section.

On this basis the map area has been divided into three fairly well-defined zones. (see Figure 3)

Thus sub-units (a), (b), (c) and portion of (d), of the Fitton Formation, can be included in the zone of dominant granitic clasts. Pebbles, cobbles and boulders of different granite types along with minor magnetite-biotite schist, biotite schist, metaquartzarenite and muscovitic metaquartzarenite are observed. (see T.S.410/2F,3F,4F, 9F,54F,55F, H.S.410/122F,257F)

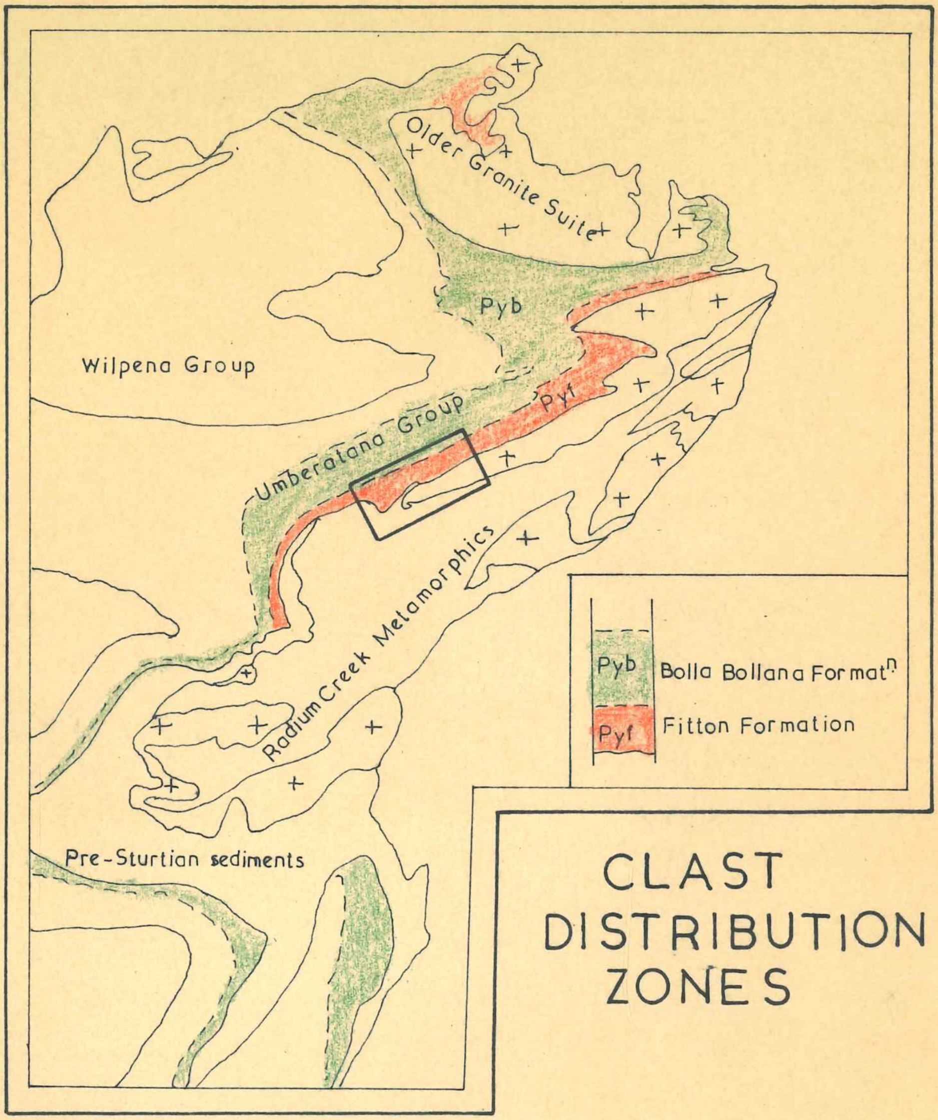
These clasts seem to be relatable to the immediately underlying Mt. Painter Complex, especially the Terrapinna Granite, Mt. Neill Granite Porphyry, Freeling Heights Quartzite, Brindana Schist and an unnamed dark grey microgranite.

This lower zone passes into a middle zone containing dominant quartzite clasts, with subordinate proportions of granite, granodiorite, dolomite and others. (see T.S.410/78F,81F,230F,256F,270F,453F, H.S. 410/155F,269F) These are probably relatable to the more southerly quartzitic basement and pre-Sturtian sedimentary cover.

Passage into an upper zone which includes the uppermost two sub-units of the Fitton Formation and carries into the Bolla Bollana Formation is observed. This zone is characterised by the presence of abundant sedimentary rock fragments, chiefly quartzite, of varying types, conglomerates, dolomites and lesser shales and siltstones. (see H.S.410/161B,173F,174B, T.S.410/177F,414B) Many of these clasts show striking similarities to specimens of pre-Sturtian sediments, collected in the Yudnamutana area by fellow Honours students. The most distinctive of these are the Skillogalee Dolomite, Wywyana Formation and Blue Mine Conglomerate.

The progression from lower to upper zone seems to correlate with a southward-migrating source area. This is consistent with the theory of southward onlap, onto an older pre-Sturtian erosion surface, of the Fitton Formation; described by Coats (Coats and Blissett, 1971). This onlap is also indicated, in the map area, by sub-units (a), (b) and (c) of the Fitton Formation. (see Figure 6.)

For the Bolla Bollana Formation Coats (op.cit.) proposes a




# CLAST DISTRIBUTION ZONES

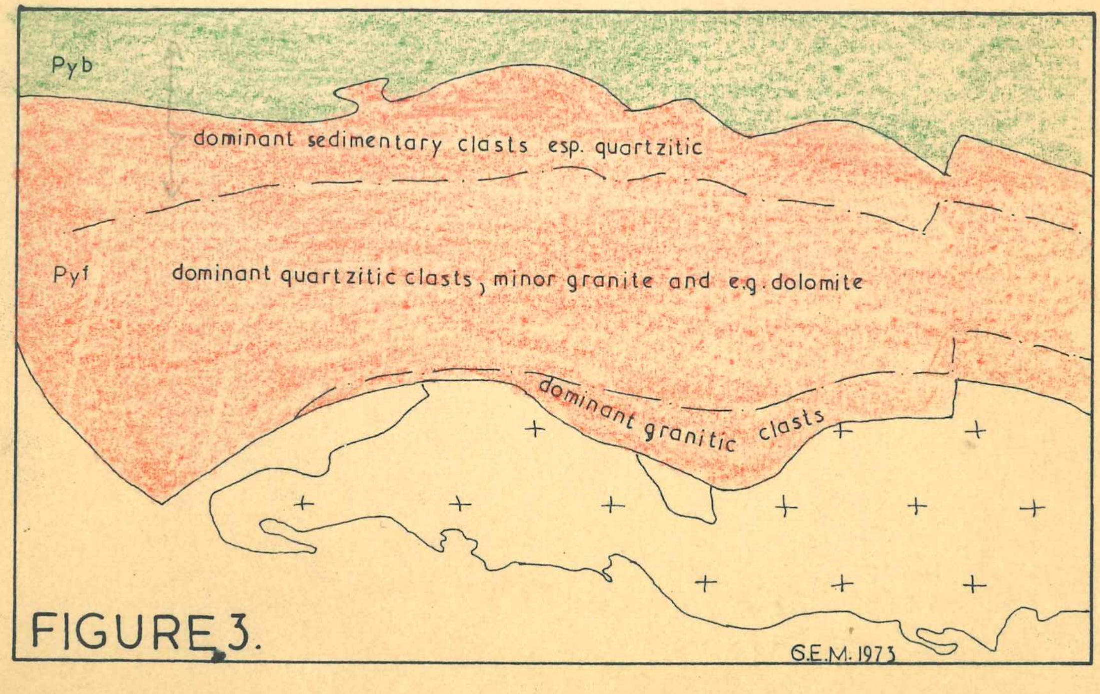



FIGURE 3.

provenance far removed to the south-west, by virtue of the occurrence of a particular distinctive clast. This may well be so, but if so outcrops of the Callanna Beds and Burra Group must occur there too, to account for the clasts cited above in the upper zone. Alternatively a dual local and exotic provenance may be represented in the Bolla Bollana Formation.

## 2.7 Depositional History

As indicated above, prior to the commencement of deposition of the Fitton Formation, an erosional surface developed on the Mt. Painter Complex and pre-Sturtian sedimentary cover. This surface, in the map area, appears to be fairly flat and possibly a peneplain.

Sedimentation was apparently initiated by subsidence, developing a large trough between Yudnamutana and Union Trig. This trough is thought to be at least partly the result of faulting at its margins (Coats, 1962), and this faulting is presumed to have controlled or at least affected sedimentation. A probable northward tilt of the floor of this trough would account for the southward onlap of the Fitton Formation.

Initial sedimentation of the coarse granitic débris and muddy silts of sub-unit (a) was probably caused by the unstable relief caused by the marginal faulting. Thus rapid southward migration of a shoreline onto a steeply inclined granitic substrate would account for the relevant sedimentological features. These features are the derivation of sediment from immediately underlying basement, the rounding of clasts, the lenticular silty interbeds possibly settling out in deeper offshore areas or sheltered small bays, the limited sorting of sediment in the conglomeratic facies possibly indicating rapid advancement of the shoreline, and the sensitivity of sedimentation to the configuration of the floor of deposition.

The contention by Campana (1958) that this sub-unit constitutes a land moraine is not supported by the lack of obvious glacially sculpted boulders, although this origin is still a possibility. Very limited ice-rafting may be indicated by a possible dropstone (see Plate 1B), although this clast may have dropped or rolled in from above in some other manner, for instance from a local topographic high.

The contention that sub-unit (a) represents a shore-line conglomerate may be substantiated by its occurrence along the basement-cover contact to the west, even past where overlying units wedge out.

Sub-unit (b) may represent an offshore facies of sub-unit (a) or alternatively may represent a period of tectonic quiescence such that torrential supply of coarse detritus was lacking. If a glacial hypothesis for sub-unit (a) is accepted it may be that glacial activity ceased such that "normal" sub-aqueous muddy silt deposition occurred.

The passage from sub-unit (a) to (b) is consistent with either interpretation, although the variability of (b) along strike persuades the present author to include this in a shoreline conglomerate model.

Renewed sedimentation of coarse granitic detritus in sub-unit (c) may have been initiated by a tectonic pulse, rejuvenating relief, or may be incorporated into a glacial model. The former is favoured by the present writer.

As onlap proceeded rising sea-level probably outstripped sediment supply such that slightly deeper water silts and muds were deposited. Coarser clastic material may have been supplied by ice-rafting as indicated by the patchiness of clast distribution, an extreme case of which is Plate 2A, a "nest" of boulders (see also Section 2.4(d)). This feature has been described by Ovenshine (1971) in Recent glacial marine sediments in Alaska, as due to the overturning of sediment-laden icebergs. The general roundness of clasts would tend to indicate the involvement of river or shore ice rather than true glacial ice.

Plate 4B shows an aggregate of sand grains apparently floating in a recrystallised muddy matrix (see also T.S.410/158) a feature which has also been described in Recent glacial marine sediments by Ovenshine (op.cit.).

Alternatively a tectonically induced subaqueous mass-flow phenomenon may be involved in the formation of the pebbly mudstones. This is suggested by the associated slumping of laminae in mudstones which indicate instability. This instability may be the result of the marginal faulting. The evidence quoted above favours an ice-rafting mechanism, but by no means disqualifies sub-aqueous mass-flow phenomena.

The occurrence of metasedimentary amphibolites in the west and thin dolomitic interbeds, indicates the deposition of carbonate and muddy carbonate sediments, presumably in a shallow marine environment.

Sub-units (e) and (f) probably indicate a shallowing of the basin such that abundant sand sheets were deposited. This may correlate with a decrease in rate of subsidence or a sea-level drop possibly correlating with the supposed growth of glaciers in adjacent land masses. Ice-rafting by shore or river ice probably still occurred to some extent depositing pebbly bands with occasional associated boulders.

The provenance at this stage has migrated southwards as southward onlap has progressively covered the local basement with sediment.

Sub-unit (g) marks variable conditions consistent with a fluctuating transition to true glacial marine conditions. Erosion of the older sedimentary cover, kilometres to the south-west, by glaciers resulted in the supply of abundant ice-rafted sedimentary rock fragments. Subsidence, possibly fault-controlled or fault-facilitated, resulted in the accumulation of a thick section of the glacial marine Bolla Bollana Formation.

The presence in the lower diamictites of the Bolla Bollana Formation of horizons of abundant shaley and silty angular pebbles and small cobbles, probably indicates a glacial reworking of earlier Yudnamutana Sub-Group sediments, possibly on the elevated fault blocks in the Yudnamutana area. This is suggested by the softness of the clasts and the low likelihood of them surviving extensive abrasion and transport.

The very crude stratification and apparent continuity of diamictite sedimentation indicates deposition from floating ice in close proximity to the floating shelf-ice zone of either a dry-based or most probably a wet-based glacier. (see Carey and Ahmad, 1961)

The group of quartzites intercalated with the diamictite of the Bolla Bollana Formation, probably documents the influx of sediment-laden melt-water streams, presumably issuing from beneath the shelf zone of a retreating wet-based glacier. Alternatively it may represent increased marine current activity, such that reworking of previously deposited till winnowed, remobilised and redeposited the sand and small pebble fraction.

The intertonguing of the Fitton Formation and Bolla Bollana Formation in the vicinity of Valley Bore indicates that glacial marine sedimentation began in different places at different times. The reason for this is unknown.

# 3. METAMORPHISM

## 3.1 General

The modification of original sedimentary features by metamorphic processes is evident in the rocks in the map area.

Presumed muddy matrices of siltstones have been recrystallized to assemblages of dominant green biotite with lesser chlorite and muscovite. Quartz sand and silt-sized grains, "floating" in this matrix material have often been corroded to a minor extent.

Quartzitic rocks have been recrystallized also, producing granoblastic mosaic textures with original detrital grain shapes being obliterated. Some suturing of grain-grain boundaries is also observed. This recrystallization is also observed in the arkosic conglomerates in the lower part of the Fitton Formation.

Metamorphic minerals are present in the dolomite marble clasts and in the thin dolomitic interbeds in the section. These minerals are talc and tremolite in the former case, and tremolite only, in the latter case.

These phenomena are all consistent with a low grade, greenschist facies of regional metamorphism (Turner, 1968).

The presence of presumed metasedimentary amphibolites in the western portion of the map area, and abundant scattered scapolite porphyroblasts, in muddy siltstones especially, are discussed in Sections 3.2 and 3.3 respectively.

## 3.2 Amphibolites

As indicated above extensive outcrop of massive to layered amphibolites occurs in the south-western portion of the map area. These apparently thin and grade out to the east, although minor occurrences of them occur low in sub-unit (d) of the Fitton Formation far to the east.

Mineralogically the dominant constituents of the bulk of these units are hornblende or actinolite, biotite, plagioclase and microcline. Other minerals occurring, often abundantly, in some of the specimens are quartz, epidote, calcite and scapolite. Sphene, opaques and lesser apatite form the main common accessories. Textures are generally completely metamorphic with only one specimen (T.S.410/126F) exhibiting possible good relic sedimentary bedding. A crude banding is present in some specimens.

Features pointing to a metasedimentary origin for these amphibolites are the presence of rare relic sedimentary bedding, the presence of pebbles of granite within some bands, the presence of abundant biotite in some specimens and the presence of abundant calcite in some specimens (e.g. T.S.410/86F). As well as this, the intercalations of two approximately 20 metres thick bands of phyllitic silt, and thin bands of quartzite and pebbly mudstone, indicate at least a sedimentary association. No discordancy with sedimentary units is observed.

It is contended that these rocks represent the metamorphic equivalents of an originally muddy calcareous section. The presence of abundant calcite in some specimens, and the presence to the east of thin dolomitic limestone interbeds lends weight to this contention.

Orville (1969) has proposed a model for the production of amphibolites by metamorphism of impure limestones or dolomitic shales. The isochemical metamorphic production of such rocks would require a dolomite content of 20 to 40 per cent. A more common sedimentary assemblage is interlayered carbonate-rich and carbonate-poor shale, which Orville (op.cit.) believes could produce amphibolites under metasomatic conditions.

Vidale (1969) discusses migration of components, via pore fluids, along concentration gradients in such a sequence. Orville (op.cit.) enlarges this theme and proposes a model for the production of amphibolites from such a sedimentary sequence by metasomatic alteration, although he believes only limited introduction of exotic material occurs. Thus he views metasomatic fluids as more an agent facilitating migration of components already present in the sediments, rather than an introducer of components.

Such a mechanism is proposed for the amphibolites of the map area.

Plate 4. Structure and Metamorphism

A Sheared and veined Terrapinna Granite, very close to basement-cover contact.

B Refraction of Cleavage, Sub-unit (f).

C Tourmalinised quartzite, Sub-unit (d).

A

B

C

PLATE 4.

Migration of metasomatic fluids, possibly associated with the Younger Granite Suite, is also indicated by a crude zonation in the amphibolites, cross-cutting the regional strike. Thus low in the section T.S.410/316F a diopside-bearing biotite rock occurs, followed by a zone of amphibolites, with an outer zone of calcite-bearing amphibolites grading into "normal" silts and the like. In the outer zone a tourmalinised quartzite is observed (Plate 4C), with this tourmalinisation being patchy and cross-cutting bedding, such that a pod of almost pure tourmaline results. These zones may be an imaginary feature as they were not mapped in the field, but became apparent in the laboratory mainly through thin-section examination and sample locating plotting.

Thus possible granite magma-derived metasomatic fluids are envisaged to have radiated outwards from a centre adjacent to the south-western corner of the map area, possibly the Younger Granite, producing a contact metasomatic zoning.

Associated with this may have been the migration outwards of volatile carbon dioxide, away from the heat source, producing the outer strongly calcitic zone.

A channel-way for these solutions may be a large fault just west of the map area on the Umberatana 1:63,360 sheet of the Geological Survey of South Australia. This fault has huge associated quartz reefs, indicating the passage of siliceous aqueous solutions.

### 3.3 Scapolitisation

The presence of abundant scapolite disseminated throughout the section has been noted already. This feature is most common in muddy, often calcareous, siltstones and amphibolitic rocks, often producing a spotted appearance in them. A fine scale and broad scale layering is present, with respect to the distribution of scapolite in the rocks. This tends to suggest a stratigraphic control on the presence or absence of scapolite porphyroblasts in particular units.

Two main theories have been formulated to account for scapolitisation in such an environment.

Shaw (1960b) states that the "principal requirement for scapolite to form is a diminution of $pH_2O$ and a concomitant increase in all or one of $pCO_2$, $pCl_2$ or $pSO_3$." This is generally bound up in a metasomatic model.

White (1959), in his description of scapolitic metasediments in the eastern Mt. Lofty Ranges, concludes that all of the components of the scapolite were present in the sediment. Regional metamorphism has resulted in scapolite formation.

In this study three non-scapolitic and three scapolitic silt-stones were analysed for the major element oxides. The most significant results are present in Figure 4. The variability within groups is attributed, at least partly, to poor choice of samples, such that no firm conclusions are possible. The data does indicate however a correlation of scapolite with $Na_2O$ and CaO and a significant negative correlation with $Al_2O_3$ and $TiO_2$. The contents of these major elements is most likely a function of original sediment composition and hence this is favoured as the controlling factor in the distribution of scapolite.

However the passage of metasomatic fluids is indicated else-where in the map area. (see Section 3.2) Thus it is possible that the special conditions of $pH_2O$, $pCO_2$, $PCl_2$ and $pSO_3$ were facilitated by the presence of a metasomatic fluid. It is still believed, though, that the major element proportions in the original sediment control scapolite distribution.

| sample | oxide* | weight | | percent | | |
|---|---|---|---|---|---|---|
| | $K_2O$ | $Na_2O$ | $CaO$ | $SiO_2$ | $Al_2O_3$ | $TiO_2$ |
| scapolitic siltstone | | | | | | |
| 1 | 3·78 | 1·43 | 6·21 | 61·61 | 12·84 | 0·79 |
| 2 | 4·34 | 1·34 | 3·94 | 61·49 | 14·68 | 0·77 |
| 3 | 4·08 | 1·42 | 3·97 | 63·24 | 15·10 | 0·74 |
| mean | 4·07 | 1·40 | 4·71 | 62·11 | 14·21 | 0·77 |
| non-scapolitic siltstone | | | | | | |
| 1 | 4·21 | 1·09 | 6·06 | 57·60 | 16·44 | 0·83 |
| 2 | 3·37 | 1·70 | 2·81 | 67·95 | 13·45 | 0·80 |
| 3 | 6·46 | 0·06 | 0·55 | 63·68 | 18·53 | 0·94 |
| mean | 4·68 | 0·95 | 3·14 | 63·08 | 16·14 | 0·86 |
| correlation coefficient oxide vs scapolite | − 0·31 | 0·42 | 0·41 | −0·16 | −0·51 | −0·13 |

FIGURE 4. GEOCHEMICAL DATA

GEM.1973

# 4. STRUCTURE

## 4.1 Regional Structure

The feature of the regional structure most relevant to this thesis, is that referred to by Coats (1962) as "fault sedimentation." In this concept, sedimentation in the Adelaidean of the Mt. Painter region is visualised as controlled by penecontemporaneous faulting. This faulting is envisaged by Coats to have controlled subsidence in the large trough between Yudnamutana and Union Trig, as previously discussed in Section 2.7. Also indicated in Section 2.7 is the present author's belief that the major features of the lower portion of the Fitton Formation are attributable to this tectonic activity. Likewise the great thickness of the Yudnamutana Sub-Group in the trough is explained, at least in part, by this fault controlled subsidence.

Subsequent deformation of the Adelaidean sedimentary cover is evident, such that major folds, generally with east-west axial plane traces, can be mapped. Associated faulting also took place.

In terms of the regional structure the map area is situated on the southern limb of the nose of the westerly-plunging Mt. Freeling Syncline. (see Figure 1)

## 4.2 Local Structure

### (a) Folding

As indicated in Section 4.1, the map area is situated on the limb of a major syncline, Thus a major north-east south-west bedding trend is observed. Smaller scale folding is also present, which seems to be related to some extent to the configuration of the unconformity surface. The change in trend of the trace of the basement-cover contact is reflected in the attitude of the sedimentary layering, although this basically simple pattern is disrupted by a radiating set of moderately large faults.

A stereographic plot of poles to bedding planes is presented in Figure 5, and indicates a majority of north-westerly dipping strata.

The plunge of the major structure deduced from this plot is 39° towards 271°.

(b) Cleavage

A pronounced cleavage is often noticed, especially in more shaley, less competent units, and frequently lies in the plane of the local bedding. Cleavage inclined to sedimentary bedding is also common. Very locally marked refraction of cleavage at the interface between shaley siltstone and quartzite is evident. (see Plate 4B)

The quality and quantity of the data obtained was not good, but the stereographic plot of poles to cleavage does indicate the approximate axial plane orientation of the major structure. This orientation has an approximate strike of 279° and a dip of 65° towards the south.

(c) Other Aspects

A significant aspect of the local structure is the overturning, in some places, of the basement-cover contact by up to approximately ten degrees towards the north-west. This trend continues a little distance into the cover, but soon the bedding assumes a steeply dipping upright attitude. Overturning of this type is present in the eastern map area, although elsewhere upward facing is the norm.

Shearing is another phenomenon associated with the basement-cover contact. This results generally, in a well-defined schistosity in the basal, micaceous, granite conglomerate. Less competent, more schistose clasts in this conglomerate are commonly "stretched and flattened." (see Plate 1A) This shearing, in places, seems to extend a short distance into the basement, producing a sheared granite commonly very similar in appearance to the matrix of the granite conglomerate. Plate 4A shows one locality where sheared and quartz-veined Terrapinna Granite occurs in this way.

The incidence of this shearing probably documents some degree of dislocation of basement and cover during deformation, with the dislocation naturally being concentrated at the unconformity surface.

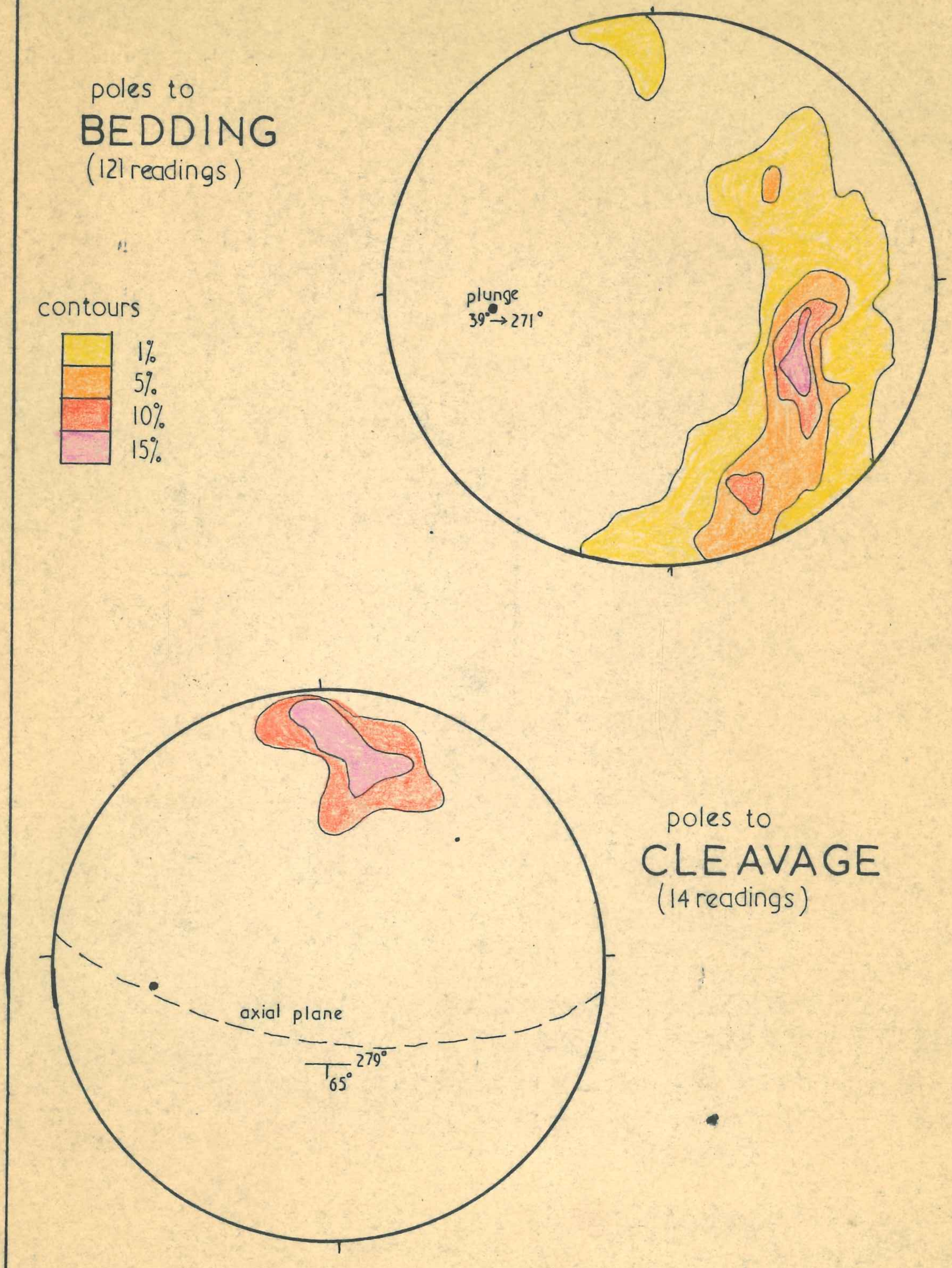



FIGURE 5. STEREOGRAPHIC PLOTS

G.E.M. '73

## 5. SUMMARY AND CONCLUSIONS

The results of field mapping of the area under investigation are represented in Figure 6. It is apparent that the previously defined type section for the Fitton Formation is not particularly suitable, as it is crossed by at least one fault, and possibly more. The present author would favour the erection of section C-D as a new type section.

The sedimentary record is interpreted as representative of a marine onlap from north to south over the Mt. Painter Complex crystalline basement and pre-Sturtian sedimentary cover. This onlap is believed to have been fairly rapid and accomplished on a moderately steeply inclined northward dipping basin floor. Subsidence in a trough between Yudnamutana and Union Trig is believed to have been controlled by marginal faulting, and to have been episodic, at least early in the Fitton Formation sedimentation. The source area of sediment migrated southwards correlating with the onlap.

Ice-rafting, probably by shore or river-ice, becomes apparent in the middle of the Fitton Formation and persists until the onset of true glacial marine sedimentation in the Bolla Bollana Formation. A shallowing of the basin is indicated near the top of the Fitton Formation and may correlate with the sea-level fall associated with growth of glacial ice. Intertonguing of the two formations indicates glacial marine sedimentation began at different times in different areas. ~~that is to say, was somewhat diachronous.~~

A possible minor retreat phase of the glacial ice may be represented by the group of quartzites occurring low in the Bolla Bollana Formation. Reworking of immediately underlying sediments to the south-west of the map area is indicated by shale and siltstone fragments in the Bolla Bollana Formation.

Subsequent metamorphism and deformation of Sturtian sediments occurred, possibly in the Lower Palaeozoic. Associated contact metasomatism of an original carbonate-shale sequence in the south-west portion of the map area, is indicated by the presence of, and possible zonation in, massive to layered amphibolitic rocks. Metasomatism is also indicated by the tourmalinisation of a quartzite adjacent to these amphibolites.

A feature of the metamorphism is the presence of abundant scapolite porphyroblasts. It is concluded that these are stratigraphically controlled and represent the original compositional nature of the sediment. The introduction of some of the components of the scapolite, from connate solutions or metasomatic fluids is a possibility.

## 6. ACKNOWLEDGMENTS

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Graham E. Mortimer,
October, 1973.

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# APPENDIX I

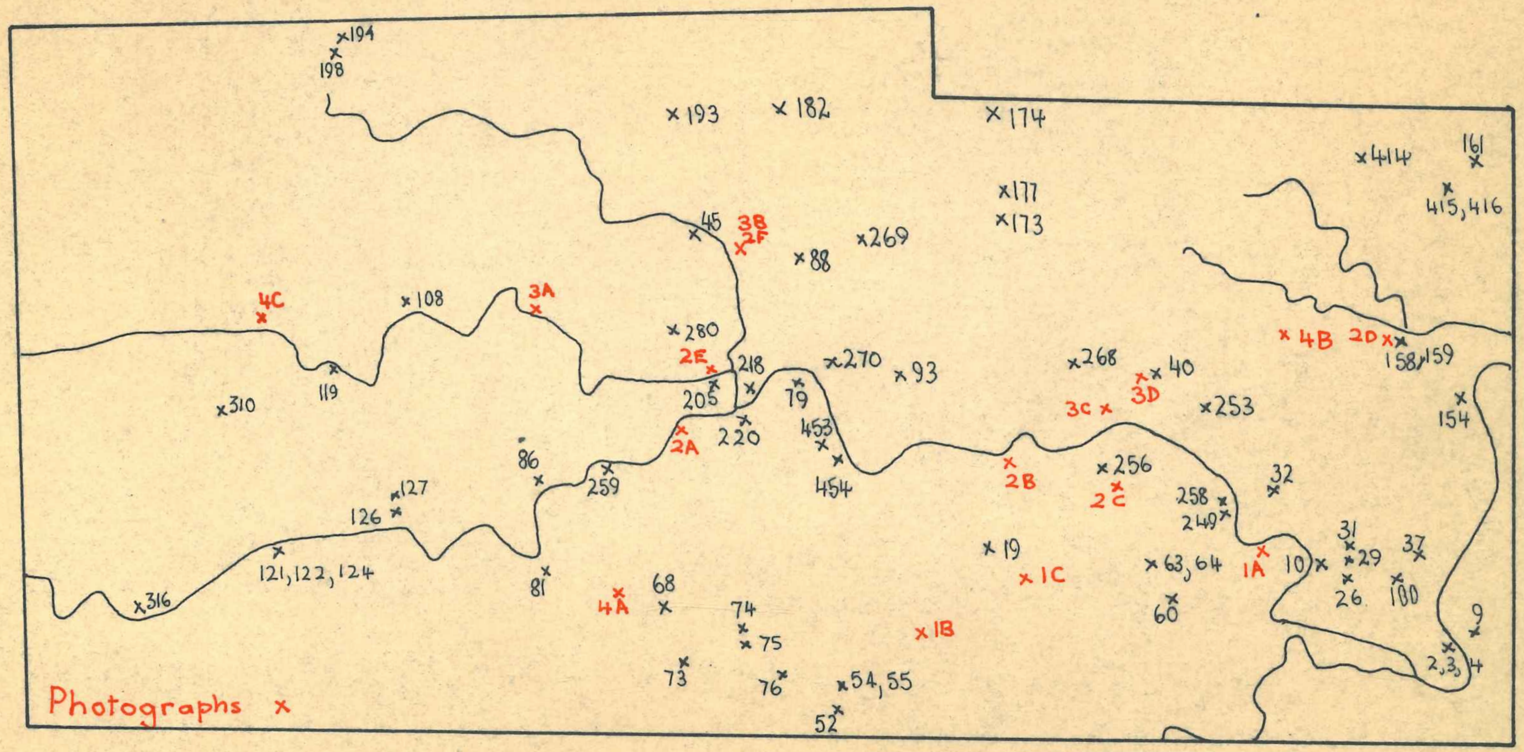
## Catalogue of Specimen Material Accompanying this Thesis

| | |
|---|---|
| T.S. | indicates thin section |
| H.S. | indicates hand specimen |
| *T.S. | indicates thin section plus hand specimen |
| F | indicates Fitton Formation |
| B | indicates Bolla Bollana Formation |
| M | indicates Mt. Painter Complex. |

| | | |
|---|---|---|
| * | T.S.410/2F | Granite clast |
| * | T.S.410/3F | Quartzite clast |
| * | T.S.410/4F | Black schist clast |
| * | T.S.410/9F | Granite clast |
| * | T.S.410/10F | Granite conglomerate |
| * | T.S.410/12F | Pebbly arkose |
| | T.S.410/26F | Granite conglomerate |
| * | T.S.410/29F | Pebbly arkose |
| | T.S.410/31F | Quartzite |
| | T.S.410/32F | Quartzite |
| | T.S.410/37F | Granular arkose |
| | T.S.410/40F | Scapolitic calcareous mudstone |
| | T.S.410/45F | Pebbly muddy siltstone |
| | T.S.410/46F | Scapolitic mudstone |
| * | T.S.410/52M | Freeling Heights Quartzite |
| * | T.S.410/54F | Magnetite-biotite schist clast |
| * | T.S.410/55F | Granite clast |
| | T.S.410/60F | Granite conglomerate |
| * | T.S.410/63F | Amphibolite |
| | T.S.410/64F | Scapolitic mudstone |
| * | T.S.410/68F | Amphibolitic pebbly arkose |

| | | |
|---|---|---|
| | T.S.410/73M | Haematite-muscovite schist. |
| * | T.S.410/74F | Pebbly arkose |
| * | T.S.410/75F | Amphibolite |
| | T.S.410/76F | Pebbly mudstone |
| * | T.S.410/78F | Granite clast |
| * | T.S.410/81F | Quartzite clast |
| * | T.S.410/86F | Amphibolite |
| | T.S.410/100F | Arkose |
| * | T.S.410/119F | Amphibolite |
| | T.S.410/124F | Granite conglomerate |
| * | T.S.410/126F | Laminated amphibolite |
| * | T.S.410/127F | Amphibolite |
| * | T.S.410/154F | Talc-tremolite marble clast |
| T. | T.S.410/158F | Pebbly siltstone |
| * | T.S.410/177F | Talc-tremolite marble clast |
| | T.S.410/198B | Pebbly mudstone |
| * | T.S.410/205F | Tremolite-dolomite marble clast |
| | T.S.410/218F | Tourmalinised quartzite |
| * | T.S.410/220F | Scapolitic amphibolite |
| * | T.S.410/230F | Granodiorite clast |
| * | T.S.410/239F | Amphibolite |
| | T.S.410/243F | Amphibolitic quartzite |
| | T.S.410/249F | Amphibolitic mudstone |
| * | T.S.410/253F | Talc-dolomite marble clast |
| | T.S.410/256F | Dolomite clast |
| * | T.S.410/258F | Amphibolite |
| * | T.S.410/268F | Tremolite-dolomite marble |
| * | T.S.410/270F | Granite clast |
| * | T.S.410/310F | Amphibolite |
| | T.S.410/316F | Diopside-biotite schist |
| * | T.S.410/414B | Talc-dolomite marble clast |
| * | T.S.410/453F | Granodiorite clast |
| * | T.S.410/454F | Amphibolitic schist. |

| | |
|---|---|
| H.S.410/19F | Micaceous quartzite clast |
| H.S.410/79F | Calc-silicate clast |
| H.S.410/88F | Conglomerate clast |
| H.S.410/93F | Quartzite clast |
| H.S.410/108F | Granodiorite clast |
| H.S.410/121F | Metaquartzarenite |
| H.S.410/122F | Granite clast |
| H.S.410/159F | Conglomerate clast |
| H.S.410/161B | Conglomerate clast |
| H.S.410/173F | Dolomite marble clast |
| H.S.410/174B | Conglomerate clast |
| H.S.410/182B | Tillite |
| H.S.410/193B | Pebbly sandy mudstone |
| H.S.410/194B | Quartzarenite |
| H.S.410/257F | Granite clast |
| H.S.410/269F | Granite clast |
| H.S.410/415B | Pebbly muddy sandstone |
| H.S.410/416B | Pebbly sandy mudstone. |




SAMPLE LOCATION MAP

# APPENDIX II

## Descriptions of Thin Sections

T.S.410/2 Macro: Medium to coarse grained massive pink granite consisting of alkali feldspar matrix with rounded quartz grains and small clot-like patches of biotite.

Micro: Coarse grained equigranular rock consisting of large microcline individuals, up to 50%, with lesser, smaller plagioclase grains, about 20%, and discrete rounded quartz crystals, up to 20%. Interstitial patches of biotite and sericite are common and comprise up to 10% of the rock. Alteration of the feldspars along cracks, producing sericite is common and the feldspars are generally cloudy due (?) to vacuolitisation. Strain shadows and sutured grain-grain boundaries are evident in the quartz. Accessory sphene, blue tourmaline and associated opaques and spinel are noticed.

Comments: Resembles texture of 411/342 ≡ White micro-granite, collected by Young, 1973.

T.S.410/3 Macro: Pink and green-black mottled medium grained massive meta-quartzarenite.

Micro: Medium to coarse grained granoblastic mosaic of quartz grains with common sutured grain-grain contacts. Minor interstitial patches of green biotite. Accessory sphene and opaques, and muscovite and chlorite associated with biotite.

T.S.410/4 Macro: Fine grained massive black schist.

Micro: Fine grained lepidoblastic aggregate of green subidioblastic biotite (75-80%) with lesser muscovite. Minor interstitial grains of quartz and/or feldspar, with scattered idioblastic opaques up to 10%. Quartz stringers fairly common on a small scale.

Comments: Possible basement schist.

T.S.410/9 Macro: Massive coarse grained pink granite, with large ovoidal alkali feldspar and smaller bluish ovoidal quartz. Interstitial patches of biotite.

Micro: Common large ovoidal perthitic, altered microcline individuals, and large ovoidal quartz grains exhibiting undulose extinction. Interstitial smaller quartz and feldspar grains commonly set in a fine grained matrix of biotite, sericite and associated opaques. Sericitisation of feldspars is common, especially in cracks, and cleavage. One small patch of quartz-potash feldspar myrmekitic intergrowth noticed.

Comments: Most probably Terrapinna Granite.

T.S.410/10 Macro: Green-grey schistose conglomerate containing blue quartz and feldspar pebbles and flattened schist fragments.

Micro: Abundant pebbles of a type petrographically very similar to T.S.410/9. i.e. microcline perthite, quartz, myrmekitic intergrowths etc. Pebbles generally subangular, some are rounded, orientations random. Matrix dominantly fine grained muscovite and biotite with a lepidoblastic texture, with patches and lenticles of silt and sand sized quartz and feldspar grains. Some reorientation of pebbles due to compaction and/or shearing appears to have occurred.

Comments: Basal conglomerate of very local provenance, at least in part.

T.S.410/12 Macro: Coarse pebbly pink and grey arkosic rock, containing rounded alkali feldspar and elongate black schist clasts in a quartzo-feldspathic, recrystallised (?) matrix.

Micro: Coarse grained granoblastic rock; a recrystallised coarse pebbly arkose. Dominant constituents are rounded to subangular microcline perthite and altered plagioclase feldspars along with strained quartz and elongate schistose clasts set in a finer grained granoblastic mosaic of quartz alkali feldspar and plagioclase, with many grains retaining approximate sedimentary shapes. Corrosion of grains fairly common. Feldspar grains showing myrmekitic texture are common, as is sericitisation, especially in plagioclase. Accessory spheme, tourmaline, biotite.

Comments: Granitic clasts very similar petrographically to T.S.410/9.

T.S.410/26 Macro: Grey schistose rock containing abundant granitic pebbles and blue quartz pebbles, arranged in a sub-random fashion.

Micro: Medium to fine grained lepidoblastic matrix of muscovite and biotite with contained silt to pebble sized clasts of quartz (often with strain shadows) and feldspars, dominantly perthitic or myrmekitic, with some poorly developed microcline twinning and often sericitised or vacuolised. A lesser proportion of altered plagioclase also present.

Comments: Basal conglomerate of very local provenance, at least in part.

T.S.410/29 Macro: Coarse white rock composed of dominant alkali feldspar with lesser quartz and dark schistose clasts.

Micro: Large, abundant pebbles of perthite, microcline and microcline perthite with lesser strained quartz and minor plagioclase. One large indistinct micaceous feldspathic clast present also. Matrix quartzo-feldspathic and with common patches of medium to coarse grained biotite and chlorite, especially associated with the clast cited above. Also associated with this clast is abundant small prismatic tourmaline and granular sphene.

Comments: Feldspathisation and tourmalinisation of black schist clast evident.

T.S.410/31 Macro: Pink and black speckled, medium to fine grained massive quartzite.

Micro: Granoblastic mosaic of dominantly quartz, medium to fine grained, with some sutured grain-grain boundaries and often strained. Minor microcline grains also present. Interstitial patches of biotite, chlorite, muscovite, and sphene are fairly common.

T.S.410/32 Macro: Massive grey medium grained quartzite.

Micro: Granoblastic mosaic of quartz, often strained, with minor altered plagioclase and alkali feldspar, with common sutured grain-grain boundaries. Common interstitial green biotite and minor blue granular tourmaline.

T.S.410/37 Macro: Massive grey-white granular conglomerate containing quartz and feldspar grains and sedimentary rock fragments.

Micro: Dominant clastic constituents are strained single and composite quartz pebbles, microcline, microcline perthite and plagioclase with some myrmekite and a few apparent siltstone clasts. Grain boundaries are commonly indistinct and corroded and feldspars altered to sericite and secondary calcite, especially along fractures. The matrix is quartzofeldspathic, calcitic, biotite rich with fairly large poikiloblastic scapolite porphyroblasts, possibly derived from alteration of feldspar. Minor zircon also present.

Comments: Granite components derived from local basement granites.

T.S.410/40 Macro: Poorly laminated grey black mudstone, showing contortion of laminae.

Micro: Granoblastic aggregate of quartz silt sized grains floating in a matrix of biotite, calcite and minor muscovite. Common poikiloblastic scapolite porphyroblasts visible, and minor euhedral opaques and granular sphene. Churned up bedding evident.

T.S.410/45 Macro: Massive black pebbly muddy siltstone.

Micro: Abundant sand to pebble size clasts, consisting of quartz, quartzite, silt, mudstone, and muddy siltstone, with larger clasts subrounded to rounded and finer clasts subangular to angular. Matrix presumably recrystallised silty mud and now contains quartz biotite, sericite and chlorite, all fine-grained.

T.S.410/46 Macro: Green-grey massive to poorly laminated rippled mudstone. Scattered indistinct scapolite (?) porphyroblasts.

Micro: Massive fine grained recrystallised mudstone consisting of quartz, biotite, sericite, chlorite with scattered prismatic scapolite porphyroblasts, which are extensively altered in places.

T.S.410/52 Macro: Light coloured green-grey crenulated quartzo-feldspathic schist.

Micro: Medium grained mosaic of quartz microcline and plagioclase feldspar grains with common foliated layers of fine grained muscovite. Fine grained opaques are commonly associated with the muscovite layers and lineated parallel to the schistosity. Crenulation of muscovite flakes between foliated layers is observable. Accessory biotite and zircon. Common quartz stringers on a small scale.

Comments: Basement Freeling Heights Quartzite.

T.S.410/54 Macro: Green-black medium grained biotite schist with scattered medium to coarse magnetite porphyroblasts.

Micro: Medium grained mosaic of quartz, biotite, minor muscovite with a lepidoblastic texture, and scattered idioblastic to sub-idioblastic magnetite porphyroblasts. Scattered accessory zircon, apatite and sphene.

Comments: Provenance uncertain; Brindana Schist?

T.S.410/55 Macro: Massive pink medium grained granite.

Micro: Weathered granite. Dominant constituents medium to coarse grained anhedral microcline and strained quartz, with lesser plagioclase. Feldspar, especially plagioclase, extensively weathered and sericitised, esp along cleavages and fractures. A few interstitial patches of brown biotite are present and associated accessory sphere. Accessory zircon also present.

Comments: Very similar to 410/1111 collected from Pepegoone Creek; hence probably local provenance.

T.S.410/60 Macro: A brownish pebbly schistose rock containing abundant granitic pebbles.

Micro: Large discrete grains of granite, quartz and feldspar set in a micaceous matrix, with common layers of silt and fine sand. Recrystallisation has produced corrosion of many of the larger clasts. Feldspars are commonly perthitic and extensively weathered and altered. Clasts are generally elongate parallel to the cleavage schistosity and many show cross-fracturing suggestive of tectonic elongation and alignment.

Comments: Local granitic provenance.

T.S.410/63 Macro: Medium grained granoblastic green and white amphibolite.

Micro: Dominant constituents are hornblende, plagioclase, microcline, quartz with minor biotite, sphene, and epidote. The hornblende occurs as bladed, prismatic porphyroblasts in a medium grained quartzo-feldspathic granoblastic matrix, with biotite flakes associated with hornblende. Granular sphene aggregates are scattered throughout the rock. Epidote appears to be an alteration product of hornblende, at least in part.

Comments: Probable metasedimentary amphibolite.

T.S.410/64 Macro: Mosaic to poorly laminated black slightly scapolitic muddy siltstone with occasional thin sandy laminae.

Micro: Massive of fine grained quartz, biotite and muscovite with scattered quartzitic sand grains approximately restricted to horizons. Cleavage evident at $60^{\circ}$ to bedding. Scattered small scapolite porphyroblasts and idioblastic opaques.

T.S.410/68 Macro: Coarsely crystalline feldspathic actinolitic conglomerate with recognisable clasts of feldspar, quartzite. One clast now coarse actinolite.

Micro: Recognisable detrital elements such as rounded microcline pebbles, composite quartz and quartzite pebbles (often strained), fine grained siltstone elongate pebble, set in a quartzo-feldspathic medium grained matrix with abundant prismatic actinolite. The matrix contains abundant plagioclase feldspar with minor microcline and quartz as the other major constituent. Associated with and occasionally intergrown with actinolite is coarsely crystalline epidote. Scattered minor granular sphene is also present.

Comments: Western facies of pebbly arkose, probably represents increased calcareous muddy matrix.

T.S.410/73 Macro: Brown stained muscovite schist with subidioblastic haematite porphyroblasts.

Micro: Lepidoblastic medium to coarse-grained rock consisting of subidioblastic muscovite flakes in a mosaic of quartz grains with abundant subidioblastic haematite porphyroblasts. Minor biotite associated with haematite.

T.S.410/74 Macro: Coarsely recrystallised pebbly quartzo-feldspathic rock, with interstitial prismatic amphibole.

Micro: Dominant constituent is pebble sized alkali feldspar such as microcline and microcline perthite, often sericitised and often with turbid appearance. Large quartz and quartzite pebbles are also common. Interstitial matrix is mosaic of quartz and feldspar with medium grained actinolite prisms, often radiating, commonly interspersed. Accessory granular sphene and epidote also present.

Comments: Eastern facies of pebbly arkose; minor amphibole only.

T.S.410/75 Macro: Medium to coarse grained massive amphibolite with minor patchy quartz and feldspar.

Micro: Framework of coarse grained poikiloblastic randomly oriented interlocking actinolite with inclusions of and interstitial quartz plagioclase and microcline. Scattered accessory granular sphene. Minor epidote intergrown with actinolite.

T.S.410/76 Macro: Massive green-black pebbly mudstone containing abundant granitic debris (e.g. quartz and feldspar pebbles).

Micro: Abundant pebble to granule sized, subangular to subrounded granitic clasts such as altered and vacuolised (?) perthite, microcline perthite, strained quartz and minor myrmekite. Matrix is fine grained and recrystallised and contains abundant quartz biotite and feldspar (?). Accessory sphene epidote and opaques.

Comments: Typical of general basal section in western portion of map area.

T.S.410/78 Macro: Grey-white medium-grained "granite".

Micro: Irregular framework of medium to coarse grained feldspars with interstitial quartz aggregates. The feldspars have been strongly altered to sericite and also calcite with some plagioclase twinning preserved. Quartz commonly shows slight undulose extinction. Minor interstitial patches of biotite and associated opaques. In the marginal portions of the slide large poikiloblastic scapolite porphyroblasts have replaced the feldspar matrix. Scattered idioblastic opaques. Accessory green tourmaline and sphene.

Comments: Granodiorite (?), provenance possibly local basement granodiorites.

T.S.410/81 Macro: Grey-red medium grained massive metaquartzite.

Micro: Dominant constituent medium to coarse grained quartz in a mosaic granoblastic texture with common sutured grain-grain boundaries. Occasional small quartzitic pebbles. Quartz grains often show strain extinction. Interstitial patches of subidioblastic muscovite and lesser biotite relatively abundant. Accessory granular sphene and idioblastic zircon also present, A poorly defined foliation is present due to the mica flakes.

Comments: Possible Freeling Heights Quartzite.

T.S.410/86F Macro: Light green massive coarse grained calcitic amphibolite.

Micro: Dominantly prismatic to fibrous, radiating aggregates of actinolite, associated with calcite, scapolite, minor sphene, quartz, epidote, microcline. The scapolite and actinolite are generally intimately intergrown.

Comments: Metamorphosed impure limestone.

T.S.410/100F Macro: Coarse green-grey massive conglomeratic arkose, containing bluish ovoidal quartz pebbles and feldspar pebbles in a minor chloritic matrix.

Micro: Coarse grained recrystallised mosaic of quartz and feldspar with intergrown grain-grain boundaries. The large quartz grains show marked undulose extinction and quartz often occurs as myrmekitic intergrowths within alkali feldspar grains. The large alkali feldspars are commonly vacuolised (?), perthitic, and altered to calcite especially in the marginal areas of the thin section. Common plagioclase and microcline finer-grained authigenic individuals are observed. Minor interstitial patches of biotite and muscovite, frequently altering to chlorite are observed. Granular sphene associated with the chlorite.

Comments: Clastic elements derived from underlying granite terrain.

T.S.410/119F Macro: Green-black and white massive medium grained pyritic amphibolite.

Micro: Poikiloblastic prismatic actinolite in a matrix of coarsely crystalline poikiloblastic scapolite. In part of the thin section common small flakes of biotite are associated with the actinolite. Scattered granular sphene and opaques are observed. Minor plagioclase and quartz also present. Scapolite alteration along cracks to calcite is noticed.

Comments: Unusually high proportion of scapolite.

T.S.410/124F Macro: Green-grey pebbly to bouldery quartzitic silt, containing abundant granitic debris.

Micro: Poorly sorted conglomeratic silt. Abundant quartz, quartzite and feldspar subangular pebbles. The quartz often shows strain extinction and the feldspars generally are microcline and are altered. The matrix is a quartz, microcline and plagioclase mosaic containing common patches of biotite, chlorite, and occasional opaques. Lesser muscovite occasionally associated with the biotite. Minor epidote scattered through the rock. Accessory tourmaline and apatite.

Comments: Western-most facies of Granite Conglomerate.

T.S.410/126F Macro: Laminated fine-grained green and white amphibolite.

Micro: Medium grained poikiloblastic hornblende in a granoblastic mosaic of quartz, microcline and plagioclase. Patchy alteration of feldspars by weathering. Minor sphene, opaques and biotite are scattered throughout rock. Accessory epidote muscovite and tourmaline are present.

Comments: Original sedimentary bedding preserved.

T.S.410/127F Macro: Massive green and white medium to coarse grained amphibolite.

Micro: Coarse grained poikiloblastic hornblende set in a medium grained granoblastic ground-mass of quartz (detrital shapes) microcline and plagioclase. Minor scattered biotite and sphene and accessory epidote, zircon and apatite are present.

T.S.410/154F Macro: Buff coloured dolomitic marble with many large decussate talc flakes.

Micro: Granoblastic medium to fine grained dolomite matrix with scattered porphyroblasts of talc and minor tremolite. Talc flakes and tremolite prisms often are associated in growth.

Comments: Clast in upper part of Fitton Formation.

T.S.410/158F Macro: Grey-black massive to laminated muddy siltstone with thin pebble bands.

Micro: Recrystallised muddy matrix producing fine grained biotite-sericite-chlorite. Common sub-angular quartz sand grains "floating" in this matrix. One horizon contains a few sand grain aggregates possibly deposited as compacted or frozen pellets.

T.S.410/177F Macro: Yellow-brown fine-grained dolomitic marble, with scattered acicular tremolite and flakes of talc.

Micro: Fine grained dolomite mosaic matrix with patches of coarser grain size. Common acicular prismatic porphyroblasts of tremolite and lepidoblastic talc. The talc often forms "armour" around tremolite porphyroblasts, indicating probably, that tremolite acted as a nucleus for the crystallisation of some of the talc.

T.S.410/198B Macro: Dark grey thinly bedded silt and pebbly mudstone alternations.

Micro: Angular to rounded quartz sand grains (often strained extinction) "floating" in a recrystallised muddy silt matrix. Common larger flakes of biotite and chlorite are present, along with a few scapolite porphyroblasts. Common small quartzite and other sedimentary rock fragment pebbles are scattered through the rock. One elongate clast has a vertical symmetry and appears to be a dropstone.

Comments: Bolla Bollána Formation; dominant clast lithologies are sedimentary rock fragments.

T.S.410/205 Macro: Saccharoidal light green-white massive medium grained tremolite-dolomite marble.

Micro: Medium to coarse grained granoblastic mosaic of dolomite with frequent very light green poikiloblastic porphyroblasts of tremolite. Minor scattered green biotite flakes and accessory granular sphene.

Comments: Very similar to Wywyana Formation samples collected by B.A. Eberhard.

T.S.410/218F Macro: Massive medium grained meta-quartzarenite, with common scattered tourmaline.

Micro: Medium to coarse grained granoblastic mosaic of quartz, minor suturing and common interlocking of grains. Scattered idioblastic and subidioblastic prismatic tourmaline.

Comments: Metasomatic (?) tourmaline.

T.S.410/220F Macro: Green-black, "spotted" white, medium grained massive scapolitic, calcitic amphibolite.

Micro: Abundant medium to coarse grained prismatic poikiloblastic to massive bladed green actinolite, in patches forming a framework and in other places occurring as interstitial aggregates. The other dominant constituent is scapolite, occurring as clear poikiloblastic prisms, often enveloping the actinolite. Common interstitial lenticular patches of medium grained calcite are present, and often abundant green biotite flakes are associated with these patches. Also minor small quartz grains occur with the calcite and biotite. Biotite is also present as small inclusions in scapolite. Accessory granular sphene scattered through rock.

Comments: Metamorphosed impure limestone

T.S.410/230F Macro: Grey-white coarse grained granodiorite.

Micro: Coarse grained granoblastic granitic rock, common interlocking of grains. Dominant constituents are quartz and altered feldspar. Quartz occurs as large solitary or composite grains usually exhibiting undulose extinction. The development of sub-grains within grains is probably a meta-morphic feature. The feldspars form an approximate framework and have been extensively sericitised and altered to calcite, especially the latter effect near the margins of the thin section. Multiple twinning is poorly preserved and indicates a dominance of plagioclase feldspar. Lesser perthitic alkali feldspar also present.

Interstitial patches of altered biotite, and chlorite are present associated with calcite and opaques. Opaques are also scattered throughout the rock. Occasional coarse muscovite flake.

T.S.410/239F Macro: Green-black and white massive coarse, pyritic amphibolite.

Micro: Abundant green pleochroic hornblende porphyroblasts in a matrix of quartz, microcline and albitic plagio-clase. Common poikiloblastic scapolite porphyroblasts also present. Minor granular sphene and weathered opaques (producing red-stained patches.) Common patches of biotite are associated with the hornblende.

T.S.410/243F Macro: Medium to fine grained yellowish amphibolite, cross-cut by thin epidote veins.

Micro: Medium to fine grained granoblastic mosaic of quartz, microcline and plagioclase with abundant scattered prismatic porphyroblasts of hornblende. Abundant scattered fine granules of sphene. Cross-cutting veins up to 4 mm wide are common.

T.S.410/249F Macro: Massive grey-black muddy silt with layers a few centimetres thick of coarser amphibolite.

Micro: Muddy silt has been recrystallised to fine grained biotite, quartz matrix with scattered radially arranged hornblende porphyroblasts and rare scapolite porphyroblasts. The coarser amphibolite contains abundant radial aggregates of hornblende porphyroblasts set in a poikiloblastic scapolite, biotite, quartz, feldspar matrix. Accessory tourmaline, opaques and sphene.

Comments: Indicates likely metasedimentary origin of amphibolites.

T.S.410/253F Macro: Yellowish massive fine-grained talc bearing dolomitic marble.

Micro: Granoblastic medium grained mosaic of dolomite, with rare coarse grained twinned individuals. Rare xenoblastic quartz grain. Scattered patches iron oxides and scattered minor talc flakes.

Comments: Possible Skillogallee Dolomite clast, metamorphosed after sedimentation.

T.S.410/256F Macro: Yellowish fine grained massive dolomite pebble in black scapolitic mudstone.

Micro: Fine grained granoblastic mosaic of dolomite with veins of biotite, quartz and scapolite extending in from the matrix. Matrix is fine to medium grained biotite with floating rounded to sub-angular, often corroded, quartz sand grains. Common scattered xenoblastic poikiloblastic porphyroblastic scapolites. Accessory sphene, rutile.

Comments: Dolomite clast - Skillogallee Dolomite?

T.S.410/258F Macro: Dark green and white, massive medium grained amphibolite.

Micro: Common randomly oriented subidioblastic hornblende prisms set in amedium grained granoblastic quartz, microcline, plagioclase matrix. Common epidote especially associated with hornblende. Accessory granular sphene and idioblastic opaques.

T.S.410/268F Macro: Yellowish coarsely tremolitic medium grained dolomitic marble.

Micro: Medium to coarse grained granoblastic mosaic of dolomite with frequent randomly oriented prismatic tremolite porphyroblasts. Extensive weathering of tremolite indicated by dolomite permeating through cracks etc. Rare flakes of talc.

Comments: Thin laterally inextensive interbed in sub-unit (d).

T.S.410/270F Macro: Weathered grey-white coarse grained granite.

Micro: Coarse grained quartzmegacrysts showing undulose extinction and irregular sutured boundaries. Composite quartz grains often. Matrix is extensively altered feldspar and mica. Biotite and to a lesser extent muscovite are altered to chlorite and feldspar is altered to calcite and scapolite.

T.S.410/310F Macro: Green and white massive, medium to coarse grained amphibolite.

Micro: Medium grained poikiloblastic "framework" of hornblende with associated felsic minerals. Finer grained quartz, microcline, plagioclase granoblastic mosaic with a few quartz grains showing undulose extinction and round "sedimentary" shapes. Poikiloblastic scapolite porphyroblasts are present as is minor interstitial calcite. Accessory granular sphene and apatite also present.

Comments: Metasedimentary amphibolite probably.

T.S.410/316F Macro: Green-black massive diopside-biotite schist.

Micro: Medium to coarse grained aggregate of lepidoblastic biotite flakes and prismatic diopside.

T.S.410/414F Macro: Yellow-weathering, grey talcose dolomite marble.

Micro: Unweathered portion is granoblastic fine-grained mosaic of dolomite with scattered medium to coarse grained sub-idioblastic flakes of talc. In the weathered rock patches of subidioblastic opaques are evident and often impregnate talc flakes. General iron staining is observed.

Comments: Very similar to Skillogalee Dolomite samples of B.A. Eberhard.

T.S.410/453F Macro: Medium to coarse grained massive grey granodiorite.

Micro: Essentially a medium to coarse grained granoblastic rock; very common interlocking of grain-grain interfaces. Dominant constituents quartz, alkali feldspar and plagioclase. Quartz has undulose extinction and sericitisation of the plagioclase especially is observed. Minor biotite, muscovite and chlorite flakes are present along with accessory calcite (as an alteration product of plagioclase), sphene, apatite and myrmekite.

Comments: Provenance in southern Mt. Painter Block?

T.S.410/454F Macro: Green-black and white poorly banded amphibolitic schist.

Micro: Dominant constituent poikiloblastic, xenoblastic coarse grained scapolite with lesser porphyroblasts of actinolite. Matrix is dominantly fine-grained biotite with very minor quartz and calcite. Coarse grained calcite associated with scapolite as well. Cluster of accessory granular sphene scattered through rock.

Comments: Metasedimentary amphibolite (?)

# APPENDIX III

## Additional Brief Hand Specimen Descriptions

**H.S.410/19F** Pinkish to greenish grey massive very fine sand sized metaquartzite with abundant minute flakes of sericite defining an apparent crenulation.

Comments: Collected from sub-unit (a); probably basement quartzite clast.

**H.S.410/79F** Massive dark green-black hornfels, consisting of radiating actinolite aggregates intergrown with fine grained biotite and medium grained scapolite.

Comments: Provenance unknown.

**H.S.410/88F** Metamorphosed muddy sandy pebble conglomerate. Dominantly rounded to sub-angular quartzitic pebbles.

Comments: Provenance unknown.

**H.S.410/93F** Massive white medium grained metaquartzarenite cobble.

Comments: Provenance unknown.

**H.S.410/108F** Massive grey coarse-grained muscovite-bearing granodiorite (?)

Comments: Provenance most probably Older Granite Suite.

**H.S.410/121F** Laminated grey micaceous fine sand sized quartz-arenite to meta-siltstone.

Comments: Provenance unknown.

**H.S.410/122F** Massive pinkish coarse grained granite containing dominant large ovoidal alkali-feldspar megacrysts, lesser smaller rounded quartz megacrysts (often bluish), interstitial patches of fine grained biotite, set in a subordinate quartzo-feldspathic matrix.

Comments: Provenance almost certainly Older Granite Suite, probably Mt. Neill Granite Porphyry.

H.S.410/159F Massive brown sandy pebble conglomerate, consisting of dominant quartz pebbles with a few smaller feldspar granules.

Comments: Provenance probably in Blue Mine Conglomerate.

H.S.410/161F Massive green-grey sandy small cobble conglomerate. The sand fraction is medium to coarse fairly well-rounded quartz sand while the cobbles are generally quartzitic, fairly well-rounded and range down to pebble-size.

Comments: Provenance unknown; maybe exotic.

H.S.410/173F Massive grey medium to fine grained dolomitic marble with abundant scattered medium to coarse grained talc flakes.

Comments: Provenance probably in Skillogalee Dolomite.

H.S.410/174F Massive brown sandy muddy pebble conglomerate, consisting of rounded quartz and lesser feldspar detrital elements in a muddy matrix.

Comments: Provenance probably in Blue Mine Conglomerate.

H.S.410/182B Massive well-indurated blue-green-black slightly pebbly medium sandy siltstone. Sand and pebbles are generally subrounded to sub-angular, quartzose and occasionally dolomitic.

Comments: Supposed tillite.

H.S.410/193B Massive indurated blue-black slightly pebbly medium sandy mudstone. Pebbles are dominantly shales and silts and subangular to subrounded.

Comments: Apparent intraformational reworking is indicated.

H.S.410/194B Banded black slightly silty fine sandstone; quartz-arenite. Sand grains are sub-angular to well-rounded and fairly well sorted.

H.S.410/257F

Leucocratic coarse grained massive granite. Intergrown alkali feldspar and clear quartz with minor small patches of biotite.

Comments: Very similar to elements of Older Granite Suite e.g. Mt. Neill Granite Porphyry.

H.S.410/269F

Coarse grained massive grey granite. Megacrystic round quartz grains set in a mass of coarse grained perthitic alkali feldspar. Small interstitial patches of mica.

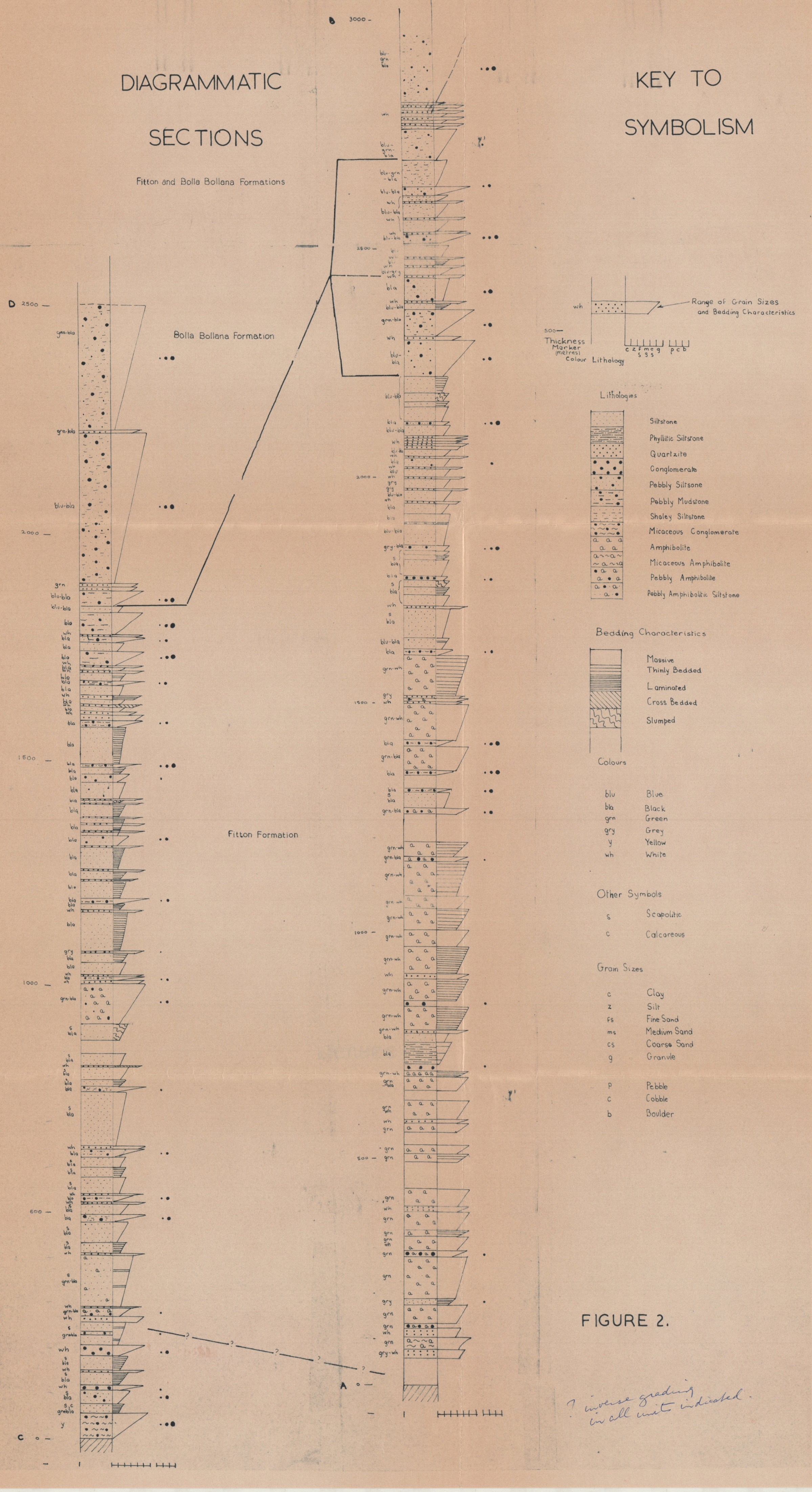
Comments: Very similar to Older Granite Suite e.g. Wattleowie Granite.

H.S.410/415B

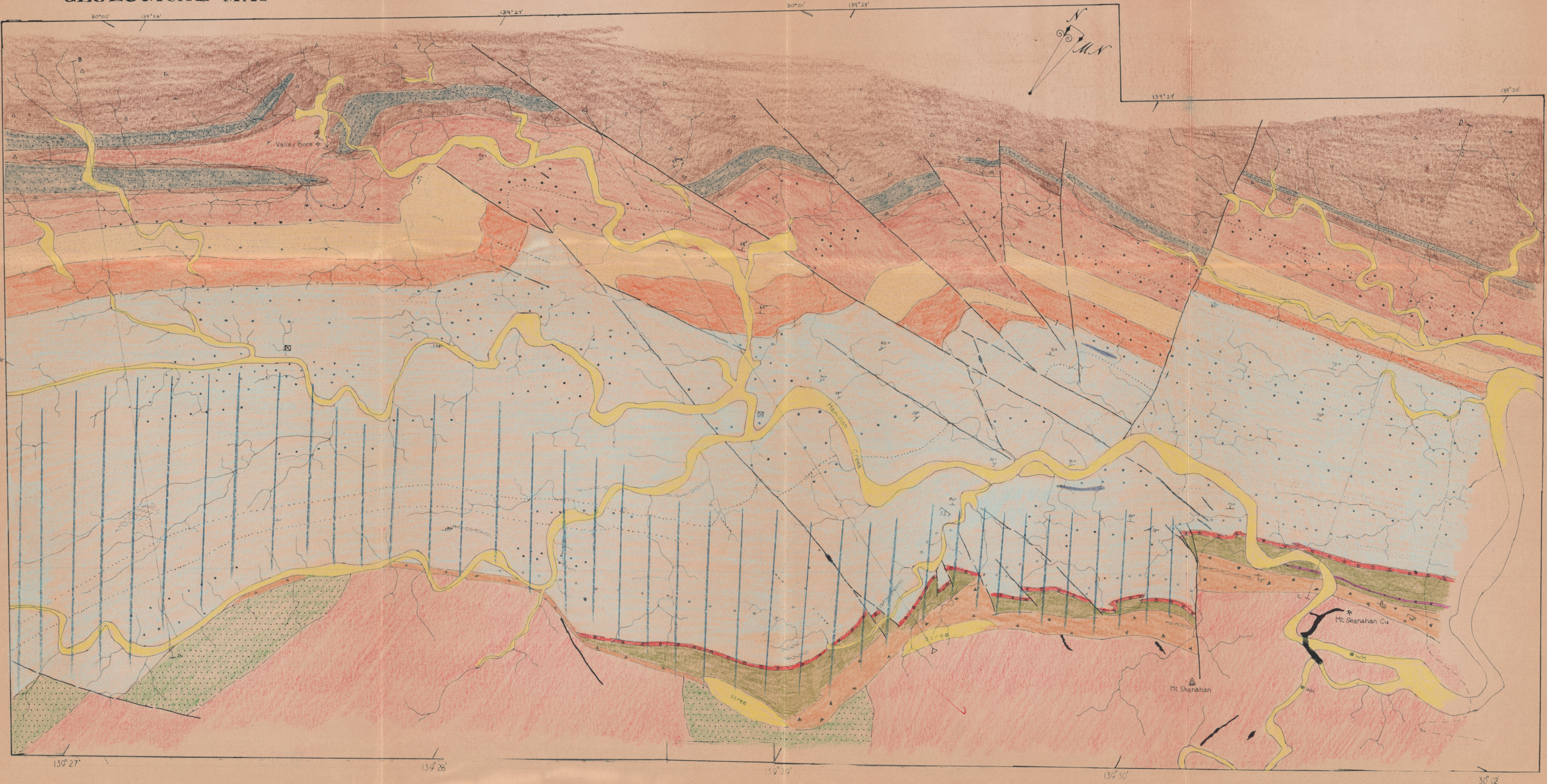
Massive well-indurated green-black pebbly muddy medium sandstone; sub-sedarenite. Pebbly fraction generally small sedimentary rock fragments angular to subrounded. Sand grains commonly well-rounded.

H.S.410/416B

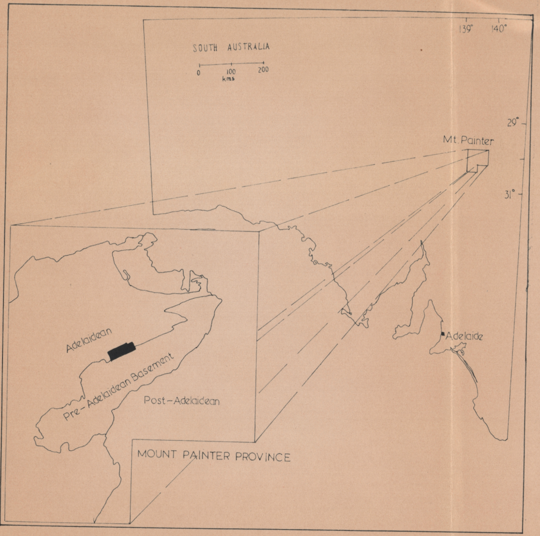
Massive indurated blue black, slightly bouldery medium sandy mudstone. Megaclastic elements generally angular to subrounded sedimentary rock fragments.


DIAGRAMMATIC SECTIONS
Fitton and Bolla Bollana Formations
Bolla Bollana Formation
Fitton Formation
KEY TO SYMBOLISM
Range of Grain Sizes and Bedding Characteristics
Thickness Marker (metres)
Colour
Lithology
Lithologies
Siltstone
Phyllitic Siltstone
Quartzite
Conglomerate
Pebbly Siltsone
Pebbly Mudstone
Shaley Siltstone
Micaceous Conglomerate
Amphibolite
Micaceous Amphibolite
Pebbly Amphibolite
Pebbly Amphibolitic Siltstone
Bedding Characteristics
Massive
Thinly Bedded
Laminated
Cross Bedded
Slumped
Colours
blu Blue
bla Black
grn Green
gry Grey
y Yellow
wh White
Other Symbols
s Scapolitic
c Calcareous
Grain Sizes
c Clay
z Silt
fs Fine Sand
ms Medium Sand
cs Coarse Sand
g Granule
p Pebble
c Cobble
b Boulder
? inverse grading in all units indicated.
FIGURE 2.

# GEOLOGICAL MAP: MT. SHANAHAN AREA




## LOCALITY MAP




## LEGEND