INTRUSIVE RELATIONSHIPS OF GRANITE AND DOLERITE AT LAGUNTA CREEK, FREYCINET PENINSULA

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(with one table, five text-figures and eight plates)

Coastal exposures immediately south of the mouth of Lagunta Creek, Freycinet Peninsula, eastern Tasmania, illustrate the temporal and spatial relationships between various Devonian granites and a dolerite dyke. The oldest granite, an equigranular grey hornblende-biotite adamellite containing abundant mafic enclaves, was intruded by a more felsic, equigranular to variably porphyritic or seriate pink alkali feldspar granite, and associated aplite, leucogranite and pegmatite dykes. Field relationships indicate brittle fracture and stoping of the adamellite during dilational emplacement of the pink granite. Minor bodies of granite porphyry are also younger than the adamellite. A dolerite dyke, of hawaiitic composition and containing plagioclase megacrysts, intrudes the adamellite and also crosscuts the aplite and leucogranite dykes, and is the youngest phase.

The granites are metaluminous to very weakly peraluminous, and are classified as I-types on both mineralogical and geochemical criteria. The adamellite is unfractionated and chemically reduced, and, together with similar rocks at Wineglass Bay and Cape Tourville, constitutes the Bluestone Bay Suite, which is geochemically distinct from, and younger than, other eastern Tasmanian granodiorite/adamellites. In contrast, both the pink granite and, to a lesser extent, the granite porphyry are fractionated and locally magnetite-bearing. Fractionation has resulted in high Rb, Y, Th and Pb and low P, Sr and Ba. The dolerite dyke, despite its alkalic major element chemistry, is depleted in Nb like some other granite-associated mafic rocks in the southern Lachlan Fold Belt.

Key Words: granite, dolerite, enclaves, Devonian, Freycinet Peninsula, Tasmania

INTRODUCTION

There are few studies of the Devonian granites that form most of Freycinet Peninsula (fig. 1), and only the southern tip has been systematically mapped by the Tasmanian Geological Survey (K. D. Corbett, pers. comm.). The inferred Ordovician–Early Devonian Mathinna Group country rocks occur only as a small area near Bluestone Bay (Cocker 1977). A major north–south trending fault, downthrown to the west, transects the west coast of the Peninsula near Hepburn Point and Weatherhead Point. Jurassic dolerite lies west of the fault, apart from small areas of Triassic sandstone west of Bryans Bay. The fault continues southward to bisect Schouten Island, the eastern half of which is composed of granitic rocks (Bacon & Corbett 1984).

Foreshore exposures near Coles Bay were examined in detail by Groves (1965), who also produced a sketch map of the Hazards area. He described the dominant rock type as a variably porphyritic "red adamellite", associated with microadamellite and quartz feldspar porphyry dykes and minor pegmatite. This was thought to be younger than an even-grained "grey adamellite with xenoliths", noted in the Bluestone Bay and Wineglass Bay areas.

A more detailed map of the Hazards Range, accompanied by field and petrological descriptions of the various granite types, was provided by Dunderdale (1989). She showed that most (> 90%) of this area consists of "red microcline granite", locally yellow due to hydrothermal alteration, with minor intrusions of quartz feldspar porphyry and microgranite. Small bodies of granodiorite at Wineglass Bay and "white granite" southeast of Fleurieu Point were both shown to be older intrusions.

McDougall & Leggo (1965) obtained a Rb/Sr age of 375 Ma (now recalculated to 368 Ma using new decay constants) from biotite in a "leucocratic pink granite" from the quarry south of Coles Bay. This was considered a minimum age. K/Ar dates from the same biotite yielded slightly younger ages of 347 to 355 ($\pm$ 10) Ma (now 353 to 361 Ma) which were attributed to resetting. A whole rock-mineral Rb/Sr isochron gave a younger age of 353 Ma (now 345 Ma), which was discounted due to the likelihood of mobility of radiogenic Sr in feldspars.

Cocker (1977) also conducted a Rb/Sr study, and provided a simple map, of granite and granodiorite in the Coles Bay–Bluestone Bay area. Probably the most reliable dates (recalculated using new decay constants) are from biotites: 370.8 ($\pm$ 3) Ma from a pink felsic granite and 372.8 ($\pm$ 3) Ma from a granodiorite, both from north of Sleepy Bay. The data are consistent with those of McDougall & Leggo (1965) and suggest that pink felsic granite was intruded shortly after the granodiorite in the late Middle Devonian (Givetian).

This paper describes the excellent coastal exposures of granite which, interrupted by small sandy beaches, extend from Lagunta Creek (at the southern end of Hazards Beach) for 3.5 km SSW to Cooks Beach. The most varied geology is within 1 km of Lagunta Creek (fig. 2).

ADAMELLITE/GRANODIORITE

The oldest granite in the area, well exposed as the country rock to the dolerite dyke at the mouth of Lagunta Creek (pl. 1), is a grey to white, medium- to fine- grained (1–3 mm) equigranular and unfoliated adamellite, in which scattered flakes of shiny black to dark green biotite and dull steel-grey hornblende are readily visible in hand specimen. It crops out along the shore southward for about 1 km, but is intruded, in places intensely, by other rock types, as described below.

The adamellite contains conspicuous and numerous (1–2% of outcrop) dark-grey to grey-green, finer grained (0.5–2 mm) mafic enclaves (pls 2, 3). They are typically
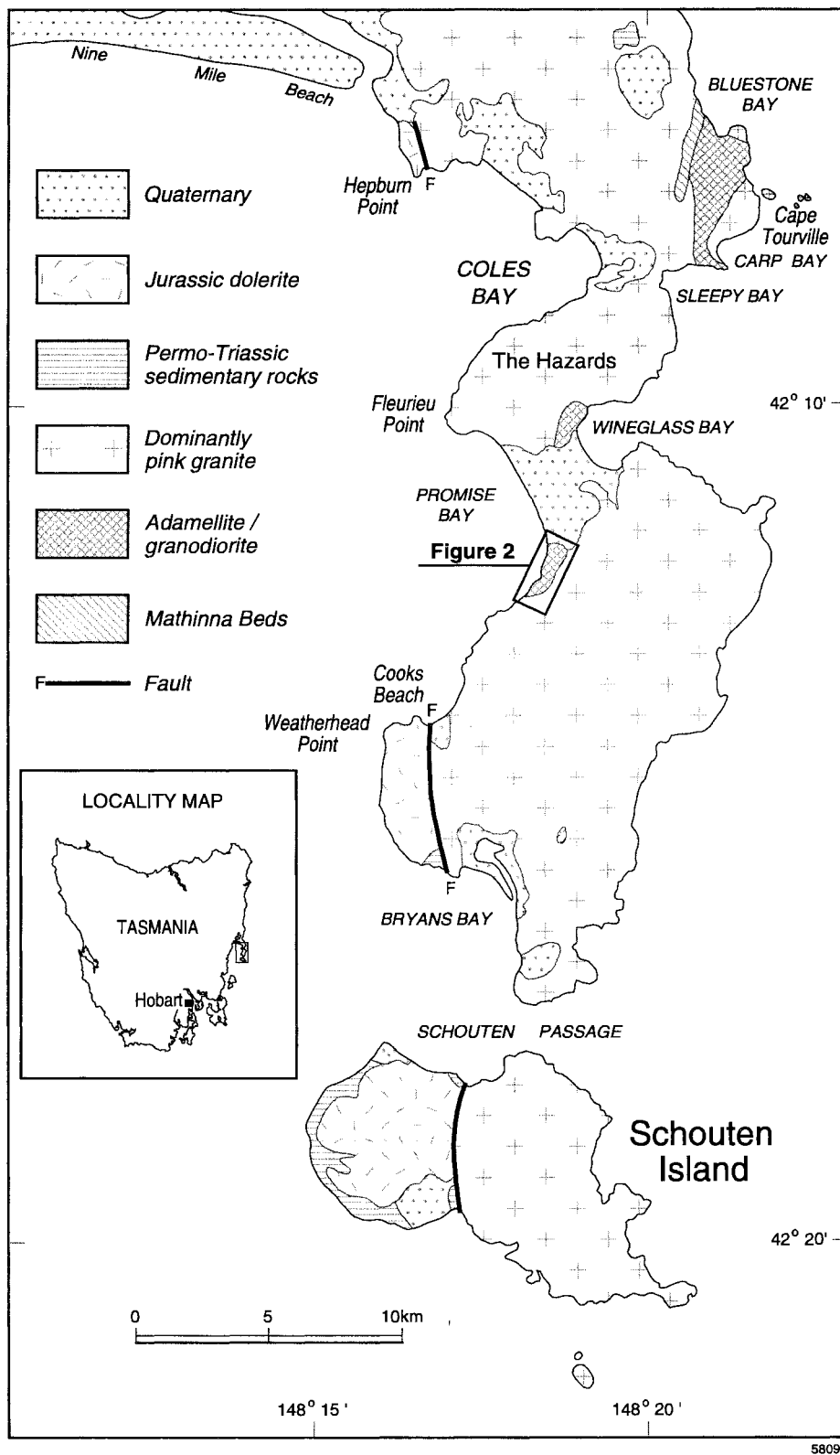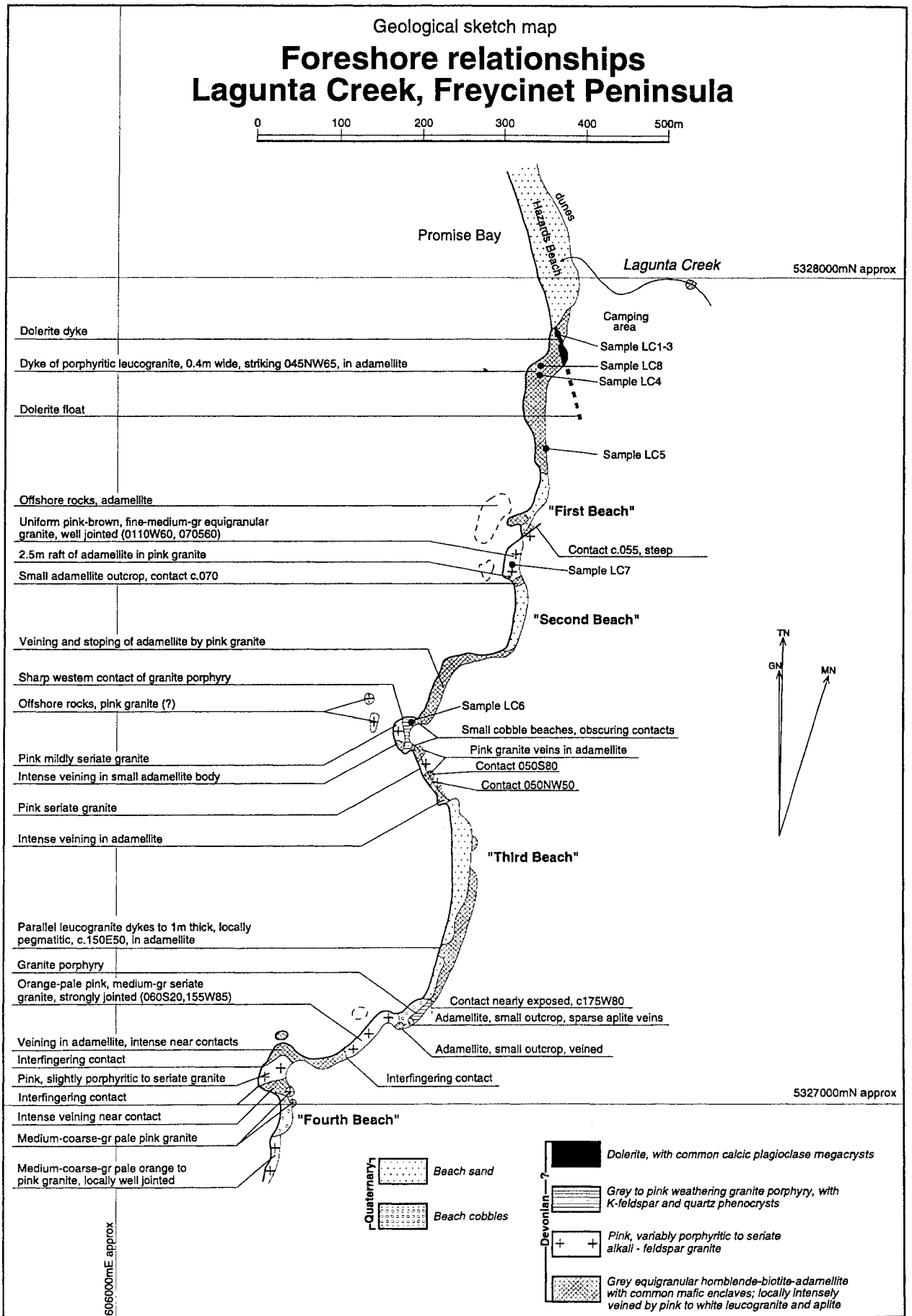
FIG. 1 — *Simplified geology of Freycinet Peninsula (after Forsyth et al. 1995 as modified to 17/8/2001; original sources include Cocker 1977, Bacon & Corbett 1984, Dunderdale 1989 and K. D. Corbett, pers. comm.).*

ellipsoidal in shape and very variable in size, with long dimensions ranging from a few tens of millimetres to commonly 0.4 m or more. A few are crudely polygonal or irregular in shape (pl. 3), but with generally rounded rather than angular corners. Contacts against the host adamellite are usually quite sharp, but without fine-grained margins, and slightly wavy on a very small scale. Some of the smaller enclaves are coarser-grained, paler (with less biotite) and less mafic. These generally also have more diffuse margins and are texturally transitional to the host adamellite. Many enclaves contain scattered microphenocrysts, oblong to equant polygonal in outline, of dull white feldspar.

Geological sketch map
Foreshore relationships
Lagunta Creek, Freycinet Peninsula

0   100   200   300   400   500m

Promise Bay

Lagunta Creek   5328000mN approx

Camping area

Dolerite dyke — Sample LC1-3

Dyke of porphyritic leucogranite, 0.4m wide, striking 045NW65, in adamellite — Sample LC8
Sample LC4

Dolerite float

Sample LC5

Offshore rocks, adamellite

Uniform pink-brown, fine-medium-gr equigranular granite, well jointed (0110W60, 070560)   **"First Beach"**

2.5m raft of adamellite in pink granite   Contact c.055, steep

Small adamellite outcrop, contact c.070   Sample LC7

"Second Beach"

Veining and stoping of adamellite by pink granite

Sharp western contact of granite porphyry

Offshore rocks, pink granite (?)   Sample LC6

Small cobble beaches, obscuring contacts
Pink granite veins in adamellite
Pink mildly seriate granite   Contact 050S80
Intense veining in small adamellite body   Contact 050NW50

Pink seriate granite

Intense veining in adamellite

"Third Beach"

Parallel leucogranite dykes to 1m thick, locally pegmatitic, c.150E50, in adamellite

Granite porphyry

Orange-pale pink, medium-gr seriate granite, strongly jointed (060S20,155W85)   Contact nearly exposed, c175W80
Adamellite, small outcrop, sparse aplite veins

Veining in adamellite, intense near contacts   Adamellite, small outcrop, veined
Interfingering contact
Pink, slightly porphyritic to seriate granite   Interfingering contact
Interfingering contact   5327000mN approx
Intense veining near contact   **"Fourth Beach"**
Medium-coarse-gr pale pink granite

Medium-coarse-gr pale orange to pink granite, locally well jointed

TN
GN   MN

Quaternary
Beach sand
Beach cobbles

Devonian—?

Dolerite, with common calcic plagioclase megacrysts

Grey to pink weathering granite porphyry, with K-feldspar and quartz phenocrysts

Pink, variably porphyritic to seriate alkali - feldspar granite

Grey equigranular hornblende-biotite-adamellite with common mafic enclaves; locally intensely veined by pink to white leucogranite and aplite

606000mE approx

5809a

FIG. 2 — Geological sketch map, foreshore relationships south of Lagunta Creek, Freycinet Peninsula.

PLATE 1

General view looking north from near the mouth of Lagunta Creek at the southern end of Hazards Beach, showing in foreground the stepped western contact of the dolerite dyke with adamellite.
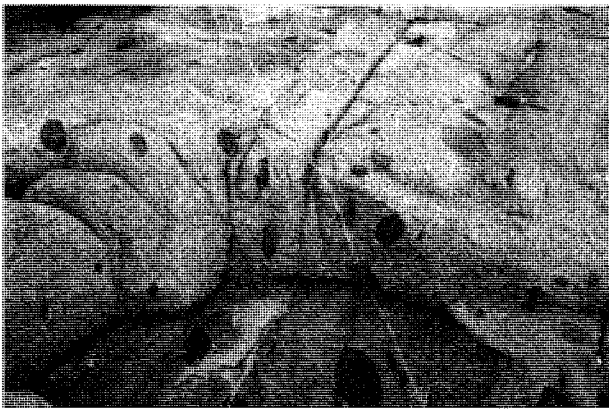

PLATE 2

General view of adamellite, showing numerous, mostly ellipsoidal to irregular enclaves and narrow aplite vein. The diameter of the lens cap is 50mm.
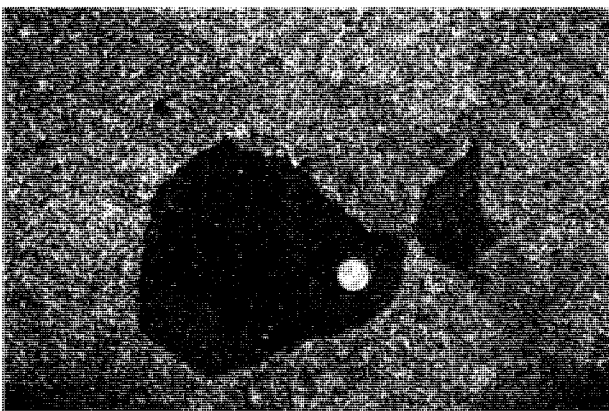

PLATE 3

Close-up of enclaves within adamellite. The larger enclave is atypical in its crudely polygonal shape. The diameter of the coin is 28 mm.

Petrography

In thin section the adamellite (sample LC4) is seen to consist mainly of quartz, feldspar (plagioclase more abundant than alkali feldspar), biotite and hornblende. Zircon, titanite, allanite, apatite, opaque minerals and chlorite (as an alteration of biotite) are accessory minerals.

Quartz occurs as clear unstrained anhedra, mostly 1–3 mm across. Plagioclase is typically oblong subhedral (up to 2 mm long) and in places shows incipient sericitisation. Extinction angles show that it may be as calcic as An_{48}, but concentric zoning is frequently apparent. Potash feldspar (orthoclase) is typically equidimensional and subhedral, and also often strongly and concentrically to irregularly zoned, and partly sericitised. Biotite is pleochroic from very dark brown to pale yellow-brown and is locally partly altered to pale green chlorite. Hornblende (pleochroic with α pale yellow-brown, β olive-green, χ sea-green) occurs as elongate bladed prisms up to 1.5 mm long and irregular clots up to 2 mm across, which may enclose cores of sieve-textured relict clinopyroxene. Hornblende and biotite are often closely associated and sometimes intergrown. Both minerals occasionally occur as inclusions in quartz, indicating that they crystallised earlier.

Allanite occurs as scattered, rather turbid, isolated equant euhedra, in section polygonal and up to 0.8 mm across. Typically it is pale orange-brown, weakly pleochroic and only partly metamict but variably altered to paler to colourless secondary minerals. Radiating cracks in enclosing quartz and feldspars, and bent adjacent biotites, are attributed to strain caused by increase in volume during metamictisation. Occasional zircon grains, small apatite rods and rare tiny opaque blebs occur mainly as inclusions in biotite and hornblende. These accessory minerals are considered to be early crystallising, or possibly restite, phases. In contrast, titanite occurs as fine-grained anhedral aggregates and is probably secondary.

The hornblende adamellite (sample LC4) is essentially non-magnetic (susceptibility 0.1–0.2 x 10^{-3} SI), and it is a reduced or ilmenite-series granite (Ishihara 1977).

A thin section of a mafic enclave (sample LC5A) shows that it is mineralogically similar to the host adamellite, but is finer-grained (mostly less than 0.5 mm), and mafic minerals are more abundant. Hornblende (pleochroic from sea-green to pale yellow-green) occurs with minor biotite (dark brown to pale yellow) in clots several millimetres across. Quartz, plagioclase and orthoclase, together with accessory zircon and apatite, are also present. Opaque phases are very sparse.

Petrographically very similar enclave-bearing equigranular hornblende-biotite adamellite/granodiorites occur at the northern end of Wineglass Bay (sample WGB, AMG reference FP07203115) and near Cape Tourville (sample CTV, FP09503530). The former is slightly more felsic than sample LC4 and apparently lacks relict clinopyroxene, whilst the latter has more extensively altered feldspar.

Geochemistry

A major element analysis (table 1) of adamellite (sample LC4) shows a relatively mafic (<70%), strongly metaluminous (ASI<1) composition. Calculated pseudomodes suggest that the rock is an adamellite in the modified Streckeisen (1973) classification scheme (fig. 3). Similar rocks from

Wineglass Bay (sample WGB; sample CD8 of Dunderdale 1989) and the Cape Tourville–Sleepy Bay area (sample CTV; samples TB6 and TB54 from database of B.W. Chappell) plot as slightly more quartz-rich adamellites, transitional to granodiorite.

In detail, sample LC4 is slightly more mafic than the Wineglass Bay and Cape Tourville rocks, with generally lower SiO_2 and higher TiO_2, total FeO, MgO and CaO. On simple two element variation diagrams (e.g. figs 4A–D) the available analyses generally plot colinearly, suggesting derivation from a common source, followed by differentiation by variable degrees of separation of entrained restite from the melt (e.g. Chappell & White 1992). It is proposed that these adamellite/granodiorites be termed the Bluestone Bay Suite.

Petrographically and chemically these rocks are clearly I-type granites. The low SiO_2, Rb (< 250 ppm) and high Sr (>50 ppm) and Ba (>200 ppm) identify them as unfractionated granites, using the criteria of Chappell et al. (1991).

For most elements, the enclave LC5 generally lies near extrapolations of the trends defined by the host granites to more mafic compositions, and on this basis it could represent an aggregate of modified restite (following White & Chappell 1977, Chen et al. 1989). However, other interpretations are possible. Similar mafic enclaves are found within other relatively mafic granites in eastern Tasmania, eastern Australia and worldwide. Most workers have interpreted them as globules of basaltic magma that were injected into the partly molten granite and incompletely mixed (mingled) with it (e.g. Reid et al. 1983, Vernon 1984), but others regard them as cumulates genetically related to the granite (e.g. Flood & Shaw 1995).

Comparison with Other Eastern Tasmanian Granites

The nearest outcropping adamellite/granodiorites are small coastal exposures on Long Point and Piccaninny Point, some 40–50 km to the north. These are apparently similar coarse, even-grained to slightly porphyritic, medium-grained, enclave-bearing hornblende-biotite granites (Turner & Calver 1987: 63–64). However, compared to the Bluestone Bay Suite, the two available analyses (Turner et al. 1986) have distinctly higher MgO (fig. 4A) and lower Na_2O, Al_2O_3, Sr (fig. 4C) and Th at equivalent total FeO.

As noted by Turner et al. (1986), the St Marys Porphyry (the partly extrusive equivalent of an I-type granodiorite) and other members of the Scamander Tier Suite are chemically dissimilar to the Long Point/ Piccaninny Point adamellite/granodiorites. The Scamander Tier suite rocks also differ from the Bluestone Bay Suite, with higher SiO_2, Y (fig. 4D) and Zr and lower Al_2O_3, MgO (fig. 4A), CaO (fig. 4B), Na_2O, Sr (fig. 4C) and Th at equivalent total FeO.

In addition, both the 388 ± 1 Ma Rb/Sr emplacement age of the St Marys Porphyry and the similar ages (385–389 Ma) of the Piccaninny Point adamellite (Turner et al. 1986) are much older than 372.8 ± 3 Ma Rb/Sr age of Cocker (1977) from north of Sleepy Bay.

The small Piccaninny Creek pluton (Turner et al. 1986) near Chain of Lagoons (not to be confused with the body at Piccaninny Point) is also chemically unlike the Bluestone Bay Suite (figs 4A–D).

Further north, the hornblende-bearing granodiorites of the Blue Tier Batholith are unlikely correlates, as there is unequivocal field and isotopic evidence that at least the Gardens and George River granodiorites are still older than the rocks of the Scamander Tier Suite (e.g. McClenaghan et al. 1992).

PINK ALKALI FELDSPAR GRANITE

About 300 m south of Lagunta Creek, a few metres to the south of a small sandy beach, a small exposure of enclave-bearing adamellite has a probably steep and northeasterly trending contact (not quite exposed) against a much more felsic, pink to red, medium- to fine-grained, equigranular granite. The pink granite is well jointed, very uniform, and lacks aplite veins or enclaves.

About 75 m further south, at the northern end of a second small sandy beach, there is a contact, striking at about 250°, against a small (3 x 3 m) flat outcrop of white enclave-bearing adamellite to the south. Here the pink granite is equigranular to variably porphyritic, locally containing small phenocrysts of potassium feldspar (5–15 mm) and quartz (≤ 5 mm). Narrow, finer grained leucogranite and aplite dykes occur within it, but unlike those in the adamellite which they otherwise resemble, their margins and terminations are frequently diffuse and indistinct. They appear to be late stage segregations directly derived from the pink granite.

South of the second sandy beach, the enclave-bearing adamellite is intruded by dykes, up to 80 mm wide, of medium-grained equigranular pink granite. The dykes become wider (up to 1 m) and more numerous southward, and form a network throughout the adamellite (pl. 4). Locally they are very coarse-grained to pegmatitic (20–
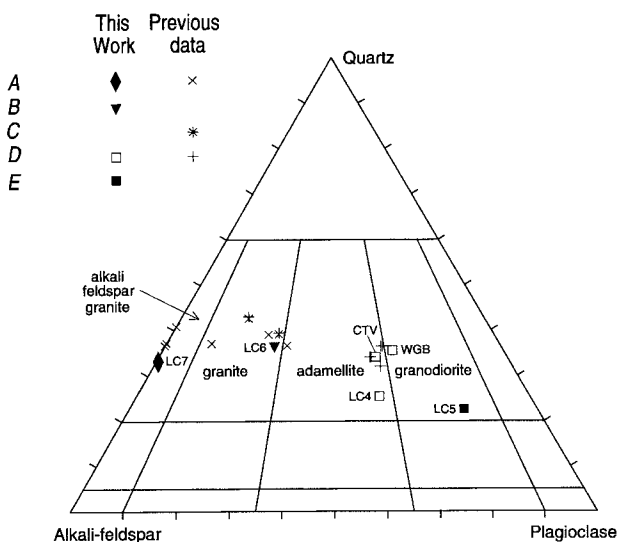
FIG. 3 — Calculated pseudomodes of analysed granitic rocks from Freycinet Peninsula, plotted on the granitoid classification diagram of Streckeisen (1973), modified by the separation of an adamellite (= monzogranite or quartz monzonite of some authors) field from the granite field. (A) Pink alkali feldspar granite and related rocks; (B) granite porphyry; (C) white granite at Fleurieu Point; (D) grey adamellite; (E) enclave in grey adamellite.

TABLE 1
New chemical analyses of Devonian granites and dolerite, Freycinet Peninsula

Field no.	LC4	LC5	WGB	CTV	LC7	LC6	LC1	LC3
Reg. no.	004439	004440	004450	004451	004443	004442	004436	004438
Analysis no.	910750	910751	980424	980423	910753	910752	910748	910749
AMG (FP...)	06512788	06522780	07203115	09503530	06482765	06362746	06532793	06532793
Rock type	adamellite	enclave	adamellite	adamellite	granite	porphyry	chilled dol	dolerite
SiO2 (wt%)	65.63	61.30	67.90	68.45	75.71	73.04	45.52	44.58
TiO2	0.60	0.79	0.57	0.48	0.09	0.20	2.89	2.61
Al2O3	15.14	15.44	14.54	14.73	12.46	12.24	14.99	15.25
Fe2O3	0.88	1.26	0.68	0.53	0.94	0.57	2.39	3.12
FeO	3.22	4.80	3.16	2.78	0.46	1.32	10.13	8.88
MnO	0.08	0.13	0.07	0.07	0.01	0.03	0.21	0.20
MgO	2.46	4.01	2.04	1.71	0.06	0.20	7.05	7.25
CaO	4.55	5.99	4.11	3.73	0.64	0.78	8.59	8.25
Na2O	3.54	3.68	2.89	2.96	3.19	2.90	3.79	3.60
K2O	3.24	1.80	3.06	3.54	5.92	5.17	1.24	0.98
P2O5	0.17	0.19	0.13	0.12	0.00	0.04	0.86	0.76
H2O+	0.87	1.11	0.72	0.80	0.19	0.79	3.31	3.37
CO2	0.11	0.04	0.13	0.08	0.09	0.07	0.07	0.06
SO3	0.04	0.03	0.04	0.03	0.03	0.03	0.03	0.04
FeS2	0.00	0.00	nd	nd	0.00	0.00	0.01	0.00
TOTAL	100.53	100.57	100.04	100.01	99.79	97.38	101.08	98.95
Sc (ppm)	<9	11	14	11	<9	<9	20	14
V	90	115	80	65	8	18	290	250
Co	8	14	12	10	<8	<8	50	58
Ni	17	29	19	16	8	7	56	64
Cu	16	11	12	7	13	13	30	25
Zn	44	64	62	67	20	30	103	92
Ga	15	17	18	18	21	18	19	21
As	<20	<20	<20	<20	<20	<20	<20	<20
Rb	142	138	145	170	320	333	76	64
Sr	346	266	320	340	31	60	366	411
Y	20	30	25	22	60	57	47	40
Zr	130	136	155	145	133	149	354	313
Nb	3	6	10	9	11	8	11	9
Mo	<5	<5	<5	6	<5	<5	<5	<5
Sn	<9	<9	<9	<9	9	<9	<9	<9
Ba	600	230	500	520	220	270	310	330
La	42	<20	44	35	72	52	<20	<20
Ce	81	36	88	61	140	100	85	67
Nd	44	43	32	21	98	68	64	60
W	<10	<10	<10	<10	<10	<10	11	11
Pb	20	<10	18	21	44	25	<10	<10
Bi	6	6	<5	<5	5	<5	8	7
Th	26	<10	31	21	43	39	<10	<10
U	15	<10	<10	<10	14	20	<10	<10
FeOt*	4.01	5.93	3.77	3.26	1.31	1.83	12.28	11.69
ASI	0.860	0.817	0.936	0.951	0.972	1.039	0.646	0.694
K/Rb	189.4	108.3	175.2	172.9	153.6	128.9	135.4	127.1

* FeOt is total iron expressed as FeO. ASI is alumina saturation index (molar Al2O3/(CaO+Na2O+K2O).

50 mm), with needles (≤ 30 mm long) and angular clots of black tourmaline. Dyke margins are sharp, usually fairly straight, and intersect with sharp corners. In places, irregularities in opposite dyke walls can be matched (pl. 5). Locally the proportions of pink granite dykes and adamellite country rock are about equal, with the latter partly occurring as angular stoped blocks, from a few tens of millimetres to metres across, in the pink granite. These features indicate dilational emplacement, and suggest that the adamellite

was solid and capable of brittle fracture at the time of emplacement of the pink granite dykes.

The tip of a small headland about 600 m south of Lagunta Creek is composed of pinkish, slightly porphyritic to seriate granite with minor biotite. Pink feldspar phenocrysts (5–30 mm) and equant quartz phenocrysts (≤5 mm) both grade into the relatively coarse (1–3 mm) groundmass. This rock type appears to be a textural variant of the equigranular pink granite further north. To the
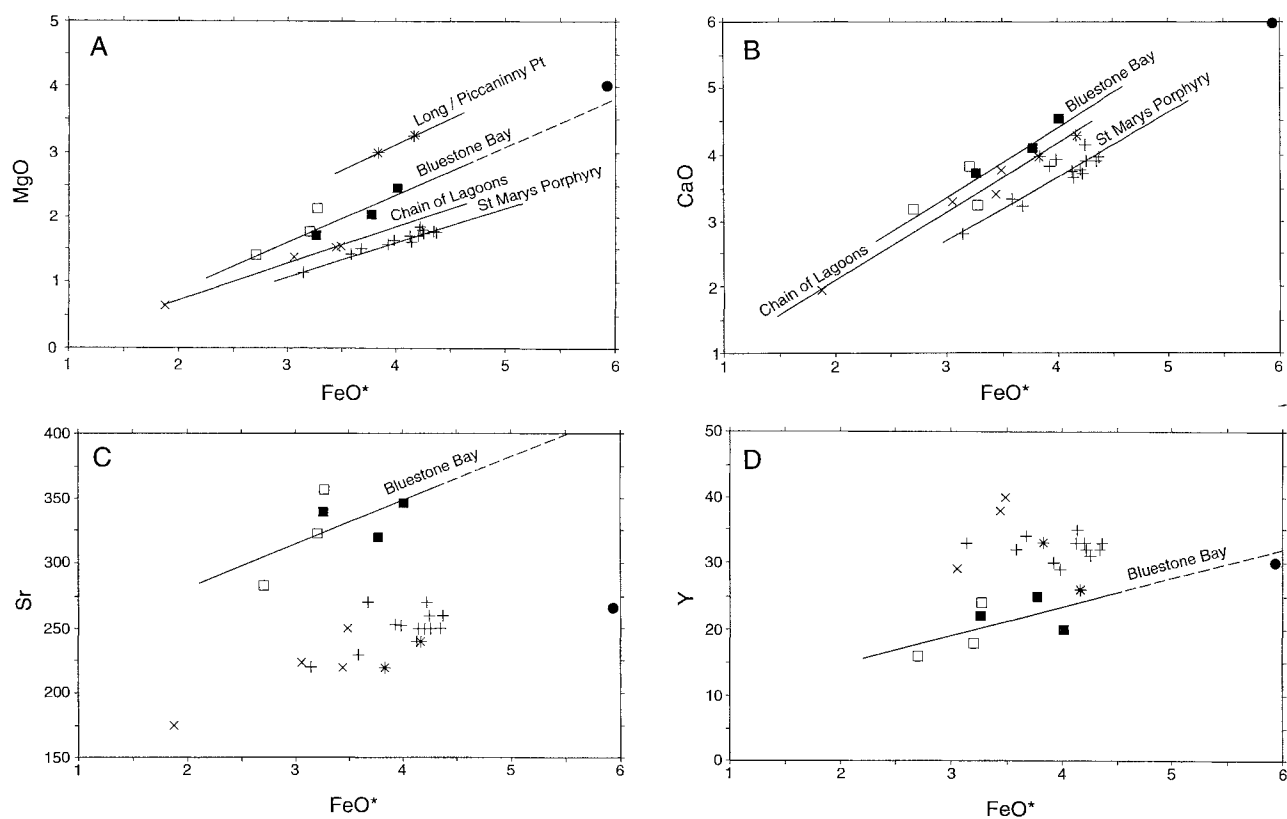
FIG. 4 — *Selected two element variation diagrams for hornblende-bearing adamellite/granodiorites from central eastern Tasmania: Bluestone Bay Suite (■ — this paper, □ — previous data), enclave LC5 (●), Long Point and Piccaninny Point (∗), Chain of Lagoons (Piccaninny Creek)(×) and St Marys Porphyry (+). Regression lines, where well-defined, are also shown. See text for further discussion and data sources. (A) MgO against total iron. (B) CaO against total iron. (C) Sr against total iron. (D) Y against total iron.*

south of the headland, which is transected by a dyke-like body of distinctive granite porphyry (see below), there is an irregular contact against enclave-bearing adamellite which contains abundant dykes of pink granite and related pegmatitic and leucogranitic veins. A complex area of intensely veined adamellite and one or more small intrusions of similar pink seriate granite extends southward for 80 m to the northern end of the third sandy beach.

More outcrops of similar pink to brown, porphyritic to seriate, usually well-jointed felsic granite intrude adamellite near a headland 1 km from Lagunta Creek. Contacts are usually interfingering, with dykes and veins of pink leucocratic granite extending into and throughout the adamellite exposures.

Further south, adamellite is absent, and almost continuous coastal exposures of pink granite and its textural variants extend to Cooks Beach.

Petrography

A sample (LC7) from about 350 m south of Lagunta Creek consists of an allotriomorphic intergrowth of mainly anhedral quartz (1–3 mm), anhedral, turbid perthitic feldspar and anhedral to subhedral, turbid, weakly zoned plagioclase (probably largely albite). Mafic minerals are sparse (<1 %) and mainly comprise ragged flakes (≤ 2.5 mm) of biotite (a pale yellowish brown, b and c dark brown to nearly opaque) partly altered to chlorite, but there is also minor interstitial biotite with different pleochroism (a pale brownish yellow,

b and c dark green). Accessory minerals include zircon and rounded to nearly square opaque grains (0.15–0.8 mm), which are larger and more abundant than in the adamellite. Slightly elongate euhedra (<0.4 mm) of an orange-brown material may be altered allanite.

Sample LC7 has a high magnetic susceptibility of about 5×10^{-3} SI, suggesting that the opaque mineral is magnetite. This may be a local characteristic, as apparently similar pink to red granite outcrops at Coles Bay township, Cape Tourville lighthouse, the eastern headland of Bluestone Bay, and the southern end of Friendly Beaches gave very much lower values (< 0.1×10^{-3} SI).

Geochemistry

The rock (LC7) has a highly felsic, mildly metaluminous composition. Its pseudomode plots as alkali feldspar granite (fig. 3), since plagioclase is essentially albite. High Rb (>250 ppm) and low Sr (<50 ppm) identify it as a fractionated granite, although Ba is a little higher than the suggested 200 ppm limit. In addition to the metaluminous character, its negligible P_2O_5 and relatively high rare earth elements (REE), Th, Y and Pb are characteristic of fractionated I-types (Chappell & White 1992). This is due to the low solubility of apatite in metaluminous melts, which results in the early removal of P_2O_5 from the liquid; thus monazite does not crystallise and REE and Th are concentrated in the liquid (e.g. Sawka *et al.* 1990). In felsic I-type granites, REE mostly occur in allanite (e.g. Bea 1996).

PLATE 4
Dilational intrusion of pink alkali feldspar granite, stoping blocks of grey adamellite, about 500m south of Lagunta Creek. The contacts have been outlined for clarity. The diameter of the lens cap is 50mm.
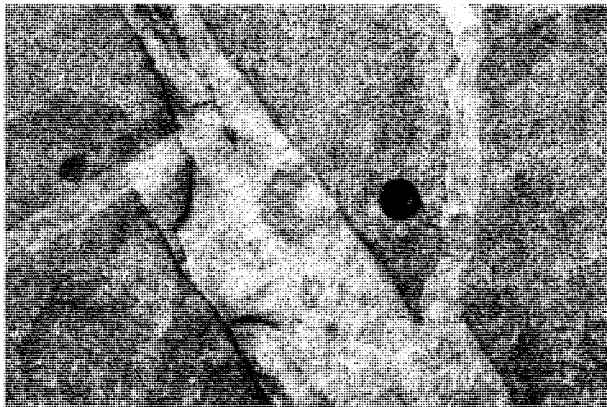

PLATE 5
Close-up showing dilational intrusion of pink alkali feldspar granite into grey adamellite. Lens cap 50 mm diameter.

PLATE 6
Irregular contact of dolerite dyke, cross-cutting earlier veins of aplite veins within adamellite, near mouth of Lagunta Creek.

Comparison with Other Eastern Tasmanian Granites

More extensive sampling (data of B. W. Chappell and others, available in MRT "ROCKCHEM" database) shows that similar felsic fractionated I-type granite is widespread on Freycinet Peninsula and extends to the eastern part of Schouten Island. It is proposed to assign these granites to the Freycinet Suite.

The only other felsic fractionated I-type granites in the region are from the southern part of the Ben Lomond granite (Chappell & White 1992; J.L. Everard, pers. obs.) and the Mt Stronach alkali feldspar granite of the Scottsdale Batholith (Robinson 1982, McClenaghan *et al.* 1982). The Ben Lomond granite in particular shows some similarities to the Freycinet Suite, such as high Y, Ce and Th and low ASI and P_2O_5, but its spatial separation and slightly younger Rb/Sr age (c. 362 Ma adjusted for new decay constants, McDougall & Leggo 1965) probably preclude a direct correlation. Granites of the Ile des Phoques, Maria Island and Deep Glen Bay (Clarke & Baillie 1984, M.P. McClenaghan and J.L. Everard, pers. obs.) are, in contrast, felsic fractionated S-types.

LEUCOGRANITE AND APLITE DYKES

Dykes of off-white to very pale grey, aphanitic aplite are fairly common within the adamellite at Lagunta Creek. They are variable in width (typically 15–80 mm) and locally pinch out. They have sharp contacts and locally truncate or dilationally transect the mafic enclaves, but terminate against the dolerite dyke (pl. 6). This establishes an order of intrusion, and also indicates that the enclaves are older than, and not directly related to, the dolerite dyke. In one place a small fault, with a throw of about 45 mm, offsets an aplite dyke.

On a small headland about 150 m south of Lagunta Creek, adamellite is cut by a 350–400 mm wide dyke of off-white to pale-grey, pale-pink to red weathering, porphyritic leucogranite. Small oblong phenocrysts of dull white (potassium?) feldspar (5–20 mm) and smaller ($\leq$ 5 mm) equant quartz phenocrysts are somewhat sparsely scattered in a fine-grained leucocratic groundmass containing very little biotite. Contacts with the surrounding adamellite are sharp and slightly wavy to curved, and truncate enclaves within it. Thin irregular to curved aplite veins (a few millimetres to 10 mm wide) shoot off the leucogranite dyke for several metres into the adamellite, in places transecting enclaves without lateral displacement.

Further south, similar leucogranite and aplite can be seen to originate in the pink granite and occur as dykes and diffuse segregations within it. Thus, they belong to the same intrusive phase, which is younger than the adamellite.

Petrography

In thin section, a sample (LC8) of porphyritic leucogranite resembles the main pink granite. Phenocrysts of quartz are set in an allotriomorphic quartz-perthite intergrowth containing rare biotite (pleochroic from very dark brown to almost colourless) and substantial amounts of opaque accessory minerals (probably magnetite). Also like the pink granite, the hand specimen has a high magnetic susceptibility (about 4×10^{-3} SI).

GRANITE PORPHYRY

This rock type occurs at two localities. The northernmost occurrence is about 600 m south of Lagunta Creek, where a north–south trending body, possibly a dyke about 15 m wide, is exposed over a strike distance of about 35 m on a small headland.

The rock is a dark-grey, reddish-brown to pink weathering, visually striking porphyritic granite, containing very abundant phenocrysts of feldspar (10–40 mm long) and globular quartz (≤ 5 mm), together with small clots of biotite (to 3 mm) in a grey fine-grained leucocratic groundmass. There is a preferred direction of alignment of the feldspar phenocrysts at an azimuth of about 10°, approximately parallel to the strike of the body. No enclaves, dykes or veins are present.

Enclave-bearing adamellite, veined by pink leucogranite, lies on the eastern side of the porphyry, but the contact is obscured beneath beach boulders (of mainly granite porphyry) on the shore, and soil behind the headland. At the northern end of the "dyke", the western contact with a pinkish, less porphyritic to seriate granite trends at about 170° to 190° but is locally slightly wavy to irregular. About 25 m to the south, on the south side of the headland and west of the porphyry, a small (less than 10 x 10 m) body of grey enclave-bearing adamellite is intensely veined by pink leucocratic granite offshoots of the seriate granite to the north. Thus, the porphyry may be later than, although possibly related to, the pink seriate granite.

Similar granite porphyry occurs 800–900 m south of Lagunta Creek at the southern end of the third sandy beach. Here grey adamellite occurs behind the beach to the northeast; the contact probably strikes at about 170° and is subvertical or dips very steeply to the west. The porphyry has a grey chilled margin 20–50 mm wide, against (to the east) a pink microgranite about 100 mm wide; sand obscures the actual contact with adamellite 1.5 m further east. These relationships are consistent with the porphyry being younger than the adamellite. About 40 m southwest of this locality, the porphyry body passes southward to a small, poorly exposed outcrop of adamellite. Here the contact is obscured, but possibly strikes at about 135°.

Petrography

In a thin section of granite porphyry (sample LC6), the quartz phenocrysts are clear, rounded euhedra and slightly embayed subhedra, whilst both potassium feldspar and sodic plagioclase phenocrysts are turbid and euhedral. The latter contain numerous small inclusions of secondary white mica. Biotite (α pale brownish yellow, β and χ dark green) occurs as small euhedral to ragged phenocrysts, irregular clots and as inclusions in quartz and feldspar phenocrysts. It is, therefore, an early crystallising mineral, although now partly altered to chlorite and muscovite. Zircon, monazite and opaque grains are abundant as inclusions within biotite. The groundmass consists of fine-grained (0.02–0.05 mm) quartz and feldspar, with subordinate splinters of partly altered biotite.

The hand specimen is essentially non-magnetic (susceptibility about 0.1×10^{-3} SI).

Geochemistry

The granite porphyry is not quite as felsic as the pink granite LC7 (lower SiO_2, higher total FeO, TiO_2, MgO and CaO), and the pseudomode plots as granite (*sensu stricto*) (fig. 3). Although Rb is slightly higher, so are Sr and Ba, and the rock is probably less fractionated. This is consistent with lower to slightly lower REE, Y, Th and Pb, and higher (but still very low) P_2O_5. Although weakly peraluminous, there is little doubt that this rock is also an I-type.

DOLERITE DYKE

Near the mouth of Lagunta Creek, a conspicuous black dolerite dyke intrudes the grey adamellite (pl. 1). At its northern end, where it disappears beneath sand at the southern end of Hazards Beach, it is about 6.5 m wide. It can be followed southward (trending at about 165°) diagonally across the shore platform for about 70 m until it disappears due to poor inland exposure.

Dyke margins are chilled for about 50 mm from the contacts, but the adjacent adamellite is uniform in appearance right up to the contact and appears unaffected by the dolerite. The central part of the dyke has a grain size of typically 0.5–1 mm but is locally coarser-grained and very feldspathic, with plagioclase laths 1–3 mm long grading up to a few microphenocrysts 5–10 mm long and larger, in a sea-green weathering mesostasis. Sporadic (< 1% by volume) but large and conspicuous plagioclase megacrysts (pl. 7), typically measuring 10–30 x 5–20 mm but up to 140 x 50 mm, are more common in the northern part of the dyke, and in its centre rather than near its margins. They are mostly oblong to rhomboid euhedra and subhedra with rounded corners, and are off-white to pale pink, sometimes with clear cores, or clear throughout.

The eastern (landward) contact of the dyke is sharp and exposed continuously for 9 m, and intermittently for a further 18 m. It strikes at 165° and dips at 75° to 85° to the east but is locally irregular. At some irregularities, fingers and offshoots of dolerite (one 130 mm long) extend into the adamellite.
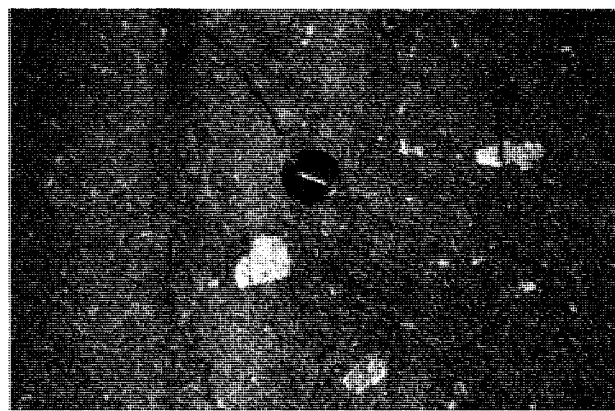

PLATE 7

Close up of dolerite dyke showing plagioclase megacrysts. Lens cap 50 mm diameter.

The western (seaward) contact is better exposed, nearly completely so for the most northern 35 m of the dyke. It has a similar overall trend and steep generally eastward dip but is more irregular than the eastern contact. Although always sharp, the contact varies from locally straight (on a scale of a few millimetres) for up to a metre or more with abrupt changes in direction, to elsewhere highly irregular. In several places, it is clearly controlled by jointing within the host adamellite.

At several places near the western contact, irregularly shaped, angular-stoped blocks of adamellite up to 0.5 m long occur within the dolerite. In some cases, their shape can clearly be matched with irregularities in the adjacent wall of the dyke, indicating dilational emplacement.

Both contacts, but especially the western one, show a tendency to step abruptly eastward as one follows them to the north (i.e. dextrally). At each of two such places near the northern end of the western contact, a finger of dolerite, initially about 0.5 m wide, shoots off northward for several metres into the adamellite (pl. 8). The two fingers are subparallel and linked by narrow cross-dykes. Each finger gradually narrows northward and tapers away, but the trends continue as joints within the adamellite. About 7 m west of the main dyke, another narrow (70–150 mm wide) dyke occurs within the adamellite. Its strike is irregular, and to the south it trends at about 150° towards the main dyke, which it probably joins beneath soil cover.

In several places, the contacts of the dolerite dyke abruptly crosscut mafic enclaves within the host adamellite. Aplite and leucogranite veins are also abruptly truncated against the contact (pl. 6), and nowhere are found within the dolerite, indicating that the latter is younger.

The sharp angular contacts of the dyke, their control by jointing in the host, the chilled margins and the stoped blocks suggest that the adamellite had already essentially cooled and solidified at the time of dyke emplacement.

Petrography

A sample (LC3) from the centre of the dyke consists of a subophitic intergrowth of weakly zoned, pinkish titanaugite granules ($\leq$ 1 mm), turbid plagioclase and ragged opaques (magnetite?), together with scattered equant pseudomorphs of former olivine ($\leq$ 0.8 mm across), now replaced by fine-grained, colourless and nearly isotropic serpentine and magnetite dust. Secondary chlorite, epidote and actinolite are also present. Some large (1 mm) crystals of a mineral (probably titanite) with very high relief and birefringence are later than plagioclase. The plagioclase megacrysts are difficult to extract, but a chip gave an electron microprobe analysis of $An_{64.5}Ab_{34.1}Or_{1.4}$ (calcic labradorite).

The chilled margin (sample LC1) is mineralogically similar. Laths of plagioclase ($\leq$ 0.3 mm long) grade down to an intergranular groundmass of plagioclase, titanaugite granules and generally elongate opaques ($\leq$ 0.05 mm long), together with secondary chlorite and actinolite. Minute fragments of a brown pleochroic mineral (probably biotite) are closely associated with chlorite. Abundant amygdales ($\leq$ 0.5 mm) are filled with strongly pleochroic (yellow to green) chlorite with anomalous blue to purple birefringence.

These samples have a high magnetic susceptibility (23–25 x 10^{-3} SI), consistent with the presence of abundant magnetite.

PLATE 8

Offshoot of dolerite dyke from western contact, intruding along joints in adamellite, near mouth of Lagunta Creek. The hammer is 400 mm long.

Geochemistry

There is little difference between analyses (table 1) of the chilled margin (LC1) and the central part of the dyke (LC3). The dolerite has an alkalic major element chemistry, and is normatively a hawaiite (ne < 5%; plagioclase normatively andesine). Low MgO, Mg# (54.7 and 56.7 at Fe_2O_3/FeO = 0.20) and Ni indicate that the dolerite is not an unmodified partial melt of primitive mantle, but has undergone olivine $\pm$ pyroxene fractionation. Other notable features of the major element chemistry are rather high Al_2O_3 (consistent with the presence of probably cognate plagioclase megacrysts, the likely crustal liquidus phase) and rather high TiO_2.

The main features of the incompatible trace element geochemistry are very low Nb (especially for an undersaturated rock with alkalic major element chemistry), low Sr, high Y and low K/Rb. This is clearly seen in a primitive mantle normalised spider diagram of available trace elements (fig. 5), which displays negative Nb and Sr anomalies relative to adjacent elements of similar incompatibility. Whilst low Sr may simply reflect fractionation of plagioclase, Nb is unlikely to have been depleted by either fractionation or alteration. By comparison, the average chilled margin of Tasmanian Jurassic dolerite (Hergt *et al.* 1989) is much lower in TiO_2, P_2O_5, Zr and Nd, whilst Triassic hawaiite from near St Marys (Everard 1987) lacks a negative Nb anomaly.

The dolerite dyke may be part of a large swarm that is widespread in northeast Tasmania, but best developed in the Blue Tier–Great Musselroe River area (e.g. McClenaghan & Williams 1983). However, similar dolerite dykes occur from south Maria Island (microdiorite of Clarke & Baillie 1984) to at least the northern tip of Flinders Island (J.L. Everard, pers. obs.). Their geochemistry (e.g. McClenaghan *et al.* 1982, 1992, McClenaghan 1984, Baillie 1986, MRT ROCKCHEM database) is highly variable, ranging from basaltic to andesitic (SiO_2 46–60%) and from tholeiitic and weakly alkaline. They pre-date the Late Carboniferous to Middle Triassic Parmeener Super-group but intrude both the Ordovician-Early Devonian Mathinna Group and the Middle-Late Devonian granites. However, one tholeiitic dyke at Lady Barron, Flinders Island is transected by quartz feldspar porphyry, suggesting at least locally a syn-granitic Devonian age (Baillie 1986: 29).
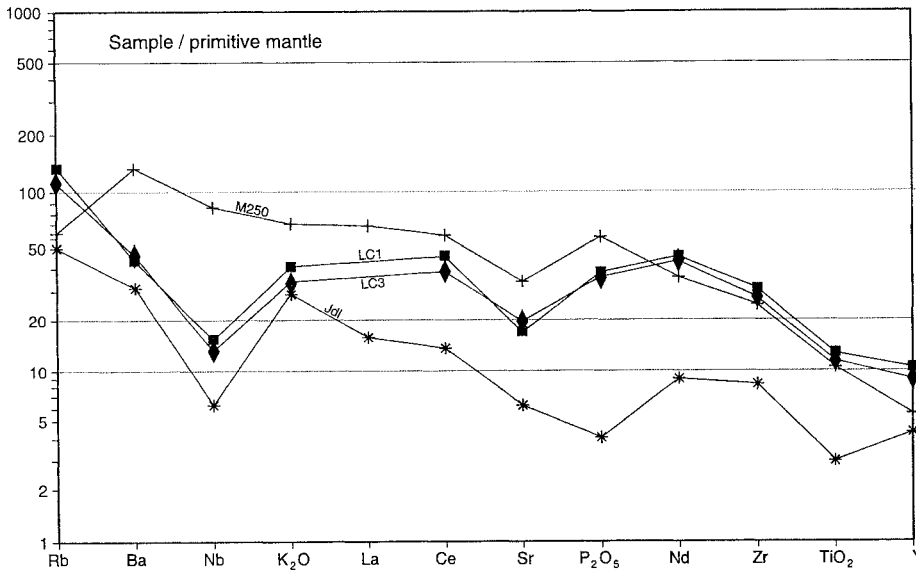
FIG. 5 — Primitive mantle normalised incompatible element spider diagram (after Sun & McDonough 1989), for dolerite dyke at Lagunta Creek (samples LC1, LC3). Average chilled margin of Tasmanian Jurassic dolerite (Hergt et al. 1989) and Triassic basalt (M250) at St Marys (Everard 1987) also plotted for comparison.

The Lagunta Creek dyke, which is younger than one of the youngest eastern Tasmanian granites (c. 373 Ma), is the one of the most mafic (the lowest SiO_2) and most alkaline (high Na_2O+K_2O) representatives yet analysed. Trace element data for other dykes are limited (especially for rare earth elements) but two dykes from the Pyengana area also display negative Nb anomalies (relative to K, Ba and Ce) on mantle-normalised spider diagrams (J.L. Everard, pers. obs.).

Soesoo & Nicholls (1999) have reported similar negative Nb anomalies from certain mafic rocks associated with Devonian Lachlan Fold Belt granites in eastern Victoria, and suggested, by analogy with modern volcanic rocks, a subduction-related, island arc or continental margin tectonic setting for them. Alternatively, it could be a crustal signature, indicating either a component derived by direct melting of continental crust (cf. Morris *et al.* 2000), or indirect contamination of the mantle source by subducted pelagic sediments (cf. Hergt *et al.* 1989).

DISCUSSION AND CONCLUSIONS

The similarity of the grey enclave-bearing hornblende adamellite at Lagunta Creek to the body exposed 3 km to the north at Wineglass Bay suggests that they are part of the same pluton. More adamellite occurs 5 km to the northwest, between Sleepy Bay and Bluestone Bay (fig. 1). These adamellites appear to belong to the distinctive Bluestone Bay Suite and, although the oldest granites in the district, are dissimilar to and younger than other I-type granodiorite/ adamellite intrusions of the Blue Tier Batholith.

A contact, accompanied by numerous quartz veins, with an altered pink granite is exposed on the headland (FP105345) between Sleepy Bay and Carp Bay. At Bluestone Bay, the eastern headland comprises pink fine-grained to pegmatitic felsic granite, whereas to the northwest there is more enclave-bearing grey adamellite/granodiorite. At each of these localities, as at Coles Bay (Groves 1965) and Lagunta Creek, the adamellites are intruded by pink granite, or by aplite and leucogranite dykes related to it. This uniform order of intrusion throughout the district is consistent with the Rb/Sr isotopic ages. The now disjunct

bodies of hornblende adamellite are probably eroded remnants of a roof pendant that was intruded from below by younger pink granite, a felsic fractionated I-type. The coastal section south of Lagunta Creek, in particular, appears to represent a thin roof pendant of adamellite, intensely intruded and stoped by the pink granite. Some of the smaller adamellite bodies may be disconnected rafts.

Chappell *et al.* (1991) listed the Coles Bay, Hazards, Freycinet (south of the Hazards isthmus) and Schouten granites as separate felsic I-type plutons, whilst a small body at Bluestone Bay was considered to be an unfractionated mafic I-type. However, all the felsic bodies (Freycinet Suite) are chemically similar, although the Hazards body is the most fractionated (Chappell & White 1992). Furthermore, granite bedrock is probably continuous below sea level beneath both the Hazards isthmus and Schouten Passage. Concealed screens of country rock are unlikely to be present, as elsewhere in eastern Tasmania hornfelsed Mathinna Group is commonly a resistant, topographically prominent lithology.

The later dolerite dyke at Lagunta Creek is a fractionated hawaiite with an unusual crustal and/or subduction-related trace element signature. Further work on other granite-associated mafic rocks in eastern Tasmania and elsewhere is necessary to evaluate its significance. However, it may represent the late escape of a small, evolved volume of mantle-derived magma that previously underplated the lower crust and induced partial melting to generate the "infracrustal" I-type granites.

Partial melting of lower continental crust by the intrusion of, or crustal underplating by, mantle-derived mafic magmas has been assigned an important role in granite petrogenesis, based on both field observations in Tasmania (McClenaghan 1984) and elsewhere in the Lachlan Fold Belt (e.g. Soesoo & Nicholls 1999) and on theoretical grounds (e.g. Huppert & Sparks 1988). However the possibility and nature of a mantle-derived chemical component in the granites themselves remains controversial (cf. Collins 1998 *vs* Chappell 1996, Chappell *et al.* 1999, and references therein).

ACKNOWLEDGEMENTS

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