BMR Journal of Australian Geology & Geophysics, 9, 33-40

A mica, pyroxene, ilmenite megacryst-bearing lamprophyre from Mt Woolooma, northeastern New South Wales

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A narrow lamprophyre dyke, dated at 85 Ma, intrudes Early Carboniferous sediments at Mount Woolooma in northeast New South Wales. The lamprophyre contains megacrysts of titanbiotite (Mg_{18-21}, 7-8% TiO_2) and rare Ti-Al salite (Mg_{67-72}, 6-9% Al_2O_3), ilmenite (5% MgO), titanphlogopite (Mg_{61}, 9% TiO_2) and apatite. The host rock consists of lamprophyric-textured titanphlogopite (Mg_{62-70}, 7-8% TiO_2), diopside-salite, olivine, kaersutite, and Ti-magnetite in a K-feldspar-rich base. The rock resembles a minette (mica-lamprophyre), but its bulk composition is richer in SiO_2 and Al_2O_3 (53-54% SiO_2 anhydrous, ~16% Al_2O_3), and poorer in MgO (3%), Ni and Cr (30 ppm) than many minettes elsewhere. The Mount Woolooma minette forms part of a diverse assemblage of alkaline igneous rocks from the Scone-Gloucester area. These include alkali olivine basalt, teschenite, biotite alnoite, kimberlite, and leucite monchiquite, many of which carry mantle xenoliths/xenocrysts and/or megacrysts.

Introduction

Mica lamprophyres (minettes) are now recognised as an important rock association: many carry xenoliths of garnet lherzolite and share chemical similarities with micaceous kimberlites (e.g. Bachinski & Scott, 1979; Roden & Smith, 1979; Roden, 1981; Rogers & others, 1982). The significance of the lamprophyre suite is reinforced by the occurrence of diamond in recently discovered olivine-rich lamproites (potash- and magnesia-rich lamprophyres) of the West Kimberley region of Western Australia (Atkinson & others, 1984; Jaques & others, 1984). This paper describes a small lamprophyre dyke from Mount Woolooma in the Rouchel District of the Scone-Gloucester area of northeastern New South Wales. The dyke was found by one of us (DJP) in 1980 during an attempt to relocate a leucite(?) monchiquite plug found by students of Sydney University during mapping of the Glenbawn Dam region in 1966. The lamprophyre is of interest because it carries megacrysts of titanbiotite, clinopyroxene, and ilmenite, and is compositionally unlike other megacryst-bearing rocks described from this region.

Geology

The lamprophyre occurs as a poorly exposed dyke in dissected country on the northern slopes of Mount Woolooma (Fig. 1). The dyke is 1-3 m wide, subvertical, and extends for a little over 100 m in an east-west direction (Fig. 2). It intrudes thinly bedded, fossiliferous marl, mudstone, and shale of the Early Carboniferous Waverley Formation (Roberts & Oversby, 1974). Basaltic lavas of the Eocene Barrington Tops volcanic field cap ridges immediately east and south (Wilkinson, 1969; Wellman & McDougall, 1974; Mason, 1982), and a small plug-like body of alkali olivine basalt, containing peridotite nodules and megacrysts, lies immediately to the north (Fig. 2). The Mount Woolooma lamprophyre has been dated by the K-Ar method (mica separates) as late Cretaceous, 85.3 ± 0.4 Ma (Table 1).

The lamprophyre contains sparse (<5%) subhedral to euhedral megacrysts of biotite up to 1 cm long in a very fine-grained, phlogopite-rich groundmass. Rare megacrysts of black lustrous clinopyroxene up to 2.5 cm across, associated with crystals of ilmenite up to 1 cm long, were found in one sample.

Table 1. Summary of K-Ar data

Sample	%K	$^{40}Ar^*$ (x10^{-10} moles g^{-1})	$^{40}Ar^*/^{40}Ar$ Total	Age (Ma)
Mica (812105003)	6.817 6.814	10.325	0.886	85.3±0.4

$^{40}K/K$ = 1.167x10^{-4} mol./mol.; λ_{β} = 4.962x$10^{-10}$$yr^{-1}$; λ_{ϵ} = 0.581x$10^{-10}$$yr^{-1}$.
Analyst: A.W. Webb (AMDEL Report GS 2679/83.

Contacts with the country rock marls are sharp and little affected. The margins of the lamprophyre are commonly veined by carbonate, and mica megacrysts show a weak flow alignment near the contact.

Petrography

Thin sections show similar petrography. Sparse mica megacrysts up to 6 mm long lie in a lamprophyric-textured groundmass, in which euhedral microphenocrysts of phlogopite and diopside up to 0.3 mm are seriate to smaller euhedra of phlogopite, diopside, olivine, rare hornblende, and titanomagnetite. A glassy base is crowded with microlites of phlogopite, diopside, apatite, titanomagnetite, and rare ilmenite. Coarser-grained vein-like segregations contain laths of alkali feldspar in a crystalline K-feldspar-rich base. Sparse subhedral to euhedral phenocrysts of diopside up to 0.6 mm across, commonly with highly sieved cores, were observed in several thin sections. On megascopic and microscopic evidence, the Mount Woolooma lamprophyre is a minette (mica lamprophyre), using the nomenclature of Streckeisen (1978).

The mica megacrysts have strongly pleochroic (α = yellowish brown, $\beta = \gamma$ = dark brown) biotite cores with sharp narrow rims (mostly 50μm) of red-brown pleochroic phlogopite (= pale yellow, $\beta = \gamma$ = brownish red). The megacrysts are strongly resorbed and embayed, and some have kink-bands, indicating solid-state deformation. The inner rim is commonly marked by the presence of granules of magnetite and/or amoeboid-shaped inclusions of glassy groundmass material. Several of the megacrysts contain rounded inclusions of highly altered silicate (formerly K-feldspar?) now mainly zeolite, secondary K-feldspar, and magnetite. Tiny granules of magnetite occur along cleavage traces of some mica megacrysts.

The clinopyroxene megacrysts occur as large (up to 2 cm), strongly embayed anhedra free of exsolution. A clear core is surrounded by a reaction zone, commonly 0.2-0.6 mm wide, composed of less aluminous clinopyroxene (commonly in quench form), phlogopite, amphibole, magnetite, and glass. The outer part of the reaction zone generally consists of a narrow rim of quench diopside, which is commonly strongly zoned.

Ilmenite megacrysts accompany the clinopyroxene megacrysts as rare strongly rounded and embayed anhedra rimmed by phlogopite. One titanphlogopite megacryst 1.2 mm across was found with these megacrysts. This mica is strongly pleochroic (α= pale straw yellow, $\beta = \gamma$= foxy

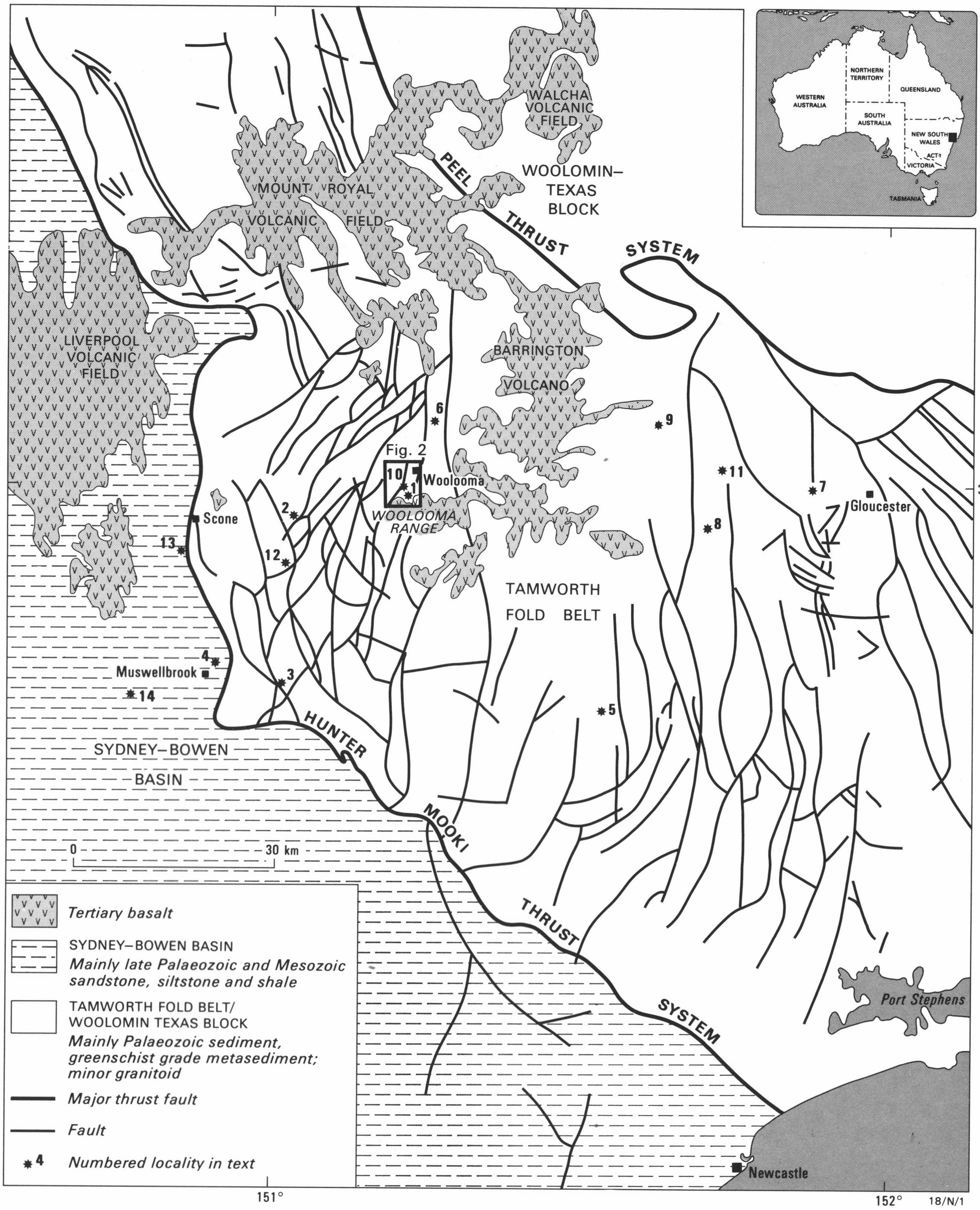

Figure 1. Simplified geology of the Scone – Gloucester area.

brownish red) and partly encased in the reaction zone surrounding the clinopyroxene megacryst.

Apatite was seen in one thin section as an elongate grain (approximately 1 mm x 0.25 mm) with strongly rounded margins; also present is a rounded xenocryst of strained quartz approximately 1 mm in diameter, which encloses a small oval-shaped crystal of K-feldspar.

The diopside phenocrysts (particularly those in sample 5) and many of the microphenocrysts have strongly sieved cores replaced by very fine-grained aggregates of phlogopite, magnetite and, in some cases, amphibole.

Megacrysts

Mica. The mica megacrysts are predominantly titanbiotites of uniform composition with high Ti and Fe contents, very low MgO contents, and low 100 Mg/(Mg + Fe) ratios (17.8–20.9; Table 2). They have low to moderate Na_2O contents (0.3–0.5%) and very low Cr_2O_3, MnO, and NiO. Structural formulae show low Si contents (Si = 5.3 atoms per 22 O atoms) with the Al in tetrahedral coordination. There is a deficiency of octahedral cations (0.5 cations) relative to ideal mica stoichiometry, suggesting that Ti is accommodated largely by the substitution $2\ Mg^{2+}_{VI} \rightleftharpoons Ti^{4+}_{VI} + \square_{VI}$ (Forbes & Flower, 1974).

A single phlogopite megacryst, $Mg_{60.6}$, has a higher TiO_2 content than the titanbiotite megacrysts and the groundmass titanphlogopites (Table 2); it is less magnesian and poorer in SiO_2 than the groundmass titanphlogopites.

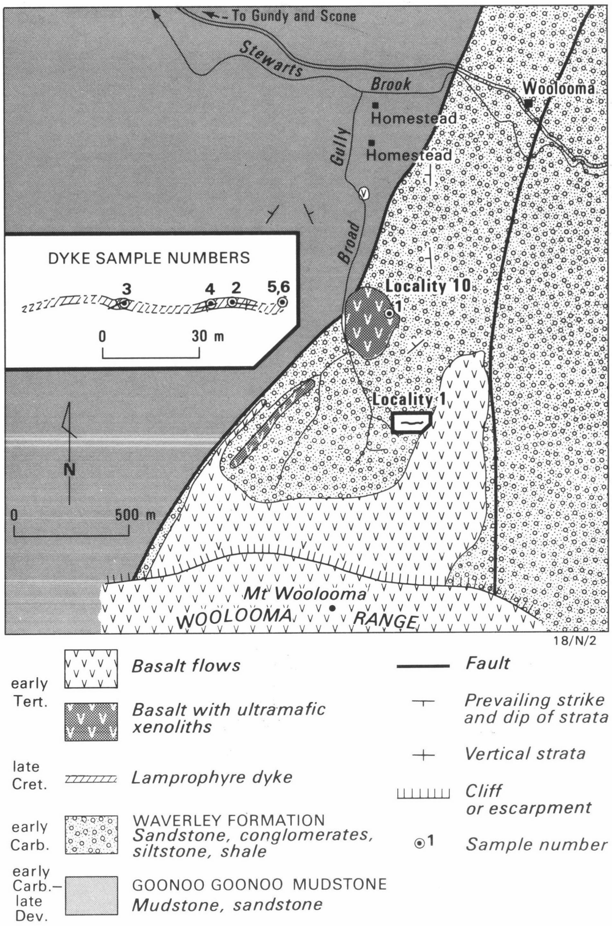

Figure 2. Geological map of the Mount Woolooma region.

(Based on mapping by students of Sydney University, University of New South Wales, and Roberts & Oversby (1974)). Sample numbers in inset have the BMR prefix 8121500.

Mica megacrysts with high TiO_2 contents are relatively common in alkali basalts (e.g. Irving, 1974; Wilkinson, 1975; Ellis, 1976), but most are titanphlogopite. Wilkinson (1962) reported titanobiotites (Mg_{55}, 6–8% TiO_2) from analcite-basalt from Spring Mountain. Irving (1974) described titanbiotite megacrysts as Fe-rich as $Mg_{35.6}$ (7.8% TiO_2) from the Anakies, Victoria. Ellis (1976) also reported similar or slightly more Mg-rich micas in a nepheline mugearite and in pyroxenite xenoliths. Similar micas ($Mg_{50\text{-}66}$) also occur in amphibolite-rich and apatite-rich xenoliths in dykes near Kiama (Wass, 1979a). To our knowledge, mica megacrysts as Fe-rich as those of the Mount Woolooma lamprophyre have not previously been reported.

Clinopyroxene. The clinopyroxene megacrysts are sodian, titanian, aluminous salites poor in Cr_2O_3 (Table 2), and show a limited range in Ca-Mg-Fe (Fig. 4). The cores are less calcic, and more aluminous, and have the lowest Mg-values (Figs. 4, 5). Al is partitioned between the tetrahedral and octahedral sites in the ratio 1:1 (Al^{IV}/Al^{VI} = 0.8–0.9). The cores are replaced by less aluminous, more calcic, and less sodic pyroxene together with phlogopite, magnetite, and amphibole in the reaction zone. Narrow rims of less Al- and Na- rich pyroxene, richer in Ca, and with a higher Mg-value (Table 2) overlap compositions of the more Al-rich phenocryst pyroxenes (Fig. 5). In general, there is a negative correlation of TiO_2, Al_2O_3, and Na_2O contents, and a positive correlation of Al^{IV}/Al^{VI} ratio with Mg-value (Fig. 5). The pyroxenes show a marked increase in Al^{IV}/Al^{VI} ratio from the megacryst cores through the reaction zone to the narrow rim (Fig. 5).

Table 2. Representative microprobe analyses of megacrysts

	1	2	3	4	5	6
SiO_2	34.08	36.02	48.98	49.26	0.68	35.90
TiO_2	6.96	7.29	1.54	1.63	44.47	9.31
Al_2O_3	14.68	15.26	9.22	4.68	1.53	15.23
V_2O_3	0.15	–	–	–	0.27	–
Fe_2O_3					16.37*	
FeO	27.72	12.56	9.86	8.49	30.88	13.99
MnO	0.20	–	–	–	0.15	–
MgO	4.11	13.84	11.14	13.17	5.32	12.09
CaO	0.27	–	17.44	22.02	0.23	0.17
Na_2O	0.50	0.55	2.16	0.58	–	0.33
K_2O	9.09	9.58	–	–	–	9.86
Total	97.76	95.10	100.35	99.82	99.90	96.87
$\frac{100\ Mg}{(Mg+Fe^{2+})}$	20.9	66.3	66.8	73.4	23.5	60.6
Ca			42.9	46.9		
Mg			38.1	39.0		
Fe			18.9	14.1		

* Fe_2O_3 calculated from ABO_3 stoichiometry

Mineral analyses were made using the TPD energy-dispersive electron microprobe at the Australian National University (Reed & Ware, 1975; Ware, 1981).

1. Biotite megacryst core, sample 81215004.
2. Phlogopite rim on biotite megacryst, sample 81215004.
3. Clinopyroxene megacryst core, sample 81215006.
4. Clinopyroxene megacryst rim, sample 81215006.
5. Ilmenite megacryst, sample 81215006.
6. Titanphlogopite megacryst, sample 81215006.

The clinopyroxene megacrysts are broadly comparable with the Al-augites and salites found as megacrysts in alkali basalts and associated lavas elsewhere (e.g. Binns & others, 1970; Irving, 1974; Ellis, 1976; Wass, 1979a). However, the Mount Woolooma megacrysts are more Fe-rich than usual and resemble Fe-rich pyroxene megacrysts in basanitic dykes in the Kiama area (Wass, 1979b), in a nephelinite sill in the Nandewar Mountains (Wilkinson, 1975), and in basanites in the Massif Central (Wass, 1979a).

Ilmenite. The ilmenite megacrysts are relatively uniform in composition, with 100 Mg/(Mg + Fe^{2+}) ratios ~ 23–24, geikelite contents of 15.7–19.8%, and hematite contents of 19.1–26.7%. They are comparable with, although somewhat richer in hematite than, those reported from eastern Australia (e.g. Binns, 1969; Ellis, 1976).

Microphenocrysts/groundmass

Phlogopite. Pale coloured titanphlogopite rims the biotite megacrysts and forms microphenocryst and groundmass phases. It is much poorer in FeO and richer in MgO than the biotite megacrysts, but has similar high TiO_2 and Al_2O_3 contents (Table 2; Fig. 3). Small differences exist in Na, Ca, and Mn contents between the two mica generations. The titanphlogopite rims on the biotite megacrysts, the microphenocrysts, and the groundmass phlogopites overlap in TiO_2 and Al_2O_3 contents and Mg/(Mg+Fe) ratios (Fig. 3). These phlogopites show minor amounts of Al^{VI} in their structural formulae, indicating very limited solid solution towards eastonite, but the dominant solid solution is annite – phlogopite.

Clinopyroxene. Clinopyroxene is present as microphenocrysts, groundmass prisms, and very rare phenocrysts. They are of diopside – salite composition and show limited Ca-Mg-Fe variation (Fig. 4). The microphenocrysts, the groundmass grains, and the phenocrysts show similar Ca-Mg-Fe contents except for lower Ca in the phenocrysts. Ti and Al vary (1–2% TiO_2, 2.4–6.2% Al_2O_3) with the most Ti-rich and Al-rich grains occurring as fine-grained granules in the

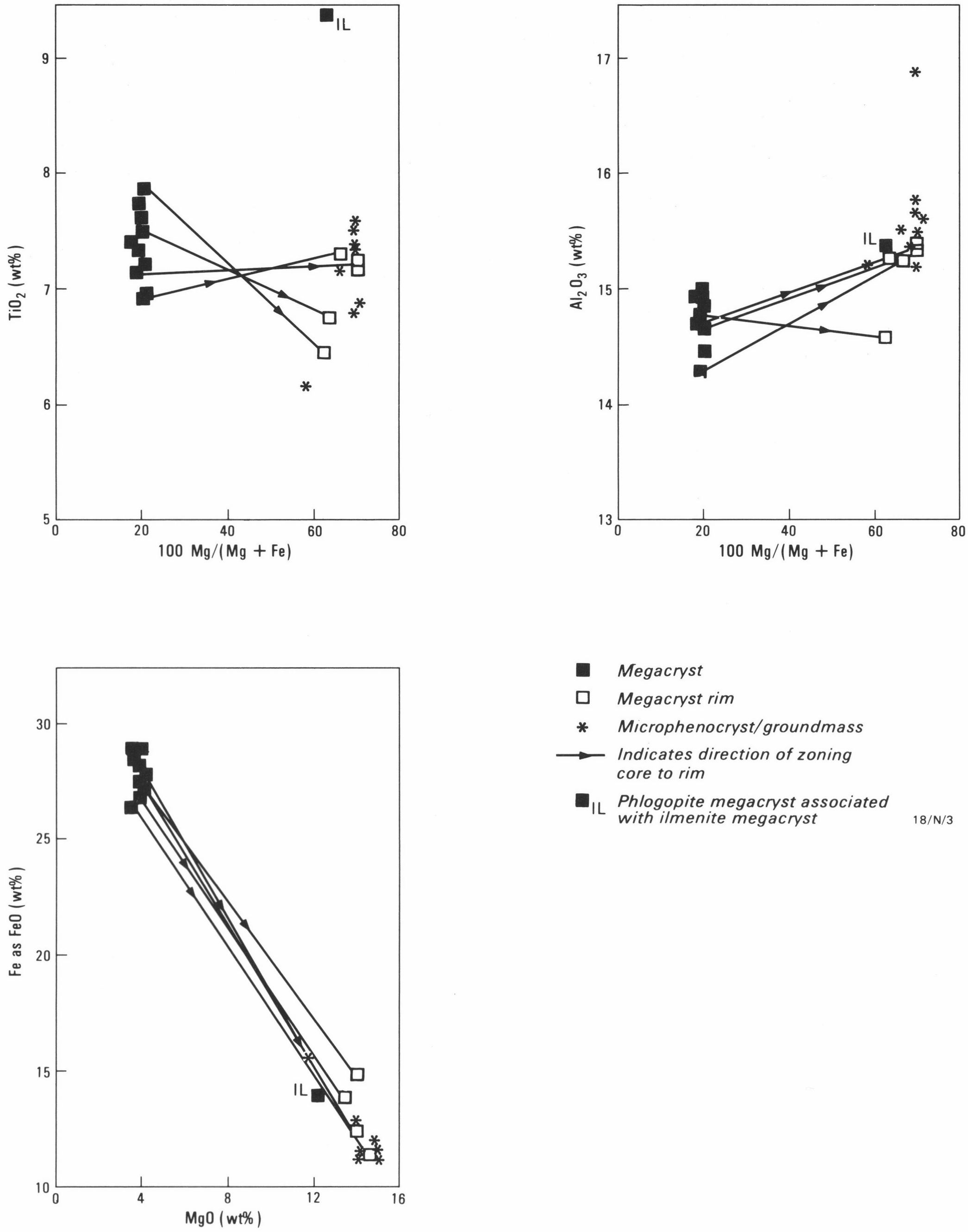

Figure 3. Compositional variation of micas in the Mount Woolooma minette. Note clear distinction of titanbiotite megacrysts (solid squares) from groundmass and microphenocryst phlogopite.

groundmass. Na contents are low, but range up to 0.9% Na_2O. The microphenocryst and groundmass pyroxenes have higher Al^{IV}/Al^{VI} ratios than the megacrysts and phenocrysts, and there is a correlation of grainsize with lower Al^{IV}/Al^{VI} ratio (Fig. 5).

Olivine. Olivine is comparatively Fe-rich ($Fo_{71\text{-}73}$) and contains appreciable amounts of Mn and Ca (0.3–0.45% MnO, 0.2–0.35% CaO). They are too Fe-rich to have crystallised from basaltic melts with an $Mg/(Mg+Fe^{2+})$ ratio of their host rock (assuming $K_{D\ \text{ol-liquid}}$ in the range 0.3–0.4, e.g. Roeder & Emslie, 1970; Nicholls, 1974). This suggests a lower original Fe^{3+}/Fe^{2+} than that of the rock analysis (Table 3). Olivine (or its alteration products) is common in minettes (e.g. Rock, 1977), but is usually more Mg-rich than those reported here (e.g. Roden & Smith, 1979).

Amphibole. Rare red-brown pleochroic kaersutite occurs as subhedral to euhedral grains in the groundmass of some samples. It is rich in Ti and Al (Table 3) with high Na and K contents. Ti contents and Mg/(Mg+Fe) ratios are comparable with those of co-existing phlogopite.

FeTi oxides. Titaniferous magnetite forms as abundant euhedra in the groundmass. It has high Ti contents (up to 20% TiO_2) and moderate amounts of Al_2O_3 and low MgO contents (Table 3). An average composition is $Ti_{0.5}\ Fe^{3+}_{0.7}\ Fe^{2+}_{1.4}\ Al_{0.2}\ Mg_{0.2}\ O_4$. Rare ilmenite grains found in one sample proved too small for analysis.

K-feldspar and groundmass. The groundmass is partially recrystallised to K-feldspar ($Ab_{48\text{-}58}\ Or_{46\text{-}37}$). One sample contains narrow vein-like segregations of coarser-grained groundmass containing abundant fine laths of alkali feldspar.

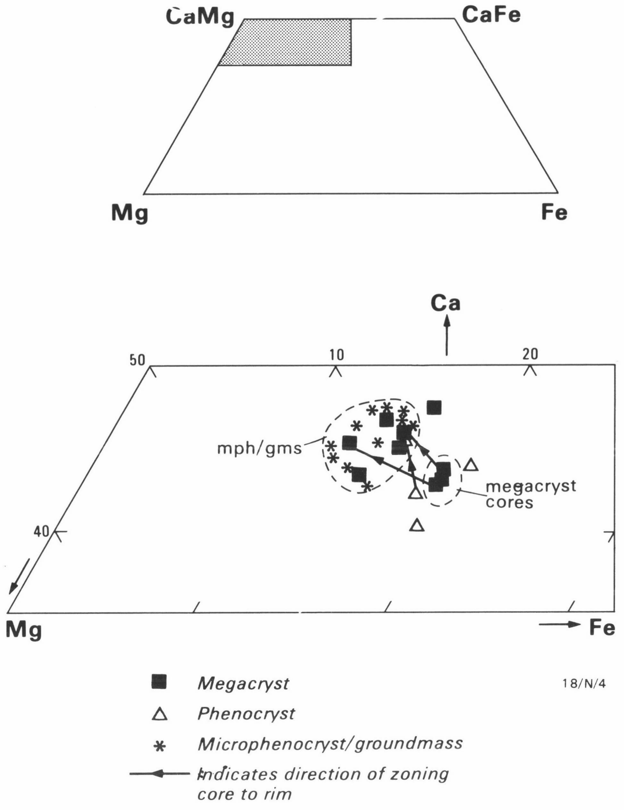

Figure 4. Portion of pyroxene quadrilateral showing compositional variation of pyroxenes in Mount Woolooma minette.

Table 3. Representative microprobe analyses of microphenocryst and groundmass phases.

	1	2	3	4	5	6
SiO_2	36.23	51.70	51.67	37.64	39.60	0.67
TiO_2	7.59	0.15	1.00	–	6.07	19.98
Al_2O_3	15.18	2.26	2.57	0.25	11.63	3.94
V_2O_3	–	–	–	–	–	–
Fe_2O_3	–	–	–	–	–	25.78*
FeO	11.48	11.67	8.40	25.44	11.44	45.81
MnO	–	0.42	–	0.45	–	0.50
MgO	14.92	14.17	14.77	35.83	12.37	3.21
CaO	0.09	19.41	21.01	0.34	11.60	0.10
Na_2O	0.50	0.24	0.29	–	2.45	–
K_2O	9.43	–	–	–	1.51	–
Cl	–	–	–	–	0.06	–
Total	95.41	100.02	99.71	99.96	96.72	100.50
$\frac{100\ Mg}{(Mg+Fe^{2+})}$	69.8	68.4	75.8	71.5	65.8	11.1
Ca		40.2	43.7		30.7	
Mg		40.9	42.7		45.5	
Fe		18.9	13.6		23.7	

*Fe_2O_3 calculated from AB_2O_4 stoichiometry.
1. Phlogopite, microphenocryst/groundmass, sample 81215004.
2. Diopside phenocryst, sample 81215005.
3. Diopside, groundmass, sample 81215003.
4. Olivine, groundmass, sample 81215003.
5. Kaersutite, groundmass, sample 81215002.
6. Titanomagnetite, groundmass, sample 81215003.

Geochemistry

The three samples of the Mount Woolooma minette are very similar in composition, with intermediate silica contents, high Al_2O_3 and alkali contents ($Na_2O + K_2O$ = 8–9%), and low MgO, FeO, CaO, and Mg/(Mg+Fe) ratios (Table 4). Their CIPW norms contain minor nepheline (4–5%) and anorthite, and abundant albite and orthoclase; differentiation indices are high (58–60). K_2O/Na_2O ratios lie in the range 0.6 to 1, and the rocks compare with a 'shoshonitic lamprophyre' group of Rock (1977).

The Mount Woolooma minette differs markedly in chemical composition from the mica lamprophyres of the Navajo volcanic field (Roden & Smith, 1979; Roden, 1981; Rogers & others, 1982) and Spanish Peaks, Colorado (Jahn & others, 1979), in having much higher Na_2O and Al_2O_3, lower MgO, and a low Mg/(Mg+Fe) ratio; a feature of these and many other minettes are their high Mg/(Mg+Fe) ratios (>0.6) and dominance of K over Na. The Mount Woolooma minette more closely resembles the 'average' minette composition given by Velde (1971), apart from being richer in Al_2O_3 and Na_20, and poorer in MgO (Table 4). There are also differences in trace-element contents: the Mount Woolooma rocks lack the high abundances of Ni, Cr, and Sc, and extreme enrichment in light rare-earth elements and other 'incompatible' elements, such as Pb, Th, U, Zr, Nb, P etc., which appear to be diagnostic of minettes (e.g. Bachinski & Scott, 1979; Jahn & others, 1979; Roden, 1981; Rogers & others, 1982).

The Mount Woolooma lamprophyre differs from most of the mildly alkaline rocks of intermediate composition previously described from northern and central New South Wales, which include hawaiite, mugearite, and benmoreite of distinctly sodic suites (e.g. Abbott, 1969; Wilkinson, 1969; Ewart & others, 1976, 1980; Middlemost, 1981). The Na_2O/K_2O ratio is similar to the shoshonites and latites of the Gerringong

Table 4. Chemical analyses of Mt Woolooma lamprophyre

	1	2	3	4	5
SiO_2	49.94	49.90	49.95	51.17	46.49
TiO_2	2.00	1.98	2.00	1.36	2.26
Al_2O_3	16.27	16.23	16.30	13.87	15.43
Fe_2O_3	2.72	2.96	2.87	3.27	3.27
FeO	5.18	4.98	5.01	4.16	8.00
MnO	0.13	0.13	0.13		0.11
MgO	3.46	3.43	3.27	6.91	9.30
CaO	5.05	5.24	4.78	6.58	9.49
Na_2O	5.10	4.30	4.80	2.12	3.19
K_2O	3.25	4.18	3.85	5.49	1.30
P_2O_5	0.38	0.38	0.58		0.71
Loss	6.01	5.80	5.64	3.72	0.46
Total	99.48	99.52	98.99	98.65	100.08
Trace elements (ppm)					
Sc	9	9	7		24
V	121	119	119		175
Cr	33	28	33		278
Ni	33	31	30		176
Cu	15	15	15		43
Zn	116	111	116		85
Ga	24	23	23		16
As	1	1	1		1
Rb	88	84	90		13
Sr	1432	1446	1146		825
Y	17	17	18		21
Zr	287	285	291		219
Nb	49	47	49		55
Sn	<2	2	2		<2
Ba	1084	1201	912		296
La	26	26	29		35
Ce	54	56	59		59
Nd	39	34	37		30
Pb	<2	<2	<2		2
Bi	<2	<2	<2		<2
Th	3	3	4		4
U	<1	<1	<1		<1
$Mg/(Mg + Fe^t)$	0.447	0.444	0.434	0.634	0.602
K_20/Na_20	0.64	0.97	0.80	2.59	0.41

1. Mt Woolooma lamprophyre, 81215002.
2. Mt Woolooma lamprophyre, 81215003.
3. Mt Woolooma lamprophyre, 81215004.
4. Average of 64 minettes (Velde, 1971)
5. Alkali olivine basalt, 81215001, northern slope of Mt Woolooma.

Analyses by BMR, using XRF, AAS, and wet chemical methods (Sheraton & Labonne, 1978).

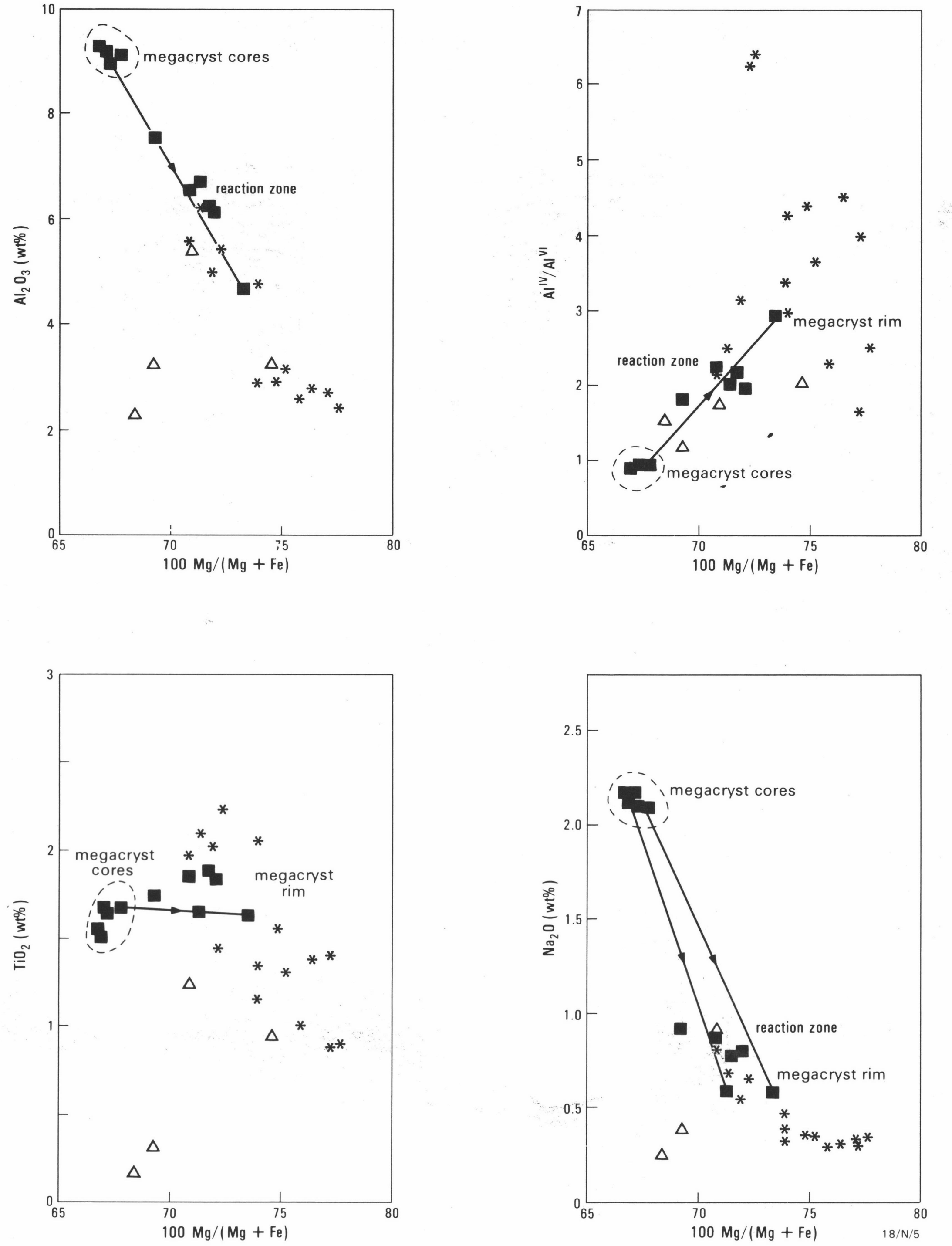

Figure 5. Compositional variation of Al_2O_3, Al^{IV}, TiO_2 and Na_2O with 100 Mg/(Mg+Fe) in pyroxenes from Mount Woolooma minette. Note the clear distinction of the megacryst cores and the trend of the reaction zone and outer rim towards the microphenocryst/groundmass compositions. Symbols as in Figure 4.

Volcanics of the south coast of New South Wales (cf. Joplin, 1971), but alkalis are higher and CaO lower. Wilshire & Binns (1961) reported megacryst-bearing and xenolith-bearing lamprophyres, mostly monchiquite, but few analyses are available; Joplin (1971) cited analyses of several nepheline-monchiquites that are distinctly more undersaturated than the Mount Woolooma lamprophyre.

Discussion

Origin and significance of the megacrysts

Similar megacrysts are widely recorded from alkali basalt suites in eastern Australia and are generally held to have crystallised at high pressure (e.g. Wilshire & Binns, 1961; Binns & others, 1970; Irving, 1974; Wilkinson, 1975; Ellis, 1976; Wass & Irving, 1976; Wass, 1979a). In some evolved rocks of intermediate composition, e.g. hawaiite, mugearite, benmoreite etc., the megacrysts are thought to result from crystal fractionation at high pressure (lower crust or upper mantle) from more mafic parent magmas (basanite, alkali olivine basalt etc.) derived from the mantle (e.g. Green & others, 1974).

The megacrysts in the Mount Woolooma lamprophyre suggest high-pressure crystallisation from the host rock or a more mafic magma. The high Al_2O_3 contents and low Al^{IV}/Al^{VI} ratios of the megacryst pyroxene, particularly, are good evidence for high-pressure crystallisation (cf. Wass, 1979a). The biotite megacrysts are inferred to have crystallised at high temperature under oxidising conditions, since high Ti in micas is favoured by high temperature and fO_2 (Arima & Edgar, 1981). The solid state deformation shown by some biotites suggests a xenocrystal origin, at least for some of the megacrysts. However, the marked similarity in Al and Ti contents of the megacrysts and the groundmass phlogopite suggests that the megacrysts may have crystallised from a magma with similar TiO_2 and Al_2O_3 content: Barton (1979) found that mica compositions in potassic alkaline rocks were related to bulk magma compositions. Because the Mount Woolooma biotite megacrysts are much more Fe-rich than the equilibrium (groundmass and rim) phlogopite in the rock, a cognate origin requires marked changes in either the Fe-Mg partitioning between mica and melt with temperature, pressure, water pressure, and/or oxygen fugacity, or a change in the $Mg/(Mg+Fe^{2+})$ ratio of the melt at lower pressure (near surface). The latter could arise either by oxidation of Fe^{2+} to Fe^{3+} or a decrease in total Fe in the melt. Oxidation by the reaction biotite + O_2 = phlogopite + Fe-oxide could explain the abundance of magnetite in the groundmass and the presence of magnetite granules at the phlogopite rims. However, the estimated Fe^{3+} contents of the groundmass phlogopites (Fe^{3+} assumed – ΔT = 8-Al-Si) are generally lower than the biotite cores. Thus, if a significant change in oxidation state occurred, it was buffered by the magnetite. The rimming of the titanbiotite megacrysts with coexisting groundmass phlogopite matches Fe-rich brown biotite (Type I mica) in kimberlite containing more Mg-rich groundmass (Type II) mica (cf. Smith & others, 1978). Type I micas are thought to be xenocrystal, perhaps derived from carbonatites (e.g. Smith & others, 1978); the origin of the biotite megacrysts in the Mount Woolooma minette remains obscure.

Relationship of the Mount Woolooma lamprophyre to other igneous rocks in the Scone – Gloucester region.

A wide range of igneous rocks occurs in the Scone – Gloucester area. The lavas of the Eocene Barrington Tops volcanic field (Wellman & McDougall, 1974) cover some 2400 km^2 and consist mainly of alkali olivine basalt, some tholeiitic olivine basalts, olivine-pyroxene basalts, ankaramites containing megacrysts of clinopyroxene, and rare theralites (Wilkinson, 1969; Mason, 1982). An analysis of an alkali olivine basalt (Table 4) from a small outcrop on the northern flank of Mount Woolooma (Fig. 2) is similar to previously published compositions from the Barrington Tops volcanic field.

Other alkaline basic volcanic and intrusive rocks, many carrying megacrysts or xenoliths, have been reported in the region (Fig. 1). They include: a small leucite(?) monchiquite body (Locality 2; D. Perkin, unpubl. data); 2 monchiquite plugs near Muswellbrook, which contain megacrysts of olivine, orthopyroxene, and possibly clinopyroxene (Localities 3 and 4; Wilshire & Binns, 1961); 2 eclogite localities, one 5 km north of Allyn Brook, 51 km east of Muswellbrook, and the other at Moonan Flat immediately north of Mt Woolooma (Localities 5 and 6; MacNevin, 1977); diamond-bearing 'parakimberlite' volcanic breccia and tuff in Prince Charlie Creek (Locality 7; MacNevin, 1977); 2 kimberlite pipes at Oaky Creek including AuK1 (Locality 8; Wilkinson, 1974; MacNevin, 1977; Stracke & others, 1979); biotite alnoite in the Cobakh River (Locality 9; F.L. Sutherland & J.D. Hollis, pers. comm., 1982); alkali basalt containing peridotite nodules (Locality 10) or peridotite nodules and megacrysts of deformed olivine, clinopyroxene orthopyroxene(?) and spinel (Locality 11; Wilshire & Binns, 1961; Wass & Irving, 1976), and olivine analcimite at Glenbawn Dam containing megacrysts of titanphlogopite and clinopyroxene (Locality 12; Irving, 1974); a carbonate-rich intrusion encountered in drill hole in the Scone area (Locality 13); teschenitic dykes and sills of late Permian-early Triassic age intruding the Permian Singleton Coal Measures in the area between Denman and Muswellbrook (Locality 14; Gamble, in press).

Of this diverse suite those most closely resembling the Mount Woolooma minette are the late Permian – early Triassic syenoteschenites (Gamble, in press). Although poorer in mica and containing abundant analcime, these differentiated slightly ne-normative rocks compare in differentiation indices and normative An/(An+Ab) contents. Differences exist in MgO and TiO_2 contents and in the trace-element abundances. Although no chemical data are available, the megacryst-bearing monchiquite plugs reported by Wilshire & Binns (1961) also show some similarities with the Mount Woolooma minette.

The diverse suite of alkaline igneous rocks in the Scone – Gloucester area dates from at least the late Permian, and was most voluminous in the Barrington Tops volcano in the Eocene. The Mount Woolooma minette is only a minor phase of this activity and its precise relationship to other magmatic episodes and the magmatic evolution of the province are unclear.

Acknowledgements

We thank Dr D. Branagan (Sydney University) for information obtained by student mapping in the Glenbawn region in the period 1966 – 1971, J. Pyke and T. Slezak (BMR) for the chemical analyses, and N.G. Ware (ANU) for access to the TPD probe. Comments on the draft manuscript by M. Duggan, J. Knutson, and the journal referees are gratefully acknowledged. DJP thanks F.L. Sutherland and J.D. Hollis for helpful discussions.

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