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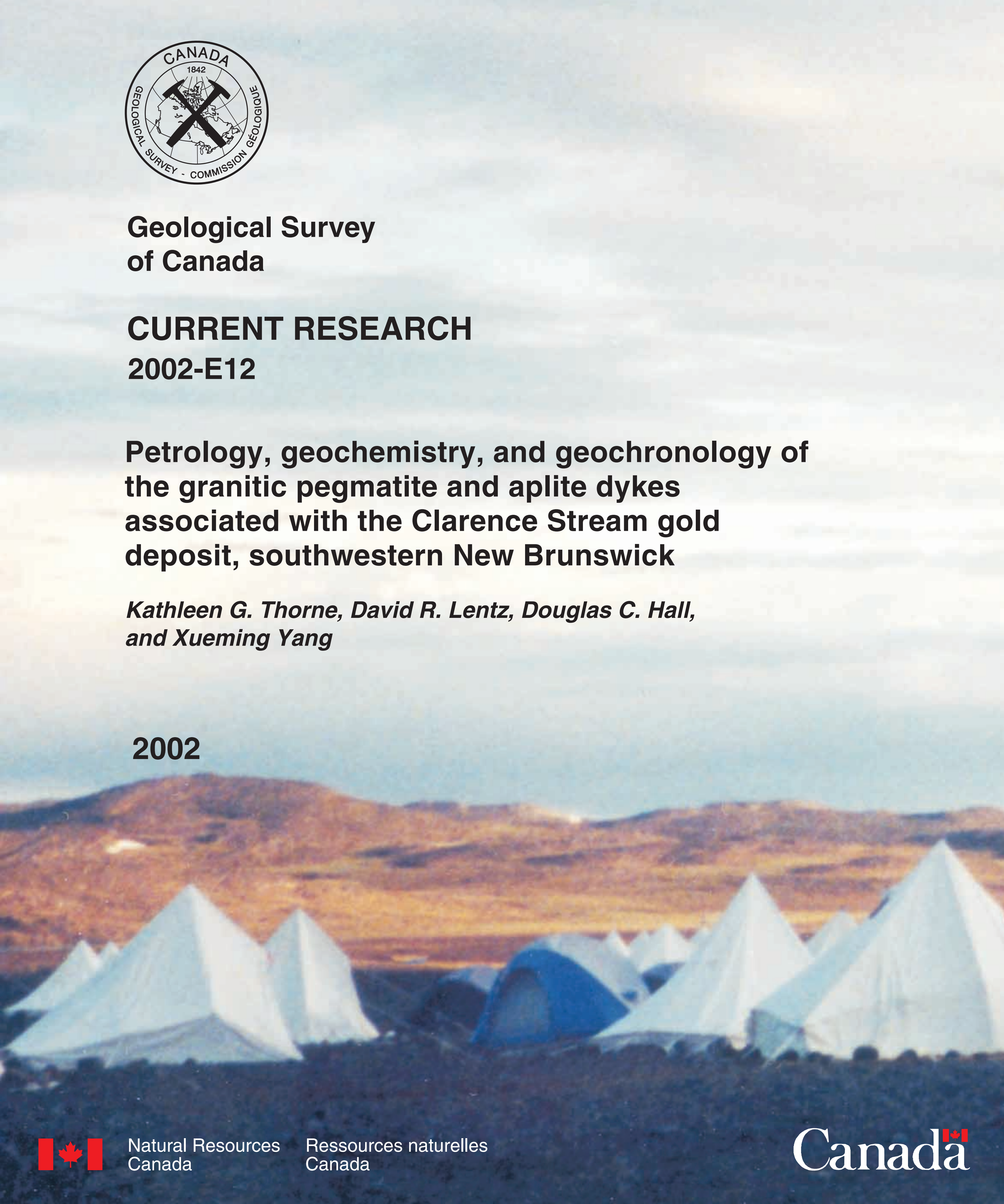

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*Kathleen G. Thorne, David R. Lentz, Douglas C. Hall,
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Petrology, geochemistry, and geochronology of the granitic pegmatite and aplite dykes associated with the Clarence Stream gold deposit, southwestern New Brunswick[1]

Kathleen G. Thorne, David R. Lentz, Douglas C. Hall, and Xueming Yang

Thorne, K.G, Lentz, D.R., Hall, D.C., and Yang, X., 2002: Petrology, geochemistry, and geochronology of the granitic pegmatite and aplite dykes associated with the Clarence Stream gold deposit, southwestern New Brunswick; Geological Survey of Canada, Current Research, 2002-E12, 13 p.

Abstract: Granitic dykes intimately associated with auriferous sulphide-bearing quartz veins crosscut metasedimentary and metagabbroic units at the Clarence Stream gold deposit in southwestern New Brunswick. Aplitic, granophyric, pegmatitic, and leucogranitic dykes of granitic composition (SiO_2 = 66.6–81.4 wt. %) are weakly metaluminous to peraluminous (A/CNK = 0.96–1.1). Low Nb, Ta, La, Y, and Yb with high Rb contents indicate a syncollisional (S-type) or fractionated volcanic-arc (I-type) affinity. Electron microprobe dating of monazite within a pegmatitic sample yielded a crystallization age of 390 ± 8 Ma (high Th+U) and another population (low Th+U) that coincides with Taconic orogenic events (449 ± 10 Ma). Low Sb, W, Mo, and Bi concentrations along with the coincident age of emplacement and trace-element systematics favour a fractional crystallization relationship with the main phase of the Magaguadavic Granite during late-stage vapour saturation. The spatial and temporal relationship to gold-bearing sulphide-quartz veins is consistent with an intrusion-related genetic model.

Résumé : Des dykes granitiques étroitement associés à des filons de quartz aurifère sulfuré recoupent des unités métasédimentaires et métagabbroïques au gisement aurifère de Clarence Stream, dans le sud-ouest du Nouveau-Brunswick. Des dykes aplitiques, granophyriques, pegmatitiques et leucogranitiques de composition granitique (SiO_2 = 66,6 à 81,4 % poids) sont légèrement métalumineux à hyperalumineux (A/CNK = 0,96 à 1,1). Les faibles teneurs en Nb, Ta, La, Y et Yb combinées aux teneurs élevées en Rb indiquent qu'ils sont contemporains de la collision (type S) ou associés à un arc insulaire fractionné (type I). La datation par microsonde électronique de monazite provenant d'un échantillon pegmatitique donne un âge de cristallisation de 390 ± 8 Ma (teneur élevée en Th + U) et un âge pour une autre population (faible teneur en Th + U) qui coïncide avec l'âge d'événements orogéniques taconiques (449 ± 10 Ma). Les faibles concentrations de Sb, de W, de Mo et de Bi, ainsi que l'âge coïncident de mise en place et l'aspect systématique des éléments traces font pencher en faveur de la cristallisation fractionnée de la phase principale du Granite de Magaguadavic pendant la phase tardive à saturation en vapeur. Le rapport spatial et temporel avec des filons de quartz aurifère sulfuré est compatible avec un modèle génétique associé à des intrusions.

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INTRODUCTION

The Clarence Stream gold deposit (Fig. 1) occurs along the northwestern margin of the Saint George Batholith, in the contact aureole of the Magaguadavic Granite, within numerous northeast-trending, brittle-ductile, gold-bearing shear zones (Thorne and Lentz, 2001a). Sheeted quartz veins and earlier gabbro dykes and sills occupy these zones of high strain within hornfelsed metasedimentary units that trend parallel to the regional structure. These shear zones are probable splays to the syntectonic Sawyer Brook Fault, which locally represents the tectonostratigraphic boundary between the peri-Gondwanan and Gander terranes (Fyffe et al., 1999).

Granitic pegmatite and aplite dykes crosscut Silurian metasedimentary rocks and East Branch Brook metagabbroic intrusions (Thorne and Lentz, in press) that intrude the shear zones and are, in part, deformed by them. The shear-zone-bounded granitic dykes transitionally evolve into sulphide-mineralized dykes, then into sulphide-bearing quartz veins in outcrop. Therefore, their spatial and temporal association with gold-bearing sulphide-quartz veins support an intrusion-related genetic model (*see* Thompson et al., 1999; Lang et al., 2000; Thompson and Newberry, 2001; Lang and Baker, 2001) for this particular gold deposit.

Several samples of crosscutting dyke material (both mineralized and barren) were obtained to develop a better understanding of the relationship of gold mineralization to the magmatic-hydrothermal Sn-W-Mo-Bi mineralizing processes related to certain granite bodies in the Clarence Stream area (Butt, 1976; Lentz et al., 1988; McLeod, 1990; Taylor, 1992; Lentz and Gregoire, 1995; Whalen, 1996). In addition, the petrochemical attributes of these dykes are compared to

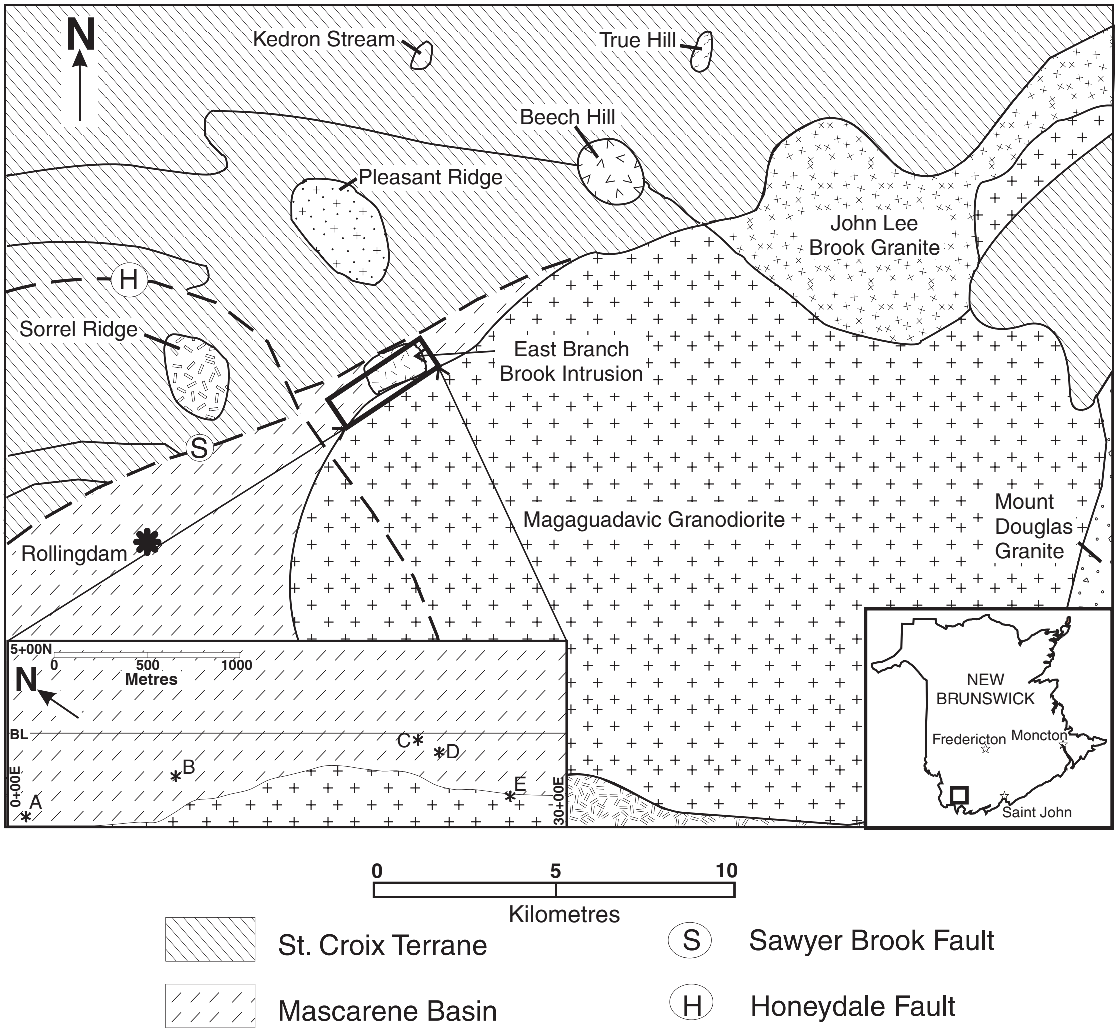

Figure 1. *Regional geology of the Clarence Stream area on the northwestern margin of the Saint George Batholith. The inset illustrates the general location of the Clarence Stream gold deposit and the sample locations discussed within this paper represented by A (KM-00-162), B (KT-01-03), C (KT-01-40, KT-01-40A, KT-01-41, KT-01-41A), D (KT-01-38A, KT-01-39) and E (KT-01-48, KT-01-49). Geology compiled from maps produced by McLeod (1990) and New Brunswick Department of Natural Resources and Energy (2000).*

those of other granitic plutons in the region and plutons associated with gold deposits elsewhere in order to constrain the origin and timing of gold mineralization in the region (Fig. 1).

REGIONAL SETTING

The Clarence Stream gold deposit is situated proximal to the suture zone between the St. Croix Terrane of the Gander Zone to the northwest and the Late Neoproterozoic New River Terrane of peri-Gondwanan affinity (Fyffe et al., 1999) to the southeast. Obscuring the boundary between the two terranes are Silurian sedimentary and volcanic sequences of the Mascarene Basin and Late Silurian to Late Devonian intrusions (e.g. Thomas and Willis, 1989; McLeod, 1990; Fyffe et al., 1999). The Mascarene Basin is separated from the St. Croix Terrane to the northwest by the postsedimentary Sawyer Brook Fault (Fyffe et al., 1999). Conglomerate belonging to the Oak Bay Formation marks the lower boundary of the Silurian section within the Mascarene Basin (Fyffe et al., 1999).

Intrusions in the Clarence Stream area comprise the Saint George Batholith, the northwestern portion of which is formed by the magnetite-bearing, I-type Magaguadavic Granite (McLeod, 1990). The Clarence Stream gold deposit is situated within the contact aureole of this megacrystic intrusion near its northwestern contact with the Silurian metasedimentary sequence. Several Sn-W-Mo-bearing evolved granitic satellite plutons, referred to as the 'Pomeroy Intrusive Suite' (McLeod, 1990), are located north of the gold deposit (Fig. 1).

LOCAL GEOLOGY

Metasedimentary units ranging from Ordovician (Cookson Group) to Silurian (Mascarene Group) and minor felsic and mafic intrusions host the Clarence Stream gold deposit located near Rollingdam, in southwestern New Brunswick. The metasedimentary units are cut by numerous felsic intrusions that produced episodes of hydrothermal alteration and cordierite-muscovite-biotite-grade contact metamorphism. Northeast-trending, brittle-ductile shear zones are prevalent in the area and locally produce a penetrative foliation.

Volcaniclastic metasedimentary rocks belonging to the Waweig Formation of the Mascarene Group are the predominant rock type associated with the Clarence Stream gold deposit. Metagabbro bodies that constitute the East Branch Brook Intrusion (Thorne and Lentz, in press) occupy the Sawyer Brook Fault (Fig. 1).

Trenching uncovered a series of aplitic to granophyric, locally pegmatitic dykes and larger bodies of aplitic to medium- and coarse-grained leucogranite. All crosscut foliated Silurian metagabbro (Fig. 2a), metasediments (Fig. 2b), and a leucocratic granitic gneiss or schist (Fig. 2c) along the northernmost contact of the Magaguadavic Granite. The smaller dykes have been transposed into the foliation.

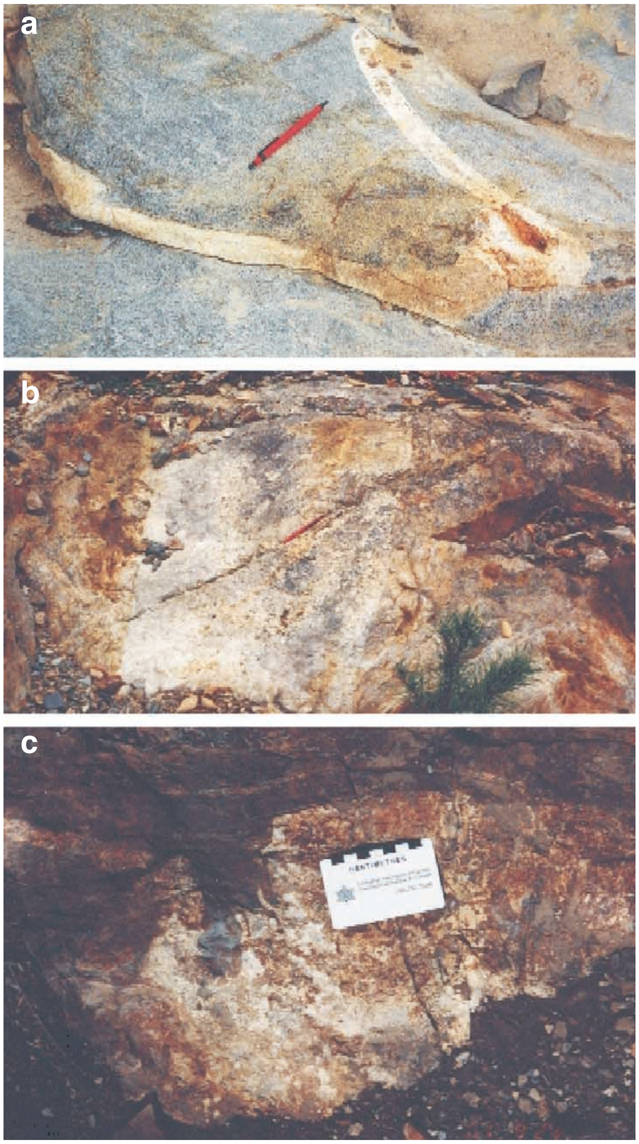

Figure 2. a*) Graphic texture within a deformed pegmatitic dyke (limonitic sulphide-bearing quartz in the core and alkali feldspar along the margin) hosted by a foliated gabbro body.* ***b****) Discordant intrusive contact between the sheared metasedimentary host rocks (Waweig Formation) and the coarse-grained leucogranite as seen in the central portion of the property.* ***c****) Aplite dyke containing minor mineralization and spessartine garnet crosscutting a sheared granitic host rock. This outcrop is located along the east side of the north-trending access road on the eastern edge of the property. Note the pencil for scale (13 cm long).*

LOCAL FELSIC INTRUSIONS

The Magaguadavic Granite belonging to the South Oromocto Intrusive Suite of the Saint George Batholith (McLeod, 1990; Fig. 1) underlies the southern portion of the Clarence Stream claim group. The younger plutons of the Saint George

Batholith, referred to as the 'Pomeroy Intrusive Suite', are located to the north and consist of the Sorrel Ridge, Pleasant Ridge, Beech Hill, and True Hill plutons (McLeod, 1990). Miarolitic cavities, aplite, graphic texture, and rapakivi texture are common within these granitic intrusions, indicating that they crystallized under water-saturated conditions near their intrusive margins. Thomas and Willis (1989) concluded from their gravity survey that intrusions underlie the entire region at relatively shallow depths.

Magaguadavic Granite

The Magaguadavic Granite is a metaluminous to slightly peraluminous, I-type, magnetite-bearing, medium- to coarse-grained porphyritic to megacrystic intrusion (McLeod, 1990). The main mass of the intrusion is comprised of a coarse-grained phase (Magaguadavic^1) that is crosscut by a finer grained, more evolved phase (Magaguadavic^2) with associated mineralization (McLeod, 1990). Geophysical surveys indicate that this intrusion is 7.6 km thick in the west and shallows eastward to a thickness of 4 km (Thomas and Willis, 1989). Dating of biotite within the oldest phase of this unit yielded a ^{40}Ar/^{39}Ar age of 400 ± 4 Ma (McLeod, 1990). A younger U-Pb (zircon) age of 396 ± 1 Ma was obtained by Bevier (1990).

This intrusion contains plagioclase, potassium feldspar, quartz, amphibole, titanite, and altered biotite (McLeod, 1990). Rapakivi texture of the potassium feldspars is common near the intrusive contacts with sedimentary country rocks (McLeod, 1990). It crystallized at a relatively high P(H_2O) (300 MPa) compared to the higher level (<100 MPa) intrusions of the Pomeroy Intrusive Suite (McLeod, 1990); the inferred temperature of crystallization is between 750°C and 680°C at 200 to 300 MPa. Geochemical data for the Magaguadavic phase is consistent with a postcollisional granitic association derived by partial melting of a Late Neoproterozoic basement (McLeod, 1990; Whalen et al., 1996). Numerous gold occurrences have been reported in the vicinity of the Saint George Batholith (Ruitenberg et al., 1990) that are thought to be related to these Devonian intrusions (Ruitenberg, 1967; McLeod and McCutcheon, 2000). McLeod (1990) documented gold-bearing veins emanating directly from the intrusion northeast of Clarence Stream.

Pleasant Ridge Granite

Chemically, the Pomeroy Intrusive Suite, of which the Pleasant Ridge Granite is a member, is similar to the weakly peraluminous Mount Douglas Granite (Lentz et al., 1988; McLeod, 1990) to the east, which is genetically related to the Mount Pleasant and True Hill tin-tungsten-molybdenum-bismuth deposits. These plutons are considered to be post-Acadian granite bodies that are epizonal to mesozonal (Butt, 1976; Ruitenberg et al., 1977) with associated tin-tungsten mineralization. The Pleasant Ridge granitic stock has yielded a ^{40}Ar/^{39}Ar muscovite age of 361 Ma (Taylor, 1992), which is much younger than the Magaguadavic intrusion. It is described as a high-silica, fluorine-rich, lithian mica-topaz-bearing granite that has a significant amount of associated tin-bearing microgranite (Taylor, 1992). Also, proximal mineralized shear zones immediately southeast of the stock contain tin minerals as well as base-metal sulphides, hematite, and magnetite (Ruitenberg and Fyffe, 1982; Taylor, 1992). The Pleasant Ridge Granite is more highly evolved and has Sr isotopic signatures that are indicative of minor assimilation of sedimentary crustal material (Butt, 1976; Lentz et al., 1988). The magma responsible for the generation of this pluton is interpreted to contain more water than magmas of the nearby Beech Hill and Sorrel Ridge stocks (Butt, 1976), implying the potential for greater amounts of associated hydrothermal activity.

Sorrel Ridge Granite

The Sorrel Ridge pluton is a porphyritic granite pluton that intrudes Ordovician metasedimentary rocks. It is classified as Late Devonian (McLeod et al., 1998) and is a component of the Pomeroy Intrusive Suite of the Saint George Batholith. The surrounding country rocks exhibit andalusite-cordierite-grade hornfelsing due to contact metamorphism (Butt, 1976; Fyffe, 1997). Butt (1976) and Lentz et al. (1988) demonstrated that the Sorrel Ridge Granite is chemically similar to the Beech Hill series that were emplaced at temperatures of 700°C to 750°C at a pressure of 100 ± 50 MPa.

DYKE AND GEOCHEMICAL SAMPLE DESCRIPTIONS

Granitic dykes in the metagabbro coexist with auriferous, limonitized (weathered sulphides) quartz veins. The texture of these narrow (1 cm to <1 m) dykes ranges from aplitic to granophyric to pegmatitic with feldspar being the predominant mineral. These dykes were locally sheared during ductile transposition and folded within the gabbro body (Fig. 2a).

Samples taken for geochemical analysis are placed into four categories depending on their field descriptions, including the following:

1. Leucocratic, creamy orange, medium- to coarse-grained, feldspar-rich granite that contains quartz and minor mafic minerals (samples KM-00-162 and KT-01-03).
2. Aplite dykes ranging from medium pink to light pink-grey, with coarser grained margins consisting of a feldspar-rich matrix with euhedral quartz crystals. These dykes crosscut metagabbro and megacrystic granite bodies. Minor amounts of biotite, spessartine garnet, and mineralization (stibnite) are found in selected samples (samples KT-01-38A, KT-01-39, KT-01-41, KT-01-41A, and KT-01-48).
3. Granophyre dykes consisting of alkali-feldspar and quartz exhibiting a graphic texture, which grade laterally into sulphide-bearing (pyrite, pyrrhotite, sphalerite) limonitic quartz veins (samples KT-01-40 and KT-01-40A).

4. Megacrystic granite with large potassium-feldspar crystals within a matrix consisting of equal proportions of potassium feldspar, quartz, and biotite. This unit is an outcrop of the Magaguadavic Granite that is crosscut by aplite (sample KT-01-49).

ANALYTICAL TECHNIQUES

Ten granitic samples were taken from selected trench exposures and crushed and pulverized at the University of New Brunswick using a mild steel swing mill. Polished thin sections were prepared for petrographic and analytical work. The samples were sent for inductively coupled plasma emission spectroscopy (ICP-ES), inductively coupled plasma mass spectroscopy (ICP-MS), and instrumental neutron activation analysis (INAA) analysis at Activation Laboratories Limited (Ancaster, Ontario) to analyze their trace-element content. Major and selected trace elements were analyzed by X-ray fluorescence spectroscopy (XRF) (Philips PW2400) on fused discs and pressed-powder discs at the University of Ottawa. Table 1 presents the results of the geochemical analyses.

GEOCHEMISTRY

In order to establish a genetic link between the granitic dykes and the surrounding felsic intrusions, analytical data from the dykes and average compositions from the local intrusions were examined. The data for the Pleasant Ridge (Taylor, 1992), Sorrel Ridge (Whalen et al., 1996), Beech Hill, True Hill and Mount Pleasant (Butt, 1976; Lentz et al., 1988) and Magaguadavic (McLeod, 1990) intrusions were compiled for comparative purposes.

On the mesonormative QAP diagram (Fig. 3) of LeMaitre et al. (1989), the dyke samples fall within three main fields, i.e. granite, granodiorite, tonalite/trondhjemite. Aplite and leucogranite fall within the granite field whereas the megacrystic sample plots as a granodiorite. Alteration of the granophyric samples may be responsible for their falling within the tonalite–trondhjemite field. All other local intrusions plot within the granite field with the exception of the megacrystic sample and the Magaguadavic^1 intrusion.

Silica variation diagrams (Fig. 4) illustrate the differences between the Magaguadavic^1 phase, the Magaguadavic^2 phase, and other intrusive phases in the region, as well as the decreasing abundance of Al_2O_3, CaO, $Fe_2O_3^T$, and MgO with increasing SiO_2 reflecting fractionation. The Clarence Stream dykes range from 66.6 to 81.4 SiO_2 weight per cent with the greatest variability related to the hydrothermally altered and mineralized leucogranite. The higher CaO, $Fe_2O_3^T$, and MgO values are consistent with a granodioritic composition for the Magaguadavic intrusion. The Magaguadavic^1 phase has much higher TiO_2 (0.58 wt. %) and P_2O_5 (0.18 wt. %) than the other phases ($TiO_2 \approx 0.08$ wt. % and $P_2O_5 \approx 0.01$ wt. %). Felsic intrusions associated with the Clarence Stream gold deposit are very weakly metaluminous to weakly peraluminous (A/CNK = 0.96–1.1). The Na_2O and K_2O contents are consistent with a subalkaline composition, although K/Na ratios vary considerably due to alkali element exchange reactions, in particular albitization.

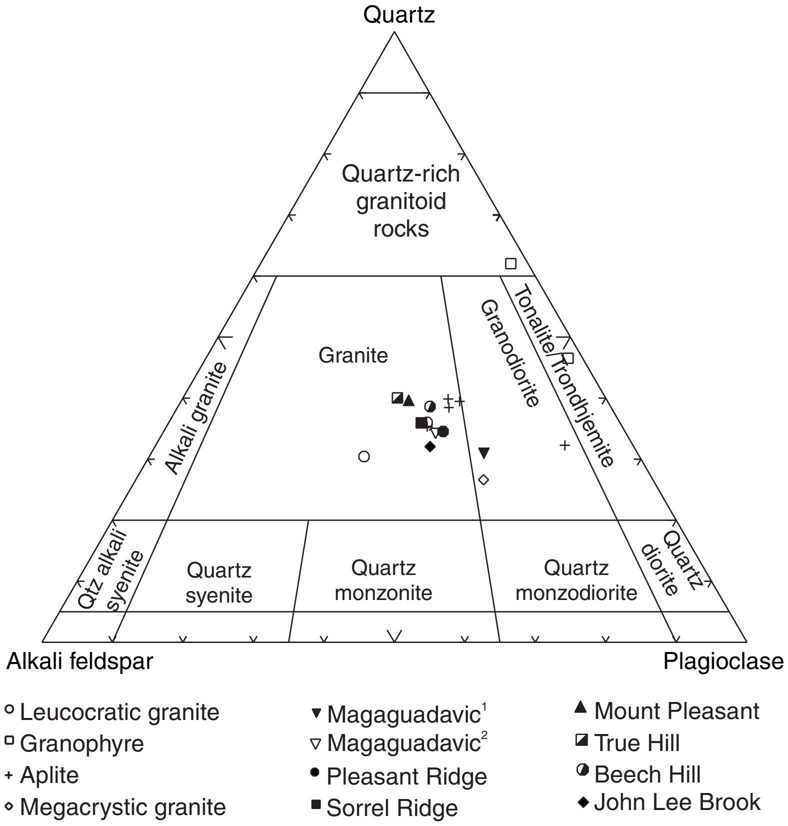

Figure 3.

Mesonormative (QAP) ternary classification diagram for plutonic rocks (LeMaitre et al., 1989) illustrating the composition of the Clarence Stream granitic dykes and local felsic plutons in the region. True Hill, Beech Hill, and Mount Pleasant (Lentz et al., 1988); Pleasant Ridge (Taylor, 1992); Magaguavavic and John Lee Brook (McLeod, 1990); Sorrel Ridge (Whalen, 1996).

Table 1. Analytical data from the Clarence Stream dykes and average geochemical compositions from surrounding felsic intrusions.

Sample	KM-00-162^{+}	KT-01-03^{+}	KT-01-38A*	KT-01-39*	KT-01-40$^{\wedge}$	KT-01-40A$^{\wedge}$	KT-01-41*	KT-01-41A*	KT-01-48*	KT-01-49$^{\sim}$	Average
SiO_2	66.57	75.73	75.43	75.33	75.76	81.37	75.48	73.31	76.48	66.82	75.05
TiO_2	0.12	0.06	0.10	0.04	0.13	0.05	0.04	0.09	0.08	0.60	0.08
Al_2O_3	12.62	12.68	12.52	12.04	12.47	8.98	12.66	13.82	12.52	14.95	12.26
Fe_2O_3	0.96	0.71	1.52	1.70	2.29	2.04	1.03	1.78	0.69	3.41	1.41
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.02	0.01	0.04	0.06	0.02	0.02	0.02	0.03	0.02	0.07	0.03
MgO	0.31	0.03	0.07	0.01	0.35	0.10	0.02	0.15	0.04	1.28	0.12
CaO	0.64	0.65	0.79	0.45	2.41	1.62	0.54	2.07	0.56	2.76	1.08
Na_2O	2.79	3.84	4.00	3.97	4.32	3.04	3.93	5.65	4.09	3.86	3.96
K_2O	5.93	4.53	3.45	3.63	0.50	0.46	4.57	1.27	3.82	3.97	3.13
P_2O_5	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.17	0.01
Total	90.1	98.3	98.0	97.3	98.4	97.7	98.4	98.3	98.4	98.1	97.2
LOI		0.4	0.7	0.5	1.2	1.1	0.5	0.7	1.1	1.2	0.8
Cr	3	6	3	3	13	10	3	9	3	18	6
Ni	11	8	7	7	20	13	8	7	4	13	9
Co	1	1	1	2	52	5	2	3	1	8	7
Sc	3	2	2	2	4	1	2	3	1	8	2
V	46	3	6	1	27	10	<2	18	4	59	14
Cu	8	25	18	22	30	67	18	21	6	16	24
Pb	53	135	28	48	12	14	55	40	46	38	48
Zn	14	15	25	24	31	12	13	34	13	59	20
Bi	1.3	2.5	0.6	0.9	1.5	0.3	0.2	0.8	0.4	0.5	0.9
Cd	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
In	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Sn	<1	1	<1	1	<1	<1	<1	<1	<1	<1	1
W	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Mo	5	<1	5	5	1	2	3	5	1	2	3
S	0.02	0.00	0.00	0.01	0.04	0.19	0.00	0.00	0.00	0.00	0.03
As	37	16	26	76	1000	17	10	15	8	2	134
Se	<0.1	1.4	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	0.4	0.8
Sb	140.0	3.7	1.8	2.0	6.4	2.0	0.9	3.9	0.8	1.6	17.9
Te	<0.1	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.3
Ag	0.2	0.5	0.2	0.4	0.2	0.2	0.3	0.5	0.2	0.2	0.3
Ir	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Au	85	<2	<2	<2	41	<2	4	5	<2	1	34
Hg	0.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4
Rb	319	193	170	297	72	59	400	111	259	158	209
Cs	8	4	6	4	3	2	5	1	6	5	4
Ba	130	25	25	25	270	25	25	25	25	580	64
Sr	62	40	52	3	184	124	22	119	24	412	70
Tl	1.7	1.3	1.0	1.6	0.4	0.4	1.9	0.6	1.3	1.0	1.1
Ga	0	15	16	16	23	16	15	18	16	16	15
Ta	2.0	<0.5	1.9	<0.5	<0.5	<0.5	1.8	<0.5	1.4	2.3	1.8
Nb	12.0	7.0	9.3	12.4	13.0	5.3	12.8	7.2	11.8	43.0	10.1
Hf	2	3	2	5	2	3	5	9	3	6	4
Zr	43	37	47	113	30	19	62	102	57	239	56
Ti	2000	354	617	246	773	276	264	546	498	3579	397
Y	3	4	3	1	3	2	2	6	2	20	3
Th	22.3	26.5	31.7	35.5	5.7	3.2	21.6	23.6	19.5	25.0	21.1
U	11.8	11.6	6.1	17.4	4.1	3.3	9.0	14.3	8.8	3.9	9.6
La	15.3	24.3	21.7	14.2	11.6	8.7	24.0	35.1	48.9	52.8	22.6
Ce	14	24	23	13	16	12	22	45	29	89	22
Nd	11.0	6.0	2.5	2.5	2.5	2.5	2.5	9.0	6.0	26.0	4.9
Sm	0.4	0.3	0.4	0.8	0.5	0.4	0.4	1.5	0.2	4.9	0.5
Eu	0.3	0.1	0.2	0.1	0.8	0.4	0.2	0.6	0.1	1.1	0.3
Tb	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Yb	0.7	0.8	0.8	0.7	0.3	0.2	0.7	1.4	0.4	2.0	0.7
Lu	0.12	0.13	0.15	0.16	0.03	0.03	0.12	0.23	0.07	0.30	0.11
Br	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Be	2	5	7	4	54	48	6	12	6	4	16

Notes: Symbols refer to leucogranite($^{+}$), aplite(*), granophyre($^{\wedge}$), and megacrystic granite ($^{\sim}$). Major elements, LOI, and S (wt. %), Au (ppb), and remaining trace elements (ppm). < is less than designated detection limit.

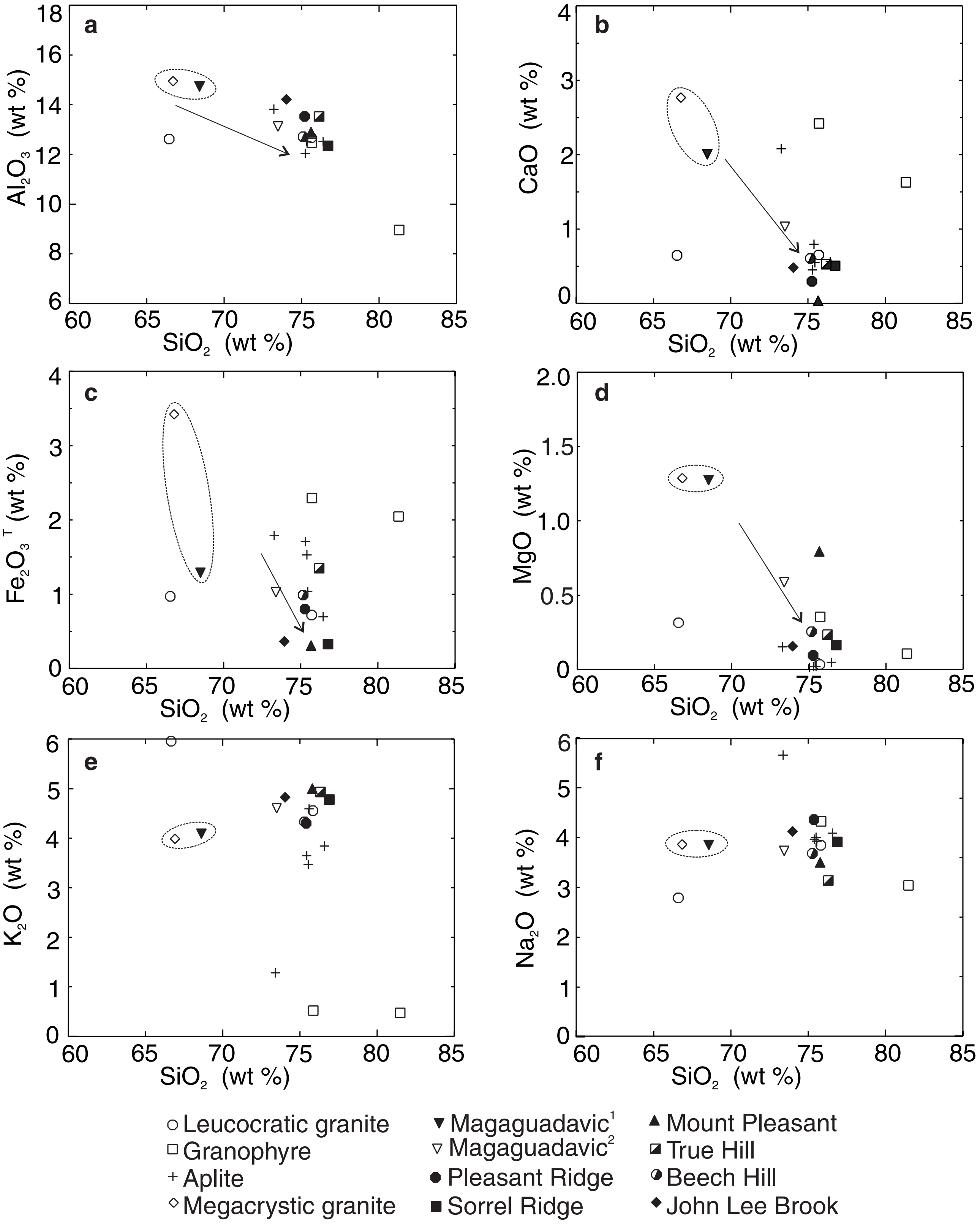

Figure 4. *Silica variation diagrams for* ***a****)* Al_2O_3*,* ***b****) CaO,* ***c****)* $Fe_2O_3^T$*,* ***d****) MgO,* ***e****)* K_2O*, and* ***f****)* Na_2O *for the Clarence Stream granitic dykes as well as average compositions from regional felsic intrusions. The solid arrow represents approximate fractionation paths. The fields represent the two megacrystic Magaguadavic samples from the initial phase of the intrusion.* See *Figure 3 for sample references.*

These granitic dykes have high Rb (210 ppm) and low Ba (64 ppm) and Sr (70 ppm) contents relative to the Magaguadavic[1] Granite. They have relatively low Nb and Y (Yb) (Fig. 5a) with moderate Ta (< 0.5 to 2 ppm) and high Rb contents (Fig. 5b), consistent with a syncollisional (S-type) affinity, although overlapping with a fractionated volcanic arc (I-type) affinity. Using the Batchelor and Bowden (1985) major-element discrimination diagram (not shown), the dyke samples fall along the syncollisional to postorogenic fields. In contrast, the Mount Pleasant, True Hill, Beech Hill, Pleasant Ridge, and Sorrel Ridge intrusions fall in the within-plate (A-type) granitoid field consistent with the findings of Whalen et al. (1996). Both phases of the Magaguadavic Granite, along with the megacrystic sample and the John Lee Brook Granite consistently fall within the volcanic-arc (I-type) field, indicating the presence of hornblende and high magnetite content.

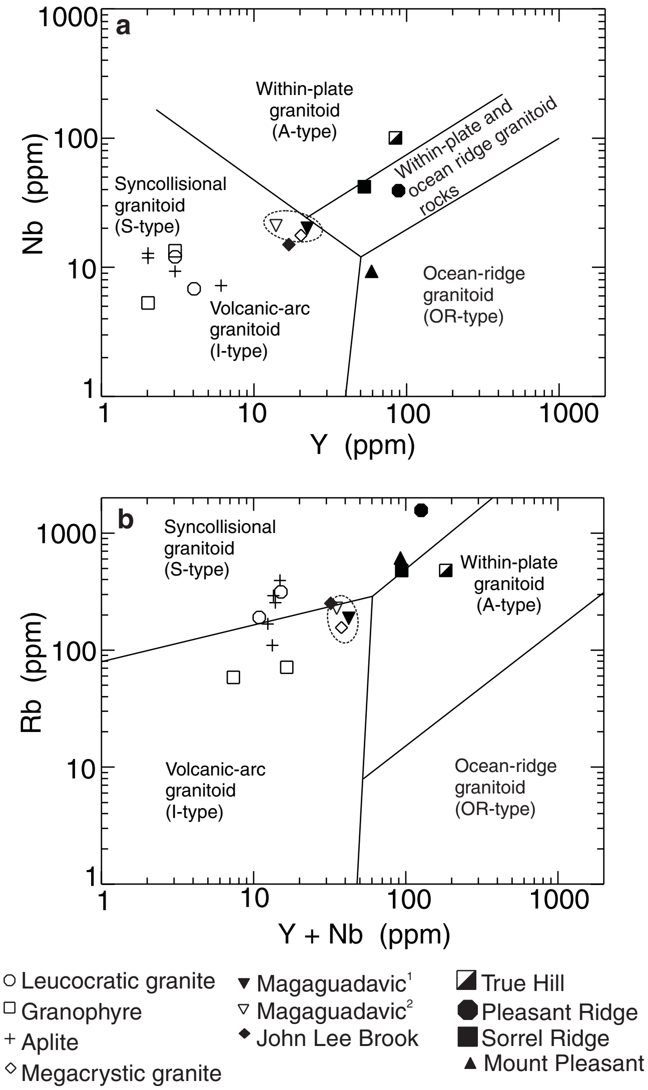

Figure 5. *Geotectonic environment trace-element discrimination diagrams for granitic rocks (Pearce et al., 1984).* ***a)*** *Nb versus Y and* ***b)*** *Rb versus Nb+Y for the Clarence Stream granitic dykes as well as averages from selected regional felsic intrusions. The fields represent both phases of the Magaguadavic Granite as well as the megacrystic sample.*

Primitive-element-normalized trace-element spider diagrams for the Clarence Stream dykes and other plutons in the region (Fig. 6) illustrate that all have notable Ba, Sr, and Ti depletion consistent with their fractionated nature. The dykes and other intrusive rocks have weak to moderate Nb- and Ta-depletion anomalies, which Whalen et al. (1996) interpret as arc-like due to inheritance from a crustal source. The dykes have slightly lower LREE and notably lower HREE contents than the other Late Devonian granite bodies and the Magaguadavic Granite, resulting in steep LREE/HREE profiles. Trace-element patterns defined by the two phases of the Magaguadavic Granite and the John Lee Brook Granite (Fig. 6a) more closely resemble those of the Clarence Stream samples than those of selected stocks from the Pomeroy Intrusive Suite (Fig. 6b).

GEOCHRONOLOGY

Sample KT-01-41A from the pegmatitic margin to the aplite dyke (in trench 4) has the highest LREE (ΣLREE = 90.6 ppm), P_2O_5 (0.02 wt. %), and Th (24 ppm) contents reflecting the presence of monazite. These monazite crystals (Fig. 7) have a range of REE and Y compositions reflecting their zoning and complex pre-magmatic history, which is reflected in the age data presented below. The average La_2O_3 (19.8 wt. %), Ce_2O_3 (29.7 wt. %), Pr_2O_3 (1.6 wt. %), Nd_2O_3 (6.0 wt. %), and Sm_2O_3 (0.9 wt. %) contents are typical of igneous monazite crystals. The Y_2O_3 (1.55 wt. %), ThO_2 (6.6 wt. %), and UO_2 (0.54 wt. %) contents are also typical of felsic igneous crystals, which have sufficient U and Th to generate detectable lead in the age range of interest. Therefore, sample KT-01-41A was selected for microprobe dating (Montel et al., 1996). Monazite analyses were performed on the University of New Brunswick electron microprobe (JEOL-733) equipped with four two-crystal WD spectrometers and Tracor-Northern TN-5600 automation. Table 2 presents the determined U, Th, Pb, and Y intensities.

The analyses were conducted with accelerating voltage of 15 kV and beam current of 100 nA. Empirical corrections for the spectral interferences of Th Mγ on U Mβ and of Y Lγ on Pb Mα were applied. Background intensities were determined on either side of each peak for half the peak counting

Table 2. Determination of U, Th, Pb, and Y intensities.

Element	Crystal	Line peak	Time(s)	Standard	Detection limit
U	PET	Mβ	200	U metal	200 ppm
Th	PET	Mα	200	ThO_2	160 ppm
Pb	PET	Mα	400	$PbCrO_4$	130 ppm
Y	TAP	Lγ	200	YAG	100 ppm

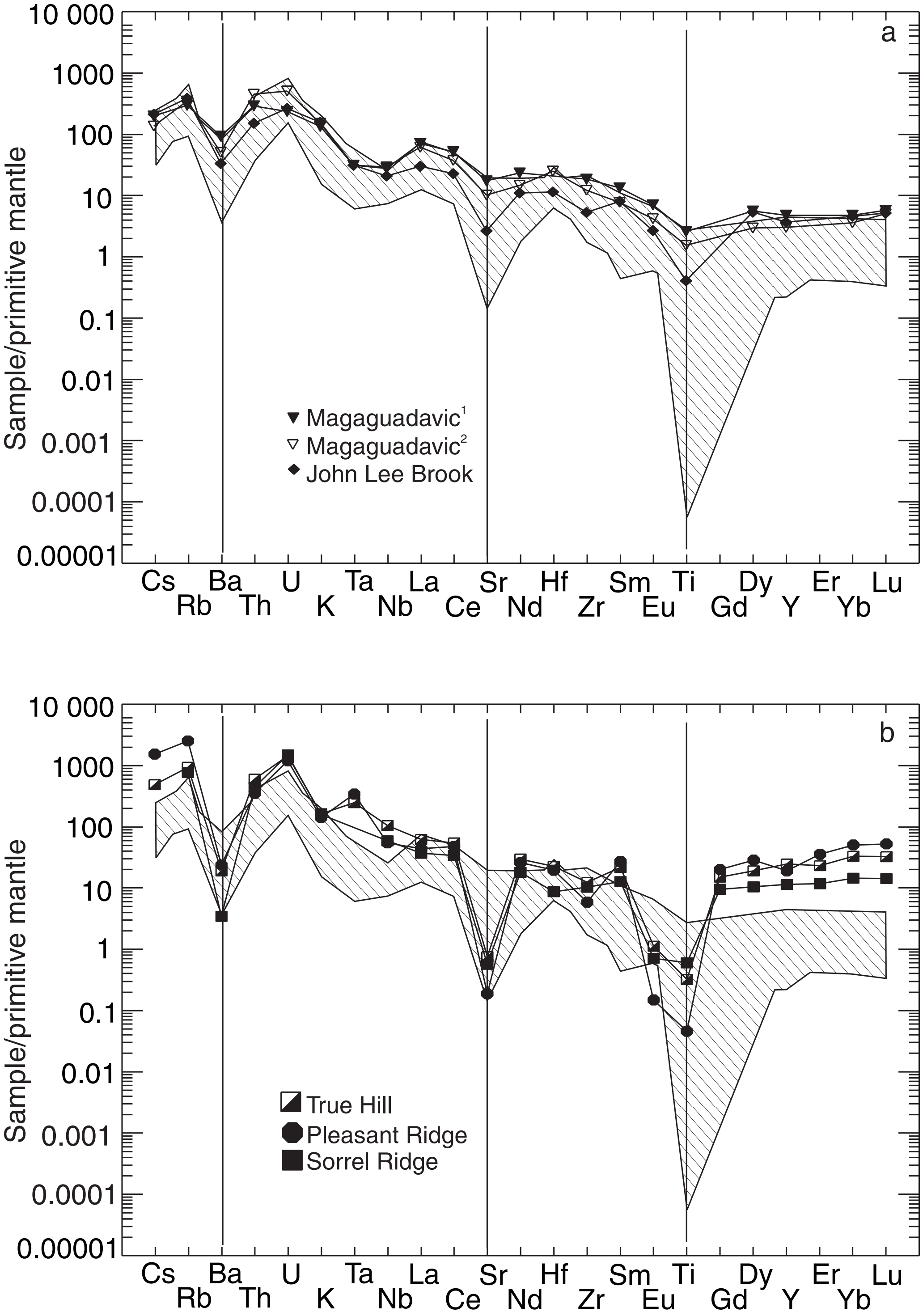

Figure 6. *Primitive-mantle-normalized trace-element spider diagrams showing ranges for the granitic samples taken from the Clarence Stream property (shaded area) compared with **a**) the two phases of the Magaguadavic Granite and the John Lee Brook Granite, and **b**) three of the intrusions of the Pomeroy Intrusive Suite. True Hill (Lentz and Gregoire, 1995); Pleasant Ridge (Taylor, 1992); Magaguavavic and John Lee Brook (McLeod, 1990); Sorrel Ridge (Whalen, 1996). Normalizing values for primitive mantle from Sun and McDonough (1989).*

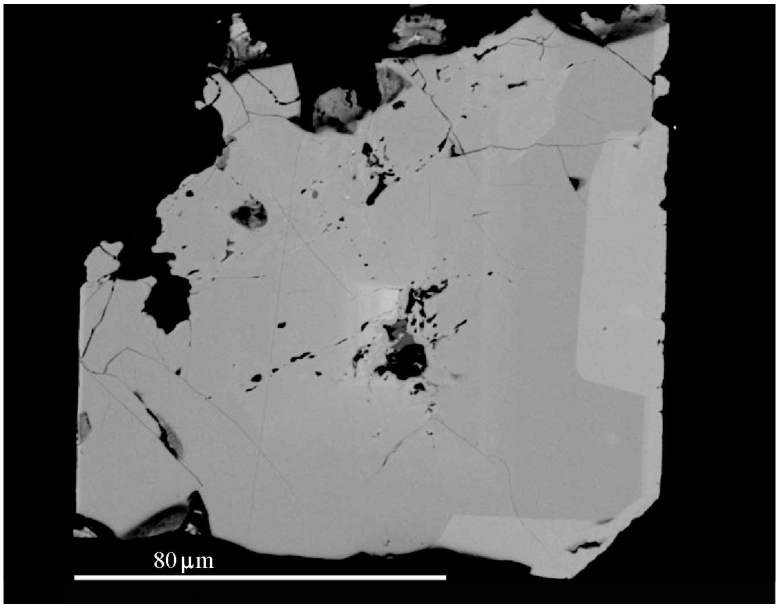

Figure 7.

Zoning within a monazite crystal (grain 17) from sample KT-01-41A. Note the bright, Th-rich core, which contrasts with the darker rim.

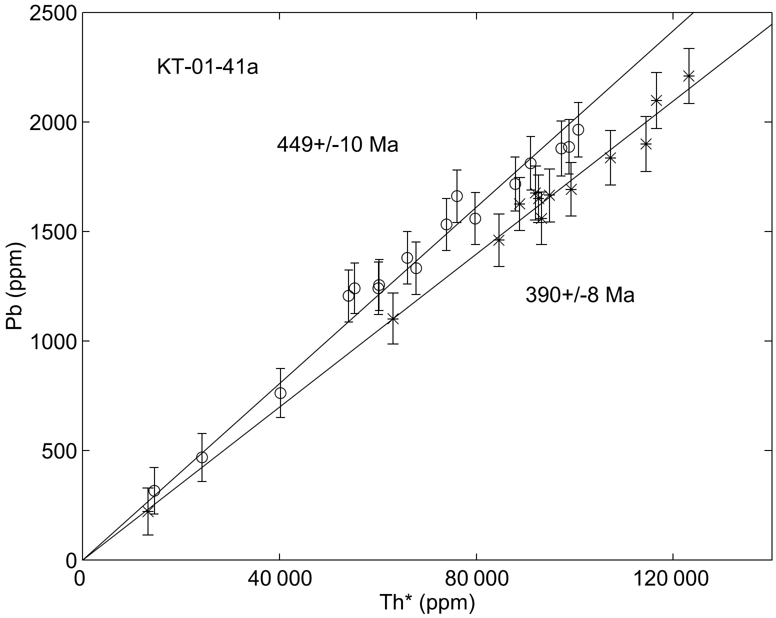

Figure 8.

Diagram of Pb versus Th illustrating the age data obtained for monazite from sample KT-01-41A (n=30). The reference lines have slopes that are representative of the mean ages of the two populations.*

times. Elemental concentrations were determined off-line by the ZAF method, using ZAF factors calculated for an ‘average’ monazite composition. The ‘average’ composition was determined by analysing several of the same grains during a separate analytical session, using a beam current of 30 nA.

Ages were calculated for each analysis, and least squares modelling followed the procedure of Montel et al. (1996). The tabulated analyses and errors (Table 3) are at the 1 σ confidence level. The Th* values (Suzuki and Adachi, 1991) represent a composite parent isotope (Th plus the equivalent Th needed to account for the Pb generated by U decay), such that the Pb/Th* ratio is a function of age. The calculated ages range from 500 to 371 Ma and define two age groups (Fig. 8).

The younger age (390 ± 8 Ma; n=13) is characterized by monazite with a limited range of Th contents and is regarded as the age of pegmatite crystallization. The older age (449 ± 10 Ma; n=17) is characterized by a wide range of Th contents and is consistent with Taconic deformation. In the older group, Th contents tend to increase as age decreases (Fig. 9), but there is no statistical reason to further subdivide this population. The 398 to 382 Ma age range is consistent with an igneous age of emplacement for the pegmatite, rather than a reset age due to hornfelsing by emplacement of the Magaguadavic Granite (ca. 396 Ma), because of the higher Th content of the younger population, consistent with pegmatitic fractionation (Fig. 9; Table 3). Also, the blocking temperature for monazite is inferred to be relatively high

Table 3. Analytical data from electron microprobe analysis of monazite crystals in sample KT-01-41A.

Grain number	Th	Th (error)	U	U (error)	Pb	Pb (error)	Age	Age (error)	Th*
2	84715	667	9212	145	1899	63	371	13	114476
6	81405	642	3474	116	1650	61	398	15	92652
7a	81692	644	12835	161	2212	63	401	12	123254
7b	84048	662	10043	145	2099	64	402	13	116572
9a	56152	454	3618	114	1334	60	438	20	67902
9b1	81403	642	3660	116	1560	60	374	15	93230
9b1(1)	73862	586	3309	114	1460	59	386	16	84565
9b2	85811	675	3544	117	1881	63	431	15	97314
10-1	82636	652	5175	124	1694	61	381	14	99368
10-1(D)	88979	699	5639	127	1836	62	382	13	107214
10-2	75995	603	5822	127	1666	60	392	14	94835
10-3	66355	531	6636	130	1717	61	436	16	87902
10-4	71970	575	5871	126	1812	61	444	15	91045
14	54410	442	2688	110	1103	58	390	21	63107
15	61178	492	5739	123	1560	60	436	17	79812
17-1	40782	341	5983	121	1257	58	465	22	60252
17-1(D)	37373	316	5100	119	1207	59	498	25	54012
17-2	10496	125	4240	113	469	55	431	51	24258
17-3	87985	691	3394	117	1890	62	426	14	98997
20-1	28478	251	3610	112	763	56	424	31	40188
20-2	89843	705	3345	116	1965	62	435	14	100704
20-3	80434	636	3568	118	1676	61	407	15	91993
20-4	78225	618	3262	114	1626	60	409	15	88794
21	63229	507	3290	113	1532	59	462	18	73993
21(D)	57588	466	2570	112	1380	60	466	21	65952
22	37406	317	6970	126	1241	59	460	22	56866
22(D)	40633	340	4481	115	1241	58	500	24	55256
23	62542	502	4151	116	1661	60	487	18	76074
24	9599	120	1141	103	222	54	373	91	13286
24(D)	9599	119	1518	103	317	53	485	82	14547

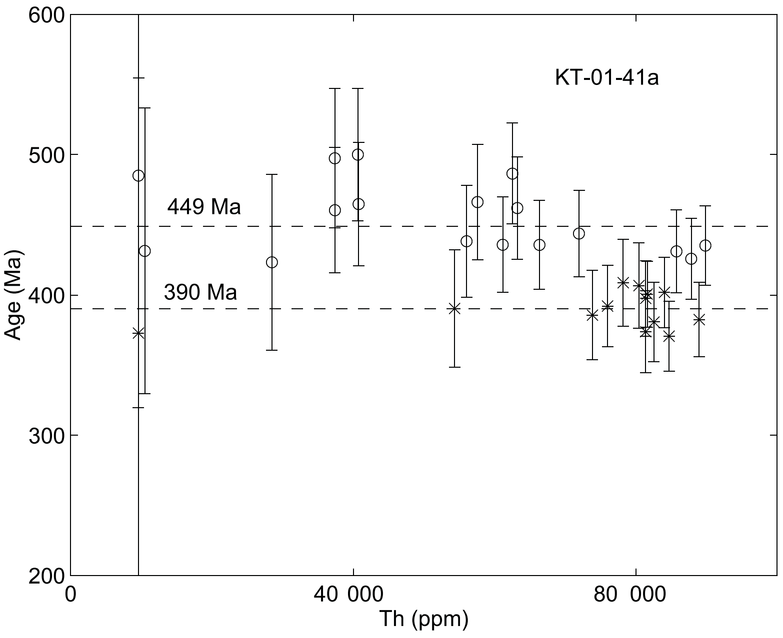

Figure 9.

Age versus Th bivariate plot for monazite from sample KT-01-41A illustrating the Th-enrichment of the younger population of monazite crystals (n=30).

(>700°C), but may be reset after prolonged upper-amphibolite-grade metamorphism (Parrish, 1990; Montel et al., 1996). For this same reason, these monazites have the older inheritance ages (scatter) due to their complex history.

DISCUSSION

The pegmatite and aplite samples analyzed in this study are relatively high-SiO_2 felsic dykes that contain slightly high Sb (≤140 ppm), As (≤1000 ppm), and Au (≤85 ppb) contents, indicative of a mineralized magmatic source. However, low average values of Cu (24 ppm), Pb (48 ppm), Zn (20 ppm), Bi (0.9 ppm), W (<1 ppm), Sn (<1 ppm), and Mo (3 ppm) are inconsistent with the geochemistry of the satellite plutons that constitute the Pomeroy Intrusive Suite (True Hill, Beech Hill, and Mount Pleasant (Lentz et al., 1988); Pleasant Ridge (Taylor, 1992); Sorrel Ridge (Whalen, 1996)) north of the Clarence Stream property, thus ruling out a genetic link between the two systems for this particular mineralizing event. Geochemical characteristics of the dykes more closely resemble those of the younger, more fractionated Magaguadavic[2] Granite immediately south of the dyke showings. The geochemical attributes and tectonic setting of this intermediate pluton bear similarities to favourable granite bodies associated with intrusion-related gold systems (Thorne and Lentz, 2001b) as described by Thompson et al. (1999), Lang et al. (2000), Thompson and Newberry (2001), and Lang and Baker (2001).

Although errors are associated with monazite dating, the younger of two ages obtained for the pegmatitic sample is considered to be reliable and fits well with the regional geology. The older population of monazite crystals may have originated from the crustal material from which the granitic dykes were derived. Recrystallization of these monazites may have occurred during metamorphism associated with the Taconic Orogeny during that particular time period. The younger age (390 ± 8 Ma) is more likely to be the age of crystallization of these dykes, as they appear to be of igneous origin because of their Th and U enrichment (Fig. 9). It might be argued that these monazites may have been reset during contact metamorphism associated with the intrusion of the nearby Magaguadavic Granite (crystallization temperature range of 680°–750°); however, this is unlikely as the closure temperature for monazite (>700°, Parrish, 1990) is higher than was reached within the contact aureole.

Field relations, such as the fact that these dykes intrude gabbroic bodies and metasediments that are also Silurian, are consistent with the younger age (390 Ma) for these granitic dykes. Although the dykes have been locally deformed, they do not appear to have undergone deformation as intense as the foliated metagabbro. In addition, their ages overlap that of the Magaguadavic Granite, pointing to a genetic link between the two with the difference in trace elements being attributed to fractionation. The depletion in Ti, P, and HREE of the dykes compared to the Magaguadavic[1] Granite is attributed to hornblende and apatite fractionation in the latter. This would be coupled with vapour saturation and pressure release of the megacrystic magma to generate these late-stage dykes with geochemical attributes similar to those of the late phase of the Magaguadavic Granite described by McLeod (1990).

The Clarence Stream gold deposit is near a major tectonostratigraphic boundary where accretionary to collisional tectonics took place, generating mafic to intermediate magmas derived from partial melting of a Neoproterozoic basement (McLeod, 1990; Whalen et al., 1996). The metaluminous to slightly peraluminous nature of the magnetite-bearing, I-type Magaguadavic Granite, thought to be responsible for the generation of the granitic dykes on the Clarence Stream property, share many characteristics with plutons associated with intrusion-related gold deposits.

These granitic dykes intrude shear zones and are locally transposed parallel to the foliation, indicating that tectonism occurred both during and after emplacement. Assuming that the younger age obtained for these dykes is correct, then that age (390 ± 8 Ma) was also the upper limit for this mineralizing event as gold-bearing quartz veins are intimately associated with the dykes.

CONCLUSIONS

Granitic dykes associated with gold mineralization that crosscut the country rocks along the northwestern margin of the Magaguadavic phase of the Saint George Batholith help to constrain the timing and genesis of the mineralizing event. Two age populations were obtained by electron microprobe analysis of monazite within a pegmatitic sample; they can be accounted for by regional geological events. The older age (449 ± 10 Ma) may be attributed to metamorphic events related to the Taconic Orogeny whereas the younger monazites (390 ± 8 Ma) are believed to reflect the crystallization age of the dyke. These dykes are seen to grade laterally into auriferous sulphide-bearing quartz veins, which can be assumed to be the same age. Geochemical characteristics, field relations, and the age of emplacement of these dykes indicate that they are most likely late fractionates of the Magaguadavic Granite as opposed to being genetically related to the much younger Pomeroy Intrusive Suite known for its associated tin-tungsten-molybdenum-bismuth mineralization. The tectonic setting and geochemical attributes of the Magaguadavic Granite match those described for intrusion-related gold systems.

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