STRATIGRAPHY AND STRUCTURE IN AND ADJACENT TO THE TALISKER FORMATION (NAIRNE PYRITE EQUIVALENT) IN THE EASTERN MOUNT LOFTY RANGES.

by

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DEDICATION

To my parents,

whose often unseen help
is much appreciated.

CONTENTS

ABSTRACT

In order to understand the relationships between the top of the Backstairs Passage Formation (dominantly laminated arkoses), the Talisker Formation (Nairne Pyrite equivalent) and the basal portion of the Tapanappa Formation (interbedded psammites and pelites) the stratigraphy was compared on both sides of the Kanmantoo Synclinorium. An upper member of the Backstairs Passage Formation occurs in both areas studied, and in the eastern area (the Rockford Heights area) a very rapid facies change was interpreted to have occurred beneath the Rockford Heights Syncline. It was found that faulting alone could not account for the change in lithologies.

Although there was an association between all of the lithologies present a facies model relating these to a deepening basin (e.g. Mancktelow, 1979a) was insufficient. Evidence suggests a combination of sources to account for the abundance of plagioclase in the Upper Member of the Backstairs Passage Formation, the Talisker Formation and the Tapanappa Formation.

In the Rockford Heights area, evidence for 5 deformations was observed. The first deformation D_1 involved major upright folding and formation of a slaty cleavage. Metamorphism began during the first deformation and reached a peak during the second. There are no macroscopic effects of the D_2 crenulation deformation. The subsequent deformations were not pervasive throughout the area.

INTRODUCTION

1.1 Location of Study Areas

The general area of interest is shown in Figure 1. Two areas were investigated in detail:

(1) A traverse was made along the South Eastern Freeway 5km south of Dawsley.

(2) The geology of the Rockford Heights area was mapped at 1:8,000 scale. The size of the area is 3km by 4km. This area is 6km southeast of Harrowgate and is about 50km east of Adelaide.

1.2 Regional Geology and Previous Investigations

A regional synthesis of the Southern Adelaide Fold Belt has been completed by Mancktelow (1979a). Based on an understanding of the structure he has re-interpreted the stratigraphy of the Kanmantoo metasediments using the nomenclature of Daily and Milnes (1972) for the type section along the south coast of Fleurieu Peninsula.

The metasediments mapped as Talisker Formation by Mancktelow (1979) and their relationships to the adjacent stratigraphy within the Kanmantoo Group are of interest in this study. In the area of interest (i.e. Figure 1) two facies were described by Mancktelow, which he called the "Nairne Pyrite facies" and the "Aluminous siltstone facies". Mancktelow described two other facies of this Formation which occur elsewhere in the Kanmantoo Trough.

All previous workers agree that the Kanmantoo Group has been deposited in a rapidly subsiding basin. The generally massive poorly sorted sediments (Drexel, 1978), the lack of carbonates and of bioturbation (Daily et al., 1976) are taken as evidence that there was a continuous supply of sediments.

The areas mapped have been metamorphosed to fibrolite grade (using the terminology of Mancktelow, 1979a).

The sequence has been subjected to major upright folding and metamorphism during the Delamerian Orogeny.

1.3 Aims of Study

The overall aim of this study was to make a more detailed investigation of the Talisker Formation using the work of Mancktelow (1979a) as a basis for interpreting the sedimentology and structure. He correlated the stratigraphy on the eastern limb of the Kanmantoo Syncline in terms of the Talisker Formation. Part of the aim of this study was to find out the nature of the thickness changes within the Talisker Formation that he represented on his map on the eastern side of the Kanmantoo Syncline. To investigate the area in detail a number of specific aims were defined:

(1) To locate stratigraphic boundaries and to define the rock types within and adjacent to the Talisker Formation and its interpreted equivalents on the eastern side of the Kanmantoo Syncline.

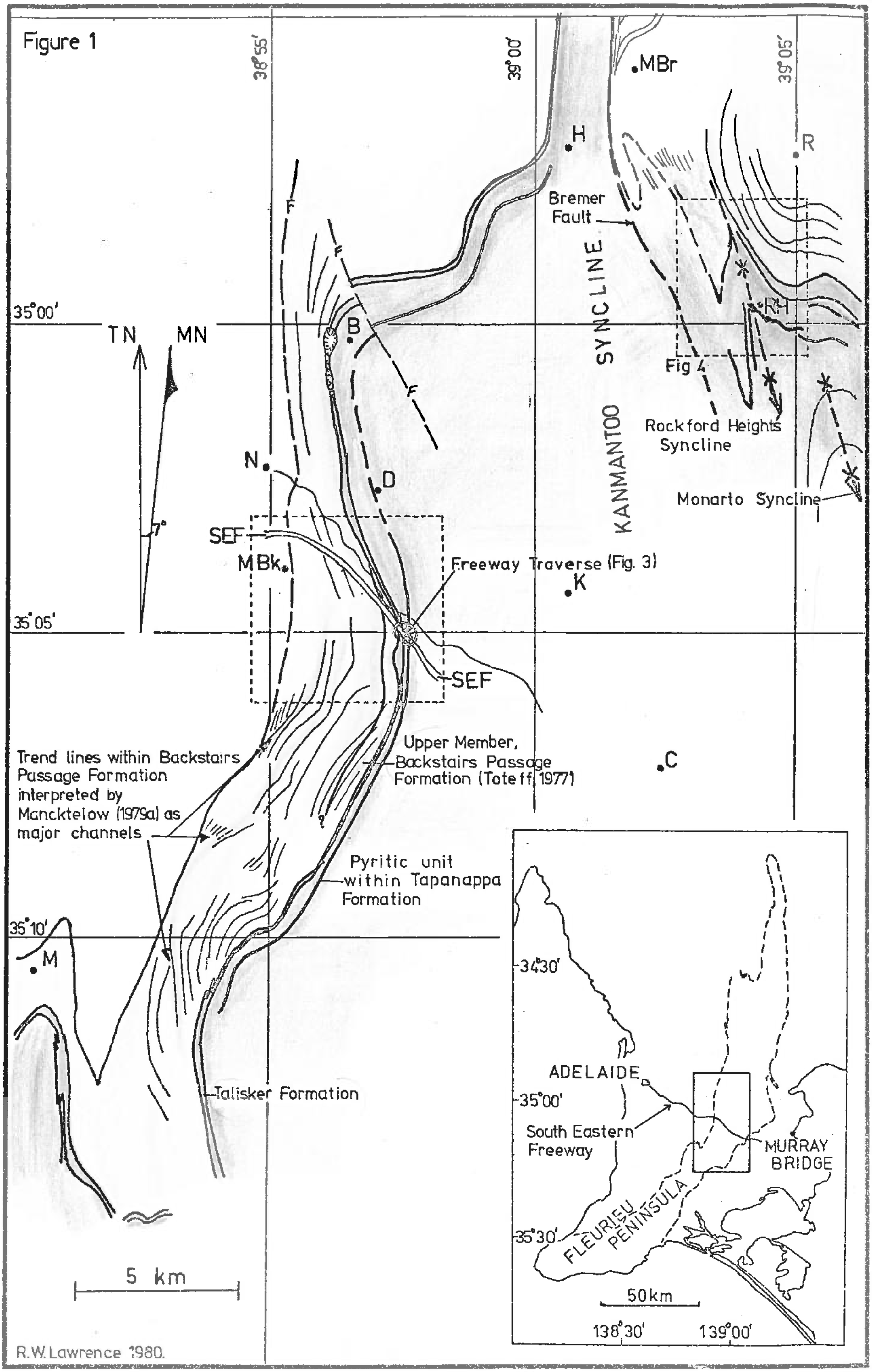
Figure 1

Summary of the regional geology based on Toteff (1977), Mancktelow (1979a) and this study. The two study areas are outlined.

Localities:

B	Brukunga
C	Callington
D	Dawsley
H	Harrowgate
K	Kanmantoo
M	Macclesfield
MBk	Mount Barker summit
MBr	Mount Bremer
SEF	South Eastern Freeway

Figure 1



38°55'
39°00'
39°05'
MBr
H
R
Bremer Fault
SYNCLINE
KANMANTOO
F
RH
Fig 4
Rockford Heights Syncline
Monarto Syncline
35°00'
TN
MN
B
7°
N
D
SEF
MBk
Freeway Traverse (Fig. 3)
K
35°05'
SEF
C
Upper Member, Backstairs Passage Formation (Toteff 1977)
Trend lines within Backstairs Passage Formation interpreted by Mancktelow (1979a) as major channels
Pyritic unit within Tapanappa Formation
35°10'
M
Talisker Formation
5 km
34°30'
ADELAIDE
35°00'
South Eastern Freeway
MURRAY BRIDGE
FLEURIEU PENINSULA
35°30'
50km
138°30'
139°00'
R.W. Lawrence 1980.

(2) To investigate thickness changes within the Talisker Formation.

(3) To look for evidence or otherwise of possible diachronism within the Kanmantoo Group.

(4) To re-examine the structural history in the light of previous interpretations of timing of major folding, fabric formation and metamorphism as represented by mineral growth and porphyroblast relationships.

1.4 Methods of Investigation

In order to test the interpretations made as a result of previous mapping on a regional scale (e.g. the interpretation shown in Figure 2 versus the interpretation of Mancktelow, 1979a), two areas were studied in detail. Firstly the western limb of the Kanmantoo Syncline was studied in detail for comparison with the stratigraphy in the second area to the east of the Kanmantoo Syncline (see Figure 1). Previous investigations as well as more detailed observations within the road cuts along the South Eastern Freeway were used to gain a more complete picture of the nature of the stratigraphy.

Secondly an area of $12km^2$ enclosing Rockford Heights property was mapped using aerial photographs at 1:8,000 scale. In general the outcrop quality was poor with better exposure occurring in some of the creeks. Only a few areas of outcrop were large enough to put on the map. Most outcrops were represented by a measurement, such as the orientation of bedding (see Figure 6), but many of these were uncertain as it was often difficult to determine if the rocks were in place. The trend of bedding was usually obvious for the more psammitic lithologies and these were either traced on the ground or interpreted from aerial photographs.

The microstructures within the different lithologies were investigated in order to determine the effects of deformation and metamorphism on the fabrics present. The orientation of (001) cleavage in muscovite was measured in two samples using a universal stage to clarify the deformation history.

2. STRATIGRAPHY

2.1 Introduction

Table 1a summarizes the nomenclature for the stratigraphy of the Kanmantoo Group which will be used in this discussion. For descriptions of these units see Section 2.2.

There are two basic interpretations for the locations of stratigraphic boundaries to the east of the Bremer Fault. Earlier mapping (see Figure 2, after Daily et al., 1976) placed the arkoses of the Backstairs Passage Formation (which until recently was referred to as the Inman Hill Formation) much further north than the Rockford Heights area. The interpretation of

TABLE 1

(a)

Top not exposed

KANMANTOO GROUP	Wattaberri Subgroup	Middleton Sandstone
		Petrel Cove Formation
	Brown Hill Subgroup	Balquhidder Formation
		Tunkalilla Formation
	Inman Hill Subgroup	Tapanappa Formation
		Talisker Formation
		Backstairs Passage Formation
	Carrickalinga Head Formation	
NORMANVILLE GROUP MARINO GROUP		

(b)

Top not exposed

Boxing Bay Formation
Emu Bay Shale
White Point Conglomerate
Smith Bay Shale
Stokes Bay Sandstone
Carrickalinga Head Formation

Base not exposed

Table 1

(a) Stratigraphic scheme for the Cambrian in the Adelaide region (after Daily et al., 1976).

(b) Cambrian formations developed on the northeast coast of Kangaroo Island (after Daily, 1976).

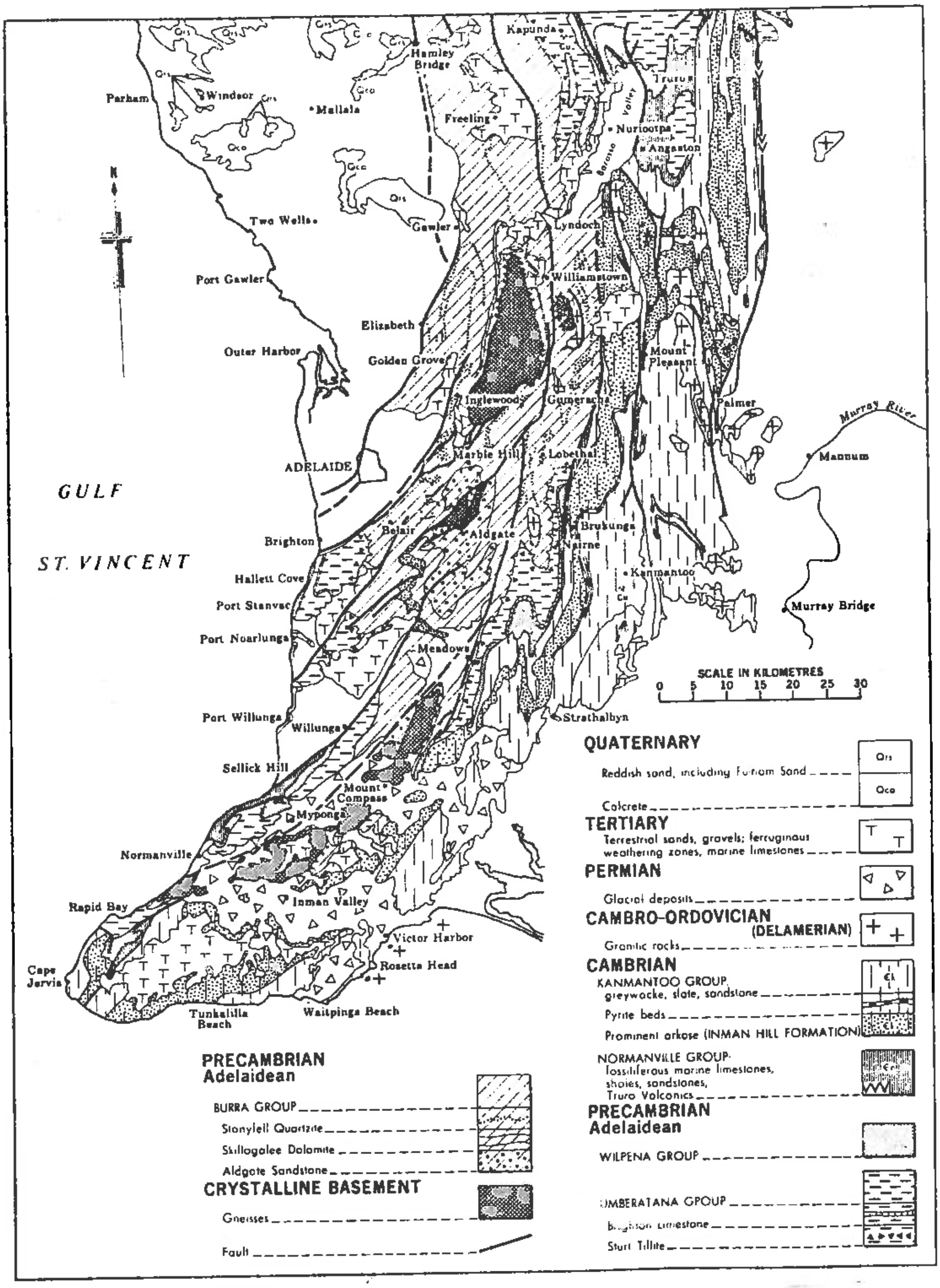


Figure 2

Generalized map of the geology of the Adelaide Region based on the Geological Atlas of South Australia 1:250,000 series, sheets SI 54-9, ADELAIDE and SI 54-13, BARKER, and contributions from The University of Adelaide (Daily et al., 1976). Note the position of the upper boundary of the prominant arkose unit (then called the "Inman Hill Formation"). In this study such lithologies have been mapped as "Backstairs Passage Formation". (Compare with Figures 1 and 4.)

Mancktelow (1979a) is shown in Figure 1, (Kanmantoo Mines geologists' interpretation is similar, Staltari: 1974). This is consistent with the overall trend of bedding in the Rockford Heights area. If the earlier interpretations were correct this trend should be southwest-northeast on both sides of the Bremer Fault and should not be southeast-northwest on the eastern side (Figure 1). To explain the stratigraphy the way the earlier workers did would require very large movements on the Bremer Fault.

To determine whether or not the formations within the Kanmantoo Group were diachronous, as suggested by Mancktelow (1979a), two areas were investigated in detail:

(1) The stratigraphy in a well exposed section of the South East Freeway was documented in detail. This section is representative of the Talisker Formation and the adjacent stratigraphy for the western limb of the Kanmantoo Syncline. The main purpose of this part of the investigation was to study a complete section of stratigraphy for comparison with the stratigraphy in the Rockford Heights Area to the east.

(2) The Rockford Heights area includes a tight syncline, here named the Rockford Heights syncline, which is a parasitic fold of the major fold named the Monarto Syncline by Mancktelow (1979a). There are no sections of complete exposure as along the Freeway. However, it was possible to compare the lithologies on both limbs of the Rockford Heights syncline and they were found to be significantly different.

2.2 Previous descriptions of the Kanmantoo Group

The stratigraphy of the Kanmantoo Group has been described for the type section along the south coast of Fleurieu Peninsula by Daily and Milnes (1971, 1972, 1973). Table 1a summarizes their nomenclature.

Mancktelow (1979a) has interpreted the environment of deposition of the Kanmantoo Group to have been a submarine fan. In order to investigate this interpretation the sediments within the whole of the Kanmantoo Group must be considered. In this section the sequence will be summarized briefly. Much of the following description has been obtained from Mancktelow (1979a).

In the type section the Carrickalinga Head Formation is dominantly a massive medium grained, grey to dark grey impure feldspathic sandstone (Mancktelow 1979a). Mancktelow describes how this formation grades into the Backstairs Passage Formation following a cessation of coarse, poorly sorted sands.

The Backstairs Passage Formation is characterized by light coloured laminated arkoses, which are interbedded with laminated siltstones (Mancktelow, 1979a). In the Nairne-Mt. Barker Creek area the laminated arkoses commonly display cross bedding with unimodal current directions, current induced slumps and liquifaction structures (Toteff, 1977). Mancktelow (1979) has interpreted aerial photographic trend lines as indicating large scale channel structures between Strathalbyn and Brukunga (see Figure 1). Channelling occurs down to a small scale at the base of some arkose units. Medium grained impure sandstones become more common toward the top of the Formation in several sections. In some sections there is 100m or so with a major portion of grey unlaminated biotite rich psammites (George, 1963; Toteff, 1977).

The Talisker Formation changes lithology along strike. Mancktelow has described four facies variants:

(1) Calc-siltstone facies. This facies, which is exposed in the type section, is composed dominantly of banded siltstones, the lighter bands having calcite. Thin arkoses occur similar to those in the Backstairs Passage Formation, and there are some darker grey more massive siltstones, which often have accessory iron sulphide minerals. The presence of interbeds of very iron rich siltstone show a relationship to the environment of the Nairne Pyrite.

(2) Aluminous siltstone facies. "This is dominated by well laminated to banded metasiltstone, the lamination being due to variation in the biotite to quartz-feldspar ratio. These siltstones are quite aluminous, and in the medium to high grade metamorphic areas recrystallize to form porphyroblastic schists rich in biotite, andalusite, garnet, staurolite, and muscovite" (Mancktelow, 1979a). Mancktelow emphasized his observation that the iron content is still high and iron sulphides are present locally, which again implies a relationship to the Nairne Pyrite.

(This facies was dominant in the Rockford Heights area and will be discussed later.)

(3) Nairne Pyrite Facies. This facies was described by Skinner (1958) and George (1967). George considered the original lithology to be iron sulphide rich, carbonate bearing siltstones. Mancktelow (1979a) suggested that it could be a more iron enriched version of the calc-siltstone facies. This facies grades along strike into the aluminous siltstone facies, the gradational facies being very rich in garnet and sometimes apatite (Mancktelow, p.24, 1979).

(4) Black Shale facies. This consists of black, very carbonaceous, laminated slate. It occurs to the north of the Kanmantoo Syncline with its outcrop not being continuous with that of the Kanmantoo Syncline.

Throughout most of the fold belt the Tapanappa Formation consists of a thick and very monotonous sequence of dark coloured metasandstones with thin grey phyllite interbeds (Daily and Milnes, 1971; Mancktelow, 1979a). Mancktelow calls this the "greywacke facies" of the Tapanappa Formation, in which he has recognized partial or complete sequences similar to the classical Bouma sequence. However, the complete Bouma sequence is only occasionally present. There are occasional iron sulphide rich metasiltstones, which now consist of quartz and muscovite, interbedded in the Tapanappa Formation, throughout the fold belt (Mancktelow, 1979a). Mancktelow found that the "greywacke facies" changes to a "sandstone facies", quite similar to the Backstairs Passage Formation over a large area of southern Fleurieu Peninsula.

The Brown Hill subgroup overlies and has similar lithologies to those within the Tapanappa Formation. This subgroup is characterized by dark blue-black carbonaceous and sulphide rich phyllites, which are known as far north as the Callington area in the eastern Mt. Lofty Ranges (Daily and Milnes, 1973). The Petrel Cove Formation, within the Wattaberri Subgroup (Table 1a) consists of fine grain clastics and is succeeded by the characteristic and cross bedded Middleton Sandstone.

2.3 Stratigraphy of the Freeway Traverse

The South Eastern Freeway was constructed through the area mapped earlier by Toteff (1977) and the roadcuts were then examined by Drexel (1978). These workers described the lithologies and a summary of their observations is included below. Figure 3 shows the location of the Freeway roadcuts and the section measured in detail in this work. The terminology for describing the lithologies used by other workers has often been modified to avoid confusion.

2.3.1 Backstairs Passage Formation

This Formation was not investigated in the field for this study in this area. A summary of previous descriptions is however included below for completeness, as it is relevant to understanding the overall environment and for making comparisons with the stratigraphy of the Rockford Heights area.

Toteff (1977) divided the Backstairs Passage Formation into three members, the Upper and Lower Members being quite variable. The Middle Member, which forms the bulk of the formation, consists of pale grey weakly laminated feldspathic sandstones and arkoses interbedded with darker, laminated more pelitic metasediments which are rarely over 0.75m and often occur as mere partings between coarser metasandstones and meta-arkose units up to 1.5m in thickness. Toteff states that current directions determined on low angle cross bedding were from the southeast.

Drexel (1978) had the advantage of complete outcrop in the Freeway cuttings he examined. He considered the sedimentation to be broadly cyclic. In the two western-most cuttings (see Inset Fig. 3) there are two sequences, grading over several tens of metres, from white metasandstone through to grey laminated metasandstone, which represents an increase in argillaceous content of the incoming sediments.

Alkali feldspar is the dominant feldspar in the Backstairs Passage Formation, whereas in the overlying Talisker Formation and in the Tapanappa Formation plagioclase, generally oligoclase, is the dominant often the only feldspar (Drexel, 1978). A similar relationship was observed in the Rockford Heights area.

According to Toteff (1977) the Upper Member is represented by a facies change with increasing mica content and decreasing lamination of metasandstones. This is more uniform in lithology than the rest of the Formation, and is a more pelitic member. These rocks which were originally poorly sorted clay rich feldspathic sandstones (with minor siltstones), typically form featureless outcrops, with well developed lamination being rare or absent. In the Mt. Barker Creek this Upper Member is 60m thick. The contact with the underlying cleaner metasandstones is gradational over a few metres. North of Mt. Barker Creek the Upper Member thins and grades into cleaner metasandstones.

Drexel (1978) records a similar change in lithologies within the top 313m (minimum) of the Backstairs Passage Formation. Here the Formation consists of a range of lithologies from metasandstone, containing biotite and lacking in alkali feldspar, through to biotite schist.

2.3.2 Talisker Formation

The basal 22m of this formation (see Figure 3) consists mainly of pyritic muscovite, quartz, feldspar phyllites. These are interbedded with occasional more resistant, commonly laminated metasiltstones to fine metasandstones. Drexel (1978) reports that the major minerals present are quartz and muscovite and that feldspar may or may not be present. These rocks are distinctly finer grained than the other rocks along the Freeway.

This Lower Member of the Talisker Formation thins out to the north of the Freeway roadcut. The schists within this member commonly contain clots around which penetrative fabric wraps. These clots were thought to be andalusite, however they were not sectioned during this study due to the degree of weathering of the phyllites. A sample was sectioned from one of the more resistant layers, which contained two graded beds. This sample was found to have small clots of plagioclase (Plate 1A). Staining revealed that alkali feldspar was absent. Drexel reports a variability in the proportions of feldspar and of the resistent layers within the schists.

The Nairne Pyrite Member overlies this basal member of the Talisker Formation. Usually (George, 1967) the Nairne Pyrite contains numerous coarse grained metamorphic segregations, which often have andalusite within them (Plate 1B). In the road cuts this is very monotonous with only variation in the size of the segregations. No layers of calc-silicate were found such as are common in the Brukunga Mine 9km to the north (George, 1967). However, these may not have been recognized due to the degree of weathering.

Within the Nairne Pyrite are interbeds at the base of the formation both of pyritic arkoses and impure metasandstones. This indicates some kind of association of these different lithologies.

An interval (2.5m) near the top of the Nairne Pyrite Member (see Figure 3) lacks metamorphic segregations. This rock is layered and contains pores, which may have formed by the weathering of iron sulphides. This lithology is similar to the pyritic lenses that occur throughout the Tapanappa Formation (Mancktelow, 1979a). It is possible that the metamorphic segregations occur in rocks of higher sulphide content.

The contact between the Nairne Pyrite and the overlying Tapanappa Formation is fairly sharp (within 1.5m), the boundary being obscured by leaching next to the iron sulphide rich sediments.

2.3.3 Tapanappa Formation

This sequence consists of a rapidly alternating sequence of impure metasandstones and pelites. A major part of this investigation in this area was to study the changes in bed thickness within the Tapanappa Formation. The data collected is summarized in Figure 3. Within the measured sequence there is a gradual decrease in bed thickness up the stratigraphic column, probably associated with increased biotite content of the psammites.

In general the thickness of the individual beds is very uniform. This is consistent with the model that these sediments represent proximal turbidites. Some changes in sediment supply occurred during the deposition of this sequence. Parts of the sequence contained no pelite interbeds, indicating a higher sediment input. In other parts of the sequence there were three or four beds where both the psammites and pelites had constant thicknesses. The pattern of bed thicknesses may have been due to the migration of broad channels which were rapidly filled with sediment. The position of the channels would have been constantly changing with respect to any one locality.

Within the psammitic intervals there are often faint laminations. No apparent pattern to the distribution of these laminations occurred. In the Bouma sequence a laminated interval often overlies a more massive unit. However, in these sediments there does not appear to be a consistent decrease in flow regime. Either the strength of the current varied during the deposition of each bed, or there was truncation of many of the beds before the complete sequence could develop.

2.4 Stratigraphy of the Rockford Heights Area

2.4.1 Summary of the eastern limb of the Rockford Heights Syncline

The best exposed section through the Talisker Formation occurs to the south of the area where the trend changes toward east-west (Figure 4). The stratigraphy in this area is relatively simple, with the Talisker Formation being interbedded with lithologies similar to those in the Backstairs Passage Formation and those in the Tapanappa Formation.

(1) The Backstairs Passage Formation consists of scattered outcrops of prominant low angle cross bedded arkoses. This lithology occurred over large areas northeast of the map area, such as the roadcut approximately 4km east of Mount Bremer. Outside of the map area the arkoses were always very clean and well bedded. In the map area the meta-arkoses contain some biotite and in general they do not appear to be as well bedded. There are rare beds of grey nonlaminated metasandstones interbedded at the very top of the formation.

From the few current directions determined, from thick sets of low angle cross bedding, all were from a westerly direction between 243^{o} and 252^{o}. There is a need for further work on current directions for use in understanding the sedimentary environment of deposition of this formation.

(2) The base of the Talisker Formation is marked by the first occurrence of iron rich and iron sulphide bearing metasediments. Where the boundary with the Backstairs Passage Formation is exposed there are thin beds (of the order of a 5cm thick) interbedded with the clean arkoses within the top few metres of the arkoses.

The lithologies within the Talisker Formation are variable. In the east-west trending section of the Talisker Formation the sequence begins with a porphyroblastic plagioclase, magnetite, biotite quartz schist (Plate 5A), this being overlain by a sequence of highly deformed laminated rocks (Plate 1C), in which it was difficult to determine if the lamination was a sedimentary feature, or a result of differentiation. The majority of the sequence is now composed of porphyroblastic andalusite schists and lesser porphyroblastic staurolite, garnet schists. The mineralogy of these rocks reflects the high aluminium content of the metasediments.

There is a well exposed section of the base of the Talisker Formation within the southern part of the Eastern limb of the Rockford Heights Syncline (Station 237). The first 10m consists of well layered biotite quartz metasandstone and metasiltstone. The metasiltstone has quartz rich metamorphic segregations (Plate 1D). Following about 1m of metasiltstone the rest of the exposed section consists of dark coloured biotite schist with a knotted appearance. These rocks are intensely weathered and are cut by jarosite veins, which are evidence of pre-existing iron sulphides. Thin section (766-41) reveals that this lithology contains small clots of fibrolite and coarse muscovite, which are characteristic of the biotite schists containing sulphides elsewhere within the Talisker Formation. This sulphide bearing facies is considered to be transitional between the Aluminous Siltstone facies of Mancktelow (1979a), which in this area is dominated by porpyroblastic andalusite schist, and a facies now represented by an iron sulphide rich layered quartz-muscovite metasiltstone. The distribution of the different facies varients within the Talisker Formation are shown in Figure 4.

A 50m thick interval of prominant, clean, low angle cross bedded arkoses, similar to those of the Backstairs Passage Formation, occurs within the Talisker Formation (Figure 4). Within these there are well developed laterally migrating channels (Plate 2A). This interval thickens to the south, and to the north it is interbedded with pyritic biotite schist. In the more pelitic lithologies of the Talisker Formation, overlying this arkosic interval, there are numerous thin (less than 4m) interbeds of clean arkoses.

One relatively thick interval of arkoses in the Talisker Formation (6m) has a convoluted bed associated with it (Plates 2C and D). The presence of these liquifaction structures is evidence that these sediments were deposited very rapidly and contained a large proportion of inter-granular water. Immediately overlying this interval of laminated and low angle cross bedded arkoses is 2m of massive grey non-laminated psammite with no visible bedding. It is important to note that this massive lithology and the arkoses occur together, as this is important to the interpretation of the location of the top of the Backstairs Passage Formation on the western side of the axis of the Rockford Heights Syncline. It is also relevant that interbeds of this grey non-laminated lithology become dominant over the cleaner arkoses when travelling north along the exposed Talisker Formation within the eastern limb of the Rockford Heights Syncline.

There is some interbedding of the andalusite schist of the Talisker Formation with the sequence of rapidly alternating psammites and pelites composing the Tapanappa Formation, but in general the change in lithology was very rapid. This boundary was not exposed due to covering by scree of the more resistant lithologies of the Tapanappa Formation.

(3) The lithologies in the Tapanappa Formation are similar to those observed in the Freeway section. Massive psammites with sharp bases are the dominant lithology within the Tapanappa Formation, and these sometimes fine upward into pelites. Faintly laminated intervals occur within the psammites.

The thickness and composition of the metasediments in the Tapanappa Formation are generally uniform except for a major Phyllitic Member 400m from the base of the Formation. In the southeast corner of the map area this unit is only 50m thick, however it thickens considerably (to at least 150m) at the hinge of the Rockford Heights Syncline. The major lithology outcropping in this unit is an iron sulphide rich laminated muscovite quartz schist (e.g. Plate 3A). Other lithologies present in this phyllitic member are layered andalusite schist and a phyllitic lithology with numerous folded quartz-garnet segregations.

Overlying the phyllitic member there was a continued deposition of grey impure metasandstones. The beds in this part of the sequence were usually massive and the thickness of the beds remained relatively constant (at about 50cm).

2.4.2 Summary of western limb of the Rockford Heights Syncline

There is a general uniformity of lithologies immediately west of the axis of the Rockford Heights Syncline. There are no prominant clean arkoses such as those which characterize most of the Backstairs Passage Formation. Much of the sequence of metasediments is similar in appearance to the grey impure psammites of the Tapanappa Formation.

In the basal part of the exposed section the most common lithology is a dark grey featureless psammite with occasional flat bedding planes present. Due to the high proportion of biotite present these rocks are strongly foliated, and when weathered the foliation may be mistaken for bedding. There are uncommon interbedded pelites consisting mainly of biotite and quartz. These are often crenulated. There are no sharp boundaries which can be used to give younging directions, and there is no obvious grading present.

Interbedded within this sequence of dominantly massive impure psammites there are aluminium rich and iron sulphide rich sediments similar to those which characterize the Talisker Formation. These layers are up to two metres thick.

There is no obvious change in lithology passing up into the Tapanappa Formation. The Tapanappa Formation on this side of the syncline tends to have a more massive appearance. It is difficult to determine if this is due to actual changes in the sediments themselves or whether their appearance is due to outcrop quality. Rare phyllite chip conglomerates and calc-silicates interbedded in the psammites of the Tapanappa Formation (see Figure 4).

2.4.3 Relationship between limbs

The difference in stratigraphy on either side of the Rockford Heights Syncline could be interpreted either in terms of a rapid major facies change or by faulting which could have removed a considerable thickness of the stratigraphy from the eastern side of the fold.

(1) If it is assumed that the stratigraphy of the western limb of the Rockford Heights Syncline is part of the Tapanappa Formation there would have to have been at least 400m of stratigraphy removed from the eastern limb, with the upward movement on the eastern side of a fault. As some of the beds can be traced around the nose of the Syncline, and because the Talisker Formation with its interbedded arkoses can be traced along most of the eastern limb, the fault would need to be close to the boundary between the Talisker and the Tapanappa Formations and subparallel to the strike direction (see line F-F', Figure 4). If such a fault existed there would have been a scissor movement with at least 400m movement to the north and no displacement of the phyllitic unit within the Tapanappa 1000m to the south. To the east of the tight syncline the distance between the phyllitic interval, within the Tapanappa, and the Talisker Formation, remains constant suggesting that faulting has not been significant in explaining the differences in lithologies. Also, there appears to have been no displacement of the stratigraphy to the west of the Monarto Syncline, as there are pelitic lithologies similar to those elsewhere in the Talisker Formation in the position expected by tracing the trend lines (Figure 1).

It is most likely, therefore, that the changes in lithology observed are due to a major and very rapid facies change within both the Backstairs Passage and the Talisker Formations. Such a change in lithologies within the Tapanappa Formation if it did occur as the lithologies of the Tapanappa Formation are already rich in biotite.

(2) Within the western limb the lithologies underlying the Tapanappa Formation are different from those in the Tapanappa Formation, although both are dominated by grey impure metasandstones. Below the Tapanappa these sandstones are massive and overall are unusually thickly bedded and have a slightly higher proportion of biotite. There is also an abundance of thin pelitic lithologies which are similar to those in the Talisker Formation.

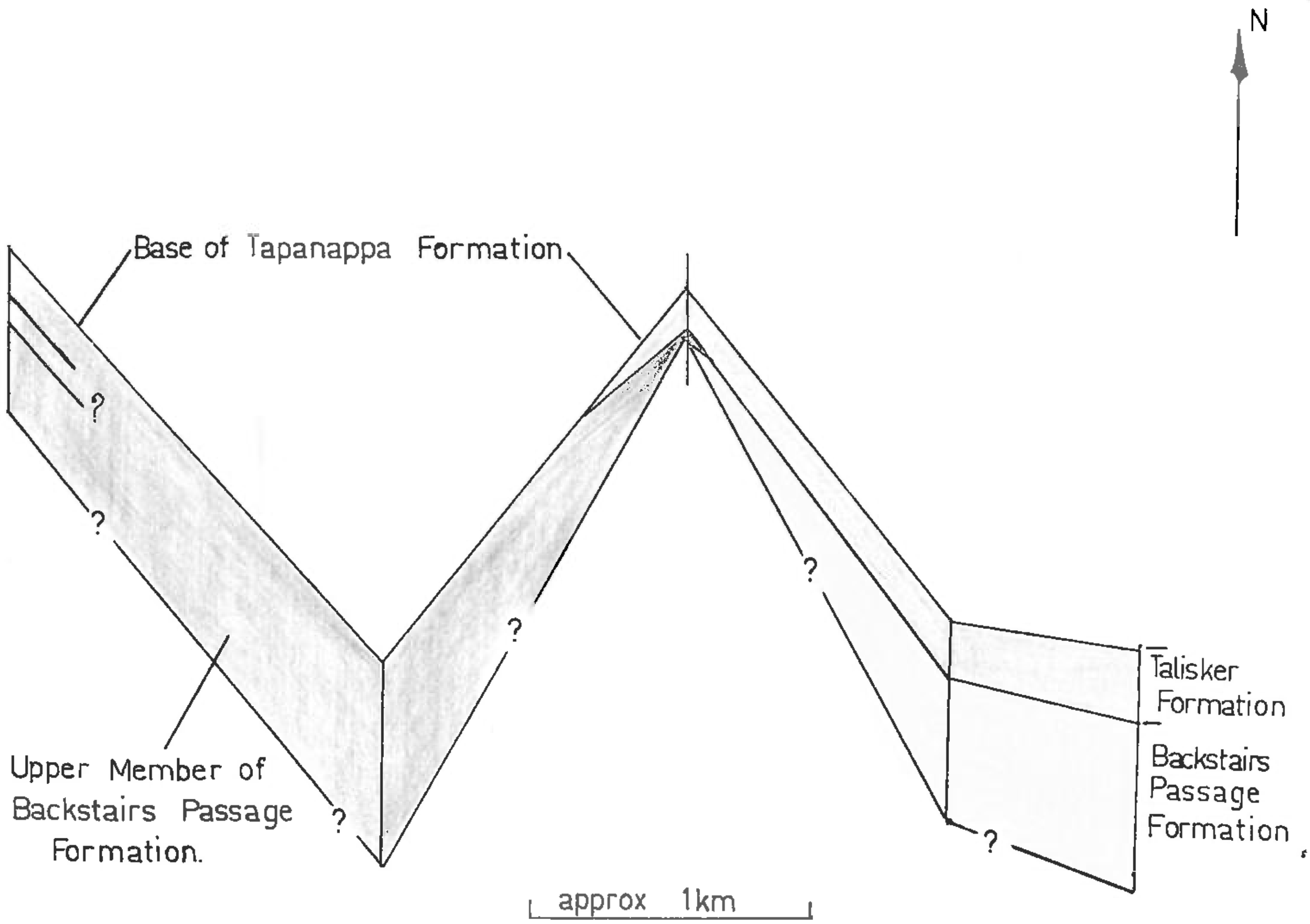


Figure 5

Fence diagram, based on information from the Rockford Heights area, showing the rapid nature of the facies change within the top of the Backstairs Passage Formation and the probably related changes **within** the Talisker Formation.

Toteff (1977) described a similar facies change at the top of the Backstairs Passage Formation along the western limb of the Kanmantoo Syncline. Neither Toteff or Drexel (1978) described any thin interbeds of pyritic or aluminous metasediments such as those mapped in the Rockford Heights area. There is no analogous change within the Talisker Formation along the western limb of the Kanmantoo Syncline. In the Rockford Heights area the Talisker Formation is interbedded with the massive impure sandstones.

Interbeds within the eastern limb of the Monarto Syncline show changes in lithology similar to that in the top of the Backstairs Passage Formation (see Section 2.4.1). On a larger scale, the arkoses of the Backstairs Passage Formation appear to be cleaner (containing less biotite) in the area to the east and northeast of the map area. It seems that the changes in composition in both the Backstairs Passage Formation and the Talisker Formation may be due to a local addition of sediment from a different source.

Another likely explanation is that the Talisker Formation was thinned locally, and that the facies change only occurred in the top of the Backstairs Passage Formation.

2.5 Environments of Deposition

Mancktelow (1979a) presented a model of depositional environments in which the sequence of lithologies from the Carrickalinga Head Formation to the Petrel Cove Formation represents a gradual deepening of the Kanmantoo Basin, and a consequent increase in the distance from the ancient shoreline, with time. In this interpretation he took into account the lack of sedimentary features indicative of shallow water deposition and that some formations have sequences of sedimentary features characteristic of classical turbidites. To determine the validity of Mancktelow's model of deposition environments within the Kanmantoo Trough, a brief investigation was made into previous descriptions of the Kanmantoo sediments, including the equivalent stratigraphy on Kangaroo Island where the grade of metamorphism is lower.

Mancktelow (1979a) described the Carrickalinga Head Formation (see Table 1a) as a "dumped, poorly sorted sequence" in which the sediments were proximal turbidites deposited "with insufficient time in turbid flow to develop size grading." Mancktelow envisaged that the Backstairs Passage Formation "formed at or near the change in slope where the main feeder channels break up into many distributaries." "Continual reworking of these sediments by current action leads to winnowing, producing clean arkose lithologies".

According to Mancktelow the Talisker Formation could have been "deposited in the more distal area away from the main channel distribution points, where the distributaries are farther apart. This leads to a prominance of interchannel deposits. There is little clastic sediment supply to these interchannel regions as they are distal from the source of the small flows which formed the Carrickalinga Head Formation, but upslope from the distribution point for most of the major turbidite flows. Lithologies developed will be calcareous or aluminous (i.e. clayey) siltstones and shales, which may be quite iron rich or carbonaceous."

The changes in sediment character in the sequence from the Tapanappa Formation to the Petrel Cove Formation are considered, by Mancktelow, to represent a change from proximal to distal within a submarine fan environment, in which the sediments were deposited from "turbidites flowing episodically from the distribution mouths (Walker, 1978)." Pyritic and carbonaceous siltstone units within the turbidite sequence were considered to represent "longer periods of quiescence without sediment supply from turbidite flows". The sandstone facies of the Tapanappa Formation (see Section 2.2) was envisaged as the result of "major feeder channels" which "extended farther out onto the basin floor, such that channel-fill sandstone deposits laterally intertongued with the greywackes of the submarine fans".

According to the model presented above, the section from the Talisker Formation through to the Petrel Cove Formation was deposited on the basin floor. The lack of aluminium and iron rich sediments in the Backstairs Passage Formation is consistent with Mancktelow's interpretation that this formation was deposited on the lower slope, rather than on the basin floor. The transitional nature of the change from the Backstairs Passage Formation to the Tapanappa Formation is reflected by the presence of grey impure sandstones at the top of the Backstairs Passage Formation (George, 1967; Toteff, 1977). Elsewhere, laminated arkoses form the first few metres of the Tapanappa Formation above the boundary with the Talisker Formation (Mancktelow, 1979a).

In contrast to this model, Daily (1976) has correlated the metasediments of the Kanmantoo Group with the much thinner, fossiliferous, red to grey-green clastics exposed on the north coast of Kangaroo Island (See Table 1b). "The basis of this correlation hinges on the fact that the fossiliferous sequence, when traced to the west along the northern coastline, gives way to a progressively more metamorphosed succession of grey coloured metasediments, unfossiliferous apart from trace fossils and which, from their sedimentary structures, are regarded as having been deposited further offshore." (Daily et al., 1980, p.380).

They have interpreted the upper part of the Lower Cambrian succession in the north east coast of Kangaroo Island to be a combination of alluvial deposits and subtidal to intertidal deposits. If this correlation is correct it means that the sediments within the Kanmantoo Group can be interpreted without reference to a "gradual deepening of the basin, and a consequent increase in the distance from the shoreline, with time" (as proposed by Mancktelow, 1979a).

Toteff (1977) found that the dominant current direction within the Backstairs Passage Formation in the Nairne-Mt. Barker Creek area was from the south-east. Of the few current directions determined in the Rockford Heights area in this study, almost all were from the west. Again these current directions are inconsistent with the model of a deep sea fan, as the expected current directions from such a fan would be away from the craton.

Daily and Milnes (1971) suggested that the Backstairs Passage Formation was deposited rapidly, in general, within a high energy regime. Toteff (1977) considers that the deposition occurred at shallow to moderate depths and suggested that the sea bed had a considerable gradient favourable for chaotic slumping. However, it is possible for liquifaction structures to develop within sediments deposited on horizontal surfaces (Dr. B. Daily, pers. comm.). The presence of these structures is evidence that these sediments were deposited rapidly such that they had a very high water content, which was expelled during liquifaction.

Rupke (1978) in a discussion of modes of fluid flow states, "Laminar flow changes into turbulent flow when the product of the flow velocity and the depth of flow surpasses a critical value for a given fluid viscosity." (p.380). One would expect turbidites to occur at the change from shallow shelf to slope, where currents would have higher velocities.

It is, therefore, hard to envisage the necessary changes in velocity or depth using the model of Mancktelow (1979a). However, the sequence from the Tapanappa Formation to the Petrel Cove Formation is perhaps best explained in terms of turbidity current deposition. It could be argued that the scarcity of complete Bouma sequences is inconsistent with the theory that turbulent flow is responsible for these sediments. However, Rupke (1978) discusses the reasons why the complete Bouma sequence is uncommon in classical flysch facies.

The Bouma sequence represents a decrease in flow regime and its recognition does not necessarily determine that turbulent flow was responsible, nor does it prove that the sediments were deposited in deep water. However, to explain the alternating massive psammites and pelites observed in this study, turbulent flow becomes the most likely mechanism for their deposition. In the sequence observed along the roadcut of the South Eastern Freeway, there was rythmic sedimentation of beds of similar thickness (figure 3). There is an overall thinning and fining upward sequence in this area. According to Rupke (1978), thinning upward sequences characterize the lateral migration or lateral abandonment of a channel. As expected this is only a local feature and fining upward sequences were not recognized in the Rockford Heights area.

A major problem arises in trying to determine the significance of the facies change observed at the top of the Backstairs Passage Formation in both study areas. In both areas there is a change from massive poorly sorted sediments to clean sandstones and arkoses along the general current direction. It is possible that the current directions at the top of the Formation were different to the general direction throughout the formation. This change in lithologies appears to be related to sedimentary processes as one of the arkosic interbeds within the Talisker Formation has the grey massive lithology at the top.

The feldspar content of the Kanmantoo Group sediments gives some clues as to the nature of the processes occurring in the basin. Drexel (1978) reported that the feldspar composition of the Backstairs Passage Formation was variable, but the dominant and often only feldspar in the overlying sediments was plagioclase. This was found to be the case in the Rockford Heights area. Most of the sediments contained no alkali feldspar yet had significant amounts of plagioclase. The impure sediments at the top of the Backstairs Passage Formation in the western limb of the tight syncline were especially free of any alkali feldspar. It is interesting to note that a phyllite chip conglomerate sampled from the Tapanappa Formation in the Rockford Heights area contained lithic fragments consisting of quartz and plagioclase, as well as rounded apatite grains. Hence it is likely that the source rocks in some areas lacked alkali feldspar.

One sample from the phyllitic unit within the Tapanappa contains a high proportion of microcline with a lesser amount of plagioclase and negligible quartz. Another sample from the same unit contained no feldspar. Hence different sources have been mixed to produce the present assemblage.

The significance of the Talisker Formation is difficult to determine. Similar lithologies occur as interbeds within the Tapanappa Formation, and must have had a similar origin. These siltstones were deposited during times of low sediment supply, yet show considerable variation of mineralogy. In the Freeway section the thickest beds of impure sandstone occur within the Nairne Pyrite member. In the western limb of the tight syncline the aluminous and pyritic intervals are also associated with thick massive beds. Hence, it appears that all the lithologies are related by sedimentary processes. To clarify these processes, further detailed work is required on current directions and the distribution of facies varients within the different formations.

3. STRUCTURAL HISTORY

3.1 Introduction

Mancktelow (1979a) found that there was an increase in complexity of the structural history with an increase in metamorphic grade throughout the Adelaide fold belt. The main folding was found by Mancktelow to have occurred during the first deformation (D_1). According to the interpretation of Mancktelow the fabric associated with the second deformation D_2, (S_2), developed in vertical zones and was associated with vertical tectonics which caused a shallowing of both the limbs and the plunges of first generation folds.

As Mancktelow pointed out, there is a difficulty in correlating deformations in different areas due to the patchy development of crenulation deformations. The two areas studied were widely spaced (Figure 1) and most likely had different metamorphic and deformational histories. The rocks between the Freeway cutting and Brukunga Mine were generally lower grade than those in the Rockford Heights area, as shown by the grainsize of the micas.

Field and thin section work has therefore revealed that the model of structural and metamorphic history presented by Mancktelow (1979a) was largely consistent.

3.2 Structure of the South Eastern Freeway traverse

There have been differing interpretations of the relations between major folding and fabric formation in this area. In the Brukunga Mine, 9km to the north of the Freeway Traverse, George (1967) considered that both the regional fabric and the folding occurred during the first deformation, but was unable to explain for example, the angle between mineral lineations and axes of minor folds. Toteff (1977), in his study of the Nairne-Mt. Barker Creek area, found evidence that the regional fabric formed during the second deformation and assumed that the folding also occurred during D_2. Mancktelow (1979a), in his regional synthesis, concluded that the major folding occurred during the first deformation, whereas the S_1 slaty cleavage (see Mancktelow, 1979a and b) was crenulated locally to form an S_2 crenulation cleavage.

A detailed study of the structure was not made during this study, yet the observations made were significant. In the Freeway roadcuts the fabric was observed to be near parallel, but has a consistent dextral asymmetry to the bedding (with an intersection lineation plunging in a southerly direction). The penetrative foliation wrapped around small clots of plagioclase and quartz (Plate 1A), which had either randomly oriented muscovites within them or muscovites at an angle to the penetrative fabric. If the penetrative fabric was S_1 the fabric within the clots should have had the same orientation. Therefore, the fabric was likely to have been S_2, and the clots may have formed either early during D_2 or in the period between D_1 and D_2.

Figure 6a

Bedding, S_o.

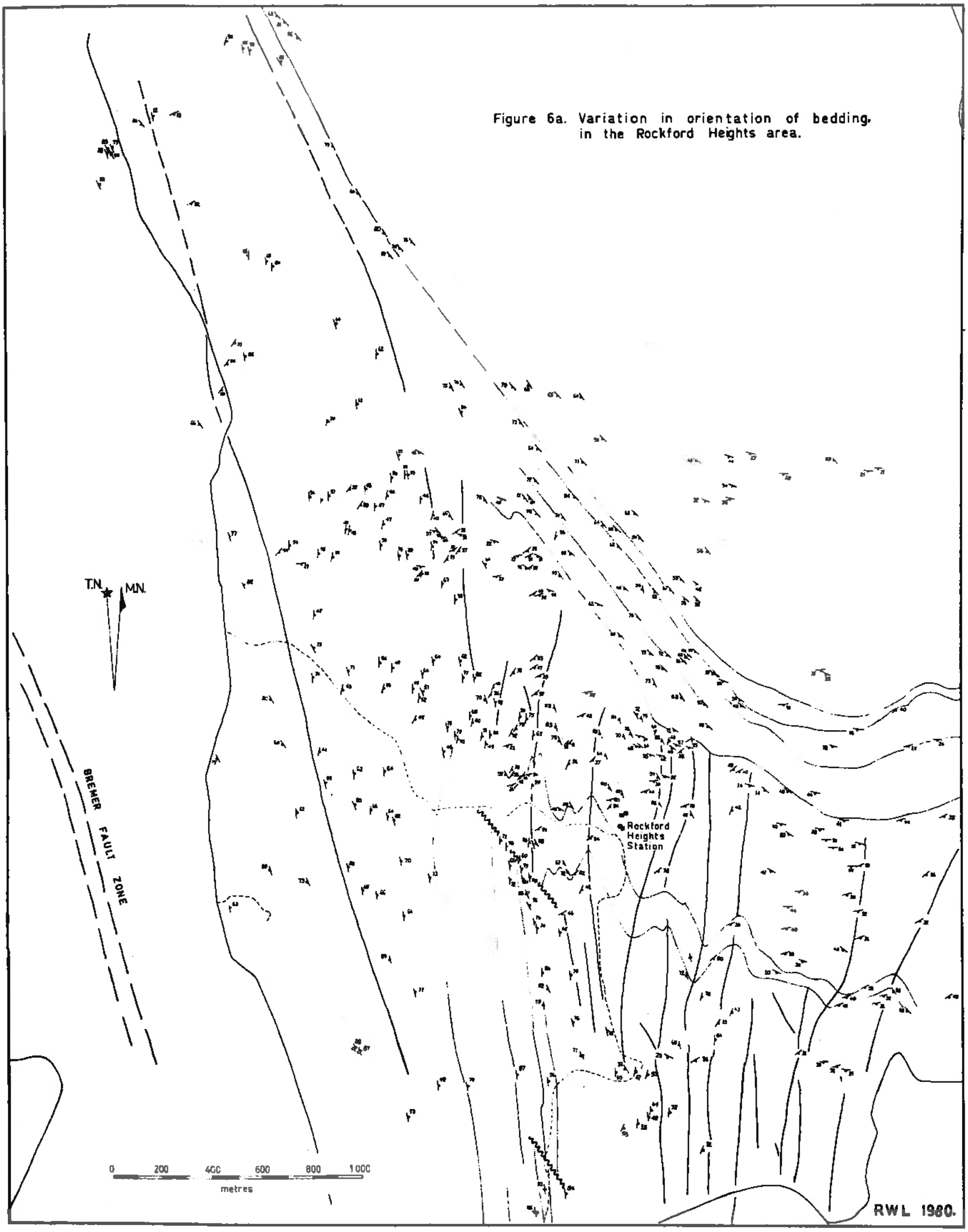


Figure 6a. Variation in orientation of bedding in the Rockford Heights area.

Figure 6b

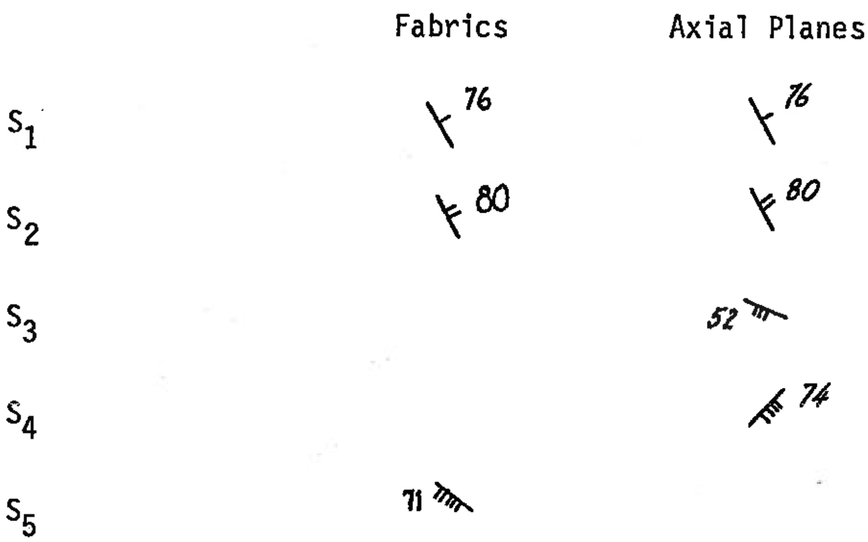


Figure 6b. Variation in oriention of fabrics and axial planes of folds in the Rockford Heights area.

Figure 6c

30	Measured biotite lineation
26	Calculated intersection lineation between S_0 and S_1
40	Plunge of D_1 folds
41	L_2 (usually from pressure shadows in andalusite schist)
44	Calculated intersection lineation between S_0 and S_2
38	Plunge of D_2 fold
40	Plunge of D_3 crenulation axes
42	Plunge of D_4 crenulation axes

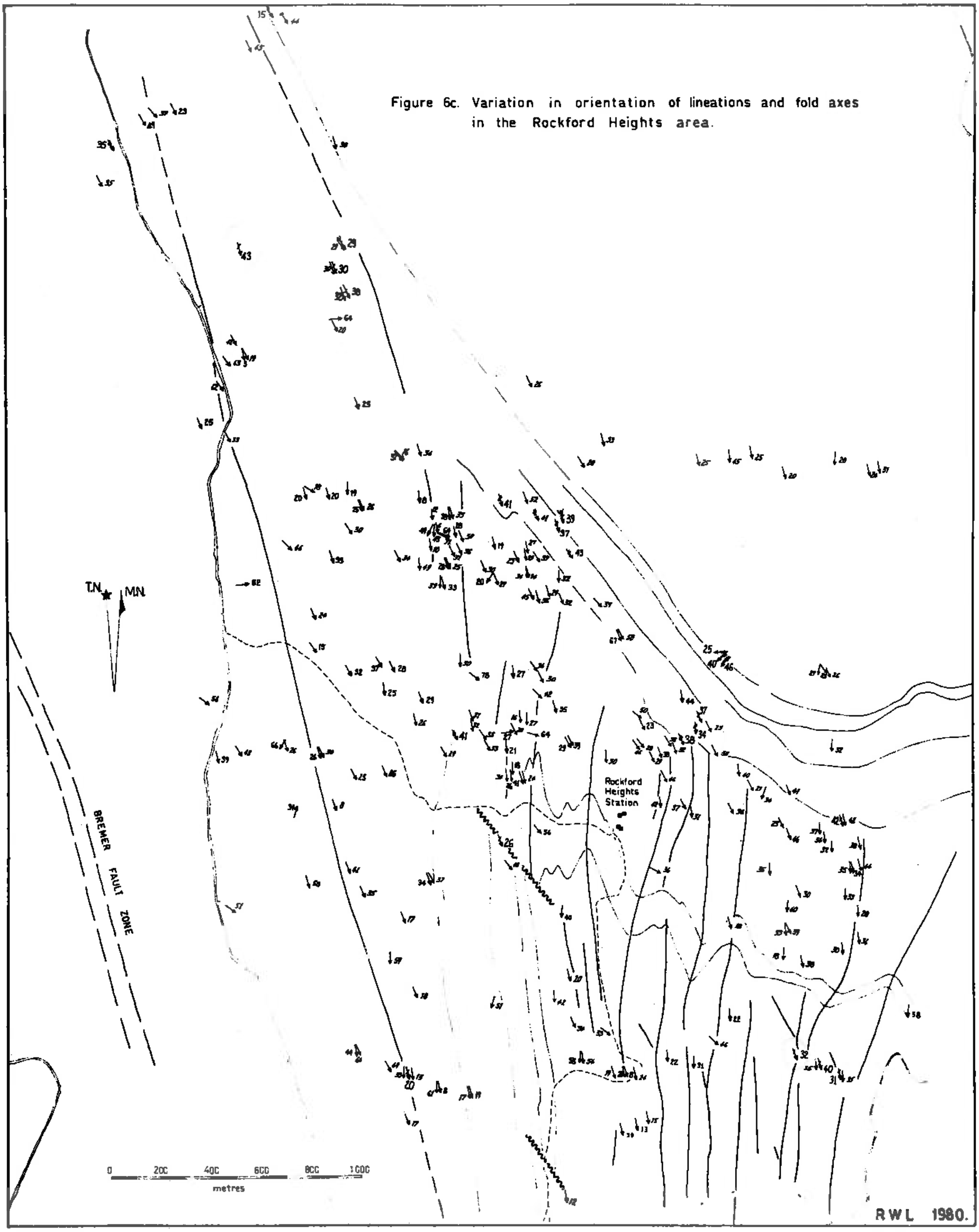


Figure 6c. Variation in orientation of lineations and fold axes in the Rockford Heights area.

Figure 6d

●	S_o
○	S_1
△	Calculated intersection lineation between S_o and S_1
▲	Measured biotite elongation lineation
◯	F_1 axis
◯	Long axis of pseudonodule
□	S_2
■	L_2
★	S_3
☆	F_3
★	S_4
☆	F_4
✪	S_5

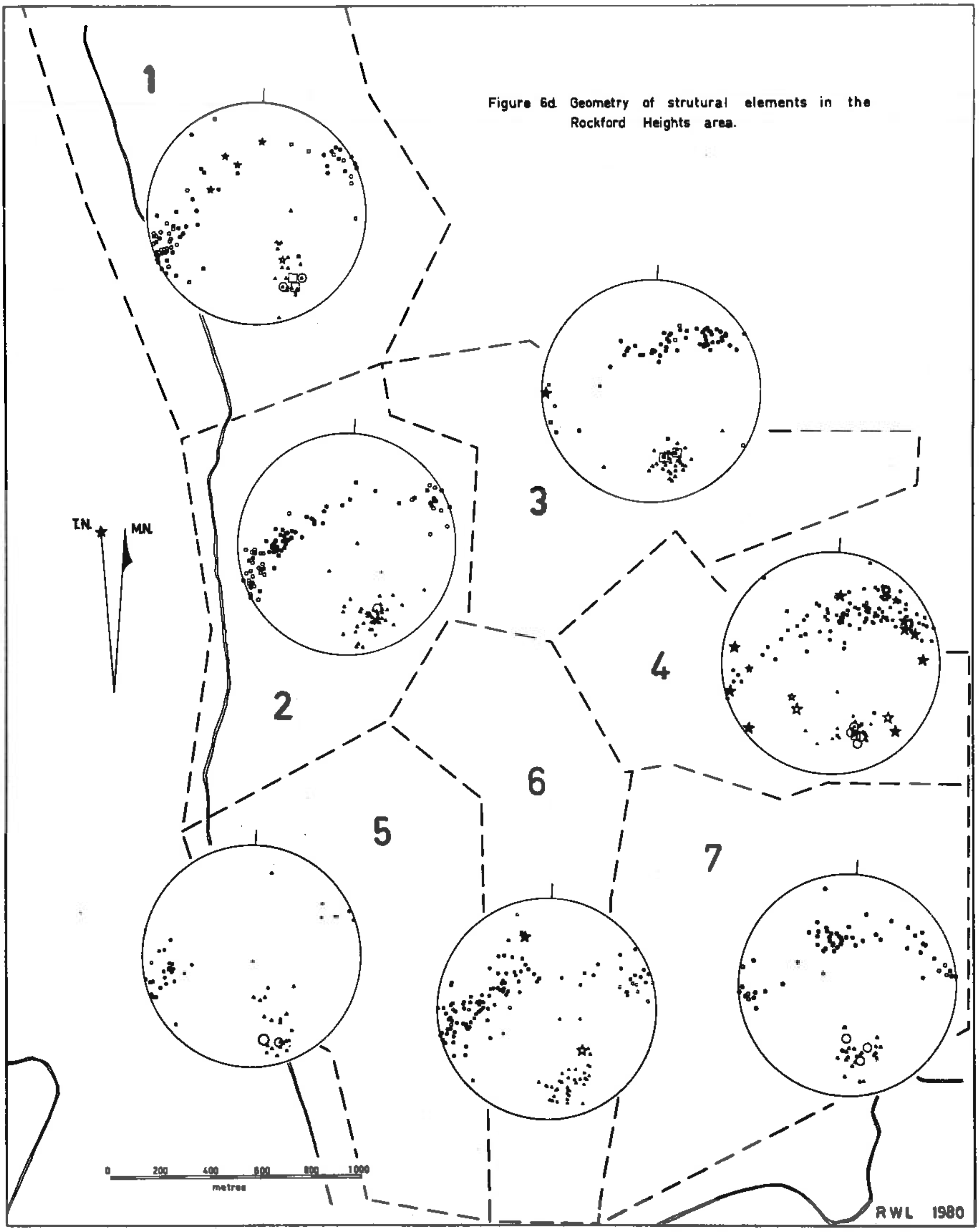


Figure 6d Geometry of strutural elements in the Rockford Heights area.
1
2
3
4
5
6
7
T.N.
M.N.
0 200 400 600 800 1000
metres
RWL 1980

The metamorphic segregations within the Nairne Pyrite were flattened within the regional fabric, which is again defined by muscovite. A thin section examined in this study showed evidence that the fine grained matrix was being replaced by the coarse metamorphic segregations (see George, 1967, for a discussion of these segregations). Andalusites within the segregations were either skeletal, with no internal fabric, or lacking in inclusions (Plate 1B). Within the coarse segregations there were coarse muscovite crystals which were found to have quite a strong preferred orientation (see Figure 9a). Hence, these metamorphic segregations appear to be syntectonic with the formation of the fabric. According to Mancktelow (1979a) the peak of metamorphism occurred during the second deformation. It was during this peak that the metamorphic segregations were likely to have formed and that the andalusite would have crystallized. Hence the fabric in these rocks is likely to be S_2.

George (1967) found that the regional fabric in which the metamorphic segregations occurred was axial planar to minor chevron folds within the Brukunga Mine. According to the interpretation of Mancktelow, for the structure of the Adelaide fold belt, the fold style would have been more typical of the first deformation than of the second, as the second deformation was an overall shear folding effect.

A southerly plunging crenulation is developed in the more mica rich lithologies. This could have formed during either the third or fourth deformatior

3.3 Structure of the Rockford Heights area

3.3.1 Introduction

The main features of this area are the more complex structural history and higher grade of metamorphism than in the Freeway section.

Mancktelow (1979a and b) has demonstrated that the major upright folding throughout the fold belt occurred during the first deformation. A slaty cleavage developed during this event. The main problem in understanding the structural history is to determine how later deformations, especially the second, have modified the major folds and their associated regional foliation.

Almost all lithologies had a well developed biotite lineation which generally plunged in a southerly direction. In this study an attempt was made to determine the significance of this lineation. Another aim was to determine the significance of porphyroblast growth in relation to the history of deformation and recrystallization.

The data measured in the field are represented in Figure 6. There is some uncertainty as to which generation the structural measurements relate to. In the field S_1 and S_2 are difficult to distinguish and, unless thin sections are available, it is difficult to be certain which fabric is being measured. Likewise, it is difficult to correlate lineations and crenulations as these have similar appearances in the field.

3.3.2 The first deformation D_1

The major folding in the area was found to be the first deformation (Figures 4 and 6). The major structure in the area is the southerly plunging Rockford Heights Syncline, which is the northernmost development of the Monarto Syncline of Mancktelow (1979a). According to Mancktelow the major domal anticlines within the fold belt are developed in an en echelon pattern migrating towards the southeast (Mancktelow, 1979a, Fig. 4.8). He suggests that the Monarto Syncline begins as a parasitic fold on the eastern limb of the Kanmantoo Syncline in the Rockford Heights area, increases in amplitude toward the south and may eventually supplant the Kanmantoo Syncline as the dominant structure.

In the eastern half of the map area the major folds are quite tight, whereas to the west the folds are more open. According to Mancktelow (1979a) this area of open folding was a zone deformed during the second deformation. However, there does not appear to be the strong development of second generation structure necessary to produce a change in geometry of the folds. Rather, the development of major first generation folds seems to be related to competance variations throughout the sequence as shown by the presence of box folds in the south-easter corner of the map (Figure 4) and the changes in direction of the axial traces of the folds according to the degree of development of D_1 folds.

Minor first generation folds were uncommon in the field due to the overall competance of the lithologies present. Folds were found in iron sulphide rich metasiltstones (Plate 3A) but most occurred in metasandstone interbeds within metapelites (Plate 2B). In the latter occurrence flame structures at the base of the sandstone beds are flattened parallel to the axial plane of the fold. A strong fabric is often axial planar to these folds and this is often strongly refracted across the contact of the different lithologies. Often there is a well developed biotite elongation lineation parallel to the plunge of the folds, although the fold at station 496 is an exception where the two are obviously at an angle.

At the base of some of the massive beds within the Tapanappa Formation, in the area of more open folding to the east of the Rockford Heights Syncline, there were open warps which had very linear fold axes and a reasonably constant wavelength. These were the only structures mapped as D_1 folds in subareas 4 and 7 (Figure 6), except for the mesoscopic fold at station 5. With some of these folds the biotite lineation could be seen to be at a slight angle to the axes of these folds, indicating that the lineation may have developed later.

The S_1 fabric is most strongly developed in the western half of the map area where the major folds are tightest. The origin of this fabric has been discussed at length by Mancktelow (1979a and b). Calculated intersection lineations between S_1 and bedding show some variation (Figure 6c,d), yet overall the plunge of bedding is relatively constant (Figure 6d). Biotite lineations measured in the field tend to mimic the orientations of the calculated lineations. Hence, there seems to be considerable local plunge variation, although overall variation between subareas is insignificant.

3.3.3 The D_2 crenulation deformation

A. Recognition of D_2 structures

In the sinistral limb of the Rockford Heights Syncline there is a well developed dextral fabric (Plates 1C and 4C) as well as dextral folds (Plates 1D and 3D). The folding and fabric could either be interpreted as earlier than the major upright folding, or as being later and cross cutting the earlier structures. However, mapping of the stratigraphy, and consistent younging directions (Figure 4) show that there has not been a refolding of earlier folds during the major upright folding (which was interpreted as having occurred during the first deformation). Hence, the dextral fabric and folding are interpreted as being associated with the second deformation.

Minor D_2 folds at the northern extremity of the map area and 1km further north (Figure 7) were dextral in vergence. Biotite rich laminae with a well developed S_1 fabric were crenulated and there was an associated axial planar fabric within the more psammitic beds. A well developed fabric in the north of the map area had a similar orientation to these folds and clearly had a differentiated fabric (Plate 3C), which must have developed as a crenulation cleavage.

B. Microstructure

Mancktelow (1979a) discussed at length the origin of crenulation cleavages. In his discussion Mancktelow considered volume changes between limbs of crenulations resulting from chemical diffusion. The short limb of a crenulation increases in volume during chemical diffusion and for rotation to occur beyond 90^0 would require diffusion in a reverse manner. Hence the buckle may "lock-up" when the angle between the short limb and boundary of the kink is approximately 90^0. This effect described by Mancktelow was also observed in this area (Plates 5A and 6A).

Mancktelow recognized both zonal and discrete crenulation cleavages association with the D_2 crenulation deformation. However, in the samples sectioned in this study, only zonal crenulation cleavages were recognized (e.g. Plates 3D, 5A and 6A).

Figure 7

Sketch of the style of D_2 folds as they are developed in different lithologies (approximately 1km north of the Rockford Heights area).

Figure 8

Sketch of hand specimen 404a showing the relationships between D_2, D_3, D_4 and D_5.

Figure 9

(a) (001) cleavage of coarse muscovite in a sample of pyritic metasiltstone with augen structures. A point maximum occurs, and the scatter is probably due to the grains wrapping around the metamorphic segregations (see also Plate 1B). Sample P.S.2 from Brukunga Mine. 194 orientations.
Contours 1.25, 2.50, 3.00, 10.00, 20.00 (Max. 21.13).

(b) (001) cleavage of muscovite in a lineated grey psammite in field orientation. Both the elongation of the micas and the pole to the girdle plunge in a southerly direction.
Sample 5. (See also Plates 4D and E.) 250 orientations.
Contours .56, 1.13, 2.25, 4.50, 9.00, 9.50 (Max 9.60).

FIGURE 7

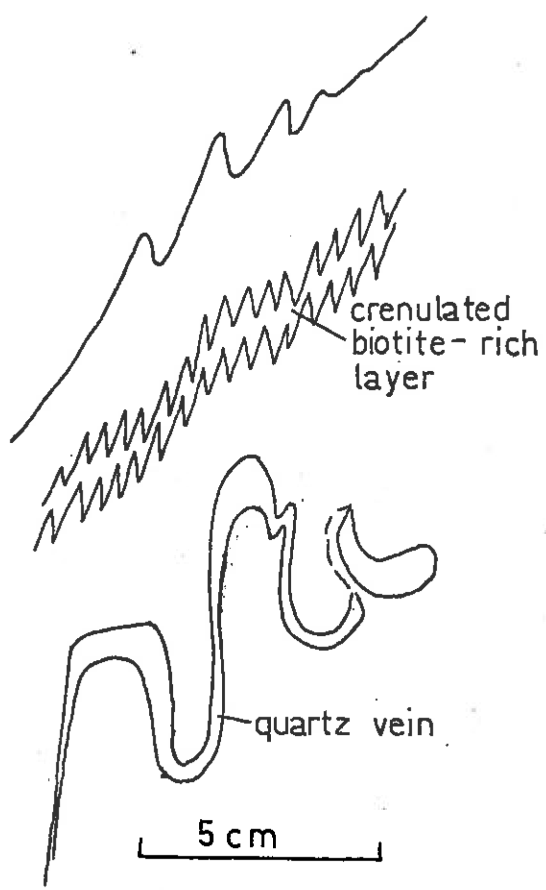


FIGURE 8

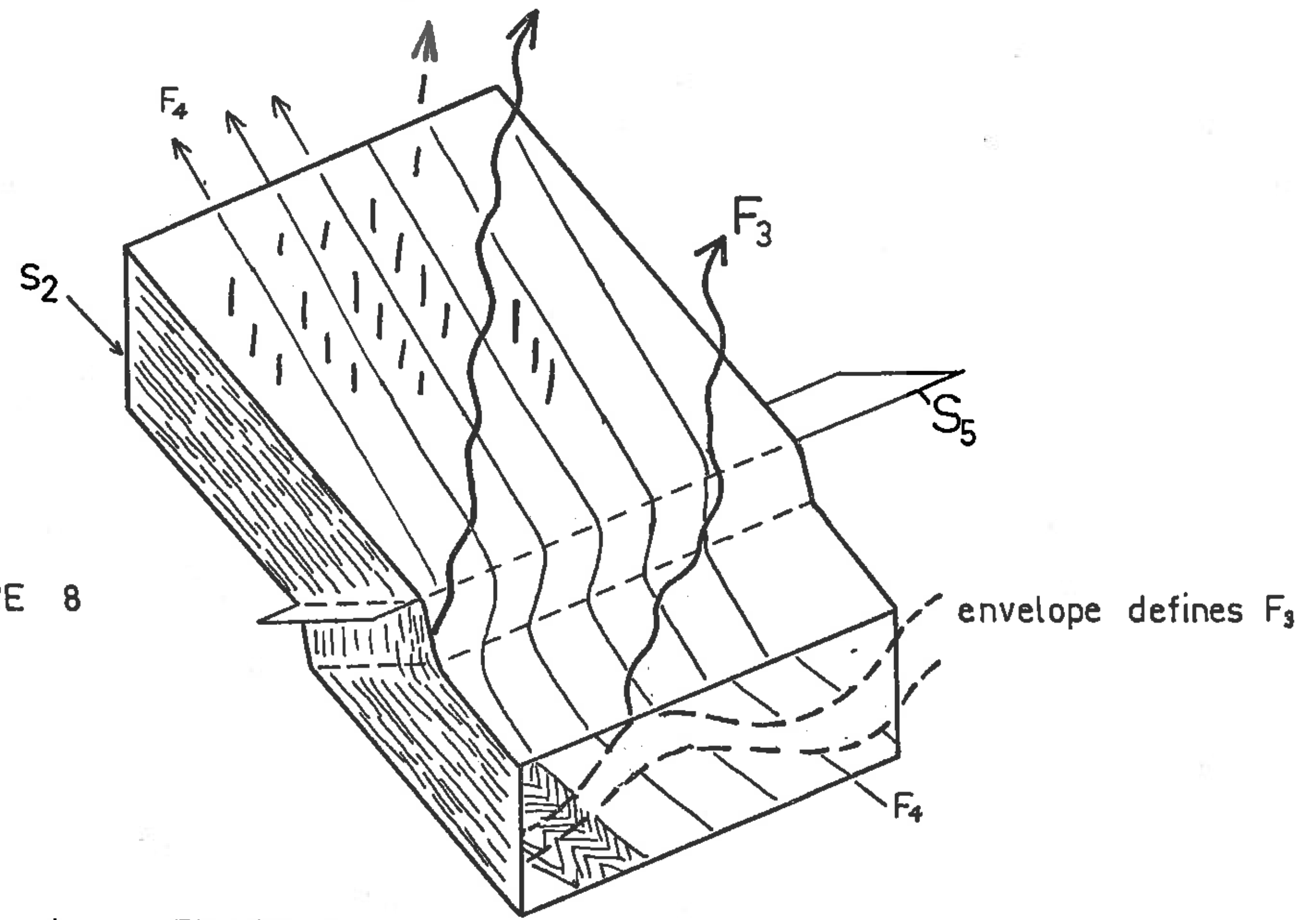
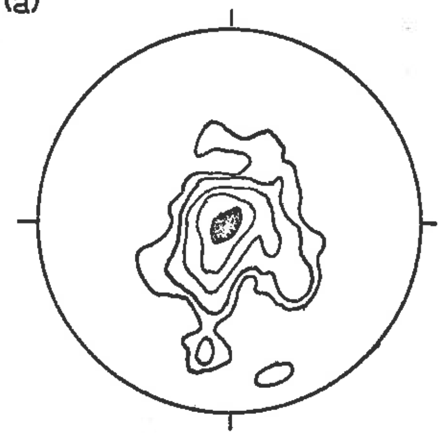


FIGURE 9

(a)



(b)

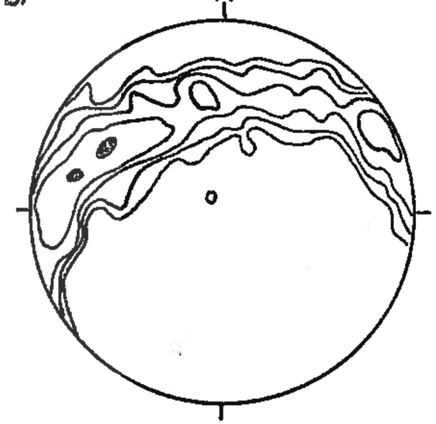


Figure 10

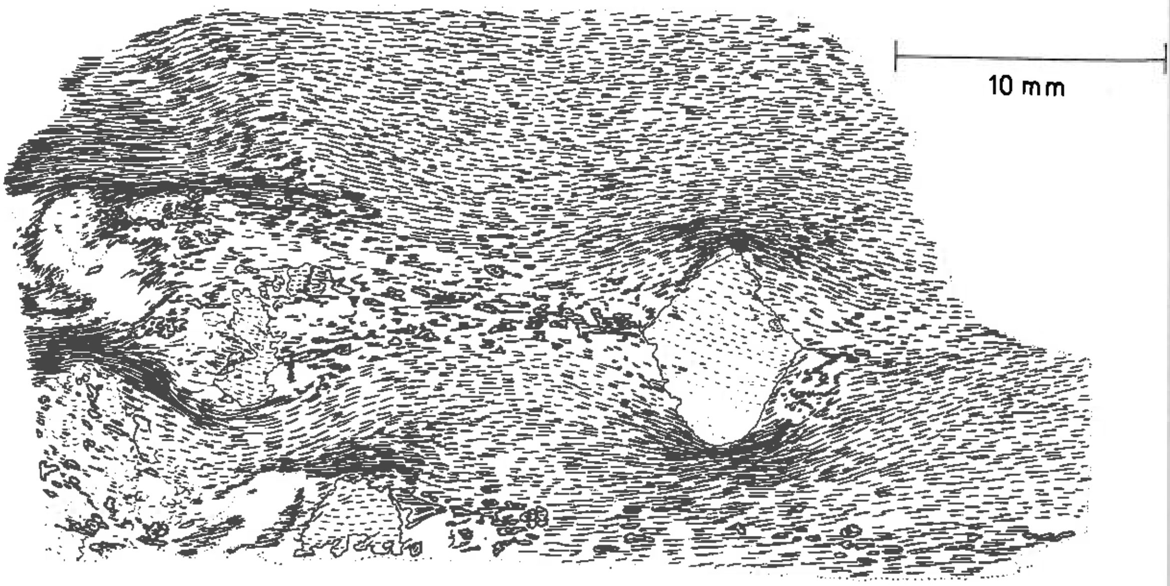
Shadowmaster sketches showing the relationships between the internal fabric of andalusites and the external fabric.

(a) Section parallel to the biotite lineation and linear pressure shadows. (Spec. 766-7)

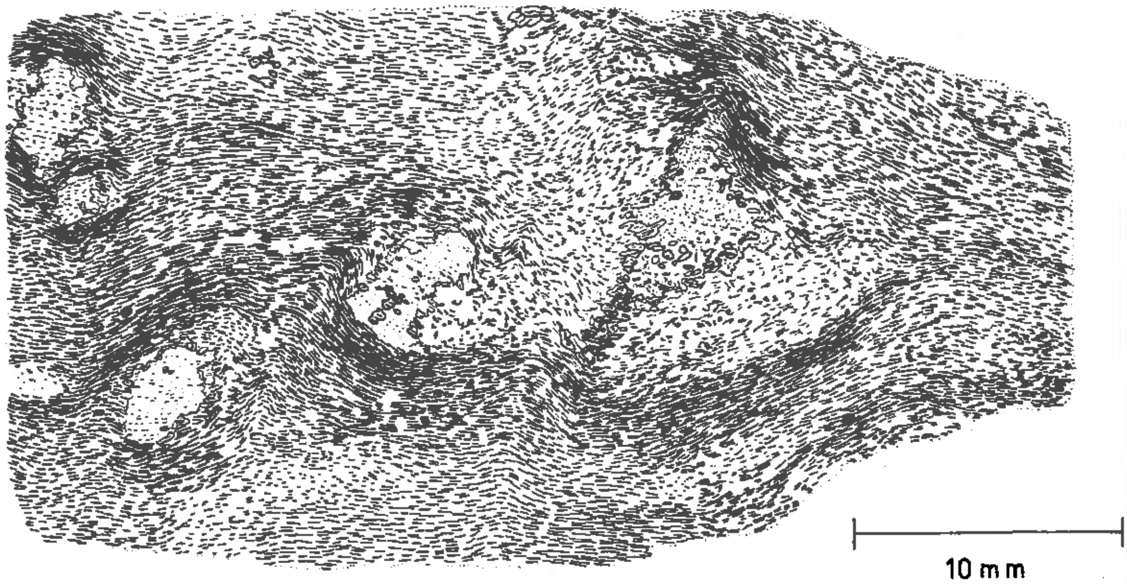
(b) Section perpendicular to the lineations. (Spec. 766-6)

(c) Higher power of one of the porphyroblasts from (b). Note the development of a later crenulation at the edge of the porphyroblast.

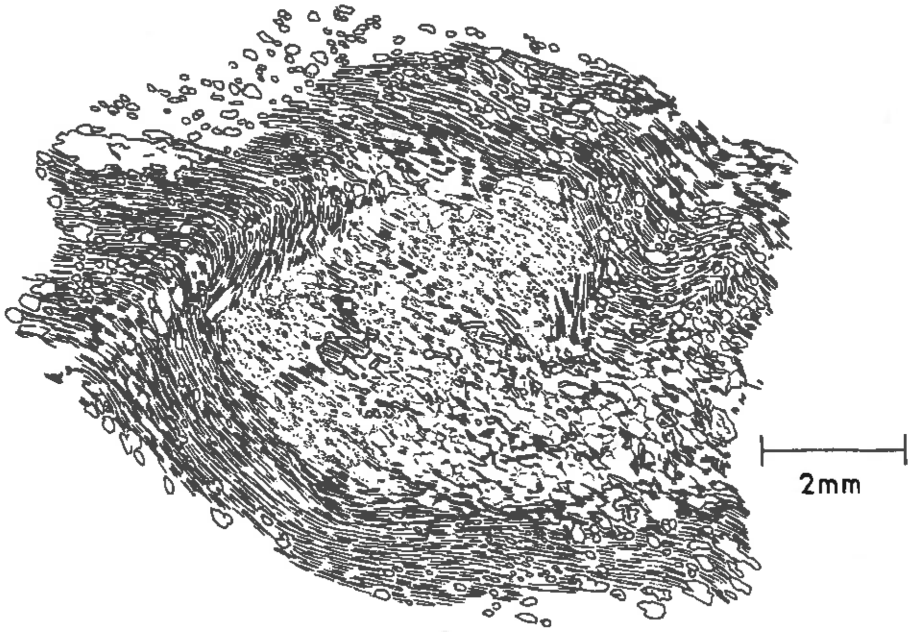
(a)



(b)



(c)



Near the region of the major open anticline, to the east of the Rockford Heights Syncline, there are structures which in the field appear to be symmetrical mullion structures. However, in thin section, tight to open crenulations have an axial plane subparallel to bedding (Plates 4A and B) and these are considered to be related to the macroscopic structures. No crenulation cleavage has developed in these layers as there is a lack of quartz to form solution gradients. In another sample of similar lithology an axial planar fabric is developed (Plate 4C). Due to the similar orientations of these structures, and the fact that their vergences are opposite to those of major first generation folds, they are interpreted as D_2 structures. Consistent with this is the observation that there are numerous short biotites at high angles to S_2 within the more quartzose layers. These are interpreted as being S_1 biotites rotated within the short limbs of D_2 folds.

The features of these folds are consistent with the kink-like nature of the D_2 crenulation deformation according to Mancktelow (1979a), as the deformation has occurred mainly by the rotation of the short limbs of crenulations. There is likely to be minimal shortening perpendicular to the S_2 fabric in these rocks.

Mancktelow (1979a) concluded that all porphyroblast growth occurred post D_1 and during D_2, and on this basis he was able to correlate the effects of D_2 in different areas throughout the fold belt. In this study it was found that the porphyroblasts could have been interpreted using a number of different models.

The simplest porphyroblasts to interpret were those consisting of andalusite. The internal fabric within these porphyroblasts (S_i) was continuous with the external fabric (S_e). These inclusion trails were curved slightly, and S_e wrapped around the porphyroblasts (see Figure 10). There was no evidence that the S_e fabric was really S_2 except for small segregations parallel to S_e defined by an enrichment in quartz and plagioclase relative to biotite. However, in one sample, there were areas within the porphyroblasts in which a fabric was orthogonal to the fabric outside of the porphyroblasts (Plate 5B). On the basis of this observation it was concluded that andalusite did crystallize after D_1, and was syntectonic with D_2. The complimentary effect of the fabric wrapping the porphyroblasts was the formation of pressure shadows which were very linear (compare Figures 10A and B). Biotite and fibrolite growth had occurred parallel to the lineation defined by the pressure shadows, and Mancktelow (1979a) suggests that this mineral growth may have been parallel to the "elongation direction of the finite strain associated with D_2."

The relationships between the staurolite growth to the deformations is more difficult to determine. The staurolite grains appear to have grown along the axial plane of dextral D_2 folds (Plate 5C). Some of the porphyroblasts in this sample appear to be warped and there is a crenulation cleavage wrapping around the ends of the bent grains. This warping is in the opposite sense to that of the D_2 folding in these rocks and is probably related to one of the later crenulation deformations. Garnet porphyroblasts within this sample were idiomorphic and were generally free of inclusions. It was not possible from this sample to determine the timing of crystallization of garnet relative to that of staurolite.

A sample examined from a higher grade area closer to Harrowgate (exact location is unknown) contained both garnet and staurolite, and the relationships between these were easier to determine (see Plate 5D). Garnets with sygmoidal inclusion trails were the first to have crystallized, probably syntectonic with D_1. The staurolite porphyroblasts in this sample appear to have grown rapidly during the development of the D_2 crenulation following which biotites wrapped around the staurolite porphyroblasts. Garnets that were not inclusions within larger staurolite porphyroblasts were rotated, probably during this latter stage of the D_2 deformation. There appears to have been later garnet growth during the recrystallization of the biotite such that biotite now abuts the rims of garnet. These rims lack inclusions. Before this latest growth of garnet the biotites probably wrapped around the garnets.

The garnets in the staurolite schist from the Rockford Heights area possibly crystallized at the same time as the rims in the sample just described. In the areas of highest metamorphic grade it is likely that high temperatures were obtained as early as during D_1 (see Mancktelow, 1979a, for a discussion of metamorphic history).

There is a lack of definitive evidence as to the timing of the growth of garnet in the samples sectioned for this study. One lithology contained folded metamorphic segregations composed of fine garnet set in a matrix of coarser quartz (Plate 6). In hand specimen it was obvious that folds of the quartz-garnet layers were dextral in vergence. An earlier fabric (S_1) has been folded with the metamorphic segregations. The fabric in this rock is therefore likely to be S_2, and is characterized by biotites being elongated parallel to the folds. The fabric in this lithology is close to being parallel to bedding.

A laminated arkose from within the Talisker Formation along the eastern limb of the Rockford Heights Syncline contained unusual ellipsoids rich in garnet and iron sulphide, these ellipsoids being oriented parallel to the fabric.

In the field the folding in this lithology was interpreted to have occurred during the first deformation as the folds approximated being class 1B, which is typical of D_1 folds (e.g. Plate 3A). However, the fabric had the appearance of being S_2 due to the variation in grainsize and orientation of biotite (see Plate 3D; compare with fabric in Plates 3B and C). These segregations do not appear to be concentrated in any particular beds, and their origin is unknown.

Another interesting lithology contained porphyroblasts of plagioclase and magnetite. Plagioclase porphyroblasts (Plate 5A) have crystallized after the crenulation "locked up" (see previous discussion). It is likely that this porphyroblast growth occurred during the D_2 deformation, or immediately following during the time of high temperature. Biotites in this sample have clearly recrystallized following the formation of the crenulations. Some growth of porphyroblasts occurred at this time as zoning within the plagioclase mimics the boundaries with biotite.

A sample of a psammitic lithology was sectioned in order to determine the nature of a well developed biotite lineation. Biotites were found to be elongated parallel to the direction of the lineation (Plates 4D and E). In the section cut perpendicular to the lineation biotites were not aligned within a foliation. The (001) cleavage of muscovite grains was measured using a universal stage and these defined a complete girdle with two point maxima. The pole to this girdle defined the direction of the lineation (Figure 9B). The biotite grains are assumed to have a similar orientation. A complete girdle would be expected if a fabric (S_1) was deformed by a crenulation deformation such as D_2, if the deformation was followed by the recrytsallization of the micas. A similar effect on the orientations of micas was obtained as a result of the crenulation of S_2; in the mica rich layers of one specimen (Plate 4C) there is a crenulation developed, whereas in the more quartzose areas of the specimen the mica orientation was similar in appearance to Plate 5D.

C. Style of folding

Mesoscopic folds were very uncommon in the field. Two examples observed were class 2 folds (Figure 7 and Plate 1C). This is consistent with the mechanism of folding being shear folding (Hobbs et al., 1976). The overall effect of an asymmetrical crenulation deformation should be to produce shear folding. Mancktelow (1979a) concluded that crenulations are analogous to kinks, which have minimal shortening perpendicular to the axial planar direction of the kink.

The fold axes of some class 1B folds of arkose beds within the Talisker Formations on the eastern limb of the Rockford Heights Syncline were parallel to the D_2 lineation defined by pressure shadows associated with andalusite porphyroblasts. Within one sample sectioned the fabric was considered to be S_2 (see Plate 6A and discussion above). Hence it is possible that different fold styles have developed within different lithologies.

D. Orientation and distribution of D_2 structures

To the east of the hinge of the Rockford Heights Syncline S_2 is usually developed in an orientation subparallel to bedding, as shown in Figure 6, subareas 1, 3 and 4. S_2 is quite well developed along this limb in all lithologies from pelites (e.g. Plates 1D and 6A) through to psammitic rocks (e.g. Plate 3B). In the metapelites the fabric is usually subparallel to bedding, whereas in the more arenaceous lithologies the fabric is shallower in dip. In the northern extremity of the map area, where the dip of the bedding is steeper, the S_2 fabric and the axial planes of D_2 folds is quite steep (Figure 6, subarea 1). It is possible that the bedding has become steeper due to the effect of D_2. Deformation of the style shown in Figure 7 would tend to steepen the dip of bedding. The second deformation may therefore be responsible for the steep dip in the northern part of the map area and in the area to the immediate north.

In the field it was difficult to determine whether the fabric present was S_1 or S_2, especially in the more psammitic lithologies. Unless the fabric was clearly a crenulation cleavage it was mapped as S_1. The recognition of S_2 in the field was especially a problem in the area west of the hinge of the Rockford Heights Syncline, where the metapsammites were relatively biotite rich. Two samples had strong fabrics defined by biotites which had varying sizes and orientations, making it appear similar to known examples of S_2 (e.g. Plates 3B and C). On the basis of its appearance this fabric was interpreted to be S_2. However, the orientation of this fabric in the field was similar to that of the fabrics mapped as S_1, and it is impossible to determine whether these fabrics formed during D_1 or D_2 without further study of thin sections. If some of the fabrics measured are S_2 this could account for the variation in orientation of calculated intersection lineations and of measured biotite lineations.

It was difficult to determine the significance of biotite lineations measured in the field. The lineations could not be correlated with either the first or second deformations on the basis of their orientations as the axes of the structures of both deformations are almost identical (Figure 6). It is suspected that the lineations are mainly related to the second deformation due to the strength of the biotite lineation within known S_2 fabrics. If this is the case there may have been significant elongate finite strain throughout the area due to the effects of D_2.

Much of the fabric developed to the west of the axis of the Rockford Heights Syncline is considered to be S_1, as this is consistent with the tighter folding in this area. On the whole S_2 was probably developed subparallel to the axial planes of the major D_1 folds except for localized regions where there were micaceous lithologies which acted as zones of weakness.

In his description of the D_2 crenulation deformation Mancktelow (1979a) emphasized that the mechanism of crenulation formation was analogous to the formation of kinks, which involves minimal shortening. He concluded that S_2 was developed in vertical zones which involved mainly vertical tectonics with minimal crustal shortening. The area of open folding immediately to the east of the Rockford Heights Syncline was represented as a D_2 syncline. On the basis of this interpretation the eastern half of the area mapped in this study should have been a zone of strong S_2 development. However, there was usually no measurable fabric at all in this area. This places some doubt on Mancktelow's interpretation of the effect of D_2, and further careful mapping of D_2 structures is needed to determine the extent of D_2 and its effect on earlier structures.

3.3.4 Post D_2 crenulation deformations

There were at least two well developed crenulation deformations developed in the Rockford Heights area. When an S_2 fabric was seen to be crenulated by two deformations the axes of both were in similar orientations, and again these plunge toward the south (Figure 6B,D). Where only one crenulation was developed it was difficult to determine if this occurred during D_3 or D_4. It was assumed during mapping that the planes of D_3 crenulations dipped toward the southeast, whereas the plane of D_4 dipped steeply, either to the east or west. On this basis, D_3 is well developed in the northwest corner of the map area, whereas throughout the rest of the area D_3 is represented by rather weakly developed folds which are strongly superimposed by the D_4 crenulation. This relationship between these two deformations is illustrated in Figure 8. In this sample there is the only example found of the fifth deformation, which is represented by a rather open kink. There is a weak fabric (S_5) developed along one surface.

It is possible that some of the biotite lineations measured in the field may have been related to either the D_3 or the D_4 crenulation deformation.

Following D_4 there was a period of recrystallization of micas. Muscovite and biotite grains that were deformed during the crenulation deformations have been recrystallized so that most of the grains do not have undulose extinction.

Faults inferred to have occurred in the southern part of the map area (Figure 4) both have similar orientations. The strike direction of these faults is similar to that of the axial plane of the D_5 fold, and may be a more brittle effect of the same deformation. Allan (1977) concluded that faulting was related to D_5 in the area she studied 45km further north along the eastern margin of the exposed fold belt.

4. METADOLERITES

Small amphibolite intrusions were mapped in the Rockford Heights area. These bodies cut across the stratigraphy locally (see Figure 4). These outcropped poorly, generally occurring in low lying areas.

One sample collected contained an inclusion with a gabbroic texture (Plate 6D). The subophitic pyroxenes have since been metamorphosed to hornblende. Generally the amphibolites consist of euhedral needles of plagioclase with interstitial hornblende. The metagabbro inclusion appears similar in texture to a coarse intrusion near Cookes Hill (23km north of Rockford Heights Station), and both may be related to the basic intrusions beneath the Murray Basin (see Wegmann, 1980).

As these rocks are metamorphosed it is considered that they were probably intruded some time during the Delamerian Orogeny.

5. POST-DELAMERIAN EVENTS

The present level of erosion was achieved by Permian times when glaciation is believed to have occurred (Daily et al., 1976). On some of the higher levels of the present topography there are remnants of a ferruginous weathering surface. These consist of red, yellow and black iron stained rocks in which the mica textures can sometimes be seen. This surface is now dipping shallowly to the east in this area. Twidale (1976) argues that the "summit surface and its lateritic capping are of "Mesozoic, probably early Mesozoic, age".

The Bremer Fault manifests itself as a prominent scarp along the western side of the Rockford Heights area (Figure 4). A zone of highly fractured rocks is associated with this scarp. Such zones have been called "crush zones" by earlier workers. To the west of the scarp some of the rocks show evidence that they were affected by the ferruginous weathering. This is in contrast to the very fresh rocks east of the scarp. It seems therefore that the fault movement occurred after the time of weathering, with the eastern side being faulted up. There is no evidence that this fault, the Bremer Fault, was active earlier and the stratigraphy does not seem to be displaced greatly. It is expected that there would be faulting parallel to the trend of the fold belt to make vertical adjustments.

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REFERENCES

ALLEN, R., 1977. Metamorphic phase relationships in the Kanmantoo. B.Sc.(Hons.) thesis, Univ. Adelaide (unpubl.).

DAILY, B., 1976. The Cambrian of the Flinders Ranges. In: Thomson, B.P. and others (eds.), Late precambrian Geology of the Adelaide 'Geosyncline' and Stuart Shelf, South Australia. 25th Int. geol. Congr. Excursion Guide No. 33A, 1-56.

DAILY, B., FIRMAN, J.B., FORBES, B.G., and LINDSAY, J.M., 1976. Geology. In: Twidale, C.R. and others (eds.), Natural history of the Adelaide Region. Roy. Soc. S. Aust., 5-42.

DAILY, B. and MILNES, A.R., 1971. Stratigraphic notes on Lower Cambrian fossiliferous metasediments between Campbell Creek and Tunkalilla Beach in the type section of the Kanmantoo Group, Fleurieu Peninsula, South Australia. Trans. Roy. Soc. S. Aust., 95: 199-214.

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

DAILY, B. and MILNES, A.R., 1973. Stratigraphy, structure, and metamorphism of the Kanmantoo Group (Cambrian) in its type section east of Tunkalilla Beach, South Australia. Trans. Roy. Soc. S. Aust., 97: 213-242.

DAILY, B., MILNES, A.R., TWIDALE, C.R. and BOURNE, J.A., 1979. Geology and Geomorphology. In: Tyler, M.J. and others (eds.), Natural History of Kangaroo Island. Roy. Soc. S. Aust., 1-38.

DAILY, B., MOORE, P.S. and RUST, B.R. Terrestrial-marine transition in the Cambrian rocks of Kangaroo Island, South Australia. Sedimentology, 27: 379-399.

DREXEL, J.F., 1978. Geology and geochemistry of the South-eastern Freeway-Mt. Barker Summit to Callington section. Department of Mines and Energy South Australia, RB 78/91.

GEORGE, R.J., 1963. Geology of the Talisker Mine area. B.Sc. (Hons.) thesis, Univ. Adelaide (unpubl.).

GEORGE, R.J., 1967. Metamorphism of the Nairne pyrite deposit. Ph.D. thesis, Univ. Adelaide (unpubl.).

MANCKTELOW, N.S., 1979a. The structure and metamorphism of the Southern Adelaide Fold Belt. Ph.D. thesis, Univ. Adelaide (unpubl.).

MANCKTELOW, N.S., 1979b. The development of slaty cleavage, Fleurieu Peninsula, South Australia. Tectonophysics, 58: 1-20.

RUPKE, N.A., 1978. Deep clastic seas. In: Reading, H.G. (ed.), Sedimentary Environments and facies. Blackwell Scientific Publications, 372-415.

SKINNER, B.J., 1958. The geology and metamorphism of the Nairne Pyrite Formation, a sedimentary sulphide deposit in South Australia. Econ. Geol., 53: 546-562.

TOTEFF, S., 1977. Geology of the Adelaidean-Kanmantoo Group sequences in the eastern Mount Lofty Ranges. Ph.D. thesis, Univ. Adelaide (unpubl.).

WALKER, R.G., 1978. Deep-water sandstone facies and ancient submarine fans: models for exploration for stratigraphic traps. A.A.P.G. Bull., 62: 932-966.

Plate 1

(a) Very fine grained meta-arkose from the Lower Member of the Talisker Formation, South Eastern Freeway. The foliation (S_2?), which is defined by crystals of muscovite, wraps around small clots containing plagioclase and opaque. Muscovite within these clots is weakly oriented at an angle to the foliation. Muscovites probably have increased in size after fabric formation. Spec. 766-23. Width of field 3.8mm (3.4m - Figure 3).

(b) Photomicrograph of Nairne Pyrite from Brukunga Mine showing the coarse grained metamorphic segregations within fine grained matrix. Andalusite is either skeletal (1) or without inclusion (2). The coarse muscovites define a fabric (see Figure 9a) which may partly wrap around the metamorphic segregations. Spec. 766-5. Width of field 9mm.

(c) Dextral second generation folds in layered semipelitic metasediments. Quartz pods are roughly parallel to layering. Station 406.

(d) Aluminous siltstone facies at base of the Talisker Formation. The fabric has a dextral vergence with quartzose metamorphic segregations parallel to the second generation fabric. There is no obvious grading within the sandstone interbeds. The sequence youngs to the right. Station 232A. Pen for scale (12.5cm) in direction of S_2 trace.

a

b

c

d

Plate 2

(a) Laterally migrating channels and low angle cross bedding in quartzites and arkoses within the Talisker Formation, in the eastern limb of the Rockford Heights Syncline. Station 234. The outcrop is 1.3m high.

(b) Folded laminated metasandstone layer within the Talisker Formation from the hinge of the Rockford Heights Syncline. The first deformational fold is symmetrical, this being consistent with it being in the hinge of the major fold. Flame structures (just to the right of the hinge) are flattened parallel to the axial plane. Station 343. Hammer 58cm long.

(c) Liquifaction structures within the Talisker Formation in the eastern limb of the Rockford Heights Syncline. The top of these structures have been truncated revealing younging direction. Station 9.

(d) Same contorted layer as in Plate 2c (below pen) 2m northwest of station 9 showing liquifaction structures. Overlying this convoluted layer are laminated quartzites (5cm), which are overlain by trough cross bedded sandstones, which have eroded into the layers below.

a

b

c

d

Plate 3

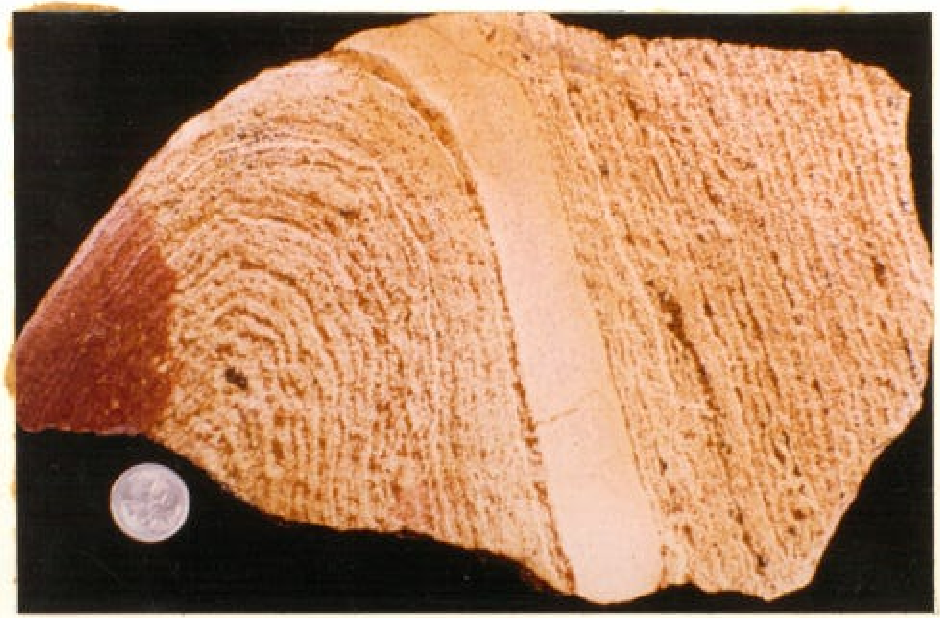
(a) First deformational fold in layered pyritic metasiltstone has a fabric which is roughly axial planar. Red colour due to iron staining. Station 56. Coin 19mm diameter.

(b) Photomicrograph of dextral S_2 fabric in laminated feldspathic sandstone. Note the variation in size and orientation of biotite crystals. Spec. 766-55. Width of field 9mm.

(c) Photomicrograph showing the development of S_2 in different lithologies. The more pelitic lithology has a well developed differentiated fabric, whereas in the more arenaceous lithology the fabric could be mistaken for S_1. Spec. 766-59. Width of field 9mm.

(d) Laminated arkose interbed from within the Talisker Formation in the eastern limb of the Rockford Heights Syncline. Bedding (S_0), defined by different concentrations of biotite, has been folded. Due to the nature of the fabric (see text) this has been interpreted as a second generation fold. Parallel to the fabric are segregations rich in garnet and lesser amounts of pyrite. The occurrence of these segregations is not related to bedding. Specimen 766-39. Width of field 9mm.

a



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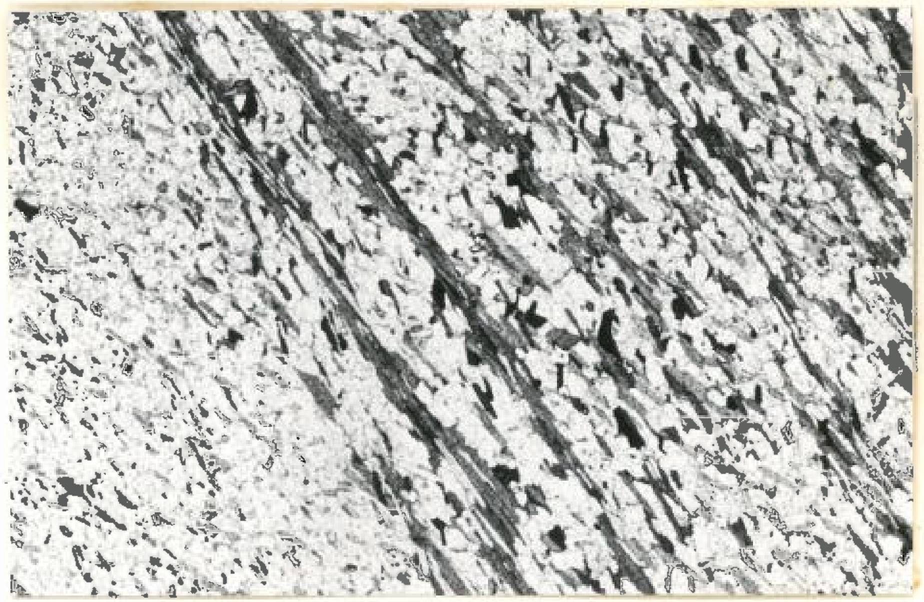

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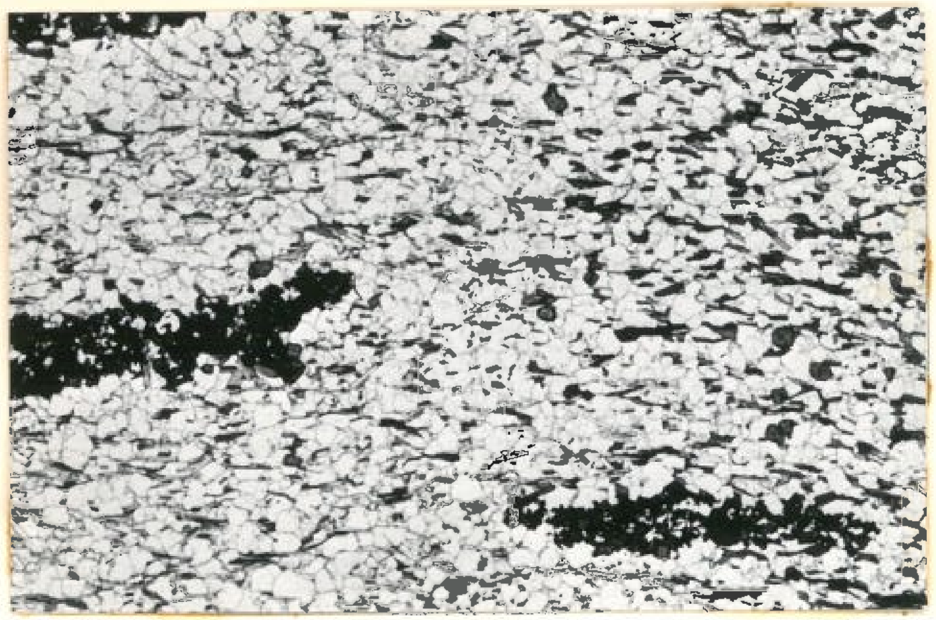


Plate 4

(a) Photomicrograph showing sinistral second generation folds of muscovite rich layers (thought to represent S_0). The tight crenulations within these mica rich layers reveal that the axial planar direction of the larger folds is subparallel to bedding. Spec. 766-36. Width of view 35mm.

(b) Higher magnification of the muscovite rich layers showing the concentrations of biotite at their edges. There has been recrystallization of the micas following the tight crenulation (D_2). Spec. 766-36. Width of view 9mm.

(c) Dextral second generation fold with an axial planar fabric defined by muscovite and biotite. Note that the style of folding is similar to that in the previous two photomicrographs. S_2 has been crenulated during either D_3 or D_4, the axial trace being almost orthogonal to S_2. Recrystallization following this crenulation causes the biotites to appear random in orientation. Spec. 766-40. Width of view 18mm.

(d) Apparently random orientation of micas in a section cut perpendicular to the lineation within a grey psammite from the Tapanappa Formation. Universal stage measurements of muscovite (001) cleavage revealed a complete girdle (see Figure 9b). Spec. 766-24. Width of view 9mm.

(e) Same specimen as in Plate 4(d) sectioned parallel to the lineation showing the elongate nature of both biotite and muscovite. Spec. 766-25. Width of view 9mm.

Plate 4

(a) Photomicrograph showing sinistral second generation folds of muscovite rich layers (thought to represent S_0). The tight crenulations within these mica rich layers reveal that the axial planar direction of the larger folds is subparallel to bedding. Spec. 766-36. Width of view 35mm.

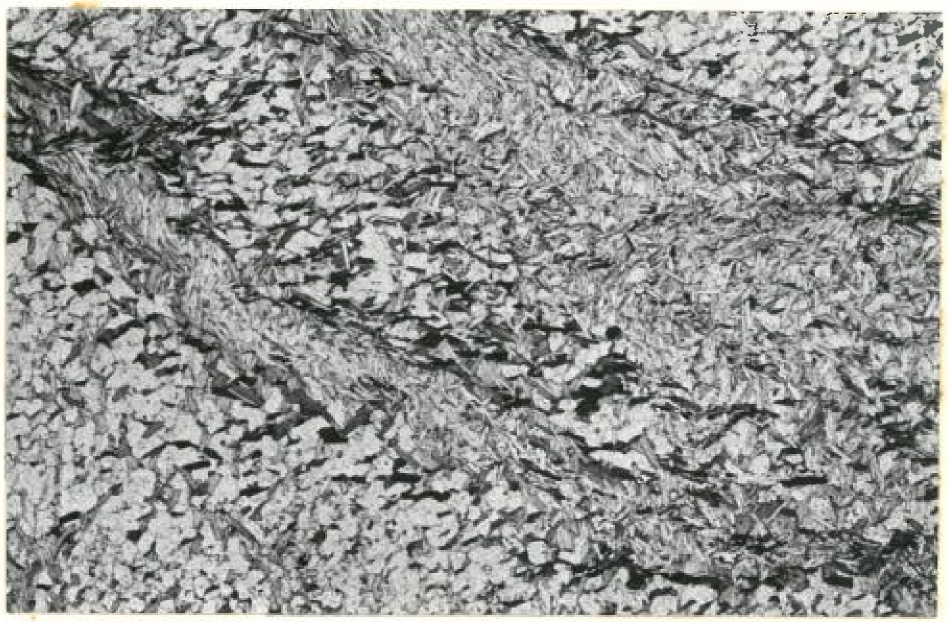
(b) Higher magnification of the muscovite rich layers showing the concentrations of biotite at their edges. There has been recrystallization of the micas following the tight crenulation (D_2). Spec. 766-36. Width of view 9mm.

(c) Dextral second generation fold with an axial planar fabric defined by muscovite and biotite. Note that the style of folding is similar to that in the previous two photomicrographs. S_2 has been crenulated during either D_3 or D_4, the axial trace being almost orthogonal to S_2. Recrystallization following this crenulation causes the biotites to appear random in orientation. Spec. 766-40. Width of view 18mm.

(d) Apparently random orientation of micas in a section cut perpendicular to the lineation within a grey psammite from the Tapanappa Formation. Universal stage measurements of muscovite (001) cleavage revealed a complete girdle (see Figure 9b). Spec. 766-24. Width of view 9mm.

(e) Same specimen as in Plate 4(d) sectioned parallel to the lineation showing the elongate nature of both biotite and muscovite. Spec. 766-25. Width of view 9mm.

a

b

c

d

e


Plate 5

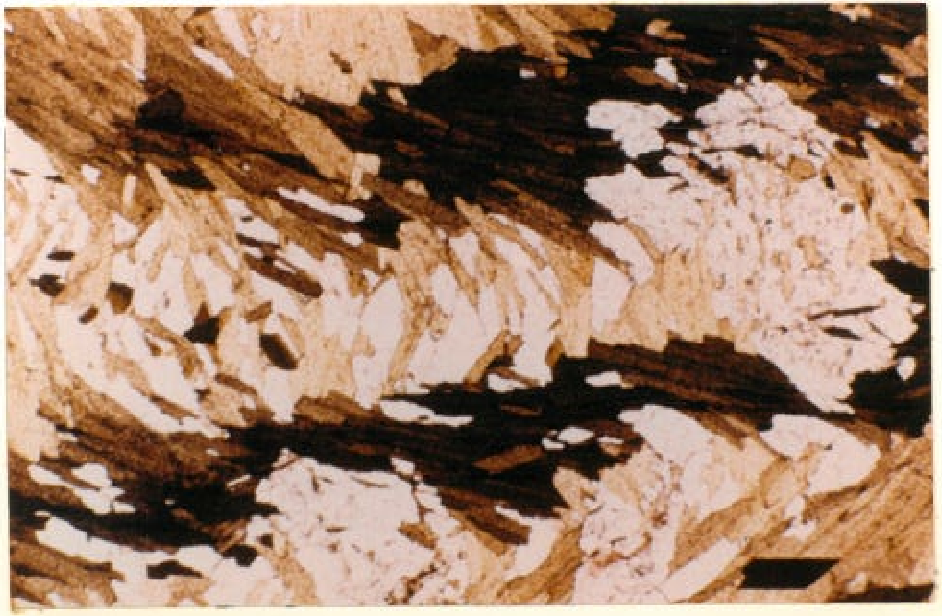
(a) Coarse crenulated biotite schist with porphyroblasts of plagioclase which have inclusions of biotite. These porphyroblasts have grown after the crenulation (probably second deformational). The biotites also have recrystallized after the crenulation. Spec. 766-48. Width of view 7.5mm.

(b) Large andalusite porphyroblast with an inclusion preserving S_1. The curved inclusion trails within part of the porphyroblast are continuous with S_1, yet in the other part they wrap around the inclusion. The fabric (S_2) wraps around the porphyroblast causing concentrations of micas at the pressure points and pressure shadows at the other edges. The history is complicated by a later crenulation (D_3?). Spec. 766-23. Width of view 9mm.

(c) Porphyroblastic garnet staurolite schist sectioned perpendicular to the lineation. Staurolites appear to have grown in the axial planes of second generation dextral folds (this section was cut on the underside of the rock so that the folds appear to be sinistral in this photograph). A crenulation weak cleavage has developed during this deformation. Garnet growth has mimicked the biotite rich layers during later recrystallization. Spec. 766-21. Width of view 18mm.

(d) Porphyroblastic garnet staurolite schist. Garnets with sigmoidal inclusion trails grew before staurolite. The staurolite grew after the broad crenulation developed and the fabric wraps around the staurolite. Spec. 171-71. Width of view 18mm.

a



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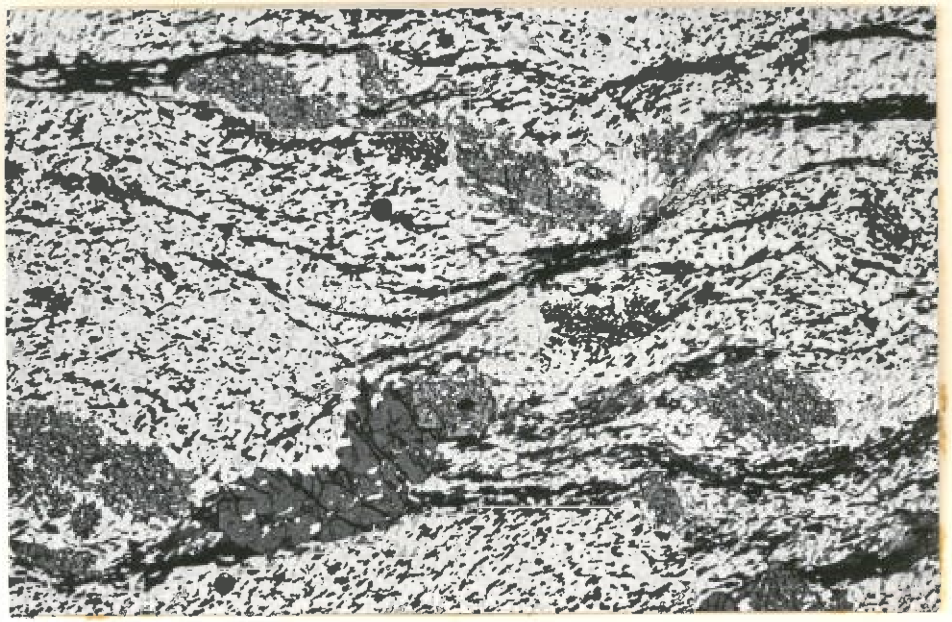

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Plate 6

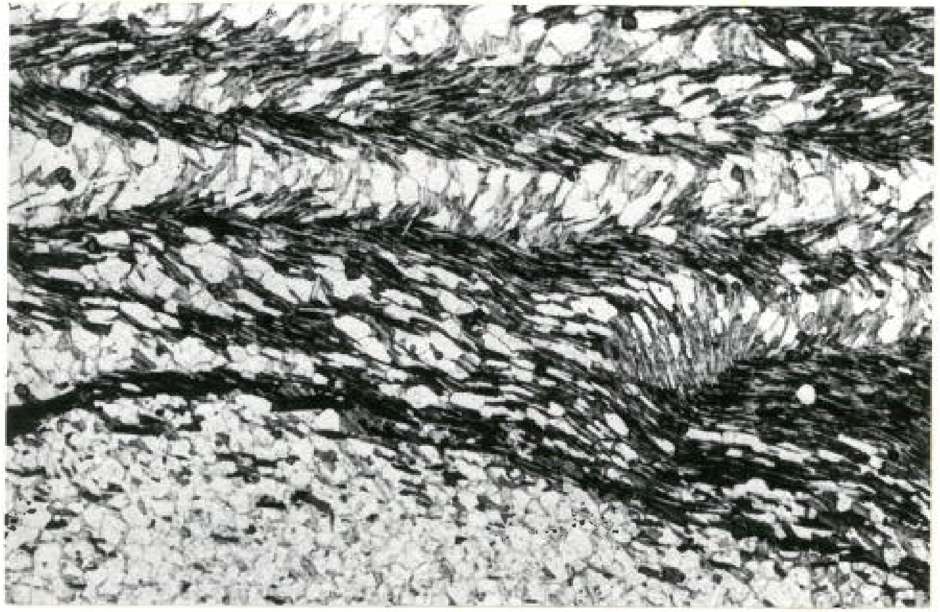
(a) Quartz biotite schist showing variable development of probable second generation folds of the S_1 fabric. Spec. 766-47. Width of view 9mm.

(b) Folded segregations of garnet and quartz within a biotite schist. Both the segregations and the early fabric (S_1) were folded during the second generation. Spec. 766-32. Width of view 9mm.

(c) Metamorphosed calc silicate from the Tapanappa Formation containing quartz, plagioclase and hornblende. Quartz occurs mainly as large grains with undulose extinction. Plagioclase (twinned) has numerous inclusions of quartz. Spec. 766-57. Width of view 3.8mm.

(d) Inclusion within a metadolerite displaying subophitic textures. The inclusion is 4cm long. Spec. 368.

a



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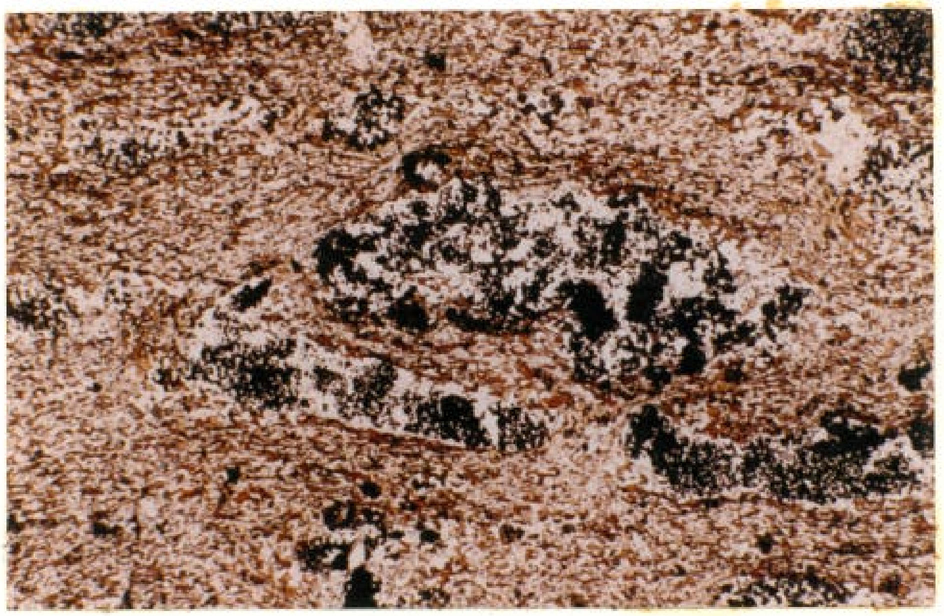

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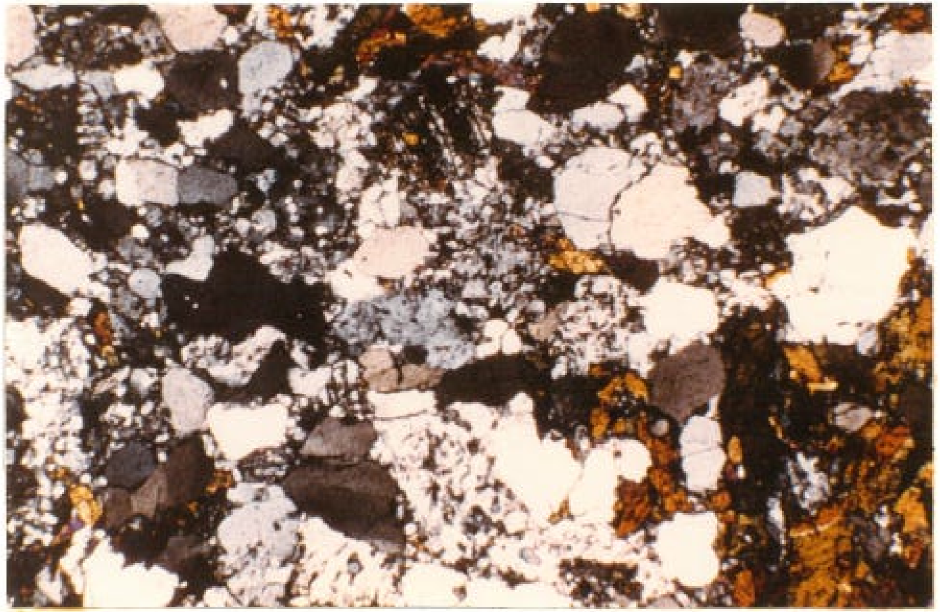

d

APPENDIX A.

Sample and photographic locations.

(S)	=	etched and stained with sodium cobaltinitrite.
U-stage	=	Universal stage measurements on 001 of muscovite.
P.M.	=	Photomicrograph.
P	=	Photograph taken in the field.

Location	Sample No.	Thin Sections		
3.4m (Fig. 3)	A	766-23	2x1 (S)	P.M. Plate 1A
Freeway roadcut	B	-2	3x1	
" "	C	-9	3x1	
83m (Fig. 3)	D			
Brukunga Mine	P.S.2	5	2x1 U-stage	Plate 1B
" "	E	4	3x1 (S)	
Monarto (234238)	F	17	3x1 (S)	
		18	3x1 (S)	
Monarto (237239)	G	16	3x1 (S)	
Tepko (266263)	H	6	3x1)	Figure 14
		7	3x1)	
"Harrowgate"	I	171-71	3x1	P.M. Plate 1C
Monarto (308223)	J	766-11	3x1	
<u>Rockford Heights Area</u>				
2	1	766-43	3x2 (S)	
3	3	47	3x2	P.M. Plate 6A
	4	39	3x2 (S)	P.M. Plate 3D
5		24	2x1 (S)	P.M. Plate 4D
		25	2x1 (S))	P.M. Plate 4E
9		25	2x1	)U-stage
				P Plates 2C and D
10	7	37	3x2 (S)	
	8	40	3x2 (S)	Plate 4C
11A	5	36	3x2 (S)	
	6	38	3x2 (S)	
21		56	2x1 (S)	
56		Photograph of hand specimen Plate 3A		
91a		766-22	3x2 (S)	
91b		35	3x2	
91c		32	3x1	
96		30	3x2	
99		27	3x2 (S)	
		28	3x2	
117b		52	3x2	
128		20	3x2	
		21	3x2	P.M. Plate 5B
232a				P. Plate 1D
e		49	3x2 (S)	
234				P. Plate 2A

Location	Sample No.	Thin Sections	
239		766-33 3x1	
296		31 3x2 (S)	
		32 3x2 (S)	P.M. Plate 6B
299a		42 3x2	
343			P. Plate 2B
350		59 2x1 (S)	P.M. Plate 3C
368		Photograph of hand specimen	Plate 6D
384B		54 2x1 (S)	
386		45 3x1 (S)	
387		57 2x1 (S)	
404a			Figure 8
406		48 3x2	P.M. Plate 5A
		2x1	Polished Thin
			P. Plate 1C
479		50 3x2	
501		51 3x1	P.M. Plate 6C
524		55 2x1 (S)	P.M. Plate 3B

APPENDIX B.

Sample Descriptions

(1) Specimens are numbered on the basis of station numbers from the Rockford Heights Map area. Other locations, unless stated otherwise, are given by a six figure grid reference from the South Australian Lands Department 1:50000 topographic map series.

(2) Specimens are grouped according to lithology to avoid repetition. The first description within each group is the most general and those following explain any differences.

(3) Mineral Abundances are described in terms of major, minor and trace amounts. These classifications are approximate. Major minerals compose at least 15% of the section, minor 5 to 15%, and trace less than 5%. Minerals are listed in terms of abundance.

(4) The main aim of these descriptions is to present data relevant to the structural histories of the different lithologies.

SPECIMENS FROM FREEWAY CUTTING

Very fine grained pyritic meta-arkose

A.

Location: 3.4m - Figure 3.

Hand Specimen: Two faintly laminated fining upwards beds (2cm). Fabric subparallel to bedding. Fabric wraps around small clots within the finer grained layers.

Thin Section: 776-23 - cut perpendicular to faint lineation on bedding surfaces.

Mineralogy: Plagioclase, Quartz, Muscovite; Biotite; Iron sulphide, Jarosite

Photomicrograph: Plate 1A.

Description: Two fining upward layers defined by a decrease in grainsize of quartz and plagioclase, and an increase in mica content. Fabric (S_2) defined by orientation of muscovite. Fabric wraps around small metamorphic segregations consisting mainly of plagioclase with lesser amounts of quartz and opaque. Quartz plagioclase and micas have recrystallized after deformation resulting in even grainsize and unstrained crystals. Micas appear to have undergone some degree of mimetic growth after the formation of the fabric.

Laminated pyrite-andalusite-muscovite-quartz-plagioclase metasiltstone with coarse grained metamorphic segregations ("Augen"). (Nairne Pyrite)

B.

Location: specific location was not recorded.

Hand Specimen: Strongly layered. Scattered slightly elongate metamorphic segregations occur throughout the specimen. These are about 5cm in diameter and are flattened in the fabric.

Thin Section: 766-2 - cut parallel to the lineation defined by metamorphic secretations.

Mineralogy: Fine grained matrix: Quartz, Plagioclase, Muscovite, Pyrite(?)

Coarse grained "augen": Quartz, Andalusite, Pyrite(?), Muscovite

766-2 (cont.)

Description: Highly weathered rock due to the presence of iron sulphides. Strong fabric (S_2) defined by the orientation of muscovite within the fine grained matrix. This is the only sample of this lithology with this feature. Fabric wraps around the coarse grained augen, and the augen are flattened in the fabric. The fine grained matrix was being replaced by the coarse grained material. Hence these metamorphic segregations are likely to be syntectonic with S_2.
Andalusite within these augen have no inclusions and are fractured. Metamorphic segregation appears to have been parallel to bedding.

C.

Location: bottom bench of Freeway cutting.

Hand Specimen: Pyrite dispersed throughout the rock. Weakly layered. Augen are not obvious.

Thin Section: 766-9 - cut approximately perpendicular to the lineation defined by the augen. Matrix consists of quartz and plagioclase Muscovite does not occur. Coarse pyrite is scattered throughout the section. Muscovite and andalusite are common in the coarse grained areas. Again augen have no plagioclase.

Laminated pyritic metasiltstone

D.

Location: 83m - Figure 3.

Orientation: 166/42 NE.

Hand Specimen: Strongly layered rock. Thin layers had concentrations of sulphides, which have been leached out. There are no augen structures.

SPECIMENS FROM BRUKUNGA MINE

Laminated pyrite-andalusite-muscovite-quartz metasiltstone with coarse grained metamorphic segregations (Nairne Pyrite).

PS2 (Sample collected by J. Schiller)

Hand Specimen: Similar to B, but augen are more numerous.

Thin Section: 766/5 - cut perpendicular to layering.

Description: Numerous metamorphic segregations containing opaques, andalusite and coarse muscovite, which was found to have a strongly preferred orientation.

Photomicrograph: Plate 1B.

Pyritic Calc-silicate

E.

Hand Specimen:	Calc-silicate layer (15mm) has coarse iron sulphides. Bedding in material surrounding the calc-silicate is defined by concentrations of sulphides. There are no metamorphic segregations. Veins with pyrite are perpendicular to bedding.		
Thin Section:	766/4 Calc-silicate layer.		
Mineralogy:	Quartz Tremolite Opaque	Phlogopite Plagioclase	Sphene Jarosite
Description:	Coarse tremolite, opaque and phlogopite in a matrix of quartz with smaller inclusions of plagioclase. Metasiltstone next to calc-silicate.		
Mineralogy:	Plagioclase Quartz	Opaque	Muscovite Chlorite Sphene.
Description:	Recrystallized very fine grained quartz and plagioclase with scattered coarse opaques. Occasionally there is coarser quartz. Muscovite does not occur until 2cm from the calc-silicate.		

SPECIMENS FROM SOUTH OF THE ROCKFORD HEIGHTS MAPPED AREA

Pyritic metasiltstone

F.

Location:	Monarto (234238)	
Hand Specimen:	White leached rock with strong fabric. Small elongate areas of red staining define a lineation on the fabric surface.	
Mineralogy:	Muscovite Quartz	Iron sulphides(?) Jarosite
Thin Sections:	766/17 - a section 766/18 - b section	
Description:	Very strong fabric (S_2) defined by muscovite. There are thin layers of coarse quartz parallel to the fabric, and these probably define the lineation. 17: Muscovite very elongate. Quartz is flattened in the foliation. 18: Muscovite not as elongate. There are a few grains of muscovite at high angles to the foliation indicating that there has been mimetic growth following the formation of the fabric.	

G.

Location:	Monarto (237239)		
Hand Specimen:	Similar to F. Small vugs contain jarosite. There appears to be tight folding.		
Thin Section:	766/16 - cut perpendicular to folding.		
Mineralogy:	Microcline	Quartz	Jarosite
	Plagioclase		
	Muscovite		
Description:	Highly leached rock. Strong fabric (S_2) defined by muscovite. Bedding is defined by coarse microcline. Fabric is axial planar to folding. Feldspars have small inclusions of quartz.		

SPECIMENS FROM THE ROCKFORD HEIGHTS MAP AREA

Metasandstone and meta-arkoses

5B.

Hand specimen:	Grey with "salt and pepper" texture defined by biotites. Has a strong lineation on bedding surface.		
Thin Sections:	766/24 - b section		
	/25 - a section		
Mineralogy:	(Point Count 766/25; 1630 points)		
	62% Quartz	6% Muscovite	1% Apatite
	Plagioclase		Zircon
	Alkali feldspar		Tourmaline
	31% Biotite		Sphene
Description:	Biotite and muscovite elongate in direction of lineation, and appear almost random in 766/24. Muscovite orientations were measured on a universal stage and these define a complete girdle with two point maxima. Quartz is recrystallized to hexagonal shapes at the expense of biotite grain boundaries. Boundaries between biotites reveal that there has been recrystallization after the deformation that caused their present orientation.		

Photomicrographs: Plates 4D and E.

21

Hand Specimen:	Faintly laminated with layers changing in biotite content. Very open fold with axial planar fabric.		
Thin Section:	766/56.		
Mineralogy:	Quartz	Biotite	Muscovite
	Alkali feldspar		
	Plagioclase		

21 (cont.)

Description: Quartz is coarser than the feldspars, and has undulose extinction. Biotites are well aligned and probably represent S_1. Coarse post-tectonic muscovite has a random orientation.

384b

Hand Specimen: Weathered surface gives the appearance of being a differentiated fabric (S_2).

Thin Section: 766/54

Mineralogy Quartz
Plagioclase
Biotite

Description: Quartz almost invariably coarser than plagioclase. Bedding defined by grainsize of quartz. There are two populations of biotite. There are elongate biotite and muscovite grains forming a strong fabric (S_2). Biotites domains of S_2 are short and at an angle. Domains of S_2 are irregular in length and differentiation is not well developed. Between these domains biotites are short and weakly oriented, at an angle to S_2.

386

Hand Specimen: Strong foliation causing parting. On cleavage surface strong lineation. White feldspars are obvious and are elongated parallel to the biotite lineation.

Thin Section: 766/45

Mineralogy Quartz
Plagioclase
Biotite

Description: Biotites very well aligned and are elongate. Fabric may be S_2. Quartz often has a convex boundary when in contact with plagioclase. Plagioclase crystals tend to be grouped together.

387

Hand Specimen: Bedding is revealed by a change composition. The more biotite layer has a well developed fabric. There is a very strong lineation on the foliation surface defined by biotite.

Thin Section: 766/57.

387 (cont.)

Mineralogy: Coarse Layer: Quartz
Plagioclase
Biotite

Mineralogy More pelitic layer:
Quartz Plagioclase
Biotite
Muscovite

Description: In the more pelitic layer the fabric is defined by an intergrowth of elongate biotite and muscovite. This anastomosing fabric wraps around areas richer in quartz and/or plagioclase. This fabric is probably S_2. In the more quartz rich layers short biotites define a fabric. These biotites vary in grain-size and are at slightly varying angles to each other. The fabric appears to be refracted between the layers.

524

Hand Specimen: Bedding defined by more biotite rich lamellae. Fabric (S_2) is dextral to bedding.

Thin Section: 766/55

Mineralogy Quartz Muscovite
Plagioclase
Biotite

Description: Fabric (S_2) defined by biotite and muscovite, which show some variation of orientation.

Photomicrograph: Plate 3B.

350

Hand Specimen: Dominantly mica rich arkose with faint lamination preserved. Has a more arenaceous layer. The more pelitic part has a dextral S_2 fabric at a low angle to bedding. There is no lineation on S_2 surfaces.

Thin Section: 766/59.

Mineralogy: Pelitic layer Quartz Alkali feldspar
Biotite
Plagioclase
Muscovite

Mineralogy: Arenaceous layer: Quartz Biotite
Plagioclase
Alkali Feldspar

350 (cont.)

Description: Biotite has unusual pleochroic colours from greenish yellow to very dark greenish brown. In the pelitic section there is a strong S_2 fabric defined by elongate biotite and muscovite. In some parts of the section the fabric is obviously differentiated with shorter biotites within the microlithons.

In the arenaceous layer the fabric could be mistaken for S_1, but the micas vary in elongation and vary somewhat in orientation.

Photomicrograph: Plate 3C.

Garnet Pyrite Laminated Arkose

3. (Sample "4")

Hand Specimen: Pale brown with laminations richer in biotite. Bedding is folded (D_1). Strong fabric close to being axial planar. Light brown patches parallel to fabric. There is no biotite lineation on cleavage surfaces.

Thin Section 766/39.

Mineralogy:	Quartz	Biotite	Garnet
	Plagioclase	Muscovite	Iron Sulphide
			Fibrolite
			Jarosite

Descriptions: Biotite pleochroism from straw yellow to foxy red. Fabric (S_2?) defined by elongate biotite and muscovite. There are thin discs at a slight angle to the fabric consisting of garnet and opaque (iron sulphide?). The fabric wraps around these in a couple of examples. These discs are 2 to 4mm in diameter and 0.5mm wide. Their distribution is not related to folding.

Photomicrograph: Plate 3D.

Metasandstone with climbing ripples

96

Hand Specimen: Due to laminations the moderately tight (F_2?) folds are visible.

Thin Section 766/30.

Mineralogy	Quartz	Garnet
	Feldspar	
	Biotite	

96 (cont.)

Descriptions: Biotite orientation is related to folds, which are therefore not due to overturned cross bedding. Biotite orientations vary greatly throughout section. Garnet in this rock has a unique appearance in that the crystals have irregular boundaries and numerous inclusions. There are post tectonic muscovites at random orientations which have grown at the expense of biotite. A section closer to perpendicular to F_1 would be needed to interpret the biotite orientations.

Phyllite Chip Conglomerate

99

Hand Specimen: Has large irregularly shaped clasts of phyllite and smaller quartzose fragments.

Thin Sections: 766/27 - b section
28 - a section.

Mineralogy:

Quartz	Muscovite
Plagioclase	Sphene (rounded)
Biotite	Apatite

Description: Lithic fragments contain quartz and plagioclase. Phyllite chips contain biotite and plagioclase. In the matrix quartz varies in grainsize and is coarser than plagioclase. Fabric wraps around coarse quartz. Phyllite chips flattened in L.S. Fabric (S_2?). Rounded apatite grains are grey in colour and have numerous aligned inclusions and clear overgrowths.

Calc-silicate

479

Hand Specimen: Lineation defined by distribution of dark amphibole.

Thin Section: 766/50.

Mineralogy

Quartz	Hornblende	Calcite
Epidote	Plagioclase	Garnet
		Clinozoisite
		Sphene
		Zircon
		Scapolite

Description: Largely quartz with crude layers with various minerals. Within these layers there are possible detrital quartz grains.

Float upstream from 505

Hand Specimen: As above.

Thin section: 766/51.

Mineralogy: Quartz, Plagioclase, Hornblende, Clinozoisite, Allanite, Sphene

Description: Quartz grains are rounded and have undulose extinction. They appear to be detrital. The other minerals have recrystallized around the quartz.

Photomicrograph: Plate 6C.

Crenulated Biotite Schist

2 (Sample "1")

Hand Specimen: Folded pelitic rock. Limbs are straight and there are crenulations in the hinge regions. Wavelength of the folding is 8cm. A strong fabric has been crenulated.

Thin Section: 766/43.

Mineralogy: Quartz, Biotite, Muscovite, Plagioclase

Description: A fabric of intergrown biotite and muscovite (S_1?) has been crenulated (D_2) and then recrystallized. Only a few long muscovite grains are slightly bent.

3 (Sample "3")

Hand Specimen: Very strong L.S. fabric defined by biotite. This is clearly a differentiated fabric (S_2). There are faint quartzose layers which are variously folded. The vergence is not consistent, so part of the folding is probably due to D_1 deformation.

Thin Section: 766/47

Mineralogy: Quartz, Biotite, Muscovite, Garnet, Plagioclase, Fibrolite, Apatite

Description: The S_1 fabric is defined by intergrowth of biotite and muscovite The D_2 crenulation is varying in development. A differentiated fabric grades a fabric characterized by anastomosing micas. Garnet occurs scattered throughout the mica-rich areas. Micas within quartz rich areas appear random in orientation.

Photomicrograph: Plate 6A.

299A (Sample "10")

Hand Specimen: Tight flat lying folds with an axial planar differentiated fabric (S_2).

Thin Section: 766/42.

Mineralogy:			
	Quartz	Plagioclase(?)	Garnet
	Biotite		
	Muscovite		

Description: Symmetrical tight D_2 folds of S_1 fabric have tight crenulations within the hinges giving the appearance of a new fabric. There has been solution of quartz associated with this deformation so that a zonal crenulation cleavage was being approached. A later deformation (D_3?) has crenulated the earlier structures and has been followed by a period of mica recrystallization. D_3 varies in orientation. This variation would not be due to later deformation as the orientation of S_2 has not changed.

404A

Hand Specimen: Strong fabric is possibly differentiated (S_2). D_3 folding has caused open folds which have been deformed by the more prominant D_4. All previous structures have been deformed by D_5 which involved kink like folds with a weak axial planar development.

Figure 8.

Layered mica-quartz rocks

10 (Sample "8")

Hand Specimen: Open dextral fold (F_2). Fabric subparallel to bedding. On the fabric surfaces there are two crenulations with about 15^o between them.

Thin Sections: 766/40 - perpendicular to axis of D_2.
41 -

Mineralogy:			
	Quartz	Garnet	Tourmaline
	Biotite	Plagioclase	Apatite
	Muscovite		Zircon

10 (cont.).

Description: Fabric (S_2) is clearly axial planar to the fold, and due to the nature of the folding is parallel to S_0 in the links (but not parallel to the envelope of S_0). Within the mica rich layers there is no evidence that the fabric is post S_1. However, in the more quartzose layers there are often short stumpy biotite crystals at high angles to the fabric and these are interpreted as the short limbs of D_2 crenulations. One of the two crenulations can be seen in the sections, almost perpendicular to S_2. There has been mimetic growth after this crenulation.

Photomicrograph: 4B.

11A (Sample "5")

Hand Specimen: There is a strong banding of mica rich layers about 1cm apart. These layers are folded into sinistral folds.

Thin Section: 766/36

Mineralogy: Quartz, Muscovite, Biotite, Plagioclase, Apatite

Description: The dominant biotite direction (S_1) in quartzose layers is at a high angle to bedding. There is a tight crenulation within the mica rich layers and this is related to the mesoscopic folding.
Muscovite rich layers are bounded by a concentration of biotite.

Photomicrographs: Plates 4A and 4B.

11A (Sample "6")

Hand Specimen: Evenly spaced mica rich layers. Mullion structures at base of beds.

Thin Section: 766/38

Mineralogy: Quartz, Biotite, Muscovite, Plagioclase

Description: Again the crenulation is related to mesoscopic folding. Similar to Sample "5".

Photomicrograph:

10 (Sample "7")

Hand Specimen: Dextral D_2 open folds.

Thin Section: 766/37

Mineralogy: Quartz, Garnet, Biotite, Muscovite, Plagioclase

Description: Fabric axial planar to D_2 folds. Fabric due to mimetic growth of tight crenulations. Later crenulation perpendicular to S_2.

Biotite Schist with porphyroblasts of plagioclase and magnetite

406

Hand Specimen: Idiomorphic plagioclase and magnetite. Plagioclase is poorly aligned parallel to the axis of the crenulation.

Thin Section: 766/48

Mineralogy: Biotite, Plagioclase, Quartz, Magnetite

Description: Relatively coarse grained green-brown biotite has been crenulated (D_2) and has undergone a large degree of recrystallization. Magnetite approaches being idioblastic. Plagioclase porphyroblasts have grown after the crenulation as they contain inclusions of biotite parallel to both limbs of the crenulation. Plagioclase is strongly zoned with zoning parallel to the boundaries with biotite.

Photomicrograph: Plate 5A.

Porphyroblastic andalusite schists

H

Location: Tepko (266263)

Hand Specimen: Strong fabric with biotite lineation. Pressure shadows are elongate parallel to biotite lineation.

Thin Sections: 766/6 b - section
/7 a - section

Mineralogy: Biotite, Andalusite, Fibrolite, Muscovite, Plagioclase, Garnet, Quartz, Tourmaline

H (cont.)

Description: Strong fabric (S_2?) defined by intergrowth of biotite and muscovite. Idiomorphic quartz and plagioclase occur within the micaceous areas.
Andalusite porphyroblasts have numerous elongate inclusions of quartz defining an internal fabric (S_i). S_i is continuous with the external fabric (S_e). S_e wraps around the porphyroblasts, and there are elongate pressure shadows rich in quartz and plagioclase. Coarse muscovite occurs within the pressure shadows at the edges of porphyroblasts. 766/7 has clots of fibrolite aligned parallel to the lineation. Fibrolite appears to have nucleated away from andalusite, but the nucleation appears to have been on biotite grains. There is a crenulation at a high angle to the fabric. These folds are open and individual folds are not very continuous. There has been recrystallization of micas after this deformation.
See Figure 10.

91b

Hand Specimen: Faintly laminated fine grained sandstone interbedded within andalusite schist. Strong fabric subparallel to bedding. Well developed crenulation forms a lineation on the cleavage surfaces and wraps around andalusite porphyroblasts.

Thin Section: 766/35.

Mineralogy of sandstone layer:

Quartz	Fibrolite
Biotite	Tourmaline
Muscovite	Sphene

Description: Appears to be a compositional layering present with varying amounts of mica. There is a lamination with a concentration of tourmaline and sphene within biotite.
Again andalusite is syntectonic with fabric.
Mica recrystallized after crenulation.

91c

Hand Specimen: Small light coloured patches parallel to fabric (1mm long).

Thin Section: 766/32.

Description: Small patches are concentrations of quartz and plagioclase These are folded during crenulation (D_3?). Two of the

91c (cont.)

Description: (cont.) andalusites have areas within them which have a fabric at right angles to the main fabric. This fabric is in part continuous with S_i in the andalusite, and elsewhere S_i wraps around the area with the anomalous fabric. The fabric preserved in these areas is interpreted as S_1 and the andalusites are therefore post S_1 and syn S_2.

Photomicrograph: Plate 5B.

Porphyroblastic Staurolite Schist

117b

Hand Specimen: Fabric appears to wrap around porphyroblasts.

Thin Section: 766/52

Mineralogy: Quartz, Plagioclase, Biotite, Staurolite, Garnet

Description: Biotites are greenish brown. Staurolites have apparently randomly oriented inclusions of quartz. Fabric is definitely older than S_1 due to the variation in size and orientation of biotite. Fabric wraps around staurolites and is probably post porphyroblast growth. Possibly this fabric is S_3.

Porphyroblastic Garnet Staurolite Schist

128

Hand Specimen: Fairly arenaceous sediment. An irregular fabric is defined by concentrations of biotite (subparallel to bedding).

Thin sections: 766/20 - a section
766/21 - b section

Mineralogy: Quartz, Feldspar, Biotite, Staurolite, Garnet

Description: Biotite is greenish brown and muscovite is absent. 766/20 - All layering approximately parallel with elongate staurolite. 766/21 - Staurolite has grown in the axial plane of D_2 folds, which are dextral in vergence. Staurolites have been folded during D_3 and S_3, which is weakly developed, wraps around the ends of folded staurolite porphyroblasts. Staurolite within biotite rich layers is idiomorphic. Garnets lack inclusions. They have grown around D_2 folds and probably reached their present size during the period when biotite was recrystallized after D_3.

Photomicrograph: Plate 5C.

I.

Location: "Harrowgate"

Thin Section: 171/71

Mineralogy: Quartz, Muscovite, Biotite, Feldspar, Stanite, Garnet

Description: Reddish brown biotites and muscovite define a fabric (S_1), which has been crenulated (D_2). Staurolite growth occurred rapidly after the folds developed and deformation continued afterwards so that the fabric wraps around the porphyroblasts. Garnet typically has sigmoidal inclusion trails and rims lacking inclusions. Usually there is less than 40^o between the limbs of S_i, and these have always suffered a dextral rotation. Within staurolite garnet crystals have rims without inclusions, but the sigmoidal trails are continuous with S_i of staurolite. Garnets outside of staurolites have often suffered additional rotation up to 90^o. The fabric wrapped around the garnets during D_2, but this is obscured by further growth of the rim of the garnet so that the fabric now appears to abut the garnet porphyroblasts.

Photomicrograph: Plate 5D.

Biotite schist with clots of muscovite

J

Location: Monarto (308223).

Hand Specimen: Has quartz rich patches of varying sizes with a fabric wrapping around them.

Thin Section: 766/11

Mineralogy: Quartz, Tourmaline, Plagioclase, Fibrolite, Biotite, Muscovite

Description: Clots of randomly oriented coarse muscovite often have quartzose pressure shadows. There appears to have been two periods of development of crenulation cleavage and on the whole biotites appear to have random orientations, although basal sections are absent.

Layered biotite schist with coarse muscovite and fibrolite

232E

Hand Specimen: Strongly developed dextral differentiated fabric (S_2). Apart from a layer (S_0) 1cm wide most of the rock has numerous knots of coarse muscovite. There is a strong lineation (L_2).

Thin Section: 766/49

Mineralogy: Quartz, Muscovite, Plagioclase, Fibrolite, Biotite

Description: Reddish brown biotites define a well developed spaced cleavage. Coarse muscovite occurs within microlithons. Fibrolite is associated with biotite and generally occurs within microlithons.

Biotite Schist with folded garnet-qtz segregations

296

Hand Specimen: Well defined white layers are folded with a dextral vergence. These layers are not very continuous. Strong fabric defined by biotite, with a lineation on cleavage surfaces.

Thin Sections: 766/31 a - section
/32 b - section

Mineralogy: Plagioclase, Garnet, Muscovite, Quartz, Biotite

Description: Strong L.S. fabric (S_2) defined by reddish brown biotite. Contains folded segregations of fine garnet within recrystallized quartz. In 766/31 the fabric wraps around the segregations. In 766/32 there is evidence that S_1 has been folded with the segregation during D_2. Throughout the section there are numerous short biotites at a high angle to the fabric and this is consistent with the fabric being S_2.

Photomicrograph: Plate 6B.

Biotite schist with tension gash

91a

Hand Specimen: Tension gash oriented parallel to biotite lineation.

Thin Section: 766/22.

91a (cont.)

Mineralogy:	Quartz	Muscovite	
	Plagioclase		
	Biotite		

Description: Strong fabric (S_2) defined by reddish brown biotite with short biotites at an angle to S_2. Tension gash is filled with quartz and has opened from the edges. There is a concentration of biotite along the edge and fabric wraps around the ends. The centre of gash has pure quartz and the edges have layers with fine plagioclase; the layers being parallel to the edges of the tension gash.

Quartz-fibrolite pod in biotite schist

144

Hand Specimen: Lineation in biotite schist is parallel to axis of dextral crenulation. Quartz pod and fibrolite are parallel to this lineation.

Thin section: 766/29.

Mineralogy:	Quartz	Andalusite	Garnet
	Biotite	Muscovite	Plagioclase
	Fibrolite		Apatite
			Pyrite

Description: Fibrolite nucleation appears to be related to biotite. Needles of fibrolite extend into andalusite, but andalusite does not appear to have been converted to fibrolite. Andalusite lacks inclusions and its growth appears to have been synchronous with the formation of the quartz pod.

Amphibolites (Metadolerites)

239

Hand Specimen: Felted mass of plagioclase and amphibole.

Thin Section: 766/33

Mineralogy:	Hornblende	Opaque	Biotite
	Plagioclase		

Description: Needle of plagioclase within a mass of recrystallized hornblende. which displays subophitic textures. Scattered fine opaques.

159b

Hand Specimen: Vein through amphibolite 9mm wide.

Thin Section: 766/513

Mineralogy: As above with quartz within vein.

Description: Vein filled with coarse quartz with coarse plagioclase at the edge. Fine needle-like hornblende extends into the edges of the vein. There is a curved elongate crystal of an opaque mineral.

368

Hand Specimen: Amphibole has an inclusion (3cm x 4cm) displaying a gabbroic texture. Large crystals of plagioclase are scattered throughout.

Photograph: Plate 6D.

Thin Section: 766/58

Mineralogy: As for 239.

Description: In "gabbroic" intrusion there is coarse orange brown biotite. Plagioclases often have sericitized cores. Throughout all of the large plagioclase grains there are needles of amphibole which are coarser in deformation bands and along cleavage surfaces.

APPENDIX C.

WORK DONE

1. One week measuring the stratigraphy along the South Eastern Freeway Traverse.

2. Approximately six weeks of detailed mapping in the Rockford Heights area.

3. Shaddowmaster sketches of andalusite porphyroblast to fabric relationship.

4. Study of microstructures from-thin sections.

5. Measurement of the orientation if (001) cleavage of muscovite in three sections.