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THE EAST KEMPTVILLE TOPAZ–MUSCOVITE LEUCOGRANITE, NOVA SCOTIA
I. GEOLOGICAL SETTING AND WHOLE-ROCK GEOCHEMISTRY

DANIEL J. KONTAK
Nova Scotia Department of Mines and Energy, P. O. Box 1087, Halifax, Nova Scotia B3J 2X1

ABSTRACT

The East Kemptville leucogranite, a *ca.* 370 Ma topaz-muscovite leucogranite occurring at the southwest termination of the Late Devonian South Mountain Batholith of Nova Scotia, is petrologically significant because it represents the first documented occurrence of magmatic topaz in granitic rocks of the Meguma Zone and is also host to the only primary producing tin deposit in North America (56 million tonnes at 0.165% Sn). Previous radiometric ages of *ca.* 300 Ma ($^{40}Ar/^{39}Ar$ muscovite) and *ca.* 337 Ma (Rb–Sr whole rock) for the East Kemptville leucogranite are herein reinterpreted to reflect updating related to thermotectonic disturbances rather than the age of crystallization. The leucogranite is medium grained, equigranular and characterized by the presence of magmatic topaz and muscovite; rare, small (<0.1 mm) biotite grains occur. The absence of fluid-saturation textures (*e.g.*, miarolitic cavities, unidirectional solidification textures, pegmatites) indicate emplacement of the leucogranite as a H_2O-undersaturated melt. Although petrographic observations indicate subsolidus modification of primary magmatic mineralogy and textures, the leucogranite is considered to reflect a magmatic, rather than metasomatic phenomenon. Chemically the leucogranite is characterized by elevated concentrations of SiO_2, Al_2O_3 ($1.13 < A/CNK < 1.84$), total Fe, P_2O_5, Rb, Cs, Ga, Li, F, Sn, Nb, Cu, Zn, W, U, Ta and depleted levels of TiO_2, CaO, MgO, Ba, B, Th, V, Co, Sc, Hf, Zr, Ni, Mo, Sb, Y. Compared to evolved units (*i.e.*, leucogranites) of the South Mountain Batholith, the leucogranite is enriched in Ta, Sr, Rb, F and Li, whereas *REE* abundances and chondrite-normalized patterns are markedly different. Geochemically the leucogranite compares favorably to other F-rich felsic suites, particularly topaz granites. The East Kemptville leucogranite is considered to represent the highly fractionated product of a strongly peraluminous melt, itself derived *via* melting of a fluorine-rich biotite phase. The leucogranite may not represent a fractionate of the South Mountain Batholith (or Davis Lake Complex). The location of the East Kemptville leucogranite within a major northeast-trending shear zone may indicate that structure was involved in both generation and emplacement of the leucogranite.

Keywords: topaz, muscovite, fluorine, tin, leucogranite, East Kemptville, Meguma Zone, Nova Scotia.

SOMMAIRE

Le massif leucogranitique à topaze + muscovite de East Kemptville (370 Ma), situé à l'extrémité sud-ouest du batholite dévonien de South Mountain, en Nouvelle-Écosse, est pétrologiquement important parce qu'il constitue le premier exemple de topaze primaire dans un granite de la zone de Meguma, et qu'il est le site du seul gisement d'étain en production en Amérique du Nord (56 millions de tonnes à 0.165% de Sn). Les âges proposés antérieurement, d'environ 300 Ma ($^{40}Ar/^{39}Ar$ sur muscovite) et 337 Ma (Rb–Sr sur roches totales) résulteraient d'un rajeunissement dû à des événements thermotectoniques postérieurs à l'âge de cristallisation. Le leucogranite possède une granulométrie moyenne; il est équigranulaire, et contient l'association topaze + muscovite primaires. Les grains de biotite sont rares et petits (<0.1 mm). L'absence de textures indicatives d'une saturation en phase fluide (miaroles, croissances unidirectionnelles, pegmatites) fait penser que le magma leucogranitique était sous-saturé en eau lors de sa mise en place. Quoique les observations pétrographiques indiquent une modification sub-solidus des textures et de la minéralogie primaires, le leucogranite reflète surtout une signature plutôt magmatique que métasomatique. Il se distingue par des concentrations élevées de SiO_2, Al_2O_3 ($1.13 < A/CNK < 1.84$), fer total, P_2O_5, Rb, Cs, Ga, Li, F, Sn, Nb, Cu, Zn, W, U et Ta, et de faibles teneurs en TiO_2, CaO, MgO, Ba, B, Th, V, Co, Sc, Hf, Zr, Ni, Mo, Sb et Y. Comparé aux unités évoluées, et donc leucogranitiques, du batholite de South Mountain, le leucogranite de East Kemptville est enrichi en Ta, Sr, Rb, F et Li; leurs teneurs respectives en terres rares sont très différentes. Le leucogranite se compare davantage aux autres suites enrichies en fluor, et en particulier aux granites à topaze. Ce massif représenterait donc une fraction très évoluée d'un magma fortement hyperalumineux, lui-même dérivé par fusion d'une source contenant une biotite fluorée. Il pourrait ne pas représenter un produit de fractionnement au sein du batholite de South Mountain ou du complexe de Davis Lake. Son emplacement, dans une zone de cisaillement importante orientée vers le nord-ouest, pourrait vouloir indiquer que cette structure a été impliquée dans la génération et la mise en place du magma leucogranitique.

(Traduit par la Rédaction)

Mots-clés: topaze, muscovite, fluor, étain, leucogranite, East Kemptville, zone de Meguma, Nouvelle-Écosse.

INTRODUCTION

The East Kemptville leucogranite is a term introduced by Kontak (1987a) to describe the muscovite–topaz leucomonzogranite host-rock at the East Kemptville Sn–Cu–Zn–Ag deposit. The deposit represents North America's only primary producer of tin, with initial reserves estimated at 56 million tonnes grading 0.165% Sn (Richardson 1984, Moyle

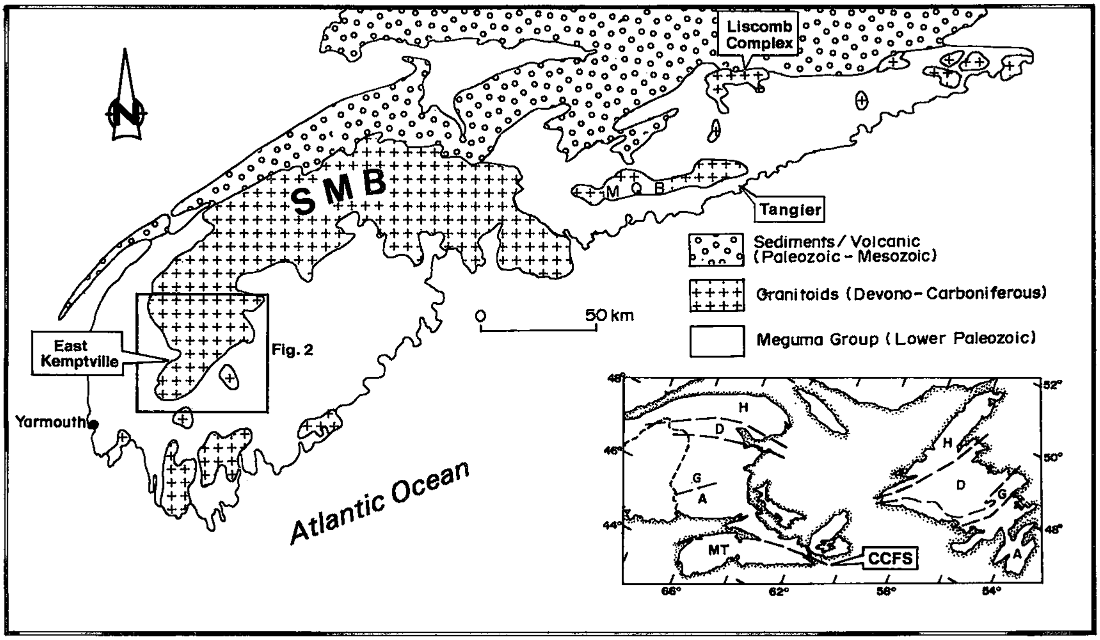


FIG. 1. Location map for the Meguma Terrane in the Canadian Appalachians, showing its relation to other major terranes and the boundary fault [(Cobequid–Chedabucto Fault System (CCFS)]. Also shown is the simplified geology of southern Nova Scotia, outline of the South Mountain (SMB) and Musquodoboit (MQB) batholiths, and location of East Kemptville area. Significance of the Liscomb Complex and Tangier (dykes) is discussed in the text. Abbreviations: MT Meguma Terrane, A Avalon, G Gander, D Dunnage, H Humber.

1985). The deposit, located in southwestern Nova Scotia, occurs at the western extremity of the 370 Ma South Mountain Batholith, where an elongate protrusion of granite intrudes metawackes of the Lower Paleozoic Meguma Group (Fig. 1).

Previous investigators (Richardson 1983, 1985a, b, Richardson *et al.* 1982, 1989, Richardson & Spooner 1982, Ford & O'Reilly 1985, Chatterjee & Strong 1984) considered the deposit to represent extreme fractionation of this part of the South Mountain Batholith, combined with extensive fluid-rock interaction, which resulted in formation of the greisen-hosted mineralization. Richardson (1988a, b) and Richardson *et al.* (1988a, 1989) have modified earlier models to accommodate recent results of Rb–Sr radiometric dating (Richardson 1988a, Richardson *et al.* 1987, 1988b), which indicate an age of *ca.* 330 Ma for the Davis Lake Complex (the westernmost intrusive phase of the South Mountain Batholith) and greisen at East Kemptville. Hence, Richardson (1988a, b) postulated a distinct petrogenetic evolution for the Davis Lake Complex, compared to the South Mountain Batholith, which accounted for its apparently younger age and potential for tin mineralization. Conversely, Kontak (1987a, b, c) and Kontak *et al.* (1986, 1988a) recognized that much of the East Kemptville deposit area is underlain by a mineralogically and compositionally distinct, but nevertheless uniform phase of muscovite–topaz leucogranite. The presence of topaz is unique to this part of the South Mountain Batholith, which suggests, therefore, that the East Kemptville leucogranite has a petrogenesis markedly different from that of other phases of the South Mountain Batholith. Thus, because of the generally recognized importance of tin mineralization and occurrence of topaz-bearing granites (Burt *et al.* 1982, Burt & Sheridan 1988, Christiansen *et al.* 1986, Kovalenko & Kovalenko 1984, Kovalenko *et al.* 1972, 1979), and the implications that such F-rich igneous suites have for the composition of basement protoliths (*e.g.*, Manning & Pichavant 1983, Christiansen *et al.* 1983, 1986, 1988, Christiansen & Lee 1986), it is important to document the petrogenesis of the East Kemptville leucogranite and to determine its relationship to the South Mountain Batholith.

Other F-rich igneous suites occur within the Canadian Appalachians, including topaz – lithium mica granite in the Fire Tower Zone of the Mount Pleasant tin deposit, New Brunswick (Kooiman *et al.* 1986, Taylor *et al.* 1985, Sinclair *et al.* 1988), the F-rich Harvey volcanic suite, also of New Brunswick (Payette & Martin 1986a, b), and mineralized (Sn, W) parts of the Ackley Granite, southeastern

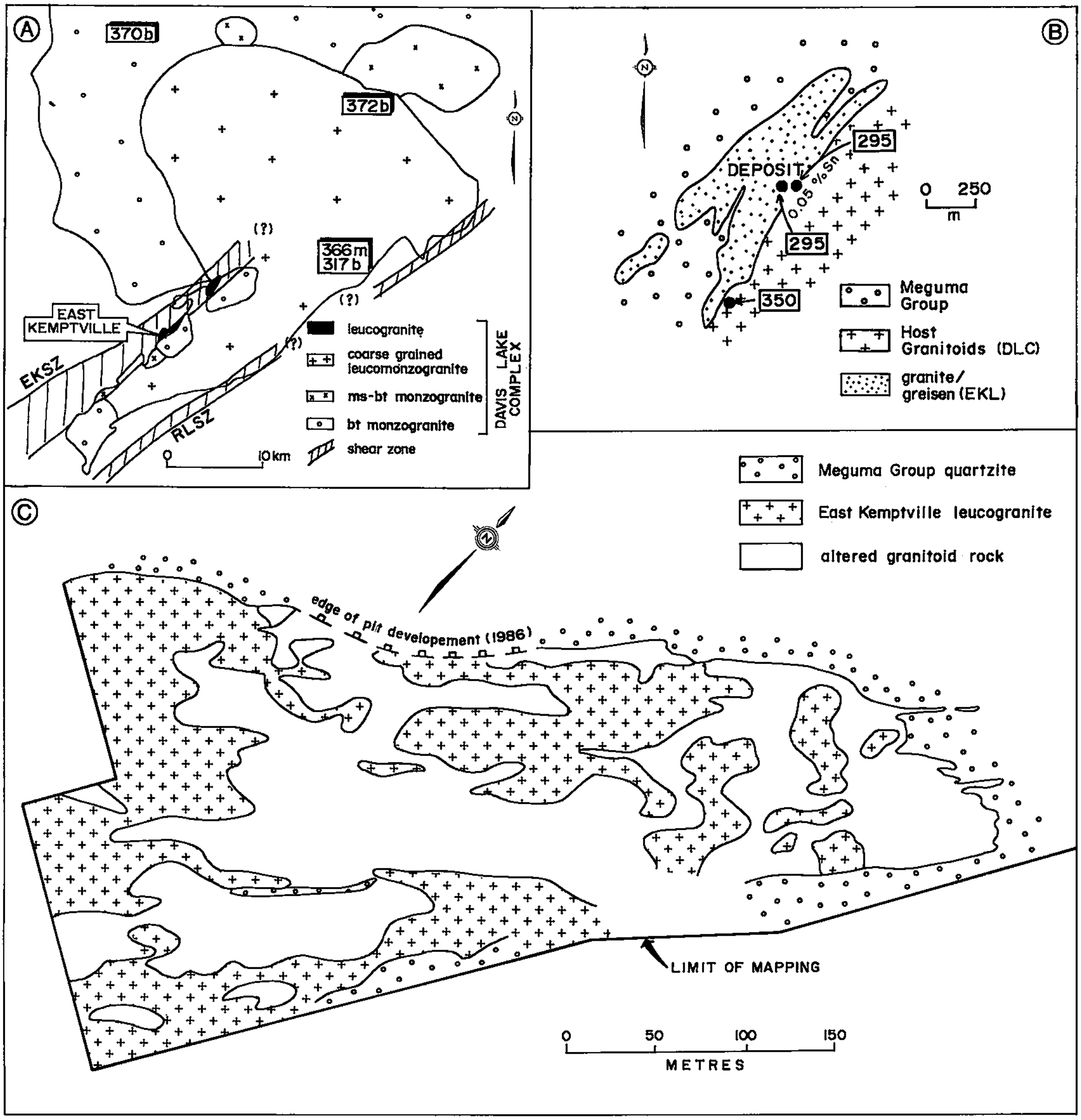


FIG. 2. (A) Simplified geological map of the southwestern part of the South Mountain Batholith (MacDonald *et al.* 1989, O'Reilly 1988a) showing location of the East Kemptville leucogranite and East Kemptville and Rushmere Lake Shear Zones (EKSZ, RLSZ). The ages represent $^{40}Ar/^{39}Ar$ biotite (b) and muscovite (m) data from Reynolds *et al.* (1981). (B) Outline of the area underlain by the East Kemptville leucogranite (EKL) and its approximate contact with granites of the South Mountain Batholith/Davis Lake complex (DLC). Also shown is the outline of the area mapped in detail by Kontak *et al.* (1986) and locations and results for muscovite dated by Zentilli & Reynolds (1985) using the $^{40}Ar/^{39}Ar$ technique. (C) Outline of the northern part of the East Kemptville deposit showing area underlain by unaltered *versus* variably altered East Kemptville leucogranite.

Newfoundland (Tuach *et al.* 1986, Tuach 1987). All of these suites, including the East Kemptville leucogranite, are of Late Devonian – Early Carboniferous age and may share common petrogenetic histories. Of course the association of lithophile element mineralization and F-rich igneous rocks is not unique to this area; in fact, it is an association that has been noted for some time (*e.g.*, Tischendorf 1977, Taylor 1979, and references therein). However, the significance of this association has perhaps only recently been realized as more occurrences are documented (*e.g.*, Taylor & Strong, 1985, 1988). Thus, the purpose of this study is to (1) document the petrology of the East Kemptville leucogranite, (2) discuss the petrogenesis of the East Kemptville leucogranite in terms of other intrusive complexes of the Meguma Terrane, and (3) discuss the implications of this study in terms of potential for tin mineralization in the Meguma and adjacent terranes of the Canadian Appalachians. The presence of a topaz-bearing granite within the Meguma Terrane also has ramifications in terms of probable basement rocks that underlie this part of the Appalachians, based on our understanding of conditions prerequisite for the production of such F-rich melts (*e.g.*, Christiansen *et al.* 1983, 1986, Manning & Pichavant 1983, 1988, Pichavant & Manning 1984).

In Part I, presented here, the petrology of the East Kemptville leucogranite, including whole-rock major- and trace-element chemistry, rare-earth-element chemistry and oxygen isotope data, are discussed in the context of the South Mountain Batholith. Part II presents the mineral chemistry of the East Kemptville leucogranite.

REGIONAL GEOLOGICAL SETTING

The East Kemptville leucogranite is located within the Meguma Terrane, the easternmost of several terranes that collectively constitute the Canadian Appalachians (Williams & Hatcher 1983; Fig. 1). This terrane was accreted during the Late Devonian Acadian Orogeny along the east–west Cobequid–Chedabucto Fault System (Webb 1969, Keppie 1982, Mawer & White 1986). Continued transpression of this terrane is documented by the presence of numerous northeast-to east-trending shear zones that were active at *ca.* 370–300 Ma (Keppie & Dallmeyer 1987, Dallmeyer & Keppie 1987, Reynolds *et al.* 1987, Hill 1988, Muecke *et al.* 1988). The presence of these high-strain zones is emphasized because of their importance for the petrogenesis of the East Kemptville leucogranite (see below).

The Meguma Terrane is underlain by inferred Precambrian ortho- and paragneiss, as indicated by recent field and geochemical investigations in the Liscomb and Tangier areas of southern Nova Scotia (Fig. 1; Giles & Chatterjee 1986, 1987, Chatterjee & Giles 1988, Clarke & Chatterjee 1988, Eberz *et al.* 1989). These authors have recognized the presence of granulite-facies rocks cropping out in the form of a gneiss dome in the Liscomb area and as xenoliths in mafic dykes and intrusive bodies in both the Liscomb and Tangier areas. The rocks are chemically distinct from Meguma Group lithologies (Eberz & Clarke 1988, Eberz *et al.* 1989) and are, therefore, interpreted to represent a partial sampling of various structural levels of the Meguma Terrane infrastructure. Recently acquired ^{40}Ar/^{39}Ar plateau ages of *ca.* 370–380 Ma (amphibole, biotite) have been obtained for the gneissic rocks (Kontak *et al.* 1989b, 1990, Kontak, unpubl. data), indicating that emplacement of the gneisses may have been coincident with later stages of the Acadian Orogeny.

Overlying the inferred basement rocks with presumed unconformity are Lower Paleozoic metasedimentary and metavolcanic rocks (*e.g.*, Meguma Group, White Rock Formation). These rocks were deformed and metamorphosed during the Mid- to Late Devonian Acadian Orogeny (Keppie 1982, Muecke 1984, O'Brien 1985). Large volumes of meta- to peraluminous granitic rock were emplaced at *ca.* 370 Ma (Hill 1988, Reynolds *et al.* 1981, 1987, Clarke & Halliday 1980, Keppie & Dallmeyer 1987, Krogh & Keppie 1988), with lesser amounts of peraluminous granite intruded at *ca.* 315 Ma (*e.g.*, Wedgeport granite: Cormier *et al.* 1988). Mafic bodies, in the form of plutons and dyke rocks, also have been recognized in the central part of the Meguma Terrane in recent years (Giles & Chatterjee 1986); ages of *ca.* 370 Ma were obtained based on ^{40}Ar/^{39}Ar dating (Kontak *et al.* 1989b, 1990, Kempster *et al.* 1989).

The presence of coarse terrestrial redbeds (*i.e.*, Horton Group) of Early Carboniferous age unconformably overlying the South Mountain Batholith indicates rapid uplift and erosion during Early Carboniferous time. Inherent in the formation of the Carboniferous basins was a regime of widespread, overall extensional tectonics (Fralick & Schenk 1981).

FIELD RELATIONSHIPS OF THE EAST KEMPTVILLE LEUCOGRANITE

The East Kemptville leucogranite occurs at the southwest termination of the 370 Ma South Mountain Batholith (Figs. 1, 2A). The batholith (10,000 km^2) is post-tectonic; it comprises compositionally and texturally variable peraluminous granitic units, from granodiorite to monzogranite. Several intrusive complexes have been recognized (*e.g.*, the Halifax Pluton: MacDonald & Horne 1988) such that the batholith results from multiple intrusions, each with its own magmatic history [see MacDonald *et al.* (1988, 1989) and references therein]. Although end-member units representative of the most evolved stages of fractionation occur (Muecke & Clarke 1981, Kontak *et al.* 1988b, Corey *et al.* 1988), such muscovite ± andalusite leucogranites are barren of topaz and are not enriched in fluorine beyond a few thousand ppm (Ham *et al.* 1989). Thus, despite the extremely large dimensions of the South Mountain Batholith and its degree of fractionation, the occurrence of topaz as a potential magmatic phase is rare. However, it is worth noting that topaz has been reported as an accessory phase from a few greisen localities in the eastern part of the South Mountain

Batholith (Logothetis 1985).

As illustrated in Figure 2, the East Kemptville leucogranite occurs as a small, lobate protrusion of the South Mountain Batholith at the granite-metasediment contact. It is volumetrically small, a feature characteristic of topaz-bearing suites in general (Christiansen *et al.* 1986, Pichavant & Manning 1984). Unfortunately, its relationship to the surrounding intrusive rocks remains ambiguous owing to lack of outcrop. Regionally the East Kemptville leucogranite occurs in a northeast-trending shear zone, referred to as the East Kemptville Shear Zone (EKSZ), which has a width of about 1–4 km and presently known strike-length of about 40 km (O'Reilly 1988a). Subparallel to this shear zone is a second major structural break, the Rushmere Lake Shear Zone (RLSZ: Smith 1985), which delineates in part the southern boundary of the South Mountain Batholith. Both structures record an intense phase of shearing, with variable amounts of hydrothermal alteration. The EKSZ is host to several mineralized centers (Sn–W–Cu–Zn–Ag); in contrast, only minor amounts of base-metal mineralization have been observed along the RLSZ. The age of the deformation along these zones is variable over the interval 330–260 Ma based on $^{40}Ar/^{39}Ar$ age spectra on muscovite and feldspar (Zentilli & Reynolds 1985, Reynolds *et al.* 1981, Soehl *et al.* 1989) and Rb–Sr whole-rock and mineral isochrons (Kontak *et al.* 1989a).

The East Kemptville leucogranite is exposed in the large open-pit mine site east of Yarmouth (Figs. 1, 2). It occupies a prominent flexure in the regional granite–metasediment contact, and its dome or whale-back configuration is due to its doubly plunging attitude (Fig. 2b). It is oriented northeast-southwest, has a surface outline of *ca.* 1.5 km by 0.5 km, and intrudes quartzites to quartz wackes of the Goldenville Formation, lowermost member of the Cambro-Ordovician Meguma Group. The sedimentary rocks define an antiformal structure in the immediate vicinity of the deposit and are notably indurated and hornfelsed, with a spotted texture; rafts or xenoliths of this unit are not observed in the leucogranite. However, the sedimentary rocks do form long, narrow roof-pendants that penetrate vertically into the leucogranite, thereby suggesting that the roof zone is presently exposed. The presence of local fluidized breccia and granitic dyke material penetrating the overlying sedimentary rocks (Fig. 3), as observed immediately north of the granite – sedimentary rock contact (Fig. 2C), also suggests close proximity to the roof zone of the pluton.

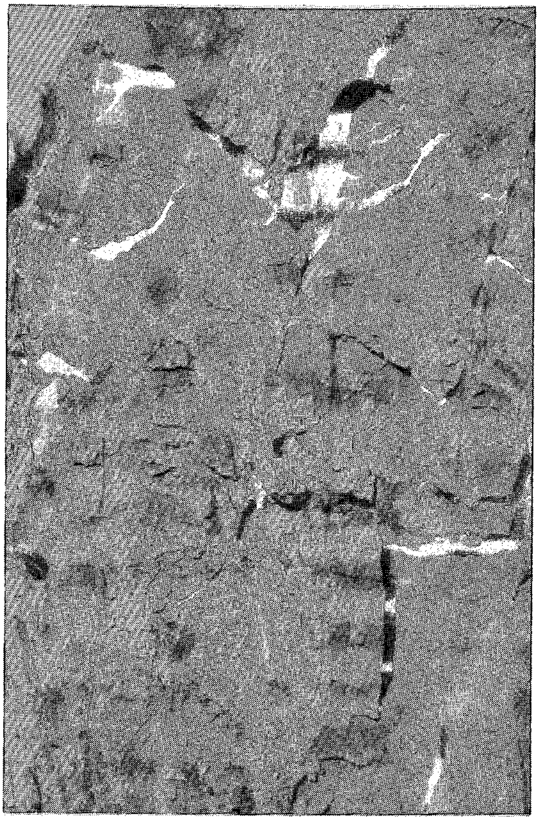
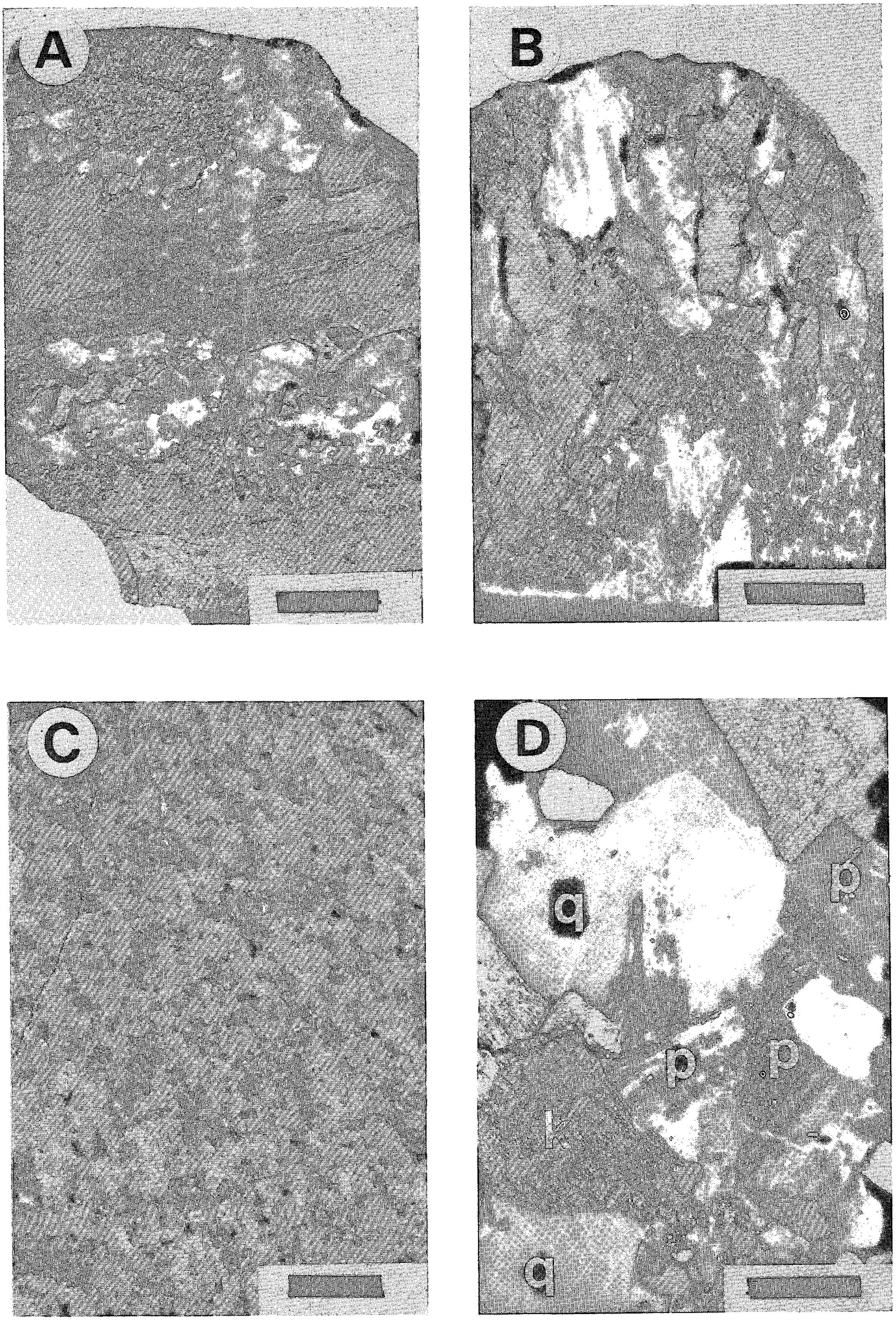


FIG. 3. Photograph of outcrop of Meguma Group metasedimentary rock cut by subvertical veinlets of fine-grained (*i.e.*, chalcedonic) quartz. In detail, veins are seen to contain angular fragments of the wall rock sediments and fine-grained granitic clasts (width of exposure 0.65 m).

Although only the northern half of the deposit area was mapped as a part of this study (Fig. 2C), the remainder of the deposit has been examined as mining has developed and, therefore, the following observations are considered to be generally applicable to the whole pluton. The East Kemptville leucogranite is generally homogeneous in its texture, grain size and mineralogy (Fig. 4) throughout the mine site. Moderately fresh leucogranite is estimated to underlie approximately 30–40% of the deposit area; the remaining rock consists of variably altered and greisenized granitic material. The granite is typically medium grained, although finer-grained textural varieties do occur. The absence of chilled margins, K-feldspar megacrysts, miarolitic cavities, breccias and unidirectional solidification textures (*USTs*) (*e.g.*, Shannon *et al.* 1982, Sinclair *et al.* 1988, Kirkham & Sinclair 1988) is emphasized. The presence of local pegmatite segregations (Figs. 4A, B) is restricted to a few localities at granite – sedimentary rock contacts. In these latter cases, a border phase of coarse quartz–feldspar intergrowth with oriented quartz crystals is cored by banded aplite (Fig. 4A). Recently, Richardson *et al.* (1988b) have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briefly discussed these localities and inferred that they represent examples of *USTs*. Although the grain size of the leucogranite may vary from medium- to fine-grained, with the former being more abundant, no intrusive contacts have been observed; the variation may reflect local thermal perturbations and, hence, rate of crystallization. Fine-grained, aphanitic, greenish dyke-rocks also occur, albeit only rarely.

The East Kemptville leucogranite is everywhere cut by a heterogeneously developed, northeast-trending fabric that is variably defined as a spaced or fracture cleavage in the least-deformed rocks to ultramylonite in the most highly strained areas (Fig. 5). C–S fabrics also are present (Fig. 5C) and represent a transition between the aforementioned fabrics. Of several hundred thin and polished sections examined, only a small percentage do not show textural evidence (*i.e.*, kinked mica, fractured feldspar grains, undulose quartz grains with subgrain development) of superimposed deformation.

AGE OF THE EAST KEMPTVILLE LEUCOGRANITE

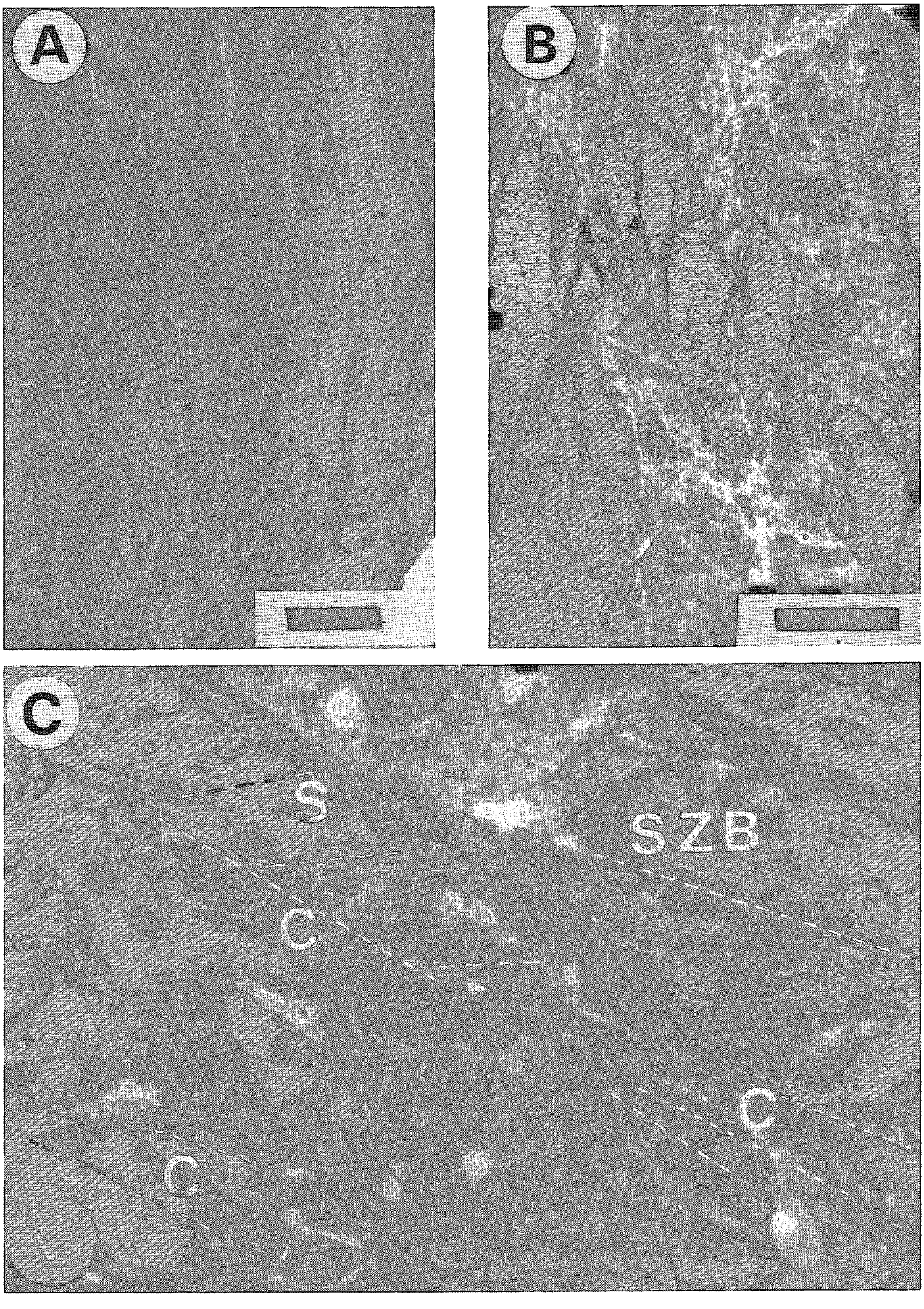
Based on field relationships, the East Kemptville leucogranite is younger than the Mid- to Late Devonian Acadian Orogeny, dated at *ca.* 400 ± 10 Ma (Reynolds & Muecke 1978, Muecke *et al.* 1988, Keppie & Dallmeyer 1987), and older than the deformation alluded to above. Previously published $^{40}Ar/^{39}Ar$ ages of *ca.* 300 Ma for two samples of greisen muscovite (see Fig. 2B) were interpreted by Zentilli & Reynolds (1985) as representing the age of the mineralizing event and, therefore, probably a good approximation of the age of intrusion. More recently, Richardson *et al.* (1988b) inferred an age of 337 ± 5 Ma for the mineralizing event based on a 5-point whole-rock Rb–Sr isochron. Thus, there appears to be contradictory evidence at present regarding the timing of mineralization and, hence, intrusion of the leucogranitic magma. Important in light of this is a third $^{40}Ar/^{39}Ar$ age spectrum for muscovite reported by Zentilli & Reynolds (1985) for a sample immediately southeast of the East Kemptville deposit but within the leucogranite (Fig. 2B). This sample gave a discordant age spectrum, but indicated a possible age of *ca.* 350–360 Ma for the high-temperature gas fractions. This latter age is consistent with a recently obtained 11-point Rb–Sr whole-rock isochron age of 344 ± 5 Ma (Kontak *et al.* 1989a) for relatively fresh samples of leucogranite.

In the studies by Zentilli & Reynolds (1985) and Richardson *et al.* (1988b), there is no discussion of the possible effects the deformation mentioned above may have had on the isotopic systems. Both the Rb–Sr and K–Ar isotopic systems are sensitive to thermal disturbance (*e.g.*, Jäger 1979); therefore, the presence of deformational textures within the study area is reason to interpret the age data with caution. The younger Ar–Ar ages are similar to published Ar–Ar ages from other areas of southwestern Nova Scotia (Reynolds *et al.* 1981, 1987, Dallmeyer & Keppie 1987; see Fig. 2A), which have been attributed to thermotectonic disturbances. A similar interpretation is offered here for both the Ar–Ar and whole-rock Rb–Sr ages obtained from the East Kemptville greisens. The older Rb–Sr whole-rock age may represent a better approximation, albeit still a minimum, for the age of the East Kemptville leucogranite because of the general unreliability of Rb–Sr isochrons in areas where a subsequent thermal disturbance has occurred (*e.g.*, Schärer *et al.* 1988, Walraven *et al.* 1985, Kontak *et al.* 1988c). Unpublished Pb-isotope data for the East Kemptville leucogranite and greisens indicate a Pb–Pb isochron age of 370 ± 1 Ma (Chatterjee & Kontak, in prep.). Hence, the age of intrusion and related hydrothermal activity is considered to be temporally equivalent to the rest of the South Mountain Batholith (*i.e.*, 370 Ma), with the younger ages reflecting episodic tectonothermal activity.

PETROGRAPHY OF THE EAST KEMPTVILLE LEUCOGRANITE

As stated earlier, the East Kemptville leucogranite is a medium-grained, equigranular monzogranite on the basis of point counts on both stained slabs and thin sections (Table 1, Fig. 6). It should be noted, however, that the plagioclase present in the rock is pure albite. In the classification scheme of Streckeisen (1976), the leucogranite would be more

FIG. 4. Photographs of the East Kemptville leucogranite showing some of the lithological variation in the unit. (A) Sample of pegmatite–aplite from the northern part of the map area (see Fig. 2c). Note the banded nature of the aplitic core and the quartz crystals projecting into the center of the sample. The chemical composition of the aplite in this photo is represented by #099 in Table 2 (bar scale 3 cm). (B) Pegmatite (chemical composition is represented by sample #098 in Table 2) showing coarse intergrowth of quartz and feldspar crystals. Note the deformation textures manifested as color bands in quartz and spaced fracture-cleavage in lower right of the photo (bar scale 2 cm). (C) Typical specimen of East Kemptville leucogranite showing the medium-grained equigranular texture characteristic of the unit. Note the absence of megacrysts and miarolitic cavities (bar scale 1 cm). (D) Photomicrograph of undeformed specimen of leucogranite showing the idiomorphic to hypidiomorphic granular texture that characterizes undeformed samples (k = alkali feldspar; p = albitic plagioclase; q = quartz) (bar scale 0.50 mm).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correctly described as an alkali feldspar granite (*sensu stricto*). However, since the albite is interpreted to be a replacement phase for a calcium-rich precursor (*i.e.*, oligoclase), the term *monzogranite* is retained. The homogeneous nature of the granite is demonstrated by the fact that point counting of thin sections and stained slabs defines comparable fields in terms of the percentages of quartz, plagioclase and K-feldspar (Fig. 6). The essential mineral constituents with their average modal percentages (± 1 standard deviation), as determined from approximately 38,000 point counts of 25 thin sections of the leucogranite, are quartz (36.8 ± 4.9), plagioclase (30.0 ± 3.7), K-feldspar (19.4 ± 5.3), muscovite (7.8 ± 4.7) and topaz (5.4 ± 1.5), with accessory biotite, zircon, monazite, apatite and ore phases (cassiterite, sulfides, oxides). Accessory phases account for much less than 0.5 modal % of the mineral constituents. The proportions of the major mineral constituents in the leucogranite are illustrated in Figure 6 and demonstrate that, except for a few samples, the mineral proportions are fairly constant. In thin section, the leucogranite is generally quite variable between idiomorphic to xenomorphic, the latter being attributed to the combined effects of postmagmatic alteration and later deformation.

Quartz is generally anhedral, but may appear as equant grains having the habit of high-temperature (β) quartz (Fig. 4D); it forms sharp contacts with all other minerals. Inclusions are not common, but small grains of plagioclase and, rarely, biotite (Fig. 7I) have been observed.

Plagioclase (Fig. 7A) is invariably subhedral to euhedral, displays albite and Carlsbad twinning, and is of albitic composition. Sharp contacts with all other mineral phases have been observed. The plagioclase always contains small inclusions of apatite (Fig. 7B). Plagioclase may also occur as subhedral to anhedral inclusions within K-feldspar (Figs. 7C, D); these are interpreted as representing vestiges of larger plagioclase grains that were replaced by K-feldspar.

K-feldspar forms the coarsest mineral phase, is generally subhedral to anhedral, and overgrows other minerals (Fig. 7C), most notably plagioclase. However, in the least altered and structurally modified leucogranites, K-feldspar is subhedral, rarely overgrows plagioclase, has straight contacts with other mineral phases, and may be similar in grain size to the other mineral constituents (Fig. 4D). Thus, much of the irregular texture and overgrowth of this mineral is presumed to be related to late magmatic growth and subsolidus modification (*e.g.*, Witt 1988). Exsolution lamellae are ubiquitous and most commonly are flame type, with lesser amounts of patch perthite (Figs. 7D, E). The K-feldspar is triclinic, and grid twinning typical of low microcline is common. The structural state of the K-feldspar has been confirmed by X-ray-diffraction studies, which indicate a triclinicity of 1 (Kontak, unpubl. data). It is not possible to say if the ordering is an early feature or related to the superimposed deformation.

Muscovite occurs as subhedral, rarely euhedral grains (Fig. 7F), with rare inclusions of accessory minerals. It shares straight contacts with adjacent phases. A magmatic origin is consistent with the textures observed (Ham & Kontak 1988).

Topaz (Figs. 7G, H) occurs in all samples, being homogeneously disseminated throughout. It is generally subhedral, but euhedral grains have been observed in dyke rocks. The topaz is most commonly fractured, even in cases where all other mineral phases are apparently pristine in habit (*i.e.*, free of structural modification); the reason for this is not presently known. Inclusions in topaz are rare, but muscovite and plagioclase do occur. All indications are that the topaz represents a magmatic phase and not a later manifestation of hydrothermal activity (see below).

Trace amounts (*i.e.*, a few grains per thin section) of a biotite-like phase occur as small (< 0.1 mm), subhedral, medium brown to light orange-brown grains (Fig. 7I). They are commonly zoned to a lighter shade toward their margin and may be mantled by muscovite. Minute inclusions of opaque phases may occur.

Accessory phases include zircon, monazite, apatite, uraninite, Nb–Ta oxides and ore minerals (sphalerite, cassiterite, pyrite, chalcopyrite, pyrrhotite, cassiterite).

Examination of thin sections shows extensive development of deformational textures (*e.g.*, Fig. 5B). Details of the structure of the leucogranite is beyond the scope of this paper and will be reported elsewhere.

FIG. 5. Photomicrographs of structurally modified East Kemptville leucogranite illustrating the degree of deformation present within the deposit area. Protoliths in all cases represented by samples shown in Figures 4c and d. (A) Blastomylonitic texture in cut slab of East Kemptville leucogranite with a few remnant grains of partially comminuted quartz visible. The fabric has a field orientation of NE/subvertical (bar scale 1 cm). (B) Photomicrograph of protomylonite (bar scale 0.50 mm). (C) Field photograph showing spaced fracture-cleavage (C) cutting pre-existing, penetrative flattening fabric (S) in high-strain zone of East Kemptville leucogranite. Note that the granite in upper right of the photo [*i.e.*, beyond the shear zone boundary (SZB)] remains relatively undeformed. Dime is shown for scale in lower left of photo.

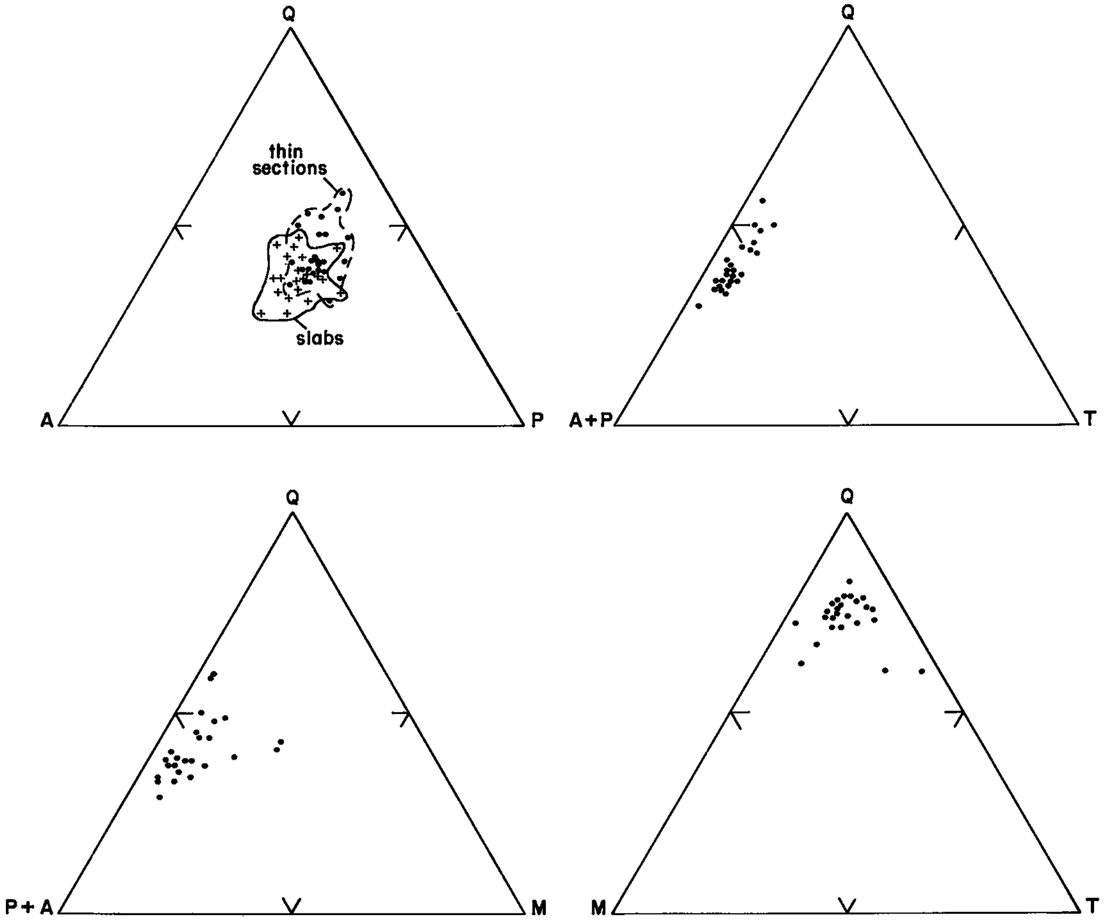


FIG. 6. Triangular plots showing results of point counting samples of East Kemptville leucogranite (see Table 1 for summary of data). Note the comparison of data for thin sections *versus* slabs in the QAP plot. Abbreviations: Q quartz, A alkali feldspar, P albitic plagioclase, T topaz, M muscovite).

WHOLE-ROCK GEOCHEMISTRY

Analytical procedures

Powdered whole-rock samples were analyzed for major elements using wet-chemical techniques at Memorial University of Newfoundland, St. John's, and the Technical University of Nova Scotia (TUNS), Halifax. All analyses for Si, Al and F presented were obtained at TUNS. Details of analytical procedures employed at these two institutions are described by Wilton (1985) and Chatterjee *et al.* (1983), respectively. Trace-element data were obtained at St. Mary's University, Halifax, using an automated Philips X-ray-fluorescence (XRF) spectrometer (Rb, Sr, Ba, Zr, Nb, Pb, Ga, Zn, Cu, Ni, V), at Bondar-Clegg Ltd., Ottawa, using neutron activation (U, Th, Cs, W, Mo, Ta, Hf, Sc), XRF (Sn), DC plasma (B), and atomic absorption spectroscopy (Li), and at TUNS using titration (S) techniques. Rare-earth-element (*REE*) data and some trace-element data (Y, Ba, Nb, Zr, U, Th, Co, Ta, Hf, Cs, Sc) were obtained by instrumental neutron activation, with data reduction done using facilities at Carleton University (Ottawa) and St. Mary's University (Halifax), and inductively coupled plasma mass spectrometry (ICP/MS, Memorial University, St. John's).

Oxygen isotopes were analyzed at the University of Saskatchewan, Saskatoon, employing conventional procedures for the isotopic analyses of silicates (Clayton & Mayeda 1963). Isotopic data are reported as $\delta^{18}O$ values in per mil (‰) relative to Standard Mean Ocean Water (SMOW) based on analysis of the NBS-28 laboratory standard. The overall reproducibility of $\delta^{18}O$ values has averaged ±

TABLE 1. MODAL MINERALOGY OF EAST KEMPTVILLE LEUCOGRANITE

Sample	#points	quartz	kfs	pl	ms	topaz
EK-86-3	1449	40.5	17.0	26.0	9.6	6.5
EK-86-9	1500	32.3	25.1	33.0	3.8	5.8
EK-86-12	1500	36.2	24.8	26.6	7.3	5.0
EK-86-13A	1829	41.8	17.0	28.6	7.9	4.5
EK-86-23A	1500	34.7	22.7	32.6	4.5	5.0
EK-86-23A	1500	36.0	21.6	32.0	4.9	4.7
EK-86-23B	1500	34.2	23.3	29.8	5.8	6.4
EK-86-23C	1500	35.0	24.6	29.4	3.1	6.4
EK-86-23F	1500	31.2	23.9	31.5	7.4	5.6
EK-86-27	1500	38.3	10.8	27.7	17.1	5.8
EK-86-40	1500	36.8	15.8	36.2	5.9	4.2
EK-86-60	1500	33.8	22.9	32.8	3.2	7.1
EK-86-68	1594	36.5	22.7	29.7	6.2	4.6
EK-86-69	1500	31.1	29.0	28.7	4.2	6.5
EK-86-71	1500	36.2	20.8	30.8	3.9	7.7
EK-86-72	1664	45.2	14.2	26.1	8.2	6.1
EK-86-91	1500	34.8	20.8	32.4	3.9	7.8
EK-86-105	743	41.9	7.2	22.7	24.8	3.0
EK-86-110	1418	30.8	17.4	36.1	10.7	4.6
EK-86-122B	1500	47.6	18.0	24.3	5.2	4.8
EK-86-124B	1500	44.6	10.8	26.7	9.8	7.6
EK-86-132	1867	35.9	20.8	28.4	12.8	1.7
EK-86-156	1550	33.2	22.0	32.7	8.1	3.8
EK-86-161	1500	27.7	23.2	38.7	7.2	3.0
EK-86-1075	1921	44.6	10.8	26.7	9.8	7.6
*Total	38035	36.8 ± 4.9	19.4 ± 5.3	30.0 ± 3.7	7.8 ± 4.7	5.4 ± 1.5

*Total number of points counted with the mean ± 1 standard deviation for each mineral.

Note that sample EK-86-23A was point counted on two thin sections to assess the homogeneity represented by this scale of observation. The results indicate that the granite is consistent with respect to modal mineralogy and that 1500 points per thin section is representative.

Abbreviations: kfs = K-feldspar, pl = plagioclase, ms = muscovite.

0.18‰ (2σ) in the laboratory (R. Kerrich, pers. comm., 1987).

During all analyses both international and intralaboratory standards were routinely included with the EKL samples; in addition duplicates of the unknowns were analyzed. The only problems encountered were for the *REE*s, where low concentrations for particular elements resulted in slightly different results (see below).

Whole-rock geochemistry

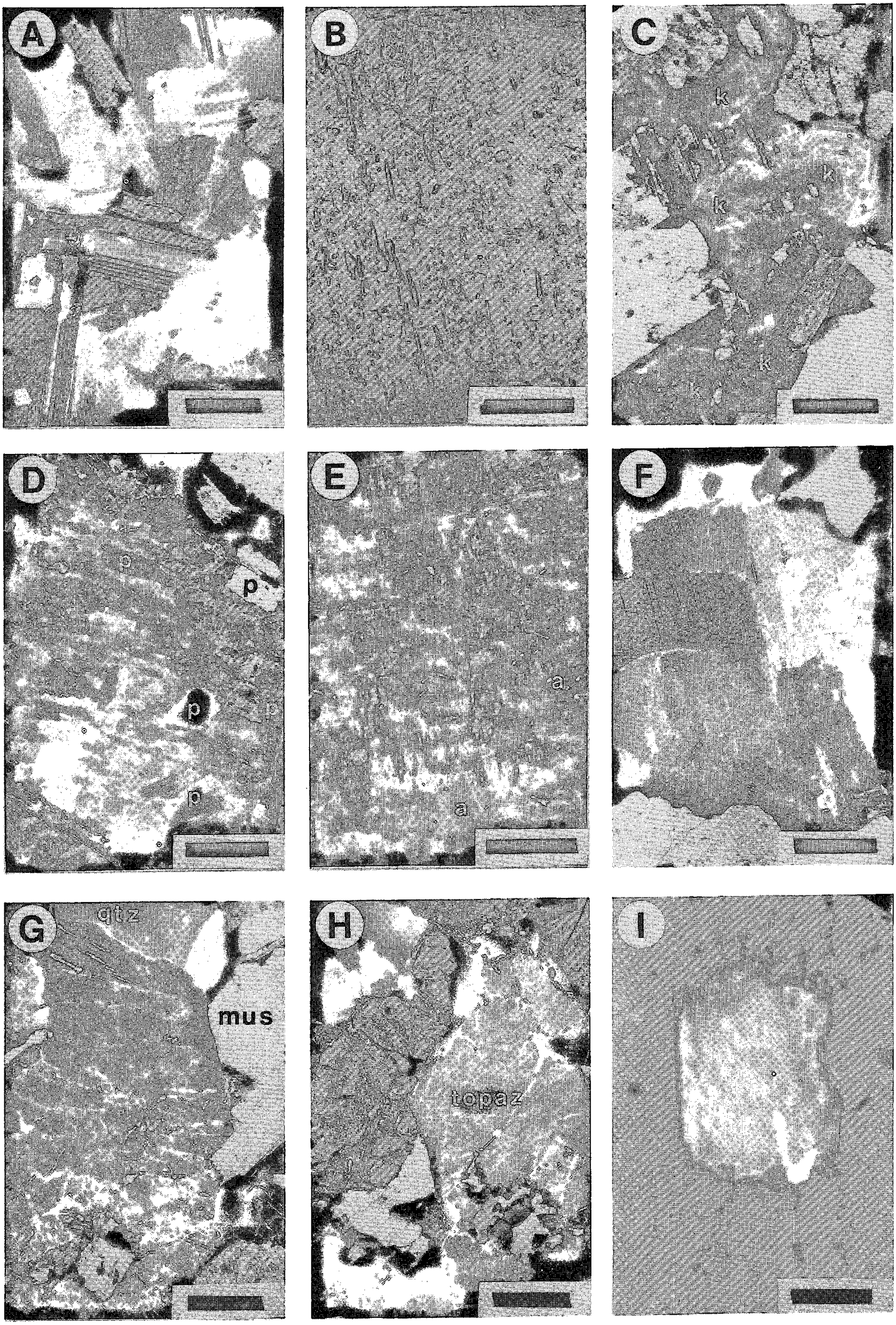
Results of 27 whole-rock analyses, presented in Table 2 (major and trace elements) and Table 3 (*REE*), were obtained from: (1) the medium-grained, equigranular phase, (2) fine-grained dyke rocks (samples 021, 091, 105), (3) a pegmatite (098), and (4) the aplitic core of a pegmatite (099). Comparison of the average leucogranite (n = 22) to other felsic igneous rocks characterized by enrichment in F and LILE is made in Table 4.

Major-element chemistry

Major-element concentrations in the leucogranite are fairly uniform, and indicate that it is rich in SiO_2, with a range of *ca.* 72–76 wt.%; the single pegmatite sample is slightly enriched at 77 wt.%. The only deviation from the apparent homogeneity of the data is the notable enrichment of the pegmatite sample and the dyke rocks in Na relative to the rest of the data set, with weight % Na_2O/K_2O ratios exceeding unity. Compared to the average low-calcium granite of Turekian & Wedepohl (1961), the leucogranite is enriched in silica (above), Al (14–16 wt.% Al_2O_3), Na (3–5 wt.% Na_2O), and P (0.2–1 wt.% P_2O_5). Similarly, very low concentrations of Ti (< 0.08 wt.% TiO_2) and Mg (0.16–0.01 wt.% MgO) characterize the leucogranite compared to the average low-calcium granite. The major-element chemistry of the leucogranite is comparable to that reported for topaz granites (Pichavant & Manning 1984), particularly the low Ca, Mg and Ti contents.

Although iron contents of topaz granites are generally low, the slightly elevated concentration of total iron in the East Kemptville leucogranite (1.41 ± 0.42 wt.%) is attributed to finely disseminated opaque phases (*i.e.*, sulfides), and the iron-rich nature of the muscovite (see Part II). As is expected, the redox state of the iron is mostly Fe^{2+}, with FeO/Fe_2O_3 ratios averaging 3.91 ± 2.04. The elevated phosphorus contents are abnormal for felsic suites in general (*e.g.*, Watson & Capobianco 1981), but not unusual for granites of the South Mountain Batholith (Ham *et al.* 1989) or granitic rocks of the Meguma Zone in general (MacDonald & Clarke 1985, MacDonald & Horne 1988, O'Reilly 1988b, Ham 1988). The elevated absolute concentrations of Na and the high Na/K ratios are not atypical for felsic igneous suites (*e.g.*, Hughes 1973). Comparable enrichment of sodium is found in other volatile-enriched suites (*e.g.*, Manning 1982, Kovalenko *et al.* 1972, 1979, Christiansen *et al.* 1983, 1986, Pichavant *et al.* 1988, Payette & Martin 1986a), where it is generally considered to reflect the influence of dissolved volatile species (*i.e.*, fluorine in this case) on the phase relationships of the melt. For example, Manning (1981, 1982) has shown that the effect of fluorine is to expand the stability field of quartz at the expense of albite such that residual melts in the quartz - albite - K-feldspar pseudoternary system are relatively enriched in sodium over potassium.

The strongly peraluminous nature of the leucogranite, consistent with its modal mineralogy, is manifested by elevated values of both normative corundum (2.88 to 7.88%; Fig. 8) and the A/CNK value (1.13 to 1.84). These strongly peraluminous compositions are comparable to those reported in topaz granite suites elsewhere [see Pichavant & Manning (1984) for summary, and also Weidner & Martin (1987) and Stone & Exley (1986)], but are unusually so compared to topaz rhyolites (Christiansen *et al.* 1983, 1986) which are commonly


A
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diopside normative (Fig. 8). The leucogranite data are comparable to values for restite-rich granites in the classification of Clemens & Wall (1981), although restite phases have not been identified. The leucogranites are more strongly peraluminous than the average Hercynian two-mica granite (LaRoche *et al.* 1980), the S-type Violet Town volcanic suite (Clemens & Wall 1984), a suite of biotite - cordierite ± sillimanite monzogranites (Kontak & Clark 1988) and andalusite - sillimanite - muscovite volcanic rocks (Pichavant *et al.* 1988) from southern Peru, and fluorine-rich granites from Mount Pleasant, New Brunswick (Kooiman *et al.* 1986) (Fig. 8). Compared to the field delineated for the average units of the South Mountain Batholith in the silica *versus* % normative corundum plot, the East Kemptville data are also seen to be markedly more peraluminous overall. In the same figure, the data also are compared to some relevant experimental data from Clemens & Wall (1981). The strongly peraluminous nature of the East Kemptville leucogranite is evident; by analogy to experimental data, the generation of such compositions requires the participation of a strongly peraluminous phase (*i.e.*, melt, topaz, muscovite).

The average fluorine content of the East Kemptville leucogranite is 0.76 wt.%, but there is considerable variation (between 0.29 to 2.01 wt.%). Compared to the abundance of fluorine in felsic igneous rocks in general (Bailey 1977), the leucogranite is comparable to topaz rhyolites and granites (Christiansen *et al.* 1983, 1984, 1986, Pichavant & Manning 1984), and ongonites (Kovalenko *et al.* 1972, 1979). A comparison of the fluorine content of the leucogranite and granitic rocks of the eastern half of the South Mountain Batholith is shown in Figure 9, where it is demonstrated that the former are relatively enriched in this element. Samples for the eastern half of the South Mountain Batholith generally fall in the range 0.03–0.3 wt.%, with a few samples approaching 0.4–0.5 wt.% in cases of extreme differentiation. However, MacDonald & Clarke (1989) have recently concluded that much of this enrichment is due to late-stage alteration related to deuteric fluids rather than reflecting primary magmatic enrichment. Also shown in Figure 9 are compositions of samples from the Davis Lake Complex determined by Richardson (1988a). Although these samples show silica enrichment, there does not appear to be a comparable enrichment in fluorine.

The normative mineralogy of the leucogranite is dominated by quartz, albite, orthoclase and corundum; the suite is compositionally similar to the haplogranite system. Comparison of the normative proportions of Q(quartz), P(albite) and A(alkali feldspar) for the leucogranite (Fig. 10A) to various polybaric cotectics in the H_2O- and F-bearing haplogranite sytems is shown in Figure 10B. As is evident, the data do not plot near the 1-kbar cotectic for the F-rich system as determined by Manning (1981), but do correspond to the low-pressure cotectic at 0.5–1.0 kbar for the haplogranite system (Luth 1976). How realistic these comparisons are remains questionable though, since the experiments were run at water-saturated conditions, whereas it is inferred that the East Kemptville leucogranite represents the product of crystallization of an H_2O-undersaturated magma.

In view of the well-documented relationship between normative composition and volatile content (*i.e.*, F) in felsic igneous rocks, the F contents of the leucogranite samples are shown in Figure 10A. There appears to be no obvious correlation between proximity of samples to the albite apex of the triangular diagram and F content, although the samples collectively define a trend toward the albite corner. Also shown in Figure 10B are other F-rich suites, *viz.* the Macusani glass (Pichavant *et al.* 1987b), topaz rhyolites (Christiansen *et al.* 1983), the Harvey Group volcanic suite (Payette & Martin 1987a, b), ongonites (Kovalenko *et al.* 1972), cryolite-bearing rhyolite plugs, Texas (Rubin *et al.* 1987), Mexican rhyolites (Huspeni *et al.* 1984), topaz granites, Mount Pleasant, New Brunswick (Kooiman *et al.* 1987) and the lepidolite–topaz Beauvoir granite, France (Pichavant *et al.* 1987a). There is considerable varia-

FIG. 7. Photomicrographs (all taken in crossed nicols except b and i) of the East Kemptville leucogranite showing mineralogical features. (A) Relatively undeformed specimen of leucogranite showing euhedral to subhedral texture typical of albitic plagioclase. Note incipient development of deformation textures in quartz (subgrain development and undulatory extinction) in lower right of photo (bar scale 0.50 mm). (B) Euhedral apatite crystals ± equant sericite flakes in albitic plagioclase host. Note the uniform distribution of both the size and distribution of the secondary phases (bar scale 0.50 mm). (C) Alkali feldspar (k) replacing earlier plagioclase with highly irregular outline (bar scale 0.50 mm). (D) Alkali feldspar containing albite as exsolution lamellae (irregular, elongate patches oriented WNW in photo) and as remnant plagioclase euhedra (p) that represent trapped, earlier crystal phases overgrown by the alkali feldspar (bar scale 0.50 mm). (E) Perthitic alkali feldspar showing grid twinning characteristic of microcline and abundant albite exsolution lamellae (a) (bar scale 0.14 mm). (F) Isolated, subhedral muscovite grain interpreted to represent a primary, magmatic phase (bar scale 0.50 mm). (G) Large topaz grain (grey phase in middle of the photo) showing subhedral crystal outline. Note the sharp grain boundary contacts with quartz (qtz) and muscovite (mus) (bar scale 0.50 mm). (H) Subhedral grains of topaz with mild deformational overprint (bar scale 0.50 mm). (I) Isolated grain of biotite in host quartz (bar scale 0.02 mm).

TABLE 2. WHOLE-ROCK GEOCHEMISTRY OF EAST KEMPTVILLE LEUCOGRANITE

Sample	003	009	012	013A	015	021	023A	023B	023C	023F	027	068	071
SiO_2	73.16	73.11	75.02	74.14	72.72	71.51	74.06	72.35	72.32	73.54	73.70	72.63	72.83
TiO_2	0.00	0.08	0.08	0.08	0.00	0.00	0.04	0.00	0.00	0.00	0.02	0.00	0.00
Al_2O_3	15.10	14.52	13.88	14.42	15.60	15.33	14.89	14.37	14.58	16.12	14.69	16.03	14.94
Fe_2O_3	0.18	0.19	0.24	0.20	0.24	0.18	0.27	0.14	0.16	0.45	0.49	0.35	0.14
FeO	0.87	0.87	0.73	0.87	1.13	0.47	1.00	1.15	1.03	1.00	1.53	1.13	1.10
MnO	0.06	0.04	0.03	0.04	0.06	0.15	0.03	0.04	0.04	0.06	0.10	0.05	0.06
MgO	0.03	0.03	0.03	0.04	0.04	0.03	0.01	0.05	0.03	0.01	0.08	0.16	0.03
CaO	0.64	0.46	0.40	0.52	0.36	0.70	0.49	0.50	0.44	0.32	0.57	0.37	0.46
Na_2O	3.59	3.81	3.90	3.79	3.44	5.31	3.77	3.49	3.68	3.55	2.86	3.72	3.64
K_2O	4.08	3.84	3.81	3.96	3.65	2.41	4.03	3.63	3.93	3.83	3.29	3.82	3.78
P_2O_5	0.60	0.49	0.53	0.48	0.44	0.97	0.43	0.51	0.49	0.43	0.48	0.45	0.45
LOI	0.83	0.71	0.79	0.87	0.86	0.62	1.20	0.86	0.76	0.84	1.11	1.09	0.81
F	0.65	1.15	0.77	2.01	0.69	1.23	0.48	0.86	0.69	0.56	0.29	0.69	1.08
	99.89	99.40	99.52	99.51	99.36	98.96	100.82	97.22	97.58	100.83	99.36	100.47	99.45
F=O	0.27	0.48	0.32	0.84	0.28	0.51	0.20	0.36	0.28	0.23	0.12	0.28	0.45
	99.62	98.92	99.20	98.67	99.08	98.45	100.62	96.86	97.30	100.60	99.24	100.19	99.00
S	290	40	30	20	90	300	410	1660	440	450	1800	690	370
B	<10	<15	<10	<10	<10	<10	<10	<10	<10	<10	NA	<10	<10
Li	170	234	224	167	200	218	680	256	417	347	218	728	754
Rb	844	892	894	876	905	447	929	875	963	958	1010	899	905
Sr	60	33	55	77	39	450	64	54	77	86	64	53	39
Ba	ND	ND	ND	ND	ND	126	9	ND	ND	ND	19	34	24
Ba*	-	-	-	28.5	13.5	81.4	-	-	-	-	13.4	18.8	-
Pb	20	30	45	33	63	57	66	65	34	73	332	104	105
Ga	32	33	35	36	37	42	32	34	38	32	35	37	38
Nb	32	33	37	34	33	63	28	30	31	30	31	32	26
Nb*	-	-	-	13.5	23.0	37.7	-	-	-	-	26.5	18.7	-
Zr	28	28	30	28	28	28	34	29	30	30	31	27	28
Zr*	-	-	-	16.1	16.4	19.5	-	-	-	-	15.4	16.8	-
Y*	-	-	-	4.6	3.7	1.9	-	-	-	-	5.1	4.3	-
U	21	19	27	16	16	21	30	29	27	28	27	27	32
U*	17.1	-	-	14.1	-	-	26.7	-	24.8	-	-	-	-
Th	5	5	6	5	6	4	6	5	5	5	5	5	6
Th*	4.5	-	-	4.8	4.4	2.8	4.9	-	5.3	-	3.7	3.8	-
Sn	77	110	87	101	239	90	210	229	97	231	890	422	354
W	14	21	25	11	15	16	42	15	24	44	83	28	44
W*	11.6	-	-	9.8	-	-	32	-	23	-	-	-	-
Zn	177	43	22	27	44	373	222	1248	286	370	193	190	112
Cu	65	13	7	7	27	11	86	167	113	94	333	236	149
Mo	4	4	2	<2	2	27	4	4	7	6	5	5	3
V	ND	ND	ND	ND	ND	3	ND	ND	ND	1	3	1	ND
Ni	1	2	3	2	4	2	4	4	4	5	5	6	8
Co*	0.3	-	-	0.3	-	-	0.4	-	0.4	-	-	-	-
Ta	14	10	15	13	12	36	11	10	11	11	12	12	11
Ta*	12.6	-	-	11.2	10.5	31.9	10.5	-	11.3	-	12.1	9.3	-
Hf	<2	<2	<2	<2	<2	3	2	<2	<2	<2	2	<2	<2
Hf*	2.1	0.3	-	1.7	1.5	2.4	1.9	-	1.9	-	1.1	1.2	-
Cs	33	39	49	25	33	11	42	31	39	38	47	41	51
Cs*	22	-	-	38	-	-	36	-	35	-	-	-	-
Sc	2.1	1.8	3.9	2.3	2.2	0.5	2.2	1.8	1.9	2.1	2.3	1.8	2.2
Sc*	2.2	-	-	2.5	-	-	2.1	-	2.3	-	-	-	-
A/CNK	1.31	1.29	1.23	1.26	1.52	1.22	1.30	1.36	1.31	1.53	1.58	1.47	1.37
%Co	4.84	4.19	3.37	3.94	6.10	4.08	4.37	4.87	4.44	6.85	6.55	5.83	4.97
Na_2O/K_2O	0.87	0.99	1.02	0.95	0.94	2.20	0.93	0.96	0.93	0.92	0.86	0.97	0.96
FeO/Fe_2O_3	4.83	4.57	3.04	4.35	4.70	2.61	3.70	8.21	6.43	2.22	3.12	2.30	7.85

TABLE 2. (continued)

Sample	072	091	098	099	105	109	110	122B	124B	132	156	161	178	1075B
SiO_2	72.85	74.00	76.99	72.52	74.29	73.36	71.85	73.73	73.48	75.18	72.10	72.97	72.70	73.50
TiO_2	0.00	0.00	0.07	0.06	0.02	0.02	0.02	0.02	0.02	0.04	0.02	0.02	0.03	0.02
Al_2O_3	13.51	15.00	13.80	15.39	14.28	14.55	17.09	15.40	15.81	13.42	16.00	15.09	14.75	15.70
Fe_2O_3	0.41	-	0.42	0.99	0.41	0.14	0.27	0.33	0.14	0.44	0.31	0.19	0.11	0.28
FeO	0.93	-	0.60	1.87	1.03	1.03	1.03	0.80	1.60	0.93	0.77	0.93	0.87	0.93
MnO	0.06	0.04	0.01	0.11	0.08	0.04	0.04	0.04	0.04	0.04	0.24	0.10	0.04	0.05
MgO	0.05	0.03	0.06	0.16	0.02	0.02	0.02	0.03	0.01	0.06	0.02	0.03	0.01	0.02
CaO	0.66	0.66	0.64	0.60	1.05	1.12	0.58	0.77	0.42	0.75	0.25	0.31	0.54	0.49
Na_2O	3.50	4.01	5.05	1.87	3.37	3.89	3.76	3.35	3.62	2.83	4.12	3.73	4.38	3.88
K_2O	3.45	3.50	1.47	3.88	2.96	4.14	3.83	3.85	3.69	4.05	3.55	4.10	3.79	3.86
P_2O_5	0.51	0.60	0.27	0.29	0.31	0.75	0.41	0.56	0.13	0.79	0.46	0.39	0.64	0.45
LOI	1.03	0.61	0.75	1.95	1.14	0.51	0.80	0.33	0.68	0.23	0.55	0.36	0.52	0.35
F	1.23	1.19	NA	0.48	0.67	0.82	0.75	0.62	1.05	0.48	0.43	0.48	0.42	0.46
	98.30	100.87	100.14	100.33	99.72	100.50	100.56	99.92	100.92	99.32	99.24	98.76	99.23	100.86
F=O	0.51	0.49		0.20	0.28	0.34	0.31	0.26	0.44	0.20	0.18	0.20	0.17	0.19
	97.79	100.38	100.14	100.13	99.44	100.16	100.25	99.66	100.48	99.12	99.06	98.56	99.06	100.67
S	600	-	1130	1670	270	310	460	1420	180	150	200	70	370	60
B	<10	<10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Li	545	424	178	811	454	525	728	705	970	292	325	661	670	500
Rb	838	786	325	1135	714	814	895	903	1150	659	748	991	858	822
Sr	55	54	68	61	221	140	72	43	33	87	70	15	52	33
Ba	28	25	32	39	45	67	14	14	9	69	34	8	27	17
Ba*	5.0	-	-	-	-	-	14.1	-	-	58.2	21.4	-	-	-
Pb	99	32	255	316	40	24	38	91	53	37	67	37	56	59
Ga	37	38	22	41	30	31	33	31	31	33	28	31	31	31
Nb	29	33	16	9	30	30	29	29	26	22	34	26	30	27
Nb*	11.9	-	-	-	-	-	16.8	-	-	10.9	25.5	-	-	-
Zr	28	27	12	10	32	32	31	30	28	29	29	27	30	33
Zr*	12.9	-	-	-	-	-	19.7	-	-	14.0	16.7	-	-	-
Y*	5.0	-	-	-	-	-	4.9	-	-	5.6	3.7	-	-	-
U	28	29	10	46	26	25	28	26	27	28	25	27	25	23
U*	26.8	25.9	-	-	-	-	-	-	-	-	-	-	-	-
Th	6	6	2	7	5	5	6	5	6	6	6	5	5	6
Th*	5.2	5.5	2.5	6.4	4.8	-	5.2	-	-	5.0	4.8	-	-	5.5
Sn	360	73	430	780	107	81	114	360	96	270	102	NA	230	155
W	37	13	10	19	17	16	18	21	39	72	12	23	19	12
W*	32	11.4	-	-	-	-	-	-	-	-	-	-	-	-
Zn	226	89	1099	610	307	178	55	543	170	44	41	52	331	66
Cu	155	86	249	576	23	82	254	110	56	88	13	30	55	23
Mo	<2	<2	2	3	2	5	2	6	2	6	3	2	<2	2
V	ND	ND	ND	ND	ND	ND	ND	1	ND	2	ND	ND	1	ND
Ni	7	5	3	6	3	5	6	7	2	4	4	4	6	6
Co*	0.4	0.3	1.6	0.9	0.2	-	-	-	-	0.3	0.2	-	-	0.1
Ta	10	15	2	4	14	12	14	14	13	8	14	16	13	NA
Ta*	7.5	14.1	1.8	3.2	12.5	-	10.7	-	-	6.1	12.0	-	-	11.2
Hf	<2	<2	<2	<2	<2	<2	2	2	<2	2	2	<2	<2	NA
Hf*	1.4	2.1	0.3	0.3	1.9	-	1.7	-	-	1.3	1.8	-	-	2.1
Cs	32	26	18	57	30	29	36	34	58	55	26	48	31	32
Cs*	29	24	-	-	-	-	-	-	-	-	-	-	-	-
Sc	1.8	1.9	1.6	5.7	2.1	2.6	2.1	2.4	2.0	2.6	2.3	2.2	2.1	1.9
Sc*	2.2	2.5	1.4	5.4	2.3	-	-	-	-	2.4	2.7	-	-	2.3
A/CNK	1.26	1.29	1.25	1.84	1.34	1.13	1.50	1.39	1.48	1.29	1.44	1.35	1.20	1.34
%Co	4.18	4.65	3.40	7.88	4.46	2.88	6.75	5.72	5.45	4.42	5.47	4.60	3.50	4.45
Na_2O/K_2O	1.01	1.14	3.43	0.48	1.13	0.93	0.98	0.87	0.98	0.69	1.16	0.90	1.15	1.00
FeO/Fe_2O_3	2.26	-	1.42	1.88	2.51	7.35	3.81	2.42	11.42	2.11	2.48	4.89	7.90	3.32

*denotes analysis of trace element by instrumental neutron activation technique along with REE
A/CNK = molecular ratio ($Al_2O_3/CaO + Na_2O + K_2O$); ND = not detected (i.e. below detection limit);
%Co = % normative (CIPW) corundum calculated on F-free basis

TABLE 3. RARE-EARTH-ELEMENT CONCENTRATIONS FOR THE EAST KEMPTVILLE LEUCOGRANITE

Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
110#	1.33	3.81	0.55	1.84	1.08	0.00	0.86	0.25	1.43	0.15	0.36	0.05	0.317	0.033
110#(R)	1.03	2.89	0.39	1.44	0.71	0.00	0.71	0.22	1.25	0.15	0.35	0.04	0.313	0.028
013A*	1.1	2.9	-	1.0	0.78	0.08	-	0.28	1.3	0.41	-	<0.1	0.2	0.09
013A#	1.06	2.71	0.36	1.38	0.65	0.00	0.61	0.18	1.02	0.13	0.30	0.04	0.297	0.031
013A#(R)	1.07	2.72	0.37	1.37	0.63	0.00	0.66	0.19	1.11	0.15	0.31	0.04	0.280	0.032
015#	0.79	2.24	0.31	1.14	0.59	0.00	0.52	0.17	0.93	0.10	0.25	0.03	0.214	0.025
021#	0.27	0.85	0.12	0.41	0.28	0.00	0.26	0.07	0.43	0.04	0.09	0.01	0.164	0.009
027#	1.12	2.95	0.31	1.45	0.70	0.00	0.69	0.22	1.22	0.15	0.39	0.04	0.317	0.033
027#(R)	1.12	2.84	0.39	1.46	0.69	0.00	0.70	0.19	1.16	0.13	0.31	0.04	0.283	0.033
068#	0.95	2.62	0.35	1.25	0.65	0.00	0.57	0.16	1.00	0.12	0.29	0.03	0.213	0.025
072*	1.1	3.9	-	0.5	0.83	0.05	-	0.28	1.7	0.69	-	0.02	0.20	0.08
072#	1.01	2.76	0.37	1.29	0.67	0.00	0.59	0.19	1.29	0.14	0.34	0.04	0.295	0.028
072#(R)	1.00	2.72	0.35	1.08	0.62	0.00	0.61	0.19	1.08	0.13	0.37	0.04	0.266	0.025
091*	0.65	1.8	-	0.8	0.79	0.04	-	0.26	1.3	0.76	-	0.2	0.2	0.10
003*	1.4	3.6	-	0.6	0.89	0.05	-	0.35	1.6	0.52	-	<0.1	0.30	0.08
132#	1.58	3.52	0.41	1.51	0.69	0.13	0.68	0.20	1.35	0.17	0.47	0.06	0.40	0.047
156#	0.85	2.40	0.29	1.23	0.56	0.00	0.55	0.16	0.85	0.11	0.23	0.02	0.20	0.023
156#(R)	0.86	2.47	0.32	1.04	0.61	0.00	0.58	0.16	0.93	0.11	0.24	0.03	0.20	0.022
023A*	0.95	2.7	NA	0.8	0.75	0.07	-	0.23	1.6	0.65	-	0.2	0.2	0.09
023C*	0.95	3.5	NA	1.1	0.88	0.05	-	0.23	1.2	0.75	-	0.2	0.2	0.10

Samples with an * denote analyses performed at Carleton University; those with #, analyses performed at Memorial University.

R indicates a duplicate sample analysis.

Note that for the Carleton analyses the errors for Yb and Tm are ± 0.2 ppm and for Nd approximately ± 1 ppm.

TABLE 4. GEOCHEMISTRY OF SELECTED FLUORINE-RICH FELSIC SUITES

	1	2	3	4	5	6	7	8	9	(± 1σ
SiO_2	72.32	70.86	69.58	73.7	72.26	75.9	71.67	71.1	73.27	(0.84)
TiO_2	0.04	-	0.00	0.03	0.03	0.10	0.03	0.04	0.02	(0.02)
Al_2O_3	15.85	15.98	16.60	12.9	15.30	12.7	14.88	14.7	15.04	(0.86)
Fe_2O_3	0.05	0.15	0.28	0.2	0.27	1.07	0.43	-	1.38	(0.26)
FeO	0.56	0.49	0.37	0.9	0.24	-	0.53	0.6	-	-
MnO	0.06	0.22	0.03	0.10	-	0.06	0.09	0.03	0.04	(0.01)
MgO	0.02	0.13	0.99	0.42	0.07	0.14	0.11	0.01	0.03	(0.03)
CaO	0.21	0.52	0.89	1.27	1.25	0.80	0.66	0.5	0.49	(0.13)
Na_2O	4.13	5.87	6.04	2.50	3.48	3.78	4.15	3.5	3.65	(0.34)
K_2O	3.64	3.53	2.21	5.12	4.54	4.92	4.31	6.4	3.78	(0.20)
P_2O_5	0.53	0.09	0.51	0.03	0.36	0.06	0.78	0.01	0.48	(0.11)
LOI	0.46	-	1.24	1.21	0.67	-	1.54	-	0.73	(0.25)
F	1.33	2.05	1.16	1.05	1.15	0.28	1.57	0.5	0.77	(0.37)
Rb	1164	1975	2895	1188	-	423	1434	-	890	(95)
Sr	1.6	20	-	18	-	28	46	-	55	(18)
B	1860	-	30	-	-	-	-	-	<10	-
Li	3220	-	4300	123	506	50	-	-	464	(233)
Ba	<10	-	-	60	-	41	14	-	23	(14)

(1) JV1 glass from Macusani volcanic field, Peru (Pichavant *et al.* 1987); (2) Ongonite (average 10 analyses, in Pichavant & Manning 1984); (3) Beauvoir granite (average 4 analyses, in Pichavant & Manning 1984); (4) Porphyritic granite, Mount Pleasant, New Brunswick (analysis 82-71, Kooiman *et al.* 1986); (5) Fluorite-topaz-muscovite granite, St. Austell, England (Weidner & Martin 1987); (6) Topaz rhyolites from Thomas Range, Utah (average 11 analyses for major elements and 5 for trace elements, Christiansen *et al.* 1984); (7) Cornish topaz granite (average 5 analyses, Manning & Pichavant 1988); (8) Glass inclusions in quartz, Harvey volcanic suite, New Brunswick (n=30, Payette & Martin 1986a); (9) Average (± 1 standard deviation) East Kemptville leucogranite (n=22).

bility among the various suites, which indicates, therefore, that the deviation of the East Kemptville leucogranite data from experimentally determined cotectics is not unique.

Trace-element chemistry

Trace-element data for the leucogranite are remarkably uniform for most elements (Table 2 and Fig. 11), although deviations from this are noted for Zn (to >1000 ppm), Cu (to >500 ppm), Pb (to >300 ppm), Sn and W. The leucogranite is notably enriched in many of the trace elements considered indicative of specialized granites (Fig. 11; *cf.* Tischendorf 1977). For example, the leucogranite contains elevated contents (average in ppm) of Rb (900), Li (250), U (25), Sn (150), W (40), Nb (40), Cs (35) and Ga (35); conversely, it is depleted in Zr

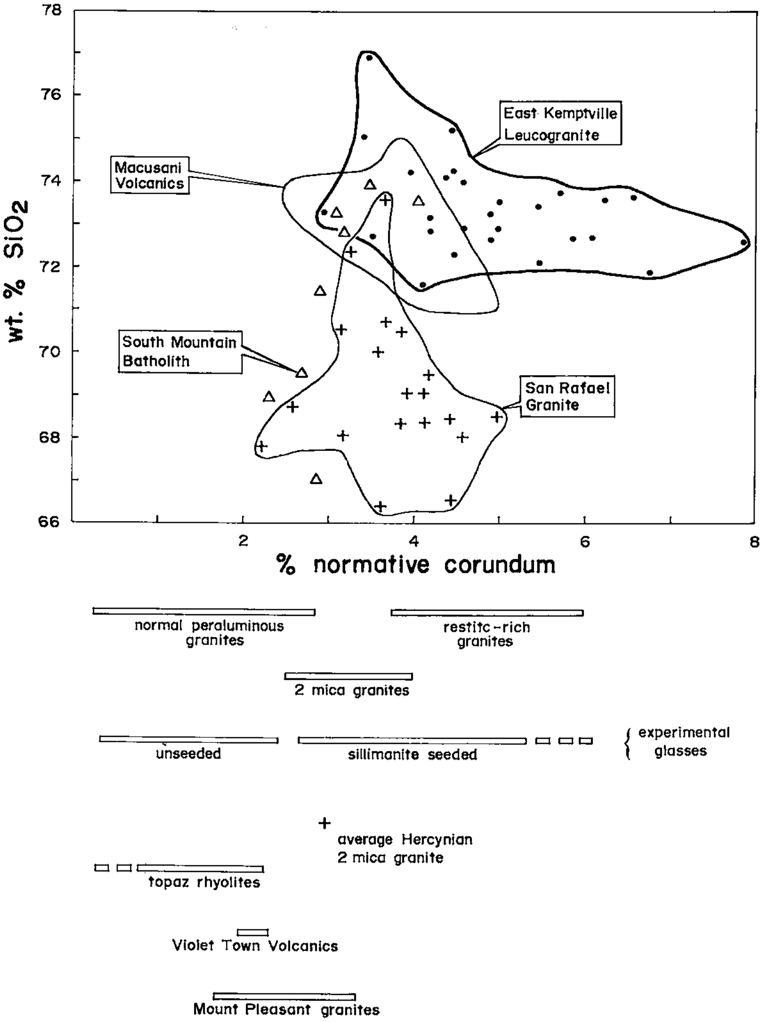


FIG. 8. Plot of SiO_2 *versus* normative corundum for East Kemptville leucogranite compared to other felsic suites, including Macusani volcanic suite (Pichavant *et al.* 1988), South Mountain Batholith (Ham *et al.* 1989; note that only the averages are shown for the major lithological units, n = 456) and San Rafael granite (Kontak & Clark 1988). Also shown are the ranges for experimental glasses (Clemens & Wall 1981) and natural metaluminous to peraluminous felsic suites, including topaz rhyolites (Christiansen *et al.* 1983), Violet Town volcanic rocks (Clemens & Wall 1984), Mount Pleasant granites (Kooiman *et al.* 1986), and average Hercynian two-mica granite (LaRoche *et al.* 1980). Classification scheme of granites is after Clemens & Wall (1981).

(20), Th (5), Ba (<5), Sc (2), V (<2), Ni (4) and Hf (<2). Notable are the very low B contents (<10 ppm) considering the evolved nature of the leucogranite (*cf.* Harder 1975) and the often close association of this element with elevated contents of both F and Li *e.g.*, Macusani volcanic suite; Noble *et al.* 1984; Pichavant *et al.* 1987b, 1988). The evolved nature of the leucogranite is also indicated by very low K/Rb ratios (average ~40), approximating the pegmatite-hydrothermal field of Shaw (1968).

Of particular interest are the elevated Sr contents, considering the otherwise evolved nature of the leucogranite. For example, compared to the Sr *versus* Rb trend for the South Mountain Batholith (Fig. 12), the leucogranite is anomalous in Sr; conversely both Zr and Ba (plots not shown) have values comparable

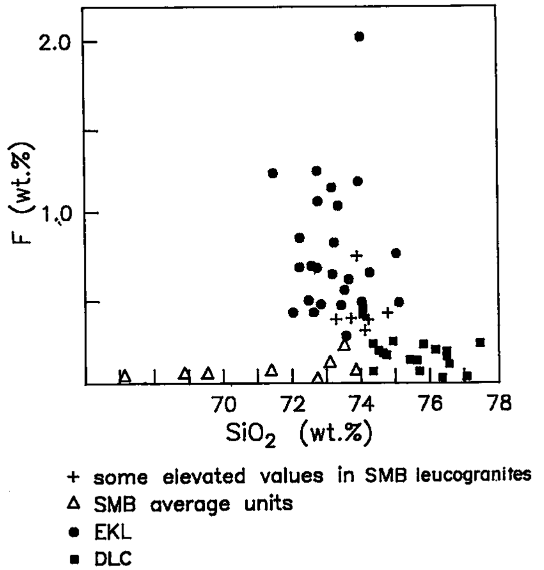


FIG. 9. Plot of F *versus* SiO_2 comparing data for East Kemptville leucogranite to those for the South Mountain Batholith (Ham *et al.* 1989; averages and leucogranites) and Davis Lake Complex (Richardson 1988a).

to the South Mountain Batholith for similar degrees of Rb enrichment. Also shown in Figure 12 is the field for the Davis Lake Complex (DLC); again, the data follow the trend defined for the South Mountain Batholith, but samples of the East Kemptville leucogranite analyzed by Richardson (1988a) also indicate an abrupt increase in Sr content.

In Figure 13 the trace elements Li and Rb are plotted against F in the classification diagrams of Taylor *et al.* (1985). These plots show that the leucogranite compares favorably to the fields outlined for topaz granites, whereas relative to topaz rhyolites the leucogranite is enriched in Li but has similar F and Rb contents. Compared to the average data for different lithologies of the South Mountain Batholith, the leucogranite shows relative enrichment in all the elements, although a few cases of comparable enrichment are found (Fig. 13). However, these latter samples reflect variable degrees of late-stage alteration, and the concentrations are not magmatic in nature (MacDonald & Clarke 1989).

Comparison of the trace-element chemistry of the leucogranite to topaz rhyolites in the spidergram diagram of Christiansen *et al.* (1986) (Fig. 14) indicates the former is enriched in Sr, depleted in Th, Zr, La, Sm and Yb, and has comparable levels of Rb, F, Ba (?), Y, U, Nb and Ta. Compared to the spidergrams and various binary trace-element plots used by Pearce *et al.* (1984) to classify granite types, the leucogranite is most similar to the syn- or post-collisional granite types (diagrams not shown), although the extremely low Ba contents of the East Kemptville leucogranite are more typical of within-plate granites, such as are found in the Oslo Rift (Pearce *et al.* 1984).

Rare-earth-element chemistry

Rare-earth-element (*REE*) data are presented in Table 3, and chondrite-normalized patterns in Figure 15. The patterns obtained for the two different analytical techniques (*i.e.*, ICP–MS *versus* INAA) agree reasonably well considering the generally low abundances, with the greatest discrepancy noted for the *HREE*s from Ho to Lu. Compared to previous data obtained by Richardson (1983) for samples from the Davis Lake Complex, the East Kemptville leucogranite is more depleted in all the *REE*s and has a larger Eu anomaly.

The most notable feature of the *REE* data is the overall depletion of all the *REE*s; chondrite-normalized values are less than 10. The average chondritic pattern for the leucogranite is unfractionated [$(La/Yb)_N = 1$], has a distinct negative Eu anomaly ($Eu/Eu^* = 0.2$), and the *HREE*s show a markedly concave shape, with an inflection at Tb. A second inflection occurs at Ho for one of the data sets, but the absence of this feature in the other data makes it difficult to interpret. However, a similar concave profile for the *HREE*s has been noted elsewhere and is considered to reflect the capacity of fluorine to complex the *REE*s (*e.g.*, Taylor & Fryer 1983, Strong *et al.* 1984). The single aberrant sample (021) shown in Figure 15 is a fine-grained dyke rock that also is anomalous with respect to its relative enrichment in both Na and Sr (Table 2). Although this sample is depleted in total *REE*s relative to the field delineated by the other leucogranite samples, it has retained the same chondrite-normalized pattern, suggesting a common genetic association.

The *REE* data are compared to other igneous suites in Figure 15. Attention is drawn to the following observations: (1) Compared to the evolved members of the South Mountain Batholith (*i.e.*, leucomonzogranites), the data are more depleted with respect to the *LREE*s, have a greater Eu anomaly, and have a concave *HREE* chondritic pattern. Kontak *et al.* (1988b) have shown that some of the evolved units of the South Mountain Batholith also may show a similar concave pattern for the *HREE*s, but such rocks are markedly more altered than the East Kemptville leucogranite owing to extensive modification resulting from interaction with a postmagmatic, F-enriched fluid phase. (2) Compared to other fluorine-rich granitic and felsic volcanic suites, the East Kemptville leucogranite has a markedly different signature than the Mount Pleasant granites, which are also similar to the *REE*

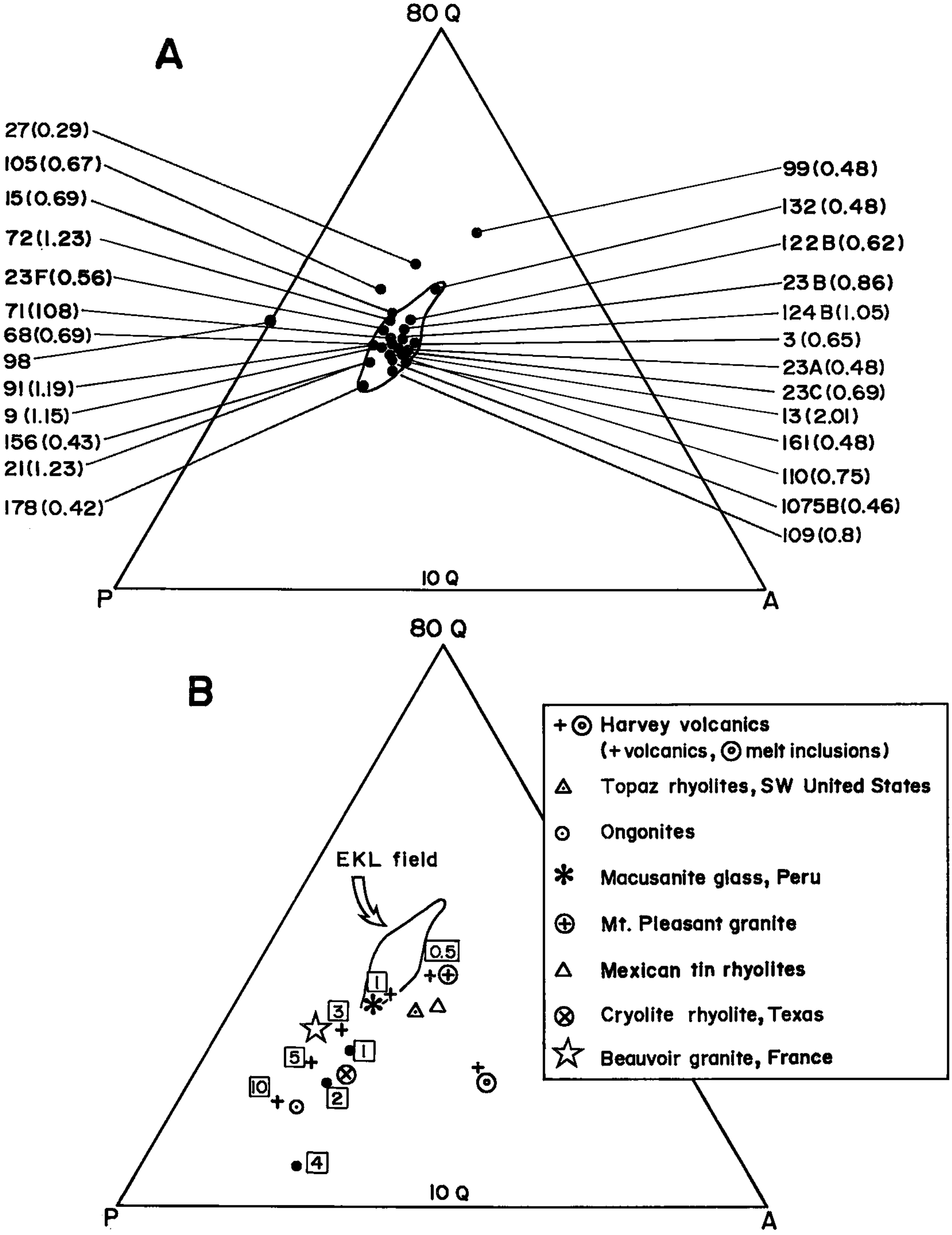


FIG. 10. (A) Plot of normative quartz (Q) - alkali feldspar (A) -albite (P) for East Kemptville leucogranite samples [numbers in brackets refer to wt.% F (see Table 2)]. Note the trend of the data toward the albite corner of the diagram (significance of this discussed in the text). (B) Normative QAP diagram comparing field for East Kemptville leucogranite to other fluorine-rich felsic suites (sources of data given in text) and experimentally determined cotectics for 4, 2 and 1 wt.% F at 1 kbar (•, Manning 1981) and F-free cotectics at 10, 5, 3, 1 and 0.5 kbar P(H_2O) (+ , Luth 1976).

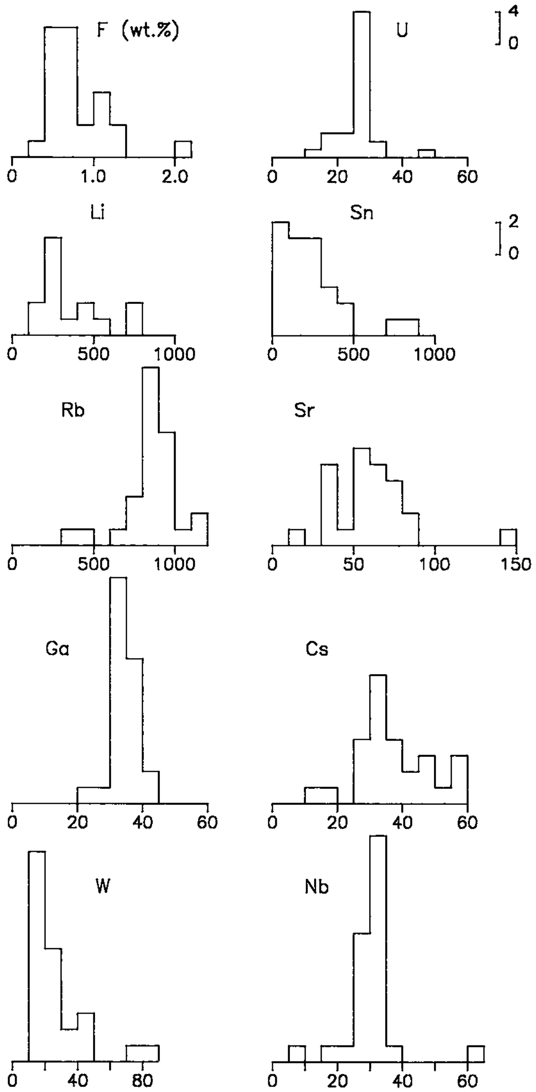


FIG. 11. Histograms for selected trace elements in East Kemptville leucogranite. All values in ppm except for F (wt.%), scale (number of analyses) the same for all elements except U.

patterns for topaz rhyolites (*e.g.*, Christiansen *et al.* 1983, 1986). (3) Depleted abundances approaching those in the East Kemptville leucogranite are found in the Macusani glass studied by Pichavant *et al.* (1987b).

OXYGEN ISOTOPIC COMPOSITION OF EAST KEMPTVILLE LEUCOGRANITE

Six whole-rock samples have been analyzed for oxygen isotopes (Table 5). Collectively, their $\delta^{18}O$ composition ranges from +8.2 to +12.2‰, with the enriched sample (#105) being a dyke rock. This latter sample is also peculiar with respect to some of its trace-element contents (*e.g.*, Rb, Sr). The remaining five samples define an average $\delta^{18}O$ value of 8.96 ± 0.71 ‰. The reason for $\delta^{18}O$ enrichment in sample 105 remains unresolved, although mechanisms such as contamination either *in situ*, along the melt path or near the source region may all be possible candidates. The enrichment is, however, clearly not a function of crystal-fractionation processes (Taylor 1978, Sheppard 1986).

The data reported here compare favorably with previously published data by Chatterjee & Strong (1985) for both granites and greisens from the Davis Lake Complex and the East Kemptville leucogranite (greisens). These authors found a uniform $\delta^{18}O$ value of 9.5 ± 0.2 per ‰ (n = 19) for both fresh granite and its greisenized equivalent at East Kemptville.

The mean $\delta^{18}O$ value of 8.9 for the leucogranite falls in the spectrum of normal igneous rocks (Taylor 1978). Such values, according to Taylor, require some input from the crust *via* processes of assimilation, partial melting, or exchange of either sedimentary rocks or modified plutonic or volcanic rocks that once resided near the earth's surface. Compared to the range for peraluminous granites on a world-wide scale, the leucogranite data are notably depleted (*i.e.*, *versus* 10-14 ‰ : Sheppard 1986) and, in the classification of O'Neil *et al.* (1977), based on their examination of granitic rocks of the Lachlan Fold Belt in Australia, the values are more typical of I-type granites.

In Figure 16 the oxygen isotopic data for granites of the Meguma Terrane are compared to the range for the East Kemptville leucogranite. The data are clearly distinguished from the ^{18}O-enriched granites of the eastern half of the South Mountain Batholith and the northern granites, whereas there is an overlap with the range for the southern granites and, as mentioned above, the Davis Lake Complex. It is worthwhile noting that the granites of the southern domain are composed of a large proportion of rocks of relatively mafic composition compared to the South Mountain Batholith and northern granites, including granodiorite, tonalite, trondhjemite and diorite (Rogers & Barr 1988, de Albuquerque 1977, Douma 1988).

DISCUSSION

The petrological data presented above indicate several important features of the East Kemptville leucogranite that are apparently unique to this part of the South Mountain Batholith and other granitic rocks of the Meguma Terrane. Questions fundamental to the petrogenesis of the East Kemptville leucogranite that require consideration are: (1) Are

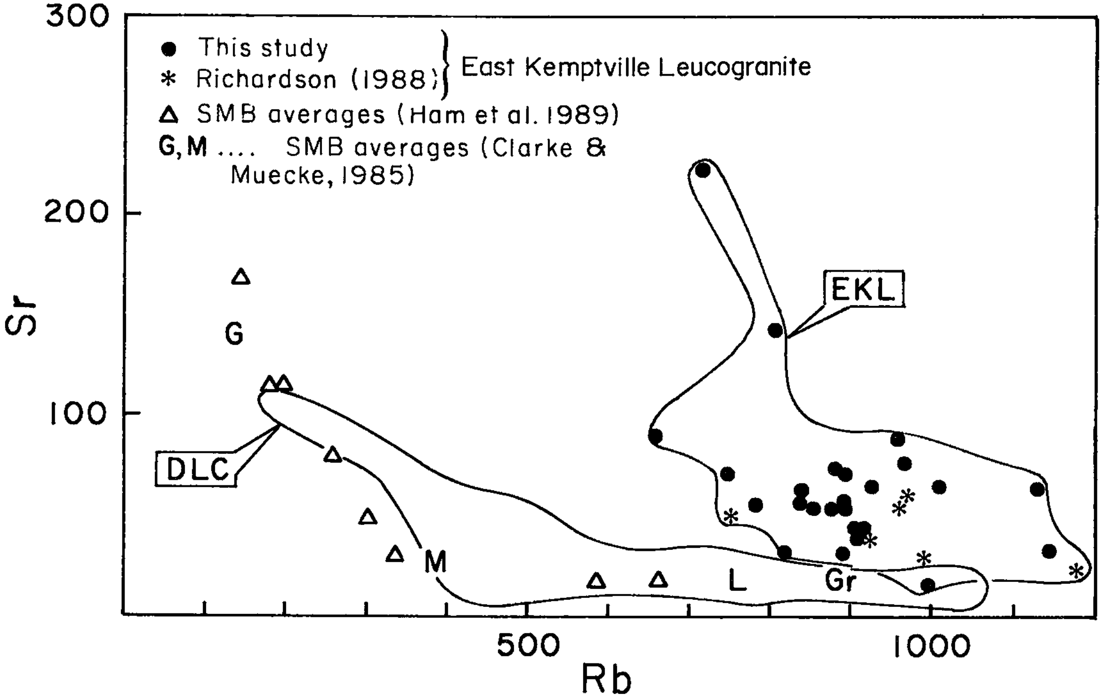


FIG. 12. Plot of Sr *versus* Rb comparing East Kemptville leucogranite data to fields for Davis Lake Complex (data from Richardson 1988a) and South Mountain Batholith. Note that G, M, L, D and Gr represent averages from Clarke & Muecke (1985) for granodiorite, monzogranite, leucomonzonite, dyke rocks and greisens, respectively.

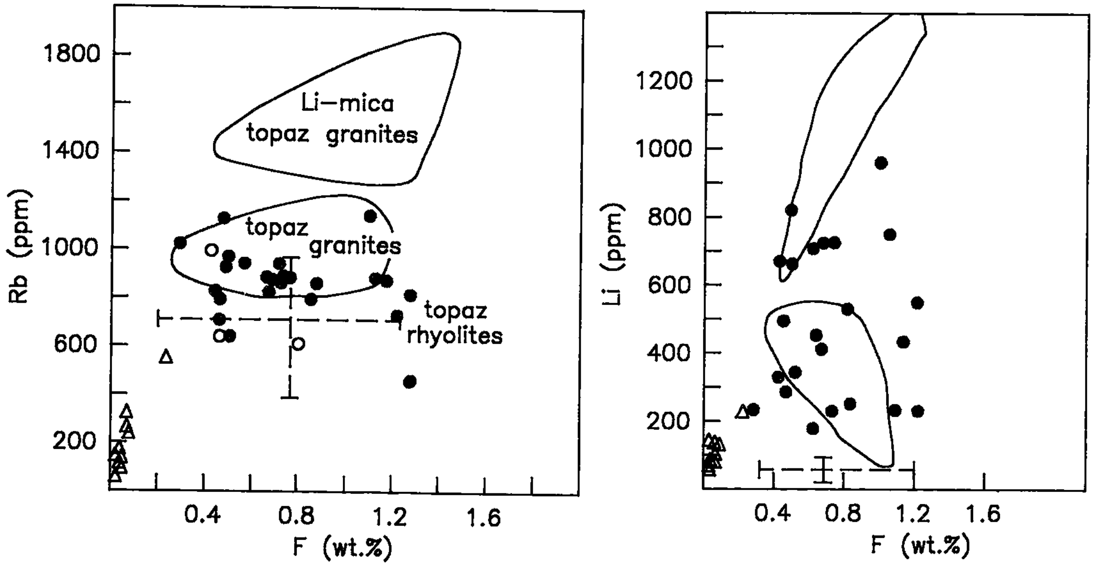


FIG. 13. Plots of Rb and Li *versus* F for East Kemptville leucogranite. Fields for Li-mica topaz granites and topaz granites after Taylor *et al.* (1985) and fields for topaz rhyolites and South Mountain Batholith (average values for different lithologic units) from Christiansen *et al.* (1983) and Ham *et al.* (1989), respectively. Symbols as in Figure 12. Open circles represent the most elevated contents for Rb and F in leucogranites of the South Mountain Batholith (Ham *et al.* 1989).

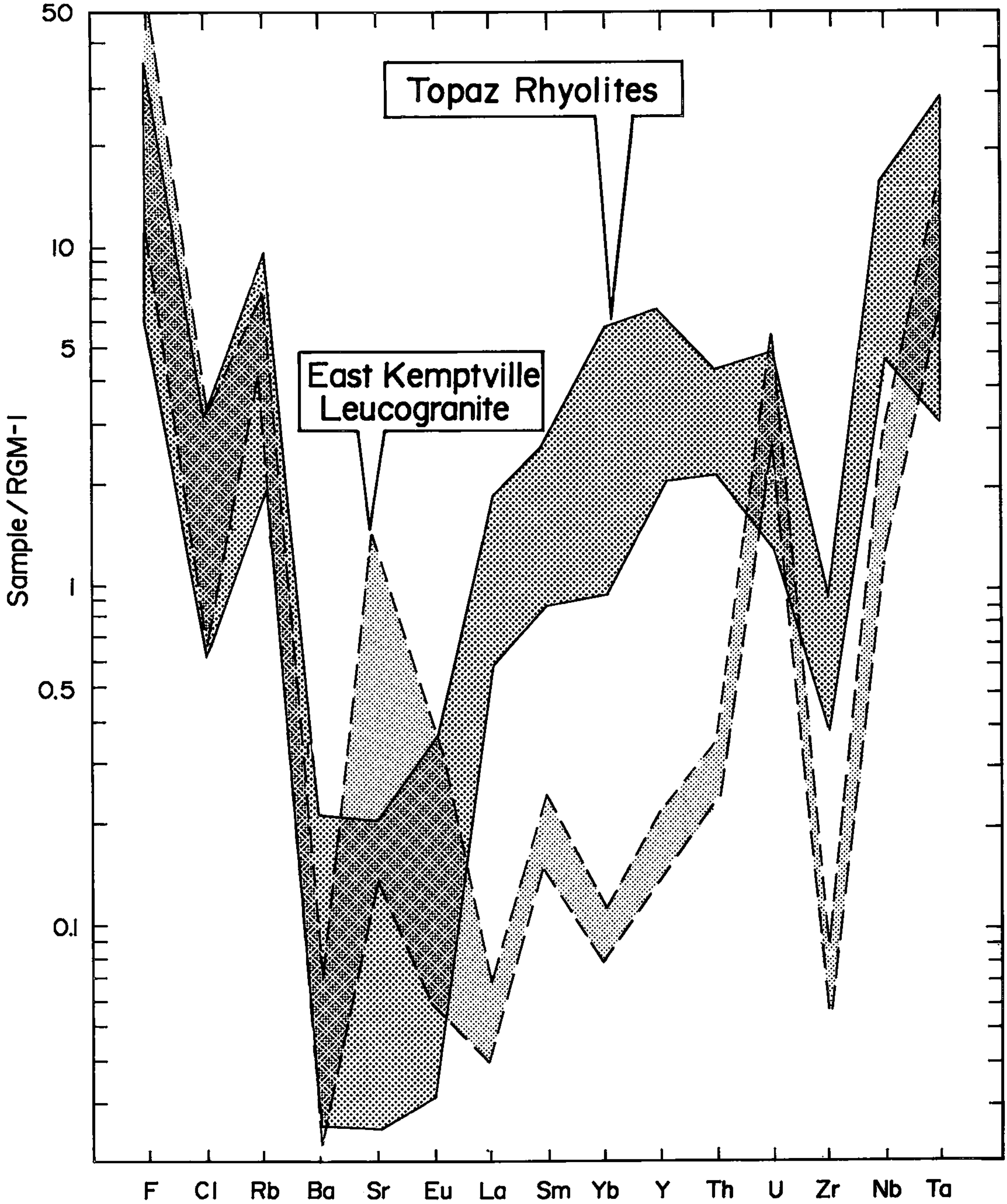


FIG. 14. Spidergram plot comparing trace-element chemistry plus F to topaz rhyolites (after Christiansen *et al.* 1986). Note that there are no Cl data available for the East Kemptville leucogranite.

the mineralogy and chemistry magmatic or metasomatic? (2) How does the petrology of the leucogranite compare to that of the South Mountain Batholith? Does it represent a product of differentiation? (3) What is the importance of the leucogranite in terms of the tin potential of the Meguma Terrane? (4) Finally, what constraints does the chemistry of the leucogranite impose for the

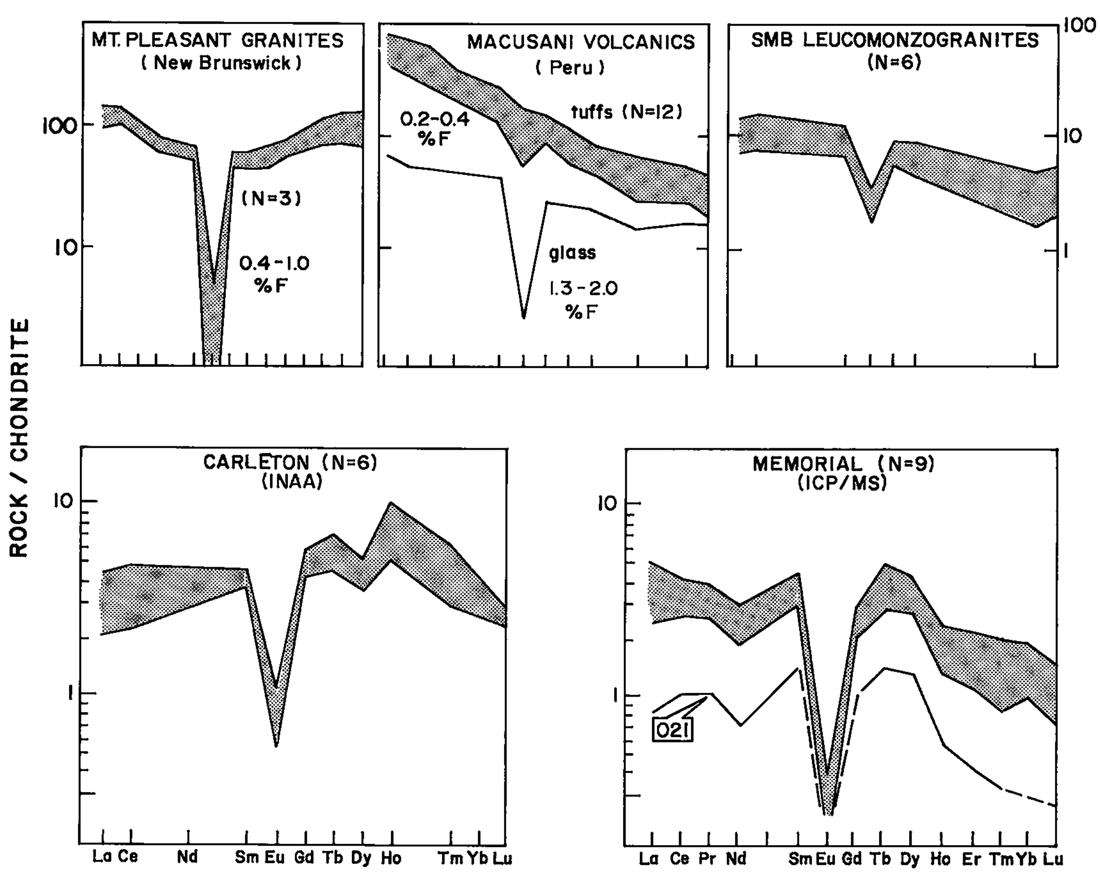


FIG. 15. Chondrite-normalized *REE* plots for East Kemptville leucogranite [data from Carleton (INAA) and Memorial (ICP/MS) Universities shown separately] compared to data from Mount Pleasant topaz granites (Taylor *et al.* 1985), Macusani volcanic rocks and glass (Pichavant *et al.* 1987b, 1988) and South Mountain Batholith leucomonzogranites (Muecke & Clarke 1981).

infrastructure of the Meguma Terrane? In the following sections these points are briefly discussed; although an unequivocal solution may not be possible with the present data-set, working hypotheses are presented and discussed.

East Kemptville leucogranite: product of magmatic or metasomatic processes?

The role of magmatic *versus* metasomatic processes in late-stage granite suites is a controversial topic; it is important to ascertain whether the features observed in the East Kemptville leucogranite are representative of a magma or a product highly modified by metasomatism. Factors considered relevant to the argument are (1) the petrographic features and geochemistry of the leucogranite, (2) comparison with volcanic analogues, and (3) experimental and thermodynamic considerations.

TABLE 5. WHOLE-ROCK OXYGEN ISOTOPE DATA FOR EAST KEMPTVILLE LEUCOGRANITE

SAMPLE #	$\delta^{18}O$ (°/..)
EK-86-023A	8.6
EK-86-072	8.7
EK-86-105	12.2
EK-86-132	10.3
EK-86-161	8.2
EK-86-1075B	9.0

The petrographic features have been discussed in detail above, but the salient points may be reiterated, namely (1) topaz coexists in textural equilibrium with the assemblage quartz - two feldspars - muscovite; (2) point counting of both thin sections and rock slabs indicates a very uniform modal mineralogy; (3) the texture of the leucogranite is generally uniform; and (4) miarolitic cavities are absent, and pegmatites

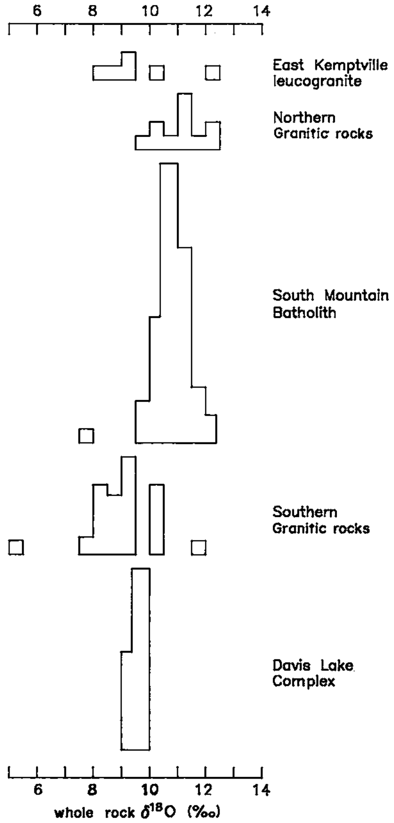


FIG. 16. Histograms of oxygen isotopic data for granitic lithologies of the Meguma Terrane compared to data for East Kemptville leucogranite. Sources of data: northern granites (O'Reilly 1988b), South Mountain Batholith (Longstaffe *et al.* 1980, Kontak *et al.* 1988b, Chatterjee & Strong 1985), Davis Lake Complex (Chatterjee & Strong 1985), and southern granites (Longstaffe *et al.* 1980).

are very rare. Also important are the observations that whereas melt inclusions in topaz were sought (*cf.* Naumov *et al.* 1972), none were observed, and that fine-grained dyke rocks cut the leucogranite.

The above mentioned features are considered to militate against transformation of the East Kemptville leucogranite to its present form by pervasive metasomatic reactions for the following reasons:

(1) Observations indicate that the leucogranite crystallized from a H_2O-undersaturated melt; hence a free aqueous phase did not appear until the very latest stages of crystallization. Thus, pervasive metasomatism in the sense of, for example, Pollard & Taylor (1986) and Taylor & Pollard (1988), is not considered to be important. Infiltration of late-stage fluids, probably *via* grain boundaries and microfractures, did occur and was ultimately responsible for, among other things, promoting re-equilibration of plagioclase to albite (+ apatite) and unmixing of homogeneous alkali feldspar to stable perthitic microcline. However, such a scenario, involving very low fluid/rock ratios, is considered inappropriate if whole-scale transformation is to have occurred, since exceptionally large volumes of fluid would be required. In contrast, where fluid focusing did occur and fluid/rock ratios were high, the leucogranite was converted to zoned greisens of markedly different modal mineralogy (quartz–topaz–cassiterite–sulfides) and geochemistry (Kontak 1988).

(2) Assuming that the uniform modal mineralogy of the leucogranite represents a terminal stage of metasomatism, then one might consider the presence of pegmatites and dyke rocks. Presumably these rocks also would have been transformed to a similar texture, mineralogy and chemistry as the leucogranite if present prior to the metasomatic overprinting. Since it is unlikely that they represent a separate, much later igneous event, their presence suggests that the East Kemptville leucogranite represents the parental melt for these phases and, potentially, a primary magmatic phenomenon.

Geochemical arguments in favor of a dominantly magmatic composition are summarized as follows:

(1) The bulk major-element composition approximates that of other volatile-rich igneous suites (Table 4), and the normative mineralogy approximates minimum-melt compositions in the haplogranite system (see above). Geochemical comparison of the East Kemptville leucogranite to ongonites, macusanite and melt inclusions in the Harvey volcanic suite (Table 4) is particularly significant since these latter rocks are clearly of magmatic origin, whereas the normative compositions of the East Kemptville leucogranite are at least consistent with a magmatic parentage.

(2) Clustering of the geochemical data with no deviation toward alkali enrichment or depletion is considered to be best explained by magmatic rather than metasomatic processes (*cf.* Pollard 1983), consistent with point 1. Thus, even though minor amounts of re-equilibration occurred, changes are considered to have been isochemical, consistent with low fluid/rock ratios.

(3) Examination of the behavior of selected compatible *versus* incompatible trace-elements indicates uniformity of all the data. For example, in plots of Rb/Zr and Rb/Ta *versus* Rb (Fig. 17), small ranges in the data are observed, the outlying points representing aplite, pegmatite and dyke lithologies. In contrast, the range for variably greisenized samples (Kontak 1988) is very broad (Fig. 17), as would be predicted in these rocks of highly variable mineralogy.

(4) Rare-earth-element chemistry of the leucogranite

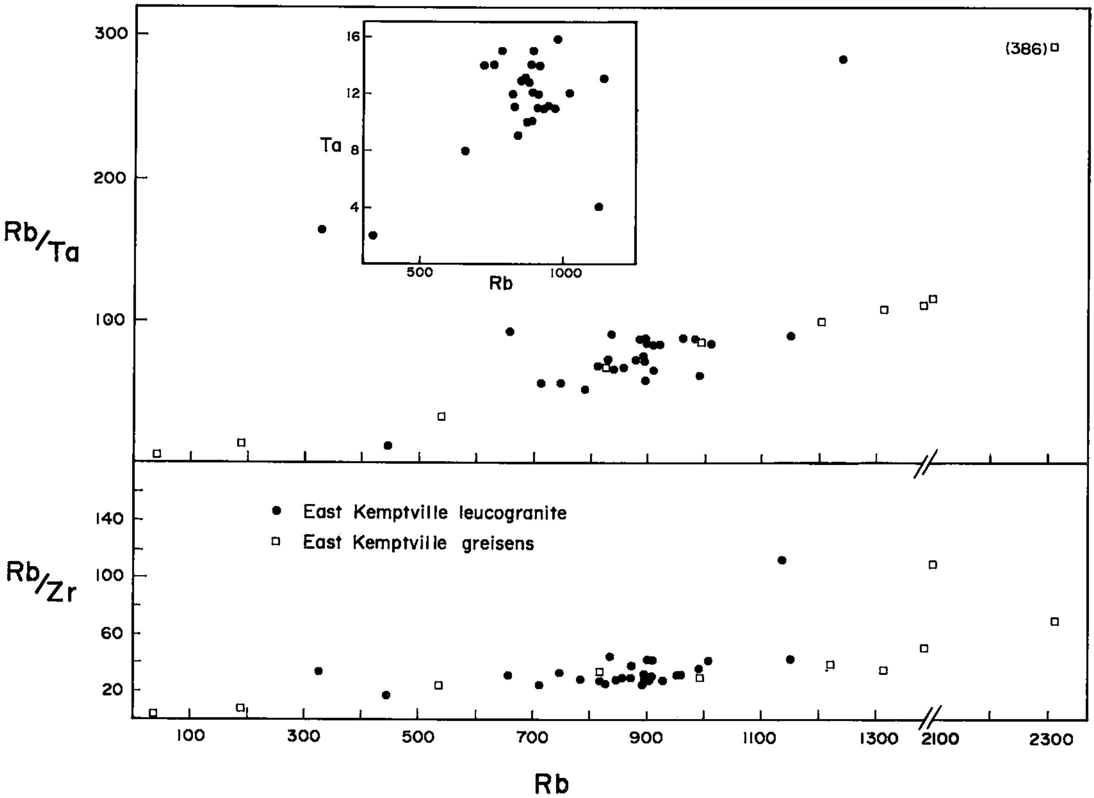


FIG. 17. Plots of Rb/Ta and Rb/Zr *versus* Rb for leucogranites and greisens at East Kemptville (greisen data from Kontak 1988).

shows consistent patterns that contrast markedly with the *LREE*-depleted, *HREE*-enriched chondritic patterns characteristic of greisenized lithologies (Chatterjee & Strong 1984). Numerous studies have shown that metasomatic processes tend to modify the *REE* chemistry of felsic rocks (*e.g.*, Taylor & Fryer 1982, 1983). Although the overall depleted pattern of the *REE* contrasts with that of typical topaz rhyolites (Christiansen *et al.* 1983, 1984, 1986) and topaz granites (Taylor *et al.* 1985, R.P. Taylor, pers. comm., 1988), it is broadly comparable to that for the volatile-rich macusanite (Pichavant *et al.* 1987b) and is, therefore, consistent with a magmatic signature rather than related to metasomatic phenomena (*e.g.*, Higgins *et al.* 1985, Tuach 1987). In fact, the *REE* pattern of the macusanite has been successfully modeled by Montel (1986) using monazite fractionation; the low Th and *REE* levels in the East Kemptville leucogranite would be compatible with a similar process.

(5) Country-rock metasediments of the Meguma Group immediately adjacent (*i.e.*, 1-3 m) to the leucogranite rarely show enrichment in elements (*e.g.*, Rb, Cs, Li, Sn, As, Zn, P) commonly considered diagnostic of lithophile-element mineralization, whereas the leucogranite is enriched in these elements (Kontak, in prep.). This apparent lack of a geochemical halo contrasts with the findings of Morgan & London (1987), who documented extreme metasomatism and elemental enrichment (K, Cs, Rb, Li, F, B) of wall-rock amphibolite adjacent to the Tanco pegmatite. The absence of a geochemical halo around the leucogranite is consistent with low fluid/rock ratios since the aforementioned elements would be partly transferred into an exsolved fluid phase (*e.g.*, Webster *et al.* 1989, Kovalenko *et al.* 1980, V. Kovalenko 1977, Morgan & London 1987) and would presumably migrate down thermal and chemical gradients into the wallrock, causing elemental enrichments.

Although the above features are considered to be consistent with a dominantly magmatic origin for the leucogranite, the elevated and erratic abundances of some elements (*e.g.*, Cu, Pb, Zn, Sn, W) and their generally good correlation with S content (Table 2) indicate that some postmagmatic, metasomatic enrichment occurred. Although it is difficult to ascertain the proportion of magmatic *versus* metasomatic contributions to such elevated concentrations, it is interesting to note that enrichment of some of these elements is found in the Peruvian macusanite glass (*i.e.*, quenched residual melt) by Pichavant *et al.* (1987b: 70 ppm W, 200 ppm Sn, 95 ppm Zn). Therefore, a certain degree of elemental enrichment in the East Kemptville leucogranite is considered related to magmatic processes, but at the same time it is clear that a metasomatic influence also is recorded.

A final point worthy of consideration is whether the phase assemblage of the leucogranite is consistent with magmatic conditions. Rocks of similar bulk composition have been studied experimentally by N. Kovalenko (1977), Weidner & Martin (1987), Pichavant *et al.* (1987a). and Webster *et al.* (1987). All of these authors report topaz as a stable magmatic phase, albeit with different ranges of stability depending on the physical and chemical constraints of the experimental conditions. In addition, Naumov *et al.* (1972) reported melt inclusions in topaz from ongonites, which proves a magmatic origin for the host, whereas Barton (1982) has shown that quartz - topaz - muscovite - alkali feldspar should constitute a stable assemblage under water-saturated conditions. The assertion of Barton (1982) that topaz cannot coexist with a Ca-bearing phase other than fluorite (*i.e.*, Ca plagioclase) is not correct; Pichavant *et al.* (1987a) found plagioclase of up to An$_{3.5}$ composition in experimental products containing topaz. Thus, for the East Kemptville leucogranite, the albite containing apatite needles is interpreted to have once been a Ca-bearing plagioclase above the solidus and to have coexisted with topaz.

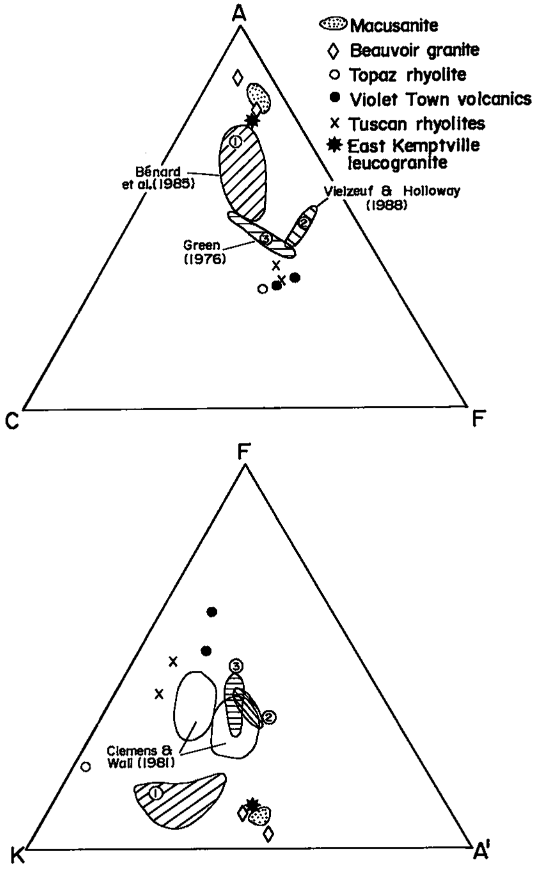


FIG. 18. A(Al_2O_3-Na_2O-K_2O)-C(CaO)-F(FeO_t + MgO) and A(Al_2O_3-Na_2O-K_2O-CaO)-K(K_2O)-F(FeO_t + MgO) plots (in moles) for the East Kemptville leucogranite, various examples of crust-derived melts and experimental glass compositions in peraluminous systems. Points for the Beauvoir granite, Tuscan rhyolites, Macusani glass, Hercynian two-mica granite, Violet Town volcanic suite and topaz rhyolites from Pichavant *et al.* (1988). Note that the two fields in the AFK diagram designated Clemens & Wall (1981) represent silimanite-seeded and unseeded compositions, respectively.

The foregoing discussion indicates that there is ample reason to seriously consider a predominantly magmatic origin for the leucogranite. However, this is not to say that some degree of subsolidus modification did not occur, since pure albite represents the sole plagioclase phase and the K-feldspar clearly reflects textural re-equilibration. But for the most part, the chemistry is considered to closely approximate that of the slightly modified precursor.

Relationship of East Kemptville leucogranite to South Mountain Batholith - Davis Lake Complex: product of fractional crystallization or separate source (?)

The spatial association of the East Kemptville leucogranite to the Davis Lake Complex, the westernmost continuation of the South Mountain Batholith, implies that there may be a genetic relationship between the two, as earlier investigators have suggested (*e.g.*, Richardson 1983, 1988a, b, Richardson *et al.* 1987). However, it is equally possible that there is no such affiliation and that the East Kemptville leucogranite represents a separate, unrelated magmatic event. As reviewed earlier, field relationships do not provide sufficient information to unambiguously resolve this problem, as nowhere can the leucogranite be observed to grade into a relatively less fractionated, potentially parental rock-unit. Thus, the best test at present remains the geochemical nature of the leucogranite relative to data for the Davis Lake Complex as presented in Richardson (1988a).

The first point to consider is whether the East Kemptville leucogranite represents a product of differentiation or perhaps a minimum melt (*i.e.*, in the sense of White & Chappell 1977) produced by batch-melting processes. This point may be assessed by comparing the leucogranite geochemistry to experimentally produced glass compositions from partial melting of various bulk compositions. The general depletion of Ti, Mg and Ca that characterizes the leucogranite contrasts with elevated values of these elements reported in experimentally produced melts by Clemens & Wall (1981), Green (1976), Bénard *et al.* (1985) and Vielzeuf & Holloway (1988).

Projection of the average leucogranite composition into the modified ACF and AKF diagrams (Fig. 18) indicates the following: (1) the composition of the leucogranite is markedly different from that of experimentally generated glass, (2) the leucogranite is exceptionally peraluminous [(*i.e.*, compare leucogranite composition to sillimanite-seeded field of Clemens & Wall (1981)]; (3) the leucogranite is strongly depleted in Ca, Fe and Mg compared to some relatively mafic peraluminous suites (Tuscan rhyolites and Violet Town volcanic suite) and experimentally generated glasses, and (4) the leucogranite compares favorably to the fields for some presumed products of extreme fractionation of peraluminous melts (*i.e.*, Macusani glass and Beauvoir granite). Thus, the aforementioned data, in addition to the elevated contents of silica, phosphorus and LILE, low K/Rb ratios and depleted values of some transition metals, alkali and alkaline earth elements, and *REE* (particularly Eu), are consistent with a strongly fractionated origin for the East Kemptville leucogranite rather than a minimum-melt composition.

In order to properly assess the role of fractional crystallization, one must first obtain appropriate mineral-melt partition coefficients for the phase assemblages. These data are not available; considering the large uncertainties that may result from using inappropriate values (*e.g.*, Christiansen *et al.* 1984), particularly in highly felsic and volatile-rich suites (Mahood & Hildreth 1983), the following discussion is limited to a qualitative approach using simple binary-element plots and monomineralic fractionation modeling.

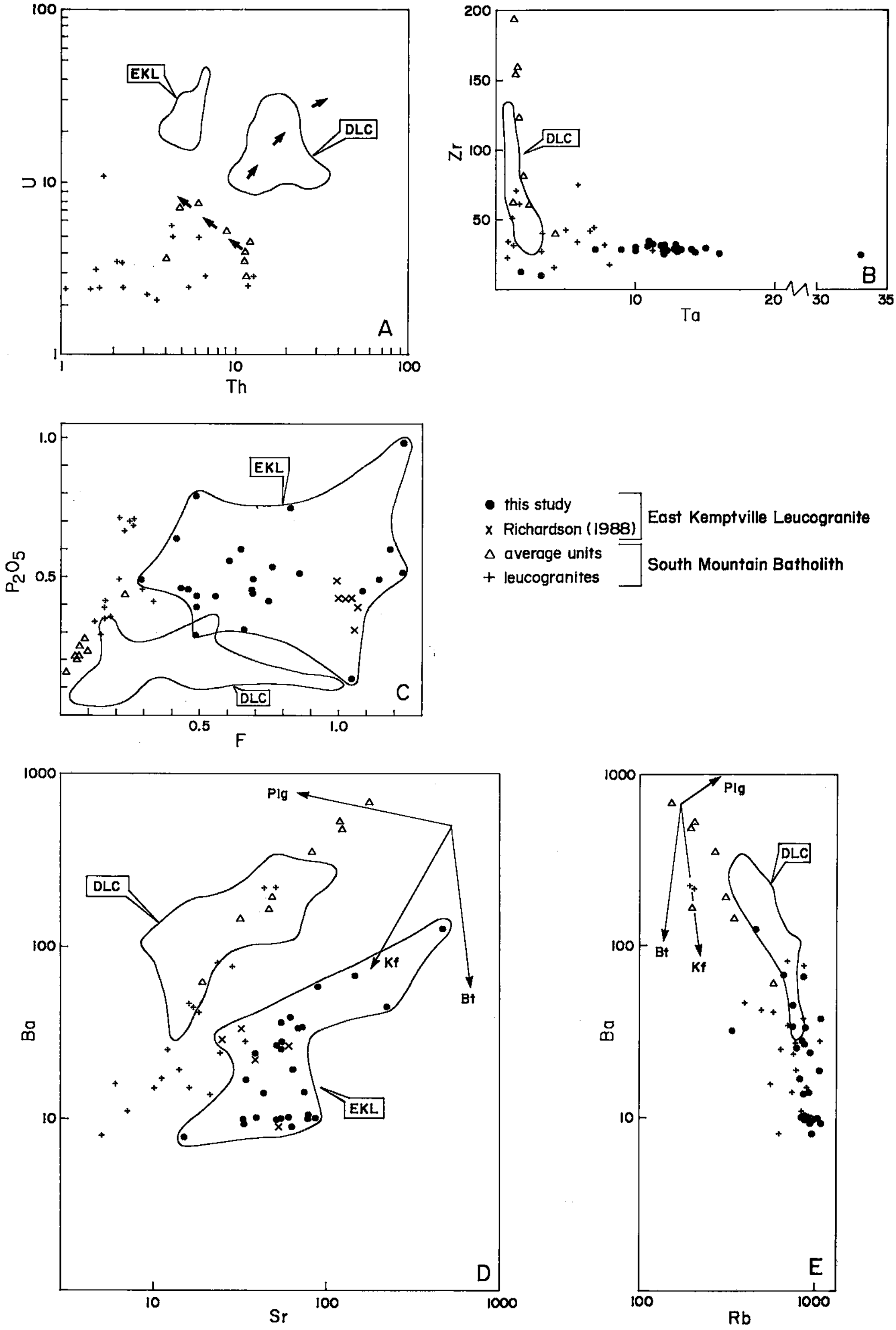
Although the East Kemptville leucogranite appears to form a continuum with Davis Lake Complex samples on a log–log plot of Rb *versus* Ba (Fig. 19E), and a genetic association is suggested *via* fractional crystallization of an alkali-feldspar-dominant biotite - plagioclase - alkali feldspar mixture, the same is not indicated by a similar plot of Sr *versus* Ba (Fig. 19D). In fact, the latter diagram serves to illustrate the uniqueness of the East Kemptville leucogranite (see also Fig. 12) and indicates that it cannot be related to the Davis Lake Complex by simple fractional crystallization since (1) there is no continuum in the data and (2) biotite, which is necessary to deplete the melt in Ba, is essentially absent in the leucogranite and therefore was not an important phase. Variation of the data within the leucogranite is adequately accommodated by removal of a plagioclase - alkali feldspar mixture.

Binary plots of U *versus* Th, Zr *versus* Ta and P_2O_5 *versus* F in Figures 19A, B and C, respectively, also serve to illustrate the unique behavior of the leucogranite with respect to both the Davis Lake Complex and the South Mountain Batholith. This uniqueness is particularly evident in the U *versus* Th plot, in which the two very divergent trends for the South Mountain Batholith and Davis Lake Complex, as determined by Chatterjee & Muecke (1982) and further discussed by Ford & O'Reilly (1985), are quite unlike the field for the East Kemptville leucogranite. In the Zr *versus* Ta plot, the relatively fractionated nature of EKL samples is again emphasized, and the gap between data for the Davis Lake Complex and leucogranite is highlighted.

In summary, the East Kemptville leucogranite is inferred to represent a highly differentiated rock similar to the extreme products of peraluminous magmas represented by, for example, the Macusani obsidian and the Beauvoir granite. The lack of a chemical continuum or supporting field-relationships precludes at present an obvious link to the Davis Lake Complex *via* progressive fractional crystallization. However, this is not to say that protracted fractionation of a common melt did not proceed at depth, with only the most evolved product presently exposed at surface, as documented, for example, by Manning & Exley (1984) (see also discussion in Weidner & Martin 1987) for the biotite granite and topaz - lithium muscovite granite phases of the St. Austell granite, Cornwall. Note that N. Kovalenko (1977) suggested that granitic melts of the ongonite type containing elevated fluorine contents can result from fractionation of a felsic magma given the high concentration of acid fluorides. Whereas the oxygen isotope data are commensurate with derivation of East Kemptville leucogranite from the Davis Lake Complex *via* a similar process, additional isotopic data will be required to further substantiate such a relationship.

Implications of the East Kemptville leucogranite for the tin potential of the Meguma Zone

The tin potential of granitoid rocks of the Meguma Terrane has been addressed by numerous authors (*e.g.*, Ford & O'Reilly 1985, O'Reilly 1988b, Smith & Turek 1976, Chatterjee & Muecke 1982, Chatterjee *et al.* 1983) using a variety of geophysical (*i.e.*, airborne radiometry) and lithogeochemical techniques. In general, comparisons are made between the geochemical signatures of the granitoid rocks of interest and those from other stanniferous districts (*e.g.*, Cornwall, Nigeria, Malaysia, Erzgebirge), with


100
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the underlying assumption that common features are present, so that extrapolations are valid. However, of utmost importance to this argument is the assumption that the progenitor of the mineralization is being sampled and analyzed, an assumption that is not always evaluated (Taylor 1979). For example, in the Mount Pleasant tin deposit, multiple periods of mineralization are spatially associated with different types of granite. At this locality, Kooiman *et al.* (1986) and Taylor *et al.* (1985) have demonstrated that the Sn stage is associated with a chemically distinct granite petrologically similar to topaz granites, whereas the W–Mo mineralization shares spatial affinity with a biotite granite of quite different character. A similar situation exists in the Peruvian part of the Central Andean tin belt, where Kontak & Clark (1988) have shown that significant centers of tin - base metal mineralization are generally hosted by biotite granites with chemical signatures typical of nonproductive granites (*cf.* Tischendorf 1977).

It is here suggested that a similar situation may be present in the Meguma Terrane, such that tin mineralization is associated with topaz-bearing (*i.e.*, F-rich) granites. A similar case has been argued by Burt *et al.* (1982) and Burt & Sheridan (1988) for lithophile mineralization associated with topaz rhyolites of the western United States and Mexico. The implication of this proposal is that the South Mountain Batholith, previously considered to offer potential for significant stanniferous mineralization on the basis of conventional trace-element signatures (*e.g.*, Smith & Turek 1976), does not possess the inherent features for producing large deposits of tin. The numerous but volumetrically very small occurrences of tin and associated lithophile-element mineralization in the New Ross - Vaughn area (O'Reilly *et al.* 1982, Charest *et al.* 1985) are thus interpreted as representing the natural termination of the crystallization of an S-type magma. In such cases, the magma must evolve a hydrous phase upon crystallization (*e.g.*, Burnham 1979, Burnham & Ohmoto 1980) and, consequently, at least a certain amount of mineralization and alteration will result because of the tendency of metals to preferentially partition into Cl-bearing fluids (Eugster 1985). This scenario contrasts with the East Kemptville leucogranite-type melt which, because of its different initial composition and liquidus path, evolves into a volatile-rich melt with the inherent potential to develop into a mineralized system (*e.g.*, Strong 1981, 1988).

The East Kemptville leucogranite and implications for the infrastructure of the Meguma Terrane

The genesis of fluorine-rich igneous suites in other geological provinces has been attributed to the presence of a source reservoir enriched in this element. For example, in a recent study of several hundred samples of granites from the Basin and Range Province of the western United States, Christiansen & Lee (1986) concluded that the elevated fluorine contents in one of the suites reflected either magma generation from or contamination by a fluorine-rich reservoir. Similar conclusions were reached by Manning & Pichavant (1983), Pichavant & Manning (1984) and Christiansen *et al.* (1983, 1986) in their petrogenetic modeling of fluorine-rich igneous suites. These authors were unanimous in their conclusions that breakdown of fluorine-bearing, Fe-rich biotite or amphibole (see also discussion in Clemens & Wall 1981) was the mechanism responsible for generating a fluorine-rich melt. The source rocks most likely to provide suitable mineralogy and satisfy the intensive parameters inferred from petrological studies of these suites are felsic granulites (*e.g.*, Christiansen *et al.* 1983).

The presence of the East Kemptville leucogranite in the Meguma Terrane has important implications for the composition of the infrastructure of this terrane, considering the nature of the protolith generally considered parental to such rocks. Granulitic rocks underlie at least part of the Meguma Terrane, as substantiated by the recent findings of Giles & Chatterjee (1986) for the Liscomb Complex, and Chatterjee & Giles (1988) and Owen *et al.* (1988), who documented the presence of granulite-facies xenoliths within mafic dykes at Tangier (Fig. 1). In addition, Clarke & Chatterjee (1988) and Eberz *et al.* (1989) presented Nd and Sr isotopic evidence that the gneissic rocks of the Liscomb Complex represent the protolith for the South Mountain Batholith. By extrapolation, therefore, it is inferred that similar rocks underlie the southwestern Meguma Terrane. This same rock would, therefore, be an ideal candidate for the generation of a fluorine-rich melt

FIG. 19. Element plots comparing data for East Kemptville leucogranite (EKL) to fields for Davis Lake Complex (DLC, Richardson 1988a), average units of South Mountain Batholith (SMB, Ham *et al.* 1989) and selected leucomonzogranite samples of the South Mountain Batholith (Ham *et al.* 1989). (A) U *versus* Th diagram showing the trends for the South Mountain Batholith and Davis Lake Complex as determined by Chatterjee & Muecke (1982); (B) Zr *versus* Ta plot; (C) P_2O_5 *versus* F plot; (D) log–log plot of Ba *versus* Sr; (E) log–log plot of Ba *versus* Rb. In Figures 19d and e the vectors shown represent the expected effects on melt composition of Rayleigh crystal fractionation of single mineral phases (bt biotite, kf alkali feldspar, plg plagioclase).

during a melting event by the mechanism of melt generation reviewed by Manning & Pichavant (1983) and Christiansen *et al.* (1983).

The highly evolved chemistry of the East Kemptville leucogranite and the dominance of muscovite to the almost complete exclusion of biotite indicate that the leucogranite represents an extreme product of fractional crystallization. Hence, although it is suggested that the leucogranite was probably generated by a mechanism involving breakdown of fluorine-rich biotite, subsequent petrological processes have substantially changed the character of the original melt.

The reason for the isolated occurrence of a topaz-bearing or extremely fluorine-rich felsic suite in the East Kemptville area remains a problem. However, it is tentatively suggested that the presence of the East Kemptville Shear Zone (Fig. 2a) may be of fundamental importance in terms of localizing the melt. In a somewhat analogous situation, Strong & Hanmer (1981) have interpreted the role of the Armorican Shear Zone to be important in both generating and localizing the leucogranites of Britanny, whereas Pitcher (1979) noted that granites commonly utilize crustal-scale structures to ascend to shallow crustal levels. In addition, Strong (1980) has emphasized that many granites of eastern Canada and western Europe owe their origin to a "megashear environment", owing to the lack of evidence for subduction processes operating at the time of granite generation. Thus, the East Kemptville leucogranite is interpreted to reflect melt ascent within an active shear-zone that penetrated a ductile infrastructure and tapped a zone of partial melting within a granulite source during the continued transpression of the Meguma Terrane in the Late Devonian. Similar leucogranites may be found along similar structures where the appropriate geological conditions prevailed. In this vein it is interesting to note that other mineralized, fluorine-rich suites in the Canadian Appalachians show intimate spatial associations to major structural breaks. Some of the more notable examples include (1) the Ackley Granite, Newfoundland (Tuach *et al.* 1986, Tuach 1987), which truncates the Dover - Hermitage Bay Fault, a major terrane boundary between the Avalon and Gander Zones (see Fig. 1), and (2) the Mount Pleasant (Kooiman *et al.* 1986, Taylor *et al.* 1985), Burnthill (Taylor *et al.* 1987, MacLellan & Taylor 1989) and Mount Douglas (McLeod *et al.* 1988) complexes of New Brunswick, which are all related to zones of wrench faulting (Ruitenberg & Fyffe 1982). In addition, Whalen (1986) has reinterpreted many of the peraluminous S-type granites of New Brunswick to be of A-type affinity, based on their trace-element chemistry. Such granites share a common genetic origin with topaz granites and rhyolites (Collins *et al.* 1982).

Petrogenesis of the East Kemptville leucogranite

The petrological evidence presented favors the hypothesis that the East Kemptville leucogranite is a product of fractional crystallization of a fluorine-rich melt generated by crustal anatexis. The derivation of the leucogranite from a crustal reservoir requires an increase in the local isotherms such that melting can occur. Mechanisms for creating such a situation might include frictional heating in a shear-zone environment, crustal thickening during regional deformation concurrent with continental collision, or transport of heat from the mantle *via* basaltic magmas. The first suggestion is discussed by Strong & Hanmer (1981) in their treatment of the Britanny leucogranites. Whereas it may be appropriate for Britanny, there is not sufficient reason to employ a similar model here since there are more differences than similarities in both regional geology and the granites between the two areas (Hanmer & Strong 1981, Jégouzo 1980, Hanmer *et al.* 1982). The second model is analogous to that used to explain the origin of the Himalayan leucogranites, described by Le Fort (1981) and Vidal *et al.* (1984). Although Keppie & Dallmeyer (1987) have interpreted Meguma Terrane granites of *ca.* 370 Ma age to reflect crustal underplating of the Meguma Zone, with concomitant upwelling of the isotherms and crustal melting, there are presently insufficient geological reasons to fully support this concept. For example, reconstruction of the Late Devonian - Early Carboniferous geological record does not indicate that a crust of appropriate thickness existed, as presently observed in the Himalayas, but the recent discussion of this problem by Thompson (1989) offers an alternative interpretation. The third model is consistent with the present status of knowledge of Meguma Zone geology. The recent delineation of mafic intrusions in the Liscomb Complex dated at *ca.* 370 Ma (Kontak *et al.* 1989b, 1990) and rocks of similar age occurring as dykes along the Atlantic coastline (Kempster *et al.* 1989) indicate that the necessary thermal component was temporally and spatially present to satisfy the inherent requirements of this model, whereas isotopic data (Clarke & Chatterjee 1988) are consistent with a mantle contribution to the granites of the Meguma Terrane. Although similar isotopic data are not available for the East Kemptville leucogranite, Christiansen *et al.* (1983, 1986), Christiansen & Lee (1986) and Pichavant & Manning (1984) have considered mantle upwelling and ensuing crustal fusion as the most likely mechanism for generation of fluorine-rich suites. Thus, the East Kemptville leucogranite is considered to have been generated *via* partial melting of a crustal reservoir as a result of input of heat from basaltic magma injected into the crust. Ascent to the surface was facilitated by a crustal-scale structure as alluded to above.

CONCLUSIONS

A petrological study of the 370 Ma East Kemptville leucogranite, a muscovite–topaz leucogranite that hosts tin mineralization, reveals the following important features:

(1) The granite represents the product of crystallization of a highly evolved, volatile-rich (*i.e.*, F-rich) felsic melt. The uniform textures and modal mineralogy and absence of extreme alkali metasomatism are interpreted to indicate a magmatic origin for both topaz and muscovite rather than late-stage metasomatism. However, a certain amount of element enrichment (*e.g.* Cu, Fe, Sn, W, Zn, P, S) is attributed to a superimposed metasomatic phenomenon.

(2) There is an absence of petrographic and textural features (*e.g.*, graphic textures, miarolitic cavities, breccias, abundant pegmatites, unidirectional solidification textures) that are commonly found in fluid-saturated melts (*e.g.*, Kirkham & Sinclair 1988), which indicates, therefore, that the East Kemptville leucogranite did not reach fluid saturation (*cf.* Richardson *et al.* 1988b).

(3) Mineralogically and chemically the East Kemptville leucogranite is similar to other fluorine-rich felsic suites, including topaz granites. It is characterized by elevated contents of Cs, F, Li, Nb, Rb and Ta, and depletion in B, Ba, Ca, Co, Hf, Mg, Mn, Ni, Sc, Ti and V.

(4) The strongly peraluminous character (A/CNK values = 1.13 to 1.84) and major- and trace-element chemistry of the leucogranite, including strongly depleted *REE* contents (particularly Eu), indicate that the granite represents the product of fractional crystallization rather than batch melting. Although it is not presently possible to unequivocally eliminate the Davis Lake Complex as a source of the parental magma, the field relationships as presently understood suggest that they are not related. Alternatively, magmatic evolution may have proceeded at depth with no manifestation of this process at the surface.

(5) The chemistry of the East Kemptville leucogranite, including whole-rock O isotopic data, indicates a crustal reservoir for the protolith. Analogies with other F-rich suites suggest that the most likely source is a felsic granulite. Hence, the leucogranite is interpreted to reflect the incongruent breakdown of a fluorine-rich biotite phase due to crustal anatexis related to injection of basaltic magma into the lower crust. The source rock is considered to be represented by similar lithologies exposed in the Liscomb Complex (Giles & Chatterjee 1986).

(6) Future exploration for tin mineralization in the Meguma Terrane should focus on similar fluorine-rich suites since their chemical nature increases the potential for development of geological conditions favorable for mineralization.

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