Transition from gneiss to migmatite and the relationship of leucosome to peraluminous granodiorite in the Cooma Complex, SE Australia

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Abstract

In the Cooma Complex, SE Australia, leucosomes first appear as small patches and veinlets in high-grade, muscovite-free gneisses containing cordierite, andalusite and K-feldspar. Simultaneously, fibrous sillimanite appears in discontinuous folia. The leucosomes consist of quartz, microperthitic K-feldspar and cordierite, rarely with minor andalusite or biotite. Plagioclase is absent, apart from exsolution lamellae in the K-feldspar. Breakdown of biotite probably produced the leucosomes. The leucosomes are largely confined to the metapelitic beds, which are plagioclase-poor; this explains the calcium-poor composition of the leucosomes. Most of the melting occurred during D_3, which is responsible for most of the macroscopic folding in the area, though some leucosomes may predate D_3. The metapelite leucosome is compositionally unsuitable as a source of the Cooma Granodiorite magma. Leucosome rich in plagioclase, which could be a source for the Cooma Granodiorite magma, was produced later (probably early during D_5) by partial melting of quartzofeldspathic metapsammitic rocks. It intrudes and disaggregates the metapelitic leucosomes, confirming that melting of the local metapelites did not produce the Cooma Granodiorite.

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Introduction

This paper is concerned with the transition from high-grade metasedimentary gneisses to migmatite and the initial development of peraluminous granodiorite in the low-pressure/high-temperature (LPHT) Cooma Complex, SE Australia, with emphasis on the prograde metamorphic and structural history.

The Cooma Complex (Fig. 1) is characterized by an eastwards transition from chlorite slates and phyllites, through biotite-cordierite-andalusite schists to cordierite–K-feldspar–andalusite–K-feldspar gneisses and granofelses, to migmatite. The migmatites have been intruded by the Cooma Granodiorite, which is a peraluminous granitoid with abundant metasedimentary enclaves (Joplin, 1942; Hopwood, 1966; Johnson *et*. *al*., 1994). Recent publications on the metamorphic and deformation history of the Cooma Complex include those of Johnson (1992), Johnson *et al*. (1994), Johnson & Vernon (1995a, 1995b) and Johnson (1999).

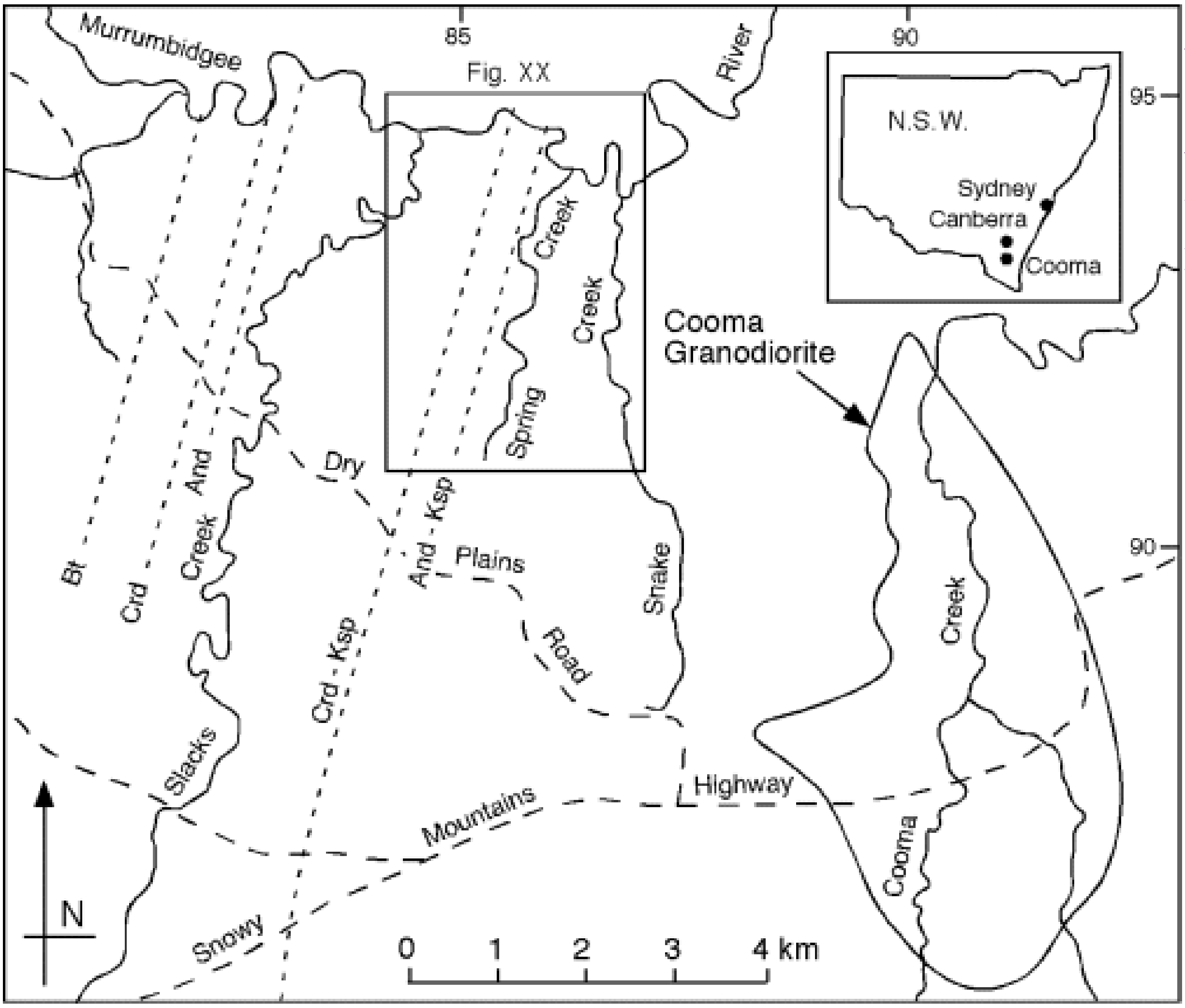

Fig. 1 Map showing the main mass of the Cooma Granodiorite (in and around the town of Cooma), the isograds, an insert (top-right) showing the location of Cooma in New South Wales, and a rectangle showing the area covered in Fig. 2.

Though the metamorphic zonation originally was considered to be of contact metamorphic origin (Browne, 1914; Joplin, 1942), most workers have regarded it as of more regional extent (e.g., Joplin, 1962), though centred around a "regional-aureole" granite, namely the Cooma Granodiorite (White *et al*., 1974). The extent of the metamorphic rocks suggests that some regional heating must have occurred, even if local magmatic heat was also involved (e.g. Vallance 1953, p. 216).

An unsolved problem is whether the granodiorite is a product of the metamorphism (e.g., Joplin, 1962; Pidgeon & Compston, 1965; White *et al*., 1974; Munksgaard 1988; Chappell *et al*. 1991; Ellis & Obata 1992) or whether it has contributed to the metamorphic heat (e.g., Johnson *et al*. 1994). Most workers have favoured the former interpretation, some suggesting that the granitic magma may have moved upwards for a small distance, though still essentially connected with its source rocks (e.g., Joplin 1962; Vallance, 1967; White *et al*., 1974; Flood & Vernon, 1978). Chappell & White (1976) and White & Chappell (1988) have put forward chemical evidence that the Cooma Granodiorite represents a partial melt that still contains the solid unmelted metasedimentary residue (restite).

Vallance (1969, p. 185) noted that "Cooma-type" granites occur in rocks of various metamorphic grades in the Lachlan Fold Belt, and that metasedimentary xenoliths in all these granites are of the highest grade metamorphic rocks. Therefore, the granites must have moved from their sources. Vallance (1969, p. 185) suggested that, though the Cooma Granodiorite probably also has moved, it is nearer its source than similar granites in lower grade rocks elsewhere in the region.

The fact that the granodiorite contains only the last foliation (S_5) recorded in the metasedimentary rocks (Johnson, 1992; Johnson *et al*., 1994) indicates that it was intruded late in the metamorphic-deformation history. However, this need not preclude a heat contribution from the granodiorite, as it could have continued to rise after contributing heat to the metamorphic rocks at the present level of exposure (Johnson *et al*., 1994), and so may have intruded the higher-grade metamorphic zones, as described by the model of den Tex (1963).

In keeping with the interpretation that the Cooma Granodiorite was formed by in situ or practically in situ melting of the adjacent metasediments, Ellis & Obata (1992, p. 95) expressed the popular view that "a progression can be seen in the field from unmelted sediments through migmatites to the granodiorite." In several places (e.g., Soho Street, Cooma and the Snowy Mountains Highway contact) the main granodiorite body (Fig. 1) appears to be gradational into the migmatites, but it also contains sharply bound xenoliths of migmatite identical to the adjacent migmatites (Fig. 4). Further work on the contacts of the main granodiorite mass is required to resolve these apparently contradictory relationships.

This paper attempts to approach the problem by examining the beginning and progression of melting and the relationships of the resulting leucosomes to the first appearance of material resembling the Cooma Granodiorite. Mineral abbreviations are after Kretz (1983).

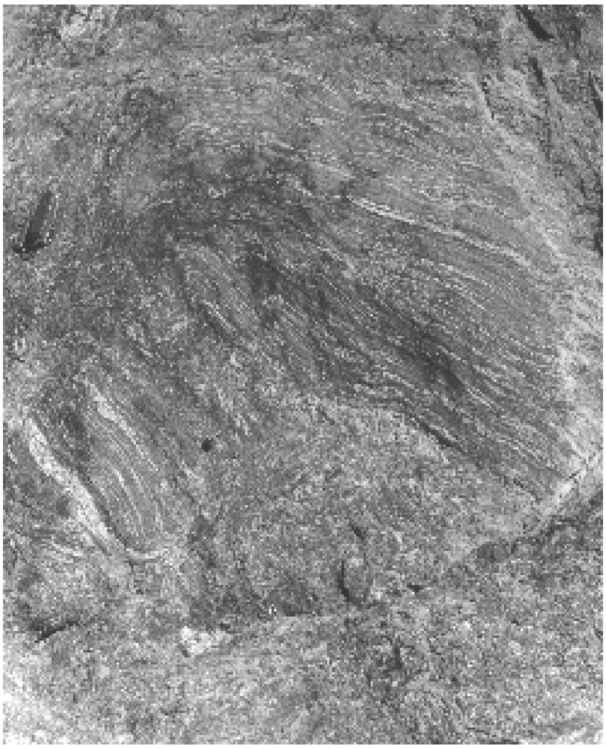

Fig. 4 Large xenolith of stromatic migmatite enclosed in the Cooma Granodiorite, Soho Street, Cooma. Pocket knife 9 cm long.

Field Relationships

Field observations were made and samples collected along an E-W traverse (Fig. 2) from schists of the cordierite–andalusite zone, through the cordierite–K-feldspar and andalusite–K-feldspar zones to migmatite (Figs 1, 2). Hillside exposures are satisfactory for observing some local-scale features and metamorphic assemblages, but the best migmatite exposures are in Spring Creek and Snake Creek (Fig. 2). Excellent exposures once also occurred in Pilot Creek, between Snake Creek and Cooma Creek (Fig. 1), but are now mostly covered by dams; they are exposed only during droughts.

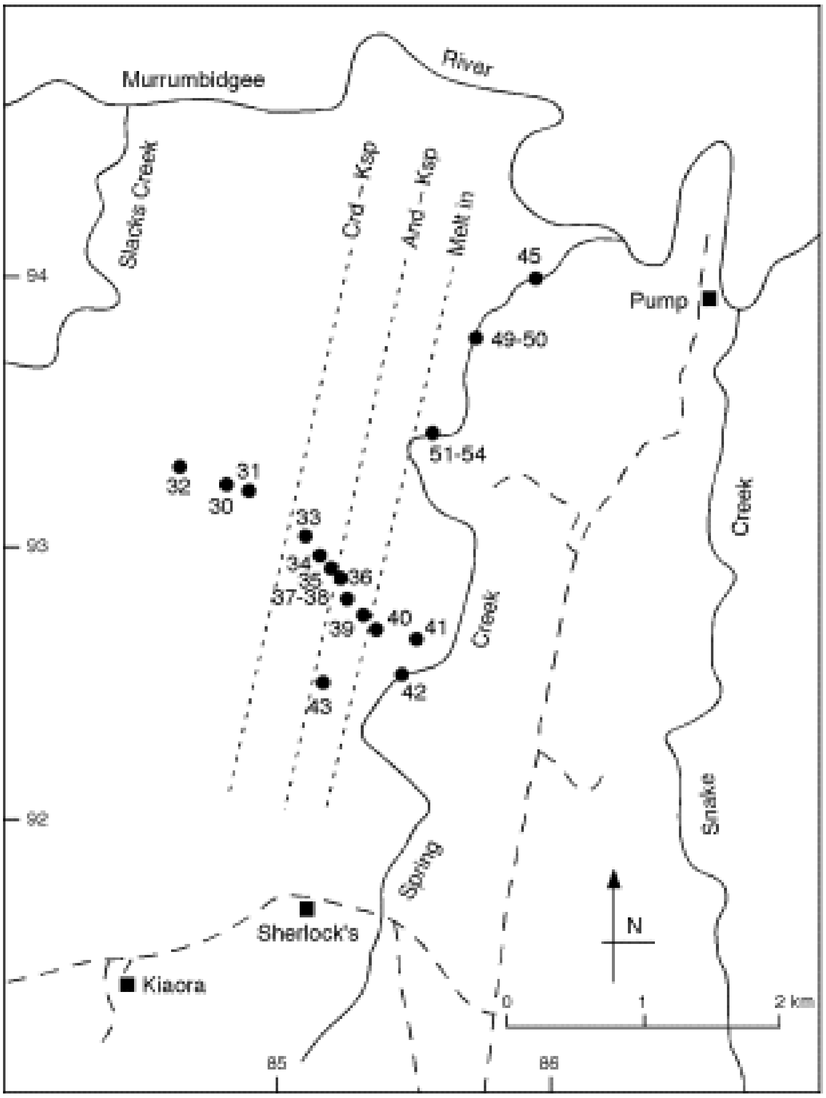

Fig. 2 Map showing Spring Creek, Snake Creek and the locations of samples used in this study.

Fig. 3 Typical outcrop appearance of the Cooma Granodiorite, showing euhedral phenocrysts of plagioclase and abundant metasedimentary xenoliths. Pocket knife 9 cm long.

The highest-grade, non-migmatitic rocks are gneisses and granofelses of the andalusite–K-feldspar zone (Fig. 5). The metapsammites have a strong differentiated layering, which has led to their being called "corduroy gneisses" (e.g., Joplin, 1942), whereas the metapelites are coarse-grained and studded with porphyroblasts of cordierite, many of which have been partly to completely replaced by fine-grained, symplectic aggregates of biotite, andalusite and quartz (Vernon, 1978). These dark pseudomorphs are why the metapelites have been called "mottled gneisses" (e.g., Joplin, 1942).

Fig. 5 Typical high-grade metasediment, largely unmelted, west of Spring Creek. The metapelite (top-right) is coarse-grained, with abundant dark porphyroblasts of cordierite replaced by fine-grained symplectite of biotite + andalusite + quartz, and light-coloured porphyroblasts of K-feldspar in between. Evidence of incipient melting, in the form of small patches and veinlets of leucosome, is present. The metapsammite (bottom-left) shows compositional ("corduroy") layering (S_3). Pocket knife 9 cm long.

In contrast to the situation at low and medium metamorphic grades, the high-grade metapelites are stronger than the interbedded metapsammites, owing to their abundant coarse-grained, strong minerals, especially cordierite, andalusite and K-feldspar. The result is that the metapsammites commonly are folded and foliated in an intricate manner, whereas the metapelites tend to fracture and undergo boudinage (Figs 6, 7). This fracturing appears to have assisted migration of melt, as discussed later.

Fig. 6 Abundant leucosome aligned in S_3 in coarse-grained metapelite beds, the finer grained metapsammitic beds having been intensely flattened, folded and foliated. Spring Creek (Fig. 1). Pocket knife 9 cm long.

Fig. 7 Magnified view of part of Fig. 6, showing the intense deformation of a metapsammite bed.

The first indications of partial melting with increasing metamorphic grade are rare, local, small patches of leucosome in the metapelites, grading into veinlets (e.g. sample 40). These veinlets have been crenulated by the main foliation, S_3, applying the foliation nomenclature of Johnson & Vernon (1995a). Therefore, they pre-date or formed during the development of S_3. A few leucosome veinlets are larger and coarser-grained, some being localized on metapelite-metapsammite contacts (Fig. 8). At slightly higher grades (e.g. sample 41), the leucosome is concentrated in small lenses parallel to S_2 and S_3, as well as along S_0, and is folded by F_3 folds. In Spring Creek (e.g. sample 42), the main migmatite zone is entered and the above relationships are well developed.

Fig. 8 Leucosome concentrated at the junction of metapelite (with porphyroblasts of cordierite replaced by dark symplectite) and metapsammite beds, Spring Creek. Coin 2.5 cm in diameter.

Prominent lenses and veins of white leucosome are oblique to S_3. These veins (Figs 9) show a strong tendency to be parallel throughout the Spring Creek-Snake Creek area (Fig. 2). We interpret them as having formed during D_3 by fracturing along S_2, together with incipient boudinage of the strong metapelitic beds, providing low-pressure sites for local segregation of partial melt. The fact that these leucosome veins generally do not follow the more prominent S_3 is consistent with fracturing during D_3, because if the direction of maximum finite elongation was parallel to S_3 during D_3, fracturing should have occurred along surfaces at moderate to high angles to S_3. Earlier leucosomes, formed before or early during the development of D_3 , tend to be folded into parallelism with S_3 (Fig. 9).

In some metapsammites, boudinage of thin metapelitic layers — M domains in a differentiated S_3 ("corduroy") layering — has occurred, with leucosomes in the interboudin zones (Fig. 10). This suggests that the leucosomes formed late during D_3.

Fig. 9 Folded leucosome veinlets confined to a metapelite bed, Spring Creek (Fig. 1). The leucosomes are mainly in S_3, but some in S_2 have been folded into parallelism with S_3. "Corduroy layering" in a metapsammite bed can be seen at the lower right. Pocket knife 9 cm long.

Fig. 10 Mica-rich layers in a differentiated crenulation cleavage ("corduroy layering"; S_3) in a metapsammite, which have been boudinaged, owing to their greater strength than the layers richer in quartz. Leucosome has segregated into the interboudin zones. Coin 2.5 cm in diameter.

The leucosomes also have a strong, though more local tendency to concentrate in the metapelites along the bases of metapsammite beds (Fig. 8), presumably owing to opening of fractures along this zone of inferred competency contrast. Some of these leucosomes have been crenulated by S_3, indicating their formation before or early during D_3. This is mainly seen in the hinges of parasitic F_3 folds, where bedding is at high angles to the direction of maximum finite elongation (S_3) during D_3(Fig. 9). Even where bedding is not at a high angle to S_3 now, presumably it was at the onset of D_3, because F_3 folds control the macroscale structural geometry in this area (Hopwood, 1976; Johnson *et al*., 1994).

A prominent feature that persists through most of the migmatites at Cooma is the strong tendency for the confinement of leucosome to metapelitic beds, so that the rocks resemble the "bedded migmatites" of Greenfield *et al*. (1997), as shown in Fig. 11. Locally, leucosomes penetrate adjacent metapsammitic beds.

Fig. 11 Abundant leucosome in metapelite beds, leucosome being rare in metapsammite beds, which show a strong foliation, owing probably to their relative weakness, compared with the metapelite beds. Some of the leucosome has segregated into openings formed by incipient boudinage of the metapelite beds. Knife 9 cm long.

Most of the Cooma leucosomes consist only of quartz and K-feldspar, though porphyroblasts of cordierite are fairly common and pink andalusite occurs locally, e.g., in Spring Creek. Melanosomes are rare. The amount of partial melting increases to a maximum in Snake Creek and further east (Figs 1, 2), the migmatites tending to become coarser-grained and more stromatic (Figs 12, 13, 14, 15), though remaining essentially "bedded migmatites" (Fig. 12). The stromatic character is more prominent further to the east, e.g., in Pilot Creek (Figs 14. 15), which may be related to the stronger deformation that these rocks appear to have undergone. Folded remnants of metapsammite occur in the most extensively melted migmatites (Fig. 15). Many of the metapelites in Snake Creek contain abundant retrograde muscovite, and pegmatitic aggregates are patchy to pervasive, many containing acicular to prismatic tourmaline. These features suggest late access of water.

Fig. 12 Coarser grained and more completely developed leucosome, but still confined to metapelite beds, Snake Creek (Fig. 1). Pocket knife 9 cm long.

Fig. 13 Intensely deformed, folded, stromatic migmatite, Snake Creek. Coin 2.5 cm in diameter.

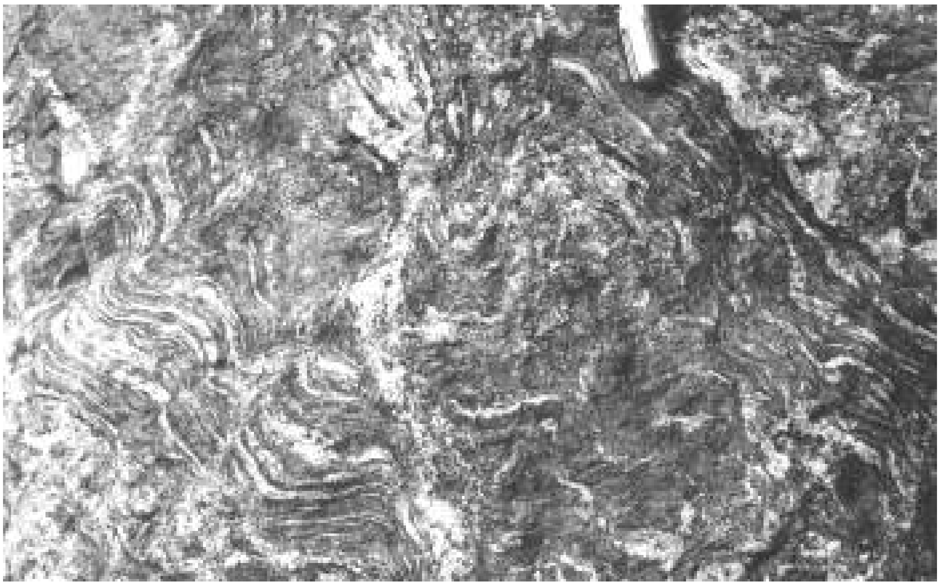

Fig. 14 Intensely folded stromatic migmatite, with leucosomes occurring in a fold axial surface (centre), Pilot Creek, between Snake Creek and Cooma Creek (Fig. 1). Pocket knife 9 cm long.

Fig. 15 Folded stromatic migmatite with coarse-grained leucosome, preserving bedding, Pilot's Creek, east of Snake Creek (Fig. 1). The metapsammitic beds have only been slightly melted, compared with the metapelites. Pocket knife 9 cm long.

Locally, patches and small, transgressive to sheet-like intrusions of plagioclase-bearing microgranitic material, with small rectangular crystals of plagioclase, occur in the highest-grade migmatites (e.g. in Snake Creek), typically with scattered metasedimentary xenoliths and migmatite remnants similar to those in the Cooma Granodiorite (Fig. 16). This plagioclase-bearing leucosome has disrupted and boudinaged the metapelite leucosomes (Fig. 17), and shows only the latest foliation (S_5), as does the Cooma Granodiorite. It appears to have originated by partial melting of quartzofeldspathic metasediments (psammitic or psammopelitic), as leucosomes of this type commonly occur in these rocks in Snake Creek, and rarely in Spring Creek. Therefore, the plagioclase-bearing leucosome is a potential source for the Cooma Granodiorite magma, although this hypothesis requires testing by mineralogical and chemical investigations, which are in progress.

Fig. 16 Large patch of intrusive material resembling Cooma Granodiorite, containing migmatite xenoliths, Snake Creek (Fig. 1). Pocket knife 9 cm long.

Fig. 17 Small intrusion of material broadly resembling the Cooma Granodiorite (top half and right of photo), transgressing the migmatite foliation (at right). The intrusive material has dismembered leucosome (white, coarser grained lenses) and mesosome (small foliated xenoliths). Pegmatite xenoliths, which are common in the main mass of the Cooma Granodiorite (Fig. 1), may have formed in this way. Southern end of Snake Creek (Fig. 1). Pocket knife 9 cm long.

Microstructural Relationships

In thin section (Fig. 18), the non-migmatitic gneisses are seen to consist of porphyroblasts of cordierite, most of which have been replaced by fine-grained symplectic aggregates of biotite, andalusite and quartz (Vernon, 1978; Vernon & Pooley, 1981), fresh andalusite, poikiloblastic microperthite, biotite and quartz; muscovite is absent, apart from local retrograde flakes and aggregates. Some disaggregated quartz-rich veins, some of which contain andalusite or cordierite, but which do not contain K-feldspar, are also present in some rocks; care must be taken to distinguish them from incipient leucosomes. We have used the following microstructural criteria for leucosome at Cooma, following Vernon (1999).

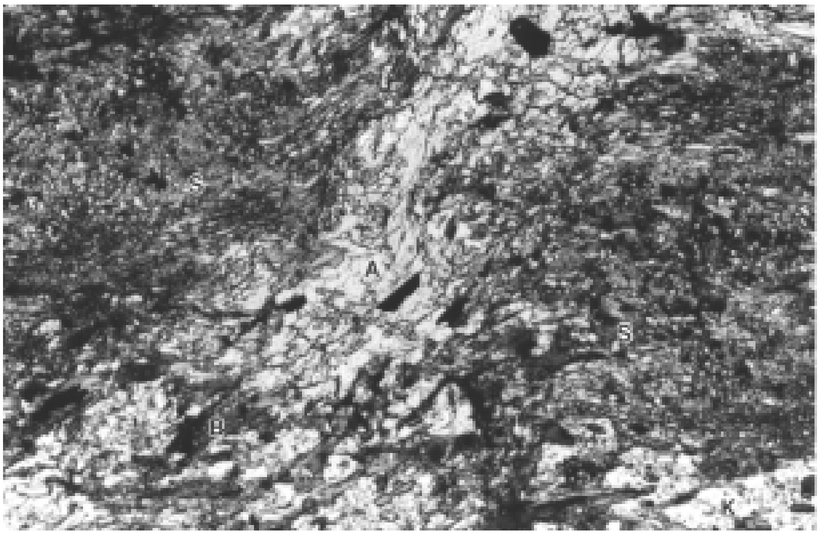

Fig. 18 Unmelted metapelite containing andalusite (A), K-feldspar (K) and symplectite (S) of biotite (B), andalusite and quartz that has replaced large porphyroblasts of cordierite. Plane-polarized light; base of photo 4.2 mm.

(1) Inclusion trails are absent, in contrast to grains of the same minerals in the mesosome (Figs 19, 20).

(2) Overgrowths free of inclusions trails may occur on minerals (e.g., K-feldspar, cordierite) with inclusion trails, as shown in Fig. 19.

(3) Crystal faces of K-feldspar (and cordierite?) may occur against quartz (e.g., Vernon & Collins, 1988), as shown in Figs 19 and 20.

(4) Simple twinning may occur in K-feldspar, which appears to be diagnostic of crystallization of K-feldspar in a melt, rather than the solid state (Vernon, 1986, Vernon, 1998).

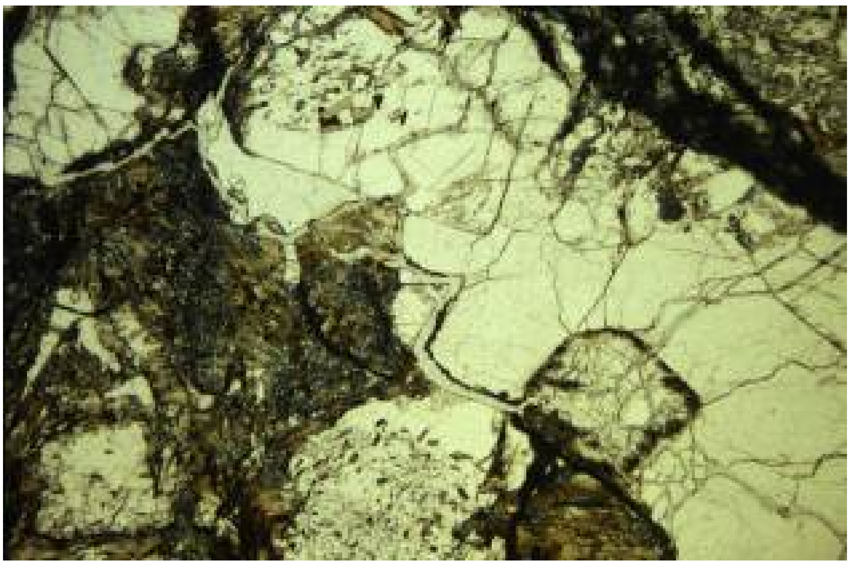

Fig. 19 Leucosome with euhedral crystals of K-feldspar (K) and cordierite (C) in quartz (Q). The K-feldspar has clear overgrowths on inclusion-rich cores. The cordierite has been partly replaced by symplectite and younger, low-grade alteration minerals. Plane-polarized light; base of photo 1.5 mm.

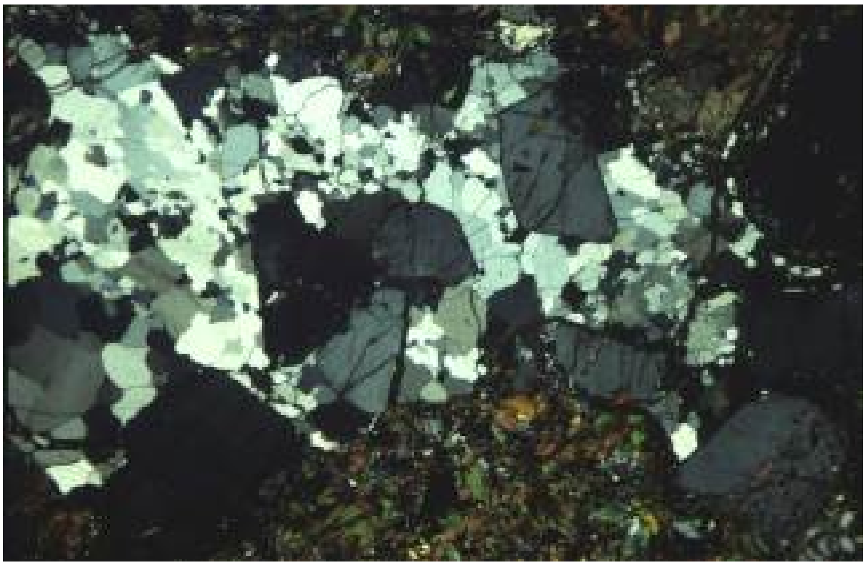

Fig. 20 Deformed leucosome in Snake Creek, showing euhedral K-feldspar (K), which has resisted the deformation and quartz (Q), which has recrystallized. Crossed polars; base of photo 1.5 mm.

Leucosome first appears in the metapelites (sample 40), in which it forms small, clear patches (a few millimetres across) and short veinlets that contrast strongly with the mesosome, in which the cordierite and K-feldspar are full of inclusions (Fig. 21). The initial leucosome patches are so small that they are not obvious in the field, but larger veinlets appear at slightly higher grade (metapelite sample 41), just west of Spring Creek. The initial leucosome is accompanied by the first appearance of fibrous sillimanite as crenulated and contorted, discontinuous folia (sample 40); this sillimanite is different in appearance and timing from the late sillimanite that has replaced all minerals, especially along grain boundaries, in some of the high-grade rocks at Cooma (Vernon 1979).

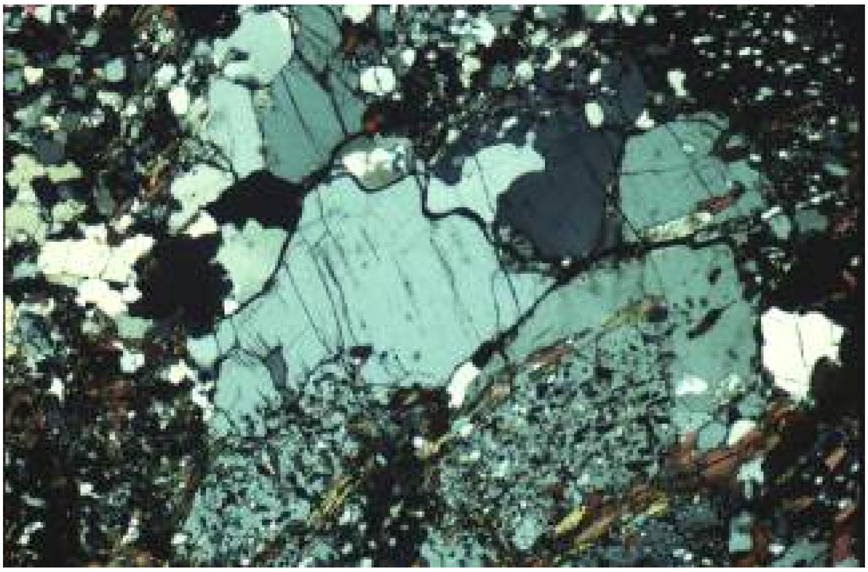

Fig. 21 Small irregular patch of leucosome, consisting of quartz (Q) and K-feldspar (K) free of inclusions, surrounded by typical high-grade metapelite with cordierite and K-feldspar full of inclusions. Some of the K-feldspar grains show overgrowths, inferred to have crystallized from melt, on earlier-formed cores rich in inclusions. The quartz shows subgrains and evidence of some recrystallization. Crossed polars; base of photo 4 mm.

In thin section, leucosomes in the Cooma metasediments are observed to consist mainly of quartz and microperthitic K-feldspar, with some cordierite, rarely with minor biotite or andalusite; plagioclase grains were not observed, although rare plagioclase in metapelite leucosome was reported by Ellis & Obata (1992, p. 101). As noticed in the field, the leucosomes observed in thin section do not have melanosomes, suggesting that either (i) the leucosomes have moved away from sites of initial segregation, leaving behind concentrations of mafic aggregates, or (ii) the cordierite produced in the biotite dehydration melting reaction (see later) was localized as porphyroblasts, by growing on existing cordierite grains, rather than growing as a continuous fringe on the leucosome. Thus, the patchy leucosomes are probably in contact with residual mafic minerals, as indicated by cordierite with inclusion trails projecting into inclusion-free cordierite in leucosome.

Some of the cordierite in the leucosomes shows evidence of replacement by symplectic aggregates of biotite, quartz and andalusite, which is very common in the mesosomes and non-migmatitic metapelitic gneisses (Vernon, 1978). However, some is unaltered, as reported for the outcrop studied by Ellis & Obata (1992). Back-reaction of cordierite to biotite as the leucosome melt cooled would be expected, and Ellis & Obata (1992) suggested that the absence of back-reaction is due to extraction of hydrous melt from the leucosome. It probably would be difficult to avoid at least some back-reaction during this process, and a possible alternative explanation is that armouring of the cordierite by the first quartz and K-feldspar to crystallize from the melt (i.e., by heterogeneous nucleation on the cordierite) prevented reaction. The water expelled from the cooling leucosomes could have entered the adjacent rocks and reacted with the cordierite to produce the abundant symplectite (Vernon, 1978; Vernon & Pooley, 1981), as suggested for cordierite in metapelites at Mount Stafford, central Australia, by Vernon *et al*. (1990).

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Metamorphic History

Prograde pressure-temperature-deformation-time (*P*-*T*-*D*-t) paths for rocks of different grade in the Cooma Complex have been suggested by Johnson & Vernon (1995a). However, a detailed prograde history cannot be inferred with confidence, because both these melting reactions and the andalusite-sillimanite transformation may all occur at practically the same temperature and pressure. For example, the first appearance of leucosome and prograde fibrous sillimanite at Cooma occurs in the same rock (sample 40). The absence of muscovite from non-migmatitic rocks of the cordierite–K-feldspar and andalusite–K-feldspar zones (except in local retrograde zones), indicates that the muscovite + quartz dehydration reaction was crossed before melting occurred, and consequently that muscovite dehydration did not contribute to the leucosomes. The metapelitic leucosomes appear to have formed by reaction of quartz + biotite and andalusite. Possible reactions are: Qtz + Bt + And = Crd + Kfs + melt or Qtz + Bt + And + Kfs + water = Crd + melt, depending on the availability of water vapour (Grant, 1985; Ellis & Obata, 1992).

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Melting of the Cooma Metapsammites

The Cooma high-grade feldspathic metasediments (metapsammites and metapsammopelites) consist of quartz, K-feldspar, plagioclase and biotite, with local cordierite, andalusite and fibrous sillimanite. Metapsammite melting first occurs at slightly higher grade than the initial metapelite melting being only incipient in Spring Creek (Fig. 2). It is most abundant in the highest-grade rocks, which are high-strain, stromatic and diatectic migmatites. The melting reaction appears to have involved breakdown of biotite, quartz and feldspars in the presence of water, probably requiring a higher temperature than the metapelite melting reaction (e.g., Ashworth, 1985, p. 12). Detailed studies are in progress.

Disruption and boudinage of the metapelite leucosome imply that it solidified before injection of the metapsammite leucosome, and this is a possible source of water for the late hydration of cordierite that is widespread in the high-grade rocks of the Cooma Complex (Vernon, 1978). Therefore, later melting of the metapsammites (1) required an external source of water and (2) involved re-heating, at least of the high-grade parts of the Cooma Complex. The heat source for the metapsammite melting is unknown, but Johnson *et al*. (1994) suggested that intrusion of the main Cooma Granodiorite body may have re-heated the higher grade rocks, producing syn-D_5 sillimanite while retrograde minerals were growing in the lower-grade rocks.

Origin of the Cooma Granite

Though Munksgaard (1988) found that chemically a mixture of subequal amounts of high-grade metapelite and metapsammite could produce the Cooma Granodiorite, our work has shown that the first (syn-D_3) melting occurs only in the calcium-poor metapelites, producing plagioclase-free magmas with compositions unlike that of the granodiorite. The fact that the incipient intrusions of granitic material (metapsammite leucosome) resembling the Cooma Granodiorite have disaggregated leucosomes in Snake Creek, implies that this granitic material post-dates the partial melting responsible for the leucosomes. In contrast to the metapelite leucosomes, this leucosome is rich in plagioclase, as is the Cooma Granodiorite. If this late intrusive material can be related to the Cooma Granodiorite (requiring more mineralogical and chemical work to be certain of the correlation), the Cooma Granodiorite cannot be regarded as a product of in situ partial melting of the adjacent metapelitic rocks. Though in situ melting of quartzofeldspathic rocks appears to have produced some leucosome of potentially suitable composition, the locally abundant volumes of Cooma Granodiorite appear to support the suggestion of Vallance (1969, p. 185) that the granodiorite magma has moved away from its source-rocks, even if only for a small distance.

Munksgaard (1988) suggested that water-rich fluid was involved in the formation of the Cooma Granodiorite, because it has slightly, but consistently lower $\delta^{18}O$ values than the adjacent metasediments. This is supported by evidence of water access into the rocks of Snake Creek, producing coarse-grained, strongly foliated, retrograde mica schists and pegmatite. It remains to be determined whether or not this water correlates with the formation of plagioclase-bearing leucosome and intrusion of the Cooma Granodiorite late in the history of the Cooma Complex.

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Conclusions

Breakdown of biotite probably produced the leucosomes in the metapelites of the Cooma Complex. The leucosomes are largely confined to the metapelitic beds, which are plagioclase-poor; this explains the calcium-poor composition of the leucosomes. Most of the melting appears to have occurred during D_3, though some could predate D_3. The first material rich in plagioclase and broadly resembling the Cooma Granodiorite intrudes, disaggregates and so post-dates the metapelite leucosomes, implying that melting of the local metapelites did not produce the Cooma Granodiorite. This confirms the mineralogical evidence that the metapelite leucosomes are compositionally unsuitable as material for the Cooma Granodiorite. Detailed investigation of the plagioclase-bearing leucosomes and their relationship to the Cooma Granodiorite is in progress.

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References

Ashworth, J.R. 1985. Introduction. In: *Migmatites* (ed. Ashworth, J.A.), pp. 1-35, Blackie, Glasgow.

Browne, W.R. 1914. The geology of the Cooma district. *Journal and Proceedings of the Royal Society of New South Wales*, **48**, 172-222.

Chappell, B.W., White, A.J.R. & Williams, I.S. 1991. A transverse section through granites of the Lachlan Fold Belt. *Bureau of Mineral Resources, Geology & Geophysics Australia, Record* **1991/22.**

Chappell, B.W. & White, A.J.R. 1976. Plutonic rocks of the Lachlan Mobile Zone. *25th International Geological Congress, Sydney; Excursion Guide* **13C**.

den Tex, E. 1963. A commentary on the correlation of metamorphism and deformation in space and time. *Geologie en Mijnbouw*, **42**, 170-176.

Ellis, D.J. & Obata, M. 1992. Migmatite and melt segregation at Cooma, New South Wales. *Transactions of the Royal Society of Edinburgh*: *Earth Sciences*, **83**, 95-106.

Flood, R.H. & Vernon, R.H. 1978: The Cooma Granodiorite, Australia: an example of in situ crustal anatexis? *Geology*, **6**, 81-84.

Grant, J.A. 1985. Phase equilibria in partial melting of pelitic rocks. In: *Migmatites* (ed. Ashworth, J.A.), pp. 86-144, Blackie, Glasgow.

Greenfield, J.E., Clarke, G.L., Bland, M. & Clark,D.J. 1996. *In-situ* migmatite and hybrid diatexite at Mt Stafford, central Australia. *Journal of Metamorphic Geology*, **14**, 413-426.

Hopwood, T.P. 1976. Stratigraphy and structural summary of the Cooma metamorphic complex. *Journal of the Geological Society of Australia*, **23**, 345-360.

Johnson, S.E. 1992. Sequential porphyroblast growth during progressive deformation and low-P high-T (LPHT) metamorphism, Cooma Complex, Australia: the use of microstructural analysis to better understand deformation and metamorphic histories. *Tectonophysics*, **214**, 311-339.

Johnson, S.E. 1999. Deformation and possible origins of the Cooma complex, southeastern Lachlan Fold belt, New South Wales. *Australian Journal of Earth Sciences*, **46**, 429-442.

Johnson, S.E., Vernon, R.H. and Hobbs, B.E. 1994. Deformation and metamorphism of the Cooma Complex, southeastern Australia. *Geological Society of Australia Specialist Group in Tectonics & Structural Geology Field Guide* **4,** 89 pp.

Johnson, S.E. and Vernon, R.H. 1995a. Stepping stones and pitfalls in the determination of an anticlockwise P-T-t-deformation path in the low-P, high-T Cooma Complex, Australia. *Journal of Metamorphic Geology*, **13**, 165-183.

Johnson, S.E. and Vernon, R.H. 1995b: Inferring the timing of porphyroblast growth in the absence of continuity between inclusion trails and matrix foliations: can it be reliably done? *Journal of Structural Geology*, **17**, 1203-1206.

Joplin, G.A. 1942. Petrological studies in the Ordovician of New South Wales. I. The Cooma Complex. *Proceedings of the Linnean Society of New South Wales*, **67**, 156-196.

Joplin, G.A. 1962. An apparent magmatic cycle in the Tasman Geosyncline. *Journal of the Geological Society of Australia*, **9**, 51-69.

Kretz, R. 1983. Symbols for rock-forming minerals. *American Mineralogist,***68**, 277-279.

Munksgaard, N.C. 1988. Source of the Cooma Granodiorite, New South Wales — a possible role of fluid-rock interactions. *Australian Journal of Earth Sciences*, **35**, 363-377.

Pidgeon, R.T. & Compston, W. 1965. The age and origin of the Cooma granite and its associated metamorphic zones, NSW. *Journal of Petrology*, **6**, 193-222.

Vallance, T.G. 1953. Studies in the metamorphic and plutonic geology of the Wantabadgery-Adelong-Tumbarumba district, N.S.W. Part I. Introduction and metamorphism of the sedimentary rocks. *Proceedings of the Linnean Society of New South Wales*, **78**, 90-121.

Vallance, T.G. 1967. Palaeozoic low-pressure regional metamorphism in southern Australia. *Dansk Geologiska Föreningens Meddedelingen*, **17**, 494-503.

Vallance, T.G. 1969. Southern and central highlands fold belt; plutonic and metamorphic rocks. *Journal of the Geological Society of Australia*, **16**, 180-

Vernon, R.H. 1978. Pseudomorphous replacement of cordierite by symplectic intergrowths of andalusite, biotite and quartz. *Lithos*, **11**, 283-289.

Vernon, R.H. 1979. Formation of late sillimanite by hydrogen metasomatism (base-leaching) in some high-grade gneisses. *Lithos*, **12**, 143-152.

Vernon, R.H. 1986. K-feldspar megacrysts in granites — phenocrysts, not porphyroblasts. *Earth-Science Reviews*, **23**, 1-63.

Vernon, R.H. 1999: Quartz and feldspar microstructures in metamorphic rocks. *Canadian Mineralogist*, **37**, 513-524..

Vernon, R.H., Clarke, G.L. & Collins, W.J. 1990. Local mid-crustal granulite facies metamorphism and melting: an example in the Mount Stafford area, central Australia. In: *High-temperature Metamorphism and Crustal Anatexis*, (eds Ashworth, J.R. & Brown, M.), pp. 272-319. Unwin Hyman, London.

Vernon, R.H. & Collins, W.J. 1988. Igneous microstructures in migmatites. *Geology*, **16**, 1126-1129.

Vernon, R.H. & Pooley, G.D. 1981. SEM/microprobe study of some symplectic intergrowths replacing cordierite. *Lithos*, **14**, 75-82.

White, A.J.R. & Chappell, B.W. 1988. Some supracrustal (S-type) granites of the Lachlan Fold belt. *Transactions of the Royal Society of Edinburgh: Earth Sciences*, **79**, 169-181.

White, A.J.R., Chappell, B.W. & Cleary, J.R. 1974. Geologic setting and emplacement of some Australian Paleozoic batholiths and implications for intrusion mechanisms. *Pacific Geology*, **8**, 159-171.