The nature and origin of enclaves in four peraluminous granitoid intrusions from the Meguma Zone, Nova Scotia

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Four mid- to late Devonian peraluminous granitoid intrusions in the Meguma Zone of southwestern Nova Scotia contain abundant enclaves typical of orogenic granitoid bodies. The Barrington Passage and Shelburne plutons contain an assemblage of granoblastic metasedimentary hornfelsic enclaves (49%) that have aluminosilicate porphyroblasts, and surmicaceous enclaves (51%) that consist of > 70% decussate biotite with apatite and zircon inclusions. Metasedimentary enclaves predominate in the Port Mouton Pluton and the South Mountain Batholith (52%), but these intrusions also contain abundant microgranular and coarse-grained granitoid enclaves (25% and 23%, respectively) that have peraluminous mineral assemblages and tonalitic to leucomonzogranitic compositions. High concentrations of metasedimentary enclaves at the country rock contacts suggest that they probably formed as xenoliths stoped from the Meguma Group. No xenoliths reflect palaeosomes of basement gneiss from the protolith of the granitoid melts, but the surmicaceous enclaves may be restite in the Port Mouton Pluton and the South Mountain Batholith; in the Barrington Passage tonalite they probably represent melanosomes after incorporated xenoliths. Microgranular and coarse-grained granitoid enclaves apparently represent stoped autoliths of both quenched and slowly cooled granitic melt in the multiply-intrusive granitoid bodies.

Quatre intrusions granitiques du Dévonien supérieur dans la zone de Meguma, dans le sud-ouest de la Nouvelle-Écosse, renferment des enclaves abondantes typiques de masses granitiques orogéniques. Les intrusions ignées de Barrington Passage et de Shelburne renferment un assemblage d'enclaves cornéennes métasédimentaires granoblastiques (49 %) comprenant des enclaves surmicacées et porphyroblastes d'aluminosilicates (51 %) constituées de moins de 70 % de biotite entrecroisée d'inclusions d'apatite et de zircon. Les enclaves métasédimentaires prédominent dans le pluton de Port Mouton et le batholite de South Mountain (52 %), mais ces intrusions renferment en outre des enclaves granitiques microgrenues et à gros grains (25 % et 23 % respectivement) comportant des assemblages minéraux hyperalumineux et dotées de compositions tonalitiques à leucomonzogranitiques. Des concentrations élevées d'enclaves métasédimentaires aux surfaces de contact encaissantes laissent supposer qu'elles se sont probablement formées en tant que xénolites abattus du groupe de Meguma. Aucun xénolite ne correspond aux paléosomes du gneiss du socle provenant du protolite des magmas granitiques, mais les enclaves surmicacées pourraient être des mélanosomes dans le pluton de Port Mouton et le batholite de South Mountain. Dans la tonalite de Barrington Passage, elles représentent probablement des mélanosomes apparus après l'incorporation des xénolites. Les enclaves granitiques microgrenues et à gros grains représentent apparemment des enclaves syngénétiques de magma granitique tant figé que doucement refroidi dans les masses granitiques intrusives multipli.

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INTRODUCTION

The Meguma Zone of southwestern Nova Scotia represents the easternmost allochthonous terrane of the Appalachian Orogen, and is characterized by flyschoid metapelite and metawacke of the Cambrian to Early Ordovician Meguma Group (Schenk, 1991; Fig. 1 and inset). The polyphase Acadian Orogeny folded and metamorphosed the Meguma Group between 410 and 370 Ma (Keppie and Dallmeyer, 1987), and Late Devonian peraluminous granitoid bodies intruded the Meguma crust between 385 and 370 Ma (Reynolds *et al.*, 1987; Clarke *et al.*, 1993). The Barrington Passage and Shelburne plutons consist predominantly of tonalite and monzogranite (respectively), whereas all other intrusions are polyintrusive suites containing more diverse tonalitic to leucogranitic lithologies (Rogers, 1984; Abbott, 1989; Clarke *et al.*, 1993). Granitoid melts ascended by a combination of both stoping and forceful emplacement (e.g., Clarke and Muecke, 1985; Douma, 1988; Ham, 1988), and Sr-Nd isotopic analysis of the South Mountain Batholith suggests the presence of ortho- and paragneissic protoliths in the basement below the Meguma Group (Clarke *et al.*, 1988; MacDonald *et al.*, 1990; Eberz *et al.*, 1991). Although the Meguma Group does not represent a viable source for the granitoid melts, enriched $\delta^{34}S$ values (> 5‰) suggest that it is a contaminant in contact-proximal granitoid lithologies of the batholith (Poulson *et al.*, 1991).

Studies of the distribution and characteristics of enclaves in orogenic granitoid rocks can test these putative sources and intrusive mechanisms (Didier *et al.*, 1982; Barbarin and Didier, 1992a). Table 1 shows the nomenclature for enclaves, indicates their supposed origins, and summarizes criteria for their identification and classification. The nature of the enclave assemblage in the Meguma Zone granitoid rocks is poorly known. Although regional mapping surveys report abundant enclaves, Jamieson (1974) provided the only detailed study, and focused on metasedimentary xenoliths in a local part of the South Moun-

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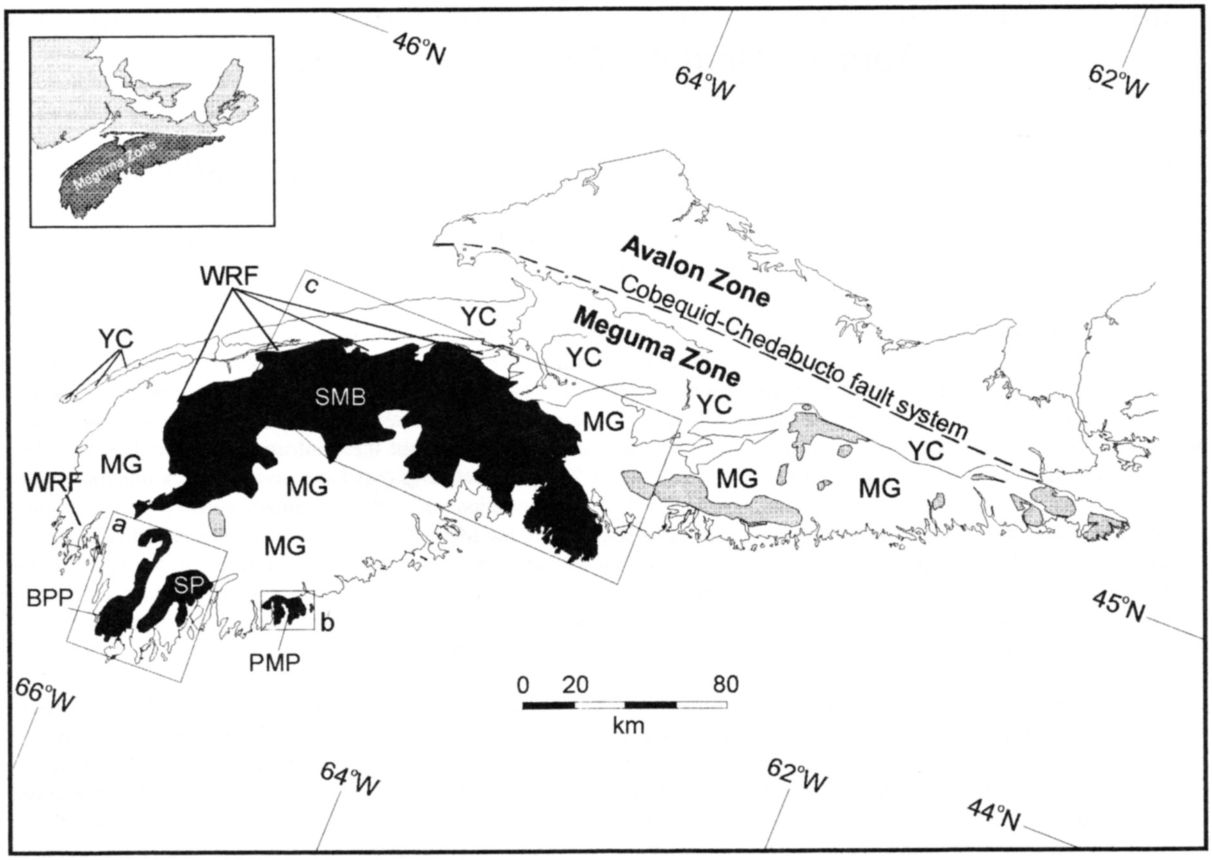

Fig. 1. Map of Nova Scotia showing the Meguma and Avalon zones and the Meguma Zone peraluminous granitoids (shaded in grey), with the intrusions included in this study emphasized in black. BPP = Barrington Passage Pluton, MG = Meguma Group, SP = Shelburne Pluton, PMP = Port Mouton Pluton, SMB = South Mountain Batholith, WRF = White Rock Formation, YC = younger cover, a = location of Figure 2, b = location of Figure 4, c = location of Figure 6.

tain Batholith. The current paper documents the first reconnaissance study of enclaves preserved in the Barrington Passage, Shelburne, and Port Mouton plutons, and the South Mountain Batholith (Fig. 1). It describes and classifies the enclaves discovered in these four intrusions, proposes origins for them, and suggests their significance for granitoid petrogenesis.

Enclaves in Four Meguma Zone Granitoid Intrusions

Sampling Strategy

All known outcrops within the Barrington Passage, Shelburne, and Port Mouton plutons were sampled, and so the number of samples from these intrusions approximately equals both the abundance and variety of exposed enclaves and the amount of exposed granitoid. In the South Mountain Batholith, sampling relied on 1:50,000 scale maps published by the Nova Scotia Department of Natural Resources (MacDonald *et al.*, 1986), which report both the presence and relative abundances of enclaves within the batholith. At each locality, every enclave with a different appearance was collected and classified in the scheme proposed by Didier (1973) (Table 1). A summary of the shapes, sizes, and classifications for 140 enclave samples collected from outcrops notably rich in enclaves appears in Table 2, and specific details regarding the abundance, distribution, and nature of enclaves in each intrusion are given below.

The Barrington Passage Pluton

The Barrington Passage Pluton forms a homogeneous intrusion of porphyritic tonalite in the southernmost onshore part of the Meguma Zone and contains patchily distributed enclaves (Rogers, 1984; Fig. 2). Concentrated screens of parautochthonous metasedimentary enclaves with sizes up to 500 cm crop out on Cape Sable Island, where they grade into migmatite complexes to the south (Rogers and White, 1984; Fig. 2). Along the western margin of the pluton near Shag Harbour, lenticular metasedimentary enclaves range in length from 20 to 90 cm and rarely exceed 1% of any outcrop by area. Metasedimentary enclaves preserve alternating horizons of foliated biotite and granoblastic quartz and feldspar with pyrite, cordierite, andalusite, and (rarely) garnet (Fig. 3a,b). Surmicaceous enclaves occur away from contacts with the Meguma Group, where they range in size from 7 to 42 cm and locally reach abundances of approximately 2% in monogenic clusters. Most samples superficially resemble the metasedimentary enclaves, except that they have millimetric thicknesses and lie secant on the magmatic flow foliation in the tonalite. All surmicaceous enclaves contain > 70% sieve-tex-

Table 1. Supposed derivations, nomenclature, and characteristics of enclaves in granitoid rocks. Classification scheme summarized after Didier (1973) and Barbarin and Didier (1992a), with descriptive criteria after Didier (1987), Larsen and Smith (1990), Vernon (1983, 1984), Barbarin and Didier (1992a, 1992b), and Bacon (1988).

Enclave lithotype	Derivation	Descriptive nomenclature	Genetic Nomenclature	Characteristics
Metasedimentary	Exocontact or country rocks at depth	Lithologic classification, e.g., metagreywacke	Xenolith or palaeosome	Angular-rounded shapes, medium-coarse grain sizes, sharp-diffuse contacts, and hornfels textures with variable high-temperature metamorphic minerals
Surmicaceous	Exocontact or country rocks at depth	Micaceous or aluminous enclave	Xenolith, melanosome, or restite	Angular-subangular (lenticular) shapes, melanocratic colours, fine-coarse grain sizes, sharp-diffuse contacts, > 90% biotite, muscovite, and aluminosilicate polymorphs
Fine-grained granitoid	Endocontact ?	Microgranular or microgranitoid enclave. Modal mineralogical classifications for granitoid rocks	Autolith, cognate enclave, or cumulate enclave	Subround-ellipsoidal shapes, fine grain sizes and equigranular-inequigranular igneous textures, sharp-diffuse contacts, and granitoid modes. May also be vesicular and have magmatic flow foliations
Coarse-grained granitoid	Exocontact or endocontact	Modal mineralogical classification for granitoid rocks, e.g., biotite tonalite	Xenolith or autolith	Angular-rounded shapes, leucocratic colours, coarse grain sizes, and porphyritic-megacrystic textures with granitoid modes
Mafic igneous	Exocontact or endocontact	Mafic igneous or mafic magmatic enclave. Classified by modal mineralogy	Xenolith or autolith	Angular-ellipsoidal (pillow-like) shapes, melanocratic colours, coarse-fine grain sizes, and diabasic or gabbroic textures. May also have chilled margins and crenulate contacts
Pegmatite, aplite, and vein quartz	Exocontact or endocontact	Classified by texture, mineralogy, and grain size	Xenolith or autolith	Variable characteristics typical of pegmatites, aplites, and massive quartz

Table 2. Summary of the macroscopic characteristics and classifications for enclaves collected in the Barrington Passage, Shelburne, and Port Mouton plutons, and in the South Mountain Batholith.

Intrusion (% of samples collected)	n	Location (abbreviation, geographic coordinates)	Enclave	Colour	Sphericity	Roundness	Length (cm)	Width (cm)	Grain size (mm)
BPP (14%)	6	New Quarry (NQ, 65°35.93' 43°33.24')	MSed	G, DG	0.3-0.5	0.1-0.5	35-99	14-21	0.5-1
			Surm	B, DB	0.3-0.5	0.7-0.9	7-42	7-21	0.15-3
	11	Old Quarry (OQ, 65°37.12' 43°31.36')	Surm	B, BR	0.3-0.5	0.1-0.7	16-32	5-28	0.2-2.5
			MSed	B	0.5	0.7	13	7	0.5-0.75
	3	Shag Harbour (SH, 65°43.15' 43°30.14')	MSed	DG, G	0.5	0.3	20-90	12	0.3-1.0
SP (5%)	2	Birchtown Quarry (BQ, 65°22.96' 43°44.63')	Surm	B, DB	0.1	0.1	3-5	2-3	0.5-0.7
	3	Birchtown intersection (BX, 65°20.92' 43°46.96')	MSed	BR, DB	0.1-0.7	0.3-0.7	8-10	20-50	1-1.5
	2	Shelburne Provincial Park (SPP, 65°20.00' 43°45.10')	MSed	LG	0.3	0.3-0.4	11-20	15-21	0.1-0.3
PMP (21%)	2	Carters Beach (CB, 64°49.63' 43°55.00')	Surm	BR, G	0.1	0.3	25-30	28-31	0.1
	3	Deadmans Rock (DR, 64°46.79' 43°52.43')	ME	DG	0.7-0.9	0.3-0.9	5-30	5-20	0.75-1.5
			CGG	LG, DG	0.5	0.5	45-100	30-89	20-25
	5	Hell Point (HP, 64°46.83' 43°52.32')	MSed	G, DG	0.5-0.9	0.3-0.5	15-31	7-18	0.5-2.5
			ME	LG	0.7	0.9	28	16	0.6-1.8
			CGG	LG	0.5	0.5	25-100	20-98	20-30
	5	Kejimkujik Adjunct (KJ, 64°49.70' 43°50.05')	MSed	DG, LG	0.1	0.1	100-125	21-38	1-5
	14	Saint Catherines River Rd (CR, 64°51.96' 43°52.70')	MSed	DG, LG, DB	0.5-0.7	0.3-0.9	3-23	5-50	0.5-2
			ME	LG	0.7	0.9	28	16	0.6-1.8
SMB (60%)	2	Beechville BV, 63°41.90' 44°37.70')	ME	DG	0.3	0.3	17	7	0.5
			MSed	DG	0.5	0.3	17	8	0.5
	2	Big Indian Lake (BI, 63°56.90' 44°50.73')	Surm	B	0.5	0.1	7	2	0.2-0.75
			ME	P, B	0.5	0.3	17	9	1
	2	Chebucto Head (CH, 63°30.67' 44°70.00')	MSed	G	0.9	0.9	17	12	1
			ME	G	0.5	0.5	7	5.5	0.1-0.2
	1	Dead Brook (DB, 64°10.60' 44°50.00')	MSed	B	0.5	0.5	36	24	0.1
	2	Harrietsfield (HF, 63°38.57' 44°33.19')	MSed	G	0.5	0.7	8	6	0.5
			ME	DG	0.5	0.3	6	1	0.18
	4	Hemlock Hill (HH, 64°15.17' 44°53.24')	MSed	LG, B	0.5	0.6	3-5	2-3	0.1-0.2

Table 2 Continued.

2	Indian Village (IV, 63°53.03' 44°42.27')	MSed	DG	0.7	0.3	3.5	2.5	0.5-1.0
		Surm	LG	0.7	0.7	16	8.5	0.8
8	Lakeside (LS, 63°42.50' 44°38.35')	MSed	B, DG, G	0.7-0.9	0.5-0.9	10-50	10-50	0.5-1.2
		ME	W, G	0.5-0.9	0.3-0.7	6.5-9	5.5-8	0.5-1
		CGG	LG, G	0.8	0.8	8	6	3-6
8	Lequille (LQ, 65°29.00' 44°47.30')	MSed	B, DG, G	0.3-0.7	0.1-0.7	4-16	3-10	0.5-2
		ME	B	0.5	0.7	10	6	0.3
		CGG	DG	0.6	0.5	16	5	5
1	Little Indian Lake (LIL, 63°54.77' 44°42.36')	ME	G	0.9	0.7	200	200	1
5	Long Lake (LL, 63°39.80' 44°37.90')	MSed	B, G, LG	0.3-0.9	0.1-0.9	5-40	5-16	0.5-0.75
		ME	LG	0.7	0.5	10	7	0.5
		CGG	LG	0.9	0.7	10	7	2-20
1	Mill Lake (ML, 63°53.35' 44°42.36')	Surm	DB	0.9	0.7	8	8	0.5-1.5
5	Mount Uniacke (MU, 63°50.18' 44°52.28')	MSed	G, DG	0.5	0.1-0.3	6-9	4-4.5	0.1-0.5
		ME	DG	0.5	0.3	11	5	0.25-0.5
1	New Ross (NV, 64°14.47' 44°46.22')	MSed	GB	0.5	0.1	6	3	1
2	Nine Mile River (NMR, 63°43.78' 44°38.43')	ME	LG	0.5	0.9	21-99	7-60	0.1-0.75
3	Northwest Arm Drive (ND, 63°37.72' 44°37.51')	MSed	G, GD	0.7	0.3	3	5	1
		ME	G	0.5	0.7	9	5.5	1
10	Prospect Bay (PB, 63°47.58' 44°28.13')	MSed	G, DG, LG	0.5-0.9	0.5-0.9	10.5-99	7-70	0.1-1
		ME	B, G	0.5-0.9	0.1-0.9	9-11	7-8	1-2.5
		CGG	G, LG	0.5-0.7	0.5	28-40	30-50	2-20
4	Portuguese Cove (PC, 63°32.00' 44°31.16')	MSed	B	0.5	0.9	17.5	10.5	0.5-0.8
		ME	G, LG	0.5	0.9	28-84	10-30	0.1-1
1	Queensland (QU, 64°10.05' 44°36.90')	MSed	G	0.9	0.3	35	32	1
4	Round Mountain (RM, 64°21.63' 44°54.16')	MSed	B, LG	0.5-0.7	0.3-0.9	7-14	6-7	0.25-1
		ME	B, DG	0.5	0.3-0.5	7	3-4.5	0.1-0.75
10	Salmontail Lake (SL, 64°32.67' 44°50.00')	MSed	DG, LG	0.3	0.3	30-100	20-53	1-2
2	Smiths Corner (SC, 64°11.78' 44°49.59')	MSed	DG	0.5	0.4	5-12	6-18	3-5
2	Timberlea (TIM, 63°45.75' 44°39.60')	ME	B	0.9	0.5	5	5	0.1
		MSed	DG	0.3	0.1	4	1	0.25-0.5
2	Upper Vaughan (UV, 64°11.07' 44°47.02')	MSed	G, P	0.3-0.7	0.3-0.5	6-42	5-28	0.1-1.6

Enclave shape classification (roundness and sphericity) follows the class system that Powers (1953) developed for clastic sedimentary grains. Enclave abbreviations: CGG = Coarse-grained granitoid enclave, ME = Microgranitoid enclave, MSed = Metasedimentary enclave, Surm = Surmicaceous enclave. Colour abbreviations: G = grey, DG = dark grey, LG = light grey, B = buff, BR = brown, DB = dark brown, P = pink, W = white. n = the number of samples collected.

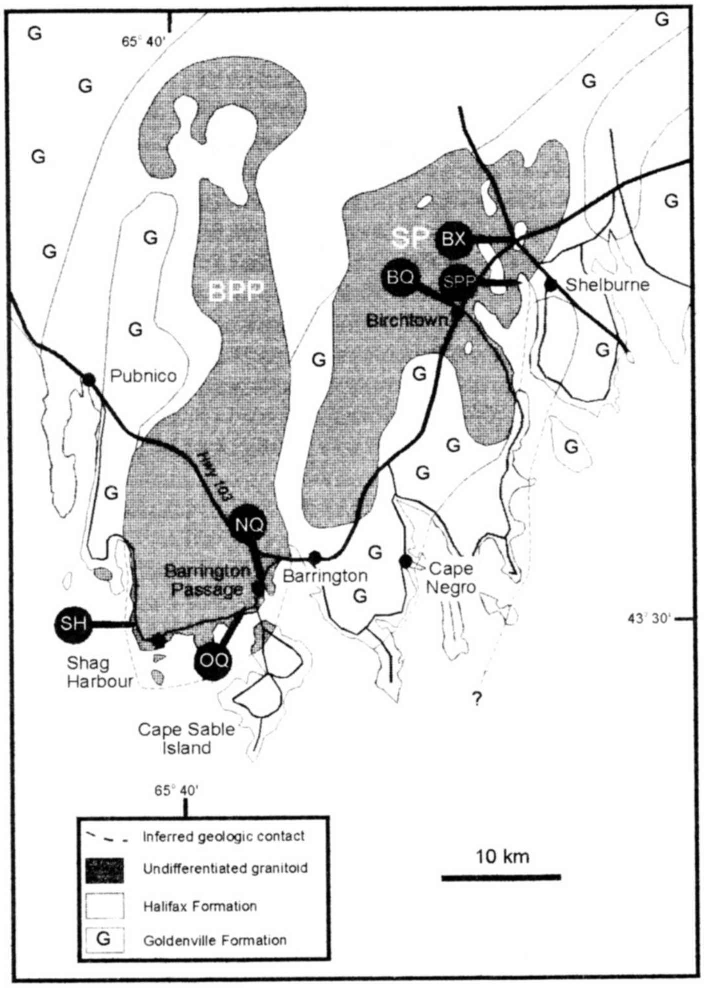

Fig. 2. Sample location map for the Barrington Passage and Shelburne plutons. Modified after Rogers and Barr (1988); refer to Table 2 for sample locality grid references and abbreviations, and Figure 1 for the location of this map in the Meguma Zone.

tured biotite with euhedral apatite and zircon inclusions and trace amounts of cordierite and andalusite (Fig. 3c,d).

The Shelburne Pluton

The Shelburne Pluton is an irregularly shaped body of equigranular tonalite, granodiorite, and predominant monzogranite; a thin zone of Meguma Group metasedimentary rocks separates it from the Barrington Passage Pluton to the west (Rogers and White, 1984; Fig. 2). Metasedimentary and surmicaceous enclaves occur in all lithologies, but they account for less than 0.2% of the available outcrop. Angular to subangular enclaves of fine-grained metapelite range in size from 10 to 50 cm and occur in proximity to Meguma Group roof pendants at the highway intersection northwest of Shelburne (Rogers, 1984; Fig. 2). Along the coast and within a small quarry at the Shelburne Provincial Park, psammitic hornfels enclaves up to 20 cm in diameter have subangular-subrounded shapes and granoblastic textures that resemble their counterparts in the Barrington Passage Pluton. Lenticular surmicaceous enclaves range in length from 3 to 5 cm and occur commonly in Birchtown Quarry. These friable enclaves contain > 90% de-

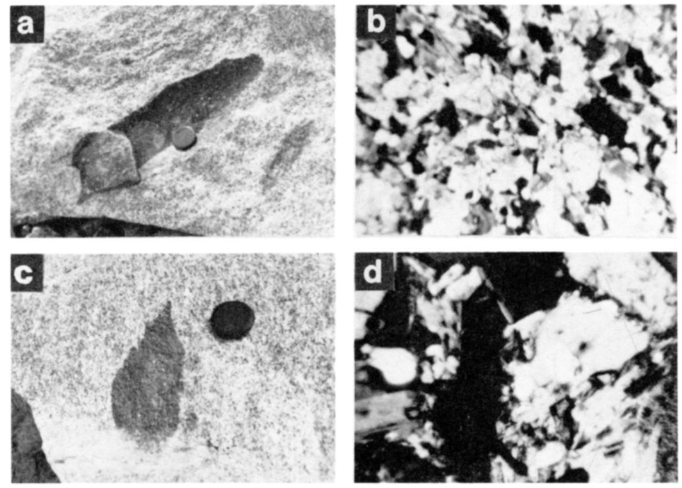

Fig. 3. Enclaves in the Barrington Passage and Shelburne plutons. (a) A typical lenticular metasedimentary enclave at locality NQ. The lens cap is 7 cm in diameter; (b) Microscopic view of the metasedimentary enclave depicted in (a) above. The granoblastic hornfels texture is weakly developed in this sample. Field of view 6 mm (XPL); (c) An ellipsoidal surmicaceous enclave with millimetric thickness at locality OQ. The lens cap is 7 cm in diameter; (d) Photomicrograph of the surmicaceous enclave depicted in (c) above. This sample consists predominantly of decussate biotite, apatite, and zircon, and the euhedral plagioclase porphyroblast (extinct central grain) resembles megacrysts in the host tonalite. Field of view 6 mm (XPL).

cussate biotite with euhedral zircon and apatite inclusions, and some samples also contain euhedral corundum. Unlike analogous enclaves in the Barrington Passage Pluton, they all have centimetric thicknesses and no examples appear texturally and mineralogically intermediate between surmicaceous and metasedimentary enclaves.

The Port Mouton Pluton

The Port Mouton Pluton is an elliptical, multiply-intrusive pluton of tonalite, granodiorite, and monzogranite that crops out south of Liverpool (Douma, 1992; Fig. 4). Large rafts of Meguma Group lithologies up to 35 m long define contact-proximal migmatite complexes in the Kejimkujik Adjunct at Saint Catherines River beach (Douma, 1988), but in the interior of the pluton metasedimentary enclaves represent 1 to 2% of the exposed granitoid and have patchy distributions. These transported enclaves range in diameter from 30 to 50 cm along Saint Catherines River Road (Fig. 4), and they have subangular to subrounded shapes; pelites are dark brown, whereas psammites have grey colours and commonly show biotite selvages at their contacts (Fig. 5a,b). Despite the lower internal abundance of metasedimentary enclaves, a concentrated tonalite breccia at Mcleods Cove (near locality KJ) contains up to 80% garnet-, andalusite-, and cordierite-bearing granoblastic hornfels enclaves up to 20 cm long (Douma, 1988). Surmicaceous enclaves occur only in the monzogranite at Carters Beach, where they form 25 to 30 cm, angular to subangular rafts of foliated biotite that are partially retrogressed to chlorite.

Microgranular igneous enclaves range in diameter from 5 to 35 cm, have subrounded to rounded shapes, and exhibit sharp

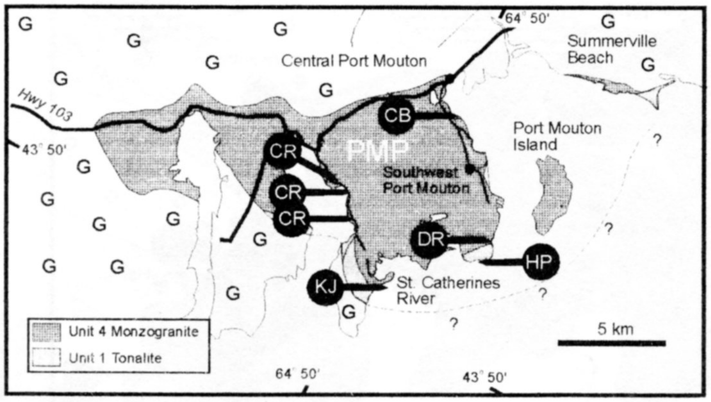

Fig. 4. Sample location map for the Port Mouton Pluton. Modified after Douma (1988); refer to Table 2 for sample locality grid references and abbreviations, and Figure 1 for the location of this map in the Meguma Zone. Other ornaments are shown in Figure 2.

or gradational contacts with their host. Microgranular enclaves along Saint Catherines River Road resemble psammites because they have surficial weathered rinds, but very fine grain sizes (*ca.* 0.5 mm) and inequigranular textures distinguish them from metasedimentary enclaves (Fig. 5c,d). All samples have granitoid mineral assemblages that consist of biotite, plagioclase, quartz and (presumed primary) muscovite, and point-counted samples show tonalitic modes (unpublished data). Coarse-grained granitoid enclaves up to 100 cm in diameter occur throughout the pluton (Douma, 1988), but they concentrate in "patch breccias" with microgranular enclaves at Hell Point and Deadmans Rock. Most examples have rounded shapes, and their grey colours, porphyritic or megacrystic textures, and variable modes match all of the *in situ* lithologies exposed in the pluton (Fig. 5e).

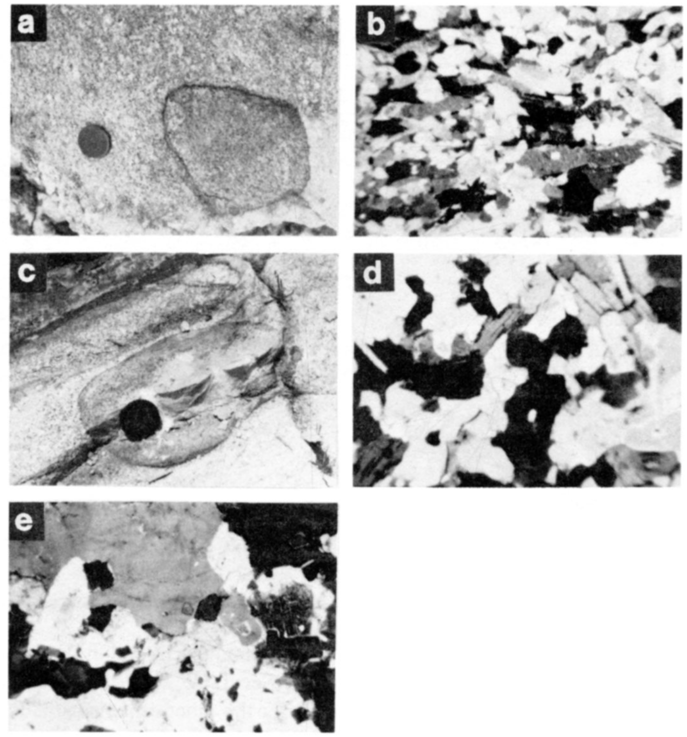

Fig. 5. Selected enclaves from the Port Mouton Pluton. (a) A subrounded psammitic enclave with a marginal biotite rind at locality CR. The lens cap is 7 cm in diameter; (b) Microscopic view of the well-developed granoblastic texture shown by the enclave depicted in (a) above. Note the aligned biotite. Field of view 6 mm (XPL); (c) An ellipsoidal microgranular igneous enclave with sharp enclave-host contacts at locality HP. The lens cap is 7 cm in diameter; (d) Photomicrograph of the inequigranular microgranitoid texture that characterizes microgranular igneous enclaves. The elongate, light grey grains at the top right are muscovite. Field of view 6 mm (XPL); (e) Photomicrograph of the porphyritic texture preserved in a coarse-grained granitoid enclave from locality DR. Field of view 1 cm (XPL).

The South Mountain Batholith

The South Mountain Batholith represents a polyintrusive granitoid complex covering an area of approximately 7500 km^2 southwest of Halifax (Abbott, 1989; Fig. 6). Enclaves occur in all of its 13 currently mapped plutons (MacDonald *et al.*, 1990; Clarke *et al.*, 1993), but poor exposure and weathered outcrops prevented sampling south of Lequille (Fig. 6). In the marginal granodiorite unit at Mount Uniacke, angular to subangular pelitic and psammitic enclaves 3 to 100 cm long locally account for up to 60% of the total outcrop (Jamieson, 1974). Psammitic hornfelses are massive and equigranular, whereas pelites contain abundant foliated biotite, and relict sedimentary bedding may control the distribution of cordierite, andalusite, and garnet porphyroblasts. Pristine (unassimilated) metasedimentary enclaves at Portuguese Cove, Prospect Bay, and Chebucto Head constitute only *ca.* 5% of the outcrop (Fig. 7a), but polygenic "breccia pipes" at Portuguese Cove and Northwest Arm Drive also contain abundant small garnet- and cordierite-bearing hornfelses (Fig. 7b). Towards the centre of the batholith, subrounded to rounded enclaves with coarse grain sizes and quartzofeldspathic mineral assemblages occupy less than 0.1% of the available outcrop, except where they are concentrated at intrusive contacts between plutons (Fig. 7c). Centimetric surmicaceous enclaves similar to those in the Shelburne Pluton exist solely in the leucogranites.

Grey microgranular enclaves occur throughout the batholith, but show particular abundance and diversity within monzogranite and leucomonzogranite near the contact of the Halifax pluton with the Meguma Group at Portuguese Cove and Chebucto Head. Internally, microgranular material occurs in monogenic swarms of rounded-ellipsoidal enclaves with *ca.* 0.5 mm grain sizes and diameters up to 100 cm. Exceptionally large examples (100-200 cm) at Portuguese Cove enclose centimetric metasedimentary enclaves with angular shapes (Fig. 7d), and enclaves at Timberlea and Nine Mile River have tonalitic modes that resemble those of the microgranular enclaves in the Port Mouton Pluton (Fig. 7e). Porphyritic or megacrystic granitoid enclaves occur as inclusions within the granodiorites and monzogranites, but the leucomonzogranites and leucogranites do not contain igneous enclaves. At Lakeside, Little Indian Lake, Long Lake, Prospect Bay, and Lequille, the coarse-grained granitoid enclaves have grey colours, rounded shapes, and peraluminous mineral assemblages dominated by garnet and cordierite (Fig. 7f). Small (< 10 cm) granitoid fragments also occur in the "breccia pipes" at Northwest Arm Drive.

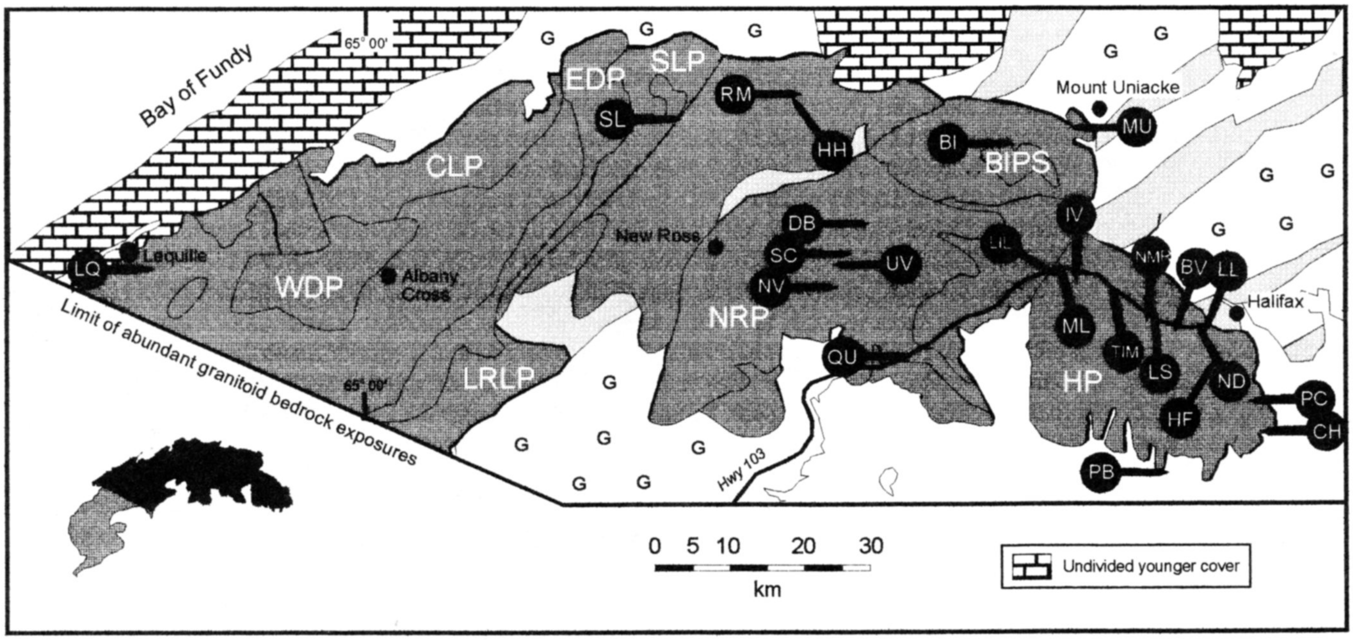

Fig. 6. Sample location map for the South Mountain Batholith. Bedrock geology after MacDonald *et al.* (1992) and the limit of granitoid bedrock exposure stylized after Stea *et al.* (1992). See Table 2 for the sample location grid references and abbreviations, Figure 1 for the location of this map in the Meguma Zone, and Figure 2 for the other ornaments. BIPS = Big Indian Polyintrusive Suite, CLP = Cloud Lake Pluton, EDP = East Dalhousie Pluton, HP = Halifax Pluton, LRLP = Little Round Lake Pluton, NRP = New Ross Pluton, SLP = Salmontail Lake Pluton, WDP = West Dalhousie Pluton.

DISCUSSION

The Barrington Passage, Shelburne and Port Mouton plutons and South Mountain Batholith contain both the micaceous and the granitoid enclaves that typically occur in orogenic granitoid rocks (Didier, 1973; Barbarin and Didier, 1992a). Given that these bodies represent the most voluminous exposed intrusions and encompass the range of granitoid lithologies exposed in the Meguma Zone, they are potentially representative of all Meguma granitoid bodies. The following sections evaluate the origins of the micaceous and granitoid enclaves separately, and suggest constraints that they place on established petrogenetic hypotheses for the granitoid intrusions.

Origin of the Metasedimentary and Surmicaceous Enclaves

Metapsammitic, metapelitic, and surmicaceous material accounts for all of the enclaves in the Barrington Passage and Shelburne plutons, and approximately 50% of the enclaves in the Port Mouton Pluton and South Mountain Batholith. Pristine metasedimentary enclaves occur predominantly at contacts with the Meguma Group, in the vicinity of Meguma Group roof pendants, or within migmatite complexes, and they lithologically resemble Meguma Group lithologies. In the South Mountain Batholith, both Nd isotopic analyses of the enclaves and S isotopic data for the marginal granodiorite suggest that they are xenoliths of Meguma Group rocks (Clarke *et al.*, 1988; Poulson *et al.*, 1991), although White Rock Formation country rocks exist adjacent to northerly areas of the batholith (Fig. 1). The considerable variety of grain sizes and mineral assemblages in the metasedimentary enclaves from all of the intrusions probably reflects a range of protoliths and/or their different residence times in granitoid melt. Metasedimentary enclaves away from the contacts have smaller sizes, more rounded shapes, and coarser grain sizes that may result from the recrystallization and disaggregation of pristine enclaves similar to those found at the contacts. Plagioclase, K-feldspar, and quartz porphyroblasts that impart pseudo-igneous textures in metasedimentary enclaves (e.g., Figs. 3d, 7b,c) probably result from metasomatism during assimilation (Jamieson, 1974).

Although no metasedimentary enclaves have gneissic textures and high-grade mineral assemblages to support the notion of basement sources for the granitoid melts, the surmicaceous enclaves probably originated from a partially melted protolith. Didier (1973) described surmicaceous enclaves with microfolds and penetrative fabrics, which preclude their formation as biotite-cumulate schlieren in the granitoid melt. Refractory mineral assemblages, coupled with sieve-textured biotites, in surmicaceous enclaves from the Meguma Zone also suggest a melanosome origin (Didier, 1987). The lithologic continuum between micaceous xenoliths and surmicaceous enclaves in the interior of the Barrington Passage Pluton strongly suggests that they formed by partial melting of included xenoliths, but the lack of a similar transition in the Port Mouton Pluton and South Mountain Batholith may reflect the much lower liquidus temperatures of monzogranitic and leucogranitic magmas relative to tonalites (e.g., Wyllie, 1977). If the more evolved granitoid melts did not melt incorporated xenoliths, then the surmicaceous enclaves in the Port Mouton Pluton and South Mountain Batholith perhaps represent true restites, although no substantiative evidence exists for either model. Regardless of the origin adopted, their occurrence with abundant metasedimentary enclaves in the studied intrusions supports the

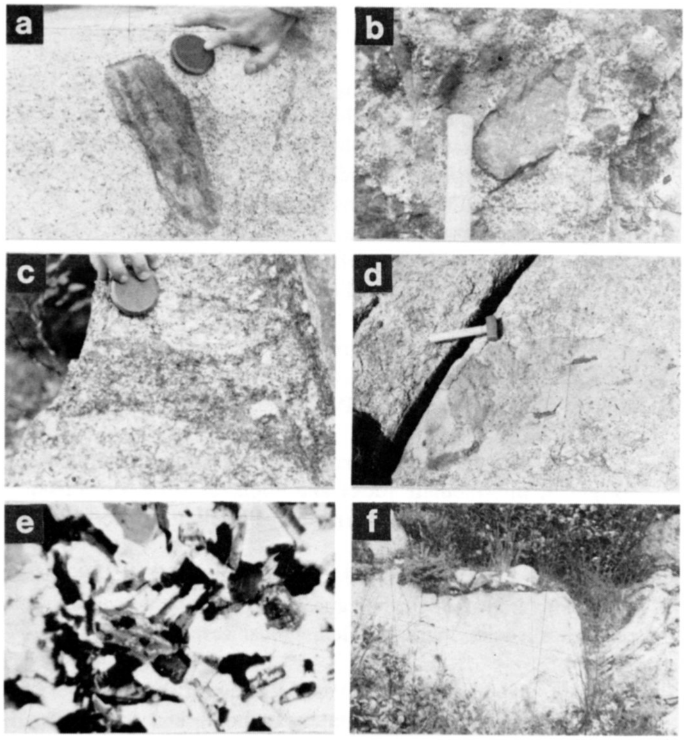

Fig. 7. Selected enclaves from the South Mountain Batholith. (a) A pristine metasedimentary enclave with a lenticular morphology and an obvious biotite foliation at locality PB. The lens cap is 7 cm in diameter; (b) Subangular metasedimentary and microgranular igneous enclaves in a "breccia pipe" at locality ND. As in Figure 3d, the white feldspar porphyroblasts in the central enclave resemble phenocrysts in the granitoid host. Viewable hammer handle 30 cm long; (c) An assimilated metasedimentary enclave from the centre of the batholith at locality SC. Note the abundant porphyroblasts of quartz, plagioclase, and K-feldspar that reflect metasomatism by the granitoid host after enclave incorporation. The lens cap is 7 cm in diameter; (d) A composite microgranular enclave at locality PB. It contains angular metasedimentary enclaves that confirm the magmatic origin of microgranular enclaves. Hammer approximately 50 cm long; (e) Photomicrograph of the inequigranular microgranitoid texture typical of microgranular enclaves in the batholith. Note that the light grey grains at the lower right are muscovite and that the texture closely resembles that of the enclave depicted in Figure 5d. Field of view 6 mm (XPL); (f) A coarse-grained granitoid enclave at locality LIL. Its megacrystic texture and colour are almost indistinguishable from those of the host. Hammer (top of outcrop) approximately 50 cm long.

very strong crustal influence that the peraluminous compositions suggest, and confirms stoping as an important intrusive mechanism.

Origins For the Granitoid and Microgranular Igneous Enclaves

Microgranular granitoid and coarse-grained granitoid material accounts for *ca.* 50% of the enclaves in the Port Mouton Pluton and the South Mountain Batholith, and it represents approximately 25% of the total samples collected. Textural and modal similarities between the coarse-grained granitoid enclaves and *in situ* granitoid lithologies suggest that they formed as slowly cooled autoliths (Fershtater and Borodina, 1976). Microgranular enclaves have more variable characteristics and alternative hypotheses explain their origins. In some intrusions, the melanocratic colours, fine grain sizes, and rounded-ellipsoidal shapes of microgranular enclaves suggest that they represent pillows disrupted from synplutonic mafic intrusions (e.g., Eberz and Nicholls, 1988; Barbarin, 1992). Also, enclaves lacking mafic microtextures may have intermediate compositions appropriate for mafic-granitoid magma hybrids (e.g., Dodge and Kistler, 1988; Larsen and Smith, 1990). To explain the fine grain sizes and granitoid compositions of many igneous enclaves, Fershtater and Borodina (1976) suggested that initial incursions of granitoid melt at any crustal level may chill rapidly and form an aplitic carapace at the contact. Flood and Shaw (in press) advocated a pressure quench caused by hydrofracturing close to the intrusion margins, whereas Chen *et al.* (1990) considered the lack of suitable country rock protoliths as an indication of restitic sources for the microgranular enclaves.

Although assimilation induces granoblastic textures in xenoliths, microgranular enclaves have inequigranular textures, and they consistently lack the sieve-textured biotite and opaque mineralogy of palaeosome or melanosome. Furthermore, the existence of xenoliths within some microgranular enclaves from the South Mountain Batholith necessitates a magmatic origin for them (Vernon, 1983). The dark colours of microgranular granitoid enclaves from the Port Mouton Pluton and South Mountain Batholith apparently reflect their fine grain sizes. Biotite is the only ferromagnesian mineral and no samples have truly mafic compositions (Cantagrel *et al.*, 1984; Orisini *et al.*, 1992); the ellipsoidal shapes of most samples may appear pillow-like, but xenoliths apparently also developed ellipsoidal shapes during assimilation. Microgranitoid samples from the Meguma Zone also lack the textural and mineralogical disequilibrium of mixed rocks (Vernon, 1984), and peraluminous tonalitic modes instead suggest an autolith origin similar to that proposed for the coarse-grained granitoid enclaves. None of the Meguma Zone granitoid bodies has chilled carapaces at currently exposed contacts (or at the peripheries of roof pendants), but the restriction of all granitoid enclaves to the multiply-intrusive granitoid bodies strongly supports the autolith hypothesis. Perhaps the tonalitic compositions of the microgranular enclaves reflect stoping of primitive thermal or pressure quenches at depth by new pulses of granitoid melt.

Summary and Conclusions

The peraluminous Barrington Passage, Shelburne and Port Mouton plutons and South Mountain Batholith contain a varied assemblage of metasedimentary, surmicaceous, and microgranular and coarse-grained granitoid enclaves that is typical of orogenic granitoid bodies and may be representative of intrusions throughout the entire Meguma Zone. Granoblastic metasedimentary hornfelses occur in all of the studied intrusions, where they have angular to subangular (lenticular) shapes, contain abundant biotite, quartz, and aluminosilicate porphyroblasts, and may preserve sedimentary bedding or tectonic foliations. Metasedimentary enclaves are concentrated at intrusive contacts or in the vicinity of roof pendants, and they show patchy distributions internally (except where "breccia pipes" occur). Lenticular surmicaceous enclaves occur abundantly only in the Barrington Passage and Shelburne plutons, and they consist almost totally of decussate, sieve-textured biotite containing apatite and zircon inclusions, with trace amounts of cordierite, andalusite, or corundum. Rounded or ellipsoidal igneous enclaves exist only in the Port Mouton Pluton and South Mountain Batholith, where they have patchy distributions. Tonalitic microgranular enclaves have very fine grain sizes with quenched textures and peraluminous mineral assemblages that consist of biotite, plagioclase, quartz, and muscovite. Coarse-grained granitoid enclaves with porphyritic or megacrystic textures may concentrate with the microgranular granitoid enclaves; their variable modes match all *in situ* lithologies in the Port Mouton Pluton and South Mountain Batholith, except leucogranite.

High concentrations of metasedimentary enclaves close to pluton contacts and roof pendants suggest that they probably originated as xenoliths from the Meguma Group, although their considerable lithological variety suggests that not all enclaves were incorporated locally. No truly gneissic enclaves exist with high-grade mineral assemblages that would reflect an origin in the basement sources of the Meguma Zone granitoid melts, but the refractory mineral assemblages and sieve-textured biotites in the surmicaceous enclaves suggest partial melting. A lithologic continuum between the metasedimentary xenoliths and the surmicaceous enclaves in tonalite of the Barrington Passage Pluton suggests that they formed after partial melting of included xenoliths, but the rarer examples in monzogranites of the Port Mouton Pluton and leucogranites of the South Mountain Batholith may be true restites. Regardless of their origin, the abundance of micaceous material in the studied Meguma Zone intrusions implies a strong crustal component in the granitoid melts and confirms the importance of stoping during melt emplacement. Tonalitic microgranular enclaves do not resemble restite and do not share any microtextural or modal similarities with mafic rocks or mafic-granitoid magma hybrids. Instead, their peraluminous mineral assemblages resemble those of the coarse-grained granitoid enclaves and their texture indicates quenching. Although the cause of quenching may be temperature- or pressure-related, the multiply-intrusive Port Mouton Pluton and South Mountain Batholith apparently stoped both quenched and slowly cooled autoliths in addition to country rock fragments, during intrusion.

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