PRECAMBRIAN ROCKS OF TASMANIA, PART V, PETROLOGY AND STRUCTURE OF THE FRENCHMAN'S CAP AREA

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(With 10 text-figures)

ABSTRACT

Mica and garnet schists with quartzite and associated amphibolites and eclogite form the Franklin, Joyce and Algonkian Groups. Quartzite and phyllite constitute the Mary, Scotchfire and Fincham Groups. All rocks belong to the Greenschist Facies and were affected by two periods of deformation (F_1 and F_2) during the Precambrian Frenchman Orogeny and at least one other (F_3) during the Palaeozoic. Prior to the Palaeozoic the rocks contained small to medium scale recumbent isoclinal folds; it is postulated that the metamorphic assemblages of F_1 were deformed into a large recumbent fold (Pillinger Fold) during F_2.

INTRODUCTION

Regionally metamorphosed mestasediments with minor meta-igneous rocks outcrop extensively between the King River Valley and the Central Plateau. The metamorphics are overlain unconformably by the Junee (Ordovician) Group at the Engineer Range, by the Middle Cambrian Dundas Group near Lake Margaret to the north-west, by the Junee Group to the east at the Loddon River, and by the late Precambrian (?) Jane Dolomite near Artists Hill and the Jane River.

The compilation (fig. 1) is based on unpublished work for the Tasmania Hydro-Electric Commission by S. Warren Carey, R. P. Mather, J. B. A. McKellar, I. McLeod, I. Threadgold, D. Zimmerman, D. Gee and the author.

The metamorphic rocks include various schists, phyllites, quartzites and amphibolites belonging to the Greenschist Facies of Turner and Verhoogen (1960); some details have been given by Spry, (1957) and Spry and Zimmerman (1958), and the general distribution is shown in fig. 1. Representatives of two sub-facies are recognized: the *schist-quartzite assemblage* belongs to the quartz-albite-epidote-almandine sub-facies and the *quartzite-phyllite assemblage* belongs to the albite-muscovite-chlorite sub-facies. The distribution of the rocks of the two sub-facies shown in fig. 2 does not show a simple zonal pattern.

The *schist-quartzite assemblage* consists of the belt around the north-west (Franklin Group), a similar mass just north of Mt. Mary (Joyce Group) and the schists of the Algonkian Mtn. (Algonkian Mountain Group). The *quartzite-phyllite assemblage* contains the Mary Group (through the centre of the region), the extensive phyllites in the south-east (Scotchfire Group), a narrow belt of quartzite along the western side (Fincham Group), and the quartzite at Mt. Elliot (Elliot Quartzite).

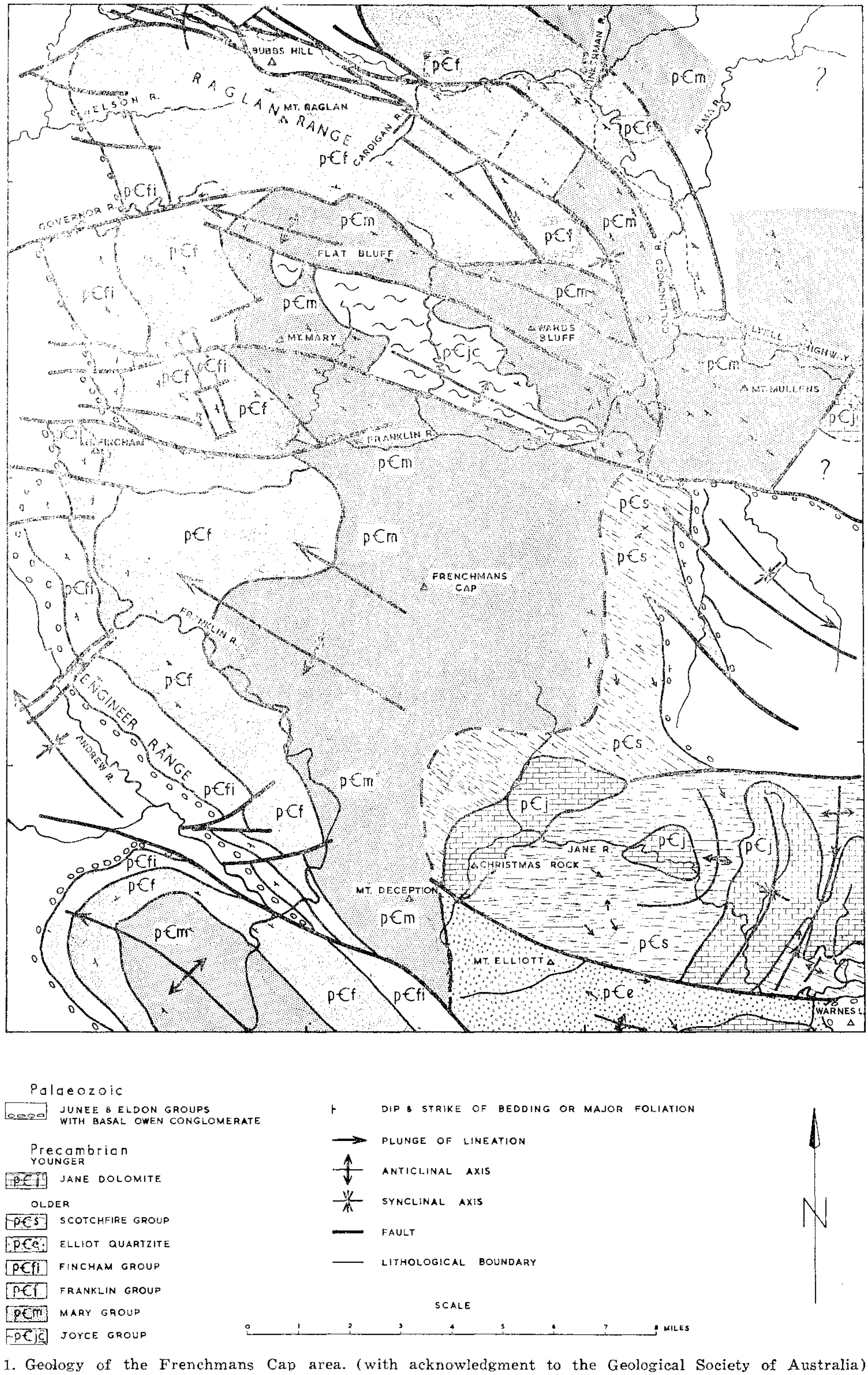
A comparison of figs. 1 and 2 shows that the sub-facies boundaries coincide with the junctions between the two major lithological assemblages and evidence given below suggests that the complex interrelations are due to large scale recumbent folding of the metamorphic zones.

The metamorphic rocks show evidence that they have undergone at least three phases of deformation and these will be referred to as F_1, F_2 and F_3. Most attention is given to the first two phases and at present F_3 will be used to include all late structures even though it is clear that they range in age from Precambrian to Devonian.

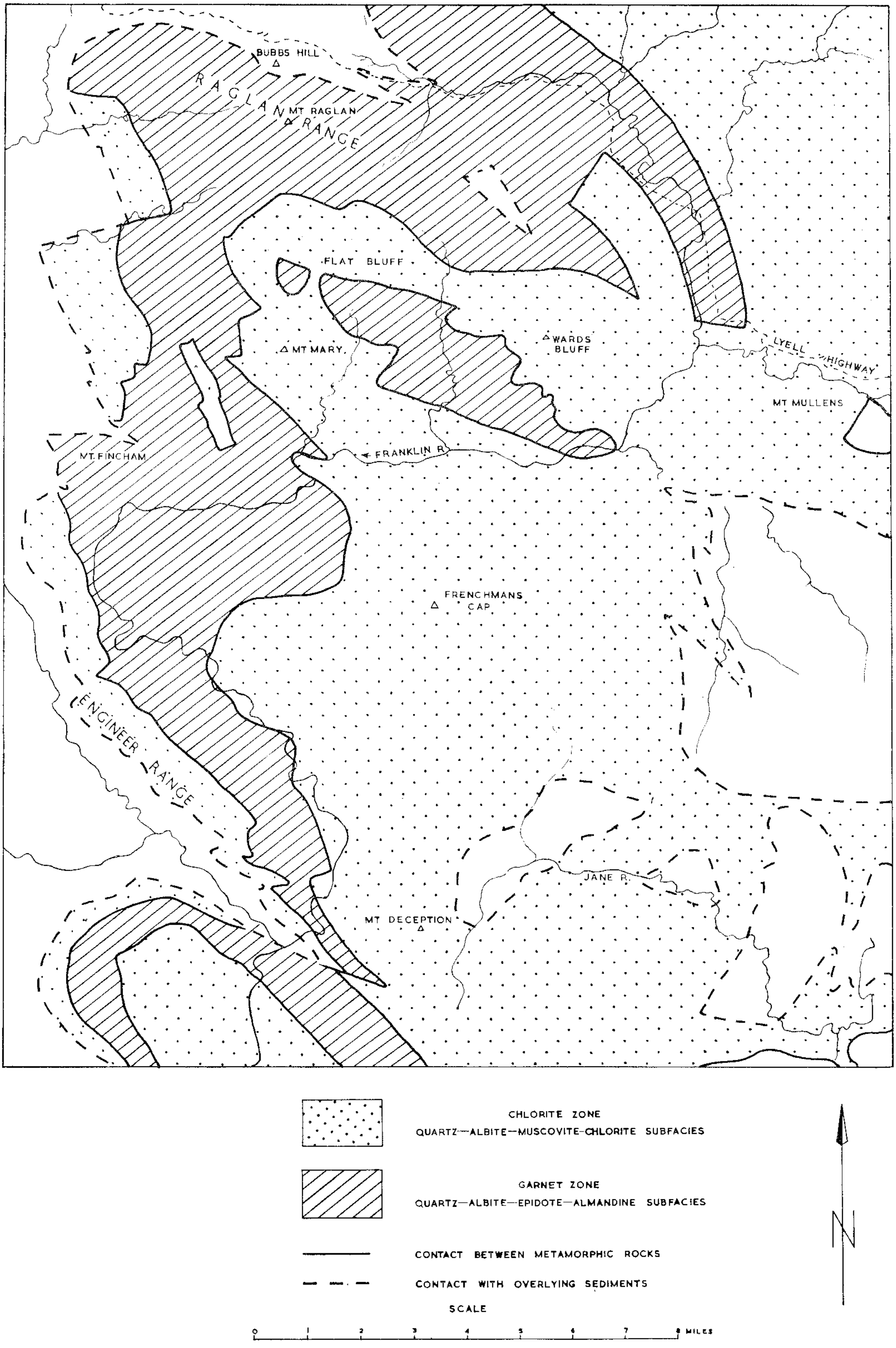
The main feature of F_1 movements was the production of a foliation S_1 which is parallel or at a low angle to S_0 (bedding). No F_1 folds have been recognized. S_1 is the weak, solitary foliation in massive quartzites, or the strong foliation in schistose quartzites; it is strongly developed in phyllites but has been largely obliterated and is only visible microscopically in the schists. The intersection of S_0 and S_1 gives a lineation L_1.

F_2 structures include the foliation S_2 which is dominant in the schists, and in many phyllites where it can be seen to be later than S_1 microscopically. It is weakly developed in quartzites but can be seen to cross the hinges of folds of S_0 and S_1; microscopically it is marked by elongate quartz and micas. Massive quartzites do not contain S_2. All of the visible isoclinal folds of all scales are attributed to this phase. S_2 is either parallel to S_1 or is so similar in direction as to be indistinguishable macroscopically except on the hinges of folds. L_2 lineations consist of fold crests, mullions, S_1-S_2 intersections, elongation of grains or grain aggregates, &c.

F_3 structures are later than the metamorphism in this area and are not associated with mineral growth. Structures include chevron folds, kinks or joint-drags, congugate folds, asymmetrical crumples, &c., with S_3 which is a fracture cleavage. The orientation of S_3 and associated L_3 is variable with respect to the older structures.



1. Geology of the Frenchmans Cap area. (with acknowledgment to the Geological Society of Australia)



2. Distribution of metamorphic facies in fig. 1.

Structural Evolution

Evidence will be adduced to show that metamorphism took place in two stages with the higher grade coinciding with F_1. The small-scale folds belong to F_2 and it is postulated that the metamorphic zones were folded into a very large recumbent fold (Pillinger Fold) during F_2. The whole region was folded again several times, most notably during the Tabberabberan Orogeny about north-south axes (Frenchman Anticlinorium) and west-north-west axes (Mary Antiform, Collingwood Synform, &c.).

QUARTZITE-PHYLLITE ASSEMBLAGE

This comprises the Mary Group, Scotchfire Group, Fincham Group, Elliot Quartzite and possibly the Mt. Maud quartzite. The Mary Group is best known.

MARY GROUP

Massive quartzites, quartz schists and phyllites occur near Mount Mary (Spry, 1957).

The sediments, particularly the phyllites, are cut by a number of foliations, of which S_1 and S_2 are prominent. In some places original bedding can be recognized where it is marked by sedimentary structures such as ripple marks and cross-bedding and the major foliation is commonly parallel or sub-parallel to the bedding. If it is assumed that the major foliation is still parallel to bedding when the bedding surface is not clearly recognizable, then the beds at Mt. Mary represent a thick succession dipping south-west and those on Wards Bluff represent the same succession dipping north-east. Both lie above the Joyce Group which occupies the core of the Mary Antiform. The lack of correspondence of stratigraphic sections a few miles apart indicates that the Antiform is not a simple structure and this is confirmed by the apparent thickening of the Mary Group around the nose of the Antiform from 500 ft. at Mary Creek to 2000 ft. at Mt. Maud. It is suspected that the rocks are tightly isoclinally folded but insufficient facings have been found to confirm this.

The three main rock types (massive quartzite, quartz schist and phyllite), consist almost entirely of quartz and sericite and the rocks differ mainly in grainsize and the relative proportions of the two minerals.

Massive Quartzites

The abundant massive white quartzites are thickly bedded and are the only rocks to contain recognizable bedding.

In thin section, massive quartzites (such as 6223*, 6225, 6251, 6296, 6311 and 7039) are seen to consist almost entirely of quartz with accessory sericite, tourmaline, zircon and iron ore. Large (.5 to 1 mm.) xenoblastic to lenticular quartz grains are set in a fine-grained ground-mass of quartz. (N.B.—No. 6225 from Mt. Mary, 6783 from Mt. Deception and 6827 from Junction Peak). The large quartz grains show pronounced undulose extinction and deformation lamellae; the small quartz crystals are fresh, clear, elongate and free from undulosity and lamellae. Some specimens consist of large quartz crystals with sutured margins and a few randomly oriented micas. As the proportion of small quartz grains increases from specimen to specimen, so does the degree of preferred orientation (by external form) of the quartz and the degree of development of a macroscopic lineation.

Petrofabric diagrams of the massive quartzites will be published elsewhere. A detailed petrofabric examination of similar rocks from Goat Island indicates that this mortar texture was developed in at least two stages. A coarse granular texture was formed at an early stage (F_1?) and was replaced wholly or partly by crushing of the large pretectonic quartz grains with syntectonic crystallization of small elongate crystals (F_2?). The later stage appears to have affected the micaceous quartzites more than the purer arenites. Chronological analysis of the relative roles of crystallization and deformation in the fabric evolution of the quartzites is rather ambiguous and largely depends on analogy with the associated metapelites.

Quartz Schists

The most common rock in the Mary Group is a white platy siliceous rock named (Spry, 1957) a micaceous quartzite or quartz schist.

Under the microscope, quartz schists (such as 6224, 6226, 6229, 6257, 6310, 6991, 6992, 7033, 7430, 7035 and 7044) consist of small, approximately equidimensional, grains of quartz averaging about .05 mm. across, with up to 5% of tiny parallel sericite flakes; accessories are tourmaline, rutile, iron ore and zircon.

A chemical analysis of No. 6220 from Mt. Mary (Table I) indicates that it contains about 97% quartz and 3% mica (mainly sericite).

Specimen No. 6970 from just west of the Franklin-Loddon River junction represents the moderately deformed quartz schists. It has a single foliation (S_1?) and a pronounced lineation. The quartz is slightly elongate and is somewhat undulose. Skeletal tourmaline is evidently posttectonic.

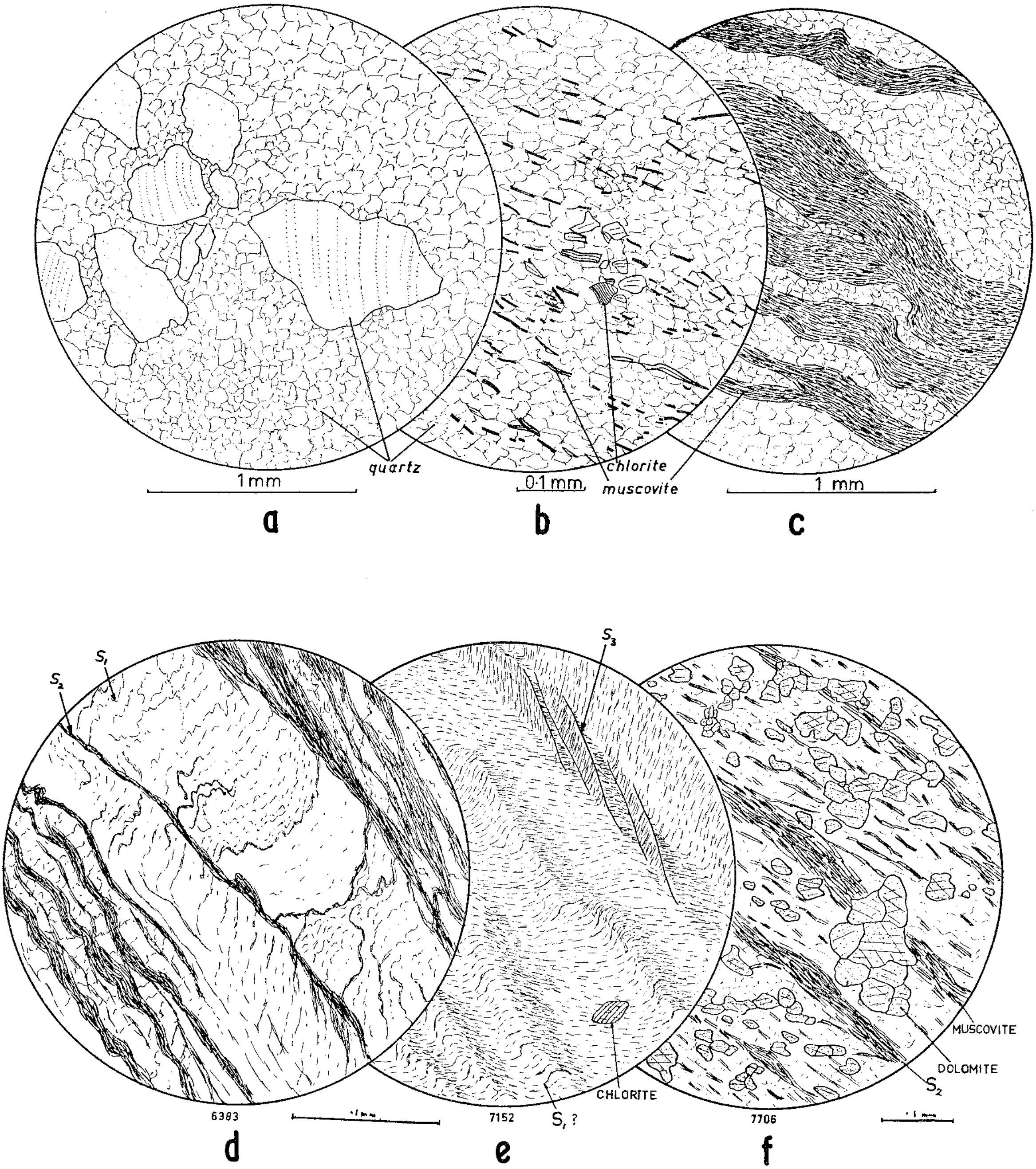
Specimen No. 6815 is apparently more deformed as the macroscopic foliation is strong, and the quartz markedly elongate.

Specimens which contain more mica than the common schist described above, have a strong macroscopic foliation, a strong degree of dimensional preferred orientation of quartz, and have apparently been more strongly deformed. The exact nature of the sediments from which the quartz schists were derived is not clear; they may have been coarse quartz-sandstones which have been strongly granulated but were probably siliceous siltstones. They are intermediate between the massive quartzites and the phyllites in composition.

Phyllites

Light to dark-grey coloured, fine grained, strongly foliated rocks occur throughout the Mary Group; particularly prominent is the apparently basal formation which rests on the Joyce Group at Flat Bluff. The phyllites are composed of quartz grains averaging about .05 mm. across with abundant

* Numbers refer to specimens in the collection of the Department of Geology, University of Tasmania.



3. Textures of Mary Group rocks:
(*a*) massive quartzite with mortar texture.
(*b*) quartz schist.
(*c*) phyllite; S_0 and S_1 essentially parallel.

Textures of Scotchfire Group rocks:
(*d*) phyllite with S_1 and S_2.
(*e*) phyllite with S_1 (?) and S_3
(*f*) calc-schist with dolomite posttectonic to S_3

sericite and accessory chlorite, tourmaline, rutile and iron ore. Typical are 6253 from Flat Bluff, 6307, 6309, 6239, 6227, 6242 and 6243 from Mt. Mary, and 7010 from Twelvetrees Range.

The chemical analysis (No. 1 in Table I) shows the rock (No. 6227) to have the composition of a siliceous siltstone, a mature sediment from a stable tectonic environment.

Although mineralogically and chemically simple, the phyllites are structurally complex and have some of the attributes of phyllonites. They are tightly contorted into recumbent isoclinal folds a few inches across, with sheared out limbs, fold-mullions, quartz-rods and quartzite boudins. The major microscopic foliation is parallel to a fine compositional banding but it will be shown that this is S_2; it is younger than another tectonic foliation S_1; bedding (S_0) has been mostly destroyed. Some phyllites of simple appearance consist of alternate layers of fine sericite and quartz but the complex structures of fig. 4 are more typical.

Three microscopic foliations can be recognized:

(*a*) a weak irregular one marked by tiny whisps of twisted sericite;

(*b*) a strong one marked by thin compositional banding;

(*c*) a fracture cleavage across crenulations of (*b*).

It is not possible to be certain from a microscopic examination of most specimens whether any of these S-surfaces correspond to bedding. In fact it is not clear in which order the S-surfaces of some specimens formed (e.g., fig. 4). The latest is certainly the fracture cleavage but the major foliation is only recognized as S_2 in a few specimens; it grades into a foliation more positively identified at S_2 in Franklin Group schist north-west of Flat Bluff.

The foliations can be clearly distinguished microscopically in some specimens; a coarse lithological layering is the oldest structure and is probably S_0. A foliation S_1 formed by parallel mica flakes is parallel to it. Both S_0 and S_1 have been crumpled and an oblique strain-slip cleavage has formed; packing of mica flakes along this S_2 produces a fine lithological layering.

FINCHAM GROUP

McLeod (1956) and Mather (1955) mapped a belt of quartzites and phyllites mainly along the Engineer Range and named it the Fincham Group from its occurrence at Mt. Fincham. The Group is overlain unconformably by Ordovician Owen Conglomerate at the Engineer Range and appears to rest on schists of the Franklin Group.

Measuring structural thicknesses perpendicular to apparent bedding suggests over 3000 ft. near Mt. Fincham, about 2500 ft. two miles to the south and about 300 ft. two miles further south. This variation must be at least partly due to overlap by the Ordovician sediments.

The rocks are somewhat similar to those of the Mary and Scotchfire Group and the group consists of phyllites and quartz-schists with rare massive quartzites. The quartz-schists and phyllites are commonly contorted on a small scale and contain isoclinal folds so that it is impossible to follow beds any distance along the strike or to correlate sections even a mile apart.

Phyllites

The simplest phyllites (e.g., 7036 from near the apparent base of the Group) are grey crenulated rocks. In thin section they are strongly foliated and consist of quartz, muscovite and chlorite. The major foliation (S_2) is produced by layers of mica but small flakes of mica in the quartz-rich bands are orientated obliquely and define another foliation (S_1).

Phyllites such as 7037 from the top of the Engineer Range are typical and possess textures with considerable chronological complexity. Two foliations are shown; the main one consists of layers alternately richer in quartz and in muscovite and is essentially planar apart from a few small undulations. It is younger than a strongly folded foliation (S_1) produced by small muscovite flakes and lenticular quartz crystals. A pair of foliations with these characteristics is very common in Precambrian metamorphic rocks from all parts of Tasmania and although the relative ages of the two foliations are not immediately apparent in all specimens, the greater deformation of S_1 is taken to be evidence that it is older than S_2. Each foliation is taken to indicate a stage in the deformation of the rock. It is not clear whether or not S_1 is bedding but as it is outlined by mica flakes it is probably tectonic. The small micas along S_1 are probably syntectonic to the first stage of deformation (F_1) and pretectonic to the second stage (F_2) and are twisted. The large micas along S_2 are probably syntectonic to F_2 but include some twisted muscovite from F_1 rotated into the later foliation. Chlorite occurs as syntectonic flakes along S_1 but much of it is randomly disposed and is posttectonic to F_2.

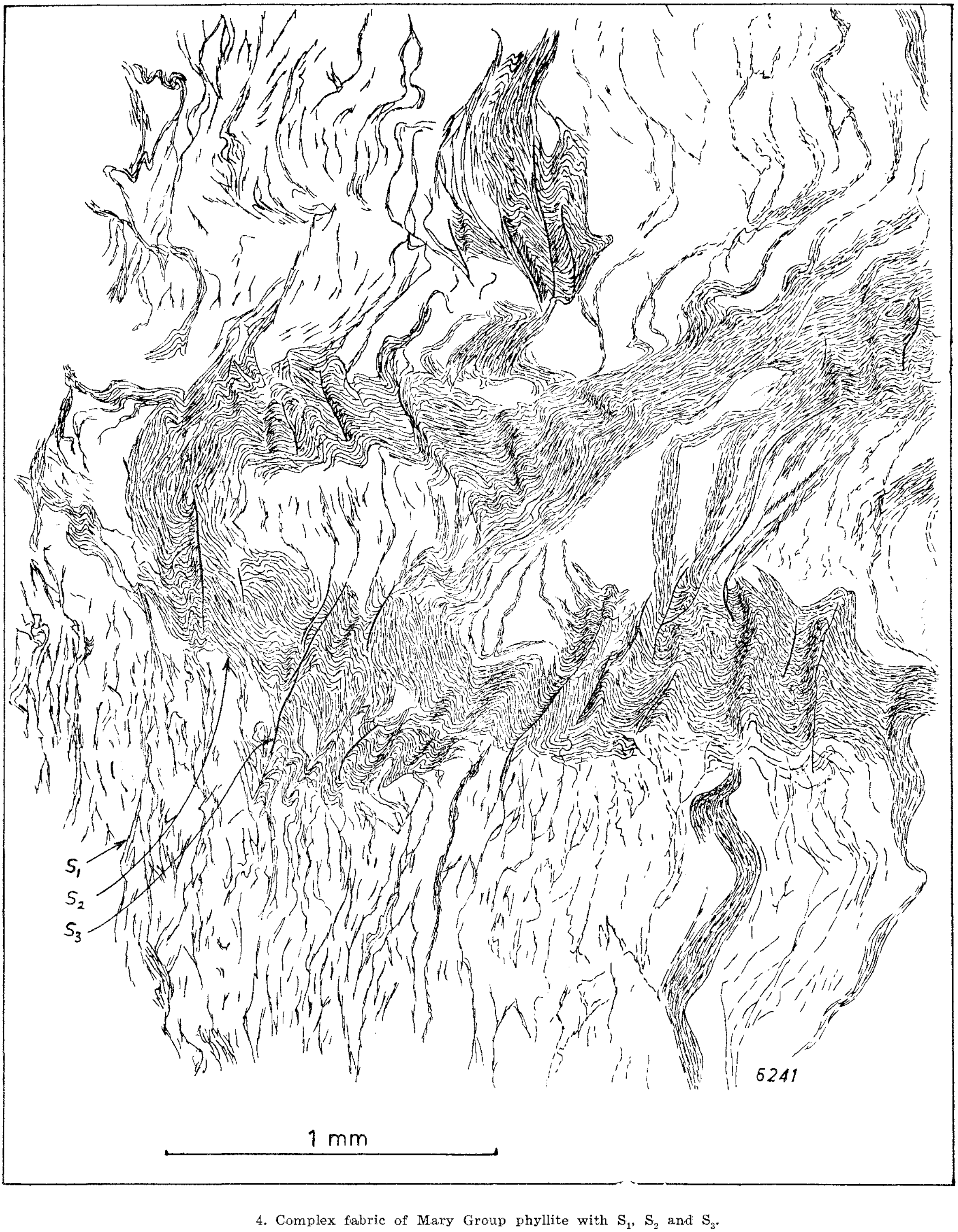
A weak and widely spaced fracture cleavage (S_3) occurs along the axial surfaces of small folds of S_2 but no mineral growth is associated with it.

Quartz Schists and Massive Quartzites

These are subordinate to the phyllites although quartz-schist is abundant. Petrographically they resemble rocks already described in the Mary Group and the descriptions will not be repeated. One specimen of massive to platy quartzite (No. 7039) from the top of the Engineer Range is intermediate in character between quartzite from the Mary and the Franklin Groups. It is medium to fine-grained and is composed largely of strongly elongate quartz crystals with a little sericite and chlorite in small parallel flakes.

ELLIOT QUARTZITE

The massive white quartzite forming Mt. Elliot extends towards the Mary Group south of Frenchmans Cap and may be continuous with it. Small ridges on the Lightning Plains were said by Wells (1957) to consist of similar quartzite (specimens 6356, 6357) and to be anticlinal crests plunging beneath the Scotchfire Group. Wells considered that the Elliot Quartzite appeared again to the east near Algonkian Mountain (specimens 6433, 6435) and at Warnes Lookout (6426).



4. Complex fabric of Mary Group phyllite with S_1, S_2 and S_3.

The Elliott Quartzite is indistinguishable both microscopically and macroscopically from the massive quartzite of the Mary Group but it cannot be assumed that the two are equivalent in the absence of detailed mapping.

Specimen No. 6335 from Mt. Elliot is a massive white quartzite with sand-size quartz grains in a white siliceous matrix. Mortar structure is visible in thin section where a few large undulose quartz grains (.5 to 1 mm. in diameter) are set in a matrix of quartz averaging .05 mm. diameter. About 2% of fine muscovite shows a weak preferred orientation.

SCOTCHFIRE GROUP

This term was first used by Wells (1957) to refer to the phyllites, schists, quartzites, and dolomites along the Scotchfire Creek and the surrounding area. Spry and Zimmerman (1959) included phyllites, dolomites and quartzites along the Lyell Highway (38 miles from Queenstown) in the Scotchfire Group.

Schists

Fine grained schists and phyllites are the most common rocks in this group. They range in colour from grey to green and are generally strongly foliated and crenulated. The three major minerals present are quartz, sericite (or muscovite) and chlorite; albite is rare and accessories are tourmaline, iron ore, zircon and rutile. Carbonate occurs in some varieties.

The simplest variety, both mineralogically and structurally (e.g., 6259), contains one foliation. Such rocks are fine grained and schistose, consisting chiefly of quartz and muscovite. The mica occurs in thin sub-parallel layers outlining the foliation and in quartz-rich bands between the micaceous layers.

Quartz is present as ragged crystals about .2 mm. across set in a matrix of smaller crystals about .05 mm. across. The micaceous layers average about .1 mm. in thickness and are gently crenulated in open folds about 1 cm. in length but the layers themselves vary in thickness and direction; the layers are approximately parallel but intersect each other and merge together. The foliation appears to be due to the aligning of mica flakes along closely spaced shear surfaces which were later crenulated.

Most of the fine grained schists or phyllites consist of about 60% quartz, 30% muscovite and 10% chlorite, but vary in the complexity of their structure.

Specimens 6362, 6364, 6465 and 7152 are moderately deformed representatives of the Scotchfire Group. They are composed of alternate, very irregular bands which are rich in quartz or in muscovite.

The quartz-rich bands are approximately 1.5 mm. thick and contain strongly elongate crystals ranging from .05 to .25 mm. across. The layers vary considerably in thickness and some are lenticular; the tiny muscovite flakes within the layers are discordant with the direction of the boundaries of the layers in some places. The micaceous layers consist of whispy muscovite flakes approximately .02 mm. long with lenticular quartz crystals. The micas are sub-parallel but are contorted and very irregular in direction. Chlorite occurs as small lenticular clots with the cleavage generally at a large angle to the foliation of the rock.

Others (e.g., 6364) are very rich in muscovite as a mass of interwoven crenulated flakes. Many mica flakes are parallel to each other and to elongate aggregates of quartz but this foliation has been crinkled and is difficult to recognize. Original bedding cannot be recognized with any certainty but is probably represented by irregular lenticular quartz aggregates; these appear to have once been quartz rich layers oblique to the foliation but movement along the foliation has folded and disrupted the layers, torn them apart, and rotated them.

The most characteristic of the Scotchfire phyllites are the fine-grained glossy, green, strongly foliated and lineated rocks such as 6336, 6366, 6393, 6966, 6974, 6430, 7152 and 7157. Under the microscope they can be seen to consist chiefly of quartz, muscovite and chlorite but their structure is very complex; three foliations are present but there is no evidence that any represents the original bedding. The most prominent foliation (S_2) is marked by layers alternately richer in muscovite or quartz. Remnants of an older foliation (S_1) are present between the layers which themselves are tightly folded. A third foliation (S_3) is a fracture cleavage along one limb of the folds of S_2. This multiplicity of foliations is present in many of the Mary and Fincham Group phyllites and some Franklin Group schists.

It is difficult to describe adequately the structure of these rocks and reference should be made to fig. 3 which depicts some typical varieties. The relative ages of the foliations can be established from the data obtainable from specimens such as No. 6336 and it is important that the strongest foliation marked by compositional banding is not bedding but is later than at least one other foliation.

A chemical analysis of a green phyllite (No. 7310) from the Scotchfire Group is given in Table I. It outcrops on the Lyell Highway below Mt. Arrowsmith and consists of approximately 40% of quartz, 50% of fine-grained muscovite and 10% of chlorite with accessory tourmaline and iron ore. The structure is similar to that described in previous specimens. The analysis indicates that the original sediment was siliceous and clay-rich, probably a siliceous siltstone. The analysis shows many similarities with that of the Mary Group phyllite given earlier except that potash is higher. The range of composition of four Franklin Group schists is so great that the Scotchfire phyllite can be said to be similar to them. The main difference is that the Scotchfire is very low in soda (albite is uncommon in the Scotchfire rocks but is common in the Franklin Group). Lime is very low in this rock as it is in all schists and phyllites from this area except No. 6372. This is a light-grey phyllite forming a thin layer within slates from the Jane River. In thin section it is a fine-grained, irregularly textured rock consisting of about 60% quartz with muscovite, chlorite, actinolite and zoisite; accessories are albite, iron ore, tourmaline, sphene and zircon.

This rock has much lower potash than most other rocks from the area and has the highest lime of any; magnesia is also quite high. Thin bands of dolomite and dolomite-schists occur in the Scotchfire Group near here and the most likely origin for the rock is that it was originally a slightly dolomitic and siliceous siltstone. An alternative explanation is that it might have had a small tuffaceous content but there is no other evidence here of contemporaneous volcanism.

Calc-mica schists from Carbonate Creek and near the 40 mile post on the Lyell Highway near Mt. Arrowsmith, were briefly described by Spry and Zimmerman (1958); Wells (1957) mentioned similar types in the Jane River area. They are grey to brown, fine-grained, foliated and lineated schists. No. 7706 contains about 40% of dolomite and 40% quartz with the remainder muscovite and chlorite. No. 7703 contains quartz, muscovite and dolomite and has three foliations. Muscovite, quartz and chlorite grow along S_1 and S_2 and are apparently syntectonic to F_1 and F_2. Only dolomite grows along S_3. As shown in fig 3 crystallization of the carbonate is mostly posttectonic as it occurs in relatively coarse patches or even veins transgressing the foliation and shows little evidence of an elongate habit. It is possible that the carbonate was introduced metasomatically quite late in the rock's history.

No. 6417 is a dark coloured, fine-grained schistose and contorted dolomite. In thin section it contains of about 55% of dolomite as shapeless grains .05 mm. across, with 30% of quartz and 15% of muscovite. The schistosity (S_2) is caused by irregular, intersecting thin bands of fine-grained parallel flakes of muscovite. Between the foliation planes are abundant contorted flakes of mica (S_1). The texture is somewhat simpler but is nevertheless very similar to that of the calcschists described above.

No. 6392 occurs as a 12′ layer within the Scotchfire schists in upper Thirkell Creek. It is a medium grained reddish coloured rock with numerout white quartz veins about ⅛″ wide. Under the microscope it consists mainly of unevenly textured dolomite with crystals ranging from .6 mm. to .06 mm. showing sutured margins. The larger dolomite crystals show various deformation effects such as weak undulose extinction, multiple twinning, curved twin planes, and twin lamellae cut by later glide planes which disrupt them and displace the lamellae in sections. Abundant small quartz crystals and haematite are also present.

Specimen No. 6416, also interbedded with Scotchfire schists in upper Thirkell Creek, is a fine-grained dolomite, strongly laminated with alternate pale grey and pink laminae. In thin section it is very fine-grained and contains about 60% of dolomite, 20% of quartz, 15% of white mica and 5% iron ore granules. The quartz, together with some of the mica, tends to be concentrated in bands which are strongly contorted on a small scale and which probably represent bedding. A foliation, caused by parellel mica flakes at 30° to the lamination, is prominent within the laminae but is difficult to see in the dolomite-rich zones between the layers. The analysis in Table I indicates that it is a dolomite with about 25% of quartz, 10% of muscovite and 2½% of magnetite.

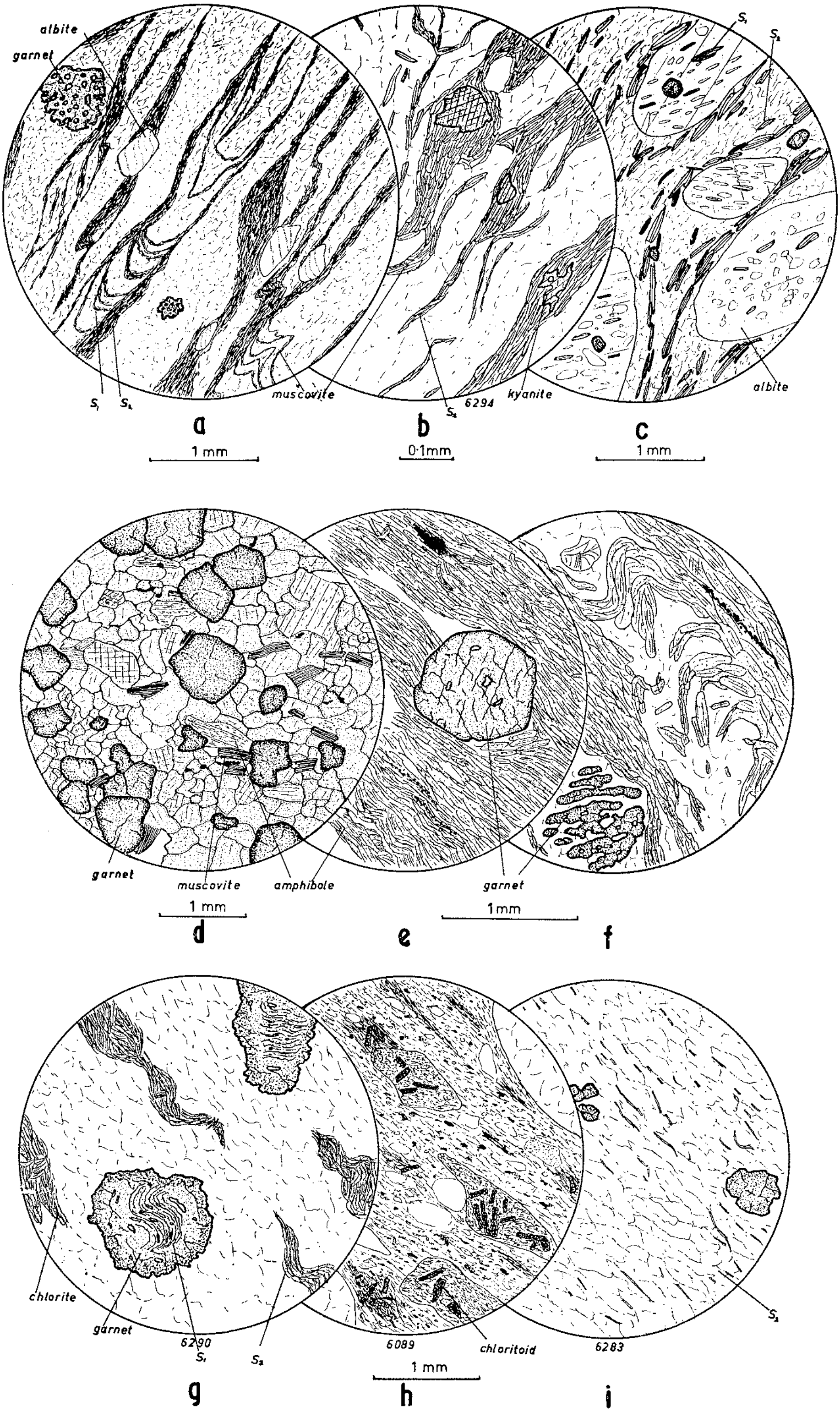
Specimen No. 6333 from Lake Tahune is rather similar and the rocks near Tahune probably should be included in the Scotchfire Group. This area has not been mapped and is shown in fig. 1 as Mary Group. In thin section the rock is fine-grained and strongly foliated. The foliation (S_2) is produced by the parallelism of warped and twisted muscovite flakes and also by the elongation of quartz and dolomite crystals. A few small relics of folds (of S_1) are present between the planes of the major foliation.

CONGLOMERATE (Lachlan)

Regionally metamorphosed conglomerate outcrops on the Lightning Plains where the formation was first recognized by McKellar and informally named the Lachlan Conglomerate. It overlies Scotchfire schist and is itself overlain (probably unconformably) by the Jane Dolomite and is regarded as a formation of the Scotchfire Group. Wells (1957) also found this formation between the Scotchfire and the Jane further to the east. Typical specimens include 7087, 6354 and 6397. The conglomerate (e.g. 7087) is a grey rock consisting of angular to rounded quartz and quartzite fragments up to

	F_1			F_2		F_3	
	Pre-	Syn- tectonic	Post-	Syn- tectonic	Post-	Syn- tectonic	Post-
muscovite		——		——			
chlorite		——		——	——		
dolomite		?	?	—— ? ——	——	—— ? ——	——
S produced		S_1		S_2		S_3	
S folded				S_1		S_1 S_2	

Chronology of crystallization and deformation of Scotchfire Group calc-schist.



5. Textures of (chiefly) Franklin Group rocks:

(*a*) garnet-mica schist with S_1 and S_2.

(*b*) kyanite in muscovite schist.

(*c*) albite-muscovite schist with S_1 enclosed in albite.

(*d*) eclogite, Lyell Highway. Chiefly omphacite and garnet.

(*e*) normal amphibolite.

(*f*) foliated amphibolite.

(*g*) snowball garnet (syntectonic and posttectonic to F_1) in schist with foliation S_2.

(*h*) chloritoid in Lachlan Conglomerate (Scotchfire Group).

(*i*) garnet-mica quartzite.

several inches in length in a moderately foliated matrix. Under the microscope many of the original clastic features of the rock are visible (fig. 5). The larger quartzite fragments may have been recrystallized but show no evidence of change of external form; most of the sand-size quartz particles are distinctly elongate; originally argillaceous fragments have been strongly drawn out into lenses or whisps; the matrix has been recrystallized and consists of quartz, parallel sericite flakes, a little chlorite and abundant haematite. The most important metamorphic mineral is chloritoid which occurs as small poikiloblastic laths generally about .6 mm. x .1 mm. but with some up to 1 mm. long. It is pleochroic from green to mauve to pale yellow and displays irregular polysynthetic twinning. The chloritoid is restricted to the pelitic fragments and part of the matrix. It shows no preferred orientation and is commonly oblique to the foliation and is posttectonic (to S_1?).

The rock was originally a very poorly sorted conglomerate somewhat akin to the paraconglomerate of Pettijohn (1957). The abundance of haematite is reflected in the high Fe_2O_3 (Table I). Turner and Verhoogen (1960, p. 533) state that chloritoid is restricted to rocks high in FeO and Al_2O_3 but low in K_2O; the bulk composition of this rock is not notable in these respects but the chloritoid is clearly restricted to certain parts of the rock which may have the appropriate composition.

No. 7087 from Thirkell Creek is somewhat similar except that chloritoid is more evenly distributed throughout the matrix. The larger clastic fragments behaved rigidly during deformation and have pressure shadows. Many of the smaller grains also have pressure shadows but some are strongly elongate parallel to the foliation. The quartz is strongly undulose and some grains have pronounced deformation lamellae.

Specimen No. 6337 does not contain chloritoid but has abundant chlorite.

Strongly sheared sub-greywacke sandstones are associated with the conglomerate. The intergranular boundaries between the quartz crystals in some of the quartzite fragments contain a film of haematite and it appears as if migration of the abundant haematite in the matrix has taken place.

SCHIST-QUARTZITE ASSEMBLAGE

A thick belt of mica schist and quartzite forms an arc from Junction Peak in the north-east, through the Raglan Range, and south along the Franklin River to the Twelvetrees Range in the south-west.

Similar garnetiferous mica schists and associated rocks occur on the Mary Creek Plain and at Algonkian Mountain. They appear to overlie rocks of the Quartzite-Phyllite assemblage in some places and to underlie them in others but the structural relations are complex and are discussed later.

The most extensive and best known rocks are those of the Franklin Group.

FRANKLIN GROUP

The Group was defined by Spry (1957) and the total apparent thickness varies from 1000 ft. at Twelvetrees Range to over 10,000 ft. south of the Raglan Range. Detailed mapping at the Raglan Range (Gee, 1962) shows that isoclinal folds ranging from microscopic dimensions to over 2 miles from hinge to hinge, with axes plunging flatly to the west, are responsible for the great apparent thickness.

The Franklin Group consists of a variety of schists with quartzites and minor amphibolites. The minerals present are almandine, muscovite, biotite, quartz, albite, chlorite, actinolite, rare kyanite and pyroxene and accessory tourmaline, rutile, zircon, magnetic, pyrite and zoisite.

Schists

Mica schists are the dominant rock type in the Franklin Group; they show a considerable variety of textures and allow detailed chronological analysis. Important varieties are muscovite schists, knotted albite schists, garnet-muscovite schists, fine-grained dark bi-mica schists, coarse schists or gneisses, and graphitic phyllites.

Muscovite and quartz are ubiquitous; garnet, chlorite and albite are very common; biotite is uncommon and kyanite is rare. The garnet in the schists is almandine. It has an R.I. of 1.801 $\pm$.001 and from x-ray data the cell size is 11.55 A. The cell size is a little greater than the figure of 11.518 A (Fleischer, 1937) or 11.526 A (Skinner, 1956) for pure almandine but the proportion of pyrope, grossular or spessaritite appears to be small.

The muscovite is optically negative and measurements of 2V range from 33° to 38°. The x-ray data compare favourably with muscovite but not with paragonite.

Chlorite is present in two forms. The apparent primary form which is aligned along the major foliation is pale yellowish green, non-pleochroic, has a + ve 2V of about 10° and a low birefringence (about 0.008). It is probably a magnesian prochlorite. The secondary chlorite clearly replaces garnet; it shows anomalous blue interference colours and is uniaxial positive. It resembles penninite.

Fig. 5g is of garnet-chlorite-quartz schist No. 6290 with a complex structure. This rock is dark-coloured and knotted without any obvious foliation. In thin section it is seen to be composed of large garnet porphyroblast set in quartz and separated by layers of chlorite. Pyrite is accessory. Some of the chlorite is secondary but much of it appears to be primary. The garnet crystals are notable because of the strong snowball structure but most crystals have an S-shaped core and a massive rim with some crystal faces; this suggests syntectonic growth for the cores and crystallization continuing into the posttectonic stage for the outer parts.

A chemical analysis (Table I) of No. 6290 shows that the rock has moderate silica and alumina, low alkalies and lime but high ferrous iron and magnesia. The garnet is probably almandine and thus the chlorite is probably rich in magnesia; Turner and Verhoogen (1960, p. 539) and Yoder (1952) indicate that almandine and magnesian chlorite may be stable together and this may explain their common association in the Franklin Group schists although fabric studies suggest that the garnet and chlorite may have formed at different times and that the garnet may have been metastable at the time of formation of the chlorite.

Specimen 6326 consists of large garnet porphyroblasts set in a matrix of contorted chlorite which wraps around the garnet and has formed later.

Many Franklin Group schists are fine-grained with two foliations (S_0 or S_1 and S_2) visible macroscopically, and two (S_1 and S_2) visible microscopically. They consist of quartz, muscovite, albite, garnet, biotite and chlorite. The major foliation S_2 is marked by thin, irregular layers rich in muscovite; the older foliation S_1 occurs as oblique lines of mica flakes, single micas or remnants of fold crests between the layers of S_2 (fig. 5). The muscovite which outlines S_1 is small and twisted and probably syntectonic to F_1; some small albites contain rotational structures and are syntectonic to S_1, others are posttectonic to S_1 (albite is discussed in detail in the albite-rich schist following). Garnet is mostly posttectonic to S_1. Garnet, albite and the S_1 micas are pretectonic to S_2; the S_1 micas are twisted and the S_2 micas are larger and wrap around the albite and garnet. The chlorite mostly forms layers in S_2 and is syntectonic to it although some randomly disposed flakes are posttectonic to S_2.

Although albite occurs in most of the schists, it is particularly abundant in some coarse, knotted albite schists. These are light coloured rocks with albite porphyroblasts up to 1 cm. across and consisting of quartz, muscovite, albite, garnet, biotite and chlorite. Examples are 6291, 6323, 6324, 6751, 6884, 6799 and 6842.

Albite is important as a chronological indicator and occurs in two forms which differ in size, type of inclusions and twinning. The smaller albites tend to be untwinned and contain helicitic folds outlined by tiny opaque granules. They are posttectonic to the oldest structure (S_1) and it is possible that the S_i is actually bedding (S_0). Similar-sized albites show true rotational structure and are syntectonic to S_1.

The large albite crystals which form porphyroblasts up to 1 cm. across are commonly twinned, the twinning being either simple or multiple. The crystals contain abundant large inclusions of quartz, muscovite and garnet in straight or slightly curved lines giving helicitic structure in which S_i (S-internal, the surface within the crystals, as opposed to S_e, S-external, the surface outside) are discordant with S_e (S_2). This is interpreted as being due to the posttectonic crystallization of albite which enveloped a metamorphic foliation differing from that enclosed by the small albites. It is a foliation older than S_2 and is taken to be S_1 which is normally recognized as remnants between the layers of S_2.

Garnet is also present in several different forms and thus is also a useful chronological indicator. Most notable are the syntectonic snowball garnets, some of which have posttectonic massive rims. Others have been fragmented and resemble the "rodded" garnets of Bailey (1923, p. 328); other evidence of pretectonic crystallization are pressure fringes and layers of muscovite wrapping around the garnet. The major foliation (S_2) wraps around the albite and garnet, and the weaker older one (S_1), is preserved mainly within old porphyroblasts.

The large albite crystals are posttectonic to F_1 and pretectonic to F_2, because they are shattered, muscovite of S_2 wraps around them, and S_1 is enclosed as S_i. Albite encloses small idioblastic crystals of garnet some of which have rotational structure and are thus syntectonic to F_1, and other are massive so that they are posttectonic to F_1 but earlier than the albite.

Muscovite laths and quartz blebs which delineate S_1 in the albites are syntectonic to F_1, but both minerals are elongate along S_2 and are also syntectonic to F_2. Coarse muscovite also forms posttectonically to S_2; it grows mimetically along S_2 and buts against the old albite crystals.

The relations of crystallization and deformation can be summarized thus:

Mineral	F_1 Pre-	F_1 Syn- (tectonic)	F_1 Post-	F_2 Syn-	F_2 Post- (tectonc)
quartz		—		—	—
muscovite		—		—	—
biotite		—		—	
garnet	—	—	—		
albite		- - -	—		
chlorite				—	—
S produced		S_0	S_1	S_2	
S folded		S_0		S_0, S_1	

Chronology of crystallization and deformation of Franklin Group albite schist.

Biotite occurs as ragged laths along S_2 and was formed simultaneously with the S_2 syntectonic muscovite. In most specimens it is notable by its absence along S_1 and within the albite crystals, but it does occur in some specimens.

Chlorite is abundant in some schists. It is not found along S_1 but is syntectonic to S_2, thus biotite and chlorite appear to have been formed simultaneously but not garnet and chlorite. Some chlorite has replaced garnet as randomly oriented flakes and is thus posttectonic to F_2. The two varieties differ in composition.

Albite crystallized in the schists in the quiet period following the first deformation phase while the temperature was still elevated; the restriction of the growth of albite to one stage in the schists suggests soda-metasomatism posttectonically to F_1. The origin of similar albite has been a source of controversy as to whether it was primary or has been introduced, and consequently the albite in the Franklin Group must be investigated. Similar albite has been described from the Dalradian schists of Scotland and Ireland and from the Otago Schists of New Zealand (Hutton, 1940; Turner and Hutton, 1941).

Despite considerable study of the albite in the Dalradian schists, the origin is debatable. Clough (1897) considered that the feldspar may have been due to " impregnation "; Cunningham-Craig (1904) and Bailey (1923) believed that the albite was an original contituent of the sediments; McCallien (1929) preferred a metasomatic origin but a later paper with Bailey (Bailey and McCallien, 1934) returned to a non-metasomatic view. Reynolds (1942) put a strong case for metasomatism along the core of the Carrick Castle fold but it was largely based on circumstantial evidence. Jones (1960) came to similar conclusions.

Most of the arguments for a metasomatic origin are not conclusive, the strongest being that the soda content of the schists is higher than that of known sediments. Reynolds (1942) described schists containing 56% albite and 4.2% soda. The proportion of soda (Table I) in the Franklin Group schists is just under 2% which is less than that of Reynolds' " normal biotite schist " and well within the range of common sediments. Thus there is no evidence at present to indicate that the albite in the Franklin schists was other than an original constituent of the sediments.

The chemical analysis of the albite schists show that the proportion of soda is not high, being only a little above that in the garnet schists. Lime is low as in most of the Tasmanian Precambrian schists and potash is high. It is difficult to estimate the exact nature of the original sediment but it was probably a quartz-siltstone. The analysis is similar in some respects to a greywacke but differs in that potash exceeds soda, thus suggesting a mature sediment. The degree of oxidation of the iron is low suggesting a lack of chemical weathering of the sediments but may be more a reflection of metamorphic conditions.

Kyanite is rare in Tasmanian Precambrian rocks, but occurs together with muscovite, chlorite and quartz in specimen No. 6298. The rock is light-coloured and coarse-grained. In thin section it consists mainly of quartz with layers of muscovite and chlorite giving a single irregular foliation. Tourmaline and rutile are accessories. It is not possible to determine the sequence of crystallization events with any certainty. The last deformational phase folded the foliation and made the quartz undulose but was not accompanied by crystal growth; it was presumably the F_3 of adjacent rocks. Muscovite and chlorite are interleaved and were presumably formed simultaneously, but the muscovite has the coarseness generally associated with growth posttectonically to F_2. The kyanite forms skeletal crystals enveloped in layers of coarse muscovite but some small micas wrap around it. By analogy with similar textures in albite schists it is probable that kyanite formed posttectonically to F_1 with the majority of the muscovite posttectonic to F_2.

Quartzites

White, platy, and saccharoidal quartzites are prominent in the Franklin Group in the Raglan Range, near the Franklin River, south-west of Frenchman's Cap, and in the quarries on the Lyell Highway about 25 miles from Queenstown.

The quartzites generally contain muscovite and some also contain garnet, biotite, haematite and accessory tourmaline, rutile, apatite and zircon. They vary from platy to massive, and from fine-grained to saccharoidal. A compositional banding is probably bedding (S_0); a tectonic foliation S_1 is commonly parallel, or almost parallel, to S_0 and curves around the hinges of folds; a later axial-surface foliation S_2 is parallel to, and indistinguishable from, S_1 and S_0 on the limbs of the isoclinal folds but cuts across them in the hinge zones. Intersections of S_0 and S_1, S_0 and S_2, S_1 and S_2, give 3 lineations (L_1 and L_2) which are parallel to the minor folds (F_2) although divergences in direction of up to 10° are not uncommon. Lineation due to rodding, mullions, corrugations, ribs, and lines of elongate mica are at least partly related to F_1 (i.e., are L_1) and thus may not be parallel to F_2 folds although it appears that F_1 and F_2 axes were very similar in direction.

In thin section the quartzites commonly consist of quartz grains which are flat in the plane of major foliation and elongate parallel to the lineation. The foliation is marked by parallel muscovite flakes.

Petrofabric diagrams of the quartzites will be published elsewhere. The mica has a strong degree of preferred orientation and marks a single foliation (S_1). The quartz shows up to 9% maxima in a well developed girdle; this appears to be a normal R-tectonic with a girdle normal to the lineation but actually the girdle is at 70° and the fabric is triclinic rather than monoclinic.

Petrofabric analysis of a recumbent isoclinal fold in quartzite and schist by Gee (1962) shows that the main foliation is independent of the axial surface and curves around the fold; this tectonic surface is S_1 and is parallel or nearly parallel to S_0. No axial surface is shown by the micas in the quartzite in this particular fold but it occurs in others. The quartz fabric is homogeneous throughout the fold and is not " unrollable "; it is thus related to F_2 (S_2).

Some quartzites contain a little garnet and biotite, others are rich in haematite, e.g., nos. 6260 and 6264. These are fine-grained, banded and knotted rocks, dark in colour. They consist chiefly of quartz and haematite; some iron oxide pseudomorphs garnet but in places has replaced quartz. Patches of very fine-grained chlorite occur along some quartz boundaries and quartz appears to have been replaced first by chlorite then by haematite. The processes are post-metamorphic and may be due to weathering.

The garnet relics are curved and web-like indicating syntectonic crystallization but the single irregular foliation S_e is discordant with S_i. It appears likely that quartz, garnet and at least some muscovite formed syntectonically to F_1 but that the foliation was formed (at least partly) in F_2 (i.e., is S_2).

METAMORPHOSED IGNEOUS ROCKS

Various kinds of amphibolites within the Franklin and Joyce Groups have been referred to by Spry (1957) as the Older Basic Igneous Group and are considered to be regionally metamorphosed basic to ultrabasic igneous rocks.

Boudins a few feet wide in schists on the Raglan Range are coated by a thin film of milky quartz. Mather (1955), McLeod (1956) and McKellar (pers. comm.) report that they form small discordant bodies.

The mineralogy of the amphibolites is simple and is congruent with that of the enclosing schists. Garnet, actinolite, biotite, chlorite, albite, quartz, zoisite and epidote are the major minerals with accessory sphene, rutile, magnetite and zircon. The textures are complex and are similar to those of the schists although the uniform nature of the original igneous rocks prevents a detailed recognition of the history. The amphibolites contain one main foliation but show evidence of three separate deformational phases.

In specimens such as 6755 and 6753, an original texture composed of coarse actinolite and garnet has been partly replaced by a new foliated texture of fine-grained actinolite, chlorite, albite, zoisite and rutile. The large pale-green actinolite crystals are undulose, fragmented and rimmed with small amphibole crystals and are pretectonic to the existing foliation. The amphibole has a $Z \wedge c$ of 20° and a 2V negative of 75°. Garnets are fragmented and are wrapped around by small amphiboles and are thus similar in age to the large amphiboles. Many garnets contain a pair of fractures at about 60° to each other and these are regarded as very late congugate shears. The foliation is produced by sub-parallel actinolite prisms, elongate quartz and granules of epidote or zoisite. Some of the small actinolite crystals are syntectonic to the foliation but most are posttectonic and have either grown mimetically parallel to the foliation or are randomly disposed. Much of the small actinolite wraps around the garnet which is older but the late posttectonic amphibole buts against the garnet. A blue-green tint which is restricted to the amphibole in contact with garnet shows that the garnet is older. Accessory rutile occurs as inclusions in all minerals and was one of the first minerals to crystallize.

Other amphibolites differ by containing biotite but no coarse amphibole. The oldest mineral is garnet as abundant porphyroblasts which are massive and well-formed in some specimens, fragmented in others, and have rotational structures in others. The garnet is either syntectonic with posttectonic rims or is entirely posttectonic to an early phase of deformation (F_1). Fractures are filled with quartz, biotite, actinolite, albite or chlorite. Biotite forms large rusty brown, twisted crystals which wrap around the garnet and are parallel to the foliation. These are pretectonic to F_2. The actinolite is pale-green and forms strings, bands or masses of matted crystals wrapping around the garnet. Amphibole, which is fresh and orientated

	F_1			F_2	
	Pre-	Syn- tectonic	Post-	Syn- tectonic	Post-
actinolite		— ? —	——	——	——
garnet		——	——		
biotite		——	— ? —	?	
albite		?	——	?	——
quartz			——	——	
calcite				——	——
chlorite				——	——
S produced		S_1		S_2	
S folded				S_1	

Chronology of crystallization and deformation of Franklin Group amphibolite.

obliquely to the foliation, is posttectonic to F_2. Albite occurs in several forms. Large, fractured and sericitized crystals (e.g., in 6883) are very old (pretectonic to all deformation) and might either be early metamorphic crystals or original phenocrysts. Small shattered and sericitized crystals of albite appear to be of similar age to the garnets; some contain helicitic structure representing the oldest recognizable foliation S_1. Small irregularly shaped fresh albites with S_i concordant with S_e are posttectonic to S_2.

The amphibolites are rather basic in composition and some specimens such as 6744, which consists of 60% actinolite, 30% garnet, and the remainder chlorite, albite, zoisite and quartz, may have been ultrabasic. Other specimens resemble basic rocks and contain about 30% of albite. A massive amphibolite (30132) from the Raglan Range consists of amphibole 64%, garnet 20%, biotite 2%, ilmenite 4%, sphene 1%, and apatite 1%.

The analysis (Table II) is similar to that of other Tasmanian Precambrian amphibolites from the Forth River and Port Davey. The rock was apparently originally a basic igneous rock but differs mainly in its lower silica and alkali content. The soda and potash contents are closer to those of an ultrabasic rock and it seems likely that some alkali loss accompanied metamorphism. Albite is common in veins in the amphibolite.

The amphibolites were first metamorphosed to coarse, weakly foliated and banded rocks rich in actinolite and garnet but a second deformational stage resulted in a reduction of grain-size, contortion of early planar structures and produced a poorly foliated structure. The evolution of fabric is similar in many respects to that of the massive quartzites in the Mary Group.

An actinolite schist (No. 30132) of uncertain affinities is interlayered with normal mica schists at the Raglan Range (Gee, 1962). It is foliated and consists of albite, biotite, quartz, amphibole, zoisite, sphene, apatite and ilmenite. A chemical analysis is given in Table II. It is midway in composition between the normal schists and the amphibolites.

Eclogite

A pyroxene-garnet-amphibole rock, previously referred to by Spry (1957) as a pyroxene amphibolite has been shown to be related to the eclogites (Spry, in press). An analysis is given in Table II.

JOYCE GROUP

The Joyce Group was defined by Spry (1957) and was shown to resemble the Franklin Group. Schists such as 6244 and 6245 are similar to garnet-muscovite-schists described previously from the Franklin Group. No. 6892 is a coarse muscovite-biotite-garnet schist with abundant porphyroblasts of albite which are posttectonic to S_1 which is preserved only as S_i and pretectonic to S_2 which is outlined by muscovite and biotite. The mineral paragenesis is identical with that given for specimen 6323 earlier. No. 6887 is an eclogitic rock from the Joyce Group at Mary Creek Plain and is identical with that from the Franklin Group on the Lyell Highway mentioned earlier.

Some very coarse muscovite schists with porphyroblasts of garnet a quarter of an inch across outcrop on the Mary Creek Plain. Muscovite-quartzites with a strong foliation and lineation and tight isoclinal folds also occur there.

ALGONKIAN MOUNTAIN GROUP

Wells (1957) named the garnet-mica schists around Algonkian Mount (just east of Warnes Lookout) the Algonkian Group. They are referred to here as the Algonkian Mountain Group to avoid ambiguity.

Dark greenish-grey, glossy mica schists such as 6440 are typical. In thin section they are fine-grained schistose rocks consisting chiefly of quartz and muscovite with small porphyroblasts of garnet, albite, a little chlorite, abundant iron ore, tourmaline and zircon. Some of the partially chloritized garnets have " snowball " structure and many albite crystals contain helicitic structure.

No. 6434 is a fine-grained rock consisting chiefly of quartz and muscovite with lesser biotite and albite (with helicitic structure). The structure is very complex and an older, very contorted S-surface can be seen to be partially obliterated by a later imperfectly developed foliation.

The similarity in composition and deformational history between the schists of Algonkian Mountain and those of the Franklin and Joyce Groups is very strong and is seen particularly in specimens 6436, 6437, 6440, 6441 and 6448. The Algonkian Group outcrops east of the south-eastern corner of the map in fig. 1, and thus is not shown. Its structural relationships are not known and no attempt will be made to fit it into the general structural or stratigraphic interpretation.

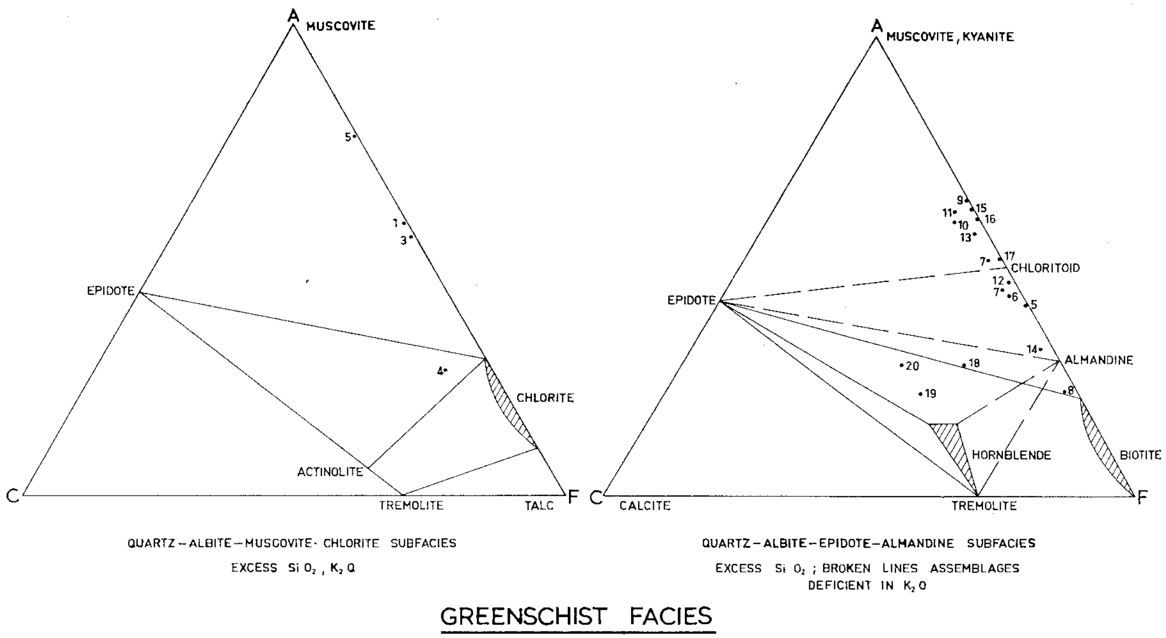
METAMORPHIC PETROLOGY

In terms of the facies classification of Turner and Verhoogen (1960) all rocks belong to the Greenschist Facies. The Mary, Scotchfire and Fincham Groups belong to the quartz-albite-muscovite-chlorite sub-facies whereas the Franklin and Joyce Groups belong to the quartz-albite-epidote-almandine sub-facies.

The rocks belonging to the two sub-facies are intimately related structurally (figs. 1 and 2) and two main problems have been recognized (Spry, 1957, 1962).

(1) Whether or not the rocks of the Franklin and Joyce Groups really differ in metamorphic grade from those of the Mary, Scotchfire and Fincham Groups.

(2) The reasons why the sub-facies boundaries coincide with the lithological boundaries.



6. Facies classification of metamorphic rocks from the Frenchmans Cap area. Numbers refer to analyses in Table.

METAMORPHIC GRADE OF THE FRANKLIN AND JOYCE SCHISTS

It is difficult to state the exact position of schists from the Franklin and Joyce Groups in the Facies Classification. This is partly because of apparently anomalous associations such as garnet and chlorite or kyanite and albite and partly because the metamorphism consisted of two episodes (F_1 and F_2) which differed in intensity. In general, the association of almandine garnet with albite in rocks rich in muscovite and quartz is typical of the lower part of the garnet zone of regional metamorphism (quartz-albite-epidote-almandine sub-facies) and this is the most probable classification for the schists for the F_1 episode. The occurrence of kyanite (albeit uncommon) the coarseness of grain and the association with eclogite however, suggest that perhaps some of the rocks are of higher grade. The schists are so deficient in lime that a more-calcic plagioclase than albite probably would not occur even at high grades. Albite however, occurs in the amphibolites which are enclosed by schists and this suggests that conditions were appropriate for albite not oligoclase but the amphibolites are comparatively uncommon, and occur as small outcrops, commonly some miles apart.

The status of kyanite as an index of metamorphic grade at Frenchman's Cap is not clear. Ramberg (1953, p. 144) stated the commonly held view that kyanite should not be present as a stable mineral in the Greenchist Facies but Turner and Verhoogen (1960, p. 539) consider kyanite to be stable in this Facies. In view of the complexity of paragenesis at Frenchman's Cap, it is quite possible that kyanite was not a stable mineral.

The common occurrence here of chlorite in garnetiferous schists is not yet understood and must await work on the exact compositions of the two minerals. Study of the chronology of crystallization indicates that garnet formed at an early stage (F_1) and chlorite at a later stage (F_2) but no evidence exists to indicate that the most abundant chlorite outlining S_2 is not in equilibrium with the garnet. Very late chlorite partially replaces garnet, but this is a different variety. It is possible that garnet and kyanite persisted as metastable relics through the later low grade metamorphic phase but a considerable body of evidence indicates that overlap exists between the stability fields of certain garnets and chlorites (Harker, 1932, p. 217; Yoder, 1962; Turner and Verhoogen, 1960, p. 339).

The first stage (F_1) in the metamorphism produced the assemblage quartz-muscovite-biotite-garnet-albite (kyanite) in the schists and the second stage (F_2) produced quartz-muscovite-chlorite. The mineralogy of the quartzites is similar to that of the schists; quartz-muscovite-biotite-garnet at the first stage and quartz-muscovite-chlorite at the second.

The mineralogy of the amphibolites is compatible; actinolite-garnet-biotite-albite during F_1 and actinolite-chlorite-albite during F_2. The amphibole appears to be a pale actinolite rather than the hornblende expected in garnetiferous amphibolites. Many of the amphibolites are rich in mafic minerals and lack feldspar suggesting that they have been derived from ultrabasic igneous rocks.

METAMORPHIC GRADE OF THE MARY, FINCHAM AND SCOTCHFIRE GROUPS

Most of the Mary Group phyllites contain only the insensitive pair quartz and muscovite but the assemblage quartz-muscovite-chlorite occurs in some Mary, Fincham and Scotchfire phyllites. The last Group also contains dolomite, chloritoid, actinolite and zoisite. Feldspar is almost entirely absent. The mineral assemblages appear to have been constant in all these rocks though both F_1 and F_2 and indicate the quartz-albite-muscovite-chlorite sub-facies of the Greenschist Facies.

RELATIVE METAMORPHIC GRADES

The Franklin and Joyce Groups are mainly distinguished from the Mary, Scotchfire and Fincham Groups by their coarser grainsize, greater degree of recrystallization and the presence of garnet and biotite. This is sufficient to indicate different intensities of metamorphism only if the rocks are of similar composition. The Franklin and Joyce Groups are dominantly meta-pelites with minor quartzites, the Mary and Fincham are mainly quartzite and the Scotchfire is mainly pelitic. Analyses in Table I show that the chemical compositions of a Scotchfire phyllite, various Franklin schists and a Mary phyllite are not sufficiently different to account for the difference in mineralogical composition. It is concluded that the difference is metamorphic grade is real.

Field-mapping shows that adjacent rock units such as the dominantly quartzite Mary Group and the schist-rich Franklin Group can be delineated and that bedding, where recognizable, seems to be generally parallel to the junction between the major units. The apparent stratigraphic boundaries are also metamorphic boundaries. Detailed work by Gee (1962) indicates discordance between Franklin and Mary structures right at the contact and also the presence of a thin layer of quartz-albite-muscovite-biotite sub-facies between them.

The distribution is revealed as even more unusual than it appears on the map when the third dimension is considered. Remnants of S_0 and S_1 in the Joyce, Mary, Franklin and Fincham Groups all dip in the same direction along certain lines of section. This suggests (Spry, 1957) that the higher grade Franklin Group is sandwiched between the lower grade Mary and Fincham Groups.

The best explanation seems to be that the Mary and Fincham Groups are equivalent as are the Franklin and Joyce. Similarities in fabric evolution appear to preclude the possibility of an unconformity between the lower and higher grade assemblages such that the former were only affected by the lower grade F_2 and the latter by the higher grade F_1 as well as F_2. Field study of the contacts between rocks belonging to the two assemblages, also rules out the possibility of unconformity.

STRATIGRAPHIC CONSIDERATIONS

It is not possible to establish a stratigraphic succession in this area, nor to correlate confidently between Groups. The most obvious similarity is between the Franklin and Joyce Groups but the main problem is that the less altered Mary Group appears to lie between them. The Joyce Group passes beneath the Franklin Group between Mt. Mary and the Raglan Range. The Joyce Group dips beneath the Mary Group at the eastern end of the Mary Antiform (Spry, 1957) but further west across the Collingwood Synform, the rocks which appear to pass beneath the Mary Group are continuous with the Franklin Group (Spry and Zimmerman, 1959). The latter contact was interpreted as a fault but this is uncertain. It seems likely that the Joyce and Franklin Groups are equivalent.

It does not seem possible to correlate between the Joyce, Mary, Franklin and Fincham Groups in the western part of the area and the Scotchfire, Algonkian and Elliot rocks in the eastern part. Spry and Zimmerman (1959) suggested a major structural break (Artists Hill Fault) between them.

It has been considered (Spry, 1957) that the Mary and Fincham Groups might be equivalent because of their topographic expression and general lithological similarity. There are differences, however, which suggest that the Fincham is closer to the Scotchfire. The Fincham Group contains about 65% of phyllite and siliceous phyllite, 25% quartz schist and 10% massive quartzite. The Mary Group contains about 20% phyllite, 45% quartz schist and 35% massive quartzite. The differences might be accounted for by difficulties in terminology between e.g. siliceous phyllite and quartz schist, and also by structural complexities.

The most likely correlations are as follows:

(1) The Franklin, Joyce and Algonkian Groups are the same but are separate from the Mary Group (= Elliot Quartzite) plus the Fincham (= Scotchfire Group).

(2) The Scotchfire Group may overlie the Elliot Quartzite (Wells, 1956) which may be equivalent to the Mary Group which is overlain by the Franklin Group. This suggests that the Scotchfire may be the lower grade equivalent to the Franklin. Gee (1962) observed that the Fincham Group (which resembles the Scotchfire) appeared to pass laterally into the Franklin Group with increase of grade. The Scotchfire and Franklin are somewhat similar but the Franklin contains abundant albite which is very rare in the Scotchfire, and the Scotchfire contains a number of dolomites which have not been found in the Franklin.

Correlation for the present will be restricted to the western structural unit where possible successions are:

(I)	(II)	(III)
Fincham	Mary=Fincham	Fincham
Franklin	Franklin=Joyce	Franklin=Joyce
Mary		Mary
Joyce		

No positive statements can be made about the stratigraphic sequence because of the lack of facings and the order of the alternatives above may be reversed. Alternative (III) is preferred here, but the major structure given later can accommodate any of the sequences.

Contacts Between Groups

The nature of the contacts between such groups as the Mary and Franklin or the Mary and Joyce are of great importance in solving the structural, stratigraphic and petrological problems of this area, but they are at present poorly understood. They have been interpreted as faulted (McLeod, 1955, pp. 6, 18; Spry, 1957), conformable (Mather, 1955, p. 22), unconformable (Spry, 1957), and as gradational (Mather, 1955, p. 22).

The evidence is as follows:

(1) Joyce-Mary Contact.

The foliation (S_2) of schists in the Joyce Group dips shallowly beneath phyllite at the base of the Mary Group at the eastern end of the Mary Antiform. There is an apparent gradation up the southern spur of Wards Bluff with the orientation of the visible foliation similar in both.

Further west on the Mary Creek Plain, the Joyce schists striking at 75° and dipping steeply north are overlain by basal phyllite of the Mary Group striking at 120° and dipping north at 10°-16°.

(2) Mary-Franklin Contact.

This contact is disturbed by Palaeozic faults in many places but is undisturbed near the junction of the Mary Creek and the Franklin River, about 2 miles N.N.W. of Wards Bluff and between Flat Bluff and the Raglan Range. The contact near the Raglan Range has been studied in most detail (Gee, 1962) and appears to be a metamorphic boundary dislocated by later "sliding" (in the sense of Bailey, 1909, p. 53-4; 1910, p. 593). The basal formation of the Franklin Group is the Governor River Phyllite (Gee, 1962). This overlies phyllites with interbedded thin quartzites of the Mary Group, and the quartzites appear to be discordant at the contact i.e. the contact is oblique to the bedding in the Mary Group. There appears to be complete gradation between Mary Group phyllite (analysis No. 15, Table I) with chlorite, Governor River Phyllite (No. 16) containing biotite, thence into schist (No. 17) containing garnet, over a distance of 600 ft. The grainsize increases from the Mary to the Franklin but is largely due to mimetic crystallization of muscovite, posttectonically to F_2 The The foliation S_1 is prominent in the Mary phyllite but becomes increasingly deformed through the transition into the Franklin Group where S_2 is the dominant foliation.

The analysis of the chronology of deformation and crystallization given earlier shows that the difference in grade between the Mary and Franklin Groups was produced during F_1, but isoclinal folds (up to 2 miles from hinge to hinge) were formed during F_2. In a discussion of the major structure later, it will be suggested that the metamorphic zones (i.e., the Mary, Franklin, Joyce and Fincham Groups) were folded into a very large recumbent fold during F_2 and that the contacts were blurred by F_2 movements.

STRUCTURE

The structures can be divided into two main groups:

1. Precambrian (F_1 and F_2) foliations (S_1, S_2), lineations (L_1, L_2) and folds (F_2).
2. Tabberabberan (Devonian) (F_3) folds faults.

Palaeozoic (Tabberabberan) Structures

The Frenchman's Cap area is part of the Tyennan Geanticline (Carey, 1953) which was a relatively stable region from Late Precambrian to Middle Palaeozoic times. The Geanticline also formed a mass against which the Palaeozoic sediments were folded but the Precambrian rocks were not completely rigid and participated in the folding. It has been shown elsewhere (Spry and Gee, in press) that all of the large scale folds and faults visible in fig. 1 are of Tabberabberan age. Also that "unrolling" the Palaeozoic anticline at the Raglan Range leaves the foliations of the Franklin Group with a few degrees' dip to the west. Thus prior to the Palaeozoic, the Precambrian rocks were sub-horizontal and folded into recumbent isoclinal folds.

The more important Precambrian structures have the following features:

Bedding (S_0). Comparatively undistorted bedding is recognizable in massive quartzites of the Mary Group where it contains ripple marks. The lamination in many of the quartzites and the contacts between thin layers of schist and quartzite may represent bedding which has been transposed in varying degrees.

Foliations. The schists and phyllites contain up to three (S_1, S_2, S_3) mesoscopic and microscopic foliations, but these are developed to different degrees in different rocks.

Phyllites and schists commonly contain two mesoscopic foliations marked by parallel mica flakes and a fracture cleavage (S_3) which may be much younger. The foliation (S_2) is marked by layers of mica flakes and is parallel to the axial surfaces of folds; it cuts across an older crumpled surface (S_1) which is parallel or nearly parallel to a colour banding which may be S_0. S_0 and S_1 have been completely obliterated by mica growth along S_2 and are not visible in the coarser Franklin Group schists.

The foliation in the Franklin quartzites and Mary quartz-schists is differently developed. It is a plane of parting due to parallel muscovite flakes; quartzites lacking mica are very weakly foliated. The foliation is parallel or nearly parallel to compositional banding (S_0) and both have been folded and are cut by a sporadic axial-surface foliation which is identical with S_2 in adjacent schists. The main foliation in the quartzites is S_1 and in most outcrops it is parallel to S_0.

Lineations

Franklin Group quartzites are the most strongly lineated; some Mary, Fincham and Scotchfire quartz schists also have a lineation but many phyllites and schists have none.

The linear structures in Franklin quartzites consist mainly of fine striations on foliation surfaces accompanied by elongation of quartz grains and large mica flakes. It is almost normal to a girdle of quartz optic axes which has been shown to be an F_2 structure so that this lineation is L_2. Other L_2 structures in these quartzites include fold axes and fold mullions in the cores of the larger isoclinal folds. S_2 is weak in most quartzites so that an L_2 formed by intersections of S_2 with S_0 is less common but does appear in the hinge zones of some isoclinal folds.

Some lineations appear to be intersections of S_0 and S_1 and thus are L_1 structures but these are difficult to recognize because S_0 and S_1 are similar in orientation.

Lineation (L_2) in the schists and phyllites is due to crenulations of S_1, to intersections of S_1 and S_2 and to a shredded fibrous appearance. Quartz-rods produce a strong lineation (L_2) in many schists and phyllites. They tend to be particularly abundant in the cores of folds. They vary from slender rods and prisms a metre in length and a centimeter or so in diameter down to irregular lenticular rods a centimeter or so long. Some can be recognized as remnants of quartz veins which have been folded together with S_1.

Lineation in some quartz-schists or quartzites from the Mary Group is due to crenulations of S_0, or intersections of S_0 and S_1 and these may be L_1; crenulations of S_1 are L_2 and L_3 structures. L_1 and L_2 are similar in direction.

Boudinage

Boudins of quartz and quartzite are enclosed in schist and phyllite. Boudins of amphibolite with circular section and unknown length occur in Franklin Group schists (Gee, 1962). All gradations may be seen between discrete quartz rods and quartz boudins, particularly in the cores of folds. The long axes of the boudins and the striations on their surfaces are parallel to the lineation in the enclosing rocks.

Folds

Folds range from microscopic dimensions up to about 2 miles from hinge to hinge. All are attributed to F_2 as S_0 and S_1 are folded and S_2 is the axial surface. No F_1 folds have been recognized. The quartz-fabric in the Franklin quartzites is related to F_2 folds but it is possible that at least part of the fabric in the Mary Group quartzites is related to F_1. Lineations are essentially parallel to fold axes.

Most folds are recumbent and isoclinal. Folds in schist range from irregular crumples and chevron folds to simple similar folds. The latter have strong axial surface foliation with attentuated limbs. Examples have been figured by Spry (1957) and Gee (1962).

Microscopic Symmetry

The mesoscopic fabric is characterized by a lineation which is an axis of rotation normal to a plane of symmetry. Axes of asymmetrical folds, lineation, rods, mullions and boudinage are parallel and constitute a B lineation. The symmetry of F_1 and F_2 structures is basically monoclinic.

Large Scale Precambrian Structure

It has not been possible to recognize the large-scale Precambrian structure by mapping and the problem is made more difficult by the uncertainty of the stratigraphic succession. Field mapping has revealed a series of thick layers (Mary Group, Franklin Group, &c.), separated by surfaces along which there may have been considerable movement. After the Palaeozoic folds are removed the layers undulate with a lineation plunging at 4° towards 290° (Spry and Gee, in press). It is regarded as most probable that the major Precambrian fold axes plunge in the same direction. Following McIntyre (1951), &c., a tectonic profile may be sketched looking down the direction of the lineation. The Devonian folds show as a series of synforms and antiforms and the general structure of the higher part of the profile is similar to that given by Spry (1957) and Spry and Zimmerman (1959).

The most striking lithological similarity in the area is that between the Joyce and Franklin Groups; that between the Mary and Fincham Groups is less close. Several structures were suggested by Spry (1957) to allow correlation of these groups and one of these was by isoclinal folding. A plan and section of such a structure is given in fig. 8 but this kind of structure is considered unlikely for the following reasons:

(1) The subhorizontal axes of the isoclinal folds curve around in plan but the lineation is not disturbed in this way.

(2) The hypothetical fold axes are not parallel to the lineation.

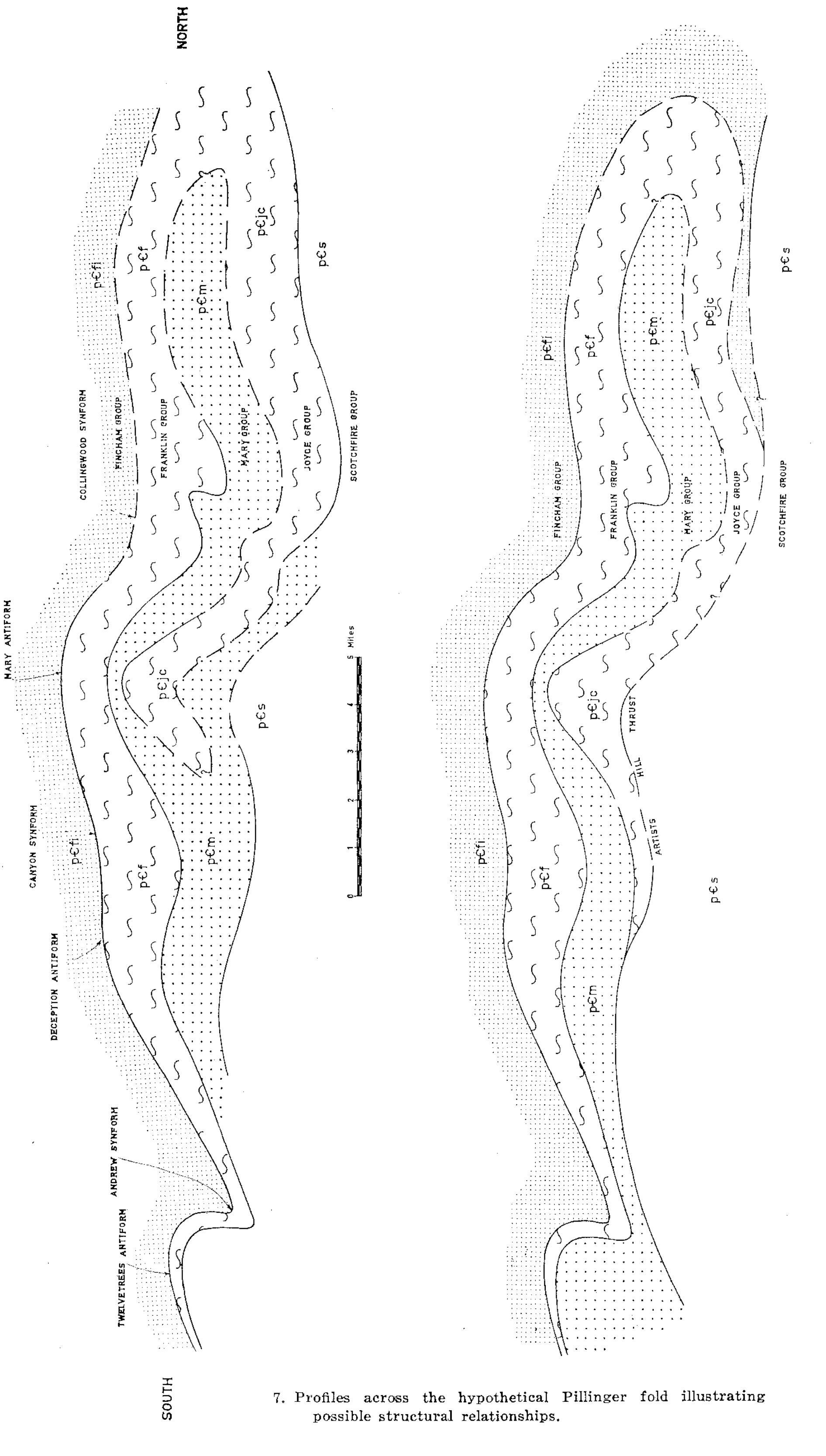
(3) The arrangement of fan folds in the cross section is not a convincing structure.

It is postulated that any major structure must have its major tectonic axes parallel to the lineation and that this structure is some kind of large recumbent fold plunging very flatly towards 290°. The kind of structure is not unlike that of McIntyre's (1952) interpretation of Beinn Dronaig and the reasoning follows his.

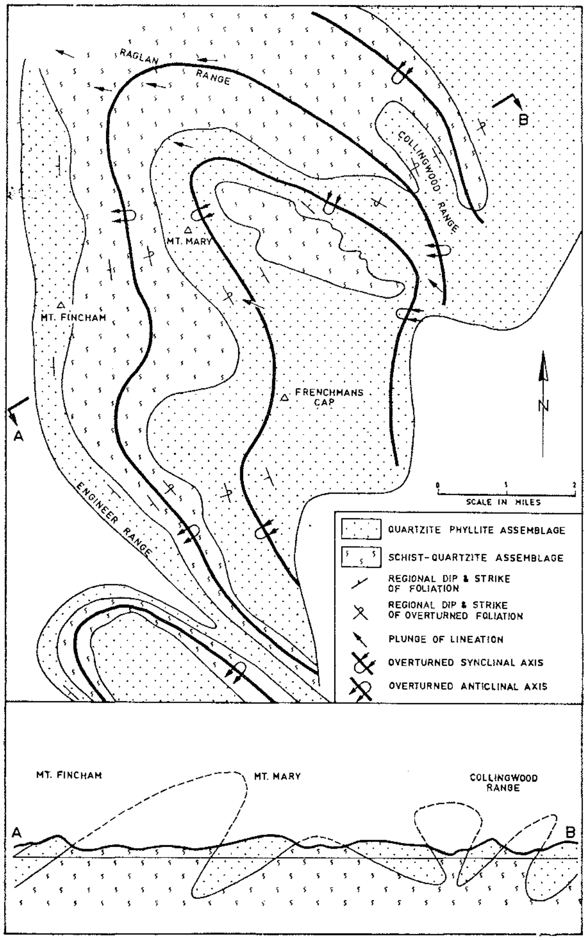
Following this hypothesis two alternative structures are possible:

(1) Two lithologies are interleaved as the Joyce, Mary, Franklin and Fincham Groups as a series of nappes.

(2) The Joyce is the same as the Franklin Group and the Mary is the same as the Fincham Group, and the two are folded into a series of recumbent folds. As there is no physical continuity between the groups correlated, the closures of the folds would lie outside the area mapped.



7. Profiles across the hypothetical Pillinger fold illustrating possible structural relationships.



8. Fan-fold hypothesis for the Frenchmans Cap area; this an unlikely explanation.

The second alternative is the most reasonable yet found as it is congruent with:

(1) All field observations on the distribution of lithologies.

(2) The style of the minor structures.

(3) The direction of the lineation.

It brings together the apparently different stratigraphic sequences suggested earlier in that the Joyce-Franklin and Mary-Fincham correlations can be made. The Scotchfire is most reasonably regarded as the upper part of the Fincham, but the hypothesis is sufficiently flexible for it to become the lower grade equivalent of the Franklin and Joyce.

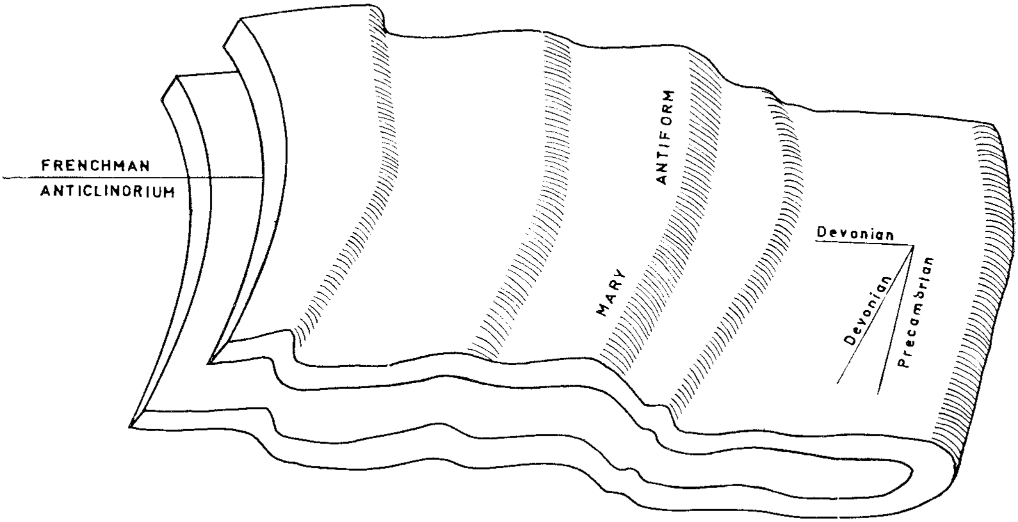
It is impossible to predict much about the size and shape of the larger Precambrian structures but in fig. 7, hypothetical profiles (looking down the lineation) indicate the kind of structure considered likely. This large hypothetical fold is named the Pillinger Fold from its occurrence in the Pillinger Quadrangle. Fig. 9 shows the fold with the Devonian structures superimposed.

TECTONIC EVOLUTION

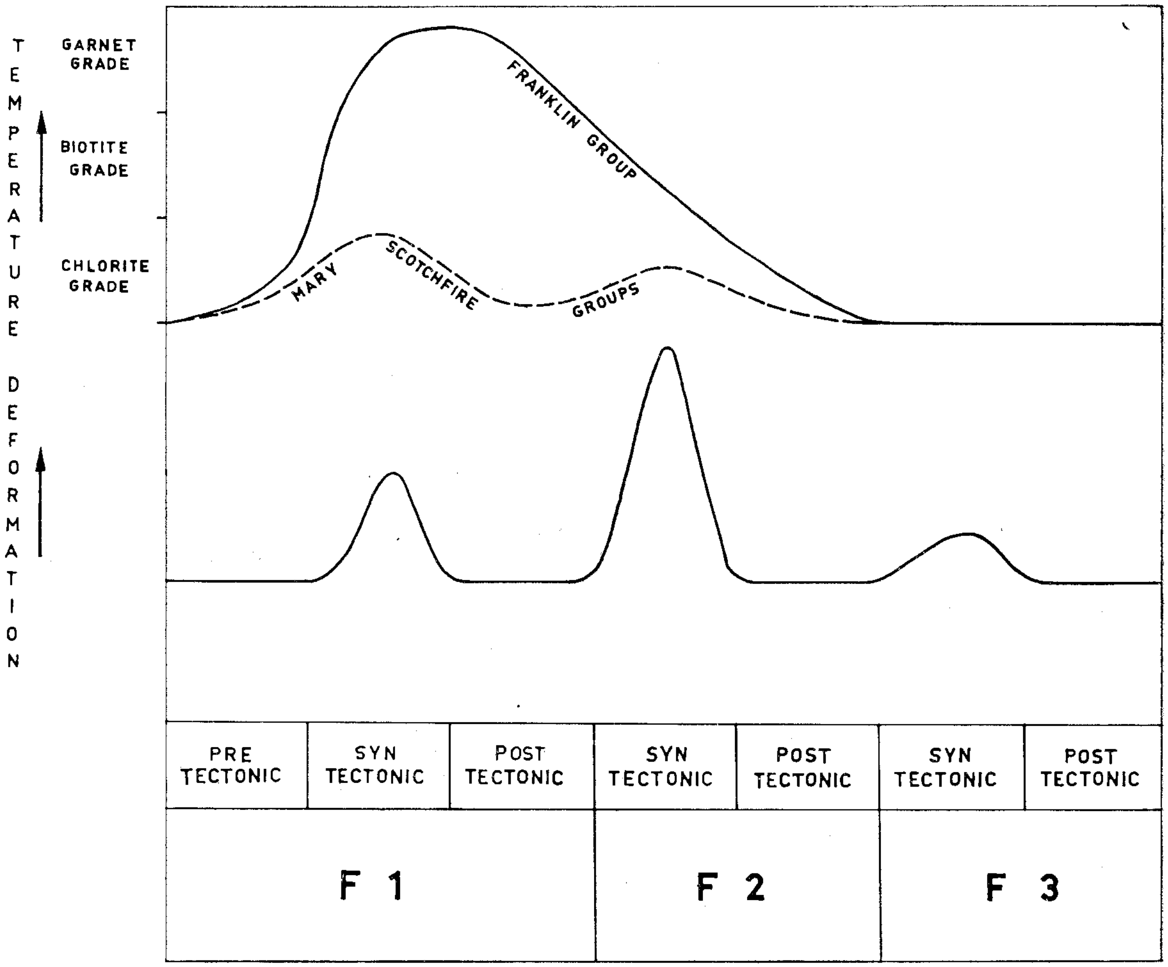
The relations between the formation of the various minerals and the successive stages of deformation are summarized in fig. 10. The main regional metamorphism contained at least two periods of deformation. A third pulse crenulated the rocks and produced a fracture cleavage but was not accompanied by mineral formation.

The first two phases of the metamorphism differed in character. The high-grade minerals (garnet and kyanite) in the Franklin Group were produced during F_1 and the lower grade assemblage (muscovite-biotite-chlorite) was formed during F_2. The Mary and Scotchfire phyllites contain no evidence that the first phase was of higher grade than the second. Albite crystallized abundantly in Franklin schists in the inter-tectonic period but there is no evidence that this was necessarily due to metasomatism. Conditions appropriate for the formation of garnet and kyanite existed in the inter-tectonic period and chlorite probably did not appear until later. The Franklin amphibolites were coarse garnet-actinolite rocks during F_1 but were reduced in grainsize during F_2 with an accompanying lowering of grade as garnet was replaced by chlorite. The massive Mary quartzites are similar to the amphibolites in that they were coarse, granular rocks during F_1 but were granulated during F_2 to give mortar structure. The Franklin quartzites were coarse quartzites in the first phase and some contained garnet; during the second phase the grainsize decreased and chlorite developed. Conditions were such that considerable posttectonic crystallization took place in the Franklin Group rocks after the F_2 phase; muscovite grew in the schists, actinolite in the amphibolites and quartz in the quartzites to obliterate some effects of earlier deformation.

The limited evidence available does not allow mesoscopic distinction between structures produced during F_1 and F_2 stages as no difference in orientation or style have been found. Isoclinal folds range in size from fractions of a millimetre to a kilometre or so across and it is suggested that the major fold is many kilometres across. The small folds belong to F_2 and it is postulated that the hypothetical major folds belongs to this stage also. Thus it is suggested that the temperature peak was reached during F_1 but that most deformation took place in F_2. It is thought that two lithological assemblages originally existed; a quartzitic and a pelitic group. The quartzitic group (Mary, Scotchfire, Fincham) was metamorphosed to chlorite grade and the pelitic group (Franklin, Joyce) to garnet grade during the first stage of metamorphism (F_1). The two lithologies were tightly infolded as a large recumbent fold during the second stage of metamorphism (F_2) and a chlorite grade in all the rocks tended to blur the effects of the first stage.



9. Three-dimensional view of the hypothetical Pillinger fold, refolded by Devonian structuers.



10. Relations between grade of metamorphism and deformation during F_1, F_2 and F_3.

TABLE I

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SiO_2	74.32	98.00	71.72	70.72	66.40	29.00	69.28	60.12	75.24	68.00	67.20	73.70	71.60	49.92	68.00	68.00	66.38	58.18
Al_2O_3	12.90	0.62	13.99	10.51	13.63	3.75	15.64	11.60	13.27	17.00	17.67	11.62	14.72	16.76	17.01	15.72	18.21	15.36
Fe_2O_3	0.43	Tr	1.67	0.97	9.44	1.70	0.57	1.00	1.28	1.96	2.30	2.95	1.04	4.81	1.96	0.92	1.46	0.79
FeO	2.69	0.77	1.20	4.91	2.83	0.66	4.61	14.47	1.41	2.54	2.72	3.69	8.84	8.84	2.54	3.02	2.34	5.31
MgO	3.27	nill	2.01	4.91	1.00	14.53	1.48	7.00	0.94	1.16	1.19	2.00	2.56	6.91	1.16	1.43	1.74	6.72
CaO	nil	0.04	0.08	1.52	Tr	18.96	0.68	0.68	0.04	0.60	0.32	0.04	0.16	0.72	0.60	0.32	0.44	5.00
Na_2O	0.44	0.18	0.05	1.29	1.21	0.12	1.93	0.16	1.98	1.31	0.98	0.09	1.71	2.12	1.31	1.18	1.25	1.69
K_2O	3.08	0.24	6.02	1.12	1.59	1.60	3.42	0.32	3.36	3.64	3.47	2.47	3.02	1.61	3.65	3.64	4.23	2.95
H_2O+	2.90	0.18	2.48	2.97	2.13	n.d.	1.96	4.20	1.43	2.93	3.06	2.96	2.94	5.33	2.93	2.79	2.93	2.61
H_2O-	0.20	0.04	0.26	0.18	0.22	0.30	0.10	0.18	0.20	0.19	0.18	0.36	0.14	0.53	0.19	0.12	0.47	0.49
MnO	Tr	Tr	nil	0.07	Tr	0.04	Tr	0.06	0.03	0.02	0.02	0.04	0.02	0.05	0.02	0.02	0.01	0.09
TiO_2	0.35	0.05	0.34	0.44	1.02	0.10	0.45	0.30	0.04	0.69	0.94	0.45	0.69	2.44	0.69	0.78	0.94	0.61
P_2O_5	0.05	TR	0.07	0.11	0.21	0.04	0.05	0.07	0.02	0.06	0.40	0.03	0.05	0.24	0.06	0.06	0.07	0.15
FeS_2																1.29		
SO_3																0.14		
	100.63	100.12	99.89	99.72	99.67	....	100.17	100.16	99.24	100.10	100.45	100.40	101.27	99.23	100.12	99.89	100.47	99.95

1. Phyllite, 6227, Mary Group, Mt. Mary. 2. Quartz schist, 6220, Mary Group, Mt. Mary. 3. Phyllite, 7310, Scotchfire Group, Lyell Highway. 4. Schist, 6372, Scotchfire Group, Lyell Highway. 5. Conglomerate (Lachlan), 7087, Scotchfire Group, Lightning Plains. 6. Dolomite, 6416, Scotchfire Group, Thirkell Creek. 7. Garnet Schist, 6275, Franklin Group, Raglan Range. 8. Garnet Schist, 6290, Franklin Group, Cardigan River. 9. Albite Schist, 6323, Franklin Group, Cardigan River. 10. Coarse garnet-albite schist, 30149, Franklin Group, Raglan River. 11. Mica schist, Franklin Group, Timber Mill, Raglan Range. 12. Chloritized garnet schist, 30125, Franklin Group, Western Raglan Range. 13. Muscovite-chlorite schist, 30150, Franklin Group, Western Raglan Range. 14. Knotted albite schist, 30115, Franklin Group, Raglan Range. 15. Governor Phyllite, Mary-Franklin Transition, Joyce Creek. 16. Governor Phyllite, Mary-Franklin Transition, Joyce Creek. 17. Governor Phyllite, Mary-Franklin Transition, Joyce Creek. 18. Amphibole Schist, Franklin Group, Raglan Range. Analyses, Tas. Dept. Mines.

TABLE II

	1	2
SiO_2	44.78	50.92
Al_2O_3	13.44	16.83
Fe_2O_3	2.41	1.11
FeO	16.22	9.18
MgO	7.01	7.99
CaO	9.12	9.87
Na_2O	1.65	1.15
K_2O	0.47	1.12
H_2O+	1.58	0.96
H_2O-	0.07	0.14
MnO	0.36	0.18
TiO_2	2.81	0.60
P_2O_5	0.40	0.02
	100.32	100.67

1. Amphibolite, Raglan Range, anal. W. St. C. Manson.
2. Eclogite, Lyell Highway, anal. W. St. C. Manson.

REFERENCES.

BAILEY, E. B., 1923.—Metamorphism of the South-West Highlands. *Geol. Mag.* 60, 137.

BAILEY, E. B. & MCCALLIEN, W. J., 1934.—Metamorphic Rocks of North East Antrim. *Trans. Roy. Soc. Edin.* 58, 1, 163-177.

CLOUGH, C. T., 1897, in W. Gunn, et al.—The Geology of Cowal. *Mem. Geol. Surv. Scotland.*

CUNNINGHAM-CRAIG, 1904.—Metamorphism in the Loch Lomond District. *Quart. Journ. Geol. Soc. Lond.* 60, 10.

FLEISCHER, M., 1937.—Relation between Chemical Composition and Physical Properties in the Garnet Group. *Amer. Min.* 22, 751-759.

GEE, D., 1962.—Structure and Petrology of the Raglan Range. *Unpub. Thesis Univ. Tasmania.*

HARKER, A., 1932.—*Metamorphism.* London.

HUTTON, C. O., 1940.—Metamorphism in the Lake Wakatipu Region, Western Otago, New Zealand. *N.Z. Dep. Sci. Ind. Res. Geol. Mem.* 5

JONES, K. A., 1960.—Origin of Albite Porphyroblasts in Rocks of the Ben More-Am Binnein Area, Western Perthshire. *Geol. Mag.* 9, 8, 1, 41-55.

MCCALLIEN, W. J., 1929.—Metamorphic Rocks of Kintyre. *Trans. Roy. Soc. Edin.* 56, 2, 409-36.

MCINTYRE, D. B., 1951.—Tectonics of the Area between Granton and Tomintoul. *Quart. Journ. Geol. Soc. London.* 107, 1-22.

MCLEOD, I., 1956.—Geology of the Mt. Maude Area. *Unpub. Rept. Hydro-Elec. Comm. Tasmania.*

MATHER, R. P., 1955.—Geology of the Andrew River Area. *Unpub. Rept. Hydro-Elec. Comm. Tasmania.*

PETTIJOHN, F. J., 1957.—*Sedimentary Rocks.* Harper, New York.

REYNOLDS, D. R., 1942.—The Albite Schists of Antrim and their Petrogenetic Relationships to Caledonian Orogenesis. *Proc. Roy. Irish Acad.* 48, 8, 43.

SKINNER, B. J., 1956.—Physical Properties of End Members of the Garnet Group. *Amer. Min.* 41, 428.

SPRY, A., 1957.—Precambrian Rocks of Tasmania, Part II, Mt. Mary Area. *Pap. Proc. Roy. Soc. Tas.* 91, 95-108.

————, 1962.—The Precambrian Rocks in "The Geology of Tasmania," *Journ. Geol. Soc. Aust.* 9, 2.

SPRY, A. & ZIMMERMAN, D., 1959.—Precambrian Rocks of Tasmania, Part IV, Mt. Mullens Area. *Pap. Proc. Roy. Soc. Tas.* 93, 1-9.

TURNER, F. J. & HUTTON, C. O., 1941.—Some Porphyroblastic Albite Schists from Waikouaiti River, Otago. *Trans. Roy. Soc. N.Z.* 71, 223.

TURNER, F. J. & VERHOOGEN, J., 1960.—*Igneous and Metamorphic Petrology.* McGraw Hill, New York.

WELLS, B., 1957.—Geology of the Jane River Area. *Unpub. Rept. Hydro-Elec. Comm. Tasmania.*

YODER, H. S., 1952.—The $MgO—Al_2O_3—SiO_2—H_2O$ System. *Amer. Journ. Sc. Bowen Vol.* 569-623.