Tasmania Department Of Mines—Unpublished Report 1987/07

Metamorphism in the Precambrian rocks of the Tyennan Geanticline — a review

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INTRODUCTION

The Tyennan Geanticline (or Tyennan nucleus) extends from the south-west coast of Tasmania to the upper Mersey–Forth district. It is bounded by the Cambrian Dundas and Fossey Mountain Troughs to the west and north, and partly by the Adamsfield Trough (also Cambrian) and Jubilee Block (relatively unmetamorphosed Precambrian) in the east. In Central Tasmania its presumed eastern margin is obscured beneath Permo-Triassic Parmeener Supergroup and Jurassic dolerite cover. During the later deformation stage of the Tabberabberan Orogeny, the Tyennan Geanticline yielded in a north-westerly zone east of Queenstown; the northern section has been termed the Cradle Mountain Block, and the southern section the Prince of Wales Range Block (E. Williams, 1976).

Largely because of difficulties of terrain and access, only a few restricted areas have been studied in detail, mainly with emphasis on the complex structural geology. For large areas information is sketchy at best, and the 1:250 000 map sheets Port Davey (Williams and Corbett, 1977), Queenstown (Corbett and Brown, 1975) and Burnie (Williams and Turner, 1973) largely summarise the available data in these areas.

The rocks of the Tyennan Geanticline mainly comprise deformed metamorphosed quartzite, grading to schist and phyllite, with rare minor carbonates and widespread but volumetrically insignificant meta-igneous rocks, predominantly small basic intrusions now metamorphosed to amphibolite or eclogite. A relict Rb-Sr age of about 1100 m.y. obtained from phyllite from the Strathgordon area has been interpreted as the age of sedimentation (Råheim and Compton, 1977, p.280).

About eighty-one chemical analyses of rocks from the Tyennan Geanticline are available (see Table 1). Those of sedimentary origin are typically of pelitic composition with very low CaO (usually <1%) and are enriched in K_2O relative to Na_2O. Clearly there has been a heavy sampling bias against the petrologically less interesting quartzites, which contain up to at least 98% SiO_2 (analysis 36). However there appears to be a continuous gradation between pelite and quartzite, the latter representing dilution of pelitic material by quartz. There is no correlation between SiO_2 content and the relative proportions of the other chemical constituents.

The Tyennan Geanticline had a complex multiphase deformation history, even before the Tabberabberan Orogeny, and bedding and primary sedimentary structures are only occasionally discernible. Two phases of Precambrian deformation have been distinguished in the Cradle Mountain area (Gee *et al.*, 1970) and near Frenchmans Cap (Spry, 1963*b*), four in the Strathgordon and Frankland Range areas (Boulter, 1974*a*, *b*, 1978; S. J. Williams, 1976), and a total of five deformations of unassigned age at Port Davey (Williams, 1982).

Usually the earliest foliation is parallel or at a low angle to bedding (where recognisable), and is crenulated and often largely obliterated by the dominant second or third foliation. Precambrian folds are usually tight to isoclinal, and range in size from microscopic to a kilometre or so across. In the Frenchmans Cap area, more open folds of regional scale have been attributed to the Tabberabberan Orogeny (Spry and Gee, 1964).

Because of the multiphase deformation, microfabric analysis using the type of criteria outlined by Spry (1963*c*) is required to determine the chronological relationship of metamorphic and textural events. Available data from several areas, described below and summarised in Figure 1, suggest that throughout the Tyennan Geanticline the main metamorphism was roughly synchronous with the first deformation event (D_1), and therefore usually predates the dominant foliation. Subsequent periods of mineral growth were weaker and of lower grade, causing retrograde metamorphism, even though the associated deformation may be more marked.

In a Rb-Sr isotope study of rocks from the Strathgordon and Collingwood River areas, Råheim and Compton (1977) attempted to date the metamorphic events. Although their data have appreciable scatter they concluded that the main, peak metamorphism, associated with the early deformations D_1 and D_2 which are attributed to the Frenchman Orogeny, occurred about 800 m.y. ago. The main, most penetrative deformation (D_3), to which retrograde metamorphism is principally due, probably occurred about 590 ± 40 years ago. Still younger ages are attributed to the Cambro-Ordovician Jukesian Movement and the Devonian Tabberabberan Orogeny.

If no microfabric analysis has been made, it may be possible to determine the grade of the peak metamorphism in rocks of appropriate composition, although because of retrograde effects such as chloritisation of garnet, even this may be difficult. The major distinction which can be made and mapped in pelitic rocks is between garnetiferous assemblages:

garnet (almandine) + biotite + muscovite + albite + quartz + chlorite

and non-garnetiferous assemblages:

(biotite) + muscovite + chlorite + albite + quartz.

In some areas, such as the Raglan Range (Gee, 1963), the biotite isograd can also be mapped, but frequently biotite is too sporadically developed or possibly too susceptible to retrograde chloritisation. Biotite has not been recorded in the Strathgordon area, even from garnetiferous rocks.

In the classification outlined by Winkler (1979), the garnetiferous pelites indicate (almandine)–low-grade metamorphism, corresponding to the upper greenschist facies or garnet zone of Barrovian-type metamorphism in more traditional terminology. The non-garnetiferous rocks are of slightly lower grade (greenschist facies or chlorite and biotite zones of Barrovian-type metamorphism).

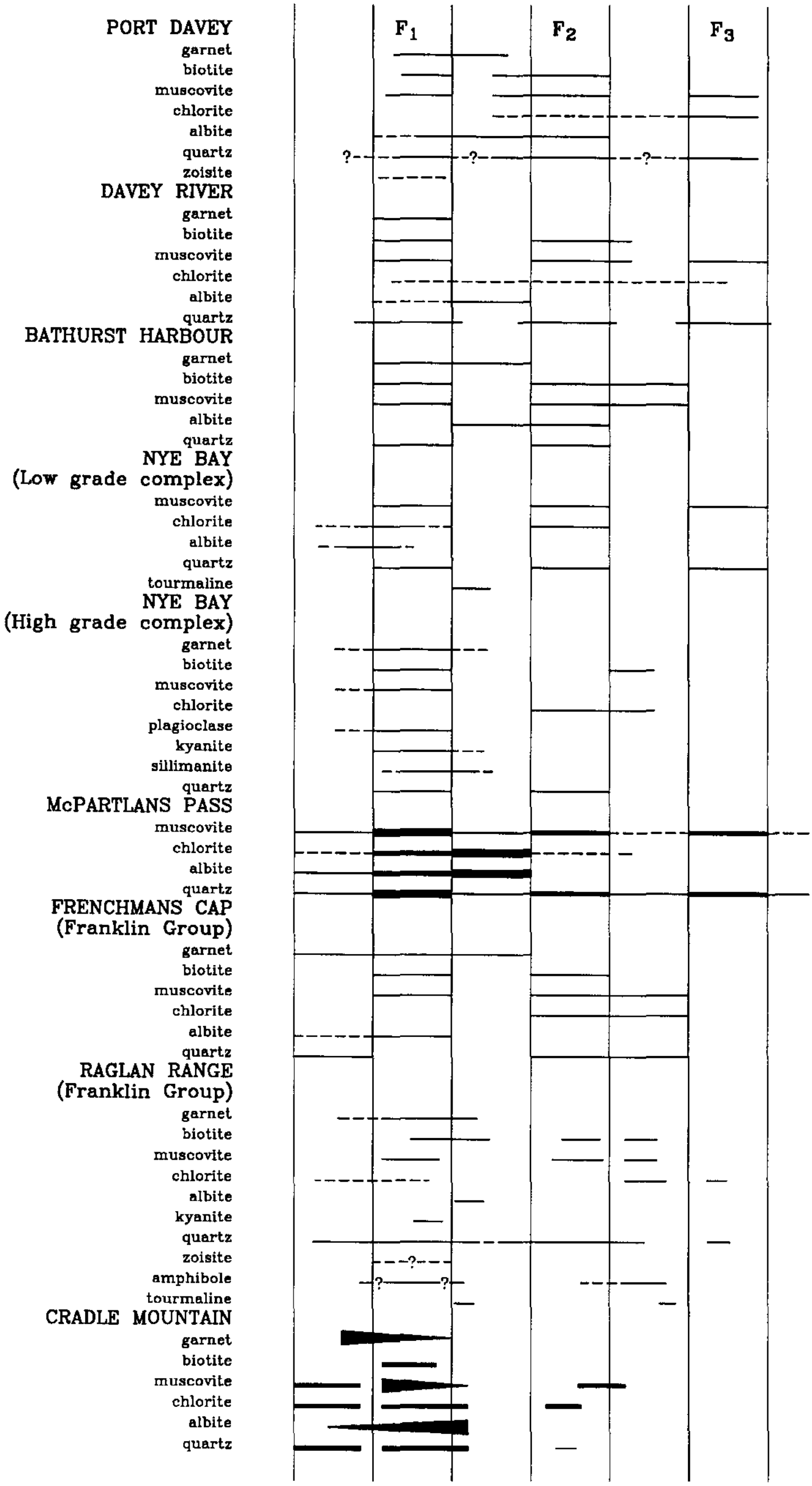


Figure 1. *Relationship between episodes of mineral growth and deformation events in metapelites from the Tyennan Geanticline. Compiled from references given in the text.*

Available analyses of garnet from metapelites (Gee *et al.*, 1970; Råheim, 1977; Williams, 1982; McNeill, 1985) show that they are 70–90 mol% almandine. They are commonly zoned, typically with Ca and Mn concentrated in cases, and Mg increasing towards the rims (Råheim, 1975). Muscovite is frequently phengitic, with up to 50 mol% celadonite component in solid solution and very variable Mg/Mg + Fe; the chemistry of phengites has been studied by Boulter and Råheim (1974), Råheim (1977), and P. R. Williams (1982). Two published biotite analyses (Williams, 1982) are siderophyllites with high Al and low Si and Mg/Mg + Fe. Plagioclase in metapelitic rocks appears to be invariably albite (although some amphibolites contain oligoclase); probably these rocks are too deficient in CaO to form more calcic plagioclase, whatever the metamorphic grade. A few analyses of chlorite, tourmaline (schorl) and ilmenite have been published from Precambrian metapelites (Williams, 1982; Råheim, 1977).

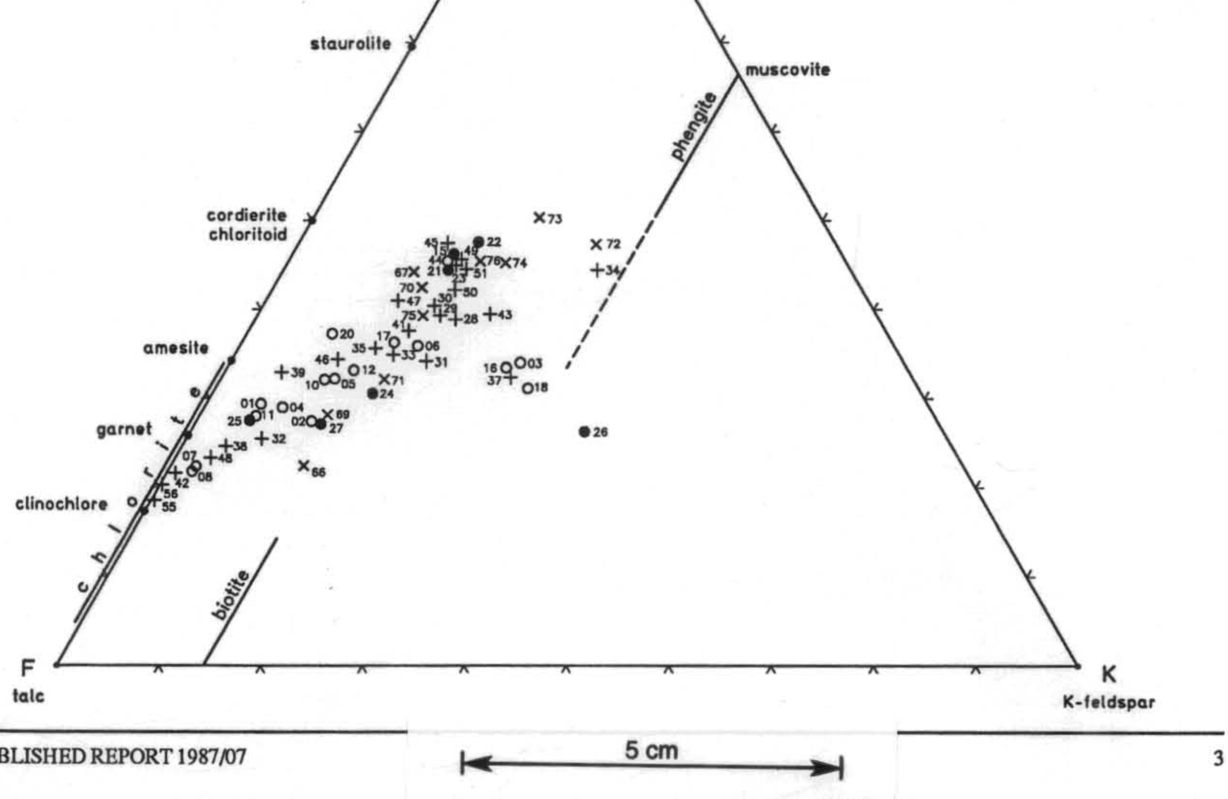
A few other minerals, although of rare occurrence, are petrologically significant. Chloritoid (Fe, Mg) $Al_2SiO_5(OH)_2$ has been reported from the 'Lachlan Conglomerate' of the Scotchfire Group at Lightning Plains, south of Frenchmans Cap, where it is associated with quartz, sericite and garnet (Spry, 1963*b*), and also from the Upper Mersey–Forth area, associated with quartz sericite and garnet (Jennings, 1963). Chloritoid is characteristic of low-grade metamorphism of pelites of special composition: high Al_2O_3 relative to Na_2O, K_2O and CaO, and high Fe/Mg (e.g. Winkler, 1979, pp 215–216, 222–223). These compositional restrictions have been studied empirically by Hoschek (1969) by analysing chloritoid–bearing and chloritoid-free natural rocks. When available analyses of Tasmanian Precambrian metapelites are plotted onto his diagrams (fig. 4, 5) only six, or about a tenth of the total (numbers 05, 10, 39, 45, 67, 70 and 39, the Lachlan Conglomerate) appear to be of suitable composition to form chloritoid. Chloritoid often occurs in very small, colourless or pale green grains which are easily overlooked (e.g. Winkler, 1979, p.215) and despite the relative paucity of rocks of suitable composition, may be more widespread in the Precambrian metapelites of Tasmania. Its higher relief and poorer cleavage should enable it to be optically distinguished from chlorite.

Kyanite, which occurs near Nye Bay (McNeill, 1985) and in Franklin Group metapelites near Frenchmans Cap (Spry, 1963*b*), is the most common Al_2SiO_5 polymorph. Sillimanite is known from only two samples near Nye Bay (McNeill, 1985) which also contain kyanite. Andalusite has been reported from near Bathurst Harbour (Everard, 1957, p.105; Baker, 1957), but Spry and Baker (1965, p.21) believe that these are misidentifications of albite. Andalusite is very susceptible to sericitisation during retrograde metamorphism or weathering, and may be difficult to positively identify under the microscope. The presence of kyanite implies that the upper temperature limit of pyrophyllite was exceeded (Winkler, 1979, p.209), under a relatively high pressure regime. According to experimental data for pyrophyllite breakdown (Kerrick, 1968) and the Al_2SiO_5 palymorphs (Althaus, 1967; reviewed by Winkler, 1979, pp.92–95), the formation of kyanite requires minimum temperatures and pressures of about 440° and 5.4 kb. As discussed below, an unusual kyanite-talc-garnet assemblage on the Collingwood River (Råheim and Green, 1974*a*) appears to imply pressures of at least 10 kb.

When plotted on the AFK diagram (fig. 2) (e.g. Winkler, 1975, p.39), nearly all of the available analyses of Precambrian metapelites lie within the composition field of muscovite (or phengite) + chlorite + biotite + garnet, consistent with the

Figure 2. *Metapelites from the Tyennan Geanticline plotted on an AFK diagram. Idealised mineral compositions also shown.*

$A = Al_2O_3 - K_2O - Na_2O$ *(moles)*
$F =$ *Total iron as* $FeO + MnO + MgO$ *(moles)*
$K = K_2O$ *(moles)*
$A + F + K = 100$



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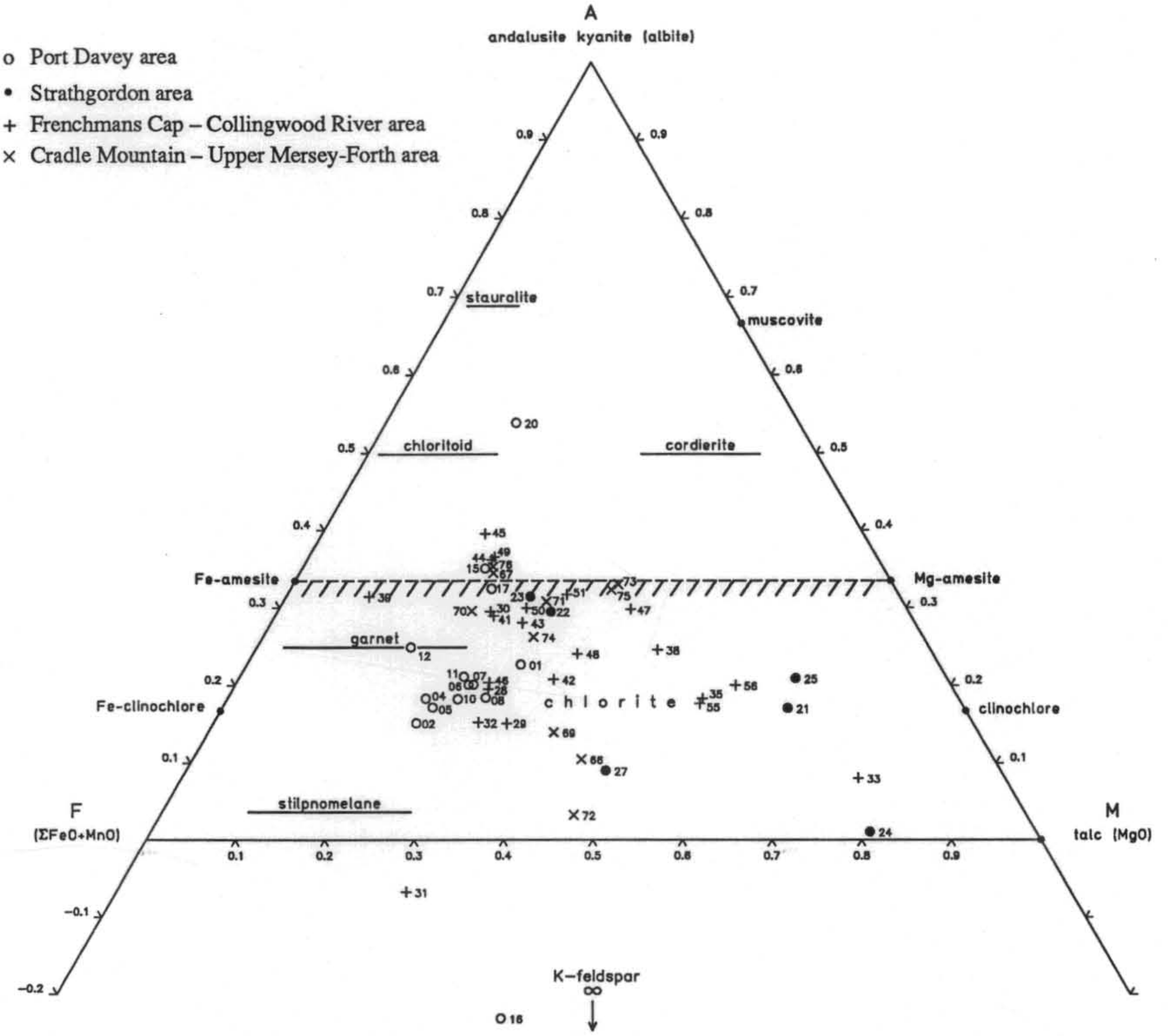

Figure 3. *Metapelites from the Tyennan Geanticline plotted on an AFM diagram (i.e. projected from muscovite onto the Al_2O_3-FeO-MgO plane). Idealised mineral compositions also shown. Analyses 03, 18, 26, 34 and 37 contain excessively high K_2O:Al_2O_3 and cannot be shown.*

$$A = \frac{Al_2O_3 - 3K_2O}{Al_2O_3 - 3K_2O + \Sigma FeO + MnO + MgO}\ moles$$

$$M = \frac{MgO}{MgO + \Sigma FeO + MnO}\ moles$$

observed mineralogy. The rarity of chloritoid and Al_2SiO_5 polymorphs is attributable to the rarity of rocks of appropriate bulk composition. This is also evident in the AFM diagram (fig. 3) which shows the broad spread of Fe/Mg values in these rocks.

The apparent absence of certain minerals is also significant. Stilpnomelane, an iron-rich phyllosilicate, is readily mistaken for biotite (e.g. Winkler, 1979, p.211), but Gee *et al.* (1970) confirmed by x-ray diffraction that biotite, not stilpnomelane, was present in schist from the Cradle Mountain area. Stilpnomelane is common in very low grade mafic rocks and ferruginous sediments, and breaks down to biotite and chlorite during low grade metamorphism by several poorly understood reactions (Winkler, 1979, p.212). Although further investigations are desirable, the apparent absence of stilpnomelane from the Tasmanian Precambrian is probably due to the lack of rocks of appropriate composition and, at least in garnetiferous rocks, excessive temperatures.

Neither staurolite nor cordierite are known from regionally metamorphosed terrains in Tasmania. Staurolite, like chloritoid at lower temperatures, forms from metapelites with high Fe/Mg ratios, but from a less restricted range of bulk compositions than chloritoid (Hoschek, 1969; fig. 5). In more Mg-rich rocks, cordierite forms instead. Many rocks from the Tyennan Geanticline have suitable bulk compositions to form staurolite or cordierite, and their absence is attributed to inappropriate physical conditions, particularly insufficiently high temperatures, during metamorphism.

Little detailed petrological work has been done on the metabasites (e.g. Råheim, 1975; Williams, 1982; McNeill, 1985). About 22 chemical analyses are available (see Table 1). Because of the possible effects of metamorphism, alteration and weathering, caution is needed in interpreting these analyses, but on the basis of major element chemistry, they appear to be predominantly derived from near-saturated basaltic rocks with tholeiitic affinities. A few are more

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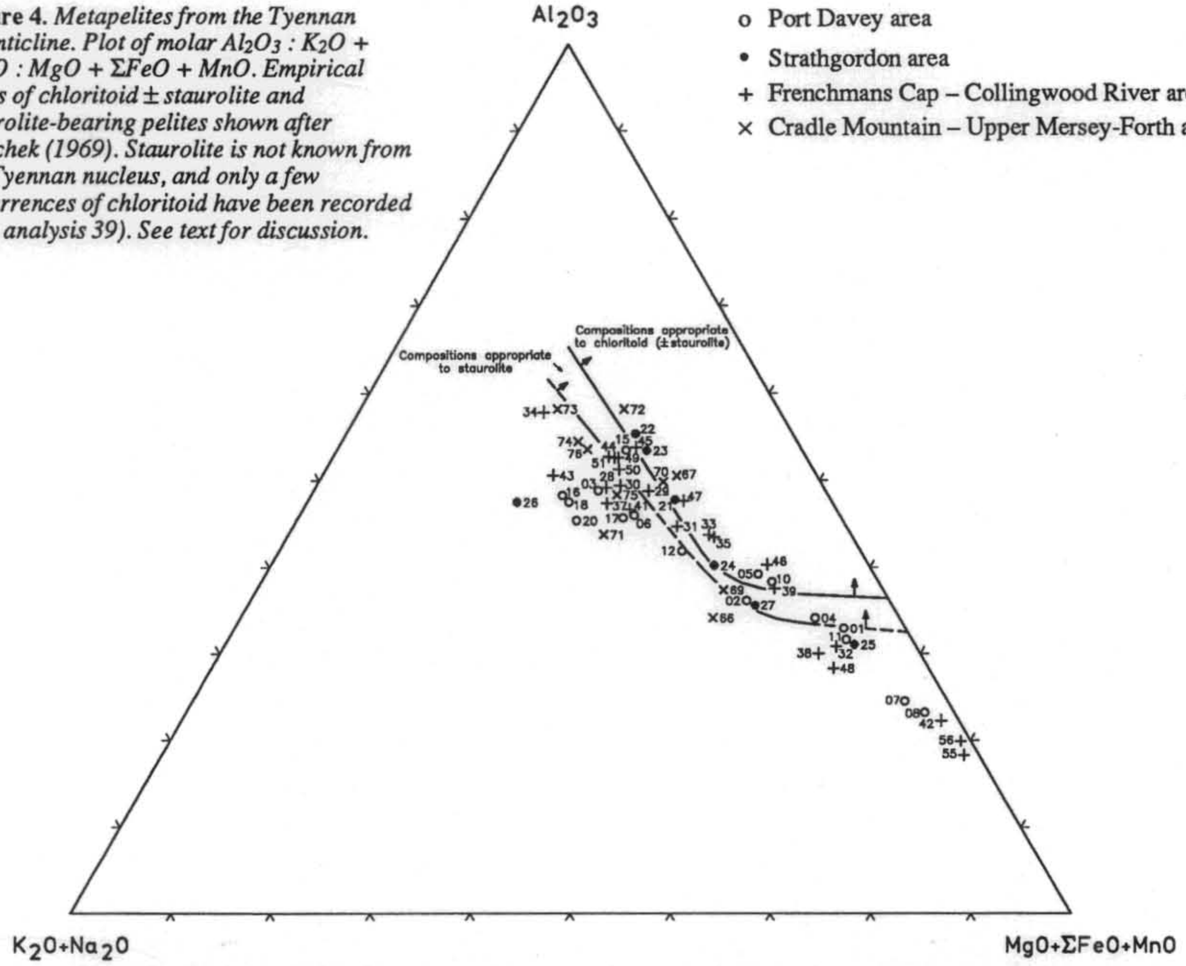

Figure 4. *Metapelites from the Tyennan Geanticline. Plot of molar Al_2O_3 : K_2O + Na_2O : MgO + ΣFeO + MnO. Empirical fields of chloritoid ± staurolite and staurolite-bearing pelites shown after Hoschek (1969). Staurolite is not known from the Tyennan nucleus, and only a few occurrences of chloritoid have been recorded (e.g. analysis 39). See text for discussion.*

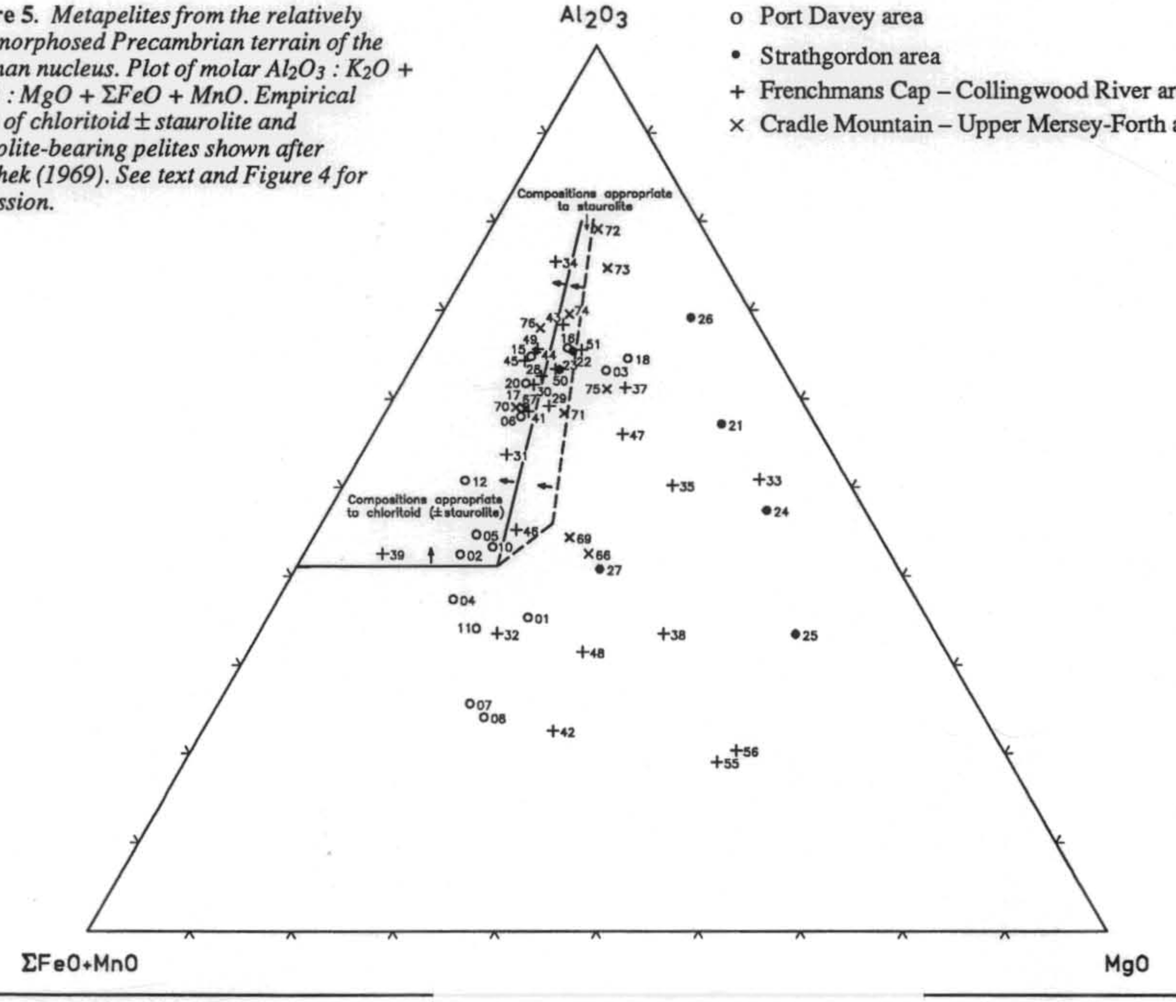

Figure 5. *Metapelites from the relatively metamorphosed Precambrian terrain of the Tyennan nucleus. Plot of molar Al_2O_3 : K_2O + Na_2O : MgO + ΣFeO + MnO. Empirical fields of chloritoid ± staurolite and staurolite-bearing pelites shown after Hoschek (1969). See text and Figure 4 for discussion.*

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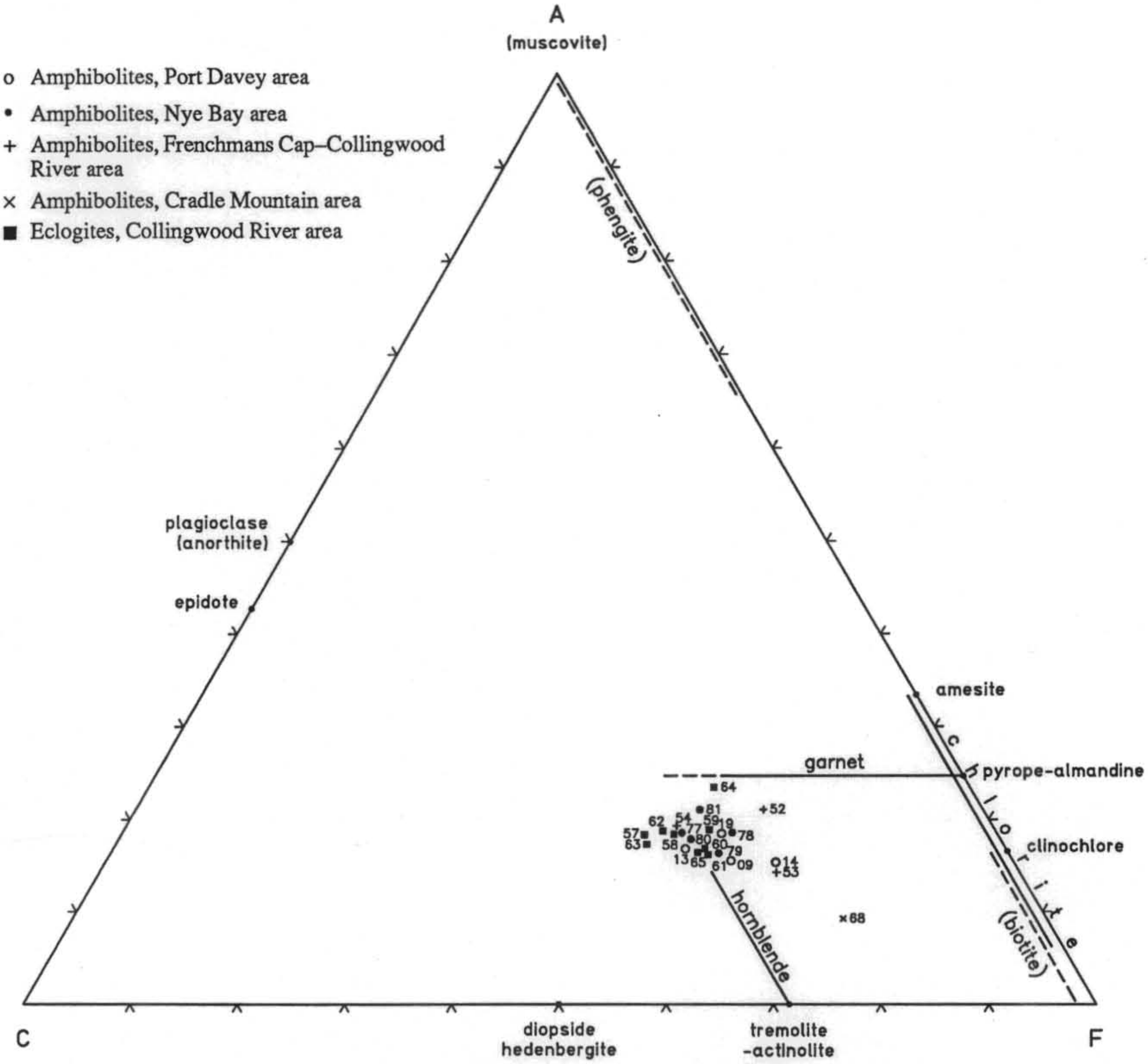

Figure 6. *Metabasites (amphibolites and eclogites) from the Tyennan Geanticline plotted on an A-C-F diagram. Idealised mineral compositions also shown.*

$$A = Al_2O_3 - K_2O - Na_2O \text{ (moles)}$$
$$C = CaO \text{ (moles)}$$
$$F = \text{total iron as } FeO + MnO + MgO \text{ (moles)}$$
$$A + C + F = 100$$

undersaturated (e.g. analysis 53), and some plagioclase-poor specimens may be derived from ultrabasic rocks, whilst an amphibolite from the Raglan Range (analysis 52) is probably derived from an andesite. Even the less basic types are chemically quite distinct from the metapelites, particularly in their higher CaO content. Usually they are metamorphosed to amphibolite, typically consisting of amphibole (actinolite or hornblende), plagioclase (albite or oligoclase), garnet (almandine), biotite, chlorite, sometimes muscovite, epidote or clinozoisite, and quartz. In most cases the amphibolite appears to be structurally and metamorphically congruent with the surrounding pelite, and therefore probably shares a common deformational and structural history. Those that contain primary chlorite (regardless of the plagioclase or amphibole composition) are characteristic of the greenschist facies, or low-grade metamorphism (Winkler, 1979, p.173).

Little work has been done on mineral chemistry, but those amphibolites containing oligoclase and/or hornblende probably represent slightly higher grades of metamorphism than those containing albite or actinolite. Mineral zoning in amphibole and garnet may be either prograde (Råheim, 1975) or retrograde (Williams, 1982). Occasionally, as at Nye Bay and in some of the amphibolite bodies at Port Davey, primary chlorite is absent, suggesting that the boundary of medium grade metamorphism (epidote-amphibolite facies *sensuo stricto*) has been attained. At Port Davey the amphibolite may appear to be of higher metamorphic grade than the enclosing metapelite, a conclusion supported by temperature estimates obtained from mineral chemistry (Williams, 1982).

Several eclogite bodies, also derived from basic igneous rocks and showing retrograde metamorphism to amphibolite, occur in the Collingwood River area. These probably indicate very high pressure metamorphism, as discussed below.

PORT DAVEY–BATHURST HARBOUR AREA

The most thorough study of metamorphism in this region is that of P. R. Williams (1982), who mainly mapped coastal outcrops at Port Davey. However useful information can also be obtained from Spry and Baker (1965), Maclean (1974), Williams (1982, pp.109–111), and Everard (1957, pp.73–74, 100–106).

Relatively unmetamorphosed Precambrian rocks (Clytie Cove Group) also occur in the Bathurst Channel area and south of Bathurst Harbour. Although the contact is faulted, the existence of an unconformity prior to faulting is inferred (Williams, 1979, pp.21–26).

The dominant lithology of the metamorphosed rocks is a flaggy quartzite, but there appears to be a gradation into more pelitic phyllite and schist containing up to 80% phengitic muscovite. North of Port Davey, in the Davey Head–Kelly Basin area (Williams, 1982) and Davey River area (Maclean, 1974), the assemblage in these more pelitic rocks is:

garnet + biotite + phengitic muscovite + quartz + albite + zoisite

Chlorite and opaque minerals appear to result from the alteration of biotite and sometimes garnet during retrograde metamorphism, but in a few rocks chlorite appears to be primary. Garnet is almandine rich (70–90%). From the study of textures, Williams (1982) concluded that metamorphism occurred in three episodes. The first and major one (M_1) was synchronous with, but rather late in, the first deformation event (D_1), and produced garnet, biotite, zoisite and muscovite. The second metamorphic episode occurred prior to D_2 and produced a second generation of garnet in garnetiferous rocks, and may have caused retrogression of biotite to chlorite.

The third metamorphic episode produced later generations of chlorite and muscovite.

A slightly different sequence was reported from the Davey River area by Maclean (1974):

M_1: garnet + biotite + muscovite + chlorite + albite + quartz, synchronous with S_1

M_2: biotite + muscovite + chlorite + albite + quartz, synchronous with S_2.

Both these events were attributed to the Proterozoic Frenchman Orogeny. A third, weaker foliation (S_3), accompanied by further crystallisation of quartz, muscovite and chlorite (M_3), was attributed to the Tabberabberan Orogeny.

Garnet-bearing rocks in the Port Davey area are apparently restricted to areas west and north of Payne Bay. Further east and south, in the Coffin Creek, Spain Bay, Bathurst Channel and Bathurst Harbour areas, compositionally similar pelites lack garnet (Williams, 1982, p.37; 1979, p.109), suggesting a slightly lower grade of metamorphism. However Spry and Baker (1965) suggest that early garnet in the Bathurst Harbour area was completely replaced by chlorite during the second deformation and metamorphic event. Garnetiferous mica schists occur at Red Point, east of Cox Bight (Everard, 1957, p.105).

In the classification of Winkler (1979), the first and major metamorphic episode (M_1) in the garnetiferous pelite was of [almandine]–low-grade. In older terminology, this corresponds to the upper greenschist facies, or the garnet zone of Barrovian-type regional metamorphism. The absence of cordierite or staurolite in these rocks indicates that metamorphism did not reach medium grade. The non-garnetiferous rocks to the east are slightly lower grade (greenschist facies or biotite zone of Barrovian regional metamorphism).

Andalusite and cordierite were reported at Umbrose Creek, south-east of Bathurst Harbour (Everard, 1957, p.105) and north-west of Bathurst Harbour (Baker, 1957), but Spry and Baker (1965, p.21) believe that albite has been mistaken for these minerals.

A few small, ovate to sheet-like bodies of metabasic amphibolite occur within pelitic schist in this region. Their petrology has been investigated by Williams (1982). On the basis of whole-rock analyses, it is likely that they are derived from olivine-bearing basaltic rocks. The texture and mineralogy varies between each body, but typically assemblages are:

hornblende + garnet + epidote or zoisite + biotite + oligoclase + quartz ± sphene ± opaques.

and

actinolite + garnet + clinozoisite + white mica + chlorite + albite + quartz.

Amphibole varies in composition from cores of actinolitic hornblende to probably retrograde rims of Na-poor and Al-poor actinolite. Garnet is typically about $Alm_{59}Gr_{22}Py_{11}Sp_4$. In the first assemblage, the presence of garnet and oligoclase (An_{19}) and the absence of primary chlorite implies lower medium-grade epidote-amphibolite facies metamorphism (Winkler, 1979), but the second assemblage is transitional to low grade metamorphism (upper greenschist facies). As there is no indication that the amphibolite has been tectonically incorporated into the surrounding, low-grade pelite, there is an apparent slight discrepancy in metamorphic grade between the two rock types. Williams (1982) used the Si^- content of phengites (Velde, 1967) and Fe/Mg partitioning between garnet and phengite (Krogh and Råheim, 1978) to estimate conditions of metamorphism as about 400°C and 4 kb in metapelite, and estimated conditions in amphibolite as 450–500°C at 4 kb. It is not clear whether this discrepancy represents a real difference or is the result of inaccuracies in the estimates.

Either estimate implies that andalusite is the stable Al_2SiO_5 polymorph in this region (or would be if rocks of appropriate composition occurred), provided the triple point of Althaus (1967) is accepted as recommended by Winkler (1979). As the andalusite–kyanite transition and its high-temperature extrapolation is used as the boundary between low and intermediate metamorphic facies series by Vallance *et al.* (1983), the Precambrian rocks in the vicinity of Port Davey are considered to belong to the low pressure facies series. The presence of almandine-rich garnet does not necessarily indicate relatively high pressures (e.g. Schreyer, 1976*b*, pp.265–267).

NYE BAY AREA

Coastal outcrops for a distance of about 10 km north-west of Nye Bay have been mapped and studied by McNeill (1985). There are two distinct Precambrian terrains, differing in both metamorphic grade and structural style, separated by a mylonite zone 60 m wide.

The northern 'low-grade complex' extends from the mylonite zone for about 6 km north-westward to Top Rocks, where it is faulted against sediments, tuffs and quartz-feldspar porphyries of probable Cambrian age. It consists of interbedded black graphitic phyllite and quartz-rich phyllite, passing northward into quartzite with minor interbedded phyllite. It is intruded by lamprophyre dykes, which are not deformed by folding nor offset by faulting in their host rocks.

Compositional banding in phyllite lacks sedimentary structures and its origin is uncertain, but rare ripple marks in quartzite indicate original bedding.

Three major phases of deformation in the low-grade phyllite are indicated by mesoscopic to rarely macroscopic folds and associated cleavages. The earliest F_1 folds are associated with the dominant north–south trending penetrative slaty cleavage, S_1, generally sub-parallel to compositional layering. At Top Rocks this S_1 cleavage appears to be continuous across the faulted boundary into Cambrian rocks, and is thus Cambrian or younger in age. Later F_2 and F_3 folds, with distinctive orientations, are associated with S_2 and S_3 crenulation cleavages and an L_3 lineation on S_1. Sporadically developed kink bands fold S_2, and are attributed to a fourth phase of deformation, probably of Devonian age.

The phyllites contain the mineral assemblage quartz-muscovite-albite-chlorite-tourmaline characteristic of lower greenschist facies. Microstructural studies indicate that the metamorphic peak occurred pre- or syn-D_1, with the crystallisation of albite in addition to chlorite, biotite and quartz. Tourmaline appears to be post-D_1. The lower D_2 and D_3 deformations were associated with weaker metamorphic events, mainly involving the recrystallisation of quartz, muscovite and, in the case of D_2, chlorite (fig. 1).

The absence of biotite on the one hand, and low-temperature clay minerals on the other, suggests a metamorphic maximum of 300–400°C (probably nearer 400°C), assuming a pressure of >2.5 kb. The 'low-grade complex' is similar in lithology and metamorphic grade to the garnet-free Precambrian rocks of the Strathgordon area.

The mylonite zone separating the low-grade and high-grade complexes strikes north–south and dips west. Microstructures indicate a normal sense of movement (i.e. the high-grade complex to the east is upthrown), with also a dextral component to the offset. The dominant foliation in the mylonite zone is subparallel to S_1 in both complexes, and the shearing which produced it may be synchronous with D_1 in the low-grade complex.

The high-grade rocks east and south of the mylonite zone comprise much more strongly deformed and metamorphosed quartz-mica schist, garnet-bearing schist, quartzite and minor amphibolite. These are intruded by several aplitic dykes and small plugs, possibly related to Cambrian granitoids, which appear to post-date the deformation in the schists, but are offset by faulting. No sedimentary structures were found in the quartzite or pelite, and the compositional layering is probably largely transposed. These rocks have undergone at least four major phases of deformation, the first two producing cleavages. The earliest folds are small, isolated, rootless interfolial folds (F_1), associated with the dominant penetrative S_1 cleavage.

Their orientations are controlled by the main SSW-plunging F_2 folds, which are common on all scales up to 200 m and are associated with an S_2 crenulation cleavage. D_1 and D_2 are possibly the result of a continuous deformation involving increasing shear, rather than discrete events. Later east-trending F_3 folds, refolded by NW-trending F_4 folds, are less common, and neither are associated with cleavages. Late kink bands, possibly F_2, were noted in two places. With the possible exception of the kink bands, which are similar in orientation in both terrains, none of the deformations in the high-grade complex can be correlated with those in the low-grade complex with any confidence.

The metapelites typically contain porphyroblasts of zoned almandine-rich garnet, locally up to 50 mm in diameter, as well as porphyroblasts of kyanite and occasionally albite, in a fine-grained well-foliated matrix of biotite, subordinate phengitic muscovite, plagioclase (usually albite, rarely oligoclase) and quartz. Rutile, ilmenite and rarely graphite are accessory minerals. Thus the characteristic composite prograde assemblage is:

garnet + biotite + phengitic muscovite + kyanite + albite + quartz.

In two samples from less well foliated garnet-biotite rich boudins, sillimanite occurs in addition to kyanite, closely associated with biotite. Microstructural analysis shows that the peak metamorphism was essentially synchronous with the dominant foliation, and therefore syn-D_1. Retrograde reactions included the formation of a second generation of biotite as clots replacing garnet, the formation of chlorite as an alteration of biotite and phengitic muscovite, and the sericitisation of kyanite, garnet and primary muscovite (fig. 1).

The above prograde assemblage indicates amphibolite-facies metamorphism, or (almandine)-medium grade in the terminology of Winkler (1979). McNeill (1985) applied a range of experimentally calibrated geothermometers and geobarometers to these rocks, and concluded that the peak metamorphic conditions were at least 630° ± 50°C and 7.5 ± 1 kb, considerably greater than the peak conditions estimated in the lower grade rocks at Port Davey (Williams, 1982).

Lenses of quartz-muscovite-albite pegmatite, up to 350 mm long and 40 mm wide, occur subparallel to S_1 in the schist. They have been boudinaged and folded by S_2. They are interpreted to have formed by partial melting of the schist, which probably requires temperatures in excess of 650°C at 7 kb.

Isolated lenticular bodies and boudins of amphibolite and garnet amphibolite, up to 10 m long, are associated with the S_1 surface in the metapelite at several places. Chemical analyses (analyses 77–81, Table 1) indicate protoliths of saturated tholeiitic basalt to basaltic andesite, somewhat more felsic than the amphibolite from Port Davey. Assemblages include:

hornblende + garnet ± clinozoisite + plagioclase (An_{36-40}) + quartz ± clinopyroxene

hornblende + garnet + biotite + plagioclase (An_{40}) + quartz

hornblende + garnet + muscovite + plagioclase + quartz

hornblende + plagioclase + quartz.

Muscovite is probably a later retrograde phase, and clinopyroxene may be a relict igneous mineral. Otherwise, the absence of prograde chlorite, the composition of plagioclase (andesine), and the presence of zoned hornblende rather than actinolite indicate medium-grade metamorphism (amphibolite facies). The more calcic plagioclase and relative scarcity of clinozoisite suggests somewhat higher grade metamorphism than the garnet amphibolite from Port Davey, as in the enclosing pelitic rocks.

STRATHGORDON REGION

Regional geological maps (1:50 000 scale) of the Huntley (Brown *et al.*, 1982) and Pedder (Turner *et al.*, 1985) Quadrangles have recently been published, and Boulter (1978) has studied the Wilmot and Frankland Ranges from a mainly structural viewpoint. However at present most of the available information on metamorphism of the Precambrian rocks of this region is contained in Boulter (1974*b*), Råheim (1977), and S. J. Williams (1976).

Rock types in the Strathgordon region range from quartzite to quartz-phengite schist and phyllite. Typical mineral assemblages are:

phengite + chlorite + tourmaline + quartz (Råheim, 1977)

phengite + chlorite + albite + quartz (Williams, 1976)

Garnet-bearing rocks are only locally developed:

almandine + phengite + chlorite + tourmaline + quartz (Råheim, 1977).

Very rarely calcite-chlorite-quartz schist is seen. The quartzite and metapelite were intruded by minor dolerite dykes before the major metamorphic and deformational events. The dolerite is strongly amphibolitised and chloritised, but no detailed work on it has yet been published.

Boulter (1974*a*, *b*, 1978) distinguished four Cambrian deformation events in the Frankland and Wilmot Ranges, with folds of the third generation (F_3) being dominant, controlling the orientation of foliations and folds related to earlier deformation and occurring on all scales and in all lithologies. S. J. Williams (1976) described a similar structural history in rocks of the McPartlan Pass area, and from microfabric analysis showed that most metamorphic recrystallisation occurred during D_1, and progressively less during D_2 and D_3. Chlorite and albite porphyroblasts grew in some rocks of suitable composition in the interval between D_1 and D_2.

The above assemblages are not very diagnostic, but suggest lower greenschist facies metamorphism, only locally reaching [almandine]-low grade (Winkler, 1979). A somewhat puzzling feature is the apparent absence of biotite, even in garnet-bearing rocks; Williams (1976) suggested that it was replaced by chlorite during retrograde metamorphism.

Boulter and Råheim (1974) and Råheim (1977) used the Si^{4+} content of phengite (Velde, 1967), associated with the various foliations, to estimate conditions of metamorphism and correlate metamorphic and structural events. They concluded that prograde metamorphism occurred at pressures of 3 ± 1 kb or 4 kb, and temperatures of 400°C, associated with D_1, and increasing to 450°C at the time of D_2. There appears to have been a sharp break before D_3, associated with minor recrystallisation at much lower temperatures (250°C) and, probably, lower pressures. The high water content of phengite associated with D_3 suggests higher fH_2O or increased availability of water, and therefore D_3 may have also been coeval with amphibolisation and chloritisation of dolerite in the area. There appears to have been some regional zonation of metamorphism in the area, with the metamorphic maximum occurring at temperatures of about 100° lower to the south-east of Strathgordon, compared to locally garnetiferous rocks to the north-west.

FRENCHMANS CAP–RAGLAN RANGE AREA

The chief studies of metamorphism in this region are found in Spry (1963*b*) and Gee (1963). Some information can be obtained from Spry (1957), Spry and Zimmerman (1959), and Duncan (1974), whilst the structure of the region is further discussed by Spry and Gee (1964).

The Precambrian quartzite, schist and phyllite of this region have been divided, after regional mapping, into several groups on the basis of their lithology. These appear to broadly reflect both stratigraphic relationships and metamorphic grade, but because of the complex structure, exact relationships are uncertain. Several groups are possibly equivalent, whilst others appear to grade into each other.

Two phases of deformation associated with the Precambrian Frenchman Orogeny have been recognised (Spry, 1963*b*). The first, D_1, is associated with a foliation S_1 parallel or at a low angle to bedding, and is most noticeable in schistose quartzite, but no associated folds have been recognised. It has been largely obliterated in schist and phyllite by a later foliation (S_2) which is nearly parallel to it, except on the hinges of folds. This later foliation (S_2) is associated with recumbent, isoclinal folds, ranging in size from microscopic to a kilometre or so across.

The highest grade rocks in this region belong to the dominantly pelitic Franklin Group, and the lithologically similar and possibly equivalent Joyce Group (Spry, 1957) and Algonkian Mountain Group (Spry, 1963*b*). The Franklin Group is better known, and extends from the Raglan Range (Gee, 1963) east to the Collingwood River area (discussed in a later section), and south to the vicinity of Mt McCall. Various types of mica schists predominate, but in some areas massive to platy quartzites is common.

Muscovite and quartz are ubiquitous in the schist, and the complete assemblage is garnet (almandine) + biotite + albite + chlorite + muscovite + quartz.

Kyanite is a rare additional mineral in some rocks. Secondary chlorite, after garnet, is common, and accessory minerals include tourmaline, graphite, zircon and pyrite. The main period of mineral growth was syntectonic to the first deformation (D_1), although textures suggest that both garnet and albite porphyroblasts are partly also post-tectonic to D_1. The porphyroblasts are enveloped by, and therefore earlier than, the dominant foliation S_2, which is defined by alignment of muscovite. During this second event there was further growth of quartz, muscovite, and biotite, but chlorite was the only new mineral to crystallise. Therefore the second deformation (D_2), although producing the dominant foliation, was accompanied by lower-grade metamorphism than D_1.

The quartzite of the Franklin Group may contain up to 97% quartz, but muscovite, garnet, biotite and hematite are commonly present, an assemblage similar to that of the schist. However S_1 is the most conspicuous foliation in the quartzite.

Small, isolated tabular bodies and boudins of metabasite (amphibolite) occur in the Franklin Group, although they are volumetrically insignificant. Typical assemblages are:

actinolite + garnet + biotite + chlorite + albite + quartz

and

actinolite + garnet + zoisite + chlorite + albite + quartz.

Garnet and, where present, biotite and coarse actinolite are syn- or post-tectonic to the first deformation event, D_1. The second event produced the dominant foliation, reduced the grain size, and was accompanied by crystallisation of finer actinolite and chlorite. As in the pelitic rocks, this may be regarded as a later, superimposed retrograde metamorphism.

The Mary Group of the Frenchmans Cap area, the Fincham Group to the west and the Scotchfire Group to the south-east, differ in both gross lithology and metamorphic grade to the Franklin and Joyce Groups. The best known and most extensive, the Mary Group, tends to form topographic highs, including Frenchmans Cap and Mt Mary. It consists dominantly of platy quartzite (quartz schist) grading to massive quartzite on one hand, and mica-rich phyllite on the other. Bedding and sedimentary features such as ripple marks and cross-bedding are occasionally recognisable. At least two foliations are visible, particularly in phyllite; an earlier, weaker one (S_1) parallel to bedding where recognisable; and the later, dominant, S_2. A third, non-penetrative fracture cleavage (S_3), also occurs in phyllite. Although structurally complex, the Mary Group is mineralogically simple, the various lithologies consisting of varying proportions of quartz and muscovite, sometimes with minor chlorite and accessory tourmaline, rutile and iron oxides.

The Fincham Group is a belt of quartzite and phyllite occurring in the western part of the area, apparently resting on Franklin Group schist and unconformably overlain by Palaeozoic rocks. Like the Mary Group it is a structurally complex but mineralogically simple group of massive to platy quartzite and phyllite, comprised of quartz, muscovite and sericite. Again there are two main foliations, both corresponding to periods of mineral growth and a later fracture cleavage.

The Scotchfire Group, in the east and south of the area, comprises schist and phyllite with subordinate quartzite and dolomite. The major minerals are quartz, muscovite and chlorite, with rare albite and accessory tourmaline, zircon, rutile and iron oxides, and dolomite in some rocks. Muscovite and chlorite grew in two generations, syntectonically to both F_1 and F_2, whilst dolomite, where present, was recrystallised at a later stage, possibly partly syntectonically to the fracture cleavage F_3.

A regionally metamorphosed conglomerate (Lachlan Conglomerate) lies at the top of the Scotchfire Group at several localities. It contains angular fragments of quartz and quartzite in a foliated matrix of quartz, muscovite, chlorite, hematite and sometimes chloritoid. The presence of chloritoid is significant, as it indicates low grade metamorphism of rocks of unusually aluminous composition. Although an analysis of a chloritoid-bearing sample (analysis 39) has no particularly unusual features, chloritoid is apparently restricted to more pelitic zones in the rock.

The Jane Dolomite (Spry and Zimmerman, 1959; Spry, 1963*b*) appears to overlie Scotchfire Group rocks in the Jane River area, and is apparently faulted against the Mary Group east of Mt Mullens. The relationship of the Jane Dolomite to the quartzite, schist and phyllite of the other Precambrian group is uncertain; an unconformity has been suggested (Spry and Zimmerman, 1959), but in some areas it appears to be interbedded with them (N. J. Turner, pers. comm.). Several authors (e.g. Spry, 1962; Corbett and Brown, 1975) have regarded the Jane Dolomite as belonging to the 'younger' or 'relatively unmetamorphosed' Precambrian. Spry and Zimmerman (1959) described it as a massive dolomite, containing a little quartz and talc, together with a dolomitic breccia. Since it is now known (e.g. Winkler, 1979, p.115) that talc is the first new mineral to form in the metamorphism of siliceous dolomite, the Jane Dolomite may have been subjected to low grade metamorphism, at temperatures of roughly 350–450°C.

LYELL HIGHWAY–COLLINGWOOD RIVER AREA

Although adjacent to the Frenchmans Cap–Raglan Range areas discussed below, this area contains several unusual rock types, and is considered separately. Because of poor outcrop and the relative lack of detailed mapping, regional relationships are unclear, but the terrain is structurally complex, has been affected by thrusting, and appears to be of mixed, contrasted metamorphic grades (N. J. Turner, pers. comm.). Several, mainly petrological, studies are available (Spry, 1963*a*; Råheim and Green, 1974; Råheim, 1975, 1976; Kamperman, 1984).

Like elsewhere in the Prince of Wales Range Block, the terrain is dominated by siliceous to pelitic quartzite, phyllite and schist (Råheim, 1976). These are usually strongly deformed, with a crenulation cleavage dominating the fabric. The various pelitic rock types are mineralogically similar, and quartz and phengite are usually the main minerals. Many contain garnet porphyroblasts. The most characteristic assemblage is:

quartz + phengite + albite + almandine-rich garnet + biotite

Tourmaline is also frequently present. Kyanite is uncommon, and occurs in rocks low in $Na_2O + K_2O$ relative to Al_2O_3. Zircon, apatite, epidote group minerals and iron oxides are accessory minerals, and secondary chlorite and biotite may also be present. The assemblage is characteristic of [almandine]-low grade, and is similar to the higher grade rocks from elsewhere in the Tyennan nucleus.

Irregular quartz-albite-biotite veins occur in pelitic schist adjacent to some eclogite bodies (see below). These have been interpreted as migmatic neosomes (Råheim, 1975, 1976) produced by partial melting of the schist. Although little petrological work has apparently been done, no high grade assemblages, such as cordierite-potash feldspar, have been reported in the surrounding rock. However if PH_2O exceeds about 3.5 kb, muscovite does not dehydrate to potash feldspar, and coexists with albite and quartz until partial melting begins at temperatures of 660°C (3.5 kb) to about 530°C (10 kb) (Winkler, 1979, pp.82–86).

The unusual assemblage

talc + quartz + pyrope-almandine-garnet + kyanite

accompanied by several types of secondary chlorite occurs interlayered with isoclinally folded garnetiferous quartzite two kilometres NW of the Collingwood River bridge (Råheim and Green, 1974*a*). Chemically the rock differs from other local pelites by its very low $Na_2O + K_2O$ content, and is probably derived from the surface weathering of ultramafic rocks, mixed with quartz-rich sediments. Kyanite-talc schist (white schist) is known from only a few other localities in the world, and is usually much lower in FeO and lacks garnet (Schreyer, 1976*a*). The coexistence of kyanite and talc requires PH_2O >10 kb, but experimental data is incomplete, and water undersaturation could possibly reduce the required pressure substantially.

A number of small eclogite bodies, up to about 30 m long, occur within garnet-biotite-muscovite-albite-quartz schists (Spry, 1963*a*; Råheim, 1975, 1976; Kamperman, 1984). Although outcrop is poor contacts appear to be sharp, and the eclogite is probably derived from quartz to olivine normative tholeiitic dolerite which intruded the sediments prior to metamorphism. The rock is medium grained, massive or weakly banded with zones richer in quartz, zoisite and phengite, and contains abundant (38%) garnet porphyroblasts (<1.5 mm). The assemblage is pyrope-almandine garnet + omphacitic clinopyroxene + phengite + sodic hornblende + zoisite + quartz + rutile.

Garnet, when fresh, is strongly zoned from almandine-rich cores (near $Alm_{45}Pyp_{24}Gr_{29}Sp_2$) to more pyrope-rich rims ($Alm_{38}Pyp_{38}Gr_{23}Sp_1$), whilst in contrast the Mg number (100 Mg/Mg + Fe) of clinopyroxene (containing about 30 mol% jadeite) and phengite decreases from core to rim (Råheim, 1975, 1976). Using the garnet-clinopyroxene geothermometer (Råheim and Green, 1974*b*) and the Si content of phengite (Velde, 1967), Råheim (1975, 1976) used the zoned minerals to estimate the PT conditions of prograde metamorphism as 7.5 ± 1 kb, 520°C ± 20°C, increasing to the peak at 11 ± 1 kb, 670°C ± 20°C. Using an improved version of the garnet clinopyroxene geothermometer (Ellis and Green, 1979), the estimated peak of metamorphism has been revised to 715–730°C, 15.6–17 kb (Kamperman, 1984).

The zoning of garnet, phengite and talc in the surrounding schist is similar to that in the eclogite, suggesting that both schist and eclogite share a common PT history of metamorphism. They are part of the same supracrustal sequence that has been carried deep into the crust, possibly by subduction, and then been subjected to increasing temperature at high pressure. The kyanite-talc schist, and possible partial melting of muscovite-bearing schist, are also consistent with regional high pressure metamorphism. This is in contrast to the earlier view (Spry, 1963*a*) that the eclogite might be a tectonic inclusion from depth, not related to the surrounding pelitic rocks.

Garnet amphibolite bodies also occur in this area (Spry, 1963*a*; Råheim, 1975, 1976). Chemically they are similar to the eclogite but in contrast contain only a few per cent garnet. The assemblage is:

sodic hornblende + oligoclase + garnet + biotite +
epidote minerals + quartz

Zoning of minerals in the amphibolite is irregular or partly reversed in comparison to that in the eclogite, and the amphibole appears to be secondary. Secondary amphibole is often also developed towards the margins of the eclogite bodies. Råheim (1975, 1976) interpreted the amphibolite as being the result of secondary amphibolitisation of eclogite at conditions of higher FH_20 during a later deformation event, possibly related to the development of the crenulation cleavage (F_3).

MERSEY–FORTH AREA

The most useful study of this area is that of Gee *et al.* (1970). The upper Mersey–Forth area, to the east of Cradle Mountain, has been discussed by Spry (1958) and Jennings (1963).

The Precambrian rocks in this area, in the northern portion of the Cradle Mountain Block, consist of steeply dipping E or ENE belts of quartzite and pelitic schist, roughly parallel to the margin of the block. Although these belts probably represent original sedimentary layering, a satisfactory stratigraphic subdivision has not been possible. In the upper Forth area the terms Dove Schist and Dove Group have been used for the dominantly pelitic rocks, and Fisher Group has been used for the dominantly siliceous rocks (Spry, 1958; Jennings, 1963). Other terms have been proposed (Howell Group, Arm Schist, Maggs Quartzite) but have proved difficult to distinguish on a regional scale.

A major pelitic belt occurs at the northern margin of the Cradle Mountain Block, extending from Mt Romulus to the Dove River–Upper Forth area and the Upper Mersey area just west of Western Bluff. In the Waldheim area the metamorphic grade increases eastward, from phyllite typically containing albite microporphyroblasts in a groundmass of quartz sericite and sometimes chlorite, to progressively coarser schist containing subordinate biotite (identified and distinguished from stilpnomelane by x-ray diffraction), and finally almandine-rich garnet. By microfabric analysis, the sequence of crystal growth during metamorphism can be determined and correlated with tectonic events. The earliest recrystallisation involved growth of muscovite and chlorite along the bedding, and culminated in the formation of almandine garnet. Garnet growth continued in the early phase of the first deformation event (D_1) in which an axial plane schistosity was produced by growth of muscovite, chlorite, and biotite. The main phase of growth of the albite porphyroblasts was later than D_1. Structures produced by a second phase of deformation (D_2) are only locally developed, and no new metamorphic minerals developed at this time, although there was further recrystallisation of quartz and minor growth of muscovite and chlorite.

The Mersey–Forth area has been studied in less detail but the pelitic rocks (Dove Schist) are frequently garnetiferous (Spry, 1958; Jennings, 1963). In this area, chloritoid has also been reported in garnetiferous quartz-sericite schist and quartz-sericite-chlorite schist (Jennings, 1963) indicating metamorphism of relatively aluminous rocks at low grades, both above and below the almandine isograd (Winkler, 1979, p.226).

Two types of quartzite were distinguished in the Cradle Mountain area by Gee *et al.* (1970). Well-bedded platy quartzite contains a microscopic foliation, due to orientation of quartz, and minor muscovite and chlorite. Schistose quartzite contains up to 5% muscovite and primary chlorite, and sometimes garnet and secondary chlorite. Albite, tourmaline, zircon and opaque minerals are probably of detrital origin. Similar siliceous rocks (Fisher Group, Maggs Quartzite) occur to the east in the Upper Mersey–Forth area (Spry, 1958; Jennings, 1963). On the limited data available, the grade of metamorphism is similar to that of the regionally interbedded pelites.

An amphibole schist, probably derived from an olivine-bearing igneous rock, occurs at Crater Lake (Gee *et al.*, 1970). It consists of albite porphyroblasts in a foliated groundmass of actinolite, biotite, and minor quartz, calcite and pyrite. Epidote and chlorite occur as inclusions within the albite porphyroblasts. This assemblage suggests low grade metamorphism (greenschist facies) similar to that of the pelitic rocks.

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[31 March 1989]

Table 1. *CHEMICAL ANALYSES OF ROCKS FROM THE TYENNAN GEANTICLINE.*

	01 PD1	02 PD3	03 PD9	04 PD14	05 PD21	06 PD22	07 PD23	08 PD32	09 PD39	10 PD44	11 PD45	12 PD46
SiO_2	70.6	63.1	65.8	67.3	59.4	68.6	58.0	51.8	46.3	63.6	55.1	65.7
TiO_2	0.83	0.57	0.38	0.47	0.71	0.53	0.63	1.6	1.3	0.60	0.51	0.60
Al_2O_3	11.4	15.1	17.1	12.6	17.7	15.9	13.2	14.1	15.2	15.7	16.9	15.8
Fe_2O_3	0.91	2.4	2.9	2.6	2.3	0.98	8.5	3.6	2.7	1.5	1.5	1.5
FeO	8.0	8.3	0.66	8.2	8.8	4.5	9.6	16.6	11.2	8.5	13.9	6.5
MnO	0.09	0.12	0.02	0.27	0.30	0.07	0.60	0.22	0.25	0.14	0.38	0.39
MgO	3.3	2.2	2.1	2.3	2.5	1.5	5.0	6.2	7.8	2.6	4.1	1.4
CaO	0.23	0.26	0.07	0.62	0.37	0.20	1.0	0.26	9.8	0.29	0.48	0.56
Na_2O	0.14	1.2	0.15	0.18	0.50	1.6	0.40	0.04	2.0	0.31	0.23	1.8
K_2O	1.6	3.5	7.1	2.4	4.0	4.0	1.1	1.2	1.1	3.4	2.5	3.3
P_2O_5	0.13	0.07	0.04	0.11	0.03	0.06	0.08	0.11	0.10	0.09	0.12	0.12
H_2O^+	2.9	3.4	2.9	2.1	2.8	2.1	2.6	3.8	2.8	3.7	3.7	2.4
H_2O^-	0.03	0.10	0.07	-	-	-	-	-	-	-	-	-
CO_2	0.13	0.08	0.10	0.17	0.34	0.22	0.21	0.27	0.27	0.24	0.22	0.20
Total	100.29	100.40	99.39	99.32	99.75	100.26	100.92	99.80	100.82	100.67	99.64	100.27

	13 DH1	14 DH2	15 DH9	16 DH15	17 DH16	18 SB3	19 4956	20 2368
SiO_2	48.2	47.7	60.0	70.8	68.5	64.8	43.16	73.1
TiO_2	1.10	0.83	0.88	0.44	0.64	0.39	2.00	nd
Al_2O_3	15.0	16.1	20.7	15.1	15.3	18.1	16.12	13.6
Fe_2O_3	3.4	1.8	1.0	0.52	0.83	2.1	2.89	0.80
FeO	8.4	9.3	4.4	2.7	4.3	0.92	14.86	3.3
MnO	0.22	0.26	0.08	0.05	0.13	0.07	0.24	na
MgO	8.3	10.4	1.4	1.3	1.4	2.3	5.89	1.05
CaO	11.5	8.1	0.42	0.26	0.65	0.03	10.22	0.66
Na_2O	1.8	3.3	1.1	1.7	2.3	1.2	1.63	4.0
K_2O	0.08	0.12	4.5	5.1	3.1	7.4	0.32	1.18
P_2O_5	0.07	0.02	0.08	0.10	0.09	-	0.12	na
H_2O^+	2.3	2.2	4.3	2.4	2.4	3.3	2.68	1.4
H_2O^-	-	-	0.19	0.03	0.02	-	0.18	0.39
CO_2	0.15	0.15	0.20	0.28	0.28	0.10	na	na
Total	100.52	100.28	99.25	100.78	99.94	100.71	100.31	99.48

(a) Port Davey area (P. R. Williams, 1982)

01	PD1	garnet biotite schist, east of Sandblow Bay (DN05061011)
02	PD3	albite biotite schist, east of Sandblow Bay (DN04301069)
03	PD9	mica schist, Sandblow Bay (DN03101055)
04	PD14	garnet schist, coast near Toogee Hill (DN03730891)
05	PD21	garnet schist, coast near Toogee Hill (DN03790922)
06	PD22	albite schist, coast near Toogee Hill (DN03790922)
07	PD23	coarse grained garnet schist, coast near Toogee Hill (DN03790922)
08	PD32	garnet schist, Sandblow Bay (DN03930975)
09	PD39	garnet amphibolite, Sandblow Bay (DN03801042)
10	PD44	coarse garnet muscovite schist, coast near Trumpeter Islets (DN03930777)
11	PD45	garnet schist, coast near Trumpeter Islets (DN03930777)
12	PD46	albite schist, coast near Trumpeter Islets (DN04020787)
13	DH1	garnet amphibolite; near Davey Head (DN09060443)
14	DH2	garnet amphibolite, near Davey Head (DN09000437)
15	DH9	garnet mica schist, Kelly Basin (DN10990837)
16	DH15	quartz schist, Saddle Bight (DN11950487)
17	DH16	albite-mica-garnet schist, Outer Saddle Bight (DN09670373)
18	SB3	quartz-mica schist, Fire Hill (DM133971)

(b) Port Davey area (Spry and Baker, 1965)

19	4956	amphibolite, Bond Bay, Port Davey
20	2368	albite schist, Bond Bay, Port Davey

	21 40955	22 40970	23 40988	24 40960	25 40976	26 40959	27 40999	28 71-320	29 71-324	30 71-327	31 71-335	32 71-336	33 71-340	34 71-344
SiO_2	60.16	66.24	69.51	73.89	79.60	84.07	87.66	69.5	66.3	65.4	69.4	85.9	79.6	54.8
TiO_2	0.85	0.65	0.70	0.29	0.27	0.28	0.49	0.7	0.7	0.7	0.6	0.2	0.2	0.8
Al_2O_3	20.69	16.23	15.25	11.81	8.30	8.24	4.84	15.6	17.1	18.0	15.4	5.1	11.4	25.7
Fe_2O_3	0.00	1.66	1.24	0.71	0.18	0.00	0.24	0.8	0.8	0.7	2.6	1.0		2.0
FeO	2.60	1.88	2.62	1.02	2.25	0.51	2.10	3.4	4.3	4.5	4.0	3.6	1.3	2.1
MnO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1	0.1	0.1	0.1	0.1		
MgO	4.85	1.47	1.42	4.22	5.20	1.14	1.40	1.3	1.8	1.5	1.6	1.4	3.6	1.1
CaO	0.01	0.01	0.01	0.03	0.01	0.00	0.01	0.6	0.9	0.4	0.3	0.2	0.1	0.1
Na_2O	0.52	0.25	0.40	0.30	0.11	0.82	0.25	1.5	0.7	1.8	0.2	0.1	0.1	0.1
K_2O	5.32	3.91	3.45	3.58	1.17	3.72	1.27	4.1	4.6	4.1	5.0	1.0	3.2	9.6
P_2O_5	0.07	0.03	0.00	0.05	0.01	0.02	0.01	0.1	0.1	0.1	0.1		0.1	0.1
¤H_2O^+)														
¤H_2O^-)	4.19	6.78	4.70	2.83	2.69	1.74	1.50	2.4	2.6	2.7	0.7	1.4	0.4	4.2
¤CO_2)														
Total	99.26	99.11	99.30	98.73	99.79	100.54	99.77	[100.1]	[100.0]	[100.0]	[100.0]	[100.0]	[100.0]	[100.6]

¤ — H_2O^+, H_2O^- and CO_2 combined as Loss on Ignition.

(c) Phyllites and micaceous quartzites, McPartlan Pass – The Sentinels area (S. J. Williams, 1976)

21	40955	Gordon River Road, McPartlan Pass (DN326554)
22	40970	Gordon River Road, McPartlan Pass (DN339547)
23	40988	Old Lake Pedder Track, Sentinel Range (DN340522)
24	40960	Gordon River Road, McPartlan Pass (DN334550)
25	40976	South of Hermit Basin, Lake Pedder (DN312544)
26	40959	South of McPartlan pass (DN329549)
27	40999	Gordon River Road, near Sentinel Range (DN355539)

(d) Mica schists, Collingwood River area (Råheim, 1976)

28	71-320	mica schist (DP060357)
29	71-324	mica schist (DP060357)
30	71-327	garnet mica schist (DP060357)
31	71-335	garnet mica schist (DP067359)
32	71-336	garnet mica schist (DP067359)
33	71-340	mica schist (DP071357)
34	71-344	mica schist (DP087349)

	35 6227	36 6220	37 7310	38 6372	39 7087	40 6416	41 6275	42 6290	43 6323	44 30149
SiO_2	74.32	98.00	71.72	70.72	66.40	29.00	69.28	60.12	75.24	68.00
TiO_2	0.35	0.05	0.34	0.44	1.02	0.10	0.45	0.30	0.04	0.69
Al_2O_3	12.90	0.62	13.99	10.51	13.63	3.75	15.64	11.60	13.27	17.00
Fe_2O_3	0.43	tr	1.67	0.97	9.44	1.70	0.57	1.00	1.28	1.96
FeO	2.69	0.77	1.20	4.91	2.83	0.66	4.61	14.47	1.41	2.54
MnO	tr	tr	nil	0.07	tr	0.04	tr	0.06	0.03	0.02
MgO	3.27	nil	2.01	4.91	1.00	14.53	1.48	7.00	0.94	1.16
CaO	nil	0.04	0.08	1.52	tr	18.96	0.68	0.68	0.04	0.60
Na_2O	0.44	0.18	0.05	1.29	1.21	0.12	1.93	0.16	1.98	1.31
K_2O	3.08	0.24	6.02	1.12	1.59	1.60	3.42	0.32	3.36	3.64
P_2O_5	0.05	tr	0.07	0.11	0.21	0.04	0.05	0.07	0.02	0.06
H_2O^+	2.90	0.18	2.48	2.97	2.13	nd	1.96	4.20	1.43	2.93
H_2O^-	0.20	0.04	0.26	0.18	0.22	0.30	0.10	0.18	0.20	0.19
Total	100.63	100.12	99.89	99.72	99.68	[70.80]	100.17	100.16	99.24	100.10

	45 (11)	46 30125	47 30150	48 30115	49 (15)	50 (16)	51 (17)	52 30132	53 30132	54 5851
SiO_2	67.20	73.70	71.60	49.92	68.00	68.00	66.38	58.18	44.78	50.92
TiO_2	0.94	0.45	0.69	2.44	0.69	0.78	0.94	0.61	2.81	0.60
Al_2O_3	17.67	11.62	14.72	16.76	17.01	15.72	18.21	15.36	13.44	16.83
Fe_2O_3	2.30	2.95	1.04	4.81	1.96	0.92	1.46	0.79	2.41	1.11
FeO	2.72	3.69	2.62	8.84	2.54	3.02	2.34	5.31	16.22	9.78
MnO	0.02	0.04	0.02	0.05	0.02	0.02	0.01	0.09	0.36	0.18
MgO	1.19	2.00	2.56	6.91	1.16	1.43	1.74	6.72	7.01	7.99
CaO	0.32	0.04	0.16	0.72	0.60	0.32	0.44	5.00	9.12	9.87
Na_2O	0.98	0.09	0.71	2.12	1.31	1.18	1.25	1.69	1.65	1.15
K_2O	3.47	2.47	3.02	1.61	3.65	3.64	4.23	2.95	0.47	1.12
P_2O_5	0.40	0.03	0.05	0.24	0.06	0.06	0.07	0.15	0.40	0.02
H_2O^+	3.06	2.96	2.95	5.33	2.93	2.79	2.93	2.61	1.58	0.96
H_2O^-	0.18	0.36	0.14	0.53	0.19	0.12	0.47	0.49	0.07	0.14
Total	100.45	100.40	100.28	100.28	100.12	99.43*	100.47	99.95	100.32	100.67

* — Includes 1.29% FeS_2 and 0.14% SO_3.

(e) Frenchmans Cap area (Spry, 1963a)

35	6227	phyllite, Mary Group, Mt Mary
36	6220	quartz schist, Mary Group, Mt Mary
37	7310	phyllite, Scotchfire Group, Lyell Highway
38	6372	schist, Scotchfire Group, Lyell Highway
39	7087	Lachlan Conglomerate, Scotchfire Group, Lightning Plains
40	6416	dolomite, Scotchfire Group, Thirkell Creek
41	6275	garnet schist, Franklin Group, Raglan Range (Cardigan River)
42	6290	garnet schist, Franklin Group, Cardigan River
43	6323	albite schist, Franklin Group, Cardigan River
44	30149	coarse garnet-albite schist, Franklin Group, Raglan River
45	11	mica schist, Franklin Group, timber mill, Raglan Range
46	30125	chloritised garnet schist, Franklin Group, western Raglan Range
47	30150	muscovite-chlorite schist, Franklin Group, western Raglan Range
48	30115	knotted albite schist, Franklin Group, Raglan Range
49	15	Governor Phyllite, Mary-Franklin Transition, Joyce Creek
50	16	Governor Phyllite, Mary-Franklin Transition, Joyce Creek
51	17	Governor Phyllite, Mary-Franklin Transition, Joyce Creek
52	30132	amphibole schist, Franklin Group, Raglan Range
53	30132	amphibolite, Raglan Range
54	5851	eclogite (pyroxene-garnet-amphibole rock), Lyell Highway

	55	56	57	58	59	60	61	62	63	64	65
	71-310	71-312	71-328	71-329	71-331	71-333	71-352	71-345	71-345	71-345	71-334
SiO_2	64.9	70.1	51.8	51.2	53.3	47.3	49.3	52.0	51.2	55.7	51.8
TiO_2	0.4	0.4	0.6	0.7	0.7	0.6	0.6	0.6	0.7	0.5	0.7
Al_2O_3	9.8	9.0	15.2	15.5	15.6	16.2	15.8	15.4	15.2	15.8	14.7
Fe_2O_3	0.1	0.1	0.4	0.5	0.2	0.7	0.7		0.7		1.1
FeO	10.0	7.0	9.1	9.6	9.9	11.0	10.2	9.0	7.4	12.0	8.9
MnO	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.3	0.2
MgO	10.7	9.6	7.8	8.3	7.1	9.1	8.9	8.5	8.8	6.3	7.8
CaO	0.9	0.4	12.2	11.4	8.7	11.1	10.5	11.7	12.5	8.2	9.8
Na_2O	0.1	0.1	1.4	1.6	1.9	2.0	2.1	1.4	1.8	0.4	2.2
K_2O	0.2	0.1	0.2	0.2	1.0	0.7	0.9	0.1	0.2		0.6
P_2O_5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
¤H_2O^+)											
¤H_2O^-)	2.3	2.5	1.0	0.8	1.3	1.0	0.9	1.0	1.3	0.7	2.1
¤CO_2)											
Total	99.6	99.5	[100.0]	[100.1]	[100.0]	[100.0]	[100.2]	[100.0]	[100.0]	[100.0]	[100.0]

¤ — H_2O^+, H_2O^- and CO_2 combined as Loss on Ignition.

(f) White schists, Collingwood River area (Råheim and Green, 1974a)

55	71-310	talc-garnet-kyanite-quartz schist, Collingwood River (DP109329)
56	71-312	talc-garnet-kyanite-quartz schist, Collingwood River (DP109329)

(g) Eclogites and related rocks, Lyell Highway – Collingwood River area (Råheim, 1976)

57	71-328	eclogite (DP059357)
58	71-329	eclogite (DP058356)
59	71-331	eclogite (DP058356)
60	71-333	eclogite (DP058356)
61	71-352	eclogite (DP058356)
62	71-345(a)	whole rock (DP058356)
63	71-345(b)	eclogitic zone
64	71-345(c)	garnet-quartz-rich zone
65	71-334	amphibolite (DP060356)

	66 63-104	67 64-29	68 64-30	69 63-105	70 64-254	71 69-13	72 69-16	73 7390a	74 7390b	75 7387	76 7388
SiO_2	66.6	66.1	50.8	68.3	63.3	76.2	76.0	70.82	72.56	76.92	64.76
TiO_2	0.49	0.35	0.85	0.37	0.51	0.20	0.50	0.77	0.62	0.42	0.88
Al_2O_3	13.7	17.5	12.7	13.5	18.9	11.5	14.1	16.72	15.03	12.08	19.00
Fe_2O_3	1.1	1.7	2.9	4.3	1.5	1.4	0.68	0.53	1.85	0.68	1.07
FeO	5.5	3.9	7.0	2.6	4.9	2.1	0.74	1.29	1.02	1.89	3.20
MnO	0.22	0.34	0.16	tr	0.14	tr	tr	0.03	0.01	0.01	0.04
MgO	3.6	1.6	10.6	3.0	1.6	1.4	0.71	1.22	1.07	1.61	1.16
CaO	1.5	0.19	5.9	0.21	0.21	-	-	0.38	0.04	tr	0.08
Na_2O	2.0	0.69	3.3	1.2	0.83	2.3	1.1	1.02	1.11	1.47	1.72
K_2O	3.5	3.4	1.7	3.3	4.1	2.4	4.3	4.29	3.91	2.59	4.35
P_2O_5	0.08	0.10	0.09	0.10	0.08	tr	tr	0.07	0.03	0.04	0.08
H_2O^+	1.09	3.6	3.1	3.2	3.7	1.9	2.1	2.08	2.34	1.86	2.98
H_2O^-	0.12	0.23	0.26	0.31	0.21	0.29	0.20	0.20	0.20	0.03	0.12
CO_2	-	-	0.23	-	-	-	-				
Total	100.31	99.70	99.59	100.39	99.98	99.69	100.43	99.42	99.79	99.60	99.44

(h) Cradle Mountain area (Gee et al., 1970)

66	63-104	biotite-albite schist, plateau north of Mt Inglis
67	64-29	quartz-muscovite-albite-garnet-chlorite schist, Mt Smithies
68	64-30	amphibole schist (igneous), SW wall of Crater Lake
69	63-105	quartz-chlorite-biotite-albite schist, Lake Rodway
70	64-254	quartz-muscovite-albite-garnet-chlorite schist, Cradle Mountain road 11 km north of Waldheim
71	69-13	quartz-albite-chlorite schist, Twisted Lakes
72	69-16	low grade quartz-muscovite-chlorite metasediment, Artists Pool, 1.5 km south of Lake Dove.

(j) Upper Mersey–Forth area (Spry, 1958)

73	7390a	slate, Fisher Group, two miles south of Fisher River junction.
74	7390b	slate, Fisher Group, two miles south of Fisher River junction.
75	7387	schist, Howell Group, Walters Marsh, Upper Mersey area
76	7388	schist, Howell Group, Walters Marsh, Upper Mersey area

	77 68301	78 68300	79 68299	80 68298	81 68297
SiO_2	51.02	55.3	48.98	53.76	53.99
TiO_2	0.60	0.70	1.15	0.97	0.25
Al_2O_3	15.22	14.64	14.12	14.49	14.79
Fe as Fe_2O_3	10.59	10.16	13.75	11.18	16.18
MnO	0.20	0.17	0.33	0.22	0.21
MgO	7.26	7.55	7.57	6.18	2.86
CaO	10.17	7.96	9.56	8.99	7.74
Na_2O	1.75	1.94	1.15	2.38	1.11
K_2O	0.64	0.79	0.88	0.59	1.42
P_2O_5	0.06	0.09	0.08	0.10	0.36
L.O.I.	1.29	1.13	2.38	1.38	0.94
Total	99.34	100.03	99.95	100.24	99.85
ppm					
V	251	247	285	368	82
Cr	65	266	223	219	52
Ni	67	71	74	48	16
Rb	27	39	50	20	47
Sr	73	82	207	170	70
Y	18	22	27	48	112
Zr	53	97	68	130	145
Nb	2	4	2	5	4

(k) Amphibolites, high grade complex, Nye Bay area (McNeill, 1985)

77	68301	garnet-hornblende-quartz amphibolite (CN913325)
78	68300	garnet-hornblende-quartz amphibolite (CN913325)
79	68299	hornblende-plagioclase amphibolite (west) (CN921324)
80	68298	hornblende-plagioclase amphibolite (east) (CN921324)
81	68297	garnet-hornblende amphibolite (CN921324)