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GEOCHEMISTRY OF LATE- TO POST-GRENVILLIAN INTRUSIONS, EASTERN GRENVILLE PROVINCE, LABRADOR

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ABSTRACT

Late Paleoproterozoic and Mesoproterozoic rocks, which make up the western Mealy Mountains and Mecatina terranes of the eastern Grenville Province, are intruded by two suites of plutons defined on the basis of mineral composition. Suite I plutons consist mainly of clinopyroxene- or hornblende-bearing syenite, quartz syenite and quartz monzonite, and Suite II plutons consist mainly of biotite-bearing granite, K-feldspar porphyritic granite and quartz monzonite. Both suites consist of fresh and undeformed to very weakly foliated rocks demonstrating that they were intruded very late syn- to post-Grenvillian deformation.

Suite I and II rocks are rich in SiO_2, FeO, and $Na_2O + K_2O$, and depleted in CaO, typical of A-type, or anorogenic granitoid rocks. Both suites have broadly similar geochemical characteristics, although generally, Suite II rocks have slightly higher SiO_2, Rb, and lower Ti, Mg and Ca contents than Suite I rocks. A sample of Suite I syenite having an emplacement age of 980 ± 2 Ma has an ϵNd signature of -5.91, whereas a sample of Suite II biotite granite, dated at 964 ± 3 Ma, has an ϵNd signature of -4.23. The Nd-isotopic data suggest that both suites incorporate a component of older crustal material, and that they do not represent juvenile additions to late Grenvillian Laurentia. On one hand, the similarities in geochemical characteristics and Nd-isotopic signatures for Suite I and II rocks may indicate that the suites evolved from a similar source. Alternatively, intersection of trends on major-element (Ca, Mg, Fe), bivariate (Harker) diagrams, significant differences in the amount of Rb, decoupling of K and Rb, and discrepancies in compatible- and incompatible-element behaviour support a two-source model for the two suites. One interpretation of the geochemical data concludes that Suite I rocks may have a lower crustal or mantle source, whereas Suite II rocks may have an upper crustal protolith.

INTRODUCTION

One of the results of recently completed 1:100 000-scale bedrock mapping of the eastern Grenville Province in NTS map areas 13C and 13D (Figures 1 and 2; *see* James *et al.*, 2002b, and references therein) was demarcation of numerous plutons that are interpreted to be late to posttectonic with respect to Grenvillian tectonothermal events. The plutons consist mainly of undeformed and unmetamorphosed syenite, quartz syenite, quartz monzonite, and granite. The plutons intrude deformed, high-grade late Paleoproterozoic and Mesoproterozoic orthogneisses and AMCG-suite rocks that dominate this part of the eastern Grenville Province. On the basis of field classification, a minor amount of U–Pb geochronological data from the area, and following the work of Gower (*see* Gower *et al.*, 2002;

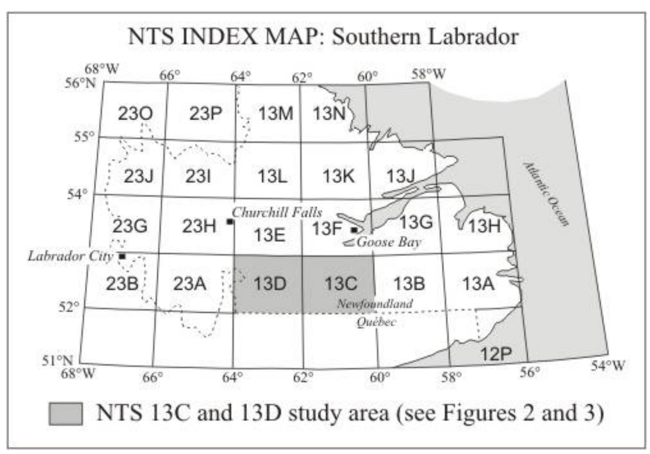

Figure 1. *NTS index map of southern Labrador showing location of the study area.*

[1] Regional Geology Section

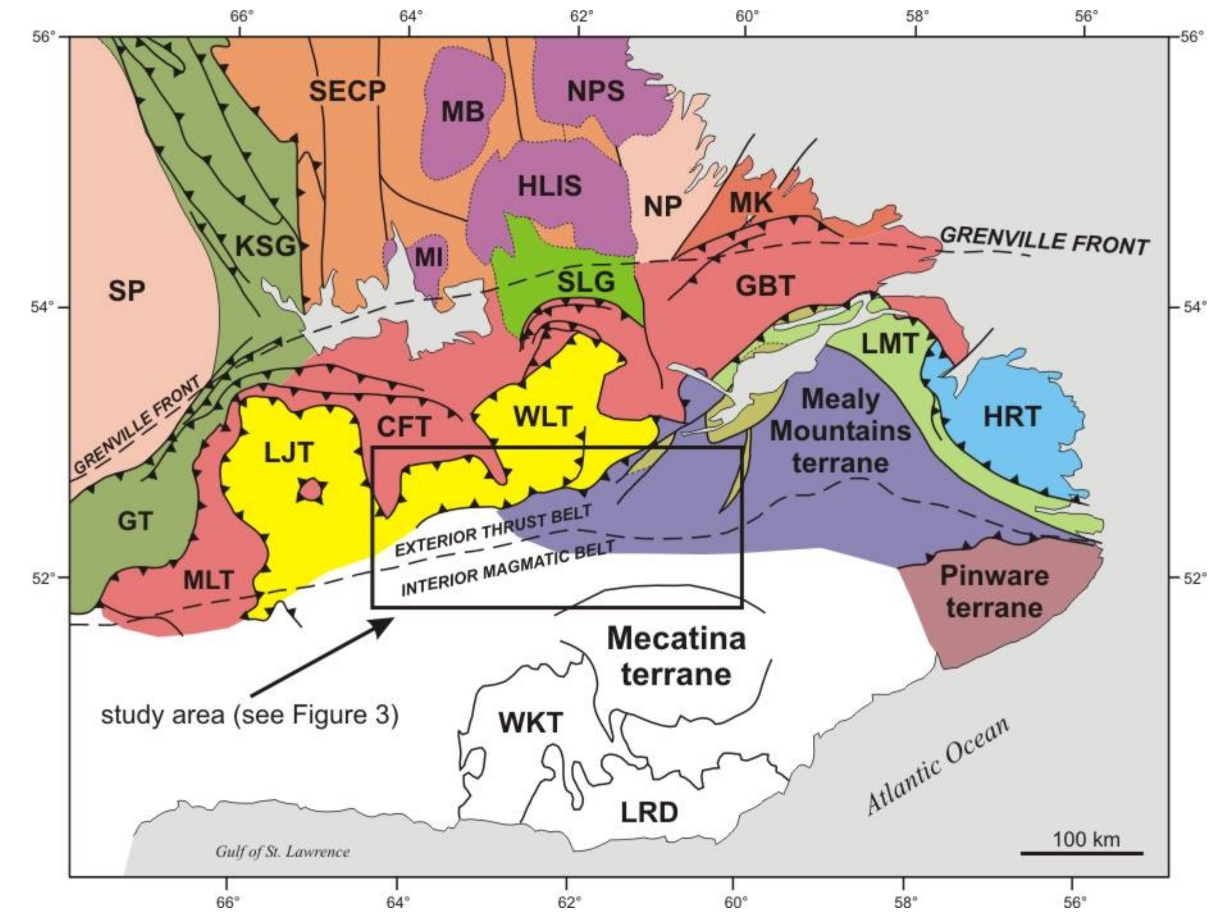

Figure 2. *Tectonic and major lithotectonic units of southern Labrador showing location of the study area. Grenville Province: HRT - Hawke River terrane, LMT - Lake Melville terrane, GBT - Groswater Bay terrane, WLT - Wilson Lake terrane, CFT - Churchill Falls terrane, LJT - Lac Joseph terrane, MLT - Molson Lake terrane, GT - Gagnon terrane, MAT - Matamec terrane, WKT - Wakeham terrane, LRD - La Romaine domain. Archean divisions: SP - Superior Province, NP - Nain Province (Hopedale Block). Archean and Paleoproterozoic divisions: MK - Makkovik Province, SECP - Southeastern Churchill Province (core zone), KSG - Kaniapiskau Supergroup (2.25-1.86 Ga). Mesoproterozoic units: NPS - Nain Plutonic Suite, HLIS - Harp Lake intrusive suite, MB - Mistastin batholith, MI - Michikamau Intrusion, SLG - Seal Lake Group.*

Gower and Krogh, 2002, and references therein) the plutons are provisionally divided into two suites; one suite consists mainly of pyroxene- or hornblende-bearing syenite, quartz syenite, and quartz monzonite, and the other consists mainly of biotite-bearing granite and quartz monzonite (*see* James *et al*., 2001, 2002a, b). For the purpose of this report, the suites are informally named Suite I and Suite II, respectively.

To better understand the nature and significance of the late to posttectonic plutons, and to test the robustness of the field classification, samples from each suite of plutons were examined as part of a B.Sc. thesis submitted by the first author to the Department of Earth Sciences, Memorial University of Newfoundland in April 2002 (Parsons, 2002). The thesis was based on a cursory examination of the rock units in the field in 2001 (*see* James *et al*., 2002b), petrographic examination of representative samples from the units, major- and trace-element analyses, and Nd–Sm isotopic analyses. This report highlights some of the data and interpretations of the thesis.

GEOLOGICAL FRAMEWORK

The study area (Figures 2 and 3) is situated in the eastern Grenville Province and straddles the boundary between the Exterior Thrust Belt and Interior Magmatic Belt (*see* Gower *et al.*, 1991). It includes, from north to south, parts of the Wilson Lake, Mealy Mountains, and Mecatina terranes. These structurally stacked terranes are Grenvillian tectonic entities, although they consist primarily of late Paleoproterozoic (Wilson Lake and Mealy Mountains terranes) and Mesoproterozoic (Mecatina terrane) crust.

The Wilson Lake terrane (WLT) is dominated by high-grade metasedimentary gneisses having protolith depositional ages predating ca. 1720 Ma (i.e., pre-Labradorian Orogeny). The gneisses are derived primarily from pelitic and semipelitic sedimentary rocks, although very minor amounts of metasedimentary rocks derived from quartzite and siliceous carbonate also occur. The northern part of the terrane, in the Red Wine Mountains area, also includes intrusions of late Paleoproterozoic gabbro, gabbronorite, and mafic gneisses possibly derived from supracrustal rocks. Intrusions of foliated granite and porphyritic granite, correlated on the basis of rock type with the ca. 1650 Ma Trans-Labrador batholith, and ca. 1650 Ma granitoid orthogneisses (e.g., James *et al*., 2002a) make up minor amounts of the terrane.

Geochronological studies of monazite contained in sapphrine-bearing diatexite, occurring in the northern part of the WLT and presumed to be derived from anatexis of the metasedimentary gneisses, indicate that high-grade metamorphism and attendant deformation are early to middle Labradorian (> 1640 Ma) (Corrigan *et al.*, 1997). Corrigan *et al.* (*op. cit.*) have also shown, on the basis of U–Pb dating of monazite, that the terrane has been locally overprinted by Grenvillian (ca. 1000 Ma) metamorphism. Regionally persistent ductile high-strain zones separating the WLT from the Trans-Labrador batholith to the north, and the Mealy Mountains terrane to the south (Figure 2), are ca. 1010 to 990 Ma structures (Corrigan *et al*., 1997).

The Mealy Mountains terrane (MMT; Gower and Owen, 1984) consists of variably metamorphosed and deformed, late Paleoproterozoic, Labradorian-age plutons of the Mealy Mountains intrusive suite (MMIS) (*see* Emslie, 1976; Emslie and Hunt, 1990; Krogh *et al*., 1996), minor amounts of Paleoproterozoic pre-Labradorian crust, and Pinwarian (1510 to 1450 Ma) intrusions (Gower, 1996). The MMIS includes an older group of anorthositic, gabbroic and local leucotroctolitic rocks, and a younger group of pyroxene-bearing monzonite and quartz-monzonite intrusions. Emplacement ages for units of MMIS monzodiorite orthogneiss, porphyritic quartz monzodiorite and pyroxene-bearing monzonite, determined by U–Pb geochronology of zircon and occurring in the Kenamu River map area (NTS 13C/NE), are 1659 ± 5 Ma, 1650 ± 1 Ma, and 1643 ± 2 Ma, respectively (James *et al*., 2000). In addition, pyroxene monzonite and pyroxene granite, inferred to be from the younger group of MMIS rocks and occurring in the northeastern part of the MMIS, have emplacement ages of 1646 ± 2 Ma and 1635 +22/-8 Ma (Emslie and Hunt, 1990), respectively. Emplacement ages of MMIS rocks overlap with tectonothermal and magmatic events of the Labradorian Orogeny, which affected northeastern Laurentia in the interval between 1720 Ma and 1600 Ma (*see* Gower, 1996).

Rocks in the western part of the MMT are variably foliated and locally gneissic; generally, they have northeast- to east-northeast-striking planar fabrics that are inferred to be Labradorian in age (James and Nadeau, 2000). However, the local occurrence of deformed, Pinwarian age (ca. 1514 Ma) granite in the Kenamu River area (James *et al.*, 2000) demonstrates the western part of the terrane has also been affected by Pinwarian and/or Grenvillian deformation.

The location and nature of the boundary between the MMT and the Mecatina terrane is somewhat uncertain. In the Fourmont Lake map area (NTS 13C/SE; *see* James and Nadeau, 2000), rare occurrences of mylonitic rocks having an undetermined kinematic history, suggest the boundary is, at least locally, a south-dipping high-strain zone. However, in general, the area inferred to contain the terrane boundary is very poorly exposed and reliable field data for its demarcation are lacking.

The Mecatina terrane (MET) consists of upper amphibolite-facies supracrustal rocks, including quartzite and pelitic gneiss, as well as granitoid orthogneiss, deformed granitic and monzonitic rocks, gabbro and anorthosite belonging to the Petit Mecatina AMCG suite. The metasedimentary rocks are provisionally correlated with the Wakeham Group. Foliated quartz monzonite and K-feldspar porphyritic granite, occurring in the MET in the Fourmont Lake area, intrude the supracrustal gneisses and have emplacement ages of 1500 ± 4 Ma and 1493 ± 3 Ma, respectively, determined by U–Pb geochronology of zircon (James *et al*., 2001). Titanite in the 1493 Ma porphyritic granite is dated by U–Pb techniques to be 1043 ± 6 Ma (James *et al*., 2001), providing evidence that the MET has been overprinted by Grenvillian metamorphism.

The western MMT and the southern Lac Joseph terrane (Figures 2 and 3) are intruded by a suite of plutons consisting of troctolite, norite, anorthosite, monzonite, quartz syenite and granite that belong to the late Mesoproterozoic Atikonak River massif (Nunn *et al*., 1986a, b, c; Nunn, 1990). The rocks have been variably overprinted by Grenvillian deformation and metamorphism. Emplacement ages of a rapakivi granite and pyroxene-bearing quartz monzonite from the massif have been determined by U–Pb geochronology of zircon to be 1133 +10/-5 Ma and 1123 ± 4 Ma, respectively (Emslie and Hunt, 1990). The Atikonak massif represents the northeastern extension of the Lac Fournier massif (Sharma and Franconi, 1975), and is part of a larger suite of late Mesoproterozoic AMCG intrusions extending south from the study area to the Gulf of St. Lawrence.

The MMT and the MET are intruded by plutons of unmetamorphosed, massive to weakly foliated and recrystallized clinopyroxene-bearing syenite, quartz syenite, quartz monzonite, and biotite granite that are the focus of this study. The field relationships demonstrate the intrusions slightly overlap and postdate, temporally, the late stages of Grenvillian orogenesis. Two plutons consisting mainly of clinopyroxene-bearing syenite, and named the Lac Arvert syenite and Mercereau syenite (Figure 3), are correlated with Suite I and have emplacement ages of 982 ± 2 Ma (James *et al*., 2002a) and 980 ± 5 Ma (S. Kamo and K. Kwok, 2002, unpublished data), respectively. Based on composition, field characteristics and emplacement ages, the Suite I intrusions are provisionally interpreted to be related to other ca. 985 to 975 Ma early posttectonic intrusions in the eastern Grenville Province (*see* Gower and Krogh, 2002). A biotite-granite correlated with Suite II, and also occurring in the western MMT, is determined to have an emplacement age of 964 ± 3 Ma (James *et al.*, 2001). The age of the biotite granite is consistent with 975 to 955 Ma ages for widespread granitoid plutons in the Pinware terrane and, locally, in the southeastern MMT (*see* Gower, 1996; Gower and Krogh, 2002; Gower *et al*., 2002).

In general, the plutons discussed in the preceding paragraph are poorly exposed and have not been mapped in detail. Plutons of both suites are commonly, but not in all cases, associated with pronounced, circular to elliptical magnetic anomalies. The regional magnetic anomaly patterns have assisted in outlining the plutons in poorly exposed areas.

DESCRIPTION OF ROCK UNITS

The International Union of Geological Sciences (IUGS) classification for felsic plutonic rocks has been employed to name rock units. Anorthite content in plagioclase was determined optically using the Michel-Lévy method. Modal compositions were determined by visually estimating percentages of minerals in thin section and in hand-specimen slabs stained with sodium cobaltinitrite.

SUITE I: CLINOPYROXENE-BEARING SYENITE, QUARTZ SYENITE AND QUARTZ MONZONITE (M_{LG} sye)

Suite I consists mainly of medium- to coarse-grained clinopyroxene-bearing syenite

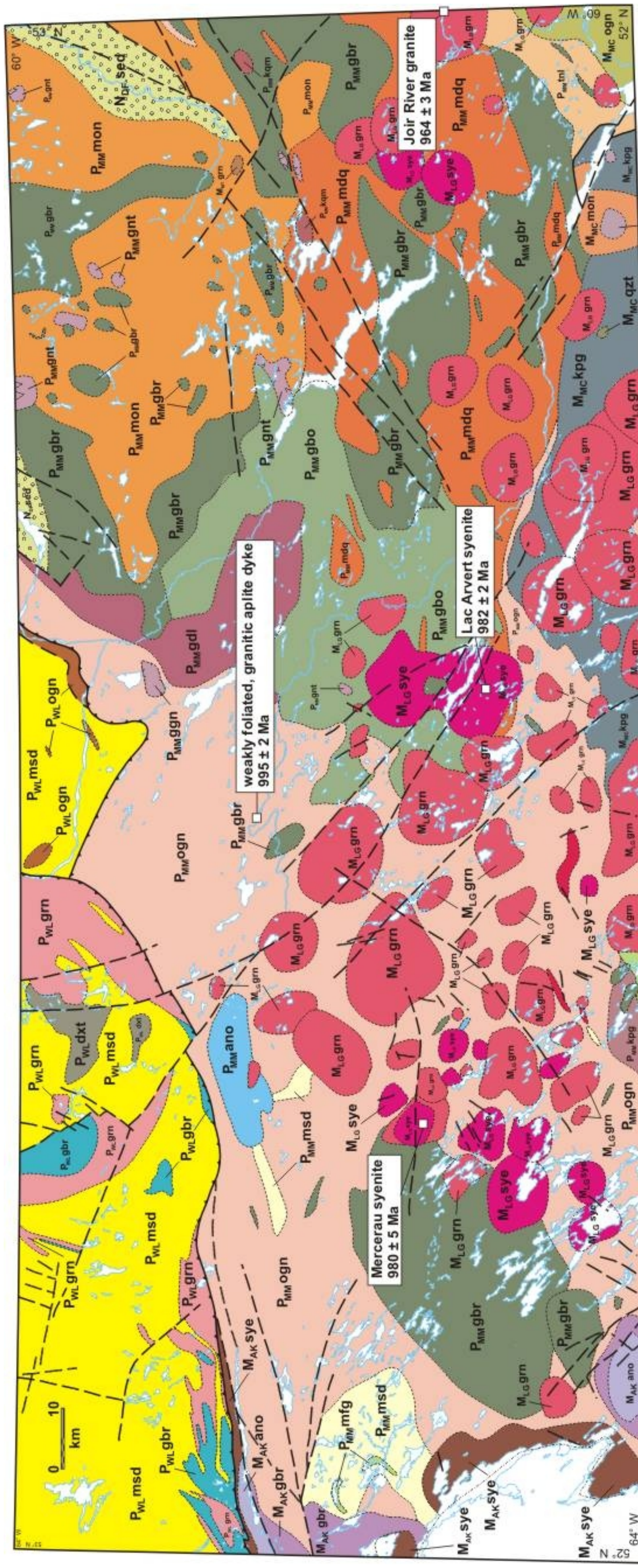

Figure 3. *General geology of the Grenville Province in NTS map areas 13C and 13D.*

LEGEND (Figure 3)

Unit	Description
	Neoproterozoic
N_{DF}sed	Double Mer Formation: arkose, conglomerate
	Late Mesoproterozoic (Late- to post-Grenvillian orogeny)
M_{LG}grn	biotite granite and quartz monzonite (ca. 975 to 955 Ma)
M_{LG}sye	clinopyroxene syenite, monzonite, quartz monzonite, and granite (ca. 985 to 975 Ma)
	MECATINA TERRANE (MET)
	Early Mesoproterozoic (deformed and metamorphosed)
M_{MC}gbr	gabbro, gabbronorite
M_{MC}kpg	K-feldspar porphyritic granite
M_{MC}ogn	granite orthogneiss, deformed granite
M_{MC}mon	pyroxene (blue quartz) monzonite, quartz monzonite
M_{MC}qzt	quartzite, and minor amounts of pelitic metasedimentary gneiss
	MEALY MOUNTAINS TERRANE (MMT)
	Late Mesoproterozoic (deformed and recrystallized)
	Atikonak River massif (ca. 1135 to 1125 Ma)
M_{AK}sye	syenite, quartz monzonite, and granite
M_{AK}gbr	gabbro, gabbronorite, norite, leuconorite
M_{AK}ano	anorthosite
	Early Mesoproterozoic
M_{MT}grn	biotite syenogranite (foliated)
	Late Paleoproterozoic (variably deformed and metamorphosed) Mealy Mountains Intrusive Suite (ca. 1660 to 1635 Ma)
P_{MM}gbr	gabbro, gabbronorite (undivided), leucogabbro, minor amounts of ultramafic rocks and diorite
P_{MM}gbo	mainly biotite gabbro, and lesser amounts of gabbro and gabbronorite
P_{MM}ano	anorthosite
P_{MM}gnt	granite
P_{MM}gdl	granite (Dominion Lake Pluton)
P_{MM}ggn	pyroxene granite, quartz monzonite
P_{MM}mon	pyroxene monzonite, quartz monzonite, and minor amounts of granite
P_{MM}kqm	K-feldspar porphyritic quartz monzodiorite
P_{MM}kpg	K-feldspar porphyritic granite
P_{MM}mdq	orthogneiss I: monzodiorite, monzonite, quartz monzonite, granite orthogneiss
P_{MM}tnl	orthogneiss II: mainly tonalite orthogneiss
P_{MM}ogn	orthogneiss III: mainly granite, granodiorite orthogneiss
P_{MM}mfg	mafic gneiss (supracrustal protolith ?)
P_{MM}msd	metasedimentary gneiss and related diatexite
	WILSON LAKE TERRANE (WLT)
	Late Paleoproterozoic (deformed and metamorphosed)
P_{WL}gbr	gabbro, gabbronorite
P_{WL}grn	granite, granite orthogneiss
P_{WL}ogn	granodioirite, granite, and tonalite orthogneiss
P_{WL}dxt	sillimanite + garnet diatexite
P_{WL}msd	metasedimentary gneiss

and lesser amounts of quartz syenite, quartz monzonite, and K-feldspar porphyritic syenite. Suite I rocks are collectively represented as Unit MLG sye in Figure 3. Rocks are medium to dark pink on weathered and fresh surfaces, commonly coarse grained to K-feldspar porphyritic, and have a consistent composition and texture. Quartz may have a light blue-violet colour. Outcrops are mainly massive. Rocks have fresh phaneritic textures, although they are weakly recrystallized, locally. Some rocks have a very weak igneous foliation defined by alignment of K-feldspar phenocrysts. Generally, K-feldspar grains are about 2 cm in length and sit in a fine- to medium-grained groundmass of plagioclase, quartz, K-feldspar and mafic minerals. The mafic minerals include clinopyroxene, and less than 10 percent hornblende and biotite. Rocks may contain accessory magnetite, ilmenite, epidote, apatite, zircon, monazite, and titanite. Locally, epidote grains have an allanite core.

Microcline is the dominant feldspar. Perthitic textures are abundant including microcline perthite having albite and pericline twinning, mesoperthite intergrowth of alkali and plagioclase feldspar, and microperthite exsolution intergrowth of sodium- and potassium-rich feldspar. Myrmekite intergrowth of quartz and plagioclase feldspar is common. Anorthite content in plagioclase ranges between 3 and 12 percent. Plagioclase is weakly to intensely sericitized.

Medium- to coarse-grained clinopyroxene is variably pseudomorphed by hornblende, and to a lesser extent by biotite. Mafic minerals are anhedral. Some biotite grains are entirely enclosed by feldspars. Minor amounts of rutile are exsolved from clinopyroxene and hornblende. Locally, biotite is replaced by minor amounts of chlorite, and titanite is replaced by Fe–Ti oxide.

SUITE II: BIOTITE-BEARING GRANITE, QUARTZ MONZONITE AND PORPHYRITIC GRANITE (MLG grn)

Suite II consists mainly of three subunits including medium- to coarse-grained biotite-bearing granite, quartz monzonite, and K-feldspar porphyritic granite (Suite II has not been subdivided into constituent subunits in Figure 3). The units have consistent composition and texture; they consist mainly of massive and fresh to slightly recrystallized rocks. Rocks having a weak foliation occur locally. The foliation is defined by alignment of quartz grains, K-feldspar phenocrysts, or biotite, and could be of tectonic or igneous origin. In addition, outcrops commonly have a prominent horizontal jointing pattern.

Suite II rocks are intruded by granitic aplite dykes and very coarse-grained, massive, granitic pegmatite dykes that locally make up a significant part of the suite. Some outcrops of Suite II rocks are composite and contain several intrusive phases distinguished by grain size and/or minor compositional differences. Locally, outcrops contain inclusions of mafic porphyritic granite or diorite.

The biotite granite and quartz monzonite are dull grey, to white, to light pink on weathered surfaces, and white, pink, and black on fresh surfaces. The rocks contain less than 12 percent biotite, several percent titanite, magnetite, and accessory rutile, epidote, monazite, and zircon. Some rocks contain less than 5 percent primary muscovite, and minor amounts of secondary muscovite in fractures. Locally, rocks contain up to 10 percent hornblende, although hornblende-bearing rocks are not common. Medium-grained concentrations of biotite and hornblende locally produce a “clotted” texture. Trace amounts of disseminated pyrite occur in a few rocks. Most rocks are very weakly to weakly magnetic.

The dominant K-feldspar is perthitic microcline. Perthitic textures include microcline perthite having albite and pericline twinning, mesoperthite intergrowth of alkali and plagioclase feldspar, and microperthite exsolution intergrowth of sodium- and potassium-rich feldspar. Some K-feldspar grains are concentrically zoned. A granophyric texture of quartz in K-feldspar is observed along with myrmekite intergrowth of quartz in plagioclase, and a “wormy” intergrowth of quartz in biotite. Anorthite content in plagioclase is estimated to be between 1 and 13 percent. Plagioclase is moderately to extensively sericitized.

The K-feldspar porphyritic rocks are pink on weathered and fresh surfaces and generally similar in composition to the non-porphyritic MLG grn rocks described in the preceding paragraphs. Rocks contain up to 10 percent medium- to coarse-grained biotite, up to 10 percent hornblende, several percent titanite, and minor amounts of rutile. The phenocrysts, up to 5 cm in length, are commonly perthitic, subhedral, and locally concentrically zoned having an albite rim. In some rocks, textures suggest that magnetite has replaced titanite. Plagioclase is moderately sericitized.

GEOCHEMISTRY

Whole-rock geochemical analyses of 14 samples of Suite I rocks and 23 samples of Suite II rocks (Appendix 1) were completed in the Geological Survey of Newfoundland and Labrador geochemical laboratory using ICP-AES multiacid decomposition for trace elements and XRF fusion analysis for major elements (Appendix 2a and b). Sm–Nd isotopic analyses were completed in the Department of Earth Sciences at Memorial University. In addition to the geochemical data presented in this report, Nadeau and James (2001, 2002) have presented some preliminary data

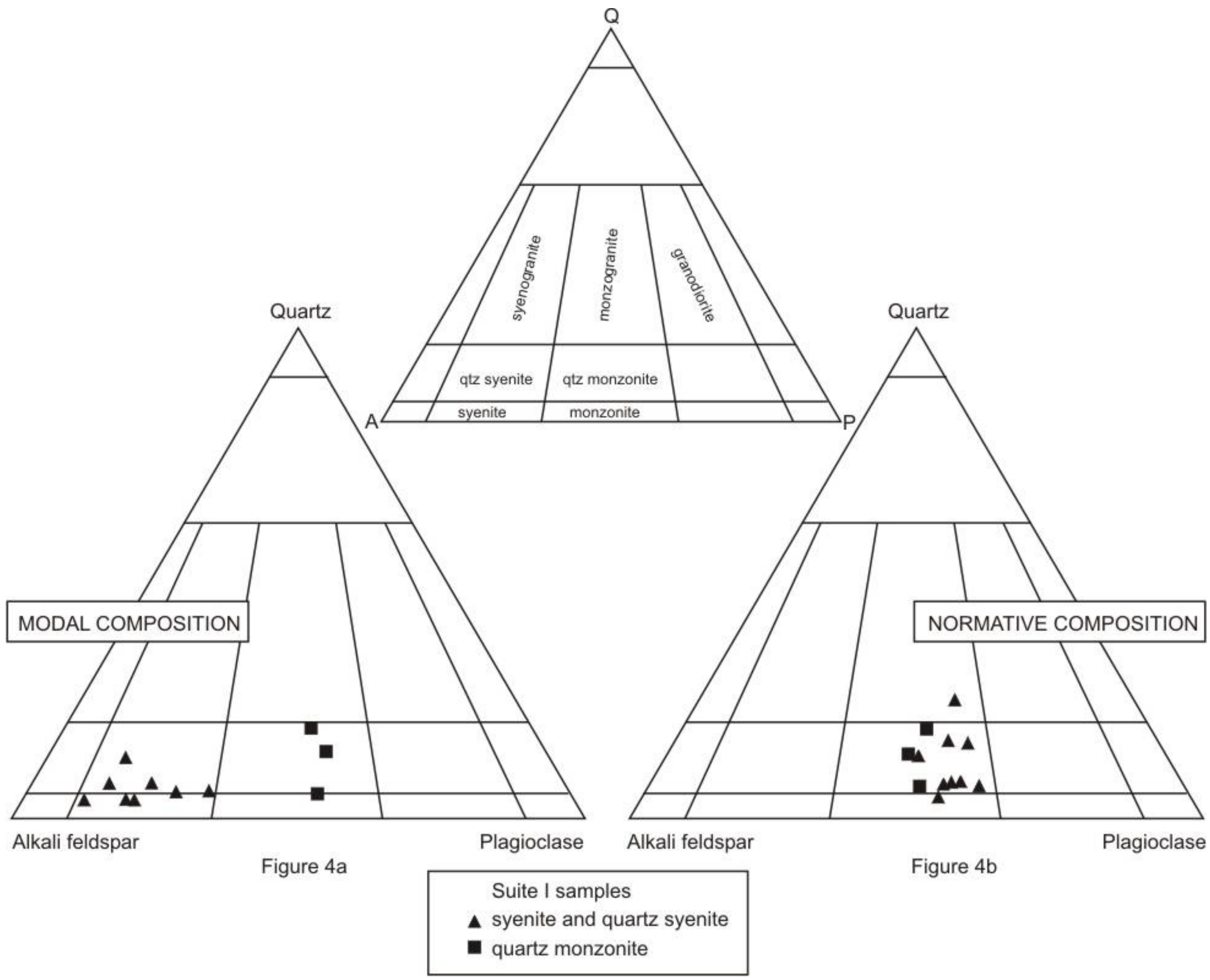

Figure 4. *Quartz(Q) - alkali feldspar (A) - plagioclase (P) diagram after Le Maitre (1989), showing inconsistent model distributions of Suite I syenite samples, as determined from petrographic (modal composition) analyses (A) and MESO norm calculations (B).*

and interpretations for intrusive units, including the Suite I and II intrusions, occurring in the study area.

CLASSIFICATION OF ROCK UNITS: MODAL VERSUS NORMATIVE COMPOSITION AND CLASSIFICATION SCHEMES

Classification of Suite I and II rocks, based on the Quartz (Q) - Alkali Feldspar (A) - Plagioclase (P) scheme defined by Le Maitre (1989), is shown in Figures 4 and 5. The classification in Figures 4a and 5a is based on modal compositions indicated as volume percentages. Alkali feldspar includes orthoclase and albite (An 0 to 5), whereas plagioclase is defined as having An 5 to 100 (*see* Streckeisen, 1967). The modal compositions plotted are visual estimates based on examination of the rocks in thin section, and stained hand-specimen slabs.

Plotting normative compositions (Appendix 3) of the same samples plotted in Figures 4a and 5a on a QAP diagram (Figures 4b and 5b) demonstrates some discrepancies between classification based on modal and normative compositions. The discrepancy is most pronounced for Suite I syenite and quartz syenite samples (Figures 4a and b). The source of the discrepancy is interpreted to be caused primarily by the amount of perthitc feldspar in the syenite. For purposes of this study, perthitic feldspar was considered to be modal alkali feldspar. However, exsolved plagioclase contained in a perthitic feldspar is calculated as normative primary plagioclase. Thus, samples containing a significant component of perthitic feldspar will plot closer to the plagioclase apex on a QAP diagram based on normative composition than on a modal composition diagram. In addition, any sodium present in pyroxene or amphibole will also affect the normative plagioclase mineralogy, further com-

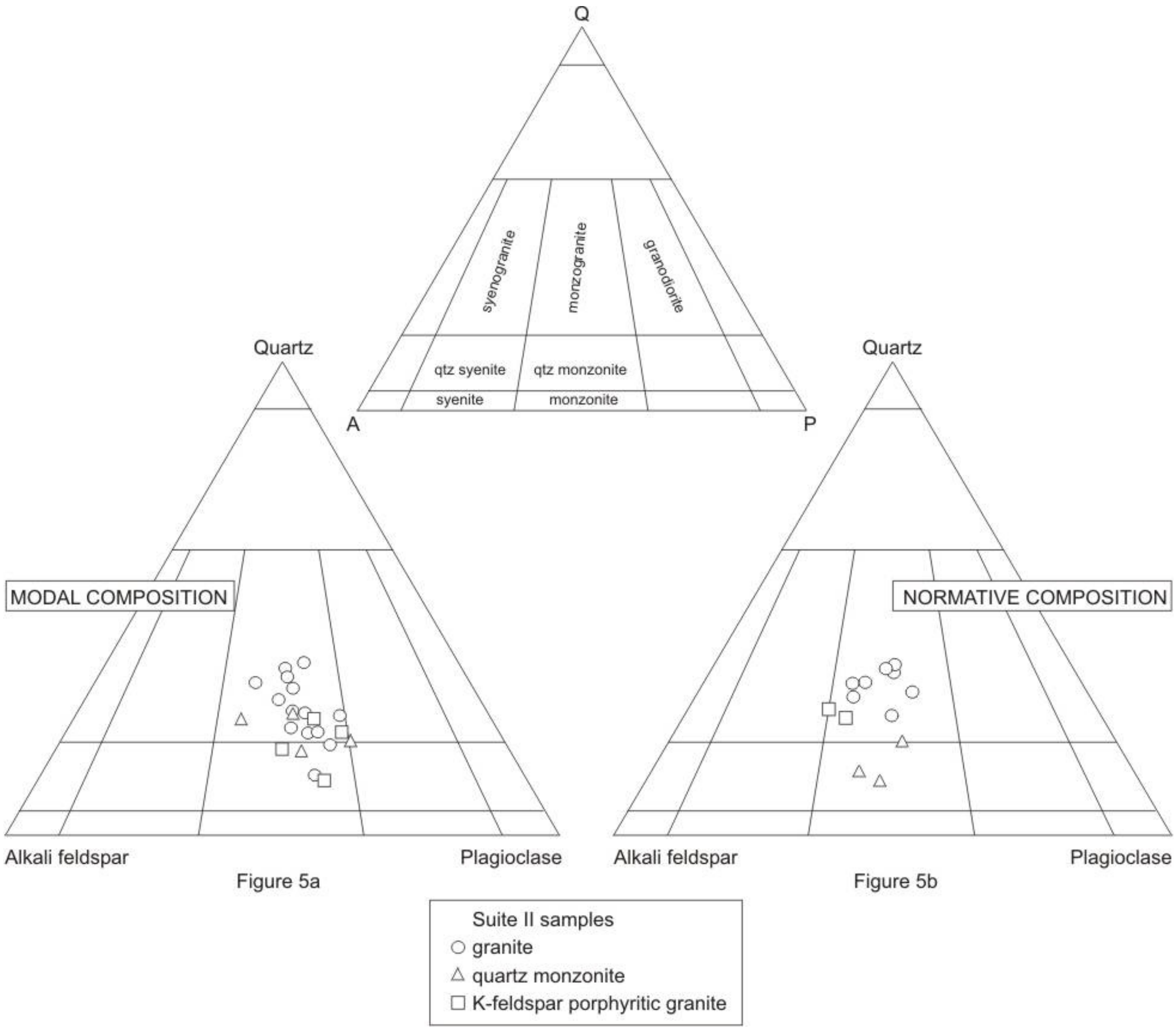

Figure 5. *Quartz(Q) - alkali feldspar (A) - plagioclase (P) diagram after Le Maitre (1989), showing model distributions of Suite II rocks as determined from petrographic (modal composition) analyses (A) and MESO norm calculations (B).*

pounding the discrepancy on a QAP diagram. In contrast to the Suite I syenites, samples of Suite II granite and quartz monzonite plot consistently on QAP diagrams based on modal and normative compositions.

Plutonic magmatic associations can be classified on plots with more complicated parameters. Debon and Le Fort (1983) developed a number of major element-based chemical-mineralogical diagrams that provide both rock name and magmatic association information (Whalen, 1993). The QBF, Q-P, and A-B diagrams (Figures 6, 7 and 8) use a measure of "quartz" (Q=Si/3-(K + Na + 2Ca/3)), dark minerals (B=Fe + Mg + Ti), feldspars + muscovite (F=(555-(Q + B)), P(K-(Na + Ca), and aluminous character (A=Al-(K + Na + 2Ca)) to classify plutonic rocks by rock name. The A–B plot (Figure 8) also distinguishes peralkaline, metaluminous and peraluminous rocks. The A–B diagram, demonstrates a peraluminous component of granitic rocks within Suite II. In general, samples of Suite I syenite have the highest abundance of Fe + Mg + Ti, and appear most "mafic" on both the QBF and A-B diagrams (Figures 6 and 8). Suite II samples plot in a range of fields from 1 to 4 (Figure 8), interpreted to reflect the variable presence of muscovite.

Frost *et al.* (2001) proposed a classification system based on major elements and using factors defined as the iron number (Fe*), modified alkali-lime index (MALI), and aluminum saturation index (ASI) (Table 1). The Fe* is determined by the FeO (total)/FeO (total) + MgO ratio, and classifies samples as either ferroan or magnesian. This component provides information about the differentiation index of a granitic magma. The MALI is defined by (Na_2O + K_2O

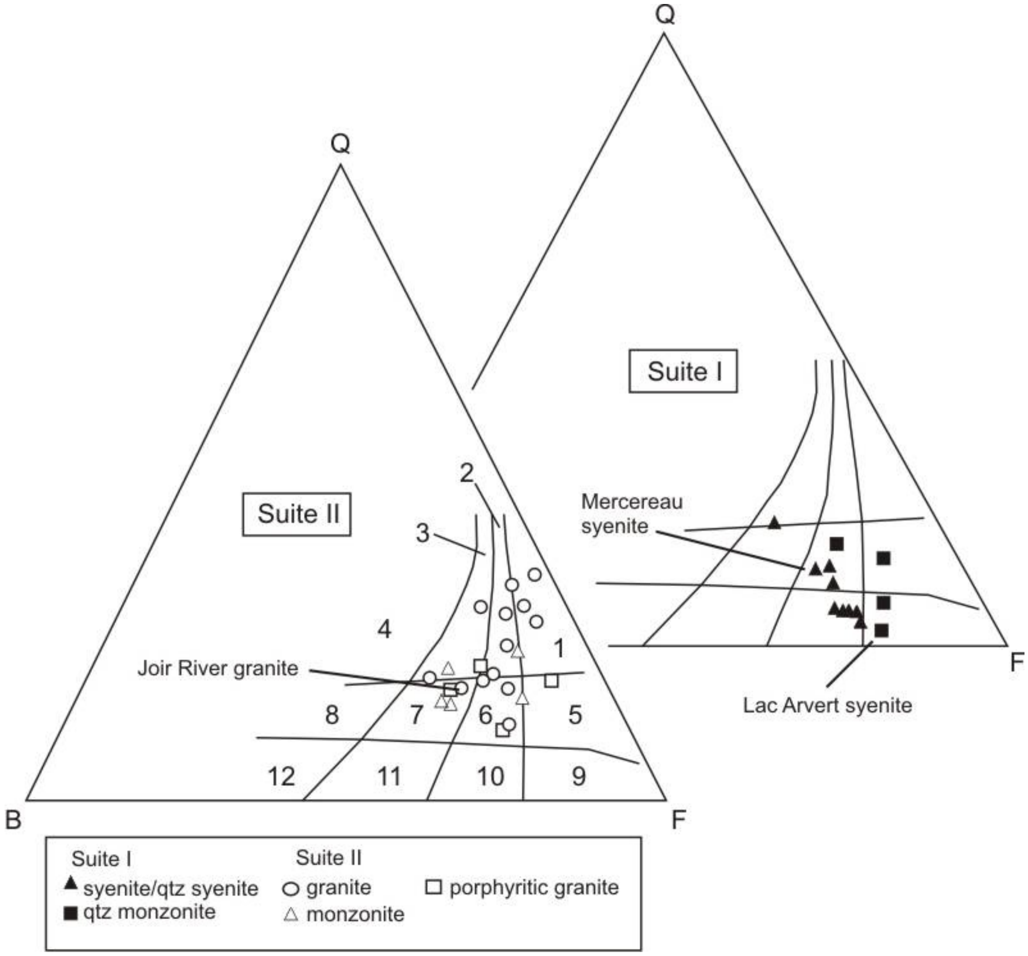

Figure 6. *QBF diagram after Debon and Le Fort (1983), showing modal distributions of Suite I and Suite II samples. 1- granite, 2 - adamellite, 3 - granodiorite, 4 - tonalite, 5 - quartz syenite, 6 - quartz monzonite, 7 - quartz monzodiorite, 8 - quartz diorite, 9 - syenite, 10 - monzonite, 11 - monogabbro, and 12 - gabbro.*

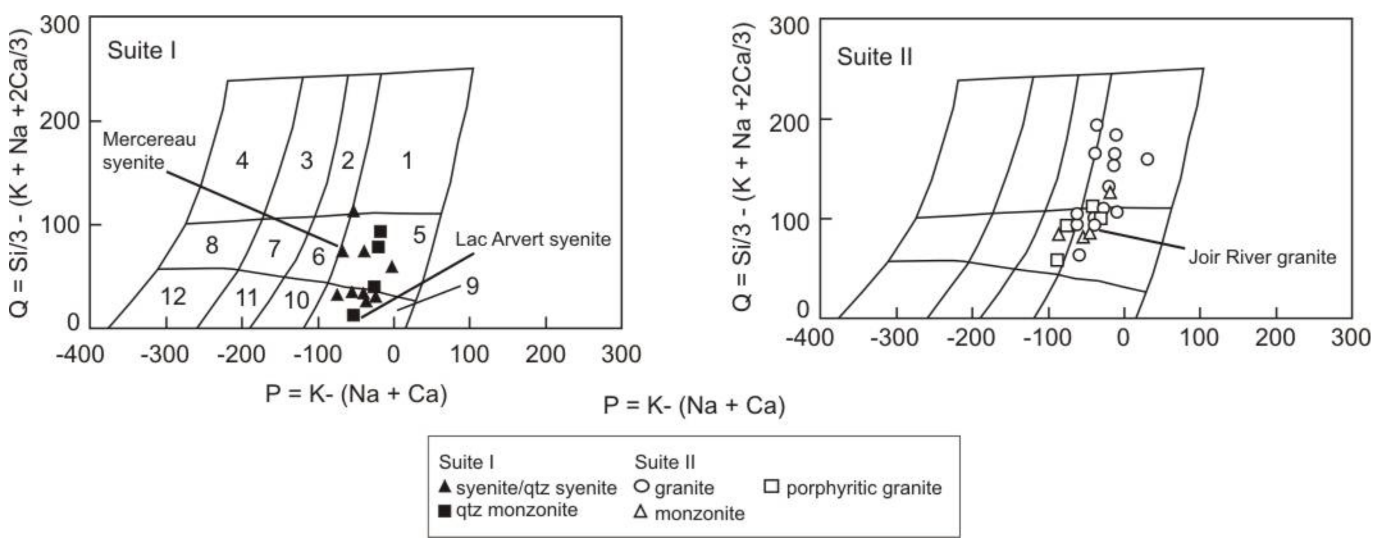

Figure 7. *Q–P diagram after Debon and Le Fort (1983), showing modal distributions of Suite I and Suite II samples. 1- granite, 2 - adamellite, 3 - granodiorite, 4 - tonalite, 5 - quartz syenite, 6 - quartz monzonite, 7 - quartz monzodiorite, 8 - quartz diorite, 9 - syenite, 10 - monzonite, 11 - monogabbro, and 12 - gabbro.*

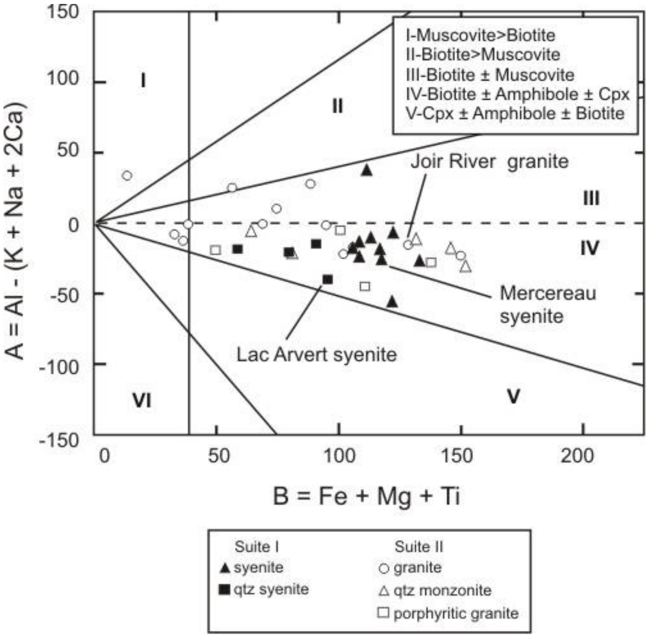

Figure 8. *A–B diagram after Debon and Le Fort (1983) of Suite I and Suite II samples. Dashed line indicates boundary between peraluminous (above the dashed line) and metaluminous (below the dashed line) fields.*

Table 1. Classification of samples using Fe*, MALI and ASI (after Frost *et al.*, 2001)

Classification Factor	Suite I	Suite II
Fe*	ferroan	ferroan
MALI	alkalic	alkalic / alkali-calcic
ASI	metaluminous / peraluminous	metaluminous / peraluminous

– CaO) and divides samples into alkalic, alkali-calcic, calc-alkalic, and calcic affinities. MALI is used to interpret magma source. ASI (Al/Ca – 1.67P + Na + K) differentiates peralkaline, metaluminous and peraluminous suites. Peraluminous suites have ASI>1.0, metaluminous suites have ASI<1.0 and Na + K<Al, and peralkaline suites have ASI<1.0 and Na + K>Al. The ASI index is a reflection of the micas and accessory minerals in the rock, and is related to magma sources and conditions of melting. All three classification parameters are plotted against silica to assess their significance (Figure 9). The Fe*, MALI, and ASI indicate that Suite I and II are ferroan, alkalic to alkali-calcic, and metaluminous to peraluminous in nature.

INCOMPATIBLE- AND COMPATIBLE-ELEMENT DIAGRAMS

Harker diagrams (Figures 10 and 11), using major and trace elements (Al, Ti, Ca, Mg, Fe, Rb, Zr, Ce, Nb, and Y),

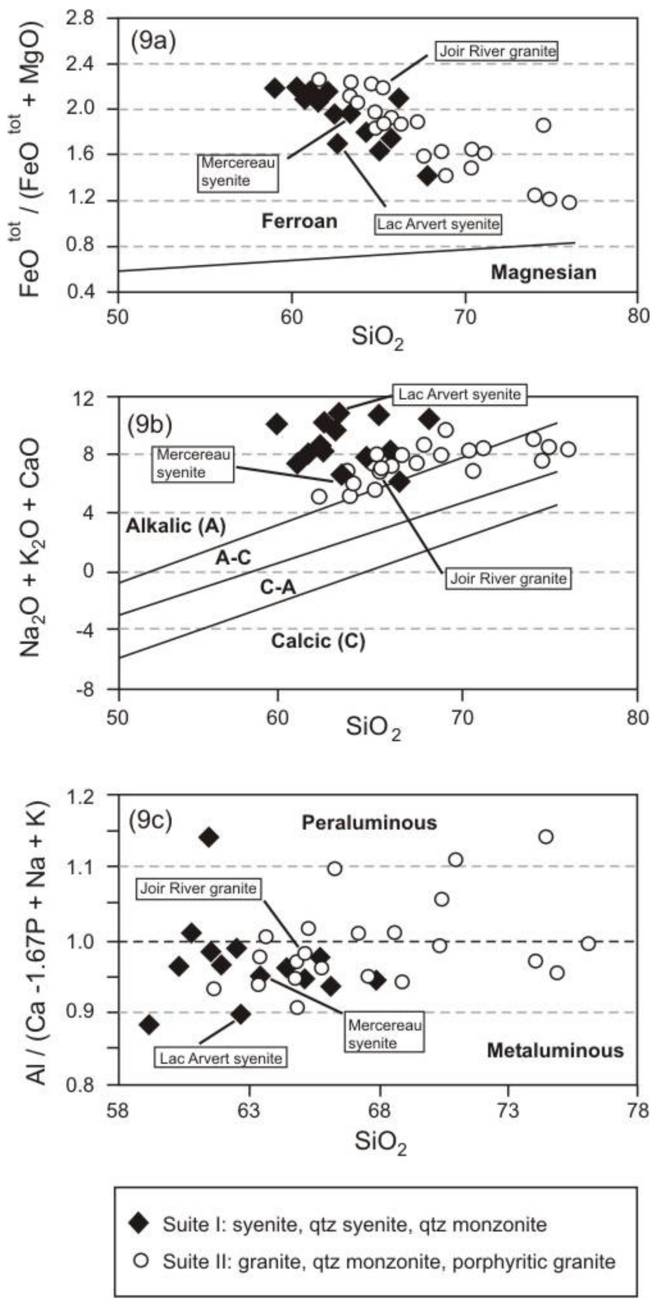

Figure 9. *Classification of Suite I and Suite II samples on the basis of Fe-number (A), Modified Alkali Lime Index (MALI) (B), and Aluminum Saturation Index (ASI) (C). Diagrams modified after Frost* et al. *(2001).*

are used to interpret the compatible or incompatible behaviour of the elements using SiO_2 as an index for increasing igneous fractionation. Rb shows a positively sloping linear trend on a Harker diagram (Figure 10f), and on this basis is interpreted to be the only element having an incompatible behaviour for Suite I and II rocks.

Harker diagrams of compatible and immobile elements, Al and Ti, versus SiO_2 (Figures 10a and 10b), show that

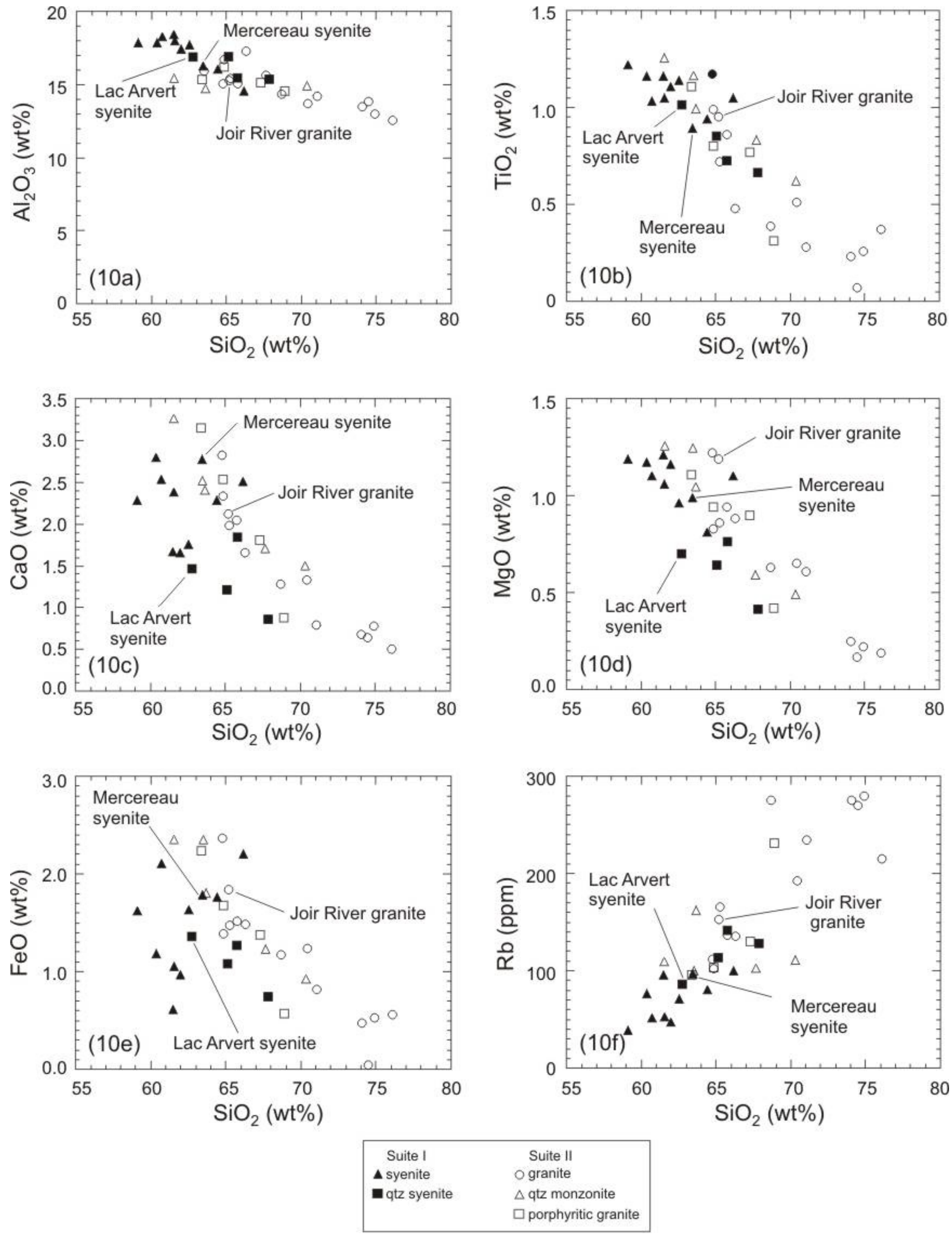

Figure 10. *Harker diagrams showing compatible trends for all major elements (A to E) and an incompatible trend for Rb (F).*

samples follow a compatible igneous, negatively sloping linear trend. Suite I rocks plot at high Al (approximately 18%) and Ti (1 to 2%) relative to low (60%) SiO_2 values. In contrast, Suite II rocks plot at low Al (approximately 14%) and Ti (0.2%) relative to high SiO_2 (approximately 75%). Samples of peraluminous Suite II granite have the highest SiO_2 content.

Plotting Ca, Mg and Fe against SiO_2 (Figures 10c, d and e) reveals subtle differences in trends for Suite I and II rocks. Suite I rocks have high Ca, Mg and Fe relative to low SiO_2. In contrast, Suite I rocks have relatively high Ca, Mg and Fe concentrations at lower SiO_2 values, and low Ca, Mg, and Fe at higher SiO_2 values. The variation in the slope of the trends, and more specifically the intersection of trends

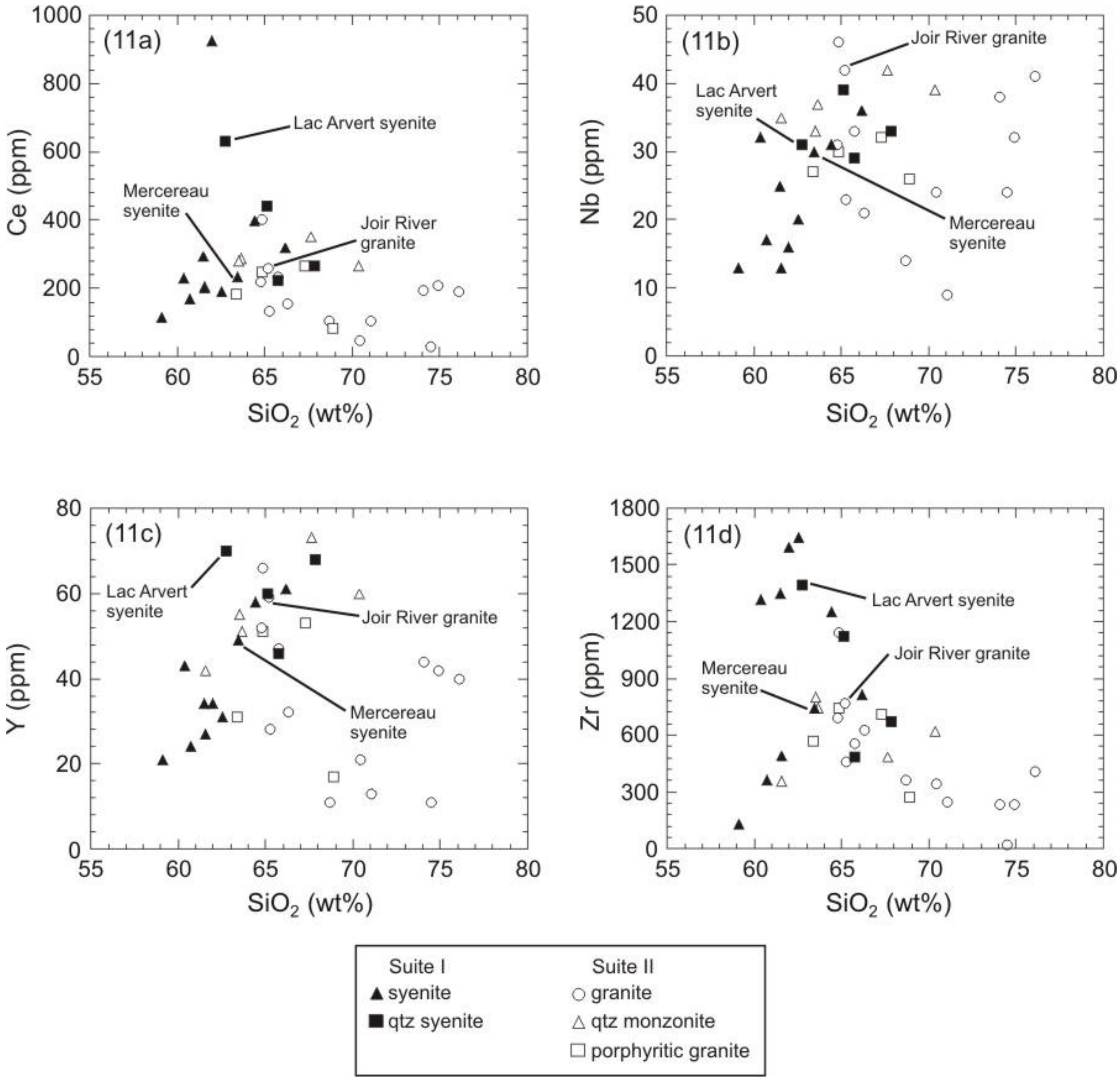

Figure 11. *Bivariate plots of Ce, Nb, Y, and Zr (A to D). In Figures A to C, Suite I samples define linear trends having positive slopes interpreted to be representative of incompatible behaviour. In contrast, Suite II samples in Figures A and D define trends having negative sloping trends. In E and F, Suite I and II samples define single, positive sloping linear trends indicating that Ce, Y, and Nb co-vary in both suites.*

(Figure 10e), for Suite I and II rocks may indicate they have been derived from different sources.

A plot of Rb versus SiO_2 (Figure 10f) illustrates that samples from both suites define positively sloping trends indicating that Rb and SiO_2 are acting incompatibly. Moreover, the linear trends for both suites suggest that Rb and Si are behaving as relatively immobile elements, unaffected by alteration. Thus, Rb and Si can be used as an index of fractionation for Suite I and II samples. Suite I rocks have relatively low Rb and SiO_2, whereas Suite II rocks have relatively high Rb and SiO_2.

A primitive mantle normalized La/Dy versus Rb plot (Figure 12) for Suite I and II rocks indicates a constant trend having a slope of approximately 16.6 (mean $(La/Dy)_N$ value) for both suites. The similarity of slope for both suites may suggest they were derived from a similar source.

Sm–Nd ISOTOPIC ANALYSES

The nature of the source region for intrusive rocks may be characterized by Sm–Nd parent/daughter isotope ratios because the ratios are not modified during partial melting and magma chamber processes, such as fractional crystal-

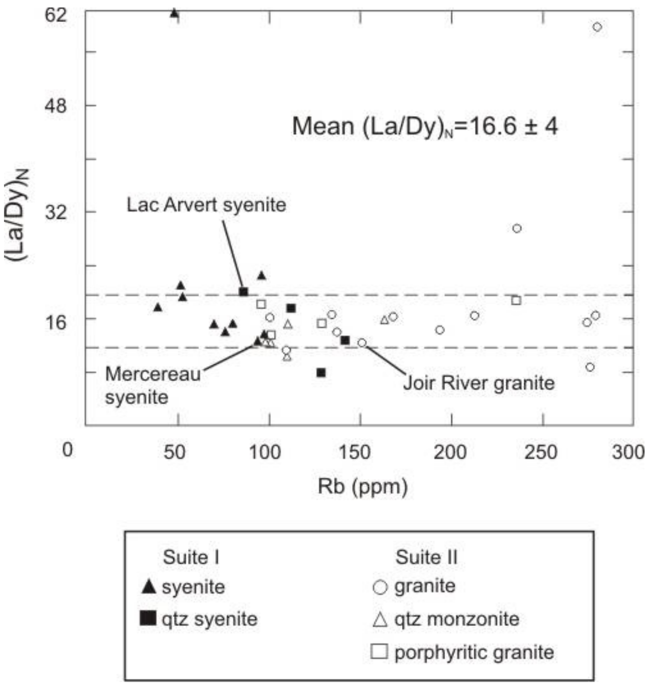

Figure 12. *La/Dy vs Rb diagram, normalized to primitive mantle, showing a relatively constant REE slope for all units. The mean (La/Dy)N value for all of the samples is 16.6 and an "error" of ± 4 (approximately 25% ; expected precision for the ratio) is shown as horizontal lines on the diagram.*

lization and mixing (Rollinson, 1993). Sm and Nd are significantly less mobile then Rb, Sr, Th, U and Pb, and are interpreted to be able to withstand alteration caused by younger events.

Table 2 includes Sm–Nd data for samples of Suite I and II rocks (*see* analytical procedures discussed by Horan, 1998). Epsilon neodymium values for each sample are −5.91 (Suite I) and −4.23 (Suite II). The differences in Sm/Nd ratio and the ϵNd values between the samples are subtle suggesting they may have evolved from a similar source. The $^{143}Nd/^{144}Nd$ (mean of 0.511776), low $^{147}Sm/^{144}Nd$ (mean of 0.10897) value, and negative epsilon neodymium values at the age of emplacement, suggest both rocks were derived from a source containing a significant crustal component.

DISCUSSION

PETROGRAPHIC INTERPRETATION

Generally, Suite I and II rocks are massive, undeformed, and have fresh or weakly recrystallized igneous textures. The textures and field relationships demonstrate that both suites were emplaced very late syn- to post-Grenvillian deformation. Some Suite I and II rocks have a weak foliation, although it is uncertain if the foliation is a primary igneous fabric or if it is tectonic. Emplacement of the Lac Arvert syenite at 982 ± 2 Ma (James *et al*., 2002a) and the Mercereau syenite at 980 ± 5 Ma (*see* Figure 3; S. Kamo and K. Kwok, 2002 unpublished data), postdate emplacement of a recrystallized and foliated granitic aplite dyke (*see* Figure 3; James *et al*., 2002a), which intrudes western MMT rocks, by approximately 15 Ma. Thus, the termination of penetrative Grenvillian deformation in the western MMT is approximately constrained between 995 and 980 Ma. (The granitic aplite dyke is not correlated with Suite I nor Suite II rocks. On the basis of the structural interpretation, the dyke is interpreted to predate emplacement of and be unrelated to Suite I and Suite II rocks.)

Perthitic textures are common in Suite I and II rocks suggesting that low pressure (~3 Kbar), water-saturated conditions prevailed during crystallization. The rocks cooled slowly enough to allow for subsolidus exsolution of feldspar into stable, K-rich and Na-rich alkali feldspars forming perthitic textures. Suite I rocks are interpreted as hypersolvus because they generally contain anhydrous pyroxene. In contrast, Suite II rocks are interpreted as subsolvus due to the presence of hydrous biotite and amphibole.

INTERPRETATION OF THE GEOCHEMICAL DATA

Classification schemes (e.g., Figures 4 to 7) based on major-element compositions are somewhat effective in distinguishing Suite I and II rocks. However, in general, the suites have similar major-element chemistry, and distinctions between the suites are, to some degree, ambiguous (e.g., Figures 8 and 9). Both suites are relatively rich in SiO_2, FeO, Na_2O + K_2O, and depleted in CaO, typical of alkaline or anorogenic, A-type, granitoid rocks.

Bivariate plots of Al, Ti, and Rb, plotted against SiO_2 (Figures 10a, b and f), show similar linear trends for both suites. This may indicate that Suite I and II rocks have common differentiation trends and may have evolved from the same source. This interpretation is consistent with a relatively flat, linear trend for La/Dy vs Rb (Figure 12) for both suites. In addition, both suites are characterized by moderately negative ϵNd values suggesting both include a significant component of older crustal material; i.e., neither Suite I nor Suite II rocks represent juvenile additions to the late-Grenvillian crust.

In contrast to the same-source interpretation presented in the preceding paragraph, variation diagrams that plot Ca, Fe, and Mg against SiO_2 (Figures 10c, d and e) indicate that Suite I and II rocks have different and intersecting trends. The different trends for the suites suggest they may not have evolved from the same source.

Table 2. Nd–Sm isotopic data for samples of Mercereau syenite and Joir River granite

Sample	Field Number	Age	^{147}Sm / ^{144}Nd	^{143}Nd / ^{144}Nd	ϵNd	
Mercereau syenite	DJ-01-1063A	980 Ma	0.10963	0.511776	-5.91	Suite I syenite
Joir River granite	DJ-99-015	964 Ma	0.10897	0.511867	-4.23	Suite II granite

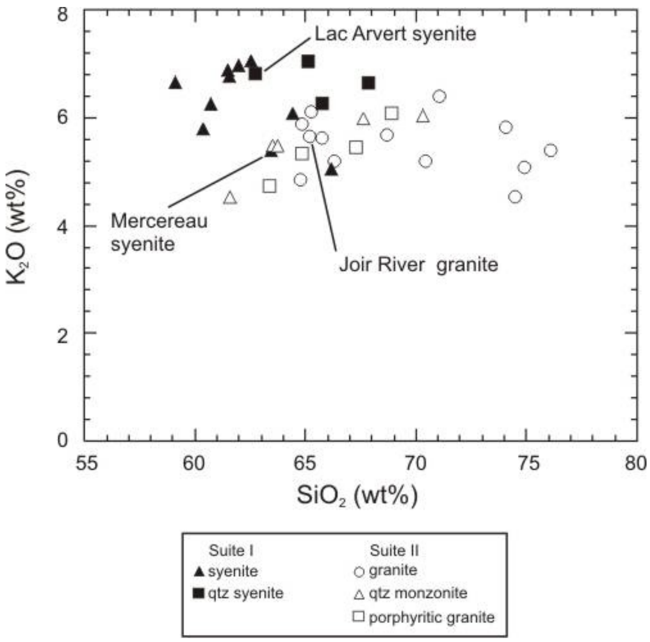

Figure 13. *Bivariate (Harker) diagram showing relatively consistent K_2O contents for Suite I and II rocks for all values of SiO_2. In contrast, Rb contents for Suite I and II rocks (Figure 10F) show a marked increase with increasing SiO_2.*

Potassium and Rb are alkali-metal elements that tend to couple during igneous crystallization. Suite I and II rocks having low and high SiO_2 contents, respectively, are consistently enriched in K (Figure 13). Enrichment of K may be correlated with the abundance of course-grained K-feldspar in both suites, although if the enrichment in K was due strictly to K-feldspar fractionation, then Rb (Figure 10f) should also be enriched in both suites. However, Suite I rocks contain low amounts of Rb relative to Suite II rocks. The “decoupling” feature of the K and Rb data support a two-source model for Suite I and II rocks. The data suggest that Suite I may have evolved from a mantle input source or possibly the lower continental lithosphere. High K and Rb in Suite II rocks are indicative of derivation from a crustal source.

CONCLUSIONS

Interpretation of the available geochemical data is equivocal. Similar major- and trace-element chemistry, and similar Nd-isotopic signatures for Suite I and II rocks suggest that the suites may have evolved from a similar source, co-genetically yet not co-magmatically having a strong crustal component. However, a two-source model should not be discounted. Intersection of trends on major-element Harker diagrams, significant differences in the amount of Rb, and discrepancies in compatible and incompatible element behaviour support a two-source model for the two suites. The data suggest that Suite I rocks may have a lower crustal or mantle source, whereas Suite II rocks may have an upper crustal protolith.

Geochronological data are very limited but suggest, at least for the western MMT, that the mainly clinopyroxene-bearing Suite I rocks were emplaced at ca. 980 Ma and may predate emplacement of the mainly biotite-bearing Suite II rocks by ca. 15 Ma. On the basis of these few data, Suite I rocks are attributed to a 985 to 975 Ma period of early post-tectonic AMCG - mafic suite magmatism (*see* Gower *et al.* 2001; Gower and Krogh, 2002). Suite II rocks are provisionally correlated with a suite of widespread 975 to 955 Ma granitoid plutons in the Pinware terrane (Figure 2) and southern MMT (*see* Gower, 1996; Gower *et al*., 2001; Gower and Krogh, 2002). However, in the Pinware terrane, a model of relatively early, mainly clinopyroxene-bearing syenite dominated magmatism followed by slightly younger, biotite-bearing granite dominated magmatism is probably not valid. The Upper St. Lewis River clinopyroxene-bearing monzonite is 966 ± 3 Ma (Gower and Loveridge, 1987; Gower *et al*., 1993), and the Rivière Bujeault Headwaters clinopyroxene-bearing quartz syenite has an age of 964 ± 5 Ma (Gower *et al*., 1991, 1993). Additional dating is required to test the correlation of age of emplacement and composition.

Generation and emplacement of the late- to post-Grenvillian intrusions may be related to post-orogenic (< ca. 995 Ma) extension. Extension may be due to delamination, or to post-orogenic collapse of over-thickened crust during the late stages of Grenvillian orogenesis.

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APPENDIX 1

Samples and sample locations

Field Number	NTS	UTM East	UTM North	Rock Type	Name	Age
Suite I Samples						
DJ-99-020	13C/8	676097	5802986	monzonite-syenite		
DJ-99-057	13C/8	677609	5796682	cpx syenite		
DJ-00-7036A	13C/4	588630	5786629	granite		
DJ-00-7049	13C/5	583279	5790026	cpx syenite	Lac Arvert syenite	982 ± 2
DJ-00-7050	13C/4	584134	5786380	monzonite		
DJ-01-1027	13D/7	522749	5794277	cpx monzonite		
DJ-01-1042	13D/7	516940	5795862	cpx monzonite		
DJ-01-1060	13D/7	508016	5803196	cpx syenite		
DJ-01-1063A	13D/7	506761	5792930	cpx syenite	Mercereau syenite	980 ± 5
DJ-01-1065	13D/2	507307	5784527	qtz syenite		
DJ-01-1075	13D/7	510145	5801911	cg qtz monzonite		
DJ-01-1114	13D/3	495701	5770446	syenite		
NK-01-3032A	13D/3	492182	5773800	porphyritic syenite		
NK-01-3033	13D/3	493777	5770410	porphyritic cpx syenite		
Suite II Samples						
DJ-99-015	13B/5	296500	5798851	biotite granite	Joir River granite	964 ± 3
DJ-99-047	13C/8	681425	5815040	porphyritic granite		
DJ-00-7003	13C/5	600476	5808565	granite		
DJ-00-7014	13C/4	591127	5763954	granite		
DJ-00-7015	13C/4	588646	5761931	porphyritic granite		
DJ-00-7019	13C/5	594765	5810207	med-cg granite		
DJ-00-9023	13D/9	548383	5820189	granite (peraluminous)		
DJ-00-9057	13D/10	523419	5821936	granite (peraluminous)		
DJ-00-9127	13D/1	566225	5763100	granite		
DJ-00-9131	13D/8	549200	5797850	biotite granite (peraluminous)		
DJ-00-9134	13D/1	556376	5767380	granite (peraluminous)		
DJ-00-9150	13D/8	541611	5811672	biotite-musc granite (peraluminous)		
DJ-01-1001	13D/7	531875	5809275	cg biotite granite (peraluminous)		
DJ-01-1003	13D/7	532158	5790094	cg biotite granite		
DJ-01-1013	13D/7	527328	5794594	cg biotite granite		
DJ-01-1043	13D/7	512710	5804521	cg qtz monzonite		
DJ-01-1047	13D/2	516678	5783531	cg porphyritic biotite granite		
DJ-01-1048	13D/2	517975	5779550	cg qtz monzonite		
DJ-01-1085	13D/6	495998	5795241	fresh qtz monzonite		
DJ-01-1097	13D/3	496035	5787264	fresh biotite granite (peraluminous)		
DJ-01-1098	13D/3	498447	5782415	qtz monzonite		
DJ-01-1121	13D/6	485347	5791575	monzonite		
NK-01-3017	13D/3	497634	5784952	porphyritic biotite qtz monzonite		

APPENDIX 2a

Trace-element geochemical data

Suite I Samples	Cr ppm	Ni ppm	Co ppm	Sc ppm	V ppm	Cu ppm	Pb ppm	Zn ppm	Cd ppm	Mo ppm	As ppm
DJ-99-020	1	4	1	15.90	33	7	28	96	0.10	1	3
DJ-99-057	1	4	3	12.20	36	1	26	80	0.10	1	6
DJ-00-7036A	1	3	1	5.80	27	10	34	58	0.10	1	4
DJ-00-7049	1	4	1	12.00	36	2	34	90	0.10	1	2
DJ-00-7050	1	4	1	9.30	31	4	38	82	0.10	1	2
DJ-01-1027	1	5	4	11.20	44	2	40	95	0.10	1	3
DJ-01-1042	1	5	5	10.10	46	12	42	109	0.10	1	3
DJ-01-1060	3	6	7	9.30	61	4	35	116	0.10	1	5
DJ-01-1063A	1	5	4	9.50	50	2	40	87	0.10	1	2
DJ-01-1065	1	5	4	13.30	34	8	44	98	0.10	1	3
DJ-01-1075	1	4	5	6.40	43	1	41	70	0.10	1	3
DJ-01-1114	1	4	2	10.20	42	1	46	95	0.10	1	2
NK-01-3032A	1	4	4	9.40	43	1	43	109	0.20	1	3
NK-01-3033	2	5	5	9.50	38	1	44	94	0.40	1	4
Suite II Samples											
DJ-99-015	2	4	7	10.90	35	2	35	122	0.10	2	2
DJ-99-047	1	3	2	2.70	23	3	44	45	0.10	1	4
DJ-00-7003	1	2	1	3.00	15	20	43	45	0.10	22	3
DJ-00-7014	1	4	4	8.60	33	1	33	99	0.10	11	5
DJ-00-7015	1	4	4	10.40	37	1	39	101	0.10	1	2
DJ-00-7019	1	2	1	3.10	20	2	46	74	0.10	1	3
DJ-00-9023	2	4	4	3.90	35	23	53	59	0.10	1	3
DJ-00-9057	2	5	5	4.10	50	192	38	61	0.10	1	3
DJ-00-9127	1	6	8	12.60	71	2	35	124	0.10	1	4
DJ-00-9131	2	4	4	5.00	32	13	57	73	0.10	1	4
DJ-00-9134	2	4	5	5.70	25	1	46	97	0.10	1	2
DJ-00-9150	1	1	1	2.90	10	3	41	34	0.10	1	3
DJ-01-1001	3	6	7	8.10	41	5	47	82	0.20	1	2
DJ-01-1003	1	5	5	7.40	45	7	39	92	0.10	1	2
DJ-01-1013	1	4	3	8.20	37	3	40	99	0.10	1	2
DJ-01-1043	1	6	8	9.40	60	7	40	113	0.10	1	2
DJ-01-1047	3	7	8	10.50	70	1	41	105	0.10	1	2
DJ-01-1048	6	9	11	10.10	80	6	38	116	0.10	2	2
DJ-01-1085	2	7	9	11.50	64	4	38	126	0.10	1	3
DJ-01-1097	1	2	1	3.10	13	3	45	58	0.10	2	2
DJ-01-1098	1	4	2	8.30	30	1	43	75	0.10	1	4
DJ-01-1121	14	21	25	15.90	179	113	20	100	0.10	1	5
NK-01-3017	1	3	2	4.70	24	1	42	60	0.10	2	3

APPENDIX 2a

(Continued)

Rb ppm	Ba ppm	Sr ppm	Li ppm	Nb ppm	Zr ppm	Ti ppm	Y ppm	La ppm	Ce ppm	Dy ppm	Be ppm
48.00	419	90	5.80	16	1590	7253	34	604	923	9.10	0.60
39.00	2702	259	5.40	13	132	8011	21	72	117	3.80	0.50
128.00	1107	176	10.00	33	674	4130	68	123	267	14.60	1.50
86.00	1182	165	9.10	31	1392	6600	70	338	630	15.70	1.40
113.00	1163	178	11.10	39	1125	5741	60	232	442	12.30	1.30
76.00	3599	828	9.70	32	1315	7494	43	127	230	8.50	2.00
96.00	3756	740	18.00	25	1350	7127	34	172	293	7.20	1.80
100.00	2210	548	14.90	36	811	6797	61	164	319	11.60	2.70
97.00	2860	689	9.70	30	742	6026	49	128	232	9.30	3.00
81.00	3261	553	7.30	31	1249	6091	58	195	397	12.00	1.50
141.00	2542	551	10.80	29	484	4728	46	112	221	8.20	2.00
71.00	2806	398	5.40	20	1645	7473	31	103	190	6.40	1.30
53.00	4344	758	5.30	13	488	6343	27	117	202	5.70	1.10
52.00	6216	1084	8.00	17	362	6980	24	101	168	4.50	1.20
153.00	1928	357	22.90	42	769	6219	59	143	260	10.80	3.80
231.00	972	219	19.80	26	272	2149	17	50	83	2.50	5.40
275.00	348	87	17.40	38	232	1541	44	112	195	6.80	4.10
130.00	2374	434	16.80	32	712	5051	53	146	267	8.90	3.10
103.00	2578	531	17.20	30	741	5216	51	132	249	9.10	3.20
280.00	308	87	32.20	32	234	1641	42	125	208	7.10	4.90
234.00	1530	497	15.50	9	243	1620	13	60	104	1.90	1.70
192.00	1415	411	13.10	24	345	3101	21	29	49	1.90	3.80
112.00	2316	547	15.80	31	693	7465	52	115	220	9.50	2.90
275.00	1115	307	25.80	14	365	2274	11	64	105	1.00	4.00
136.00	2568	505	20.40	21	629	3223	32	96	154	5.40	4.00
270.00	189	83	34.30	24	20	454	11	15	29	1.60	4.10
166.00	2929	677	21.50	23	462	4654	28	77	132	4.40	2.70
137.00	2187	505	13.60	33	557	5453	47	123	233	8.20	2.60
102.00	2381	580	12.60	46	1139	6533	66	212	402	12.20	2.20
162.00	2119	565	25.40	37	740	6072	51	160	286	9.50	3.30
96.00	2532	793	13.10	27	566	7340	31	103	184	5.30	3.70
110.00	2360	790	17.80	35	358	8148	42	118	206	7.30	3.50
100.00	2435	575	15.40	33	803	7309	55	144	279	10.80	2.80
215.00	430	69	23.00	41	405	2316	40	102	189	5.80	3.40
102.00	2283	414	13.10	42	485	5498	73	186	350	14.00	1.90
10.00	1642	1743	9.50	4	39	4088	13	28	54	0.80	1.00
111.00	1928	372	12.90	39	617	4204	60	134	266	12.10	1.90

APPENDIX 2b

Major-element geochemical data

	SiO_2 wt%	TiO_2 wt%	Al_2O_3 wt%	Fe_2O_3 wt%	FeO wt%	MnO wt%	MgO wt%	CaO wt%	Na_2O wt%	K_2O wt%	P_2O_5 wt%
Suite I Samples											
DJ-99-020	61.95	1.11	17.44	3.99	0.97	0.13	1.16	1.66	4.72	6.98	0.22
DJ-99-057	59.08	1.22	17.85	4.38	1.62	0.10	1.19	2.28	5.72	6.64	0.41
DJ-00-7036A	67.88	0.66	15.35	2.38	0.73	0.04	0.42	0.86	4.57	6.67	0.06
DJ-00-7049	62.72	1.01	16.86	3.74	1.36	0.11	0.70	1.46	5.36	6.86	0.15
DJ-00-7050	65.12	0.85	16.82	3.14	1.08	0.08	0.64	1.22	4.86	7.09	0.12
DJ-01-1027	60.38	1.16	17.88	4.58	1.18	0.10	1.17	2.80	4.57	5.80	0.31
DJ-01-1042	61.49	1.16	18.43	4.66	0.61	0.06	1.21	1.67	3.67	6.89	0.32
DJ-01-1060	66.14	1.05	14.52	5.16	2.20	0.10	1.10	2.51	3.60	5.06	0.36
DJ-01-1063A	63.46	0.88	16.30	4.64	1.79	0.09	0.99	2.77	4.12	5.40	0.40
DJ-01-1065	64.42	0.94	16.08	4.27	1.76	0.11	0.81	2.28	3.98	6.08	0.45
DJ-01-1075	65.74	0.72	15.43	3.56	1.27	0.06	0.76	1.84	3.64	6.29	0.24
DJ-01-1114	62.54	1.14	17.71	4.38	1.63	0.12	0.96	1.76	4.50	7.04	0.24
NK-01-3032A	61.55	1.05	18.01	4.41	1.06	0.10	1.06	2.38	4.30	6.76	0.37
NK-01-3033	60.74	1.03	18.25	4.33	2.11	0.10	1.10	2.53	4.37	6.24	0.33
Suite II Samples											
DJ-99-015	65.17	0.95	15.28	5.06	1.84	0.15	1.19	2.12	3.72	5.64	0.39
DJ-99-047	68.88	0.31	14.57	1.90	0.57	0.03	0.42	0.88	4.46	6.08	0.06
DJ-00-7003	74.05	0.23	13.50	1.37	0.48	0.04	0.25	0.68	3.87	5.82	0.01
DJ-00-7014	67.27	0.77	15.14	4.11	1.38	0.09	0.90	1.81	3.78	5.45	0.35
DJ-00-7015	64.82	0.80	16.22	4.48	1.68	0.10	0.94	2.54	4.85	5.32	0.40
DJ-00-7019	74.90	0.26	12.97	1.64	0.53	0.06	0.22	0.78	4.07	5.08	0.05
DJ-00-9023	71.03	0.28	14.22	2.07	0.82	0.02	0.61	0.79	2.80	6.39	0.15
DJ-00-9057	70.44	0.51	13.66	2.74	1.24	0.04	0.65	1.33	3.10	5.20	0.20
DJ-00-9127	64.75	1.17	15.06	6.06	2.37	0.11	1.22	2.82	3.57	4.85	0.57
DJ-00-9131	68.67	0.39	14.34	2.49	1.17	0.04	0.63	1.28	3.58	5.67	0.14
DJ-00-9134	66.31	0.48	17.28	3.27	1.48	0.09	0.88	1.66	4.40	5.20	0.13
DJ-00-9150	74.51	0.07	13.80	0.59	0.05	0.02	0.17	0.64	3.67	4.54	0.01
DJ-01-1001	65.28	0.72	15.40	3.42	1.47	0.06	0.86	1.98	3.20	6.10	0.25
DJ-01-1003	65.78	0.86	15.03	4.03	1.52	0.06	0.94	2.05	3.71	5.62	0.28
DJ-01-1013	64.82	0.99	16.70	4.11	1.39	0.11	0.83	2.33	4.40	5.88	0.20
DJ-01-1043	63.66	0.99	14.72	5.36	1.81	0.08	1.05	2.41	3.06	5.46	0.55
DJ-01-1047	63.37	1.11	15.35	5.24	2.24	0.09	1.11	3.15	3.69	4.74	0.54
DJ-01-1048	61.58	1.25	15.39	5.77	2.34	0.09	1.25	3.26	3.84	4.54	0.53
DJ-01-1085	63.48	1.16	15.91	5.64	2.34	0.10	1.24	2.52	3.84	5.47	0.46
DJ-01-1097	76.07	0.37	12.57	1.71	0.56	0.06	0.19	0.51	3.56	5.39	0.01
DJ-01-1098	67.66	0.83	15.65	3.15	1.23	0.06	0.59	1.71	4.39	6.00	0.28
DJ-01-1121	53.48	0.72	19.66	7.76	3.69	0.14	3.80	7.34	4.92	1.52	0.47
NK-01-3017	70.38	0.62	14.91	2.50	0.93	0.06	0.49	1.49	3.66	6.02	0.20

APPENDIX 3

Meso Norm (normative) compositions for Suite I and II rocks

Suite I	Qtz	An	Ab	Or	Bt	Hbl	Ap	Il	Mt	Cor	Cc	Hm	R	SU3
DJ-99-020	4.1	4.8	40.0	33.3	13.5	3.3	0.5	1.0	0.0	0.0	0.0	0.0	-0.6	100.0
DJ-99-057	-6.8	-1.8	48.4	35.5	6.1	17.1	1.0	1.2	0.0	0.0	0.0	0.0	-0.6	100.0
DJ-00-7036A	12.7	-0.6	39.0	37.5	3.6	7.3	0.1	0.6	0.0	0.0	0.0	0.0	-0.3	100.0
DJ-00-7049	-0.4	-3.0	45.4	38.3	3.7	15.1	0.4	1.0	0.0	0.0	0.0	0.0	-0.4	100.0
DJ-00-7050	6.0	1.0	40.9	37.4	7.1	7.0	0.3	0.8	0.0	0.0	0.0	0.0	-0.4	100.0
DJ-01-1027	6.0	10.4	38.9	25.1	16.0	2.4	0.7	1.1	0.0	0.0	0.0	0.0	-0.6	100.0
DJ-01-1042	11.1	6.2	31.2	31.1	16.5	0.0	0.8	1.1	0.0	2.7	0.0	0.0	-0.6	100.0
DJ-01-1060	20.2	6.8	30.1	19.7	17.0	5.2	0.8	1.0	0.0	0.0	0.0	0.0	-0.7	100.0
DJ-01-1063A	13.2	8.9	34.8	22.7	15.7	3.6	0.9	0.8	0.0	0.0	0.0	0.0	-0.7	100.0
DJ-01-1065	14.0	7.7	33.5	26.4	16.1	1.1	1.0	0.9	0.0	0.0	0.0	0.0	-0.6	100.0
DJ-01-1075	17.1	6.9	31.1	29.9	13.1	1.2	0.6	0.7	0.0	0.0	0.0	0.0	-0.5	100.0
DJ-01-1114	6.2	7.0	37.5	30.9	17.3	0.0	0.6	1.1	0.0	0.0	0.0	0.0	-0.6	100.0
NK-01-3032A	6.6	9.3	36.2	30.1	16.4	0.0	0.9	1.0	0.0	0.2	0.0	0.0	-0.6	100.0
NK-01-3033	6.9	10.3	36.8	25.7	18.8	0.0	0.8	1.0	0.0	0.5	0.0	0.0	-0.7	100.0
Suite II	Qtz	An	Ab	Or	Bt	Hbl	Ap	Il	Mt	Cor	Cc	Hm	R	SU3
Granite														
DJ-99-015	18.3	7.9	31.2	21.4	20.0	0.0	0.9	0.9	0.0	0.1	0.0	0.0	-0.8	100.0
DJ-00-7003	27.1	1.2	32.7	32.8	2.7	3.4	0.0	0.2	0.0	0.0	0.0	0.0	-0.2	100.0
DJ-00-7019	29.2	0.6	34.3	28.5	2.4	4.8	0.1	0.2	0.0	0.0	0.0	0.0	-0.2	100.0
DJ-00-9023	29.3	3.0	24.0	33.0	8.8	0.0	0.4	0.3	0.0	1.6	0.0	0.0	-0.3	100.0
DJ-00-9057	30.6	5.4	26.6	24.4	11.6	0.0	0.5	0.5	0.0	1.0	0.0	0.0	-0.4	100.0
DJ-00-9127	20.6	10.1	29.7	14.7	23.3	0.0	1.3	1.1	0.0	0.2	0.0	0.0	-0.9	100.0
DJ-00-9131	24.2	5.5	30.9	27.9	10.8	0.0	0.3	0.4	0.0	0.3	0.0	0.0	-0.4	100.0
DJ-00-9134	17.4	7.3	37.0	22.4	13.9	0.0	0.3	0.4	0.0	1.7	0.0	0.0	-0.5	100.0
DJ-00-9150	35.1	3.2	31.7	26.1	2.1	0.0	0.0	0.1	0.0	1.7	0.0	0.0	-0.1	100.0
DJ-01-1001	20.1	8.3	27.5	28.2	14.6	0.0	0.6	0.7	0.0	0.5	0.0	0.0	-0.5	100.0
DJ-01-1003	18.8	7.2	31.6	24.8	14.8	2.0	0.7	0.8	0.0	0.0	0.0	0.0	-0.6	100.0
DJ-01-1013	10.9	6.5	36.8	27.6	11.4	5.9	0.5	0.9	0.0	0.0	0.0	0.0	-0.5	100.0
DJ-01-1097	33.3	2.3	29.9	28.3	5.8	0.2	0.0	0.4	0.0	0.0	0.0	0.0	-0.2	100.0
Monzonite														
DJ-01-1043	21.6	8.5	26.3	20.9	20.5	0.0	1.3	1.0	0.0	0.7	0.0	0.0	-0.8	100.0
DJ-01-1048	15.6	10.0	32.8	15.4	20.1	4.6	1.3	1.2	0.0	0.0	0.0	0.0	-0.8	100.0
DJ-01-1085	15.8	9.3	32.0	18.8	22.5	0.0	1.1	1.1	0.0	0.2	0.0	0.0	-0.8	100.0
DJ-01-1098	15.2	3.8	36.7	29.8	9.0	4.5	0.6	0.8	0.0	0.0	0.0	0.0	-0.4	100.0
NK-01-3017	23.2	6.0	30.7	29.6	9.7	0.0	0.5	0.6	0.0	0.1	0.0	0.0	-0.4	100.0
Porphyritic Granite														
DJ-99-047	16.8	-0.5	38.6	35.5	2.0	7.4	0.1	0.3	0.0	0.0	0.0	0.0	-0.2	100.0
DJ-00-7014	21.4	6.6	31.8	22.9	15.8	0.0	0.8	0.7	0.0	0.6	0.0	0.0	-0.6	100.0
DJ-00-7015	9.6	3.4	40.4	25.2	9.7	10.5	0.9	0.8	0.0	0.0	0.0	0.0	-0.6	100.0
DJ-01-1047	18.0	10.5	31.2	16.8	19.4	2.6	1.3	1.0	0.0	0.0	0.0	0.0	-0.8	100.0

List of Abbreviations:

- Qtz - Quartz
- An - Anorthite
- Ab - Albite
- Or - Orthoclase
- Bt - Biotite
- Hbl - Hornblende
- Ap - Apatite
- Il - Ilmenite
- Mt - Magnetite
- Cor - Corundum
- Cc - Calcite
- R - Rutile
- Hm - Hematite