Geology of the Southern Lobe of the Brazil Lake LCT-type Pegmatite (NTS 21A/04), Yarmouth County, Nova Scotia

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Introduction

Rare-element pegmatites are important resources for their economic concentrations of rare elements (e.g. Sn, Li, Ta, Rb, Cs, etc.), presence of high-quality industrial minerals (e.g. muscovite, spodumene, feldspar, mica), and occurrence of gem minerals (e.g. tourmaline, beryl). LCT-type pegmatites are rare-element pegmatites enriched in Li, Cs and Ta, and are often related petro-genetically to fertile, progenitor granites (see Černý, 1991a, for classification of pegmatites). Examples of LCT pegmatites that are currently mined include the Tanco pegmatite (Li, Ta, Cs, Be, Rb) of Manitoba, the Bikita (Li) and Kamativi (Li, Sn) pegmatites of Zimbabwe, the giant Greenbushes pegmatite (Sn, Ta, Nb, Li) of western Australia, and the spodumene pegmatites of North Carolina. Although spodumene-bearing pegmatites occur elsewhere in the Appalachians (e.g. Kings Mountain, North Carolina, and Peg Claims, Maine), the Brazil Lake pegmatite (BLP) is at present the only known occurrence in Nova Scotia.

The occurrence of spodumene and associated columbite-tantalite in the Brazil Lake area of southwestern Nova Scotia (Fig. 1a, b) has been known since 1960 (Taylor, 1967), but the occurrence has attracted only limited and sporadic work (see below) until recently. A more extensive program of drilling and stripping in 2002 by Champlain Resources Inc. exposed a large amount of pegmatite that was previously unknown. Work to date indicates that this pegmatite has the potential to produce high-quality feldspar, quartz, mica and spodumene with appreciable grades of tantalum (D. Black, personal communication, 2003). In order to assess this resource, develop a model for its petrogenesis, and assess the potential of the surrounding area, a detailed mapping program, with follow-up petrological studies, was initiated during the summer of 2003. This report presents the preliminary findings of this work. In addition, initial results of an integrated geochronological study are presented and, for the first time, an absolute age constraint on the time of emplacement of the pegmatite is provided. This age has important implications, not only for the petrogenesis of the Bazil Lake pegmatite, but also for exploration in this part of the Meguma Terrane.

Summary of Previous Work

Two separate lobes of pegmatite are currently exposed in the Brazil Lake pegmatite. These lobes are referred to informally as the northern and southern pegmatites, with reference to their location to the Holly Road (Fig. 2a). The Brazil Lake pegmatite was discovered in 1960 when a spodumene-bearing pegmatite boulder was found beside the Brazil Lake - Pleasant Valley Road (i.e. the Holly Road). Subsequent stripping of outcrops in the area revealed the presence of pegmatite north and south of the road. The first map of the area, indicating the distribution of pegmatite bodies, was produced by Taylor (1967), who also provided a modal analysis from an exposure of the southern outcrop (52% feldspar (K-feldspar and albite), 34% quartz, 11% spodumene, 3% muscovite, minor to trace beryl, apatite, and tourmaline). Metallurgical work done on a 272 kg sample of spodumene-rich (34.4% modally) pegmatite indicated 0.18-0.3 wt. % Fe_2O_3 in the spodumene. Shell Canada Ltd. evaluated the site with mapping, geophysics and geochemical sampling, and found variable, but elevated levels of Li (<275 ppm), Rb (<190 ppm), Cs (<100 ppm), Sn (<177 ppm) and Ta (<95 ppm) (Palma *et al.*, 1982). A mineralogical study was done on four representative samples from outcrops south of the Holly Road by Hutchinson (1982), collected as part of the Shell Canada Ltd. exploration program. Significantly, Hutchinson

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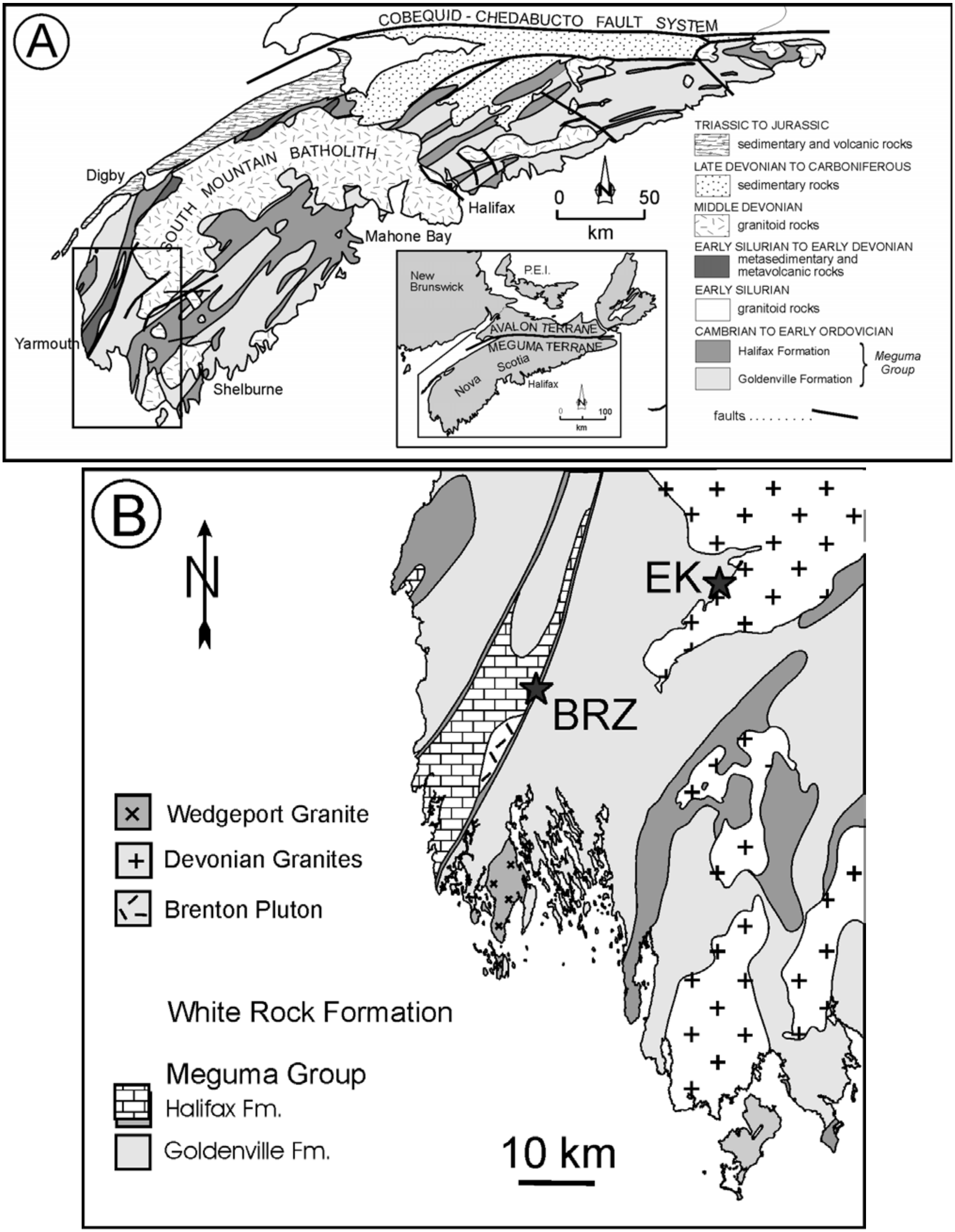


Figure 1. (A) Regional geological map of southern Nova Scotia showing the location of the study area (Fig. 1B inset). (B) Geological map of southwest Nova Scotia (after White *et al.*, 2001) showing location of Brazil Lake pegmatite (BRZ) and the East Kemptville tin deposit (EK).

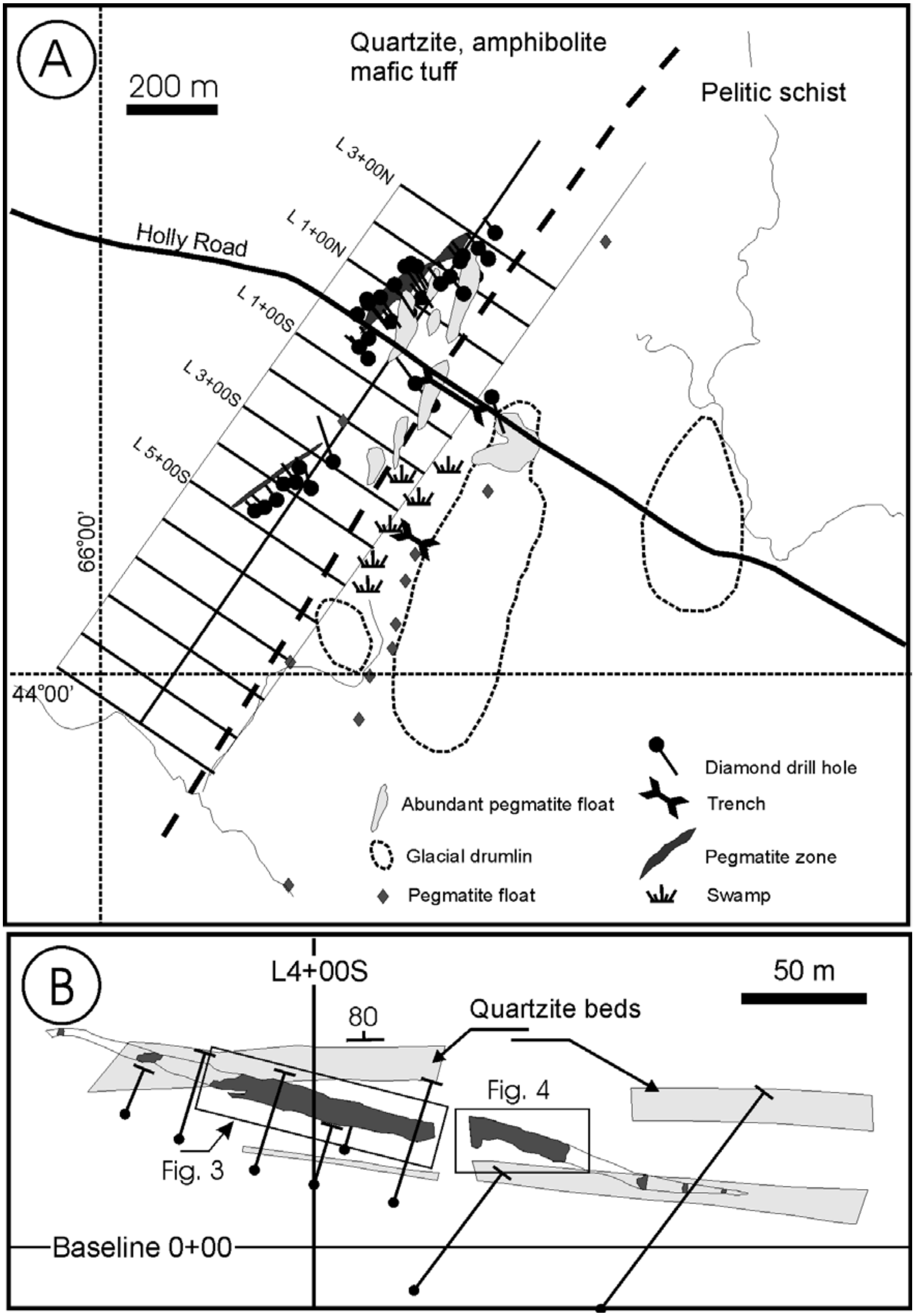


Figure 2. (A) Geological setting of the Brazil Lake pegmatites with reference to the Holly Road (map modified after map of D. Black, Champlain Resources Inc., 2003). The pegmatites located north and south of the Holly Road are referred to informally as the northern and southern pegmatites, respectively. (B) Geological setting of the southern pegmatite, Brazil Lake.

(1982) recognized a metasomatic halo about the Brazil Lake pegmitite, revealed by the conspicuous presence of tourmaline in the quartzite and the rare occurrence of the Li-bearing amphibole homquistite, generally diagnostic of nearby Li-bearing pegmatite (e.g. London, 1986a).

MacDonald *et al.* (1992) conducted a geochemical study over the pegmatite area in order to evaluate the signature of this deposit within the surficial environment, including the vegetation. Corey (1993) drilled the northern pegmatite as part of a larger program undertaken by the Nova Scotia Department of Natural Resources, and concluded that it was a single, zoned, sub-vertical dyke of 10-25 m thickness. Sampling and analysis of this core by Gwalia Resources of Australia in 2002 provided the first extensive geochemical data set (see below). Hughes (1995) provided a more comprehensive petrological investigation of the northern pegmatite that included mineral chemical data, recognition of new minerals, the first fluid inclusion observations and data, and a modern petrogenetic model.

Geological Setting

The study area is located in the southwestern end of the province, just past the western extent of the 380 Ma, peraluminous South Mountain Batholith (SMB), and roughly 25 km from the past-producing (1985-1992) East Kemptville tin deposit (Fig. 1b). The Brazil Lake area is underlain by a mixed package of metasedimentary and metavolcanic rocks, which are cut by small pegmatite bodies, and the Brenton Pluton, which is also transected by pegmatites. The oldest rocks are part of the Cambro-Ordovician Meguma Group, which consists of an older, sandstone-dominant Goldenville Formation, and younger, overlying siltstone and shale-dominant rocks of the Halifax Formation. Overlying the Meguma Group are mixed sedimentary and volcanic rocks of the Silurian White Rock Formation. The sedimentary stratigraphy is dominated by massive quartzite with minor pelitic beds. The volcanic rocks are of basaltic composition, although west of the study area near Yarmouth felsic rocks also occur (White *et al.*, 2001). A recent U/Pb zircon age of 438 Ma was obtained for the volcanic rocks (MacDonald *et al.*, 2002). The Breton pluton, a probable subvolcanic intrusion related to the White Rock Formation based on its chemistry (MacDonald *et al.*, 2002) and 439 Ma U/Pb zircon age (Keppie and Krough, 2000), is in fault contact with both the White Rock and Halifax formations. The intrusion is highly deformed and corresponds compositionally to a biotite-muscovite syenogranite to monzogranite. Within the intrusion are two mica-bearing, garnet-tourmaline pegmatites that commonly cut the fabric of the granite.

Deformation in the area occurred during the Acadian Orogeny and produced northeast-trending, upright folds with a shallow southwest plunge and a related penetrative fabric. An overprinting, probably Alleghanian age fabric (Culshaw and Reynolds, 1997), crenulates the S1 fabric and the fold axis is gently south-southeast plunging (White *et al.*, 2001). The metamorphic facies varies from greenschist to amphibolite, with higher facies localized to the contact area between the White Rock and Goldenville formations on the south side of the Yarmouth Syncline (MacDonald, 2000). This also coincides with a boundary between two distinct trends of vertical gradient magnetics, which O'Reilly *et al.* (1992) termed the Deerfield Shear Zone.

In the area of the BLP, the host rocks are a northeast-trending sequence of folded meta-volcanics and metasediments of the White Rock Formation that fall in the middle of the Yarmouth Syncline (Fig. 1b). Rock types include fine- to coarse-grained amphibolite, minor mafic tuff, dark green-black pelite, psammite and a fine-grained, tourmaline-bearing, silica-rich rock adjacent to the pegmatite. The pelitic unit typically contains staurolite, garnet and andalusite, whereas tourmaline occurs in the amphibolite adjacent to the pegmatite (thin section observation). In addition, elliptical, buff-colored plagioclase clots, with steep lineations, occur in amphibolite near the pegmatite. The silica-rich nature of the quartzite may be primary or, in part, an exomorphic alteration (i.e. silicification) related to pegmatite emplacement (D. Black, personal communication, 2003).

Geology of the Brazil Lake Pegmatite

The Brazil Lake pegmatite consists of two distinct sheets that occur south and north of the Holly Road (Fig. 2a), referred to informally as the northern and southern pegmatites. Previously, the few scattered outcrops of these pegmatites that represent their surface expression were mapped by Hutchinson (1982) and Hughes (1996), respectively. Essentially, both these workers recognized three zones within the BLP that were characterized by modal enrichment in spodumene, K-feldspar (KF) and albite (their aplitic albite). The southern pegmatite is dominated by zones of megacrystic blocky K-feldspar (BKF), spodumene (Spd), fine-grained albite, and coarse-grained pegmatite composed of variable proportions of Spd-KF-quartz. Further subdivisions can be made based on textures, grain size and mineral proportions. Subdivision of the BLP compared in general with that observed in albite-spodumene rare-element pegmatites, which are otherwise generally characterized by a heterogeneous and complex internal structure (Černý, 1991a).

The pegmatites are steeply-dipping sheets (i.e. 75-80° SE) of 10-20 m width that strike north-easterly at ca. 30-40°. Although the pegmatites lie within the White Rock Formation, they obliquely crosscut bedding, such that they are in direct contact with quartzite, pelitic schist and amphibolite along their strike length. In the quartzite unit marginal to the pegmatite, tourmaline occurs disseminated as isolated grains or aggregates, often with radial habit and rarely exceeding 3-5%. The overall dimensions of this zone remain to be defined as part of future work. There is no regional structure that the BLP appears to have accessed during emplacement, and contacts between pegmatite and wallrock are welded with no apparent structural discontinuity or locus of subsequent displacement. On strike and southwest of the southern pegmatite is a recently exposed quarry that does not contain pegmatite; thus, the southern pegmatite body either plunges to the southwest beneath these exposures, pinches out, or is faulted off.

Geology of the Southern Pegmatite

Stripping of the southern pegmatite in 2002 provided complete exposure of this unit and it was mapped in detail in 2003 (Figs. 3, 4). Below is a summary of findings resulting from this mapping. The northern pegmatite is scheduled to be stripped in 2004 and will be subsequently mapped in detail.

Wallrocks

The immediate wallrock consists of an interbedded sequence of mafic volcanics (amphibolites), pelitic schist, and quartzite. There is no apparent structural continuity between the pegmatite and wallrocks, the contact is a zone of faulting or shearing. The sequence strikes northeastwards and dips steeply to the northwest. Adjacent to the pegmatite, all three rock types are found due to the fact that the pegmatite is oblique to the strike of the beds. Within the amphibolitic rocks occur thin, beige ellipses, ca. 0.5-1 cm long, of plagioclase aggregates that are oriented subvertical in the cleavage plane. Along the margin of the pegmatite occur tourmaline-rich (i.e. 40-50%) xenoliths of altered amphibolite; tourmaline grains are <1-2 cm long. In thin section tourmaline locally comprises 10-20% of the mode of amphibolite adjacent to the pegmatite. The quartzite beds locally lose their buff colour adjacent to the pegmatite, as noted above, which may relate to silicification. Chemical analysis of these rocks indicates up to 98.5% SiO_2 (D. Black, personal communication, 2003). No megascopic change is noted in pelitic beds adjacent to the pegmatite.

Zoning in the Southern Pegmatite

There is a distinct development of zones within the southern pegmatite that permits mapping out areas that are characterized by a dominant mineral or texture, and these are discussed below. It should be emphasized that some variability may occur in such zones, but in general one zone can be easily distinguished from a contrasting zone. These zones (Figs. 3, 4) are dominated by blocky K-feldspar or their albitized equivalents, spodumene-rich areas,

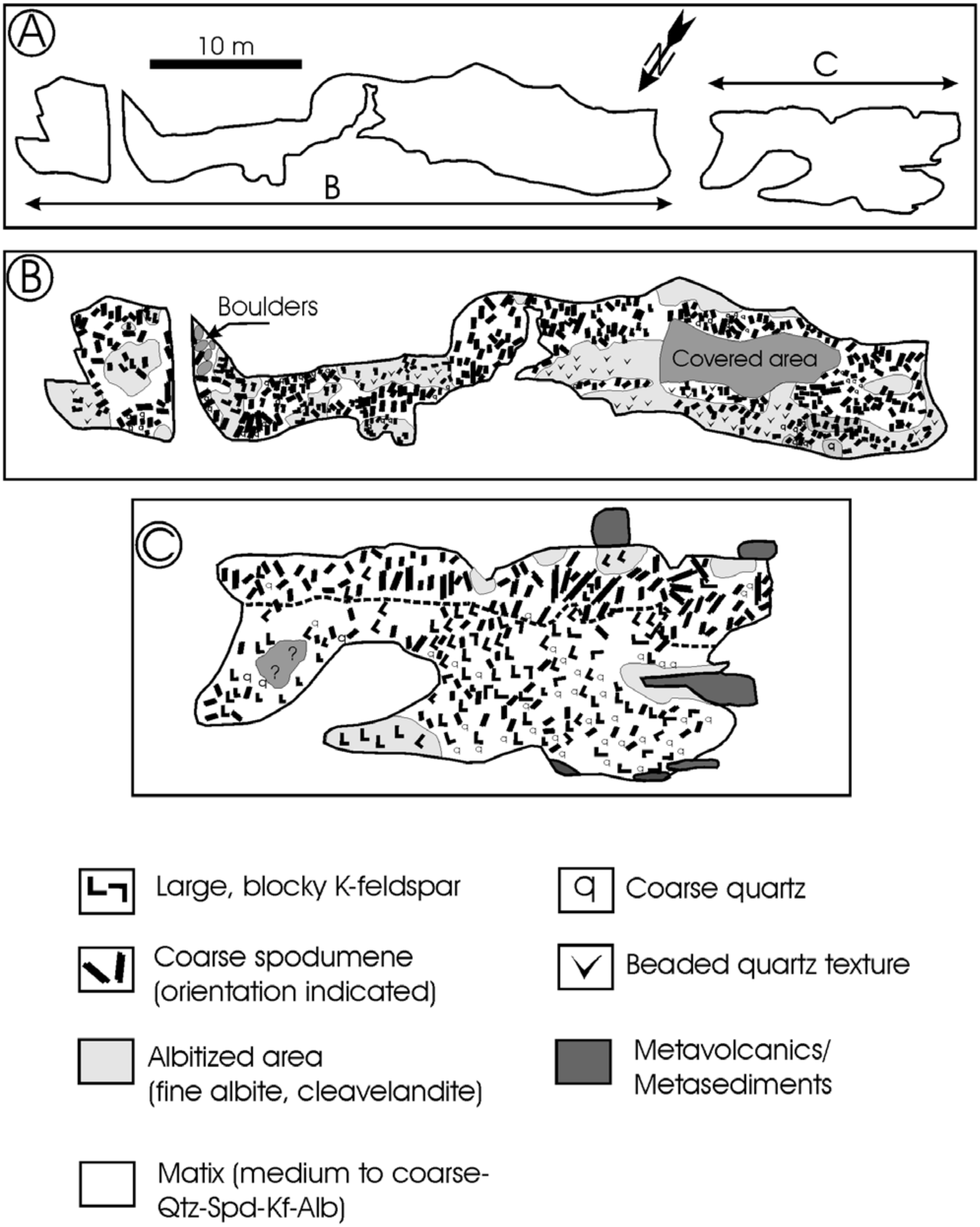


Figure 3. Detailed geological maps of outcrops comprising the southern pegmatite (see Fig. 2 for location). Figure 3A shows the location of the outcrops and in Figures 3B and C are the detailed geological features of these pegmatitic outcrops.

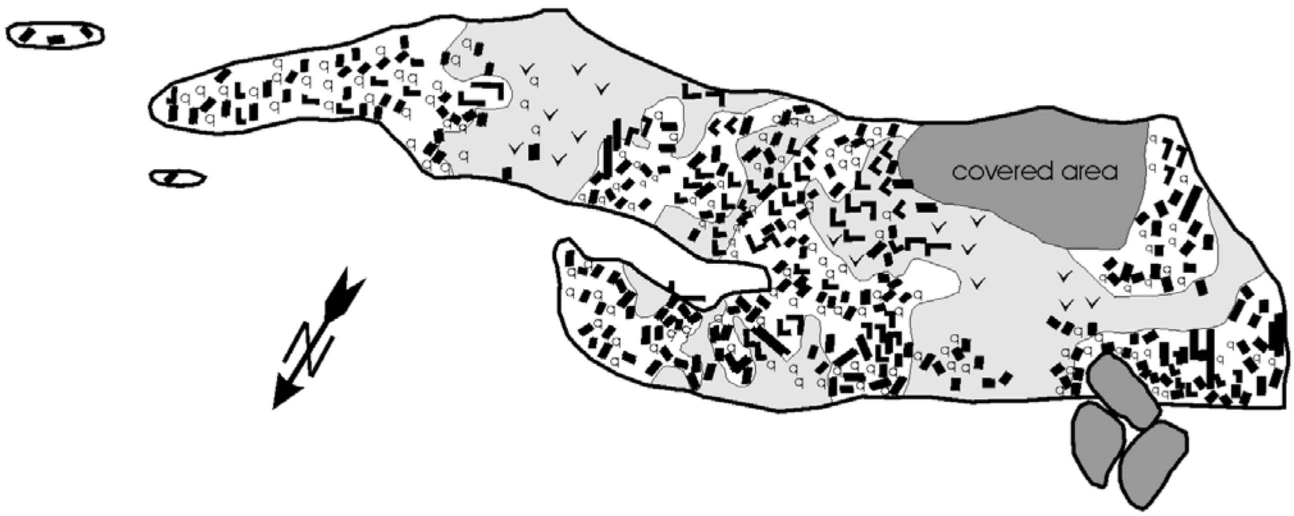


Figure 4. Detailed geological map of part of the southern pegmatite. See Figure 2B for location of the outcrop and Figure 3 for the legend.

coarse matrix pegmatite, and a beaded quartz-textured zone.

Marginal or Contact Zone

There is no well-developed, continuous wall zone to the southern pegmatite. Wall zones consisting of fine-grained granite or aplite are common in other zoned rare-element pegmatites (e.g. Černý, 1991a; Simmons *et al.*, 2003). However, locally within 1 m of the contact there is a marked decrease in the grain size and euhedral spodumene oriented perpendicular to the contact is surrounded by smaller quartz euhedra within an aplite matrix (Fig. 5). The mineralogy of this matrix is presently undetermined. Elsewhere the contact zone may become more siliceous, as seen along the southwestern contact where both the abundance and grain size of quartz increases (Figs. 3c, 8g). Although there may be alignment of quartz and spodumene subparallel to the contact (Fig. 4), this contrasts markedly with the general orientation of megacrystic K-feldspar and spodumene perpendicular to the contact elsewhere (Figs. 3b, c, 6c, e).

Blocky K-feldspar (BKF) Zones

Zones of BKF, with individual crystals of <1.5 m (Figs. 6a, c, e), occur throughout the pegmatite (Figs. 3b, c), but in the northeastern end such zones are rarely preserved and, instead, have been albitized (Fig. 6b). These large megacrysts are subhedral to euhedral (compare Figs. 6a to e) and are generally inclusion free on a macroscopic scale. Although zones may be dominated by K-feldspar, they may also contain variable amounts of quartz and spodumene (e.g. Figs. 6a, e). The BKF crystals vary from equant to elongate and, in the latter case, the long axis is oriented perpendicular to the contact (Fig. 6c). Where the K-feldspar has an elliptical shape (e.g. Fig. 6b), the outline may reflect post-crystallization modification due to superimposed stress, which is not uncommon in pegmatites (Černý, 1991a). The BKF zone varies from greyish, representing the freshest material, to various hues of pinkish-red, and white where altered to fine-grained albite. On fresh surfaces the K-feldspar contains a flame perthite texture.

Intergrown with the BKF zones may be coarse (<10-15 cm) quartz of anhedral elliptical shape to euhedral grains (Figs. 6a, 8c). Where this type of quartz coalesces and becomes continuous, the term beaded quartz texture (BQT) is used to describe the feature and it can be mapped within the pegmatite (Figs. 3, 4, 6b, d). Thus, there is a continuum between BKF and BQT zones. In addition, there is a continuum between BQT zones dominated by quartz, and more polymineralic (i.e. quartz±muscovite±spodumene±feldspar) areas where the proportions of minerals vary. In these areas the

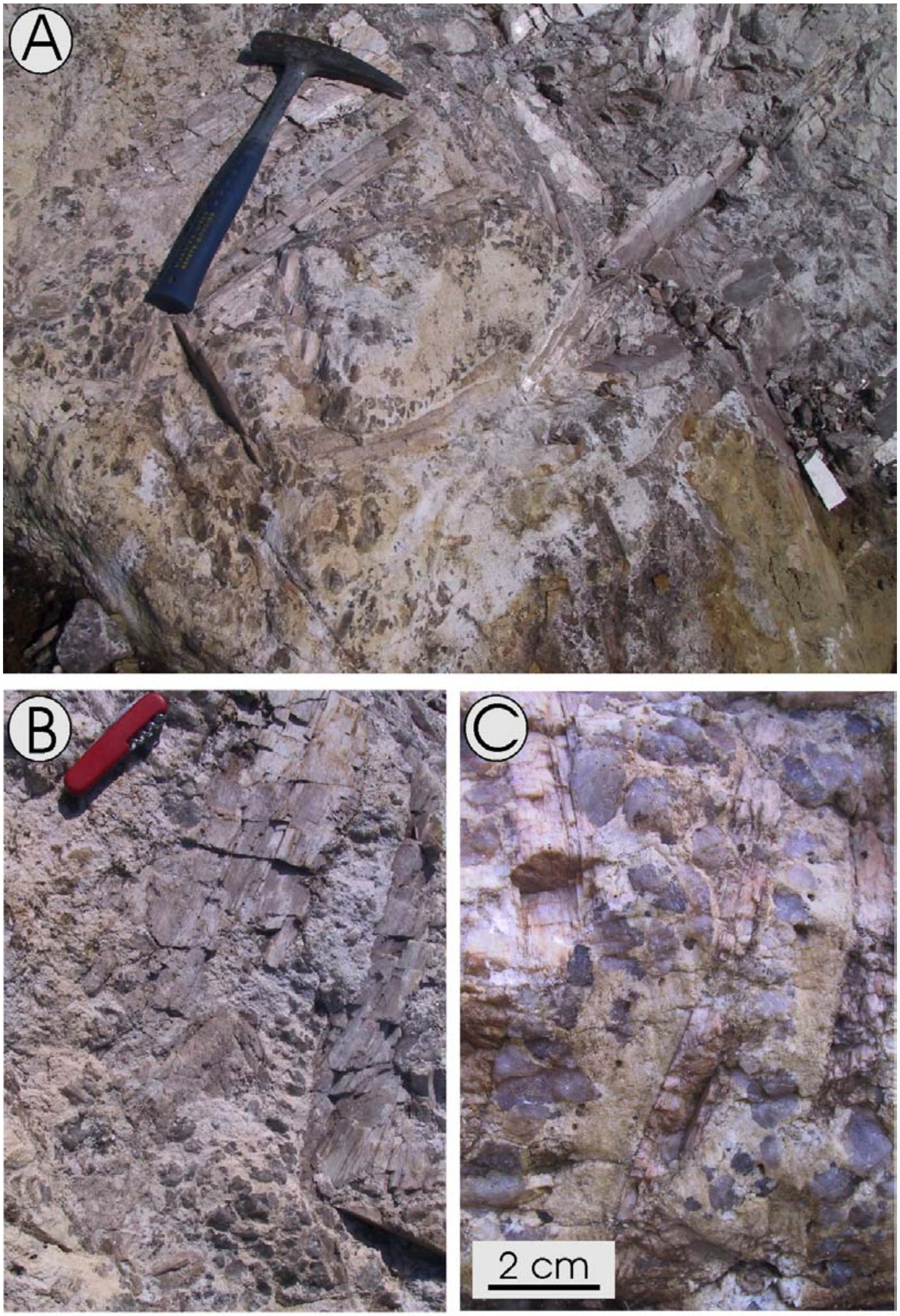


Figure 5. Outcrop photos of border zone, southern pegmatite, Brazil Lake. (A) Spodumene megacrysts in upper right bordered by smaller spodumene crystals in matrix of fine-grained, sacchroidal-textured aplite/albite with quartz grains. Note that the long dimension of the spodumene crystals are oriented perpendicular to the contact (lower left).
(B) Enlargement of part of Figure 5A showing intergranular material between spodumene megacrysts. Note the quartz grains that are growing with their c-axis perpendicular to the spodumene crystals. (C) Close up of wall zone texture showing the euhedral, translucent quartz grains in the fine-grained aplitic material.

BKF is often replaced by either fine-grained sacchroidal albite or cleavelandite (Figs. 6b, f, g). Cut slabs of this K-feldspar indicate that the albitization process is controlled by fractures (Fig. 6a inset) that gradually coalesce to form massive albite, and further alteration may result in the fine-grained albite becoming cleavelandite (Fig. 6f).

Spodumene Zones

Spodumene-rich zones are dominated by megacrystic spodumene that reaches is maximum size (i.e. <1.5-2 m) in the central part of the pegmatite and diminishes in grain size toward the margin (<0.5 m) (Figs. 7a, b, f). One particularly spodumene-rich zone is observed along the southeastern part of one of the exposed outcrops where the spodumene defines a distinct fabric (Fig. 3c). Where the megacrysts of spodumene are preferentially oriented, their long axis generally lies perpendicular to the contact zone (Figs. 3, 4, 7b, f), although internally more random orientations occur. Spodumene is often intergrown with BKF as subparallel grains oriented perpendicular to the contact (Fig. 6a) and penetrating grains (Figs. 6e, 7c, d). The megacrysts of spodumene are euhedral and inclusion free, except for subhedral to euhedral quartz along their margins. The pods of spodumene consist of several interlocking grains of different size with minor amounts of intergranular quartz (euhedral to anhedral), feldspar (K-feldspar or albite), finer-grained spodumene, and muscovite (Fig. 7f). In some cases, quartz grains are oriented perpendicular to spodumene, as if the grains had acted as a site of nucleation for quartz (Fig. 5c). The spodumene is rarely deformed, but rare cases of kinking have been observed.

Albite Zones

Large areas (many square metres) of pegmatite contain fine-grained albite after primary BKF (see above and Fig. 6b). The occurrence of residual K-feldspar as irregular-shaped, multi-centimetre crystals is the evidence for this replacement (Fig. 6g), along with the presence of albite lining fractures that transect BKF where the albitization process was arrested (inset Fig. 6a). These albite zones are massive, have a sacchroidal texture, and may contain disseminated apatite and shiny dark phases that include tantalite and dark brown cassiterite. As already noted above, the zones are generally subdivided into several ellipitical subzones by the BQT material. Internally these albite zones may develop into coarser albite (cleavelandite) and also have a vuggy texture with 1-2 cm pockets lined with clear euhedra of albite and quartz. In one exceptional case where this was observed, a zone of coarse, primary BKF is overgrown by a layer of comb quartz and radial albite (?), which is succeeded by a zone of fine-grained albite and then a distinct vuggy zone dominated by secondary fine-grained albite and cleavelandite.

The vuggy albite-rich zone is dominated by fine-grained albite, but locally a variety of quartz types occur along with concentrations of coarse, clear to light brownish and silvery mica. The quartz occurs in the following manner: (1) elliptical to rounded, anhedral aggregates (?) of clear to dark grey quartz in a sea of albite, and (2) as millimetre to centimetre euhedra within multi-centimetre size vugs.

In thin section the albite zone is >98% albite with minor residual K-feldspar and accessory amblygonite, white mica, Ta-Nb oxides, garnet, triplite, cassiterite and zeolite (identified to date). The albite is subhedral to euhedral, is free of mineral inclusions, albite twinned and exceptionally fresh. Albite crystals are preferentially aligned, but not strained. Thus, thermal annealing of the albite outlasted any stress that may have been responsible for the orientation of albite. Accessory phases are subhedral to euhedral and are preferentially concentrated in zones, perhaps reflecting fracture-controlled fluid migration. Zeolite occurs as the latest stage accessory mineral and occurs alone along fractures. The texture of the K-feldspar is described in detail below.

Intergranular Zones

The areas between megacrystic spodumene and BKF, including albitized zones, consist of coarse-grained (<20-30 cm), intergrown quartz, spodumene, feldspar (K-feldspar or albite) and muscovite, in varying proportions (e.g. Fig. 8a). For purposes of this general description, the material is referred to as coarse leucogranite (lcgr) and may include the beaded quartz texture material (Fig. 6b) described previously. Textures in the

leucogranite zones are variable, and include:
(1) delicate intergrowths of quartz and cleavelandite (secondary albite; Fig. 8b), (2) anhedral to euhedral quartz in fine-grained albite (after K-feldspar, Fig. 8e, f), (3) coarse cleavelandite-spodumene, (4) coarse books of muscovite intergrown with quartz ±feldspar± spodumene, and (5) coarse euhedral intergrowth of quartz-feldspar between metre-size spodumene (Fig. 7g).

This leucrogranite material also includes large areas that are not dominated by BKF or spodumene megacrysts and, instead, consists of coarse leucogranite and is referred to as matrix in Figures 3 and 4. Such material is best seen along the western side of the outcrop shown in Figure 3c, where there is a distinct enrichment in quartz, in places including intergrowth of quartz and euhedral K-feldspar. Such an area may be a candidate for the best estimate of the primary bulk composition of the pegmatitic melt.

White Mica Zone
There are no zones of significant size that are dominated by white mica, such that they can be mapped out. Instead, mica occurs as pods replacing parts of BKF, disseminated within albitized zones, and intergrown with coarse leucogranite zones as both primary and secondary phases. Thus, although there is some primary mica as part of the leucogranite intergranular zones, the majority of the mica is secondary in origin.

Wallrock Inclusions
Xenoliths of wallrock amphibolite occur as small to medium size (<1 m) inclusions within the marginal parts of the pegmatite. The xenoliths may contain abundant, black to dark brownish, coarse-grained (<2-3 cm) tourmaline. In thin section they are uniformly dark brown to slightly zoned.

Mineralogy and Mineral Chemistry of the Southern Pegmatite

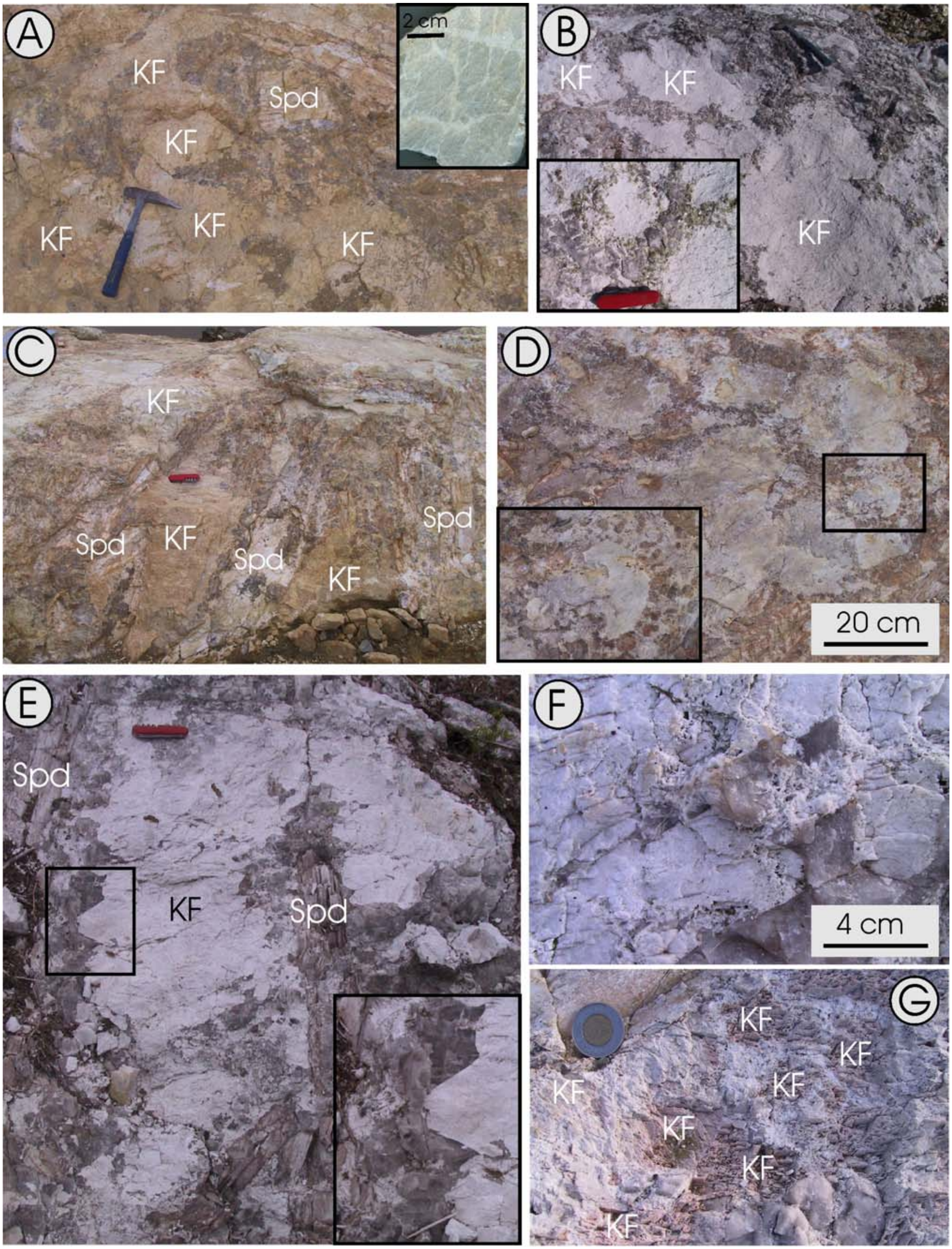
A detailed evaluation of the mineralogy and mineral chemistry of the pegmatite is currently in progress. A preliminary assessment is presented below. Major and minor element analyses were determined using wet chemical methods (DalTech, Halifax) and electron microprobe analysis (EMPA; Dalhousie University Earth Science Department), whereas trace elements were determined by ICP-MS (Memorial University, Newfoundland). Imaging of mineral phases and qualitative analyses of some minerals were also done using the electron microprobe with an energy dispersive operating system. The mineralogy can be subdivided into primary and secondary stages; the first represents formation during the magmatic stage, whereas the latter is of hydrothermal origin. There is a continuum in formation of some minerals (e.g. apatite) such that it is difficult to distinguish primary and secondary origins. As is the case for other minerals (e.g. K-feldspar) their texture and chemistry is a mixture of primary and secondary stages.

Major Mineral Phases

K-feldspar

This was the most dominant mineral phase in the

Figure 6. (next page) Outcrop photos showing features of K-feldspar (KF), along with some spodumene (Spd) in southern pegmatite, Brazil Lake. Knife for scale is ca. 10 cm long. (A) Megacrysts of fresh KF in blocky KF zone; note the subhedral to euhedral outlines of the megacrysts. Dark material between the KF are quartz-rich areas, in part with beaded quartz texture (BQT). Inset photo is cut slab of a partially altered KF showing albite invading along fractures. (B) Blocky KF zone with intergranular quartz with the BQT. Note that the white color of the KF is due to partial to complete replacement by fine-grained albite. Inset photo shows close up of the BQT, which consists of euhedral quartz, muscovite books, and minor Spd here. (C) Oriented KF and Spd megacrysts near contact of the pegmatite (lower part of photo). (D) Blocky KF zone with megacrysts of KF. Inset photo shows a mushroom-shaped KF with zonally arranged quartz grains around it. Note the BQT in the background. (E) Large KF megacryst intergrown with Spd and oriented perpendicular to pegmatite contact. Note that the KF is in contact with translucent quartz on left side with euhedral faces (see inset). The KF is whitish here because of alteration to albite that includes both fine-grained sacchroidal albite and euhedral cleavelandite. (F) Close up of previous area in Figure 6E showing albitized KF, secondary cleavelandite, and porous texture of the feldspar that was generated during alteration. (G) Close up of albitized KF megacryst with residual patches of KF (marked KF).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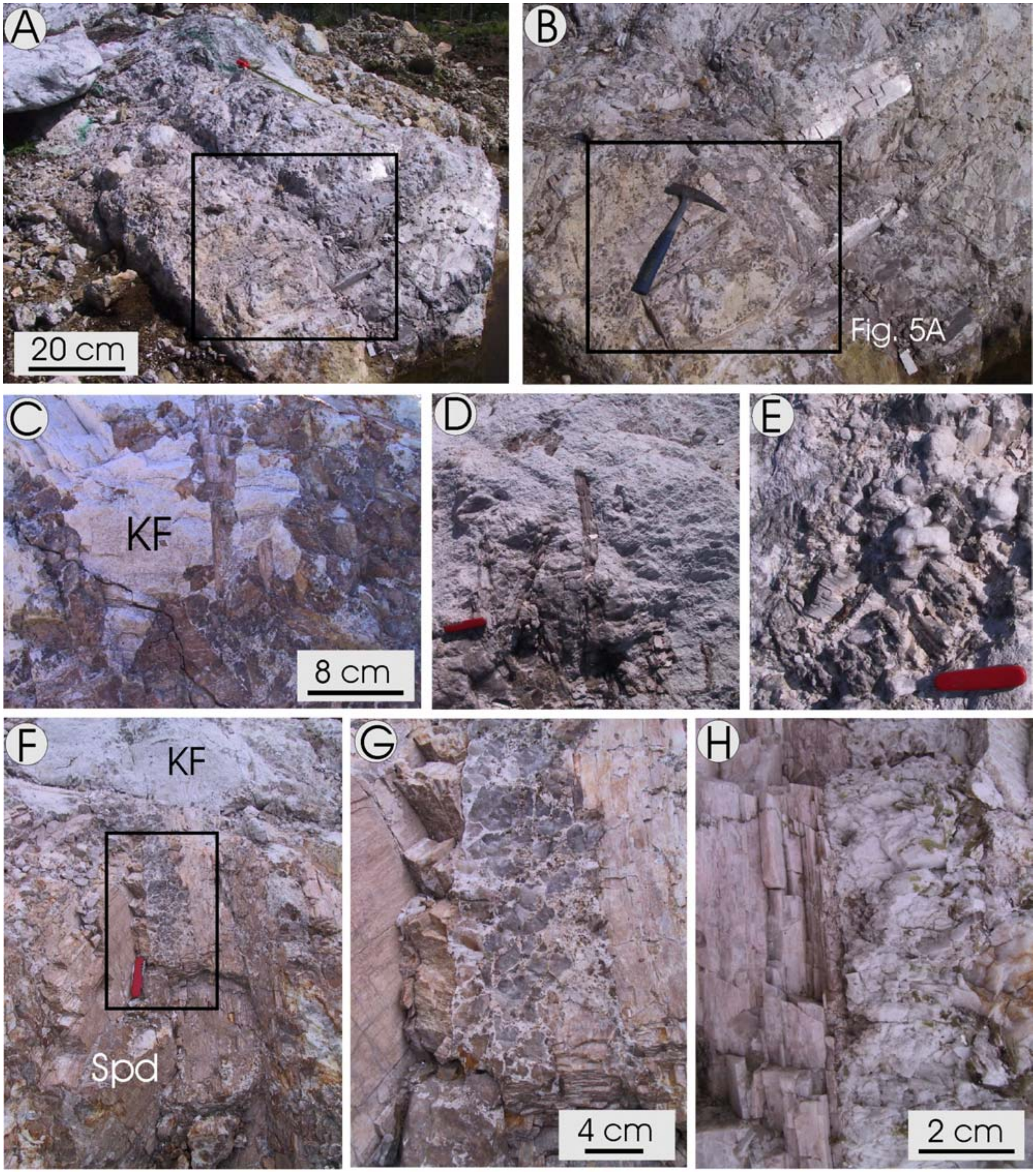


Figure 7. Outcrop photos showing features of spodumene (Spd) in southern pegmatite, Brazil Lake. Knife scale ca. 10 cm long. (A, B) Outcrop dominated by Spd megacrysts oriented perpendicular to contact of pegmatite. (C) Intergrowth of Spd and blocky K-feldspar (KF) at contact between zones enriched in these minerals. (D) Spd crystals penetrating KF megacryst, which is now albitized. (E) Intergrowth of Spd and quartz in beaded quartz texture zone between KF megacrysts. (F) Spd-rich zone at margin of pegmatite with blocky KF zone on top of it. Note that the Spd is oriented perpendicular to the contact. Box outlines area enlarged in next photo. (G) Close up of intergranular material between Spd megacrysts consisting of subhedral to euhedral quartz with albite and cleavelandite after earlier KF. (H) Close up of Spd against cleavelandite in albitized zone showing that the Spd was not affected by the metasomatism.

pegmatite prior to sodium metasomatism, which converted much K-feldspar to sacchroidal albite and cleavelandite. However, remnant areas of fresh K-feldspar remain, particularly in the southwestern part of the study area where BKF domains of beige to light orange occur. Cut slabs of this K-feldspar show perthitic textures with minor albite, consistent with bulk analysis (n=4) of $Or_{70-80}Ab_{30-20}$ (Fig. 9a) and a minimal An component (<0.02 wt. % CaO). These bulk analyses are similar to bulk compositions of K-feldspar from leucogranite-hosted pegmatites of the South Mountain Batholith and suggest primary compositions (Fig. 9b; Kontak *et al.*, 1995). Trace element chemistry (n=4) of the same K-feldspar separates indicates elevated Rb (3870 to 4870 ppm), but depleted Sr (17-75 ppm) and Ba (32-190 ppm) contents. Similar concentrations of these elements were also obtained by Hughes (1995) for K-feldspar concentrates (n=4) from the northern pegmatite, although he detected up to 5600 ppm Rb in one sample. Chondrite-normalized rare-earth element patterns are depleted compared to, for example, K-feldspar from pegmatites at East Kemptville and the Brenton Pluton and compare, instead, to patterns for K-feldspar from pegmatites in the most evolved parts of the SMB (Fig. 10). Phosphorus levels in the K-feldspar are low (<0.2 wt. % P_2O_5) and contrast with high levels (to 1.5 wt. %) in K-feldspar from pegmatites of the SMB (Kontak *et al.*, 1995).

Imaging of the freshest K-feldspar indicates typical flame perthite lamellae occur with no vestige of film perthite, as found, for example, in pegmatitic K-feldspar at Peggys Cove (Kontak *et al.*, 2002). Instead, coarser bleb perthite is more common (Fig. 11a) and pitted textures are not uncommon (Figs. 11a, b). Remnant patches of K-feldspar in albite domains (i.e. metasomatic rocks) are characterized by a very porous sieve texture (Figs. 11b, c) and secondary apatite is common (Fig. 11b). In detail, the porous texture is seen to consist of a network pattern with isolated domains of residual K-feldspar (Fig. 11c). The chemistry of the Or and Ab domains of K-feldspar indicates equilibrated compositions of Or_{90-100} and Ab_{100}, respectively (Fig. 9b), which reflect exchange down to below 300°C. In rare cases such remnant patches of K-feldspar are replaced by clay and Fe-Mg mica (i.e. chlorite phase). Traces of Fe, Cr, Ni and Cu phases, either as native elements or oxides, occur in the porous-textured areas (Fig. 11l). This type of mineralization is common in pegmatites and reflects a lack of sulphur in the melts and fluid (Černý, 1991b).

Spodumene

Spodumene is present as a very pure phase with megacrysts rarely containing mineral inclusions, although small quartz euhedra (<l cm) locally occur along margins of grains. Spodumene has a glassy lustre and can be transparent; colours vary from whitish, beige, grey-blue to green and, rarely, clear. Prized gem varieties such as kunzite, heddenite and triphane have not been observed. Where fractures are present or deformation induced recrystallization, alteration to muscovite or a green phase (chlorite ?) is found. However, where metasomatic albite occurs after K-feldspar, the spodumene appears unaffected by the process (Figs. 7d, h). Although few thin sections of spodumene from the southern outcrop have been observed, it is noted that Hughes (1995) mentions that alteration of spodumene is common in the northern pegmatite, with pseudomorphic replacement by albite, muscovite, K-feldspar, cookite, and chlorite. In addition, a spodumene-quartz intergrowth noted by Hughes (1995) has also been observed in one sample, which may represent spodumene-quartz intergrowth formed after petalite (e.g. Černý and Ferguson, 1972). Compositions of spodumene approximate a pure end member, with minor Fe at levels <0.3 wt. % FeO and trace Mn (177 to 610 ppm) (Hughes, 1995).

Quartz

Quartz varies considerably in its habit and colour within the pegmatite. Rarely is it subhedral to euhedral where intergrown with K-feldspar (Fig. 6e) or as part of the BQT zones, but instead anhedral forms are the most common and this is, in part, a result of post-crystallization deformation (Figs. 8d, e). Where fractured or brecciated, quartz is surrounded and invaded by cleavelandite, often with a comb or radial texture about the quartz, or intergrown with it, which suggests continued crystallization. Although most quartz is translucent to transparent, colours range from cloudy white through clear to black, with no consistent pattern observed (Fig. 8), except that deformed quartz is generally darker. No chemical analyses are available for quartz, but slabbed samples indicate that micro-inclusions of apatite and Ta-Nb oxides are locally common.

Albite

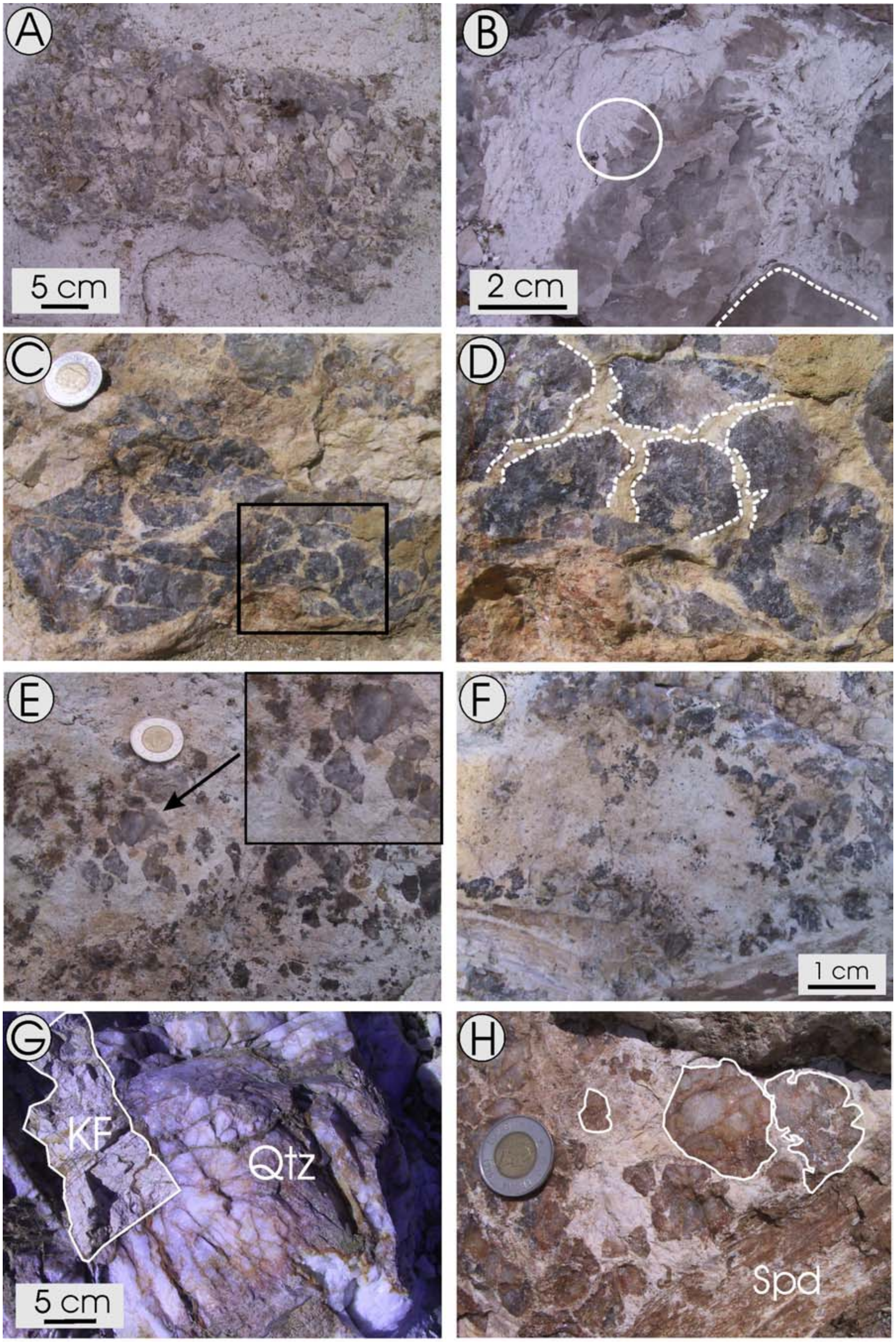
Two varieties of albite occur, a fine-grained sacchroidal-textured type, and platy to acicular cleavelandite; both types are of Ab_{100} composition (Fig. 9). The former occurs as a replacement of blocky K-feldspar (Figs. 6b, g), which has a fabric defined by subparallel laths in thin section; this fabric is inferred to be of syntectonic origin. In some cases the albite is crystal clear and lines cavities in metasomatized BKF zones. Imaging indicates the albite is clear to pitted in texture with such grains adjacent each other (Figs. 11d, e) and often they terminate within voids (Fig. 11d). The albite also contains disseminated euhedra of apatite (Figs. 11d, e). Cleavelandite occurs as euhedral to subhedral grains in a variety of settings that represent various types of metasomatism:
(1) replacement, either along linear to irregular fractures cross-cutting K-feldspar megacrysts (Fig. 6f), (2) patches within or entirely replacing K-feldspar, and (3) intergrown with quartz as part of intergranular areas to coarse spodumene or K-feldspar. All types of albite generally contain disseminated fine-grained apatite and Nb-Ta oxides, and slabbed samples of the massive albite indicate that in some cases these minerals can be abundant. Chemical analysis of two albite pods indicated trace amounts of Rb (10-65 ppm) and Sr (13-175 ppm); other elements analyzed were at very low levels (e.g. Li, Nb, Ta, Cs, Ba).

Muscovite

Muscovite in the southern pegmatite is both of primary and secondary origin, based on its habit and textural relationship with other phases. Primary muscovite is part of the beaded quartz texture or leucrogranite zones that surround megacrysts of BKF, leucogranite around coarse spodumene, and part of the coarse leucrogranite matrix. The primary muscovite, estimated at <1% modally, occurs as coarse books <1-2 cm and is mostly light brown to clear. In contrast, secondary muscovite is generally associated with albitized zones, either after BKF or in beaded quartz texture, or occurring as fracture coatings or veins <5-10 mm wide. Boulders of massive (i.e 80-90%) muscovite have been observed, but such material has not been seen *in situ*. The secondary muscovite is fine- to coarse-grained, and may be silvery, brown, clear or green.

Muscovite is close to its end member in composition, with minor Fe (to 1.0 wt. % FeO) and Na (to 0.4 wt. % Na_2O), as seen in the ternary (M^{2+}-Al-Si) plot of Monier and Robert (1986; Fig. 12). Compositions for a variety of textural types are all similar and suggest high temperature (i.e. 600°C) equilibration, regardless of paragenesis. Bulk analysis of muscovite from massive pods of the same material (n=3) indicates high abundances of Rb (3000-4600 ppm), Nb (120-160 ppm), and Ta (211-61 ppm). Hutchinson (1982) also noted high contents of Rb in muscovite from the northern pegmatite.

Figure 8. (next page) Outcrop photos showing features of quartz in Brazil Lake pegmatite. Knife scale ca. 10 cm long. (A) Close up of the beaded quartz texture (BQT) developed between blocky K-feldspar (KF) megacrysts. The quartz is intergrown with spodumene and albite (after KF). (B) Translucent quartz intergrown with secondary cleavelandite. Note the penetrating nature of some cleavelandite crystals (circled) and euhedral outline of the quartz (dashed line). (C, D) Megacryst of quartz among blocky KF. This quartz is typically dark grey to black in color and has a jig saw pattern possibly due to autobrecciation, as highlighted by the outline in dashed white line. Note that albite occurs as part of the intergranular matrix and some cleavelandite is developed that is intergrown with the quartz. (E) Anhedral quartz disseminated within mixture of fine-grained albite and acicular cleavelandite after KF megacryst (slightly darker areas are patches of orange KF). Inset shows possible autobrecciated quartz grain. (F) Similar feature as in previous photo, but here there is apatite intergrown with the angular quartz grains and in the fine-grained albite. (G) Intergrowth of coarse smoky quartz and euhedral KF in quartz-rich part of pegmatite near contact. (H) Intergrowth of quartz and albite (after KF) in intergranular matrix to Spd megacrysts. Some of the quartz grains have been traced to show the variation in habit from euhedral to anhedral(where ruptured) with albite filling what was once open space between the quartz grains.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Accessory Minerals

Accessory mineral phases include tourmaline, apatite, garnet, beryl, chlorite, Ta-Nb oxides, carbonate, triplite, amblygonite, cassiterite, wolframite, sphalerite, zeolite, zircon, epidote, clay and a variety of phosphate phases. The chemistry and distribution of these phases are currently being studied; only some of the minerals are discussed here and a more complete description of these phases is in preparation.

Tourmaline occurs as brown-black to green-brown and dark blue, centimetre-size euhedra within altered wallrock inclusions (i.e. amphibolites) along the margin of the pegmatite and also as smaller grains (<0.5 mm) in amphibolites adjacent to the pegmatite. The grains are both homogeneous or complexly zoned. Preliminary analysis of pegmatite-hosted tourmaline indicates dravite-schorl compositions with some extreme Fe enrichment noted (Fig. 13). Trends of the chemical data are typical of pegmatitic tourmaline originating from contamination due to pegmatite-host rock interaction (Fig. 13; Tindle *et al.*, 2002). Hughes (1995) has also identified elbaite and indicolite (Na+Li type) in the northern pegmatite.

Garnet occurs as multi-centimetre, subhedral to euhedral grains within albite-rich zones, with or without secondary muscovite. The garnet often has subgrain development due to fracture-related deformation. Several grains have been analyzed (this study and Hughes, 1995) revealing a uniform chemistry dominated by Fe and Mn with a general composition of $Alm_{20\text{-}28}Spess_{72\text{-}80}$.

Beryl crystals, either as isolated grains or in clusters, are clear to pale green, <3-4 cm in size, and occur along the eastern side of the pegmatite. No chemical data are yet available for the beryl. Of the grains observed, the internal fracturing and faint green colour precludes their use as gem material (B. Wilson, personal communication, 2003).

Apatite occurs as euhedral to anhedral macro- (<1-2 cm) or micro-crystals (mm size) within leucogranite areas, intergrown with cleavelandite or disseminated in sacchroidal albite after BKF. The smaller grains are also common along fractures in deformed quartz. Fine-grained apatite euhedra intergrown with albite may locally be abundant (Fig. 11f) and are complexly zoned (inset in Fig. 11f). This apatite may be inclusion rich, including carbonates and sulphides (Fig. 11g). Apatite also occurs along fractures and fills voids in albite (Fig. 11h), and pitted textures occur associated with a second generation, Mn-rich apatite (Fig. 11i). Micrograins of euhedral to anhedral apatite occur as disseminations within

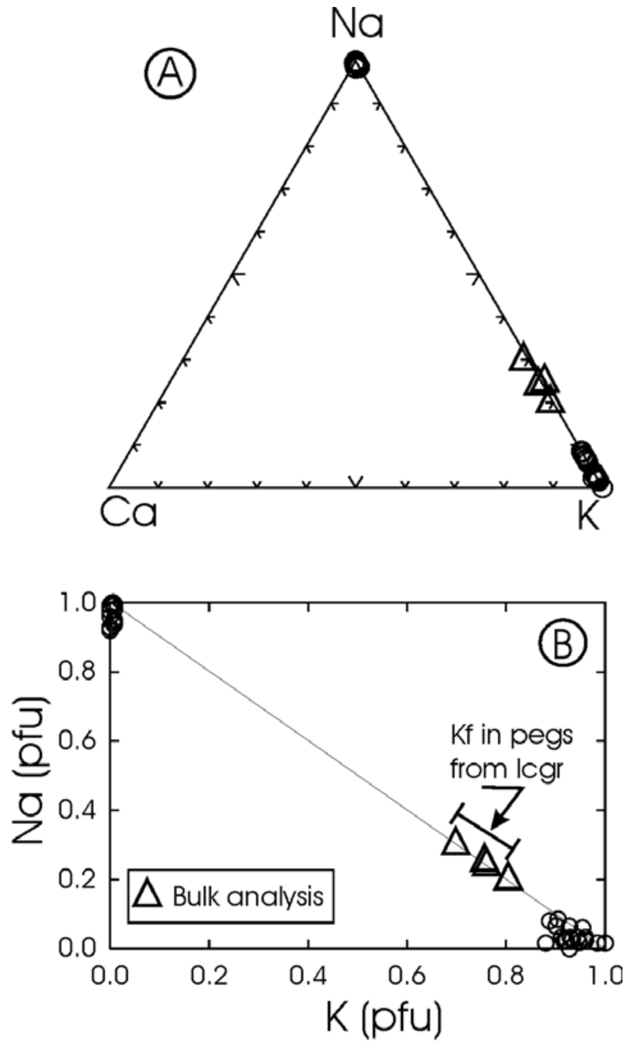


Figure 9. Electron microprobe (circles) and bulk analysis (triangles) of feldspar phases in Brazil Lake pegmatite plotted in ternary (Ca-Na-K) and binary (Na-K) diagrams. Note that it is the cationic proportions, based on 8 oxygens per formula unit (pfu), that are plotted in the diagrams. The range of KF in pegmatites in lcgr refers to samples from the South Mountain Batholith, as discussed in the text.

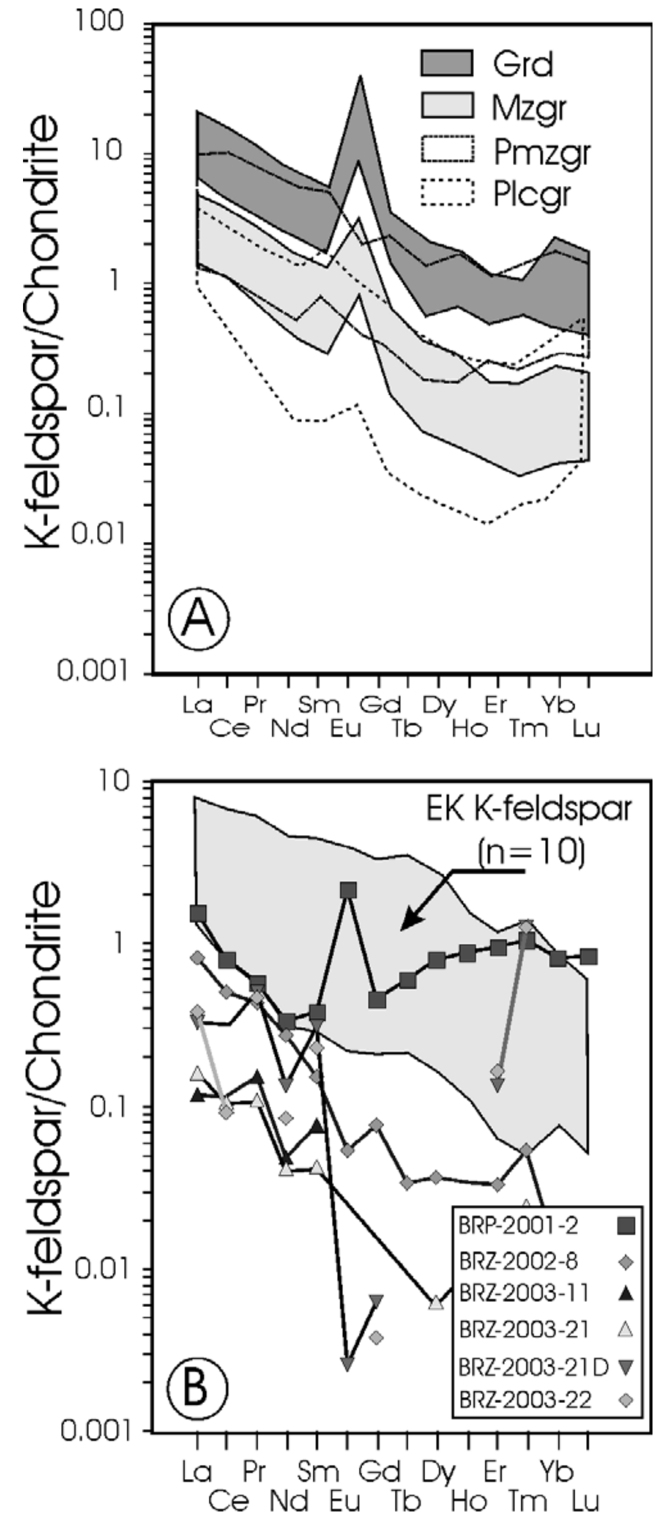


Figure 10. Chondrite-normalized rare-earth element diagrams for K-feldspar (KF) separates from southern pegmatite, Brazil Lake. (A) Compiled data set for KF separates from the South Mountain Batholith (Kontak and Martin, 1997) showing general decrease in REE with fractionation: Grd=granodiorite, Mzgr=monzogranite, Pmzgr=pegmatite in monzogranite, Plcgr=pegmatite in leucogranite. (B) KF from Brazil Lake pegmatite compared to field for KF from East Kemptville pegmatites (Kontak *et al.*, 2001). Sample BRP-2001-2 is from the pegmatite in the Brenton Pluton and BRZ-2003-21D is a duplicate of sample BRZ-2003-21.

K-feldsparr (Fig. 11b) and secondary albite, (Fig. 11d) or along fractures in quartz and albite. Similar euhedral apatite crystals are also common in pitted K-feldspar and albite (Fig. 11e).

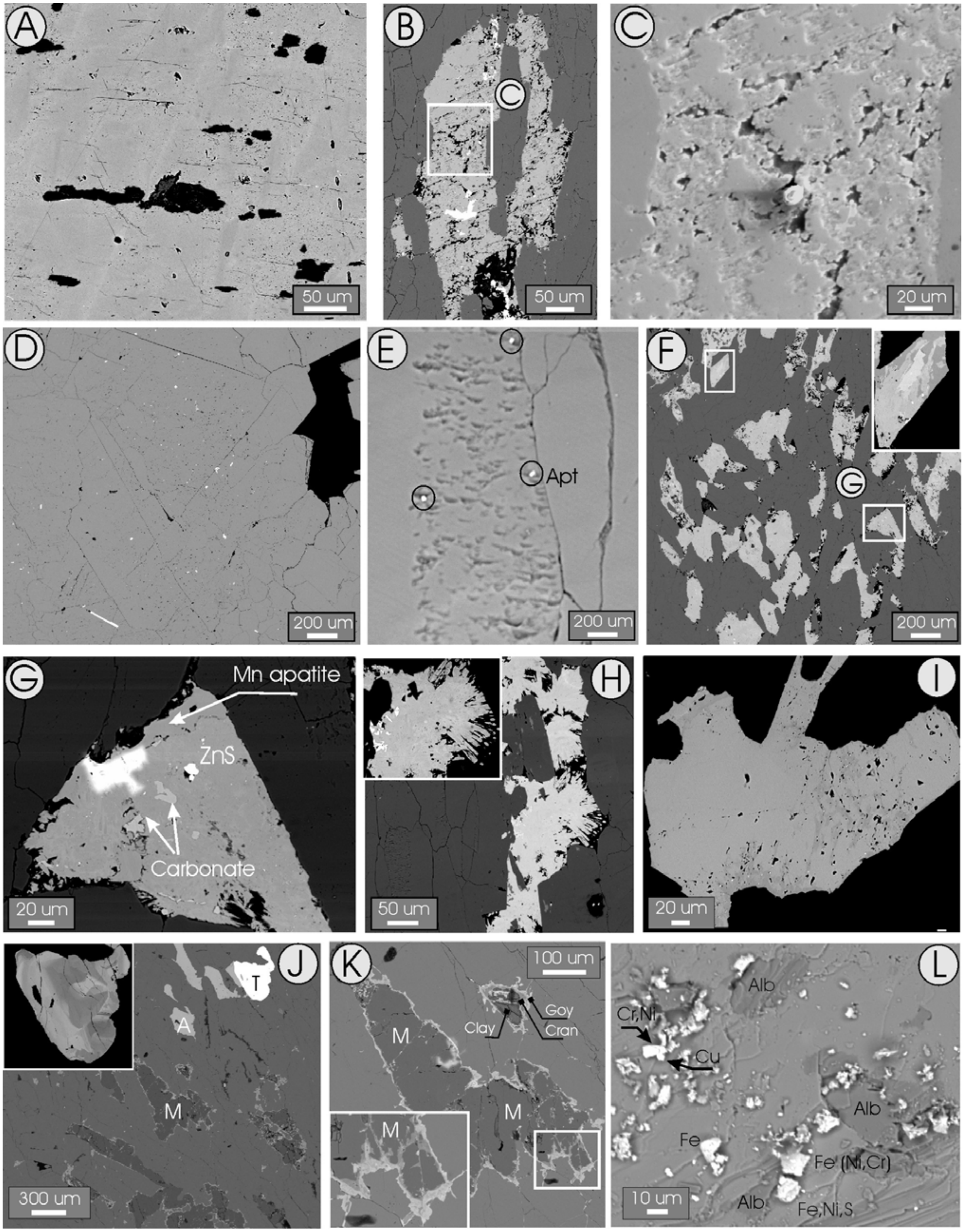
Compositions of apatite vary considerably and grains may be homogeneous to complexly zoned reflecting continued re-equilibration with a fluid. The early, coarser-grained and subhedral to euhedral apatite is generally Mn poor and contains several wt. % Cl. In contrast, texturally late stage and finer-grained apatite, or apatite overgrowing earlier apatite (Fig. 11g, i), is enriched in Mn via the substitution of Mn⇆Ca and up to 15-18 wt. % MnO occurs. The Mn-rich apatite is Cl deficient and, therefore, inferred to be hydroxylapatite. Hughes (1995) reports the occurrence of fluorapatites with 4 wt. % F in albitic aplite zones.

Tantalite-columbite occurs within the albite-rich zones, along fractures in quartz and in leucogranite areas. Most of this oxide mineralization shows a spatial association with albite, an observation that is supported by whole-rock chemistry discussed below. Chemical analysis of selected grains indicates highly variable Ta:Nb ratios, although most are enriched in Nb>Ta. Grains vary from homogeneous to intricately zoned (Inset in Fig. 11j). Ongoing work is required to sort out the nature of this oxide mineralization, and the origin of the Ta:Nb variability.

A complex group of phosphate phases occurs, including montebrasite, goyazite, crandallite, lithiophillite and fillowite. The most common phase is montebrasite which occurs in fine-grained sacchroidal albite as a subhedral to euhedral phase (Fig. 11k), but Hughes (1995) also reports it within coarse K-feldspar. The montebrasite has a uniform composition [LiAl $PO_4(OH)$] and its F-rich equivalent, amblygonite, has not been found in the pegmatite. Montebrasite is invariably altered to crandallite and then goyazite, which record the low temperature (300°C) alteration of the precursor phosphate phase. In some cases the montebrasite is also altered to an unidentified clay mineral (Al-Si phase from EDS spectra).

In a few rare cases, native elements and oxide phases of Fe, Cr, Ni and Cu were observed in K-feldspar associated with secondary albite (Fig. 11l). Determining the nature and origin of this material requires further work, but such phases are not uncommon in pegmatites due to the lack of sulphur to combine with these elements to form sulphide phases (Černý, 1991b).

Figure 11. (next page) Electron microprobe images of samples from Brazil Lake pegmatite. All images except C and L are back scattered electron(BSE) images where the higher the average atomic number of the phase the brighter it is (e.g., see tantalite (T) in Fig. 11J hosted by albite). Images in C and L are secondary electron images (SEI) that reflect the surface topography of samples (e.g., holes, defects, etc.). (A) K-feldspar (KF) host with albite blebs. The KF is characterized by a pitted texture with intervening areas free of pits. (B) Residual grain of KF in albite (dark background). Note the porous nature of the KF and presence of anhedral apatite grains (bright phases at bottom and top) in it. Area in box enlarged in C. (C) SEI of part of KF in previous figure showing the ver porous texture of the grain that relates to Na metasomatism of the KF. (D) Albite with pitted texture in places, disseminated grains of apatite (bright phases), and euhedral grains that terminate in the open space. (E) Close up of albite with pitted texture with rare apatite (Apt) filling the pores. (F) Apatite grains of euhedral to subhedral shape in albite. Note that there is dissolution along the margins of some grains and in detail they contain micro-inclusions and are chemically heterogeneous. Inset shows close up of apatite grain with large variation in Mn content (bright areas have up to 18 wt. % MnO). (G) Close up of apatite grain from previous image showing inclusions of Fe-poor sphalerite (ZnS) and carbonate (Mn-bearing) in Mn-poor apatite that is rimmed by Mn-rich apatite. (H) Apatite filling open space in albite host. Note the euhedral terminations of the apatite indicating it once filled a void. Inset shows the apatite euhedra and small inclusions of an Fe oxide phase. (I) Apatite grain of uniform composition with second generation Mn-bearing apatite along fractures that are lined with pitted texture. (J) Albite hosting montebrasite (M), apatite (A) and tantalite (T) phases. Inset diagram shows tantalite grain in high contrast mode to emphasize the zoning in Ta and Nb ratio. (K) Close up of montebrasite grain in previous image to illustrate the secondary alteration of this phase to crandallite (Cran), goyazite (Goy) and clay. Inset is enlargement of part of the big grain to show the secondary phases. (L) Chip of KF with inclusions of albite blebs (Alb) and various mixtures of Fe, Ni, Cr oxides and Cu oxide phase. Note that only minor amounts of S were detected in the analysis.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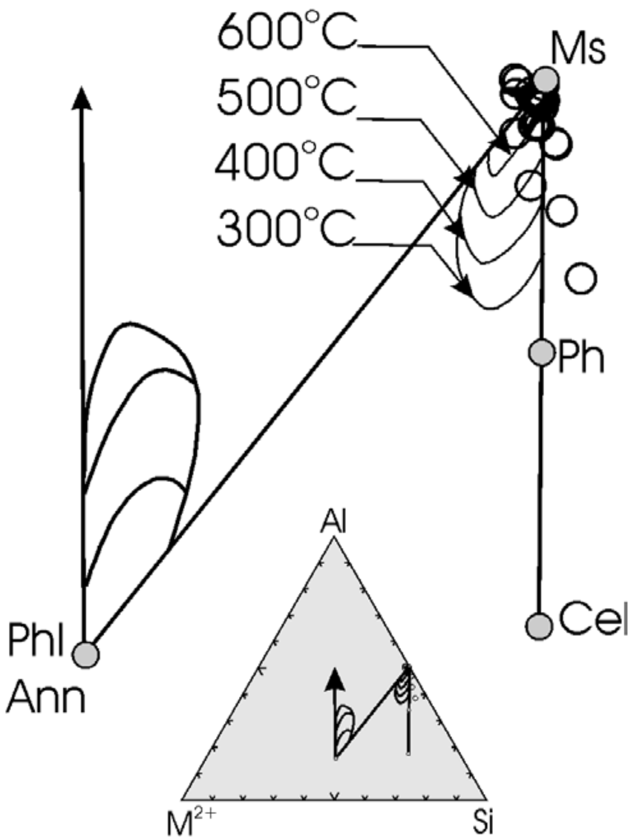

Figure 12. Electron microprobe analysis of muscovite from Brazil Lake pegmatite plotted in Monier and Robert's (1986) ternary diagram with isotherms. Abbreviations are Cel=celadonite, Ph=phengite, Ms=muscovite, Ann=annite, Phl=phlogopite.

Whole-rock Chemistry

A database of 250 whole-rock geochemical analyses has been generated by Gwalia Resources of Australia and Champlain Resources Inc. Samples of 0.4-1.8 m long core intervals, although the majority were about 1 m long, were assayed for major and trace elements. Only some salient highlights of these data are discussed below; a more detailed assessment of the results is in preparation. The following points are noted with reference to Figures 14 and 15.

(1) As expected, there is a negative correlation of both lithium and potassium with sodium.
(2) Both calcium and phosphorus show a positive correlation with sodium, thus confirming the association of phosphates, in particular apatite, with albite-rich zones. Manganese (not shown) also shows a positive correlation with phosphorus.
(3) Enrichment of both Ta and Sn are associated with increasing sodium abundance.
(4) There is no association of Rb with sodium (not shown) or phosphorus enrichment. Instead, Rb is strongly correlated with potassium and occurs in either K-feldspar or muscovite based on the mineral chemistry discussed above.

Structural Features of the Southern Pegmatite

Detailed mapping of structural elements of the pegmatite is incomplete, but a few pertinent observations are noted.

(1) The overall features of the pegmatite indicate that a single stage of open-space infilling occurred, such that the pegmatitic melt was injected into a dilatant zone in the host rocks. The orientation and size of the megacrysts indicate a single dilation event, rather than multiple injections of magma.
(2) Quartz megacrysts are often oval or elliptical, but subhedral outlines may reflect the original shape of megacrysts (Fig. 8c). These grains were subsequently ruptured during deformation (Figs. 8d, e) and, in certain cases, the subgrains have serrated or irregular outlines and the intervening space is filled with oriented albite grains (Fig. 8d). These textures suggest that pegmatitic melt was injected into an active shear zone environment, and that the pegmatite was subjected to deformation prior to complete crystallization.
(3) Shear zones oriented subparallel to the pegmatite-wallrock contact occur throughout and are manifest by flattened quartz megacrysts, kinked spodumene and shear fabrics in muscovite-rich areas. The fabric is generally oriented northeasterly with a subvertical dip, and the kink folds have subvertical axes.

Age of the Brazil Lake Pegmatite

The age of the Brazil Lake pegmatite has previously been constrained by field relationships, with a maximum age equivalent to the host White

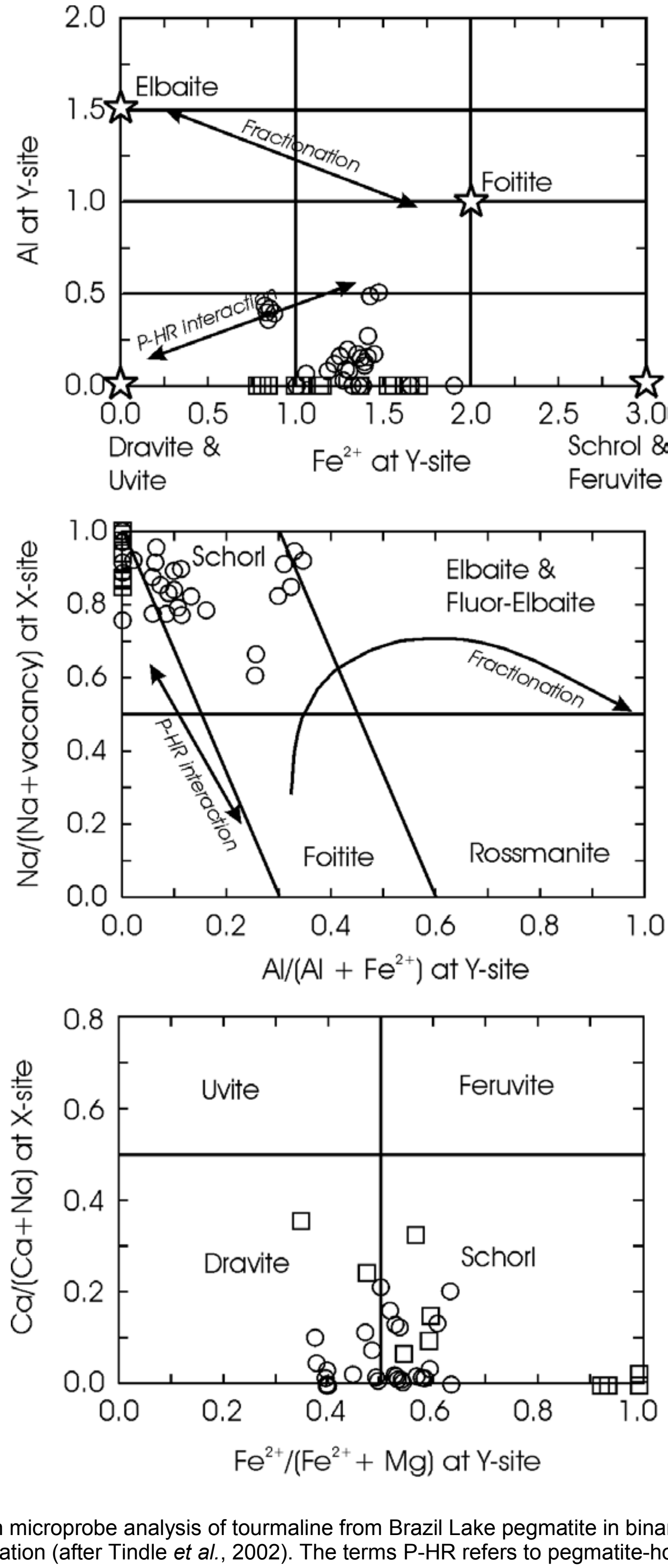

Figure 13. Electron microprobe analysis of tourmaline from Brazil Lake pegmatite in binary plots with fields for tourmaline classification (after Tindle *et al.*, 2002). The terms P-HR refers to pegmatite-host rock interaction and reflects contamination. Circles are from this work and squares are from Hughes (1995).

Rock Formation and a minimum age being the time of the deformation that affected the pegmatite. However, the presence of both Acadian and Alleghanian deformation in the region (White *et al.*, 2001) makes it difficult to infer a minimum age for the pegmatite. In order to resolve the absolute age of pegmatite formation, samples from the southern pegmatite were selected for U/Pb (tantalite), Re-Os (molybdenite) and Ar/Ar (muscovite) analysis. The results will be discussed in detail elsewhere (Kontak *et al.*, in prep.), thus only a summary is given below.

Analysis of a single fraction of separated, euhedral, columbite-tantalite grains disseminated within an albite-spodumene-muscovite assemblage, part of a blocky K-feldspar zone, yielded a concordant U/Pb age of 378 ± 1 Ma. Three Re-Os age determinations for various size fractions of molybdenite from wallrock quartzite on the northwest side of the southern pegmatite yielded ages of 351.7, 351.9 and 354.2 Ma (all ± 2.5 Ma). Finally, several Ar/Ar spot laser ages for a coarse, euhedral muscovite flake, of primary magmatic origin, from a beaded quartz-textured zone gave ages of 318 to 348 Ma, with the former from the rim and the latter from the core of the grain.

The aforementioned ages indicate that the time of pegmatite formation is constrained by the U/Pb tantalite age, which coincidently is similar to a U/Pb age of 380 Ma for the nearby South Mountain Batholith (Kontak *et al.*, 2003). The ca. 353 Ma Re-Os molybdenum age is similar to a U/Pb age of 357 Ma for the Wedgeport Pluton south of Yarmouth (White *et al.*, 2004), whereas the Ar/Ar ages approximate the time of the Alleghanian deformation in the area (e.g. Culshaw and Reynolds, 1997).

Discussion

Implications of the Age of Pegmatite Formation

The age reported here for the BLP is 378 Ma, which is indistinguishable from the time of emplacement of the South Mountain Batholith (SMB) (Kontak *et al.*, 2003; Carruzzo *et al.*, 2004). Although the SMB is located some 20-25 km from the Brazil Lake area, a distance considered to be excessive for transport of a pegmatite melt from a fertile, progenitor granite (Baker, 1998), this does not preclude the possibility that an unexposed granite was the source. As noted by Černý (1991b), there is no plausible model for rare-element pegmatite genesis other than a magmatic one, thus a granitic source is assumed and the 378 Ma age is very suggestive that granite underlies the Brazil Lake area. Relevant to this argument is the presence of numerous tin and base metal showings throughout the Meguma Group metasedimentary rocks east of the study area (Chatterjee, 1983; Kontak *et al.*, 1990) and on strike with the East Kemptville tin deposit. This mineralization likely originated in underlying granite, such as occurs at the Kempt Snare Lake (Soehl, 1988) and Duck Pond (Pitrie and Richardson, 1989) mineralized centres. As noted by Dostal and Chatterjee (1995), the Davis Lake Pluton of the SMB is strongly fractionated toward the west and the nature of contours for a variety of elements (e.g. Rb, Li, F) and ratios (e.g. K/Rb) suggests that there may be highly-fractionated granitic phases beneath the veneer of sediments overlying the continuation of this pluton, which fed the mineralization noted above. Thus, it may also be possible that one of these centres is also the fertile source of the Li-rich melt that gave rise to the Brazil Lake pegmatites.

P-T Conditions of Emplacement of the Brazil Lake Pegmatite

The pressure-temperature (P-T) conditions of pegmatite formation are relevant to petrogenetic modeling of the Brazil Lake pegmatite. The constraints imposed on P-T conditions are: (1) presence of primary muscovite in beaded quartz texture material; (2) occurrence of primary spodumene as the dominant sink for Li rather than petalite or eucryptite. However, the presence of rare spodumene-quartz intergrowth (this study and Hughes, 1995) suggests that rare early crystallization of petalite may have occurred locally, although alternate interpretations of this texture are possible; (3) occurrence of aqueous fluid inclusions in spodumene with homogenization temperatures of ≤315°C and salinities of 5 wt. % equivalent NaCl (Hughes, 1995); (4) solidus of Li-

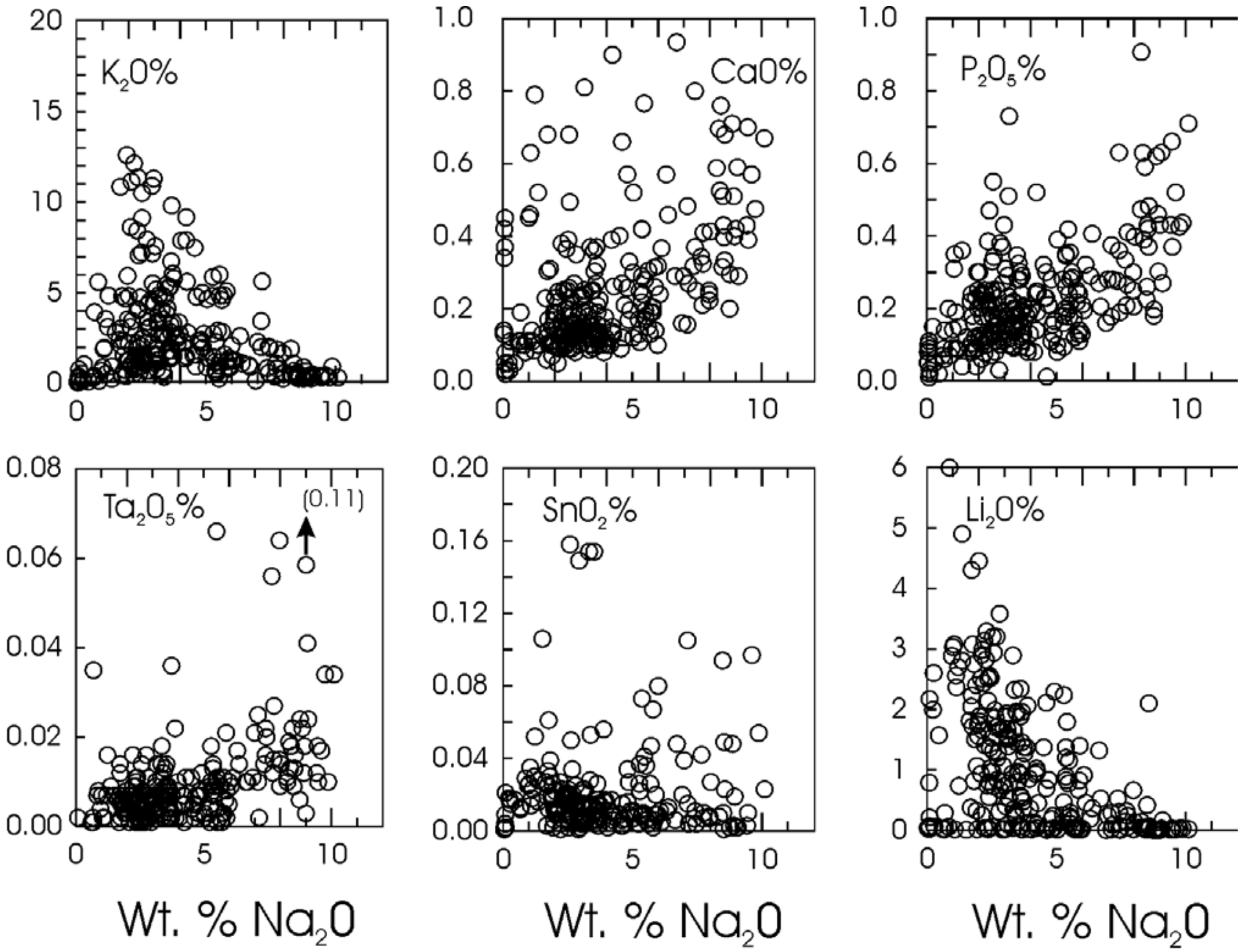

Figure 14. Whole-rock geochemical plots for pegmatite samples from Brazil Lake. See text for discussion.

rich felsic melt (Martin, 1983). Using the stability of the phase assemblages and projecting the isochore for a 5 wt. % equivalent NaCl fluid, an estimated P-T path for emplacement and crystallization of the pegmatite is derived, which indicates initial emplacement at ca. 3.5-4 kbar and near 600°C, which is comparable to that inferred for the spodumene-bearing Harding pegmatite, New Mexico (London, 1984). These conditions compare to the estimated level of emplacement of the SMB of 3.5 kbar (Raeside and Mahoney, 1996) and granite and pegmatite formation at the East Kemptville tin deposit of 3.5-4.0 kbar (Halter and Williams-Jones, 1999; Kontak *et al.*, 2001).

Metasomatism (?) in the Brazil Lake Pegmatite

The origin of the voluminous albitic or mica-rich units in rare-element pegmatites is sometimes equivocal, but of economic interest because of the concentrations of Be, Li, Rb, Cs, Nb, Ta, Sn and U (London, 1990). In the case of the BLP, there is a clear association of rare elements with sodic enrichment (Figs. 8f, 14, 15). Whereas small amounts of metasomatism are easily explained because of pseudomorphic replacement textures, the large areas underlain by albite/cleavelandite or mica are more equivocal since such textures are lacking, although Soviet geologists have long argued for a metasomatic origin (e.g. Ginzburg, 1960; Beus, 1960). As noted by others, the large Li-bearing minerals, in this case spodumene, often project into these albite areas with no evidence of alteration (e.g. Figs. 8c, d). However, in these cases the fact that such Li minerals provide the substrate for nucleation of coarse radiating cleavelandite, of assumed magmatic origin, is used to argue for a

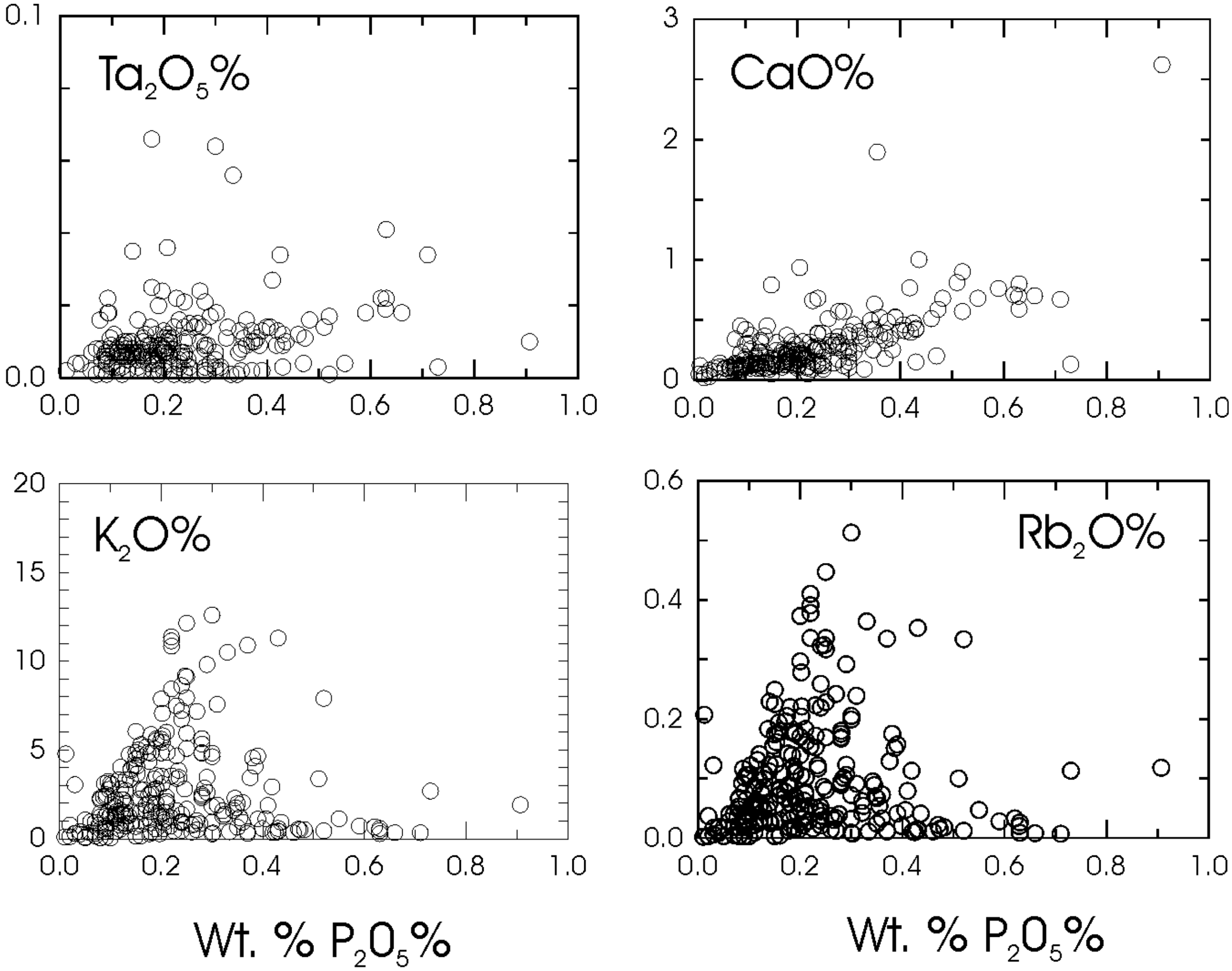

Figure 15. Whole-rock geochemical plots for pegmatite samples from Brazil Lake. See text for discussion.

late, residual magmatic origin for the spodumene, along with the coexisting quartz and mica (Jahns and Tuttle, 1963; Jahns and Burnham, 1969; London 1990). Although the petrological observations discussed above are interpreted to favor a metasomatic origin for albite-rich zones in the BLP, both sacchroidal albite and cleavelandite, an alternative model presented by London (1990) is discussed below.

London (1990) explains that the inferred late alkali-sodic metasomatic units (e.g. albite-mica zones) were related to formation of a late solution-melt, as represented by silicate-rich fluid inclusions found in pegmatites (e.g. London, 1986b, c). The sudden formation of ore-bearing albite-mica zones, according to London (1990), occur due to sudden vapor saturation and the concomitant loss of boron and other volatiles, which suddenly raises the solidus temperature of the residual melt and thereby promotes crystallization (i.e. boron quench model, London, 1987). Upon crystallization of these melts, as bodies of albite ± mica and quartz, the exsolved aqueous vapor phase, formed from the elements not conserved by the crystalizing components, promotes the metasomatism of adjacent areas. Formation of the exsolved vapor also results in extensive fracturing of the pegmatite, which leads to an open bimetasomatic exchange between pegmatite and wallrock, as manifest, for example, by the presence of exomorphic tourmaline in the host rock.

The origin of the extensive albitic zones in the

Brazil Lake pegmatite requires additional work to resolve; however, the presence of these zones is emphasized for two reasons: (1) such zones destroy the blocky K-feldspar areas which, due to their high rubidium content, are a valued industrial mineral; and (2) the albitic zones are enriched in muscovite and also rare elements (e.g. Ta, Nb). Thus, the recognition of such zones and their extent is relevant to exploitation of these pegmatites and future work will address this issue.

Exploration Potential for Li-rich Pegmatite in the Brazil Lake Area

Exploration potential in the Brazil Lake area is inferred based on analogies with other rare-element pegmatite fields globally, where numerous pegmatites occur over large areas, some with considerable strike length (e.g. Černý, 1991b). Often these pegmatites are laterally zoned with LCT types generally distal from the fertile granite source, although the source is not always identified (e.g. Little Nahanni pegmatite field; Groat *et al.*, 2003). Excellent examples of such fields occur in, for example, the Superior Province of Canada (Breaks and Moore, 1992) and the Wodgina pegmatite district of the Pilbara Craton of western Australia (Sweetapple and Collins, 2002). This latter area, with some of the world's largest reserves of Ta (-Sn), is of particular relevance because of many similarities between it and the Brazil Lake pegmatite and evolved Davis Lake pluton of the South Mountain Batholith.

The occurrence of the highly-evolved and chemically-zoned Davis Lake Pluton (Dostal and Chatterjee, 1995) at the western end of the SMB, with all the attributes of a fertile granite related to LCT pegmatite fields (Černý, 1991a), is considered potentially significant. As already noted, there are numerous tin and base-metal occurrences between the termination of this pluton and the BLP and a semi-continuous boulder terrain of pegmatite float (D. Black, personal communication, 2003). In addition, along the western edge of the most evolved part of the Davis Lake Pluton southwest of the East Kemptville tin deposit, small centres of Ta-Nb occur in coarse-grained, albite-topaz - rich rocks. Collectively, both the style and abundance of lithophile-element mineralization suggest that fertile granites underlie the metasedimentary landscape, and that the Brazil Lake pegmatite is probably related to one of these fertile intrusions, as suggested for the pegmatite fields in the Wodgina district of Australia (Sweetapple and Collins, 2002).

As discussed by London (1990), the absence of early phenocrystic phases in rare-element pegmatites, including the BLP here, indicates that the pegmatites were emplaced as already fractionated melts rather than evolving *in situ*. This implies, therefore, that there should be an along-strike variation in the mineralogy and chemistry that can be used as an exploration guide. Pegmatite fields can be characterized by both unidirectional or concentric zonation; however, this zonation style can be discerned by using the mineralogy (e.g. beryl versus spodumene rich; Breaks and Moore, 1992) and mineral chemistry (e.g., K/Rb, K/Cs of BKF; Černý *et al.*, 1985) to define the type of zonation. With such limited outcrop as characterizes the Brazil Lake area this approach could prove useful.

Finally, local control on the occurrence of the Brazil Lake pegmatite remains unresolved. However, in many pegmatite fields, structure is considered to be a dominant feature controlling the locus of intrusion (Černý, 1991b). Future work will focus on the regional geology and potential influence of a dominant structural feature that may have localized the pegmatitic melt. It is, therefore, relevant to note that the mineralization at East Kemptville lies within a regional shear zone (East Kemptville-East Dalhousie Fault Zone; Horne *et al.*, 1992) and greisen formation was structurally controlled.

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