the greater part of these rocks, which are not unlike their counterparts in the low-grade zone. Biotite is not common and in some cases is quite absent. Occasionally pale greenish mica flakes are apparent. Quartz is the major constituent of all these rocks. It is usually finely granular but distinct grain-size variations are common even in the one thin section. Quartz veins frequently occur and the coarser quartz-rich patches are often associated with them. Some of these veins in the more massive rocks display intricate fold-patterns (cf. ptygmatic veins in granitized regions). Where the carbonaceous matter is present in patches the carbon-rich portions have the finest-grained quartz associated with them. Local haematite staining is rather common and some, at least, of the iron oxide has been derived from the breakdown of pyrite.

(ii) *Psammopelites and Psammites.*

The mineralogical changes typifying the pelites of the biotite zone also occur in the sandier rocks. Chlorite and green mica are converted to biotite just as in the pelites. Most of these sandy rocks have sufficient matrix material available to produce the index mineral biotite and are thus quite useful for zoning purposes. Biotite appears to form in the sandy rocks earlier than in the pelites but the lag is never great. Harker (1939, p. 224) considered that the more psammitic rocks should lag behind the pelites during progressive metamorphism, but the opposite relations found during the present study also obtain at Cooma (Joplin, 1942, p. 170). Ray (1947) suggests that "more quartzose schists are prone to indicate by virtue of their inherent rigidity a slightly lower grade of metamorphism than a pelitic schist showing the same index mineral". In the present case (as at Cooma) the metamorphism has an important thermal factor (Ray and Harker were considering almost exactly equivalent zonal sequences) which may overcome the "inherent rigidity". Joplin (1942) suggested that the pelite lag might have been due to enhanced diffusion related to the presence of pore-fluid in the sandy rocks.

Quartz is the major constituent of these rocks and is usually associated with muscovite, biotite, chlorite and green mica (near the biotite isograd) and the usual accessories. Epidote has been noted as a rare accessory. As in the low-grade zone the large quartz grains tend to become granulated and recrystallized but original clastic characters often remain (preservation of original features has been observed in the biotite zone of the Woomargama and Burrumbuttock districts at Albury (Joplin, 1947); at Cooma they have usually been obliterated). Detrital plagioclase may survive well into the biotite zone, though it is definitely unstable under these conditions. The general tendency is, however, for the plagioclase to be replaced by albite.

III. Knotted Schist Zone.

With increase in metamorphic intensity the pelitic rocks acquire the appearance of knotted schists by the development of porphyroblasts. These "knotted" rocks are readily recognizable in the field and an isogradal line may be drawn joining the points where the porphyroblasts appear. Such an isograd was used at Cooma and Albury by Joplin to introduce a zone of knotted schists (at Cooma called andalusite zone) and to separate it from the biotite zone. Tattam and Crohn (see Crohn, 1950, p. 16), working on the Victorian end of the metamorphic complex, have noted the development of porphyroblasts of cordierite in biotitic schists. Crohn believes, however, that this feature "cannot be used to define a new zone" because of the difficulty of distinguishing between spots of incipient cordierite and micaceous aggregates due to retrogressive alteration of the cordierite. He therefore considers these rocks as members of the biotite zone rather than as characteristic of a separate zone. Whilst there may be some justification for Crohn's claim, my experience in this area has been that a knotted schist zone can be defined and mapped without undue ambiguity. The term knotted schist zone is used here rather than, say, andalusite and/or cordierite zone because it is often a matter of some difficulty to prove unequivocally which of these minerals was present originally as porphyroblasts.

Schists characteristic of this zone are found in proximity to the Wantabadgery mass except at its south-eastern end where high-grade rocks occur. A definite high-grade zone separates the knotted schists from the Green Hills granite mass. As in the case of the biotite isograd, the outer limit of the knotted schist zone roughly parallels the margins of the granite masses. Knotted schists occur along part of the northern end of the Ellerslie mass and have been traced as far as Bangandang Trig. Station. Again, like the biotite zone, this zone appears widest where it transgresses the regional strike of the metasediments. The eastern belt of knotted schists becomes increasingly narrow as one passes from south to north. The western (i.e. to the west of the granites) belt is widest to the east of Tarcutta and is more restricted both to the north and south. The Belmore mass has not had much effect on the knotted schist zone, for in many places knotted rocks do not appear at all and the granite comes into contact with biotite-zone rocks. Where the zone swings round sympathetically with the Wantabadgery granite it increases in width as it passes westwards and finally achieves a surface width of about five miles in the vicinity of Alfred Town. To the south-west of Westbrook the knotted schist zone narrows and finally disappears. South of Tumbarumba, along the valley of Tumbarumba Creek, fragments of knotted schists have been found in the tributaries draining the country to the west (Mt. Garland area). This seems to indicate that away from the fault line the knotted schists reappear in this southern area.

(i) *Pelites.*

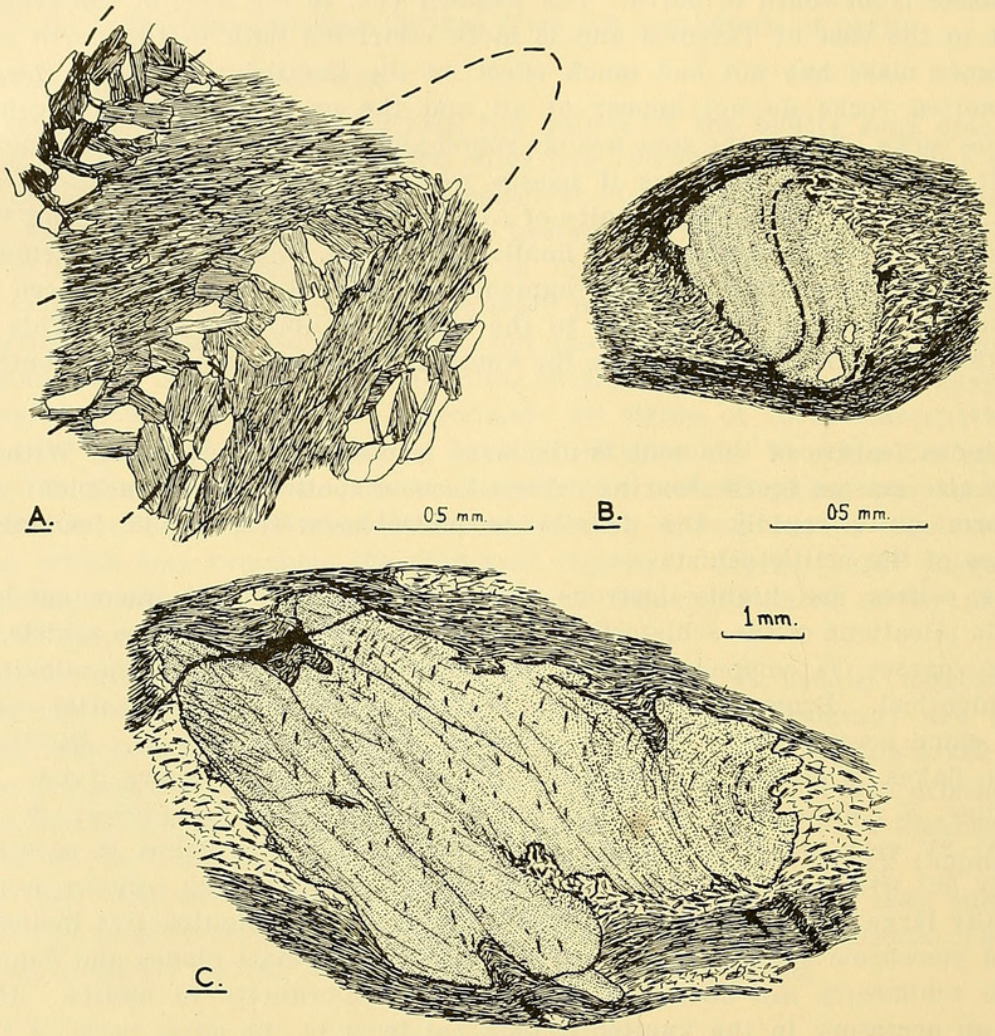
The index feature of this zone is displayed typically by the pelites. With approach to the granite masses biotite-bearing schists become spotted by the incipient clots from which form quite rapidly the definite porphyroblasts responsible for the knotted appearance of the pelitic schists.

These pelites are highly lustrous and micaceous and not uncommonly display small-scale plications of the schistosity. The lepidoblastic base of these schists, although somewhat coarser, is comparable with the biotite-zone schists. Mineralogically they may be identical. Brown biotite, muscovite and quartz are the essential constituents with the same accessories as were noted in the biotite-zone schists. Biotite as well-developed flakes is of the strongly pleochroic brown or red-brown type: X = pale straw-yellow; Y = dark brown or red-brown; Z = dark brown or red-brown; $Z = Y \gg X$; $\gamma = 1{\cdot}639$; 2V very small. Generally the orientation of the flakes is parallel to the schistosity but with advancing recrystallization exceptions to this rule are not unusual. Occasionally large porphyroblasts (up to ca. 2 mm.) occur. Radioactive inclusions with associated pleochroic haloes are sometimes present. Muscovite blades and flakes aligned along the schistosity are abundant though often subordinate to biotite. Untwinned albite is an accessory in the knotted schists (at least in the outer parts of the zone). Potash felspar (untwinned), presumably a relic, has also been recorded on rare occasions. The presence of carbonaceous matter appears to cause a slight lag in the formation of porphyroblasts in the carbon-rich rocks.

The porphyroblasts usually stand out as dark knots on weathered surfaces. Traces of original idioblastic outlines are common but deformation has, in some cases, induced oval or almond shapes. The knots increase in size with approach to the granite margins and occasionally reach a length of from three-quarters to one inch. In all cases the porphyroblasts are more or less, often completely, altered to pseudomorphic greyish micaceous aggregates. Where cores of unaltered material have been found the original mineral is a clear, colourless variety of andalusite. The alteration products are mainly sericitic mica, with some biotite and occasionally a little chlorite. Biotite becomes more important in the altered knots of the higher-grade zone and usually has a minor role in the aggregates found in the knotted schist zone. In addition to micaceous aggregates with andalusite cores (and the more abundant comparable aggregates without such relics), pseudomorphs with a distinctly yellowish colour and relict poikiloblastic structure suggestive of pinitized cordierite are occasionally apparent. Fresh cordierite has, however, not been found in these rocks. Cordierite is recorded as an important constituent of knotted schists at Albury and in the Kiewa region of Victoria (Tattam,

1929), but in view of the extent of alteration in the present case it is difficult to assess the relative importance of cordierite and andalusite as porphyroblast minerals. The impression gained from an examination of thin sections would suggest that andalusite was the commoner of the two minerals.

Thin section examination often reveals that the knots have suffered a rotation which has tended to twist them into the plane of the schistosity. Rotation has therefore been greatest in the case of the porphyroblasts elongated directly across the schistosity. Text-figure 6, B, illustrates such a rotated porphyroblast. Patches richer in quartz and



Text-figure 6.

A. Camera lucida sketch of folds in a banded psammopelite showing undeformed biotite flakes in the crests and troughs of the folds. The dark lines in the pelitic bands represent post-crystalline shears.

B. Micaceous pseudomorph after andalusite (?) showing signs of rotation in a somewhat carbonaceous pelite.

C. Large pseudomorph after andalusite (?) showing signs of rotation as well as deformation due to post-crystalline shears. Undeformed biotite has, in places, crystallized along the sutured margin of the porphyroblast.

of coarser grain-size than the rest of the base are often developed on the "protected" sides of the porphyroblasts. Even when alteration to mica is complete the lines of inclusions in the pseudomorphs indicate the degree of rotation.

Study of these porphyroblasts leads to some interesting information concerning time relations of crystallization of the various constituents in these rocks. The factors causing deformation of the porphyroblasts may also have produced minor plications in the base of these rocks. Such plications are shown in Text-figure 6, A. It can be seen that on the inside of the folds the biotite has crystallized without distortion, suggesting a para-crystalline environment (cf. Read, 1949, p. 117). Text-figure 6, C, shows a

porphyroblast which has suffered apparent post-crystalline deformation and associated with this are plications in the micaceous base displaying para-crystalline features. This suggests that the porphyroblast crystallized before the final crystallization of mica. Evidence of rotation is also seen in this porphyroblast, but the twisting apparently took place before the final deformation. Local shears in such rocks are not unusual and indicate stress influence even after the final mica crystallization. Although there is a tendency for the porphyroblasts to be aligned along the schistosity or rotated towards that plane, there does not appear to be much orientation of them parallel to the lineation. This may be because the lineation and the schistosity were initiated before the porphyroblasts formed, although it is clear that some stress influence and mica crystallization continued after this stage. The evidence available regarding the growth of these schists seems to point to a sequence of events rather like the following: (*a*) initial crystallization of micas producing a schistosity, (*b*) formation of porphyroblasts, and (*c*) final (minor) crystallization of mica. The suggested sequence may be related to variations in the thermal/stress balance during the metamorphism with the thermal peak coinciding with the porphyroblast formation.

These observations suffice to indicate that the metamorphic processes which affected these rocks were by no means simple and that the knotted schists as seen today were built in stages. It seems logical to regard all these stages as parts of the one overall metamorphism rather than as completely unconnected events. "The dictum of our master Becke", as Read (1949, p. 106) has remarked, must be rejected, for, in actual fact, simultaneous crystallization in schists is often the exception rather than the rule. It is reasonable to expect that the other rocks here bear cryptic evidence of comparable relations, for all of them have, in a general way, suffered the same metamorphism though they have been affected to different degrees.

Garnet has been mentioned as a constituent of certain schists in the Parishes of Cunningdroo and South Wagga Wagga by Whiting (1950). The former locality has been examined during the course of this work, but the occurrence of garnet has not been confirmed.

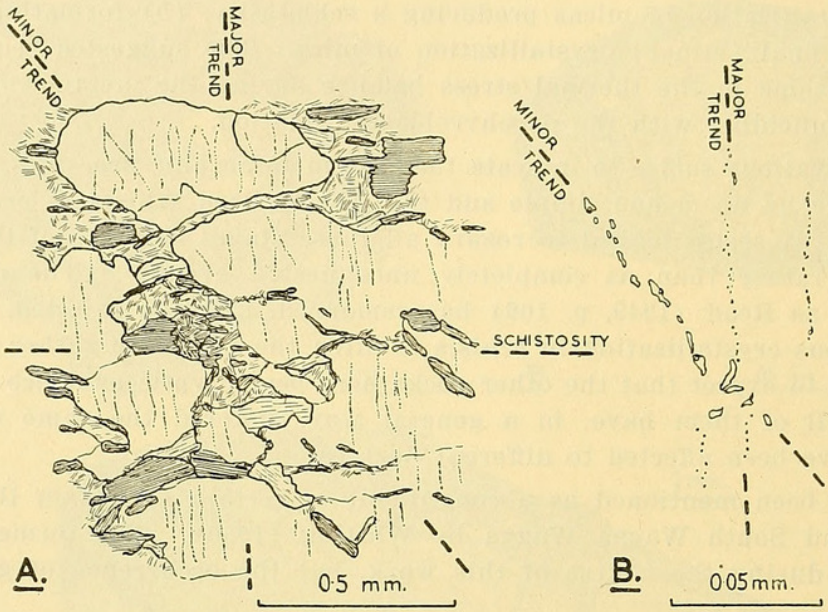
Black siliceous pelites appear to pass into a knotted schist zone environment to the north-west of Yabtree Trig. Station, but elsewhere they do not figure in this zone. Their composition precludes the development of andalusite or cordierite and thus they display no superficial indication of a change in metamorphic grade. Recrystallization merely causes an increased grain-size of the mineral constituents, which are the same as those found in comparable rocks of the biotite zone.

(ii) *Psammopelites and Psammites.*

The reaction of the sandier rocks to knotted schist zone conditions has been foreshadowed by the remarks already made. Quartz-rich psammites, poor in alumina, obviously would be unable to develop andalusite or cordierite no matter what the grade of metamorphism. On the other hand, it is quite conceivable that the more aluminous psammopelitic rocks could provide the materials necessary for the growth of andalusite or cordierite porphyroblasts, and this is exactly what happens in the rocks studied. The mica-rich portions of the banded psammopelites behave in the same manner as do the pelites themselves. The porphyroblasts make their appearance in such rocks before they do in the more homogeneous psammopelites. In the latter rocks the knots are quite comparable with those in the true pelites, except that where the supply of material is limited the grain-size of the porphyroblasts is diminished.

In the absence of "knots", a coarser grain-size is the only feature which might distinguish sandy rocks in this zone from their analogues in the biotite zone. Some of these metasediments still bear witness to their original clastic nature. Irregularities in size and a certain angularity of the sand grains may persist, but in the more intensely recrystallized parts of this zone such features often disappear. In the banded metasediments even such fine structures as graded bedding may be preserved into the knotted schist zone.

Quartz remains the dominant component of these rocks but a little felspar (plagioclase and relict K-felspar) may also be represented in the sand fraction. The orientation of the optic axial directions of quartz grains in a psammopelite from this zone has been represented in a fabric diagram (Text-fig. 5). Not infrequently the quartz grains in these rocks are traversed by lines of minute inclusions. These small inclusions are often opaque but occasionally larger examples are found which are rather irregular in outline and may contain small bubbles suggesting that the inclusions are liquid. Often the lines of inclusions can be proved to be end-sections of planes which display a remarkable constancy of orientation from grain to grain. Text-figure 7 gives sketches of these liquid inclusion planes which here cut across the schistosity. Tuttle (1949) has given an excellent discussion of the subject of liquid inclusions. He



Text-figure 7.

A. Camera lucida sketch of a knotted schist zone sandy rock showing planes of liquid inclusions, in the quartz grains, cutting across the schistosity.

B. Camera lucida sketch giving details of the inclusions in one of the quartz grains.

found that, at times, such planes have a remarkably uniform orientation over large areas. In Text-figure 7, B, it will be noted that there are two major orientations of planes of inclusions in these rocks and, applying Tuttle's (1949, p. 334) criteria, it can be seen that the "subordinate" group (minor trend) is probably of somewhat later age than the "dominant" group. It is quite obvious that there is no uniform relation between the orientation of these inclusion planes and crystallographic directions in the quartz. The planes of inclusions have certainly formed in the rocks after consolidation and cannot have been present in the original clastic grains. Tuttle believed that deformative processes were responsible for the development and uniform orientation of the inclusion planes in the Washington, D.C., area, and the same explanation seems reasonable in this case. No attempt has been made to apply petrofabric methods to this problem, but observations made suggest that such studies would bear fruitful results.

In addition to the sandy rocks with admixed clay as matrix material, odd bands of calcareo-arenaceous rocks are found in this zone. Mineralogically these latter rocks consist mainly of quartz and granular clinozoisite-epidote with subordinate dirty pale green amphibole and iron ore. Rocks of similar composition occur as inclusions in the Wantabadgery granite. It is interesting to note that it is such limy rocks which display boudinage structures at Mundarlo (Vallance, 1951). A few examples of psammopelites with abnormal lime have been found to the west of Bangandang Trig. Station. The development of crystals of pleochroic bluish-green or green amphibole along with brown biotite indicates an enhanced lime content. A rock containing a few subhedral, colourless

garnets (associated with quartz and small aggregates of colourless amphibole) was also found here. This is the only occurrence of garnet in the country rock metasediments found during this study and is perhaps due to an unusual lime content; the rock has not been analysed.

IV. High-grade Zone.

When discussing the knotted schist zone it was mentioned that, whereas the knotted schists extended almost to the margin of the Wantabadgery granite, these schists were separated from the Green Hills granite by a zone of higher-grade rocks. The latter are typically more granular than the schists and may contain sillimanite. Near the granite contact they may become migmatites or injection rocks.

Actually these high-grade rocks do occur at the margin of the Wantabadgery granite mass but they are usually restricted to a zone often only a few feet wide. At the south-eastern end of this mass, however, such rocks are more extensive and a separate high-grade zone is mappable. Continuing southwards along the strike from Yaven Trig. Station, the high-grade zone widens rather remarkably until in the vicinity of Sargood Trig. Station it is about four to five miles across. The zone then narrows to the south, passing between the Green Hills and Belmore masses, and finally disappears some miles to the north of Tumbarumba. From the map it will be seen that the isograd defining this zone roughly follows the western margin of the Green Hills granite mass. Isolated masses of similar metasediments with the appearance of roof pendants occur at Hugel Trig. Station and in the area east of Tumbarumba (for example in the Nurenmerenmong Range).

The boundary drawn between the zone of knotted schists and the high-grade zone lacks the precision that characterizes the other isograds because of the personal factor probably involved in its mapping. The isograd has been drawn through points where knotted schists tend to lose their good cleavage and high lustre and acquire a more granular appearance. Joplin (1942) at Cooma was faced with a similar problem and remarked that "the boundary between this [i.e. the andalusite or knotted schist zone] and the succeeding permeation-zone was a somewhat arbitrary one, determined in the field by the appearance of slightly more granular and less schistose rocks". It will be noted that at Cooma the term permeation-zone was used to include the high-grade rocks which did not show injection by tongues of gneiss (injection zone). Because of the lack of a sharp contrast between these permeation and injection rocks in this area compared with Cooma the two zonal subdivisions have not been used in this study and all the rocks are considered in the one high-grade zone.

(i) *Pelites.*

Within the zone defined on the map there is a gradual change in the appearance of the rocks with approach to the granite contact. At the outer edge of the zone the rocks retain some schistosity and have knots apparently comparable with those of the knotted schists. In thin section, however, it may be seen that the knots have a slightly different appearance from those in the lower-grade zone. Typically, the knots, which in the knotted schist zone were composed of fine flakes of sericite, now consist of much coarser aggregates of mica flakes with a base of sericite and iron ore fragments. Muscovite blades are quite common, whilst a green biotite (pleochroic from pale yellow-green to medium greenish-brown) may also occur as less well-defined flakes (brown biotite is found in some cases). Both micas in the aggregates show little trace of preferred orientation which is in contrast to the mica of the base of these rocks. Brown pleochroic (pale straw to dark reddish-brown) biotite is the characteristic dark mica of the two-mica base. Occasionally unaltered cores of andalusite (clear and colourless) remain in the knots and the occurrence of both biotite and muscovite replacing it surely indicates an addition of bases from some external source. Compared with the altered porphyroblasts in the knotted schists these knots often have more diffuse boundaries against the micaceous base. Definite K-felspar and oligoclase have not been recorded here and in this respect these rocks differ from the higher-grade types in this zone.

These rocks are followed in the metamorphic progression by varieties comparable with the spotted granulites of Cooma. Schistosity is much less obvious and the term granulite seems quite appropriate for such rocks. Their characteristic appearance is due to the dark micaceous aggregates or spots scattered through a much lighter-coloured base. With increase in grade the spots tend to merge with the base, but right to the granite contact some heterogeneity expressed by a mottled appearance is preserved. Red-brown biotite similar to that of the base becomes commoner in the micaceous patches and along with it may occur sub-radiating patches of pale chlorite flakes (pleochroic, pale yellow-green to mid brownish-green; parallel extinction; +ve (?); sometimes anomalous blue interference tints; length-fast). The chlorite is probably of a later age than the biotite. Blades of muscovite become more numerous and extensive as the granite is approached. Quartz is usually not abundant in the pelites and is commonly interstitial.

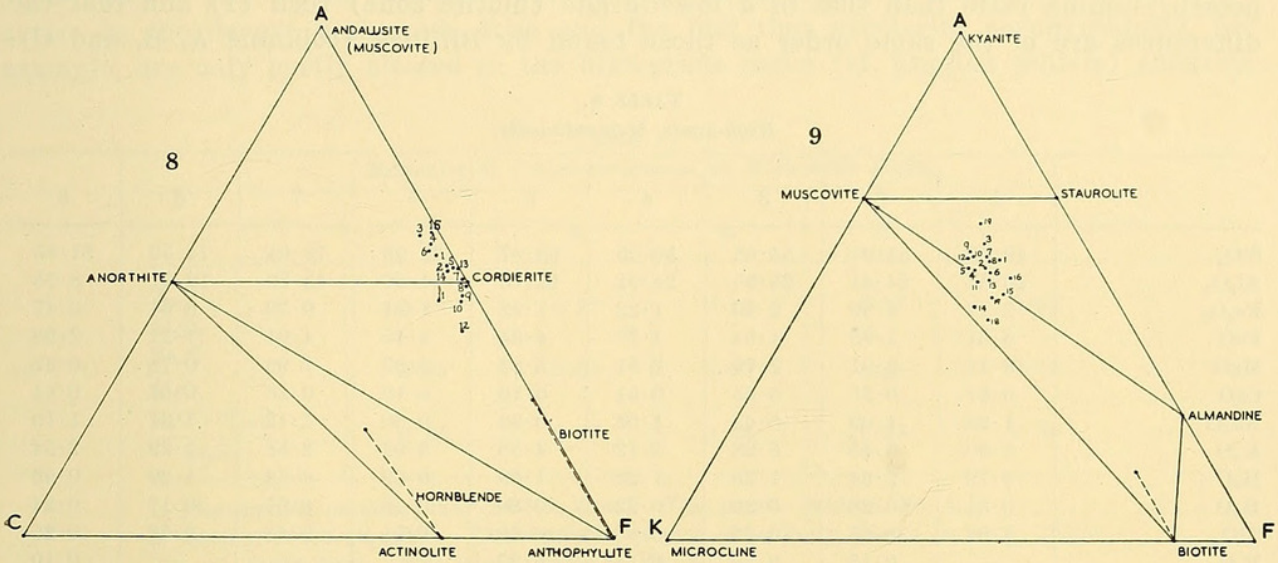
Andalusite may occur in these rocks as pleochroic (Z, Y = colourless; X = pale pink; pleochroism variable within a single grain) porphyroblasts with markedly ragged and poikiloblastic (mainly quartz and biotite inclusions) margins and almost inclusion-free centres. These porphyroblasts are often surrounded by zones enriched in biotite. Thin wisps and needles of sillimanite may be associated with the andalusite which, in contrast to the colourless andalusite of the knotted schists, shows no sign of alteration to micas. Joplin (1942, p. 180) has suggested that the pink pleochroic andalusite, occurring in a similar environment at Cooma, has been deposited from solution, i.e. it is of metasomatic origin. The colourless andalusite of the knotted schists is certainly of metamorphic origin. Whether any general relation exists between colour and origin of andalusite is not known, but in the literature there does seem to be a tendency for coloured andalusite to be recorded more often in granitic or metasomatic than in purely metamorphic environments (see for example, Hills, 1938; Santos Pereira, 1950). Cordierite poikiloblasts which are sometimes associated with the andalusite in these rocks are always more or less altered. In places the cordierite has subidioblastic outlines against quartz and the mica pseudomorphs have a markedly tabular form. The cordierite is sometimes large enough to be easily visible to the naked eye and may attain a diameter of from one-quarter to one-half inch. That the mica is replacing cordierite may be proved in many cases by the unaltered cores in the aggregates. It will be remembered that fresh cordierite was never found in the knotted schists and although the diagnosis of the mineral in that zone was always rather doubtful, it did not appear to be as abundant as andalusite. In the high-grade zone, however, cordierite is quite an important constituent of the pelites.

A glance at an ACF diagram (Text-fig. 8) on which the pelites have been plotted suggests that all of them (both knotted schists and high-grade rocks) should have abundant cordierite, yet it seems that the mineral becomes more important in the high-grade rocks. This brings to mind the suggestion of Potgieter (1950), who says that in rocks where both andalusite and cordierite are possible mineral phases the formation of andalusite might be favoured by a slight stress influence which would perhaps prevent crystallization of cordierite (because of its lower crystalloblastic force). It may be that when the knotted schists were formed a certain stress environment existed which favoured the andalusite (it is realized, however, that cordierite is reported to appear abundantly in knotted schists at Albury and in Victoria) whereas cordierite came into its own in the high-grade zone where the stress influence was slight.

At this stage of the metamorphism potash felspar may appear, but examination of the role it plays is rendered difficult by the amount of alteration (mainly sericitization) which it has suffered. Commonly, however, there is no extensive development of felspar porphyroblasts as has been described in the high-grade rocks at Cooma and it is not until the granite contact is reached that relatively large felspars are seen. The potash felspar is typically untwinned and is commonly associated with grains of albite-twinned (and some untwinned) oligoclase (Ab_{85-90}). Perthitic intergrowths are a common feature and they become obvious in the porphyroblasts at the granite

contact. Small felspar grains displaying myrmekite have been noted in some high-grade rocks. As both felspar and cordierite tend to be converted to micaceous aggregates it is sometimes difficult to distinguish the completely altered patches. Usually, however, the sericitic aggregates after felspar have a greyish or brownish colour and a more patchy appearance than the alteration products of cordierite, which are often yellowish, have iron oxide-stained cracks and, occasionally, haloes round small inclusions.

Both biotite and muscovite are abundant in the high-grade rocks. The biotite is normally of the red-brown, intensely pleochroic variety (Z = dark red-brown; Y = dark red-brown; X = pale straw-yellow; $Z \geqslant Y \gg X$; $\gamma = 1{\cdot}637$–$1{\cdot}640$) characteristically rich in inclusions with pleochroic haloes. Near the granite contacts the biotite often



Text-figure 8.—ACF diagram for the cordierite-anthophyllite subfacies of the Amphibolite Facies. Rocks with deficient K_2O and excess SiO_2. (After Eskola.)

Key: 1-4, This paper, Table 6, nos. 1-4. 5, Joplin (1947), Table 1, no. IV. 6, Joplin (1942), Table 7, no. VII. 7, This paper, Table 6, No. 5. 8, Tattam (1929), Table III, no. 22. 9, This paper, Table 6, no. 6. 10, Joplin (1942), Table 5, no. IV. 11, This paper, Table 6, no. 8. 12, This paper, Table 6, no. 9. 13, This paper, Table 2, no. 1. 14, Joplin (1942), Table 3, no. IV. 15, Joplin (1947), Table 1, no. I. Nos. 1-12 high-grade rocks; 13-15 knotted schists.

Text-figure 9.—AKF diagram for rocks with excess SiO_2 and Al_2O_3 in the staurolite-kyanite subfacies of the Amphibolite Facies. (After Turner, 1948.)

Key: 1, This paper, Table 2, no. 1. 2, Joplin (1942), Table 3, no. IV. 3, Joplin (1947), Table I, no. 1. 4, Tattam (1929), Table 1, no. 3. 5, Tattam (1929), Table 1, no. 5. 6, Tattam (1929), Table 1, no. 6. 7, This paper, Table 6, no. 1. 8, This paper, Table 6, no. 2. 9, Joplin (1942), Table 7, no. IV. 10, Joplin (1942), Table 7, no. V. 11, Joplin (1947), Table 1, no. IV. 12, Joplin (1942), Table 7, no. VII. 13, This paper, Table 6, no. 5. 14, Tattam (1929), Table 3, no. 22. 15, This paper, Table 6, no. 6. 16, Joplin (1942), Table 5, no. IV. 17, This paper, Table 6, no. 8. 18, This paper, Table 6, no. 9. 19, This paper, Table 1, no. 1.

Nos. 1-6 are knotted schist zone rocks, 7-18 are high-grade rocks, 19 belongs to the biotite zone.

seems to become unstable and breaks down to chlorite, with the TiO_2 of the mica being released as rutile forming sagenite webs. Such rutile is sometimes seen in the red-brown biotite (though more common in chlorite), apparently indicating that the TiO_2 is lost (in part at least) before the mica is changed to chlorite. Contrasted with the behaviour of the coloured mica, muscovite increases in importance near the granite and large plates of white mica are often developed enclosing pre-existing mineral grains.

Near the granite contact at the north-western end of the Green Hills mass large porphyroblasts (up to half an inch long) of sillimanite appear in the pelitic granulites. In every case the sillimanite displays extensive alteration to white mica, only small unaltered cores remaining to indicate the original nature of the porphyroblasts. Small rods and needles of the mineral occur further from the granite margin but the porphyroblastic development is quite localized. Biotite has, in some cases at least,

provided the material for the formation of sillimanite (the change biotite → sillimanite is particularly obvious in the pelitic inclusions in the granite). The production of sillimanite probably represents the peak of the thermal metamorphism. As needles of sillimanite occur in the pink andalusite (Plate vi, F) in some cases it is suggested that the latter formed after the sillimanite.

The alteration of sillimanite to mica is probably due to the metasomatic addition of bases (mainly potash) and is reminiscent of the New England region studied by Billings (1938) where sillimanite-schists have been "muscovitized" by the introduction of potash. Owing to the absence of analyses of completely "unmuscovitized" high-grade rocks we cannot demonstrate the chemical changes involved as well as Billings did. Table 7 does, however, show that a high-grade rock (2) has a distinctly higher potash/alumina ratio than that of a lower-grade (biotite zone) rock (1) and that the differences are of the same order as those found by Billings (columns A, B, and C).

TABLE 6.
High-grade Metasediments.

	1	2	3	4	5	6	7	8	9
SiO_2	49·53	54·01	54·63	56·05	63·97	69·98	73·64	74·59	81·85
Al_2O_3	26·53	24·41	25·35	24·91	18·13	14·66	13·89	12·71	8·75
Fe_2O_3	2·17	1·39	2·40	1·22	1·92	1·91	0·70	0·61	0·47
FeO	6·01	5·95	4·64	4·76	4·34	4·45	4·04	4·21	2·68
MgO	3·15	2·91	2·75	2·51	2·83	2·39	1·98	0·78	0·82
CaO	0·37	0·36	0·65	0·51	0·19	0·19	0·28	0·67	0·34
Na_2O	1·23	1·09	0·62	1·06	0·92	0·50	1·12	1·31	1·19
K_2O	5·90	5·45	6·28	6·12	4·58	3·92	2·88	3·29	2·54
H_2O+	3·79	2·64	1·25	1·23	1·60	0·89	0·42	1·29	0·96
H_2O-	0·31	0·28	0·26	0·22	0·26	0·18	0·07	0·17	0·24
TiO_2	1·03	0·85	0·86	0·86	0·69	0·71	0·63	0·63	0·25
P_2O_5	—	0·15	0·20	0·14	0·27	—	—	—	0·10
MnO	0·06	0·07	0·05	0·11	0·03	0·04	0·06	0·03	0·05
Etc.	—	—	0·15	0·09	—	—	—	—	—
	100·08	99·56	100·09	99·79	99·73	99·82	99·71	100·29	100·24

1. Spotted granulite. East end of Yaven Creek bridge, Por. 51, Par. of Dutzon, Co. Wynyard. Anal. T. G. Vallance.
2. Spotted granulite. Mt. Pleasant Creek, Por. 32, Par. of Wallace, Co. Wynyard. Anal. T. G. Vallance.
3. Spotted granulite. Cooma area. Anal. G. A. Joplin. PROC. LINN. SOC. N.S.W., 67, 1942 : 181.
4. Mottled gneiss. Cooma area. Anal. G. A. Joplin. *Ibid.*, p. 181.
5. Granulite. Por. 32, Par. of Wallace, Co. Wynyard. Anal. T. G. Vallance.
6. Cordierite-rich granulite. East side of Por. 35, Par. of Dutzon, Co. Wynyard. Anal. T. G. Vallance.
7. Corduroy granulite. Cooma area. Anal. G. A. Joplin. PROC. LINN. SOC. N.S.W., 67, 1942 : 168.
8. Quartz-rich granulite. Por. 66, Par. of Cunningdroo, Co. Wynyard. Anal. T. G. Vallance.
9. Granitized quartz-rich granulite. Near granite margin, east side of Por. 228, Par. of Tenandra, Co. Clarendon. Anal. T. G. Vallance.

Obviously potash has been concentrated and one explanation of this increase might be by the late addition of K_2O from the granite. Billings suggested that potash is derived by the hydrolysis of potash felspar in the plutonic rocks:

$$\underset{\text{orthoclase}}{6KAlSi_3O_8} + 2H_2O \rightarrow \underset{\text{muscovite}}{2H_2KAl_3Si_3O_{12}} + 2K_2O + 12SiO_2$$

Muscovite does occur in the granites but it would be a matter of difficulty to prove whether it is wholly or partly related to the release of potash to the nearby metasediments. The late glassy-quartz veins which cut the high-grade rocks in a few places may represent the destination of some of the silica freed by such a process as that postulated by Billings.

Holmes and Reynolds (1947) have suggested a similarity between Billings' New Hampshire occurrence of "muscovitization" of high-grade rocks and certain Dalradian rocks in Donegal in which quartzite is converted to mica schist. They disagree with Billings' explanation and state that "the migrations involved in the metasomatic metamorphism of the Malin Head Quartzite (and presumably that of the Loon