Biotite chemistry as a monitor of magma fertility and mineralisation potential: Results from the Devonian granitoids of New Brunswick

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Abstract: There are over 150 granitoid intrusions in the New Brunswick; however, all the mineralised intrusions formed in relation to Acadian and Neoacadian orogenic phases of Appalachian accretion. These granitoids range in age from 423 to 360 Ma, and include examples of pre-, syn-, late-, and post-tectonic emplacement with affinities ranging from primitive to highly evolved A-, S-, and I-types granitoids along with their hybrid varieties. Many of these are spatially and temporally related to specific styles of mineralization, producing deposits of Sn, Ta, Li, Sb, W, Mo, Cu, and Au, as well as other base-metals and U.

Igneous biotite crystallises over a wide range of conditions and reacts very sensitively to physio-chemical conditions like halogen and oxygen fugacities, pressure, temperature and chemical composition of the magmas. This sensitivity makes biotite a suitable mineral for identifying the petrogenetic processes, mineralization and alteration of the host granitic rocks. The following features make biotite a valuable probe of magma composition: i) It is the most important reservoir of any excess aluminium in granites that do not contain modal garnet, cordierite, or the Al_2SiO_5 polymorphs; therefore, it directly reflects the peraluminosity of the host magma in such rocks; ii) it is the most readily available indicator of oxidation state; and iii) it can provide information about the F and Cl composition of the magma.

Previous studies have shown that biotite, and to lesser extent hornblende and magnetite, continuously equilibrates with host liquids. Consequently, a core-to-rim study of these minerals and their compositional zoning can provide a record of magma evolution so that the origin and evolution of granitoids can be documented.

The aim of this study is to calculate fluoride and chloride activity of aqueous fluids based on measuring F and Cl contents in the minerals containing hydroxyl and halogens, using a combination of electron microprobe and Laser Ablation ICP-MS. These data will be combined and compared with whole-rock trace element geochemistry. The results are expected to help constrain crystallisation conditions, volatile exsolution, and fluorine-chlorine activity of fluids associated with these intrusions, and also to examine the degree of subsolidus re-equilibration using various geothermobarometry techniques. By linking these results to the various styles/types of granitoids and their associated mineralisation it is hoped to establish biotite composition as a robust indicator of an intrusions ore potential.

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Biotite Chemistry as a Monitor of Magma Fertility and Mineralisation Potential: Results From the Devonian Granitoids of New Brunswick

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ABSTRACT

There are over 150 granitoid intrusions in the New Brunswick; however, all the mineralised intrusions formed in relation to Acadian and Neo-Acadian orogenic phases of Appalachian accretion. These granitoids range in age from 423 to 360 Ma, and include examples of pre-, syn-, late-, and post-tectonic emplacement with affinities ranging from primitive to highly evolved A-, S-, and I-types granitoids along with their hybrid varieties. Many of these are spatially and temporally related to specific styles of mineralization, producing deposits of Sn, Ta, Li, Sb, W, Mo, Cu, and Au, as well as other base-metals and U.

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INTRODUCTION

Mica group minerals are among the most common mafic minerals of intermediate to felsic igneous rocks; they can also be found in most of metamorphic and some of sedimentary rocks. Among them, biotite is particularly characteristic of the intermediate rocks of calc alkaline affinities and occurs in a wide range of rocks of hybrid origin (Deer et al. 1992).

Mineralized and barren rocks are characterized by different chemical variations in biotite. For instance, mineralized biotite is characterized by lower Mg and Ti contents relative to biotite from barren rocks; they also have higher amount of Al comparing to biotite from barren phases (Boomeri et al. 2010).

Biotites in the granitoid of New Brunswick area usually altered to chlorite and to some extent muscovite along their cleavages, and some of them totally replaced by chlorite; they usually contain apatite, zircon, titanite, ilmenite, rutile, and sulfide minerals (e.g., pyrrhotite, pyrite) as mineral inclusions. Their colour also varies from green to brown and reddish brown reflecting differences in their redox conditions (cf. Lalonde and Bernard 1993).

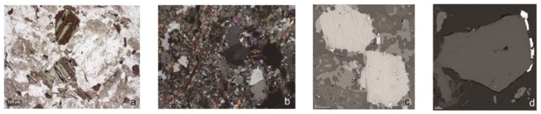


FIG. 1. Photomicrographs and SEM-BSE images of some New Brunswick biotite-bearing assemblages illustrating the mineralogy and texture. (a) Partly altered brownish biotite to chlorite along their cleavages, Lake George granodiorite, sample 1567, PPL, (b) Partly altered brownish biotite to muscovite along their cleavages, Lake George granodiorite, sample 612, XPL, (c) Apatite inclusions (BSE, bright gray) in a biotite grain from the Lake George granodirite, sample 1647, (d) Pyrrhotite crystals (white) adjacent to a biotite grain from the Lake George granodiorite, sample 1190.

TECTONIC SETTING

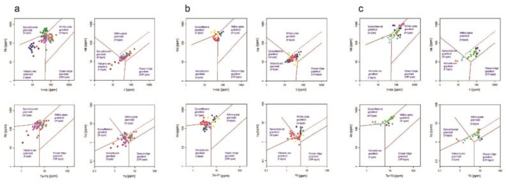
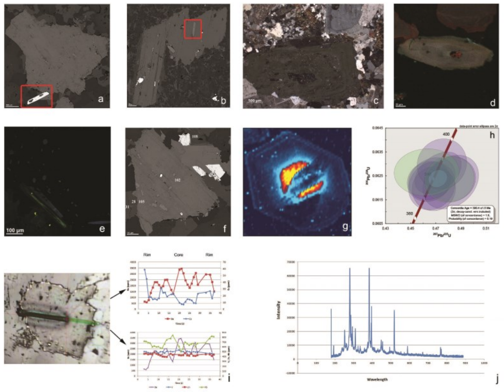
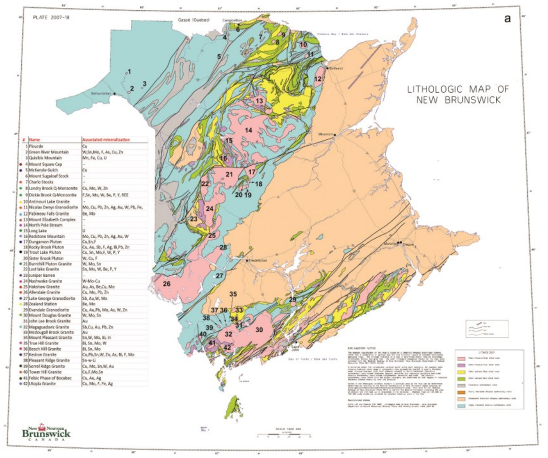


FIG. 2. Tectonomagmatic discrimination diagrams of New Brunswick Devonian granitoids data from Whalen (1993).Field boundaries are from Pearce et al. (1984) as modified by Christiansen and Keith (1996); colour code and description is annotated in figure 3; (a) 1-16, (b) 17-28 and (c) 29-42.

FUTURE STUDIES

(a) Calculating zircon saturation temperature, (b) calculating apatite saturation temperature, (c) studying zoning in plagioclase, (d) apatite, and (e) zircon and trying to correlate their zoning in order to better understanding the history of magma evolution, (f) calculation of the trace element distribution and partition coefficient of elements between K-feldspar and biotite, (g) trace element mapping of the studied grains (h) U-Pb dating of all the intrusions (zircon &/or monazite) that are imaged by SEM-BSE and ChromaSEMCL, (i) analyzing the studied grains using laser from rim to rim, and calculating trace element distribution between whole rock and biotite grains, (j) Advancing the LIBS method done at the University of New Brunswick.





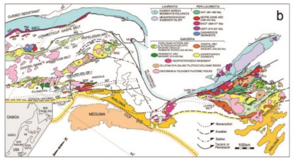


FIG. 3. Geological map of New Brunswick showing the location of Devonian granitoid intrusions and their associated mineralization, (b) Geology of the Canadian and adjacent New England Appalachians with the geographical distribution of the major tectonic elements discussed in text. A, Arisaig Group;AC, Ackley granite; B, Burgeo batholith; BB, Badger basin; BBF, Bamford Brook fault; BBL, Baie Verte Brompton Line; BVOT, Baie Verte oceanic tract; CCF, CobequidChedabucto fault; CF, Cabot fault; CL, Chain Lakes Massif; CO, Cookson Group; DBL, Dog Bay Line; FO,Fournier Group; F, Fogo Island pluton; GBF, Green Bay fault;GRUB, Gander River ultrabasic belt; HH, Hodges Hill pluton; LBOT, Lushs Bight oceanic tract; MP, Mount Peyton pluton; RBF, Rocky Brook–Millstream fault system;RF, Restigouche fault; RIL, Red Indian Line; SGB, St. George batholith; SM, South Mountain batholith; U, Utopia granite; VA, Victoria arc; TP, Tally Pond Group. (van Staal et al. 2009)

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