LATE DEVONIAN PERALUMINOUS GRANITIC PLUTONS IN THE CANSO AREA, EASTERN MEGUMA TERRANE, NOVA SCOTIA*

J.D. Hill
Geological Survey of Canada
601 Booth Street, Ottawa, Ontario K1A 0E8

present address:
Department of Mining Engineering
Technical University of Nova Scotia
P.O. Box 1000, Halifax, Nova Scotia B3J 2X4

Date Received October 10, 1987
Date Accepted January 10, 1988

Late Devonian granitic rocks are well exposed in coastal outcrops near Canso in the eastern part of the Meguma Terrane. They form numerous, relatively homogeneous plutons of peraluminous biotite-muscovite granite and minor granodiorite which are enriched in muscovite, aluminum and alkalis and depleted in biotite and cafemic components relative to comparable rocks in other Meguma Terrane granites such as the South Mountain and Musquodoboit Batholiths. Individual plutons, which crystallized between 371 and 373 Ma based on U-Pb isotopic data, show a variable relationship between composition and relative age of intrusion. This implies crystallization from two or more separate batches of slightly different magma supplied from below the current level of exposure. Highly felsic, peraluminous compositions and initial $^{87}Sr/^{86}Sr$ ratios ranging from 0.703 to 0.709 favour magma derivation from heterogenous intermediate to felsic continental crust containing some pelitic material. Intrusions were emplaced syntectonically during the early part of a ductile shearing event related to dextral transcurrent movements in the Cobequid-Chedabucto Fault System.

Des roches granitiques tardidévoniennes forment de vastes affleurements littoraux près de Canso, dans la partie orientale de la Lanière de Méguma, où elles déterminent des plutons nombreux, relativement homogènes, constitués surtout de granites péralumineux à biotite et muscovite avec quelque granodiorite, qui sont enrichis en muscovite, aluminium, alcalis et déficitaires en biotite et composants cafémiques par rapport aux roches semblables des autres granites de la Lanière de Méguma tels que les batholites de South Mountain et de Musquodoboit. La méthode U-Pb atteste d'une cristallization entre 371 et 373 Ma. La relation entre leur composition et l'âge relatif de leur intrusion varie selon les plutons. On en déduit une cristallization à partir de deux (ou plus) venues magmatiques distinctes, légèrement différentes et provenant d'un niveau sous-jacent à l'affleurement actuel. Leur compositions hautement felsiques et péralumineuses ainsi que des rapports initiaux $^{87}Sr/^{86}Sr$ s'échelonnant de 0,703 à 0,709 permettent d'envisager comme provenance magmatique la remobilisation d'une croûte continentale hétérogène, intermédiaire à felsique, incorporant un apport pélitique quelconque. Les intrusions furent emplacées syntectoniquement durant l'amorce d'un épisode de cisaillement ductil relié à des mouvements transcourants dextres dans le système de failles de Cobequid-Chedabucto.

[Traduit par le journal]

INTRODUCTION

A large amount of data has been published in recent years on peraluminous granitic plutons in the Meguma Terrane (e.g., McKenzie and Clarke, 1975; de Albuquerque, 1977; MacDonald, 1981). However, there is very little information available about intrusions in the Canso area, despite the fact that they probably offer the best exposure in all of the Meguma Terrane. This paper provides an interim report based on a two-year mapping project for the Geological Survey of Canada (Hill, in press). A brief summary of field relationships and compositions of granitic plutons in the Canso area is given and their age relationships and tectonic setting are discussed.

GENERAL GEOLOGY

The Canso area lies at the extreme eastern end of the Meguma Terrane, a suspect orogenic belt separated from the Avalon Terrane to the north by the Cobequid-Chedabucto Fault System (Williams and Hatcher, 1982). The Canso area is underlain by the Cambro-Ordovician Meguma Group which is intruded by minor tonalite and numerous granitic plutons (Fig. 1). The Meguma Group is made up of a thick sequence of older psammitic (Goldenville Formation) and younger pelitic (Halifax Formation) sedimentary rocks interpreted as a continental embankment composed of coalescing deep-sea fans derived from western Europe or Africa (Schenk, 1978). Seismic data suggest that the Meguma Group was deposited on continental rather than oceanic crust (Dainty *et al.*, 1966).

A few small bodies of peraluminous biotite tonalite are preserved as xenoliths up to 0.3 km^2 in area in younger granitic plutons east of Dover (Fig. 1). Preliminary evaluation of concordant U-Pb zircon data indicates that one of the tonalite bodies crystallized at about 378±2 Ma (T.E. Krogh, personal communication, 1987). Granitic rocks intruded both the Meguma Group and tonalite during the Late Devonian. They form numerous bodies ranging from miscellaneous dikes and xenoliths to plutons up to 40 km^2 in area. The few contacts observed suggest that they are steep-walled. An east-west gravity profile calculated by M. Thomas

*Geological Survey of Canada Contribution No. 30887

0711-1150/88/010011-9$2.35/0

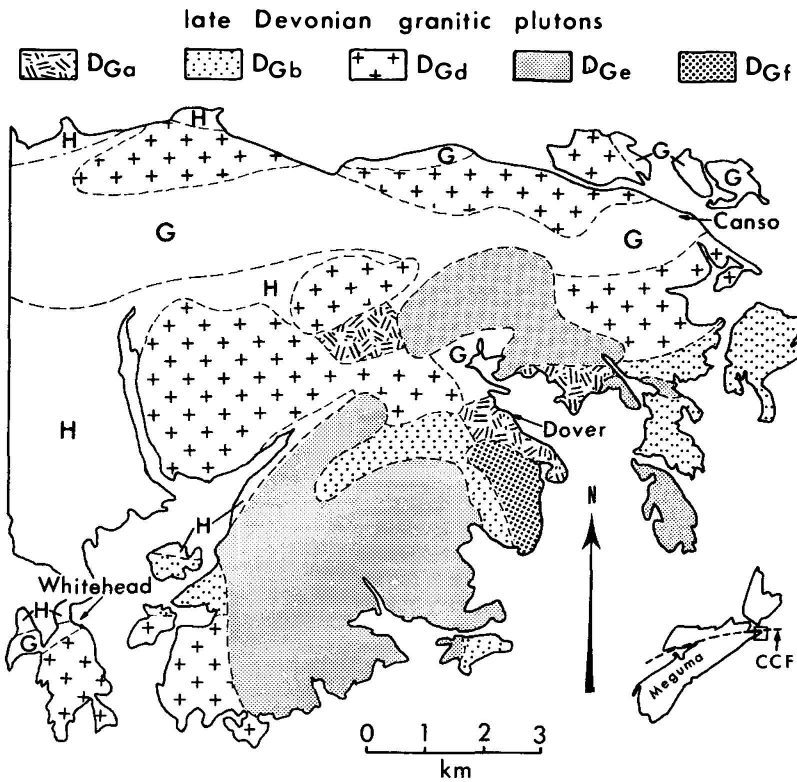

Fig. 1. Sketch map showing the distribution of the Cambro-Ordovician Meguma Group (G - Goldenville Formation; H - Halifax Formation) and 18 Late Devonian granitic plutons (Units D_{Ga} to D_{Gf}) in the Canso area. A few other plutons, including those in Unit D_{Gc} as well as Middle Devonian tonalite bodies, are too small to be shown. The Goldenville Formation in close proximity to some plutons includes agmatite formed by the injection of numerous dikes and lenses of aplitic to pegmatitic granite. Insert shows the location of the Canso area and the approximate trace of the Cobequid-Chedabucto Fault System (CCF).

of the Geological Survey of Canada (personal communication, 1986) indicates that plutons in the southern part of the area extend to a maximum depth of about 3 km. Agmatite is widespread north of Dover and east of Canso where the Goldenville Formation is intruded by numerous dikes and irregular lenses of aplitic to pegmatitic granite.

The eastern Meguma Terrane was deformed and metamorphosed during two main events. D_1, which is the dominant event throughout most of the Meguma Terrane, was caused by collision between the Meguma and Avalon Terranes during the Early Devonian (Schenk, 1978; Keppie, 1985). It produced east to northeast-trending, km-scale, open to tight anticlines and synclines with subhorizontal axes. D_1 metamorphism has been dated at 384-415 Ma based on $^{40}Ar/^{39}Ar$ mica ages (Reynolds and Muecke, 1978; Dallmeyer and Keppie, 1987). The boundary between the Meguma and Avalon Terranes is marked by the Cobequid-Chedabucto Fault System. Movement associated with this fault system in the Middle to Late Devonian resulted in ductile shearing and subsequent brittle deformation (D_2) along the northern margin of the eastern Meguma Terrane (Keppie, 1985; Mawer and Williams, 1986). Kinematic indicators point to an overall subhorizontal dextral sense of shear (Mawer and White, 1987). D_2 deformation may have been caused by post-accretionary adjustments and additional collisions among the outboard blocks in that part of the Appalachian Orogen (Williams and Hatcher, 1982; Keppie, 1985).

PETROGRAPHY OF GRANITIC ROCKS

Eighteen granitic plutons as well as numerous dikes, xenoliths and intrusions too small to show in Figure 1 have been recognized in the Canso area. Each pluton is relatively homogeneous in composition and texture compared to the total range of granitic rock types observed. In addition, interplutonic contacts are intrusive wherever seen in outcrop. Thus, the term "pluton," as used herein, refers to a body of granitic rock which, in most cases, is lithologically distinct from its neighbours and appears to represent a single pulse of magma at the current level of exposure. The 18 plutons shown in Figure 1, as well as four others too small to plot, are assigned to six units (D_{Ga} to D_{Gf}) based on age relationships, composition and texture. Units D_{Ga} (oldest) to D_{Ge} (youngest) are inferred to represent sequential emplacement of five batches of magma, each of which gave rise to more than one individual pluton (see below). The relative age(s) of Unit D_{Gf} plutons is unknown. Brief descriptions of each unit are given in Table 1. Average chemical analyses, CIPW norms and modes of each unit are given in Table 2. Compositional features are described in the following sections in terms of average unit and pluton compositions rather than individual rocks.

The granitic rocks are composed of only five essential minerals - quartz, biotite, muscovite, microcline, and plagioclase. Amphibole was not identified. Using a modified Streckeisen (1976)

Table 1. Lithologic characteristics of the six granitic units recognized in the Canso area. Plagioclase compositions were determined by microprobe analysis in 25 samples, and represent both zoning in individual grains as well as inter-sample variation.

Unit	Description
D_{Ga}	- fine to medium grained leucogranite containing 2-3% biotite and 9-12% muscovite; equigranular except for a few small phenocrysts of microcline and mica. Plagioclase is An_{3-8}.
D_{Gb}	- very coarse grained, porphyritic to seriate granite and minor granodiorite with 5-8% biotite and 1-7% muscovite; characterized by 10-30% microcline phenocrysts up to 15 cm long; cordierite(?) pseudomorphs and subsolidus sillimanite are common accessories. Plagioclase is An_{12-29}.
D_{Gc}	- fine grained porphyritic granite with 6% each of biotite and muscovite; contains 1-10% small phenocrysts of all essential minerals.
D_{Gd}	- medium to medium-coarse grained granite with 2-9% biotite and 4-14% muscovite; generally equigranular except for a few oucrops containing small phenocrysts of microcline or muscovite; includes several plutons of unknown age which may not be correlative with this unit. Plagioclase is An_{1-14}.
D_{Ge}	- coarse grained, porphyritic to seriate granite with 6-7% biotite and 4-5% muscovite; characterized by 1-20% microcline phenocrysts up to 8 cm long; cordierite(?) pseudomorphs and subsolidus sillimanite are common accessories. Plagioclase is An_{7-23}.
D_{Gf}	- medium grained equigranular leucogranodiorite with 1% biotite and 10-12% muscovite. Plagioclase is An_{0-1}.

plot in which albite is included with plagioclase, all of the average pluton modes are monzogranite except for three which plot in the granodiorite field close to the granite-granodiorite join (Fig. 2). Two of the granodiorite plutons (both Unit D_{Gf}) contain plagioclase which is essentially pure albite. Thus, they are chemically akin to granite and would plot on the quartz-alkali feldspar join if albite was included with microcline. These two plutons contain less than 1% biotite and are distinguished by the term leucogranodiorite. The remaining granodiorite pluton has the most calcic plagioclase found (i.e., An_{17-29})[1]. Individual plutons have 1-9% biotite and 1-14% muscovite. Overall, granitic rocks in the Canso area are much more enriched in muscovite and depleted in biotite than other Meguma Terrane intrusions such as the Musquodoboit and South Mountain Batholiths (Fig. 3). Accessory minerals include apatite, monazite, zircon, ilmenite, garnet, tourmaline and sillimanite and rare allanite, sphene, spinel, fluorite, anatase and rutile. In addition, smectite aggregates inferred to be pseudomorphs after magmatic cordierite are common in some plutons in the southern part of the area.

The granitic rocks have been variably deformed by D_2 within 9 km of the northern margin of the Canso area. As a result, all gradations between virtually undeformed granite and true mylonite with well-developed S-C fabric are present. Unless otherwise noted, the following description is restricted to undeformed rocks which occur only in the southern half of the area. Undeformed granitic rocks range from fine- to very coarse-grained with medium-grained rocks being predominant. Coarse grained varieties are distinguished by the presence of microcline phenocrysts from 1-15 cm long. Phenocrysts locally define an impersistent subhorizontal magmatic foliation and gently-plunging lineation. Compositional layers similar to some of those described by Smith (1975) in the South Mountain Batholith are oriented parallel to the phenocryst foliation in a few outcrops.

Although the undeformed rocks have relatively typical granitic textures in hand specimen, textural evidence in thin section indicates subsolidus recrystallization has occurred that is much more extensive than is typical of most granites with which the writer is familiar. Only plagioclase and accessory minerals appear to partly preserve early magmatic textures. Microcline commonly protrudes into and replaces adjacent plagioclase grains. Muscovite and biotite form primary-looking subhedral laths as well as secondary grains which crosscut and replace both feldspars. Optical continuity and compositional homogeneity between adjacent primary and subsolidus-looking micas indicate both types re-equilibrated during the final stages of subsolidus crystallization. Acicular sillimanite grains crosscut all essential minerals without regard to crystal boundaries or structure. Subsolidus grains

[1]Mineral compositions were determined by microprobe analysis in 25 granitic samples.

Table 2. Unweighted average anhydrous chemical analyses, CIPW norms and modal compositions of the six granitic units in the Canso area. Unit compositions were determined from 130 individual rock analyses. Modes were determined by counting 2500-10,000 points in several stained thin sections for each unit. They should be considered as approximate only. Modal data partly reflect both deuteric subsolidus and D_2 metamorphic crystallization. ac = accessory minerals. N = number of individual chemical analyses. n = number of plutons. % = aerial percentage of total granitic rocks in each unit.

	D_{Ga}	D_{Gb}	D_{Gc}	D_{Gd}	D_{Ge}	D_{Gf}
SiO_2	72.74	72.01	73.08	73.84	73.79	74.15
TiO_2	0.17	0.28	0.21	0.18	0.32	0.09
Al_2O_3	15.52	15.47	15.21	14.96	14.26	15.28
Fe_2O_3	0.22	0.27	0.13	0.25	0.23	0.22
FeO	0.83	1.29	1.00	0.85	1.31	0.64
MnO	0.04	0.05	0.03	0.04	0.04	0.04
MgO	0.31	0.55	0.40	0.35	0.49	0.14
CaO	0.61	0.97	0.79	0.59	0.64	0.50
Na_2O	4.07	3.63	3.63	3.84	3.16	4.22
K_2O	5.19	5.23	5.19	4.80	5.46	4.32
P_2O_5	0.32	0.24	0.32	0.30	0.30	0.42
Ba	349	543	523	322	377	127
F	640	475	403	512	685	1514
Li	157	93	90	77	89	200
Rb	402	305	277	340	345	695
Sn	12	7	9	10	8	22
Sr	62	130	87	59	73	10
Th	6	13	nd	5	18	3
U	5	5	4	5	5	13
Zr	45	90	80	43	102	24
			CIPW NORMS			
qz	27.85	27.88	30.10	31.72	32.49	32.60
or	30.66	30.90	30.66	28.36	32.26	25.52
ab	34.44	30.72	30.72	32.49	26.74	35.71
an	0.94	3.24	1.83	0.97	1.21	–
co	2.87	2.65	2.95	3.10	2.71	3.76
hy	1.91	3.14	2.43	2.00	2.98	1.27
ap	0.70	0.53	0.70	0.66	0.66	0.92
il	0.32	0.53	0.40	0.34	0.61	0.17
mt	0.32	0.39	0.19	0.36	0.33	0.32
				MODES		
qz	32.2	26.9	27.6	31.0	35.5	35.1
mi	24.0	30.8	27.3	25.7	29.9	17.0
pl	31.7	30.8	33.1	31.5	23.9	35.8
bi	3.0	6.5	5.6	3.3	6.2	1.1
ms	9.0	4.6	6.3	8.2	4.2	11.1
ac	0.3	0.5	0.2	0.2	0.5	0.2
N	10	20	3	60	30	7
n	2	4	1	9	4	2
%	4.5	16.1	0.1	46.6	30.3	2.5

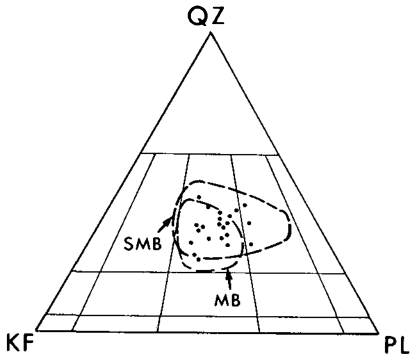

Fig. 2. Average modal compositions of the 18 granitic plutons shown in Figure 1 as well as four others in the Canso area which are too small to plot. Field boundaries are taken from Streckeisen (1976) except that plagioclase includes albite. The approximate ranges of the South Mountain Batholith (McKenzie and Clarke, 1975; Ham and Horne, 1986) and Musquodoboit Batholith (MacDonald, 1981) are shown for comparison.

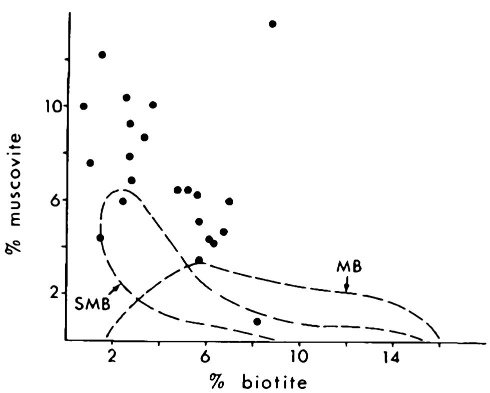

Fig. 3. Modal contents of biotite and muscovite in 22 granitic plutons in the Canso area. Symbols same as in Figure 2.

are deformed by post-granite ductile D_2 fabrics in the northern half of the Canso area. Since ductile D_2 deformation was closely related to granitic intrusion in time (see below), subsolidus crystallization in the undeformed rocks must have closely followed (and was probably continuous with) magmatic crystallization at near-magmatic temperatures.

CHEMISTRY

Average chemical compositions of the six granitic units are given in Table 2. Individual rock analyses from which unit averages were calculated are given in Hill (in press). Major elements were done by X-ray fluorescence by X-Ray Assay Laboratories Limited of Don Mills, Ontario. The use of a chrome steel mill for grinding has introduced an absolute error in FeO of +0.05–0.15%. Trace elements were done by a combination of wet chemistry and instrumental methods by Bondar-Clegg Company Limited of Ottawa, Ontario and X-Ray Assay Laboratories Limited. Precision is estimated at ±0.5% (relative), ±5% and ±10% at the 70%, 1% and 100 parts per million levels of concentration, respectively.

Average pluton compositions given in Table 1 include analyses from both deformed and undeformed rocks. However, analysis of several deformed and undeformed samples from the same part of the same pluton suggests that D_2 deformation and metamorphism were essentially isochemical (Hill, in press). Each pluton is relatively homogeneous in composition and texture compared to the total range of granitic rock types observed. Compositional variation of individual samples in three plutons is compared to that for all Canso granitic rocks in Figure 4. Each pluton shows a specific range of compositions which is much less than the total range, even though they have similar SiO_2 contents (see caption, Fig. 4). The lithologic homogeneity of each pluton suggests that average pluton and unit analyses give <u>approximate</u> compositions of the granitic magmas emplaced at the current level of exposure.

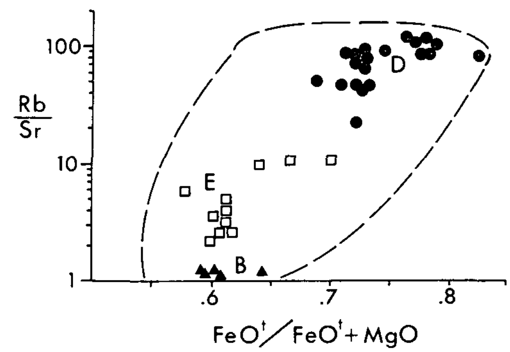

Fig. 4. Variation in Rb/Sr and FeO^t/FeO^t+MgO (mole %) within individual plutons compared to all granitic rocks in the Canso area. Capital letters designate the three plutons--one each from Units D_{Gb}, D_{Gd} and D_{Ge}. Dashed line encompasses the total field for all granitic rocks in the Canso area. The three sets of samples partly overlap in SiO_2 content, containing 70.0–72.2% (B), 70.6–73.8% (E) and 73.4–75.3% (D).

Granitic plutons in the Canso area have a rather narrow compositional range, containing 70.7–75.6% SiO_2 and 0.1–0.8% MgO. All rocks are peraluminous, with normative corundum varying between 1.5% and 4.8%. Selected major and trace elements are plotted in Figure 5. Inter-element correlation is good for some pairs (e.g., FeO and MgO) and poor for others (e.g., Al_2O_3 and MgO). The plutons have many but not all of the characteristics of S-type granites (see Chappell and White, 1974). They have high normative corundum, restricted compositional range and contain Al-rich minerals. On the other hand, compared to S-type granites in the Lachlan fold belt in Australia (Chappell and White, 1974), the Canso plutons have relatively high Na_2O (2.9–4.4%) and low initial $^{87}Sr/^{86}Sr$ ratios[2] (0.703–0.709[2]).

---

[2]Rb-Sr isotopes were determined in eight whole rock samples by R. Theriault of the Geological Survey of Canada and initial ratios were calculated using a U-Pb monazite crystallization age of 372 Ma.

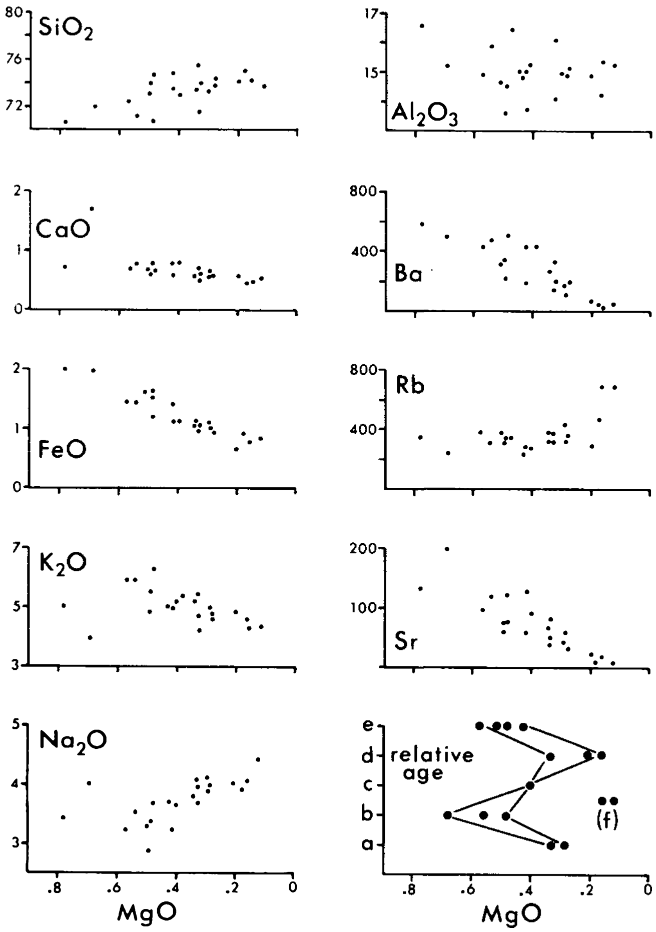

Fig. 5. Variation diagrams for selected major and trace elements in 22 granitic plutons in the Canso area. Data are in weight % and ppm. The lower right diagram shows the variation in MgO with relative age for plutons in Units D_{Ga} to D_{Ge}, using only the 13 plutons with wholly or partly known relative ages (see Fig. 7). Unit D_{Gf} plutons (f), the relative ages of which are unknown, are plotted separately for comparison.

The Canso plutons are enriched in Al_2O_3, Na_2O, K_2O and Rb and depleted in FeO, CaO and MgO relative to comparable rocks in the South Mountain and Musquodoboit Batholiths. The South Mountain Batholith and Canso plutons are effectively distinguished by plotting Al_2O_3 + Na_2O + K_2O against FeO + MgO (Fig. 6). The Musquodoboit Batholith falls at intermediate values. Average compositions of four other eastern Meguma Terrane plutons lie within the Canso field in Figure 6. This suggests that the chemical characteristics of granitic rocks in the Canso area may also be applicable to other plutons in the eastern Meguma Terrane. The most distinctive plutons of all are those belonging to Unit D_{Gf}. They are muscovite-rich and have high F, Li and Rb and low MgO, Ba, Sr and Zr. Their only counterpart farther west in the Meguma Terrane appears to be the East Kemptville leucogranite which has similar but more extreme chemical features (Kontak, 1987).

RELATIVE AND ABSOLUTE PLUTON AGES

Superb coastal outcrops in the southern and eastern parts of the Canso area have resulted in excellent exposure of a large number of interplutonic contacts. Contacts vary from simple and abrupt to agmatitic over large areas, and all those observed in the field are clearly intrusive. Partly or wholly known relative ages have been determined by dike-host-xenolith relationships for 13 plutons (Fig. 7). They resolve into a minimum of five episodes of intrusion (i.e., Units D_{Ga} to D_{Ge}) based on correlation of relative age with composition and texture. The two Unit D_{Gf} plutons of unknown age are assigned to their own unit because of their distinctive compositions. Seven other plutons have unknown relative ages and are correlated with Units D_{Ga} to D_{Ge} on the basis of lithology only. Taking into account all of the plutons, including miscellaneous dikes and plutonic xenoliths which cannot be correlated with recognized units, requires at least six episodes of intrusion. This is only a minimum number--the sequence could be more complicated. The relationship between time of intrusion and MgO

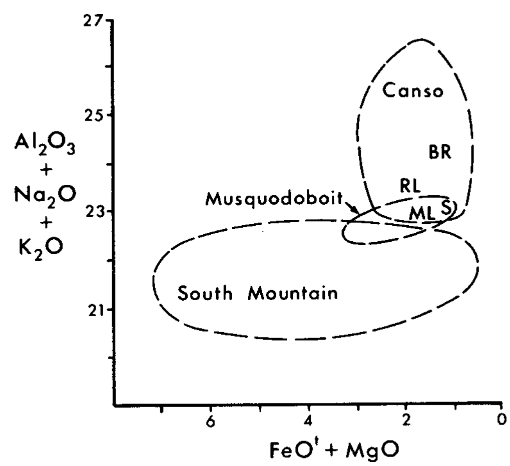

Fig. 6. Bivariate plot illustrating the differences between granitic plutons in the Canso area and comparable rocks in the South Mountain Batholith (Smith, 1974; McKenzie and Clarke, 1975) and Musquodoboit Batholith (MacDonald, 1981). Average compositions of the Sherbrooke (S - Alizay, 1981), Bull Ridge (BR - Chevalier, 1983), River Lake (RL - Thomas, 1982) and Mulgrave Lake (ML - Dwyer, 1975) plutons plot within the Canso field.

Fig. 7. Relative ages of intrusion of 13 granitic plutons in the Canso area. Thick vertical lines indicate inferred age and dashed lines indicate possible age range. The plutons are divided into five units (D_{Ga} to D_{Ge}) based primarily on relative age and secondarily on composition and texture. The relative ages of the remaining nine plutons, including those assigned to Unit D_{Gf}, are unknown.

content for the 13 plutons with partly or wholly known relative ages is shown in the lower right diagram in Figure 5. Clearly there is no simple correlation between relative age and composition. This relationship could become even more complex (but not less so) if relative ages of all plutons were known.

Three granitic plutons (assigned to Units D_{Ga}, D_{Gb} and D_{Ge}) give concordant to almost concordant $^{207}Pb/^{235}U$ monazite ages of 370±3, 371±2 and 372±1 Ma respectively (Krogh, personal communication, 1987). These dates do not define an age sequence since they overlap within analytical uncertainty. Taking relative pluton ages into account implies that all intrusions in Units D_{Ga} to D_{Ge} crystallized between 371 and 373 Ma. This range may not cover the whole intrusive sequence since the ages of Unit D_{Gf} intrusions as well as miscellaneous dikes and plutonic xenoliths are unknown. However, age constraints on post-granite D_2 deformation (described below) suggest that all plutons were emplaced at approximately the same time. The short time span available for at least six episodes of granitic intrusion raises the possibility, indeed the probability, that magmas may have coexisted. However, no age reversals or evidence for magma mixing were observed in the field, although the latter would be difficult to detect because of similarity in pluton compositions.

TECTONIC SETTING

The granitic plutons were emplaced syntectonically after the beginning but during the early stages of D_2 dextral transcurrent shearing in the eastern Megumá Terrane. This deformation event has been described in some detail by Keppie (1985), Mawer and Williams (1986), Mawer and White (1987), Hill (in press), and Hill and Raeside (1987) and only a brief summary is given here. D_2 is comprised of a series of overlapping phases of deformation and metamorphism that are believed to be part of a single progressive event. Three phases of initial ductile deformation (D_{2a}, D_{2b}, D_{2c}) have been recognized (Hill, in press), each of which produced transposition foliation and Z-shaped folds (looking down plunge) of similar orientation (east to northeast-trending) and style. D_2 culminated with the formation of locally-developed crenulation cleavages and small open folds (D_{2d}) followed by low-temperature brittle deformation associated with development of a Riedel shear package of transcurrent faults and brittle-ductile shear zones (D_{2e}). Although overprinting relationships are obvious, Mawer and Williams (1986) have argued that separation into structural generations may not be useful in the Canso area since the evidence is compatible with a single event of progressive deformation. However, a sense of age progression is given by the fact that granitic intrusion occurred mainly between D_{2a} and D_{2b} (see below) and that brittle structures invariably overprint ductile fabrics. For this reason, the concept of deformation phases (i.e., D_{2a}, etc.) within a single progressive event (i.e., D_2) is retained here.

Granitic plutons truncate D_{2a} fabrics in the country rocks and are deformed by D_{2b} and younger structures (see Fig. 2, Hill and Raeside, 1987). This suggests that they were emplaced between D_{2a} and D_{2b}. However, two lines of evidence indicate that some plutons were still partly liquid after the beginning of D_{2b}:

a) Aplite and pegmatite dikes associated with the granitic plutons are almost invariably deformed by D_{2b} structures. However, a few dikes in deformed agmatite east of Canso partly crosscut D_{2b} mesofolds and have locally intruded along S_{2b} cleavage planes oriented parallel to the axial surfaces of the folds.

b) Sillimanite fibers in two metasedimentary hornfels xenoliths in a granite pluton 2 km southwest of Dover define a faint schistosity. Although the adjacent granite is not recognizably deformed, the schistosity in the xenoliths is concordant with S_{2b} observed in deformed granite 1 km to the north. This suggests that the sillimanite, which probably crystallized in response to contact metamorphism, developed preferred orientation in a weak D_{2b} stress field.

The older age limit of D_2 is given by tonalite which occurs as xenoliths in granite 2-4 km east of Dover. In general, D_{2b} fabric crosscuts both tonalite and granite without regard to contacts. But a different relationship was observed in one outcrop where the effects of D_{2b} are only barely visible. There, angular tonalite xenoliths with an obvious mylonitic foliation are variably oriented within a granite intrusion (Fig. 8). A weakly developed east-trending D_{2b} foliation is present in the granite. The foliation in the xenoliths must have formed after crystallization of the tonalite at ca. 378 Ma and prior to intrusion of the granite at ca. 372 Ma. Since D_1 has been dated at 384-415 Ma (Reynolds and Muecke, 1978; Dallmeyer and Keppie, 1987), the fabric in the tonalite appears to be related to D_{2a}. This places a maximum age of about 378 Ma on D_2. The younger age limit of D_2 is provided by the Early Carboniferous (Tournasian) Horton Group which oversteps part of the Cobequid-Chedabucto Fault System and Meguma Terrane 200-300 km west of the Canso area (Belt, 1968). Horton Group fanglomerates, which are coarsest and most abundant along the fault contact with the Meguma Terrane, contain Meguma-derived clasts which have apparent D_2 fabrics and which were metamorphosed to at least upper greenschist facies prior to erosion (e.g., Keppie, 1985; Hill, in press). These relationships indicate that the ductile phases and possibly much of the brittle phase of D_2 were complete by 350-360 Ma. Thus, D_2 dextral shearing occurred between 378 and 350-360 Ma. This age range is in agreement with isotopic dates of 362-373±7 Ma for porphyroblasts and mica related to D_2 in the eastern Meguma Terrane (Dallmeyer and Keppie, 1984) as well as 371-373 Ma for granitic plutons in the Canso area (this report).

DISCUSSION

The Canso area is underlain by 18 granitic plutons larger than 0.2 km^2, each of which is relatively homogeneous in lithology compared to the total range of rock types observed. They, as well as numerous smaller bodies, are composed of biotite-muscovite granite and minor granodiorite which plots close to the granite-granodiorite boundary. They formed by the intrusion of at least six separate pulses of magma at ca. 372 Ma.

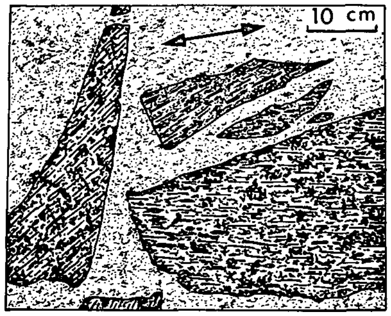

Fig. 8. Angular tonalite xenoliths (dark) are enclosed in granite 4 km east of Dover in the Canso area. Note the variable orientation of the mylonitic foliation in the xenoliths compared to the weakly-developed D_{2b} foliation (parallel to arrow) in the granite.

Detailed analysis of the petrogenesis of the granitic plutons is beyond the scope of this paper. However, the lack of simple correlation between pluton chemistry (e.g., MgO, Ca/Na, etc.) and relative age of intrusion suggests that the model of a single cogmatic suite of rocks related by *in situ* fractional crystallization of a uniform parent, as has been inferred for the South Mountain Batholith (McKenzie and Clarke, 1975), is not applicable. Instead, a supply of magma that varied irregularly in composition with time must have been available below the current level of exposure. The highly felsic, peraluminous compositions and wide range in initial $^{87}Sr/^{86}Sr$ ratios (0.703-0.709) suggest that the most plausible mechanism involved two or more different batches of magma generated at about the same time in a heterogenous source of intermediate to felsic continental crust containing some proportion of pelitic material. However, processes such as restite unmixing, variable accumulation of early-formed crystals or periodic replenishment of an underlying chamber with a uniform magma composition cannot be totally discounted at this time with the data available. In this regard, zircons in some of the granitic plutons contain rounded cores typical of inheritance (Krogh, personal communication, 1987). The relatively low initial $^{87}Sr/^{86}Sr$ ratios compared to many S-type granites suggests that the source material was low in rubidium and/or had a short residence time in the crust.

The plutons were emplaced syntectonically after the beginning but during the early stages of D_2 ductile shearing associated with dextral transcurrent movements along the Cobequid-Chedabucto Fault System. The presence of tonalite, which has liquidus temperatures of 1000-1100°C, suggests that mafic magma may have been involved in some way-- either by supplying heat or by giving rise to the tonalite plutons directly (Wyllie, 1977). Tonalite intrusion temperatures could have been much lower if they were restite or cumulate-rich mushes. However, a restite origin is partly opposed by the fact that zircons in the tonalites are clear, euhedral and lack inherited cores (Krogh, personal communication, 1987). No other igneous rocks of different composition are associated in time with the tonalite so a cumulate origin is not favoured either. Thus, crustal thickening during D_1 and D_2 possibly augmented by uprise of mafic magma is believed to be the most likely heat source for the generation of the granitic magmas. A period of amphibolite-grade static metamorphism (Keppie, 1985), which is not obviously related to *in situ* contact metamorphism, occurred at about the same time as granitic plutonism (Hill and Raeside, 1987). Under the scenario outlined here, both static metamorphism and granitic plutonism were caused by the same thermal event (see also Keppie, 1985). Metamorphic mineral assemblages in the granitic plutons and metasedimentary country rocks suggest that the current level of exposure represents intrusion at depths of 10 to 13 km (Raeside *et al.*, this volume; Hill, in press).

ACKNOWLEDGEMENTS

This report is based on work done under the Canada-Nova Scotia Mineral Development Agreement of 1984-1989. T. Krogh of the Royal Ontario Museum and R. Theriault of the Geological Survey of Canada completed all isotopic work. The manuscript has benefitted from reviews by J.B. Whalen, S.M. Barr and D.J. Kontak.

ALIZAY, K.M. 1981. Zur geologie und geochemie des Sherbrooke-plutons, Nova Scotia, Kanada. M.Sc. thesis, University of Hamburg, Hamburg, West Germany, 107 p.

BELT, E.S. 1968. Post-Acadian rifts and related facies, eastern Canada. *In* Studies of Appalachian Geology. *Edited by* E-An Zen, W.S. White, J.B. Hadley and J.B. Thompson. Interscience, New York, pp. 95-113.

CHAPPELl, B.W., and WHITE, A.J.R. 1974. Two contrasting granite types. Pacific Geology, 8, pp. 173-174.

CHEVALIER, B.A.M. 1983. Petrography and geochemistry of the Bull Ridge pluton, Guysborough County, Nova Scotia. B.Sc. thesis, Acadia University, Wolfville, Nova Scotia, 104 p.

DAINTY, A.M., KEEN, C.E., KEEN, M.J., and BLANCHARD, J.E. 1966. Review of geophysical evidence on crust and upper-mantle structure on the eastern seaboard of Canada. *In* The Earth Beneath the Continents. *Edited by* J.S. Steinhart and T.J. Smith. American Geophysical Union, Monograph Number 10, pp. 349-369.

DALLMEYER, R.D., and KEPPIE, J.D. 1984. Geochronological constraints on the accretion of the Meguma Terrane with North America. *In* Geological Society of America, Abstracts with Programs, 16, p. 11.

DALLMEYER, R.D., and KEPPIE, J.D. 1987. Polyphase late Paleozoic tectonothermal evolution of the southwestern Meguma Terrane, Nova Scotia: evidence from $^{40}Ar/^{39}Ar$ mineral ages. Canadian Journal of Earth Sciences, 24, pp. 1242-1254.

de ALBUQUERQUE, C.A.R. 1977. Geochemistry of the tonalitic and granitic rocks of the Nova Scotia southern plutons. Geochimica et Cosmochimica Acta, 41, pp. 1-13.

DWYER, G.J. 1975. Petrology of the Mulgrave Lake adamellite pluton. B.Sc. thesis, Dalhousie University, Halifax, Nova Scotia.

HAM, L.J., and Horne, R.J. 1986. Geology of the South Mountain Batholith on the eastern half of NTS Map Sheet 21A/16. *In* Mines and Minerals Branch, Report of Activities. *Edited by* J.L. Bates. Nova Scotia Department of Mines and Energy, Report 86-1, pp. 149-159.

HILL, J.D. *In press*. Geology of the Canso and Forest Hill area, eastern Meguma Terrane, Nova Scotia, with emphasis on the petrology, tectonic setting and economic potential of Devonian peraluminous granitoid plutons. Geological Survey of Canada Bulletin.

HILL, J.D., and RAESIDE, R.P. 1987. Discussion of 'structural study of highly deformed Meguma phyllite and granite, vicinity of White Head Village, S.E. Nova Scotia' by C.K. Mawer and P.F. Williams. Maritime Sediments and Atlantic Geology, 23, pp. 151-154.

KEPPIE, J.D. 1985. Geology and tectonics of Nova Scotia. *In* Appalachians Geotraverse (Canadian Mainland). Geological and Mineralogical Associations of Canada Annual Meeting, Guidebook to Excursion 1, pp. 23-108.

KONTAK, D.J. 1987. The East Kemptville leucogranite: a possible mid-Carboniferous topaz granite. *In* Mines and Minerals Branch, Report of Activities 1986. *Edited by* J.L. Bates and D.R. MacDonald. Nova Scotia Department of Mines and Energy, Report 87-1, pp. 81-94.

MACDONALD, M.A. 1981. The mineralogy, petrology and geochemistry of the Musquodoboit Batholith. M.Sc. thesis, Dalhousie University, Halifax, Nova Scotia, 272 p.

MAWER, C.K., and WHITE, J.C. 1987. Sense of displacement on the Cobequid-Chedabucto fault system, Nova Scotia, Canada. Canadian Journal of Earth Sciences, 24, pp. 217-223.

MAWER, C.K., and WILLIAMS, P.F. 1986. Structural study of highly deformed Meguma phyllite and granite, vicinity of White Head Village, S.E. Nova Scotia. Maritime Sediments and Atlantic Geology, 22, pp. 51-64.

MCKENZIE, C.B., and CLARKE, D.B. 1975. Petroloy of the South Mountain Batholith, Nova Scotia. Canadian Journal of Earth Sciences, 12, pp. 1209-1218.

RAESIDE, R.P., HILL, J.D., and EDDY, B.G. 1988. Metamorphism of Meguma Group metasedimentary rocks, Whitehead Harbour area, Guysborough County, Nova Scotia. Maritime Sediments and Atlantic Geology, 24, pp. 1-9.

REYNOLDS, P.H., and MUECKE, G.K. 1978. Age studies on slates: applicability of the $^{40}Ar/^{39}Ar$ stepwise outgassing method. Earth and Planetary Science Letters, 40, pp. 111-118.

SCHENK, P.E. 1978. Synthesis of the Canadian Appalachians. Geological Survey of Canada, Paper 78-13, pp. 111-136.

SMITH, T.E. 1974. The geochemistry of the granitic rocks of Halifax County, Nova Scotia. Canadian Journal of Earth Sciences, 11, pp. 650-657.

SMITH, T.E. 1975. Layered granitic rocks at Chebucto Head, Halifax County, Nova Scotia. Canadian Journal of Earth Sciences, 12, pp. 456-463.

STRECKEISEN, A. 1976. To each plutonic rock its proper name. Earth-Science Reviews, 12, pp. 1-33.

THOMAS, W.C. 1982. Petrology and geochemistry of the River Lake pluton, Halifax County, Nova Scotia. M.Sc. thesis, Acadia University, Wolfville, Nova Scotia, 133 p.

WILLIAMS, H., and HATCHER, R.D. 1982. Suspect terranes and accretionary history of the Appalachian orogen. Geology, 10, pp. 530-536.

WYLLIE, P.J. 1977. Crustal anatexis: an experimental review. Tectonophysics, 43, pp. 41-71.